CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

Effects of Taekwondo Intervention on Postural Control in Youth with Autism Spectrum Disorder

A thesis submitted in partial fulfillment of the requirements

For the degree of Master of Science in Kinesiology

By

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Dedication

To my Lord,

For preparing me for His Work and establishing your covenant with me

"He is like a tree planted by streams of water,

which yields its fruit in season and whose leaf does not wither.

Whatever he does prosper (Psalms 1:3)."

To my parents,

For encouraging me with their love and trust

and supporting me with their endless prayers

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Abstract

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Children with autism spectrum disorder (ASD) have underdeveloped postural control compared to typically developing children (Minshew, Sung, Jones, & Furma, 2004). Poor postural control may inhibit children with ASD from acquiring more advanced motor skills or even sport-specific skills, possibly limiting opportunities for engaging in physical activity. Taekwondo (TKD), a form of Korean martial arts, has been shown to improve balance in typically developing children and children with other forms of neurological disability. This study aimed to investigate the effects of TKD training on postural control in youth with ASD.

Methods: Fourteen youth with ASD (aged 8 to 14 years) participated in this study. Eight youth with ASD completed TKD training twice per week for 8 weeks (50min per session). Six children with ASD received no intervention as controls. Postural control was evaluated using the NeuroCom Balance Master, including the double leg stance, the single leg stance, and the step-quick-turn tests. Pediatric Balance Scale was used to measure functional balance performance. For statistical analysis, mixed model ANOVA was used for between-group comparison. A paired t-test used for within-group comparison.

Results: TKD group showed significant improvement with decrease of postural sway in the right leg with eyes closed condition (p=.046) while postural sway of control group did not change. There was a statistical main effect for both groups in within-group comparison. Separating the two groups to find the main contributor, the TKD group showed significant decrease of postural sway in single leg stance (left leg with eyes open condition) after 8-week intervention (p=.014). The control group showed no significant difference before and after the intervention.

Conclusions: Postural control for youth with ASD improved following 8-week TKD training. TKD may provide an effective and enjoyable therapeutic option. This study outcome will aid clinicians, rehabilitators, and researchers, when developing a therapeutic intervention for youth with ASD.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social communication and interaction. Individuals with ASD also display restricted or repetitive patterns of behavior, interests, and activities (American Psychiatric Association [APA], 2013). Symptoms must be presented before the age of three, and ASD is typically diagnosed in early childhood (Landa, 2008; Brian et al., 2008). However, it may be diagnosed later, when characteristics become apparent and social demands exceed limited capacities (APA, 2013). The most recent report on the prevalence of ASD stated that one out of every 68 children was diagnosed with ASD (Centers for Desease Control & Prevention [CDC], 2014). This is an increase of 30% in comparison to the 2008 findings (one in 88 children) (CDC, 2010). Additionally, there were twice as many children with ASD in 2010 than in 2002 (one in 156 children) (CDC, 2000). ASD is currently one of the fastest growing disabilities in the United States. The male-to-female prevalence ratio varied among states, but relatively has remained in the 4:1 and 5:1 range between males and females (CDC, 2014).

Motor impairments in children with ASD can be seen during infancy (Koterba, Leezenbaum, & Iverson, 2014; Lloyd, MacDonald, & Lord, 2013) and are apparent throughout the lifespan. Numerous studies have identified motor impairments in children with ASD compared to peers without ASD (Green et al., 2009; Jansiewicz et al., 2006; Jasmin et al., 2009; Provost et al., 2007; Staples & Reid, 2010). Compared to the fine and gross motor assessment scores of children without ASD, the scores for children with ASD fell significantly lower and often were below the 15th percentile (Green et al., 2009; Jasmin et al., 2009). A lack of motor skills in children with ASD is typically associated with limited manual dexterity (Green et al., 2009; Jansiewicz et al., 2006; Jasmin et al., 2009; Provost et al., 2007) as well as impaired balance and gait (Green et al., 2009; Jansiewicz et al., 2006; Jasmin et al., 2009; Provost et al., 2007; Staples & Reid, 2010).

Deficits in motor skills can be caused by poor postural control. Postural control is the maintaining, achieving, or restoring of a state of balance during any posture or activity (Pollock et al., 2000). It is maintained through the sensory systems. This involves efficient use of information from the vision, vestibular, and somatosensory functions. Without good postural control, individuals may have a high risk of falling during daily activities such as standing and walking. Moreover, a lack of postural control may inhibit children with ASD from acquiring motor skills and limit their opportunities for participating in sports or leisure activities. Plus, a lack of physical activity often leads to sedentary lifestyle that causes other health problems. Recent evidence shows that children with developmental disabilities such as ASD are more likely to become overweight and obese than peers without a disability (Hwang et al., 2014; Must et al., 2013).

Studies in recent decades have reported greater deficits in postural control in children with ASD compared to peers without ASD (Fournier et al., 2010; Kohen-Raz, Volkmar, & Cohen, 1992; Minshew, Sung, Jones, & Furman, 2004; Molloy, Dietrich, & Bhattacharya, 2003; Memari et al., 2013). Children with ASD have display greater unstable postural control in the mediolateral (ML) direction than along the anteroposterior (AP) axis whereas children without ASD display higher sway in the AP than in the ML direction (Fournier et al., 2010; Kohen-Raz et al., 1992; Memari et al., 2013). This is a different phenomenon than that which occurs in their peers without ASD. Memari and colleagues (2013) explained that children with ASD may acquire a muscle balance between the AP and the ML stabilizing muscles later in life (Memari et al., 2013). Therefore, this muscle imbalance in children with ASD might be related to directional instability and postural immaturity.

Other studies have evaluated the postural control of children with and without ASD while sensory input was modified (Minshew et al., 2004; Molly et al., 2003). In one study, the researchers compared postural control under four different conditions with eyes open (EO) and with eyes closed (EC) on a stable and on an unstable surface (Molloy et al., 2003). Results of study showed that children with ASD had more difficulty maintaining postural control when they closed their eyes (blocked visual input) compared to the healthy children (Molloy et al., 2003). In another study, Minshew and colleagues reported that children with ASD showed significantly increased postural sway while standing on a foam pad (disrupted somatosensory input) compared to peers without ASD (Minshew et al., 2004).

In addition, studies have shown that children with ASD display underdeveloped postural control relative to their age (Minshew et al., 2004). Children without a disability show significantly increased postural control from five to seven years of life while standing still and continue to develop throughout the children’s lifespan (Sobera, Siedlecka, & Syczewska, 2011). Additionally, Peterson and colleagues (2006) reported that 12-year old children without ASD demonstrated mature postural response and use of sensory information in a manner that is comparable to that of an adult (Peterson, Christou, & Rosengren, 2006). However, Minshew and colleagues (2004) found in this study that postural control in children with ASD did not begin to improve until the age of 12 and that it rarely achieved adult levels (Minshew et al., 2004). These findings corroborate that age might not independently improve postural control in children with ASD whereas postural control increases as age increases for TD children (Fournier et al., 2010; Kohen-Raz et al., 1992; Memari et al., 2013).

The postural control impairments in children with ASD may persist into their adolescence and even adulthood. As a result, alternative therapeutic options have been proposed for children with ASD including specific balance training (Yanardag, Erkan, Yılmaz, Arıcan, & Düzkantar, 2015) and recreational activities such as horseback riding (Silkwood-Sherer, Killian, Long, & Martin, 2012; Wuang, Wang, Huang, & Su, 2010) and swimming (Yilmaz, Yanaradag, Birkan, & Bumin, 2004). These studies provide evidence that participation in recreational activities can be a therapeutic exercise option for children with ASD; however, these activities may not appeal to everyone or be available to all children with ASD. Thus, it is important to continuously investigate forms of exercises that could help to increase the postural control in children with ASD. Sport activities also can be a challenging, yet enjoyable, therapeutic activities for children with ASD.

Taekwondo (TKD) is a traditional form of Korean martial arts that is primarily composed of offensive and defensive combat skills. TKD has been modified for modern sports and exercise since the late 1950s, and it is now one of the world’s most popular sports among children and adolescents. Training in TKD generally involves punching, kicking, sparring, breaking, and practicing in self-defense techniques and Poomse, a combination of offensive and defensive movement sequences (Fong & Ng, 2011a).

The kicking practice of TKD can be an excellent way to develop postural control since it has opportunity to practice single leg stance while maintaining a stable body posture (Brudnak, Dundero, & Van Hecke, 2002; Fong, Chung, Chow, Ma, & Tsang, 2013d; Fong & Ng, 2012b; Fong, Tsang, & Ng, 2012c). Standing on one leg can also develop muscle strength in lower extremity, which may have improved postural control (Fong et al., 2013d). In addition, Poomse in TKD training involves frequent changes in movements and directions for the connections amongst different techniques. The spinning movement and directional changes in TKD training may have helped to stimulate the use of sensory systems to have better postural control. Overall, TKD practice involves maintaining good postural control while performing movements.

Several studies have identified the positive influence of TKD on postural control in healthy adults and adolescents (Brudnak, Dundero, & Van Hecke, 2002; Cromwell, Meyers, Meyers, & Newton, 2007; Pons van Dijk, Lenssen, Leffers, Kingma, & Lodder, 2013). In a comparative study by Fong & Ng (2012b), the researchers reported that adolescent TKD practitioners had better use of sensory function and postural control compared to non-TKD practitioners. A computerized dynamic posturograpy machine, NeuroCom Smart Equitest system, detected the different strategies of sensory system usage while participants were standing still on a platform. The results demonstrated that adolescents who practiced TKD had improved vestibular function compared to peers who did not practice TKD. In explaining their findings, the authors theorized that the frequent jumps and spinning kicks in TKD training might stimulate the development of the vestibular system (Fong et al., 2012b). Additionally, the researchers compared sway velocity of COP (degrees per second) during the single leg stance between TKD practitioners and non-TKD practitioners. Their findings revealed significantly slower postural sway among the adolescent TKD practitioners compared to the non-TKD practitioners (Fong et al., 2012b). Similar results were seen in other studies, researchers stated that TKD-trained adolescents might have more effective cerebral mechanisms for integrating sensory input (Del Percio et al., 2007).

In another study, Pons van Dijk et al. (2013) recruited 24 healthy adults (aged 40-71 years old) to investigate the effects of TKD training. The intervention consisted of one hour of TKD training per week for one year. A force plate was used to measure static balance including total length of COP sway (cm) and sway area (cm^2) while participants stood on two feet. The participants also performed single leg stance (second) in both EO and EC conditions as well as one leg hip test (cm) as a functional measure of balance. After the TKD training, the participants significantly improved postural control during the double leg stance test, including sway path and sway area. Additionally, the duration of the single leg stance increased significantly after the TKD training (Pons van Dijk et al., 2013). This finding was consistent with a previous study by Brudank and colleagues (2002) that found that TKD training effectively increased the duration of single leg balance in the senior population after 17 weeks of TKD training (Brudank et al., 2002). Furthermore, the one leg hop test showed a mean distance increase. However, the authors stated that the test has not been validated for balance and may not serve as a functional balance measure. Cromwell and colleagues (2007) also studied the effects of TKD training on functional balance and walking ability in order adults. They found that the participants reaching ability, gait stability, and walking velocity had significantly more improvements after 11 weeks of training than those participants in a control group who did not receive any training. The researchers concluded that TKD was effective for improving balance and walking ability in the elderly population (Cromwell et al., 2007).

The effects of TKD training on postural control also have been investigated in children with developmental coordination disorder (DCD) (Fong et al., 2012c, 2013d). DCD children have similar motor delays to ASD, including postural control impairments. Forty-four children with DCD and 18 children without DCD participated in this study. The children with DCD were divided into two groups: a TKD group (one hour per week for 12 weeks) and a non-TKD group. Postural control was measured using a NeuroCom Smart Equitest System, including the double leg stance with various sensory conditions and the single leg stance test. After 3 months of TKD training, the children in the TKD training group significantly improved their postural control and decreased postural sway during the single leg stance test compared to the controls who did not received the TKD training (Fong et al., 2012c).

Fong and colleagues also conducted another study (2013d) in which the researchers measured static and dynamic postural control using the NeuroCom Smart Equitest system. The single leg stance test measured postural sway while standing on leg at a time with EO and EC condition. The motor control test recorded reaction time (millimeters per second), which measured the initial pressure of feet into the forceplate after the unexpected movement of forceplate. The participants were divided into three groups: children with DCD (TKD group), children with DCD (non-TKD group), and age-matched healthy controls. After 3 months of TKD training (one hour per week for 12 weeks), the TKD group showed significantly decreased sway velocity during the single leg stance compared to the non-TKD group and the healthy controls. There was no significant improvement in the motor control test. These findings indicate that TKD training may improve static single leg standing balance but that the benefits were minimal for reactive balance control (Fong et al., 2013d). However, the authors also explained that a three month

TKD intervention is a relatively short time frame for finding a significant improvement in dynamic balance control.

An additional outcome in this study was the difference between knee muscle strength before and after the intervention. Fong and colleagues (2013d) found improved muscle strength in knee extensors (quadriceps) after the TKD intervention (Fong et al., 2013d). The researchers stated that postural control improvement can be associated with improved isokinetic knee extensor muscle strength (only 180 degrees per second, but not at 60 or 240 degrees per second). Overall, there is consensus in the literatures that TKD training was effective in improving postural control during the single leg stance performance.

Children with ASD display poor postural control compared to children without ASD of the same age. This may limit opportunities for engaging in physical activities. Previous researchers found positive health outcomes including improved balance in children with ASD through horseback riding and swimming intervention. Yet, there is an overall lack of research examining early childhood interventions for children with ASD for improving their postural control.

However, studies of TKD training have shown improvement of postural control in adults without disabilities (Pons van Dijk et al., 2013) and in adolescents with another form of neurological disorder (Fong et al., 2012c; 2013d). But, no study has assessed the effects of TKD on balance for children with ASD. Based on the other findings, TKD training could be beneficial for the ASD population as it could improve overall fitness including postural control and balance-related skills. Such postural control development in children with ASD also may help to establish age-appropriate functional motor skills. All of this can prepare individuals for community-based fitness programs or inclusive physical activity settings.

Therefore, it is important to examine the role that TKD training could play as an enjoyable, yet challenging, therapeutic exercise program for the ASD population. Thus, the purpose of this study is to investigate the effects of TKD on postural control in children with ASD. We hypothesize that TKD training will positively affect postural control in youth with ASD.

Hypotheses

It was hypothesized that there would be biomechanical differences on postural control between TKD group and control group.

1. The TKD group would decrease postural sway during the static balance tasks (double leg stance and single leg stance tests).

2. The TKD group would decrease the time to complete the functional balance task (step-quick-turn test).

3. The TKD group would increase the scores of the functional balance tasks (Pediatric Balance Scale).

Independent and Dependent Variables

Independent Variables

1. TKD training

Dependent Variables

1. Sway velocity (degrees per second)

2. Time of completion (second)

3. Pediatric Balance Scale (Maximum score is 56)

Operational Definitions

Postural control: The act of maintaining, achieving, or restoring of a state of balance during any posture or activity.

Sway Velocity: The ratio of the distance traveled by the center of gravity (in degree) to the time of the trial (second). Closer to zero indicates very little sway and stable posture; Twelves represents a fall during the static balance tasks.

Time of completion: The amount of time (in second) used to complete the task during functional balance activity.

Assumptions

1. Learning did not affect test results while performing repetitive balance tests through the randomized balance test protocol.

2. Participants truly closed their eyes and blocked their vision.

Delimitations

1. Only children and adolescents who have been diagnosed with ASD were asked to participate in this study to reduce subject variability.

2. Children and adolescents with ASD were accepted only when they met the following criteria:

   Inclusion Criteria

   - Diagnosis of ASD
   - Aged 6 to 15 years old
   - Obtained medical release form from primary clinician
   - Ability to understand verbal instruction, as well as communicate and comprehend English to promote the safety of instruction
   - Ability to adhere to entire study protocol (12 weeks)
   - Ability to participate in an exercise program for 50 minutes and for the duration of study (8 weeks)

Exclusion Criteria

- Medical/surgical treatment within 6 months of the study
- Currently participating in a martial art program
- Additional physical complication that would prevent them from participating in moderate to vigorous physical activity
- Unable to follow instructions
- A plan to participate in any new structured physical activity program that conflicts with the duration of the study, not including school-based physical activity

Limitations

1. There was a lack of statistical power and generalizability, due to the small sample size.

2. There was a lack of quantified assessment for the percentage of task engagement during the interventions.

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Literature Review

Definition and Prevalence of ASD

Autism spectrum disorder (ASD) is a neurological disorder with onset in the early developmental period of a child's life. The disorder is characterized by persistent deficits in social communication and social interaction. Children with ASD also show restricted and repetitive patterns of behavior, interests, or activities (American Psychiatric Association [APA], 2013). Symptoms must be presented before the age of three, and ASD is typically diagnosed in early childhood (Landa, 2008; Brian et al., 2008). However, it may be diagnosed later, depending on the symptom severity or when social demands exceed limited capacities (APA, 2013).

The Centers for Disease Control and Prevention (CDC) reported that the estimated prevalence of ASD continues to increase. The following studies were carried out at 14 sites of the United States including Alabama, Arizona, Colorado, Florida, Georgia, Maryland, Missouri, New Jersey, North Carolina, Pennsylvania, South Carolina, Utah, and Wisconsin. In 2010, one out of every 68 children aged 8 years was diagnosed with ASD (CDC, 2014). The current incident of ASD indicated an increase of 30% in comparison to the 2008 findings (one in 88) (CDC, 2010). The results also revealed twice as many children with ASD in 2010 than in 2002 (one in 156) (CDC, 2000). Furthermore, APA reported that the incidence of ASD in both the United States and other countries is nearly 1% of the population, with similar estimates in both child and adult samples (APA, 2013). The male-to-female prevalence ratio varied among the sites, but relatively has remained in the 4:1 and 5:1 range between males and females (CDC, 2014).

Motor Characteristics in ASD

Motor impairments in children with ASD can be seen during infancy (Koterba, Leezenbaum, & Iverson, 2014; Lloyd, MacDonald, & Lord, 2013) and are apparent throughout their lifespan. Numerous studies have identified poor motor abilities in children with ASD compared to those in peers without ASD (Green et al., 2009; Jansiewicz et al., 2006; Jasmin et al., 2009; Provost & Lopez, 2007; Rinehart et al., 2006; Staples & Reid, 2010; Stoit, van Schie, Slaats-Willemse, & Buitelaar, 2013). These studies quantified performance using standardized motor assessments such as the Movement Assessment Battery for Children (M-ABC), the Test of Gross Motor Development (TGMD-2), the Physical And Neurological Examination of Subtle Signs (PANESS), or the Peabody Developmental Motor Scales-second edition (PDMS-2).

One aspect of fundamental motor abilities is fine and gross motor skills. A lack of fine motor skill in children with ASD is typically associated with limited manual dexterity (Green et al., 2009; Jansiewicz et al., 2006; Jasmin et al., 2009; Provost & Lopez, 2007). Gross motor skill are also impaired in children with ASD including balance, gait, and limb coordination (e.g. jumping, hopping, and skipping) (Green et al., 2009; Jansiewicz et al., 2006; Jasmin et al., 2009; Provost & Lopez, 2007; Staples & Reid, 2010). These fundamental motor skills in children with ASD were scored significantly fell lower and often were below the 15th percentile compared to those in children without ASD (Green et al., 2009; Jasmin et al., 2009). In addition, children with ASD exhibited more difficulty in motor planning than peers without ASD (Rinehart et al., 2006; Stoit et al., 2013). Rinehart and colleagues (2006) examined the time differences in movement preparation and execution. Participants were instructed to move a stylus towards the target in response to the illumination of a small light. Researchers found that children with ASD show significantly slower response to the light and execution of the movement compared to peers without ASD (Rinehart et al., 2006). These findings also supported by Stoit and colleagues (2013) that execution of movement in children with ASD was significantly delayed compared to those in children without ASD. However, preparation time of movement was similar in children with and without ASD. Authors suggested that children with ASD have greater deficits in movement execution rather than movement preparation (Stoit et al., 2013).

Balance

Balance is a fundamental aspect of gross motor skills that allows individuals to maintain stability in a place or during locomotion. Without good balance, individuals may have high risk of falling during daily activities such as standing and walking. Therefore, maintaining good balance is also essential for obtaining locomotion or advanced sport skills. Balance is defined as the ability to keep the center of gravity (COG) within its base of support (BOS) (Winter, 1995). COG is an imaginary point and roughly in the center of your body at about 55% of your height. BOS is the area within an outline of all ground contact points. The line of gravity of a body, center of pressure (COP), helps you determine balance, and it can be represented by drawing a straight line from the COG to the ground. When the line of gravity falls within the BOS, the person has better stability. When the COP moves outside the BOS, the person becomes unstable. Two types of balance are used in everyday activities: static and dynamic. Static balance refers to keeping the COP within BOS while standing still. Dynamic balance requires the ability to return the COP within the BOS during walking or under various external disturbances (Pollock, Durward, Rowe, & Paul, 2000). Balance is maintained through the postural control system and coordination of the body parts.

Postural Control

Postural control is defined as the act of maintaining, achieving, or restoring a state of balance during any posture or activity (Pollock et al., 2000). Three major systems are involved in maintaining postural control: vision, vestibular function, and somatosensory. First, vision determines how one's body is positioned relative to the environment. Based on these perceptions of body and space, a person can prepare and perform movements in a specific situation. Next, the vestibular system provides information about changes in head position and body movement to determine equilibrium. Lastly, somatosensory system is responsible to perceive the information about the surface or BOS changes. To maintain stable body posture, a person has to select appropriate sensory input, adjust timing of movement, and determine body position from the environmental changes. Thus, deficits in the postural control systems can limit the development of balance, mobility, coordination, and action performance during physical activity.

Postural Control in Infants and Young Children with ASD

In the first year of life, infants achieve a series of motor milestones in postural control from supine lying to independent sitting and standing (Haywood & Getchell, 2009). The development of postural control is crucial to obtain advanced motor skills such as walking, running, jumping, climbing stairs, and ball throwing. Postural delays are evident in young infants who later develop ASD. A few studies have examined delays on postural control in young children with ASD compared to those in peers without ASD (Nickel, Thatcher, Keller, Wozniak, & Iverson, 2013; Lloyd et al., 2013; Landa & Garrett-Mayer, 2006).

Nickel et al. (2013) compared postural control differences between infants with an older sibling diagnosed with ASD (high risk group) and infants with a typically developing older sibling (low risk group). Daily activities and play were recorded at 6, 9, 12, and 14 months of the infancy using retrospective home video. The postural behaviors were coded such as prone, supine, sitting, supported standing, and independent standing. Researchers found that infants in the high risk group spent less time in advanced postures (e.g. sitting and standing) and more time in less-advanced posture (e.g. supine and prone) compared to infants in the low risk group (Nickel et al., 2013). In addition, three infants in the high risk group were diagnosed with ASD by the end of the study period. Those later diagnosed with ASD were significantly older when they attained the most mature forms of sitting and standing posture. These findings indicate that infants at high risk of ASD have postural delays in the first year compared to infants with no family history of ASD (Nickel et al., 2013).

Researchers also examined the differences between chronological age and age-appropriate motor skills in young children with ASD (Lloyd et al., 2013; Landa & Garrett-Mayer, 2006). Lloyed and colleagues (2013) recruited young children with ASD aged 12 to 36 months and divided them into three groups (12-24 months, 25-30 months, and 31-36 months). The Mullen Scales of Early Learning (MSEL) was administrated, which includes postural control assessment scores in supine, prone, sitting, and upright positions. The scores of young children with ASD are compared with age-matched norms to see the amount of motor delay in months. Researchers found that the skill level of postural control for all the children in each age group were below what would be expected for their chronological age (Lloyd et al., 2013). The findings are consistent with a previous study by Landa & Garrett-Mayer (2006). Additionally, the developmental gap increased progressively as the children got older (Lloyd et al., 2013; Landa & Garrett-Mayer, 2006).

Postural Control in Children and Adults with ASD

Previous studies over recent decades have reported greater deficits in postural control in children with ASD compared to those in typically developing children (Fournier et al., 2010; Kohen-Raz, Volkmar, & Cohen, 1992; Minshew, Sung, Jones, & Furman, 2004; Molloy, Dietrich, & Bhattacharya, 2003; Memari et al., 2013). A recent study by Memari and colleagues (2013) reported deficits in postural control in 21 children with ASD (aged 9-14 years old) compared to age-matched typically developing children. Each participant was asked to stand still for 20 seconds and completed two trials. A force plate measured COP trajectory including sway area (cm^2), mean velocity (degrees per second), as well as COP displacement (cm) in the anteroposterior (AP) and the mediolateral (ML) directions. The results demonstrated that children with ASD have greater postural sway compared to typically developing children. Furthermore, children with ASD display more unstable postural control in the ML direction rather than the AP axis while typically developing children have higher sway in the AP than ML direction. The authors explained that children with ASD may acquire a balance between the AP and the ML stabilizing muscles later in life. Therefore, the muscle imbalance might be related to directional instability and postural immaturity in children with ASD (Memari et al., 2013).

These findings are supported by Fournier and colleagues (2010) who found that children with ASD have more difficulty maintaining postural control in the ML direction. The researchers evaluated postural sway during static stance for 13 children with ASD and 12 children without ASD. Each participant performed static standing for 20 seconds and completed four trials. A force plate measured the COP displacements in the ML and the AP directions (cm) as well as total sway area (cm^2). Children with ASD displayed 438 % greater ML sway and 104% greater AP sway compared to their peers without ASD (Fournier et al., 2010).

Kohen-Raz and colleagues (1992) also reported directional instability of postural control in 91 children and adults with ASD (aged 6-20 years old) compared to 166 age-matched controls. Researchers used tetra-ataxiametric method, which measured COP displacements in the AP and the ML direnctions by four force plates, one for each heel and toe. Postural contol was measured under four different conditions with eyes open (EO) and eyes closed (EC) on a stable and unstable surface. The surface condition was modified using a foam mat to challenge somatosensory input. Children with ASD had greater variability in lateral sway compared to those in children without ASD, which is consistant with Fournier et al. (2010) (Kohen-Raz et al., 1992). An intersting finding in this study was that children with ASD performed equal or better when confronted with the difficult task of postural control on an unstable surface with EC conditions. On the other hand, children without disability had better postural control on the stable surface with vision. The authors hypothesized that children with ASD demonstrated a "paradoxical postural stress" in which they had better stability with decreased afferent input (e.g. standing on pad).

Another study by Molly and colleagues (2003) also evaluated postural control of children with and without ASD while sensory input was modified (Molloy et al., 2003). The double leg stance test was carried at under four different conditions with EO and EC on a stable and unstable surface. Mean of sway area (cm^2) and total length of sway (cm) were calculated. Children with ASD had greater sway on stable and unstable surfaces during the EC conditions compared to peers without ASD. The results also showed significantly decreased postural control of children with ASD, whether or not somatosensory input was also modified. Based on the findings, authors stated that children with ASD seem to rely much on the visual information to reduce sway and maintain balance. There was no significant group difference in the mean sway area during EO conditions (Molloy et al., 2003). These findings are inconsistent with the previous study by Kohen-Raz and colleagues (1992).

Minshew and colleagues (2004) compared postural control in 79 individuals with ASD and 61 healthy controls between ages 5 to 52 years (Minshew et al., 2004). Computerized dynamic posturography, NeuroCom Smart Equitest System, was assessed the different use of sensory information while double leg stance balancing. The Neurocom is a type of angle-adjustable force plate that can measure the amount of sway by tracking COP during different tasks. The sensory organization test produces six different conditions including (1) normal vision and fixed support; (2) absent vision and fixed support; (3) sway-referenced vision and fixed support; (4) normal vision and sway-referenced surface; (5) absent vision and sway-referenced surface; (6) sway-referenced vision and sway-referenced surface. The results showed that individuals with ASD had significantly reduced postural control for the conditions in which somatosensory input was disrupted (condition 4 and 6) compared to the healthy controls.

Additionally, the researchers reported postural control impairments in individuals with ASD relative to their age (Minshew et al., 2004). Children without a disability show significantly increased the ability of postural control from five to seven years of life while standing still and continue to develop throughout children’s lifespan (Sobera, Siedlecka, & Syczewska, 2011). Moreover, Peterson and colleagues (2006) reported that 12 year old children without ASD demonstrated mature postural response and use of sensory information comparable to that of an adult (Peterson, Christou, & Rosengren, 2006). Minshew and colleagues (2004) also found that the healthy controls displayed steady improvements in postural control from 5 years to 20 years of age, at which time balance plateaued at adult levels (Minshew et al., 2004). However, postural control in children with ASD did not begin to improve until the age of 12, and rarely achieved adult levels. These findings corroborate that age might not independently improve postural control in children with ASD as occurs for TD children (Fournier et al., 2010; Kohen-Raz et al., 1992; Memari et al., 2013). Overall, there is consensus in the previous literatures that children with ASD have deficits in postural control.

Postural control and Symptom Severity of ASD

Previous studies have documented an association between the symptom severity of ASD and the amount of postural sway in children with ASD (Memari et al., 2013; Travers, Powell, Klinger, & Klinger, 2013; Graham et al., 2014; Molloy et al., 2004). Two studies have evaluated COP displacement in the ML direction and total length of sway using the Nintendo Wii Balance Board, which can be used as a type of force plate (Travers et al., 2013; Graham et al., 2014). The double leg stance test was measured postural control under four different conditions on a stable and unstable surface with EO and EC conditions. Symptom severity of ASD was measured by the Autism Diagnostic Observation Schedule (ADOS), the Autism Diagnostic Interview-Revised (ADI-R), the Repetitive Behavior Scales-Revised (RBS-R), and the Social Responsiveness Scale (SRS). The researchers found that children with severe symptom of ASD displayed greater deficits in postural control compared to those with less severe symptoms (Travers et al., 2013; Graham et al., 2014). These findings are also consistent with Memari and colleagues (2013), using a force plate and the Autism Treatment Evaluation Checklist (ATEC). In contrast, Molloy et al. (2004) did not reveal any association between those postural control deficits and symptom severity, which was measured by the Autism Behavior Checklist (ABC).

Physical Activity and Postural Control in ASD

A lack of postural control can inhibit children with ASD from acquiring physical skills, which may limit opportunities for engaging in sports or leisure activities. Physical inactivity often leads individuals to sedentary lifestyles and other health problem. Recent evidence shows that children with developmental disabilities such as ASD are more likely to become overweight and obese than peers without a disability (Hwang, Wu, Nan, Cheng, & Chen, 2014; Must et al., 2013). Therefore, it is important to improve postural control of children with ASD and to promote their physical activity participation in school and community. Previous researches have focused on finding new form of therapeutic exercise for children with ASD to improve postural control. Alternative therapeutic options have been proposed, including specific balance training (Yanardag, Erkan, Yılmaz, Arıcan, & Düzkantar, 2015) and recreational activities such as horseback riding (Silkwood-Sherer, Killian, Long, & Martin, 2012; Wuang, Wang, Huang, & Su, 2010; Yilmaz, I., Yanardağ, M., Birkan, B., & Brumin, G., 2004).

Yanardag and colleagues (2015) investigated the effect of progressive balance training on postural control in children with ASD (Yanardag et al., 2015). Twenty children with ASD participated in six-week of specific balance training (45minutes per session, three times per week). Postural control was tested under four different conditions on a stable and unstable surface with EO and EC conditions. A force plate measured COP displacement in the AP and the ML directions as well as sway velocity while the participants stood still with double leg stance. Intervention consisted of maintaining balance in double leg stance and single leg stance on a stable surface with EO. The exercises progressed to standing on an unstable surface with EC. 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. After six-week training, the results showed that the specific balance training program efficiently improved the postural control in children with ASD (Yanardag et al., 2015).

Postural control can be also improved from participating in recreational activities. Horseback riding, also known as hippotherapy, has been recognized as a type of therapy for individuals with ASD and other disabilities to help increase postural control (Silkwood-sherer et al., 2012; Wuang et al., 2010). A study by Wuang and colleagues (2010) implemented a simulated developmental horse riding program to improve postural control in children with ASD. Seventy-one children with ASD participated in this study. The intervention consisted of one hour sessions, twice per week for 20 weeks (total of 40 sessions). Motor ability, which was assessed using the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), includes balance, bilateral coordination, agility, and response speed. Researchers found that children with ASD exhibited significant improvement in overall motor proficiency scores including balance (Wuang et al., 2010).

Another study, by Silkwood-Sherer and colleagues (2012), assessed the effects of horseback riding using the Pediatric Balance Scale (PBS). PBS consists of 14 items of balance-related skills including sit to stand, standing balance, and forward reach. Functional performance of activities of daily living were also measured using the Activities Scale for Kids-Performance (e.g. personal cares such as bathing and toileting, dressing, locomotion, standing skills, transfer skills, and basic self-care such as making a snack and performing chores at home). The intervention consisted of 45 minute sessions, twice per week for six weeks. Following six weeks of hippotherapy, participants significantly improved standing balance and functional tasks such as sit-to-stand, turning, and reaching (Silkwood-sherer et al., 2012). The findings suggest that hippotherapy may be a strategy for reducing balance deficits and improving the performance of daily life skills in children with ASD.

Swimming is another type of recreational physical activity that may be effective for improving postural control in individuals with ASD. Yilmaz and colleagues (2004) investigated the effects of swimming education program, Halliwick. The motor ability of one child of ASD (nine-year-old) was trained including the adjustment to water, rotation, and control of movement in the water. The participant performed Halliwick therapy for one hour session, three times a week for 10 weeks. Primary outcome measures included static balance, agility, flexibility, grip strength, running speed, and cardiorespiratory endurance. To assess balance, the child was tested under four different conditions which were made up of alternating single leg standing with and without vision. The child showed significant improvements in balance under all conditions: single leg stance with eyes open and closed. Other components of fitness, such as running speed, power score, muscular strength, upper and lower extremity, flexibility, and agility, also improved significantly (Yilmaz et al., 2004). From this study it appears that balance in individuals with ASD may benefit from an aquatics program.

Previous studies have shown positive effects of physical activity programs on overall fitness outcomes, including postural control. These studies provide evidences that postural control in children with ASD can be improved by utilizing specific balance training and recreational activities. However, these activities may not appeal to everyone. Therefore, it is important to continuously investigate challenging, and yet enjoyable therapeutic exercise programs for children with ASD. A new form of therapeutic exercise should be considered to provide better recommendations for clinicians, to assess physical activity levels, and to promote physical fitness in children and adolescents with ASD.

Taekwondo

Sport activities also can be a challenging, yet enjoyable, therapeutic activities for children with ASD. Taekwondo (TKD) is a traditional form of Korean martial arts that is primarily composed of offensive and defensive combat skills. TKD has been modified for modern sports and exercise since the late 1950s, and it is now one of the world's most popular sports among children and adolescents. Training in TKD generally involves punching, kicking, sparring, breaking, and practicing in self-defense techniques and Poomse, a combination of offensive and defensive movement sequences (Fong & Ng, 2011a). Previous studies have shown that TKD training benefits the health and sports-related physical fitness of children by improving muscular strength and endurance (Melhim, 2001), cardiovascular endurance (Pieter et al., 2009), and body composition (Toskovic, Blessing, & Willford, 2002).

The kicking practice of TKD can be an excellent way to develop postural control since it has opportunity to practice single leg stance while maintaining a stable body posture (Brudnak, Dundero, & Van Hecke, 2002). Standing on one leg can also develop muscle strength in lower extremity (Fong, Chung, Chow, Ma, &

Tsang, 2013d), which may have improved postural control. In addition, Additionally, Poomse in TKD training involves frequent changes in movements and directions for the connections amongst different techniques. The spinning movement and directional changes in TKD training may have helped to stimulate the use of sensory systems to have better postural control. Overall, TKD practice involves maintaining good postural control while performing movements.

Taekwondo and Individuals without Disabilities

Several studies have identified the positive influence of TKD on postural control in healthy adults and adolescents (Brudnak et al., 2002; Cromwell, Meyers, Meyers, & Newton, 2007; Fong & Ng, 2012b; Fong, Tsang & Ng, 2012c; Pons van Dijk, Lenssen, Leffers, Kingma, & Lodder, 2013). In a comparative study by Fong and Ng (2012b), the researchers reported that adolescent TKD practitioners had better use of sensory function and postural control compared to non-TKD practitioners (Fong et al., 2012b). Twenty-one adolescent TKD practitioners (aged 11-14 years old) and 21 age-matched controls were recruited in this study. The practitioners had trained TKD for 1-9 years with a minimum of four hours per week. The controls had no previous experience in TKD or other types of martial arts. A computerized dynamic posturograpy machine, NeuroCom Smart Equitest system, detected the different strategies of sensory system usage while participants were standing still on a platform (sensory organization test). The results demonstrated that adolescents who practiced TKD had improved vestibular function compared to peers who did not practice TKD. In explaining their findings, the authors theorized that the frequent jumps and spinning kicks in TKD training might stimulate the development of the vestibular system (Fong et al., 2012b). Additionally, the researchers compared sway velocity of COP (degrees per second) during the single leg stance between TKD practitioners and non-TKD practitioners. Their findings revealed significantly slower postural sway among the adolescent TKD practitioners compared to the non-TKD practitioners (Fong et al., 2012b).

In another study, Pons van Dijk and colleagues (2013) recruited 24 healthy middle-aged participants (aged 40-71 years old) to investigate the effects of TKD training. The intervention consisted of one hour of TKD training per week for one year. A force plate was used to measure static balance including total length of COP sway (cm) and sway area (cm^2) while participants was standing still with double leg stance. The participants also performed single leg stance in both EO and EC conditions, and the duration of standing time was measured (second). Lastly, the participants performed one leg hopping test, and the mean distance (cm) was measured as a functional balance skill before and after the intervention. After the TKD training, the participants significantly improved postural control during double leg stance test, including sway path and sway area. Additionally, the duration of single leg stance was significantly increased after the TKD training (Pons van Dijk et al., 2013). This finding was consistent with a previous study by Brudank and colleagues (2002) that found that TKD training effectively increased the duration of single leg balance in the senior population after 17 weeks of TKD training (Brudank et al., 2002). Furthermore, the one leg hop test showed a mean distance increase. However, the authors stated that the test has not been validated for balance and may not serve as a functional balance measure. Cromwell and colleagues (2007) also studied the effects of TKD training on functional balance and walking ability in order adults. They found that the participants reaching ability, gait stability, and walking velocity had significantly more improvements after 11 weeks of training than those participants in a control group who did not receive any training. The researchers concluded that TKD was effective for improving balance and walking ability in the elderly population (Cromwell et al., 2007).

Taekwondo and Individual with Disabilities

The effects of TKD training on postural control also have been investigated in children with developmental coordination disorder (DCD) (Fong et al., 2012c, 2013d). Children with DCD have similar motor delays to children with ASD, including postural control impairments. Forty-four children with DCD and 18 children without DCD participated in this study. The children with DCD were divided into two groups: a TKD group (one hour per week for 12 weeks) and a non-TKD group. Postural control was measured using the NeuroCom Smart Equitest system, including the double leg stance with various sensory conditions and the single leg stance test. After 3 months of TKD training, the children in the TKD training group significantly improved their postural control and decreased postural sway during the single leg stance test compared to those controls who did not receive the TKD training (Fong et al., 2012c)

Fong and colleagues (2013d) also conducted another study in which the researchers measured static and dynamic postural control using the NeuroCom Smart Equitest system. The single leg stance test measured postural sway while standing on leg at a time with EO and EC condition. The motor control test measured the reaction time (millimeters per second) from the unexpected movement of forceplate and to the initiation of force produce on their feet. The participants were divided into three groups: children with DCD (TKD group), children with DCD (non-TKD group), and age-matched healthy controls. After 3 months of TKD training (one hour per week for 12 weeks), the TKD group showed significantly slower sway velocity during the single leg stance compared to the non-

TKD group and the healthy controls. There was no significant improvement in MCT. These findings indicate that TKD training may improve static single leg standing balance but that the benefits were minimal for reactive balance control (Fong et al., 2013d). However, the authors also explained that a three month TKD intervention is a relatively short time frame for finding a significant improvement in dynamic balance control. An additional outcome in this study was the difference between knee muscle strength before and after the intervention. Researchers found that postural control improvement is also associated with improved isokinetic knee extensor muscle strength (only 180 degrees per second, but not at 60 or 240 degree per secconds). Overall, there is consensus in the literature that TKD training was effective in improving postural control during the single leg stance performance.

Significance of the Study

Children with ASD display poor postural control compared to children without ASD of the same age. This may limit opportunities for engaging in physical activities. Previous researchers found positive health outcomes including improved balance in children with ASD through horseback riding and swimming intervention. Yet, there is an overall lack of research examining early childhood interventions for children with ASD for improving their postural control. However, studies of TKD training have shown improvement of postural control in adults without disabilities (Pons van Dijk et al., 2013) and in adolescents with another form of neurological disorder (Fong et al., 2012c, 2013d). But, no study has assessed the effects of TKD on balance for children with ASD.

Based on the other findings, TKD training could be beneficial for the ASD population as it could improve overall fitness including postural control and balance-related skills. Such postural control development in children with ASD also may help to establish age-appropriate functional motor skills. All of this can prepare individuals for community-based fitness programs or inclusive physical activity settings. Therefore, it is important to examine the role that TKD training could play as an enjoyable, yet challenging, therapeutic exercise program for the ASD population. Thus, the purpose of this study is to investigate the effects of TKD on postural control in children with ASD. We hypothesize that TKD training will positively affect postural control in youth with ASD.

Methods

This study was a convenience sampling, progressive cohort intervention study. After confirming the diagnosis, initial data was collected. The participants self-selected into either the TKD intervention or the control group. Eight youth with ASD were in the intervention group and participated in TKD training. During the eight-week intervention, six youth with ASD in the control group were asked to continue their daily routine. After eight weeks, post-data was collected.

Participants

A total of 14 youths with ASD, between the ages of 8 and 14 years, participated in this study. The participants were recruited for this study through autism support groups, community centers, organizations, flyers, presentations, and word-of-mouth. The inclusion criteria for the participants were (1) a formal diagnosis of ASD confirmed by a physician; (2) aged 6 to 15 years old; (3) the ability to follow instructions; (4) the ability to participate in a fifty-minute exercise program for the duration of the study (8 weeks). The exclusion criteria included: (1) a medical or surgical treatment within six months of the study; (2) current participation in any forms of martial art programs; (3) additional physical complications that would prevent participation in moderate to vigorous physical activity; (4) a plan to participate in any new structured physical activity program that conflicts with the duration of the study, not including school-based physical education. This study was approved by the institutional review board at California State University, Northridge, where the study was carried out. Prior to the initial data collection, written consent forms were obtained from the participants' parents or guardians and assent forms were also collected from the participants. Participants' demographic information is summarized in the Table1.

Instrumentation

Postural control was evaluated using a clinically validated long-dual force plate (NeuroCom Balance Manager, International Inc. Clackamas OR, USA). Postural control during static activity (double leg stance and single leg stance) was measured by COG sway velocity (degrees per second). Postural control during functional activity (step-quick-turn test) was measured in time (second). The Pediatric Balance Scale (PBS) was also used as a functional measure of postural control.

Assessment

The children were tested individually in a quiet laboratory room. During pre- and post-data assessment, one or two active spotters were positioned around the force plate for safety. Each child's foot position was marked on the force plate and recorded to ensure that all trials were performed at the same spot. The children were asked to stand barefoot with their heels on a mark on the force plate with their arm at their sides. They were required to look straight ahead at a marker on a screen which was adjusted to their eye level. Before the functional balance test (step-quick-turn), the participants watched a short video, showing exactly what they needed to perform, and were asked to follow the same movement. The video was originally provided by NeuroCom software. One practice trial was suggested for both sides. The participants were required to perform three trials under each condition with one-minute rest interval between trials. The data of three trials were averaged for each test conditions. The trials that were eliminated by challenging behaviors such as stereotypical ASD movements and foot displacement were excluded and replaced by additional trials.

Static Balance Tests

The double leg stance test (Modified Test of Sensory Interaction on Balance [mCTSIB]) was measured by COG sway velocity (degrees per second) under four different test conditions: (1) a stable surface with eyes open; (2) a stable surface with eyes closed; (3) an unstable surface with eyes open; and (4) an unstable surface with eyes closed. Three ten-second trials were recorded for each test conditions. The surface condition was modified using a foam mat (46 x 46 x 13 cm) to challenge somatosensory input. The average sway velocity of the participant's center of gravity was calculated for each trial and averaged for each test condition (a total of 12 trials, four different mean values under the four conditions).

The single leg stance test (Unilateral Stance) was also measured by COG sway velocity (degrees per second) under four different conditions while participants were standing: 1) on the right leg with eyes open; 2) on the right leg with eyes closed; 3) on the left leg with eyes open; and 4) on the left leg with eyes closed. Three ten-second trials were recorded on each leg. The trials were performed on a firm surface, and testing was terminated if the participant experienced a loss of balance before the completion of 10 seconds single leg standing. Participants were encouraged to try the second trial under the same condition. If participants fall in the second trial, COG velocity was recorded as 12, indicating a fell. Mistrials were not scored. The COG velocity was recorded for each leg under each condition.

Functional Balance Tests

The step-quick-turn (SQT) test measured time to complete (second) a turn in both left and right directions. The participants were asked to stand on a long force plate, take two steps forward on cue, quickly turn (180 degrees), and walk back to the starting position.

Pediatric Balance Scale (PBS) consists of 14 items balance-related skills, with a maximum score of 56. The skill items include sitting to standing, standing to sitting, transfers, standing unsupported, sitting unsupported, standing with eyes closed, standing with feet together, standing with one foot in front, standing on one foot, turning 360 degrees, turning to look behind, retrieving object from floor, placing alternative foot on stool, and reaching forward with outstretched arm. PBS was scored after completion of the static balance tests in pre- and post-assessments.

Intervention

Participants in the Taekwondo intervention group performed 50 minutes of various martial art techniques two times per week for eight weeks. The intervention was offered at either Kyu martial arts studio in the City of Northridge or in the activity room in an activity room at All Nations Church in the City of Sunland. The first cohort of the intervention group participated in TKD training at the Kyu martial arts studio. The second cohort practiced TKD at an activity room at All Nations Church. The site condition was similar with mirrors and foam mat on the floor. The TKD intervention program consisted of 10 minutes of warm-up, 20 minutes of block, punching, and kicking, 10 minutes of Poomse, and 10 minutes of cool-down. Sample of TKD intervention plan was provided at Table 2. The TKD sessions were led by qualified TKD instructors including the primary researcher.

Data Analysis

To analyze the overall effect of TKD training, a 2 x 2 mixed model ANOVA was used. The between-subject factor was two groups (intervention versus control group) and the within-subject factors were time (pre- versus post-test). Independent t-test was performed to see if there was any significant baseline between-group difference in all measures. When group interaction was found, paired t-tests were used to investigate whether there were any pre- and post-differences within each group.

The following dependent variables were analyzed: COG sway velocity (degrees per second) and time of completion (second) under the double leg stance (stable and unstable surface with EO and EC condition), the single leg stance (standing on right and left leg with EO and EC condition), and the step-quick-turn tests (turning time to right and left). It was hypothesized that the 8-week TKD training would affect postural control, which would be shown by slower COG sway velocity during static standing and faster turning time. The significance level was set at 0.05 (two-tailed). All statistical analyses were performed using SPSS version 22.0 software (SPSS Inc., Chicago, IL).

Participants' attendance was recorded for each TKD session. Participants were considered to complete a session if they completed 80 % or more (40 minutes) of the session. For example, when a child showed atypical behavior such as a tantrum and left the session less than 40 minutes into the session, that day was considered an absent and eliminated from the attendance rate. After the eight-week TKD training was completed, a mean adherence rate (percentage) in the TKD group was found. Furthermore, a mean value of PBS was found in pre- and post-assessments.

Results

After 8-week intervention, a total of 14 youth with ASD completed pre- and post-tests in this study. Eight youth with ASD participated in TKD intervention and six youth with ASD did receive no intervention as control. Three youth with ASD were excluded after the pre-test due to the inability to follow instruction and test protocol. A youth with ASD was excluded from the control group due to the different diagnosis (Asperger Syndrome). Participants' information is summarized at Table 1. The eight youth with ASD in the TKD group showed 92.3% of adherence rate.

The results indicate that the group difference was shown in the right leg standing with eyes closed condition. Overall multivariate test shows no statistical significant differences (Pillai's Trace = 0.145, $F_{(1,12)}$ = 2.041). Also, the main within-subject effect is not statistical significant neither the interaction ($F_{(1,12)}$ = 2.041, *p*=0.590). However, the between-subject effect is shown statistically significant difference ($F_{(1,12)}$ = 4.974, *p*=.046). Therefore, sway velocity under this condition was overall not statistically significant different; however statistical significance was found between groups (see Table 2 and Figure 1).

The single leg stance on the left leg with eyes open condition showed statistically significant difference in sway velocity within subjects on pre- and post-tests based on the overall multivariate test (Pillai's Trace =0.332, $F_{(1,12)}$ =5.974). There was no statistical significant difference in two group interactions ($F_{(1,12)}$=1.611, *p* =.228). Between-subject effect wan not statistically significant ($F_{(1,12)}$=1.802, *p*=.204). On the other hand, the within-subject effect has shown statistical difference ($F_{(1,12)}$= 5.974, *p* = .031).Therefore, both control and TKD group improved from pre to post condition. Although there was no significant between-group difference, the paired t-test was used for further looking of each group. The TKD group (pre: 4.50 ± 4.16, post: 2.14 ± 1.28) showed a significant decrease of mean score after the intervention and the t-score was statistically significant ($t_{(7)}$= 3.240, p=0.014). The control group (pre: 5.09 ± 4.39, post: 4.61 ± 3.99) did also show slight decrease of mean score, but it was not statistically significant ($t_{(5)}$=.6175, p=0.530). Therefore, overall within-subject main effect can be attributed to improve their TKD group (see Table 3 and Figure 2).

There was a trend for the TKD group to be different from the control group (unstable surface with eyes closed condition). Although there was no between- and within-group interaction, the TKD group demonstrated small trend of improvement. In order to examine their initial state of groups, paired t-test was used. The mean values of TKD (pre: 2.17 ± 0.79, post: 1.61 ± 0.56) was different before and after the intervention. The t- score was ($t_{(2)}$=2.298, p=0.055), which has a strong trend but it is not statistical different. The mean values in control group were (pre: 2.32 ± 0.62, post: 2.00 ± 0.35) and also stayed non-statistically different with a strong trend as the t- score was ($t_{(12)}$=2.046, p=0.096). Therefore the main effect difference within groups in pre-post is coming from the combination of two groups as one increasing the degrees of freedom and the statistical power. The slope of improvement in TKD was more profound and demonstrated (see Table 3 and Figure 3) a stronger effect along with the fact that TKD showed a stronger trend.

The study outcome was hypothesized that the turning time of left and right side will be decreased after the TKD training. Using pairwise t-tests on pre post measurements the right leg turning time (pre: 2.10 ± 1.02, post: 1.52 ± 0.59) on TKD group showed a trend of decrease ($t_{(7)}$=2.103, p=0.073). Whereas the control group did improve ($t_{(5)}$=1.380, p=0.226) (see Table 3 and Figure 4).

The mean value of the PBS in the TKD group was 54.38 points before the intervention and 55.25 points after the intervention. Four youths with ASD in the TKD group received a maximum score of the PBS in the pre-data collection. However, following the eight-week intervention, a total of seven youth with ASD achieved maximum scores. The mean value of the PBS in the control group was 54.83 points before the intervention and 55.5 after (see Table 5).

Discussion

This study aimed to examine the effects of TKD training on postural control in youth with ASD. After the eight-week TKD training, youth with ASD showed a significant improvement in postural control compared to those who did not participate in the training. The TKD training was effective in improving the single leg stance of the right leg without vision in youth with ASD while control stayed same. After the eight-week intervention, youth who received TKD training significantly improved their postural control in the single leg stance of the left leg with vision as compared to their baseline performance. Youth in the control group who did not participate in TKD training also showed slight improvement of postural control under the same condition. Additionally, trends of improvement in postural control were found under the double leg stance test with the most challenging condition (unstable surface with eyes closed condition) and the functional balance test (step-quick-turn test). The task-specific clinical balance scale (PBS) did not show any significant changes in balance performances.

Our findings of increased postural control during the single leg stance test after the TKD training are consistent with previous studies (Fong & Ng, 2012b, 2012c, 2013d; Pons van Dijk et al., 2013). Two studies have identified the positive influence of TKD training on postural control in healthy adult and adolescents (Fong & Ng, 2012b; Pons van Dijk et al., 2013). Fong and Ng (2012) reported that adolescent TKD practitioners demonstrated significantly lower postural sway during the single leg stance. Based on their findings, the TKD practitioners rely more on their vision and vestibular function compared to those who did not have experience in TKD (Fong & Ng, 2012b). In addition, another study documented improved duration of single leg stance in individuals over 40 years of age after

TKD training (Pons van Dijk et al., 2013). Previous researchers also reported the benefits of TKD training in children with Developmental Coordination Disorder (DCD) (Fong et al., 2012c, 2013d). After 3 months of TKD training, the children with DCD significantly improved postural control during the single leg stance compared to those who did not receive the TKD training (Fong et al., 2012c; Fong et al., 2013d).

The improvement of single leg stance found in our results can be explained by kicking practice in TKD. Kicking is a primary component of TKD and requires a stable body balance on one leg. Repeated practice in kicking while standing on one leg may improve the ability to balance during the single leg stance. In a previous study, children with ASD showed postural control improvement through specific balance training, including standing on one leg with eyes open and closed (Yanardag et al., 2015). The kicking of TKD training provides similar opportunities to perform one leg standing. Therefore, children who practice TKD kicking may develop better postural control and body alignment while single leg standing. Kicking practice also develops strength in the lower extremities and core. Improvements in knee extensors (quadriceps) strength were found after 3 months of TKD practice in children with DCD (Fong et al., 2013d). Positive changes found in postural control during single leg stance may be related to the improved isokinetic knee extensor muscle strength after TKD training.

Furthermore, TKD training may have stimulated the use of sensory systems, which aids in maintaining efficient postural control. Fong & Ng (2012b) reported that experienced TKD practitioners rely more on their vision and vestibular function while balancing (Fong et al., 2012b). Based on their findings, the authors theorized that the frequent jumps and spinning kicks in TKD training might stimulate the development of the sensory systems. The TKD intervention in this study did not involve high levels of kicking techniques or spinning movements. However, the participants practiced Poomse, which incorporates frequent changes of movements and direction. Practice of Poomse movements may enable children with ASD to cope with highly demanding sensory inputs while balancing. Therefore, TKD training might enhance the effective usage of sensory systems for integrating somatosensory, visual and vestibular inputs.

From the double leg stance test with various conditions, we found a strong trend of improvement in postural control after the TKD training. The balance improvement was found when the test was more challenging, standing on a foam pad and without vision, out of four different conditions. The rest of conditions did not show any significant increases or decreases in postural control. As the test increases in difficulty, the participants expressed difficulty more to complete the tasks as these get more challenging in the beginning. The participants demonstrated more visible reduction of postural sway while performing the most challenging task after the eight-week TKD training. This trend may indicate that the most difficult balancing task has the most room for improvement between the beginning and the end of the TKD training. Most of the participants (five out of eight youth with ASD) improved the postural control after the TKD training, but some of them were maintained or did not improve as much. These factors increased the standard deviation and the paired t-test did not show any statistical difference before and after the intervention. This might become more effective with prolonged training and result in less body sway while standing or preparing balance tasks.

In the functional balance task (step-quick-turn), the paired t-test also did not show any statistical difference in the TKD group due to the increased standard deviation. However, most of the participants (five out of eight youth with ASD) who received the TKD training improved their turning performance (right turn). The results identify that youth with autism can improve functional balance through TKD training as shown in our result. Compare to other balance tasks, turning ability is a more important influence on the occurrence of falls than other abilities. Thus, the functional balance skills may impact their physical activity or sport activity participation. In a study by Pons van Dijk and colleagues (2013), the participants improved distance (cm) on a one leg-hop test after TKD training. However, the authors mentioned that the test has not been validated for balance and may not serve as measure of a dynamic balance (Pons van Dijk et al., 2013).

The turning ability to the left side did not change before and after the intervention compared to the baseline. This result is particularly interesting because seven out of eight children with ASD in the TKD group used their right side as their dominant foot. Although the TKD program was designed to practice both legs equally, favorable results were seen on their dominant side. Based on the observation, the participants showed more effort into their dominant leg (kicking leg). This may explain why the left leg improved the postural control in the static balance task, and the right leg enhanced the functional balance task. While performing the right side kick in TKD, the left leg was forced to support their body weight and repeatedly undergo left single leg stance. This circumstance may explain the improvement in single leg standing balance on the left leg. On the other hand, while standing on the left leg, the right foot continuously practiced the motor control such as aiming the target and changing the ankle movement. This practice may have transferred to the pivoting movement of right foot when they turn to the right side.

Although the PBS did not reveal clear balance problems in postural control, the participants showed large amounts of postural sway, which resulted in a larger mean of COP sway velocity. Although our participants had high scores on this scale in the baseline, they showed poor balance ability with a more sensitive clinical test. These findings indicate that the PBS seems to lack sensitivity in detecting changes in balance for this population. Additionally, the participants in this study began with high scores on the PBS from the baseline balance test. After the intervention, the participants showed improvement of postural control with a more sensitive clinical test. However, the PBS demonstrated a ceiling effect and did not detect the further improvement of postural control. Therefore, functional balance measurements with a more effective tool is needed such as a M-ABC, which provides impairment scores for different items at each age band but with similar skills.

A couple of limitations need to be taken into account when interpreting our results. First, the sample size of this study is too small to represent our findings to the entire population with ASD. Second, test protocols such as the double leg standing with a less challenging conditions and the PBS were not suitable to detect differences before and after the TKD intervention. Lastly, due to the short intervention period of this study, a few of the test conditions showed only a trend of improvement and did not show findings of statistical significance. Therefore, future studies are suggested using a larger sample size and conducting a longer duration of intervention. Additionally, it is recommended that future studies explore the relationship between symptom severity and the effectiveness of Taekwondo. 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. It is highly important to control the possible confounding variables such as the severity in the presentation of the disorder.

In conclusion, children with ASD have shown improvements of postural control during the single leg standing balance after the TKD training. Our findings indicate that eight-week TKD training can increase postural control in youth with ASD. Moreover, the participants showed high adherence in the Taekwondo sessions (92.3%). This finding may support that TKD training also can be an enjoyable therapeutic exercise option for youth with ASD. Based on the findings in this study, TKD may provide an effective and enjoyable therapeutic option. This study outcome will aid clinicians, rehabilitators, and researchers, when developing a therapeutic intervention for youth with ASD.

References

American Psychiatric Association, A. (2013). Diagnostic and Statistical Manual of Mental Disorders : DSM-V. Washington, DC.

Brudnak, M. A., Dundero, D., & Van Hecke, F. M. (2002). Are the `hard' martial arts, such as the Korean martial art, TaeKwon-Do, of benefit to senior citizens? *Medical Hypotheses*, 59(4), 485–491. http://doi.org/10.1016/S0306-9877(02)00203-7

Centers for Disease Controls and Prevention (2014). Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States, 2012. *Morbidity and Mortality weekly report. Surveillance summarie* , 63(2), 1-21.

Centers for Disease Controls and Prevention (2010). Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 14 sites, United States, 2008. *Morbidity and Mortality weekly report. Surveillance summaries*, 61(3), 1-19.

Centers for Disease Controls and Prevention (2002). Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, six sites, United States, 2000. *Morbidity and Mortality weekly report. Surveillance summaries*, 56(1), 1-11.

Cromwell, R. L., Meyers, P. M., Meyers, P. E., & Newton, R. A. (2007). Tae Kwon Do: An Effective Exercise for Improving Balance and Walking Ability in Older Adults. *The Journals of Gerontology Series A Biological*

Sciences and Medical Sciences, *62*(6), 641–646.

Fong, S., & Ng, G. (2011a). Does Taekwondo training improve physical fitness?. *Physical Therapy in Sport,* 12(2), 100-6.

Fong, S., & Ng, G. (2012b). Sensory integration and standing balance in adolescent taekwondo practitioners. *Pediatric Exercise Science,* 24(1), 142-151.

Fong, S., Tsang, W., & Ng, G. (2012c). Taekwondo training speeds up the development of balance and sensory functions in young adolescents *Journal of Science Medicien in Sport.*15(1), 64-68.

Fong, S., Chung, J., Chow, L., Ma, A., & Tsang, W. (2013d). Differential effect of Taekwondo training on knee muscle strength and reactive and static balance control in children with developmental coordination disorder: A randomized controlled trial. *Research in Developmental Disabilities,* 34(5), 1446-55.

Fournier, K. A., Kimberg, C. I., Radonovich, K. J., Tillman, M. D., Chow, J. W., Lewis, M. H., . . . Hass, C. J. (2010). Decreased static and dynamic postural control in children with autism spectrum disorders. *Gait & Posture,* 32(1), 6-9.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., & Baird, G. (2009). Impairment in movement skills of children with autistic spectrum disorders *Dev Med Child Neurol.* 51(4), 311-6. England.

Haywood, K.,& Getchell, N. (2014) *Life span motor development 6th edition,* Human Kinetics.

Hwang, A.-W., Wu, I.-C., Nan, C. C., Cheng, H. Y., & Chen, C.-L. (2014). The Correlates of Body Mass Index and Risk Factors for Being Overweight Among Preschoolers With Motor Delay. *Adapted physical activity* *quarterly,* 31(2), 125-143.

Jansiewicz, E. M., Goldberg, M. C., Newschaffer, C. J., Denckla, M. B., Landa, R., & Mostofsky, S. H. (2006). Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. *Journal of Autism & Developemntal Disorders*, 36(5), 613-621.

Jasmin, E., Couture, M., McKinley, P., Reid, G., Fombonne, E., & Gisel, E. (2009). Sensori-motor and daily living skills of preschool children with autism spectrum disorders. *Journal of Autism & Developmental Disorders,* 39(2), 231-241.

Kohen-Raz, R., Volkmar, F. R., & Cohen, D. J. (1992). Postural control in children with autism. *Journal of Autism & Developmental Disorders*, 22(3), 419-432.

Koterba, E. A., Leezenbaum, N. B., & Iverson, J. M. (2014). Object exploration at 6 and 9 months in infants with and without risk for autism. *Autism,* 18(2), 97-105.

Landa, R. J. (2008). Diagnosis of autism spectrum disorders in the first 3 years of life. *Nature Clinical Practice Neurology,* 4(3), 138-147.

Lloyd, M., MacDonald, M., & Lord, C. (2013). Motor skills of toddlers with autism spectrum disorders. *Autism,* 17(2), 133-146.

MacDonald, M., Lord, C., & Ulrich, D. A. (2014). Motor skills and calibrated autism severity in young children with autism spectrum disorder. *Adapted physical activity quarterly,* 31(2), 95-105.

Melhim, A. F. (2001). Aerobic and anaerobic power responses to the practice of taekwon-do. *Journal of Sports & Medicine*, 35(4), 231-234.

Memari, A. H., Ghanouni, P., Gharibzadeh, S., Eghlidi, J., Ziaee, V., & Moshayedi,

P. (2013). Postural sway patterns in children with autism spectrum disorder compared with typically developing children. *Research in Autism Spectrum Disorders*, 7(2), 325–332. http://doi.org/10.1016/j.rasd.2012.09.010

Minshew, N. J., Sung, K., Jones, B. L., & Furman, J. M. (2004). Underdevelopment of the postural control system in autism. *Neurology*, 63(11), 2056-61.

Molloy, C. A., Dietrich, K. N., & Bhattacharya, A. (2003). Postural stability in children with autism spectrum disorder. *Journal of Autism & Developemntal Disorders*, 33(6), 643-652.

Must, A., Phillips, S. M., Curtin, C., Anderson, S. E., Maslin, M., Lividini, K., & Bandini, L. G. (2013). Comparison of sedentary behaviors between children with autism spectrum disorders and typically developing children. *Autism*, 18(4), 376-84.

Nickel, L. R., Thatcher, A. R., Keller, F., Wozniak, R. H., & Iverson, J. M. (2013). Posture Development in Infants at Heightened vs. Low Risk for Autism Spectrum Disorders. *Infancy*, 18(5), 639-661.

Pieter, W. (2009) Taekwondo, in Epidemiology of Injury in Olympic Sports, Volume XVI (eds D. J. Caine, P. A. Harmer and M. A. Schiff), Wiley-Blackwell, Oxford, UK. doi: 10.1002/9781444316872.ch19

Pons van Dijk, G., Lenssen, A. F., Leffers, P., Kingma, H., & Lodder, J. (2013). Taekwondo training improves balance in volunteers over 40. *Front Aging Neurosci*, 10(5),1-6. http://doi.org/10.3389/fnagi.2013.00010

Peterson, M. L., Christou, E., & Rosengren, K. S. (2006). Children achieve adult-like sensory integration during stance at 12-years-old. *Gait & Posture*, 23(4), 455-463.

Pollock, A. S., Durward, B. R., Rowe, P. J., & Paul, J. P. (2000). What is balance? *Clinical Rehabilitation,* 14(4), 402-406.

Provost, B., & Lopez, B. R., (2007). A Comparison of Motor Delays in Young Children: Autism Spectrum Disorder, Developmental Delay, and Developmental Concerns. *Journal of Autism and Developmental Disorders,* 37(2), 321-328.

Rinehart, N. J., Bellgrove, M. A., Tonge, B. J., Brereton, A. V., Howells-Rankin, D., & Bradshaw, J. L. (2006). An examination of movement kinematics in young people with high-functioning autism and Asperger's disorder: further evidence for a motor planning deficit. *Journal of Autism and Developmental Disorders*, 36(6), 757-767.

Silkwood-Sherer, D. J., Killian, C. B., Long, T. M., & Martin, K. S. (2012). Hippotherapy—An Intervention to Habilitate Balance Deficits in Children With Movement Disorders: A Clinical Trial. *Physical Therapy*, 92(5), 707–17. http://doi.org/10.2522/ptj.20110081

Sobera, M., Siedlecka, B., & Syczewska, M. (2011). Posture control development in children aged 2-7 years old, based on the changes of repeatability of the stability indices. *Neuroscience Letters*,491(1), 13-17.

Staples, K. L., & Reid, G. (2010). Fundamental movement skills and autism spectrum disorders. *Journal of Autism and Developmental Disorders,* 40(2), 209-217.

Stoit, A. M., van Schie, H. T., Slaats-Willemse, D. I., & Buitelaar, J. K. (2013). Grasping motor impairments in autism: not action planning but movement execution is deficient. *Journal of autism and developmental disorders,* 43(12), 2793-2806.

Travers, B. G., Powell, P. S., Klinger, L. G., & Klinger, M. R. (2013). Motor difficulties in autism spectrum disorder: linking symptom severity and postural stability. *Journal of autism and developmental disorders*, *43*(7), 1568-83.

Winter, D. (1995). Human balance and posture control during standing and walking. *Gait & Posture*, 3(4), 193–214. http://doi.org/10.1016/0966-6362(96)82849-9

Wuang, Y.-P., Wang, C.-C., Huang, M.-H., & Su, C.-Y. (2010). The effectiveness of simulated developmental horse-riding program in children with autism. *Adapted Physical Activity Quarterly: APAQ*, 27(2), 113–126.

Yanardag, M., Erkan, M., Yılmaz, İ., Arıcan, E., & Düzkantar, A. (2015). Teaching advance movement exploration skills in water to children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *9*, 121–129. http://doi.org/10.1016/j.rasd.2014.10.016

Yilmaz, I., Yanardağ, M., Birkan, B., & Brumin, G. (2004). Effects of swimming training on physical fitness and water orientation in autism. *Pediatrics International*, 46(5), 624–626. http://doi.org/10.1111/j.1442-200x.2004.01938.x

Appendix A

Table 1.

Participants' demographic information

	TKD group (n=8)	Control group (n=6)
Age, years	10.25 ± 2.38	10 ± 2.83
Sex (M/F), n	8/0	5/1
Height, cm	121.31 ± 0.60	138.68 ± 14.02
Body weight, kg	97.19 ± 44.65	87.55 ± 30.20
Ethnicity	Asian (5)	Asian (2)
	Caucasian (1)	Caucasian (3)
	Hispanic (2)	Hispanic (1)

Note. Values are mean ± SD

Table 2.

Sample of Taekwondo Intervention Plan

	Duration	Types of activity (Basic)	Types of activity (Progression I)	Types of activity (Progression II)
Warm-up	10 min	Stretching, jogging, & Strengthning (sit-up & push-up)		
Basic motions	20 mim			
Blocks		Upper, down, inside & outside blocks with wide stance	Repeat basic Add duck and jump with narrow stance	Repeat progression I with walking forward/backward
Punching		Body punch with wide stance	Repeat basic Add Jab & Reverse punch with walking stance	Repeat progression I Add hook & uppercut with walking forward/backward
Kicking		Front Kick Round house kick with walking stance	Repeat basic Add Side kick with walking forward	Repeat progression I Add Back kick with running & jumping
Form	10 mim	Form #1 (motion #1-6)	Form #1 (motion #7-10)	Form #1 (motion #11-18)
Cool down	10 mim	Stretching, group game, breath control		

Table 3.

Comparison of outcome measurements in between-groups

	TKD group (n=8)		Control group (n=6)			
	Pre	Post	Pre	Post	$F_{(1, 12)}$	*P*
Double Leg Stance						
Stable EO	0.63 ± 0.20	0.59 ± 0.13	0.61 ± 0.23	0.78 ± 0.30	0.687	0.423
Stable EC	0.88 ± 0.35	0.80 ± 0.18	0.87 ± 0.37	0.85 ± 0.22	0.030	0.865
Unstable EO	1.21 ±0.44	1.08 ± 0.26	1.31 ± 0.44	1.26 ± 0.55	0.508	0.490
Unstable EC	2.17 ± 0.79	1.61 ± 0.56	2.32 ± 0.62	2.00 ± 0.35	0.890	0.364
Single Leg Stance						
Right EO	4.50 ± 4.16	2.14 ± 1.28	5.09 ± 4.39	4.61 ± 3.99	0.650	0.436
Right EC	**10.03 ± 2.36**	**8.26 ± 4.09**	**12.00 ± 0.00**	**11.47 ± 1.31**	**4.974**	***0.046**
Left EO	4.56 ± 3.52	2.49 ± 2.47	6.39 ± 4.66	5.73 ± 4.10	1.802	0.204
Left EC	9.29 ± 2.56	8.14 ± 3.63	11.49 ± 1.25	9.51 ± 3.90	1.630	0.226
Step-Quick-Turn						
Right turn	2.10 ± 1.02	1.52 ± 0.59	2.10 ± 1.27	1.64 ± 0.70	0.019	0.893
Left turn	1.71 ± 0.70	1.68 ± 0.77	2.20 ± 1.35	1.86 ± 0.99	0.488	0.498

Note. Values are mean ± SD or p values.

* Between-group significant (Taekwondo versus Control group) ($p < .05$)

Table 4.

Comparison of outcome measurements in within-groups

	TKD group (n=8)		Control Group (n=6)	
	t	*p*	t	*p*
Double Leg Stance				
Stable EO	0.863	0.417	-1.361	0.232
Stable EC	0.590	0.574	.0178	0.866
Unstable EO	1.035	0.335	0.293	0.781
Unstable EC	**2.298**	**0.055**	**2.046**	**0.096**
Single Leg Stance				
Right EO	1.630	0.147	0.489	0.645
Right EC	1.336	0.223	1.000	0.363
Left EO	**3.240**	***0.014**	**0.675**	**0.530**
Left EC	1.081	0.316	1.398	0.221
Step-Quick-Turn				
Right turn	**2.103**	**0.073**	**0.380**	**0.226**
Left turn	0.227	0.827	1.072	0.333

* Within-TKD group significant (pre- versus post-test) ($p < .05$)

Table 5.

Individual Scores of Pediatric Balance Scale

Number of participant	TKD group		Control group	
	Pre	Post	Pre	Post
1	55	56	55	55
2	55	56	56	56
3	52	56	56	56
4	56	56	56	56
5	56	56	53	56
6	49	50	53	54
7	56	56	.	.
8	56	56	.	.
Mean	**54.38**	**55.25**	**54.83**	**55.5**

Note. Maximum score is 56.

Appendix B

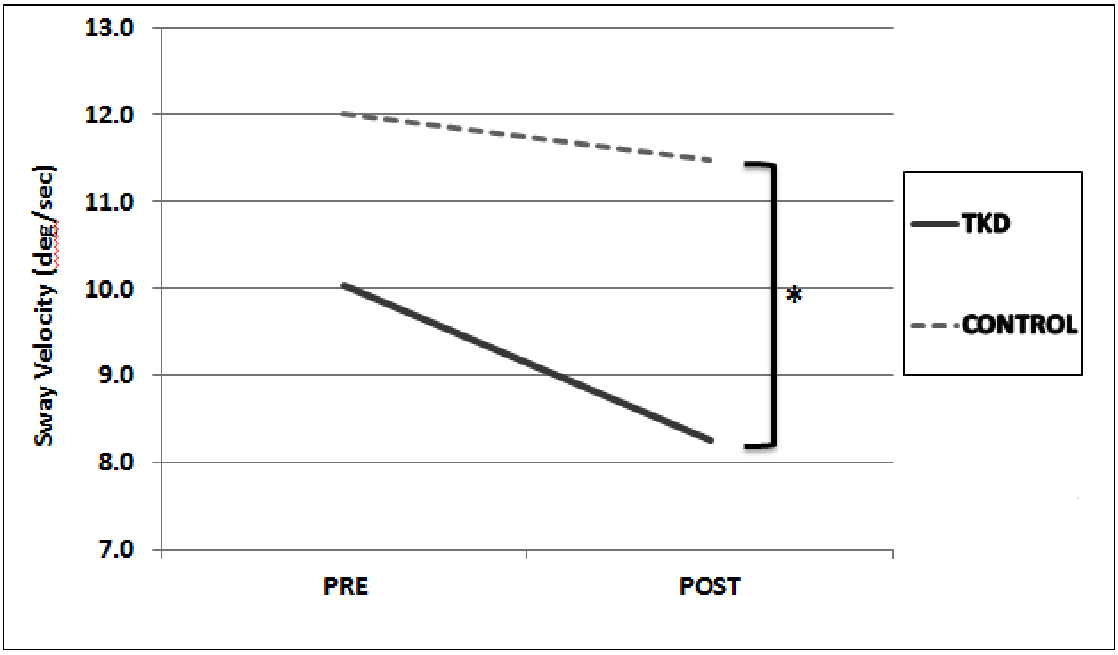

Figure1. Between-group comparison of single leg stance test

Right leg with eyes closed condition

TKD (Taekwondo group) versus control group

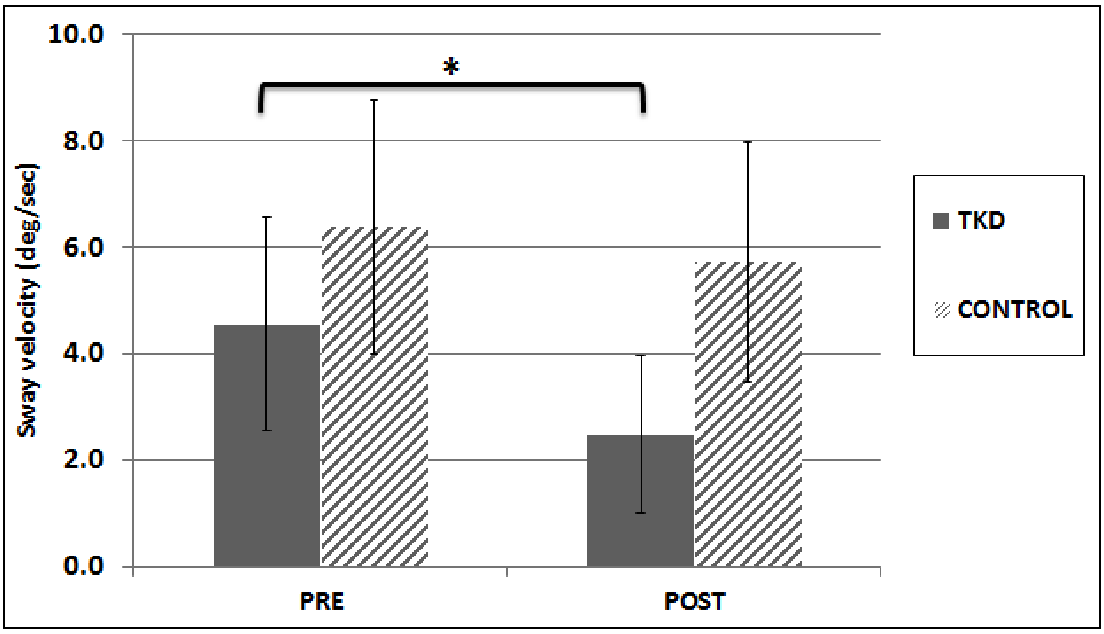

Figure 2. Within-group comparison of single leg stance test

Left leg with eyes open condition

Pre- versus Post-test in TKD (Taekwondo) group

Pre- versus Post-test in control group

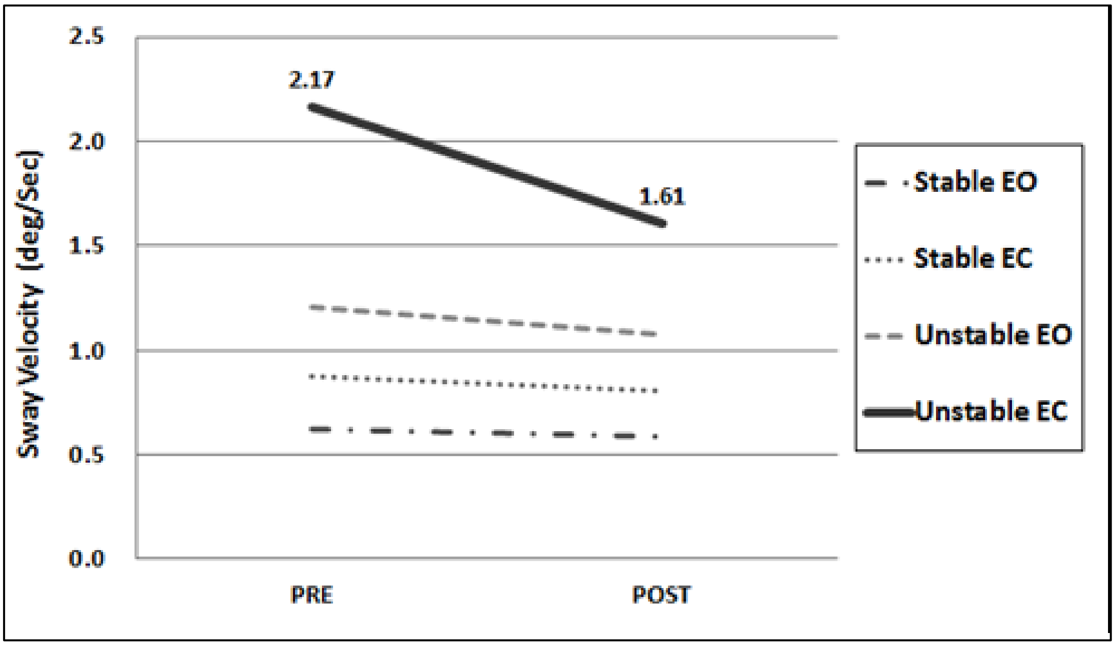

Figure 3. Mean COG sway velocity during double leg stance test

EO (eyes open), EC (eyes closed) condition

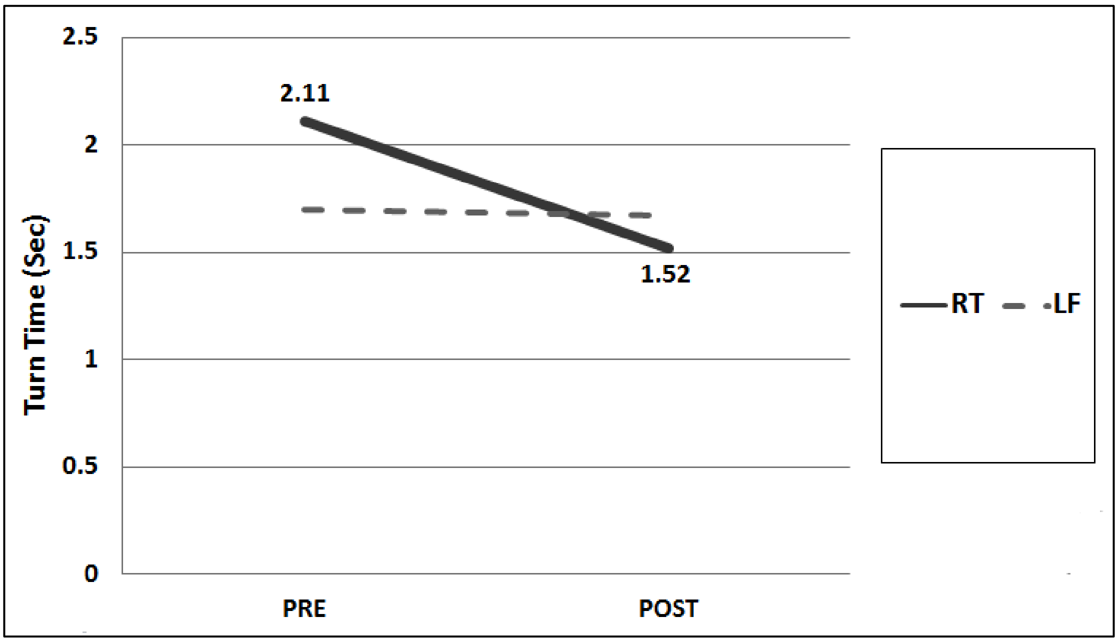

Figure 4. Mean time during step-quick-turn test

RT (right), LF (left) turning time (second)

Appendix C

IRB Human Subject Protocols

C1. Parent or Guardian Consent Form

California State University, Northridge

PARENT OR GUARDIAN CONSENT FOR CHILD PARTICIPATION IN RESEARCH

Effects of Taekwondo and Nintendo Wii Intervention on Postural Control in Youth with Autism Spectrum Diagnosis

You are being asked to provide consent for your child to participate in a research study titled "Effects of Taekwondo and Nintendo Wii intervention on postural control in youth with autism spectrum diagnosis (ASD)", a study conducted by Yumi Kim and Jae Chun Lim as part of the requirements for the M.S. degree in Kinesiology at California State University, Northridge. Participating in this study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want to allow your child to participate.

PURPOSE OF STUDY

The purpose of this study is to investigate the effectiveness of Taekwondo and Wii intervention on postural control in youth with ASD.

PARTICIPATNS

Inclusion Requirements

Your child is eligible to participate in this study if he/she is

- A medical diagnosis of ASD
- Ages 6 to 15 years old
- Medical release form obtained from primary physician
- Able to understand verbal instruction, as well as communicate and comprehend English to promote the safety of instruction
- Able to participate in an exercise program for 50 minutes for the duration of study (12 weeks)

Exclusion Requirements

Your child is not eligible to participate in this study if he/she is

- Medical/surgical treatment within 6 months of the study
- Current participation in a martial art program
- Regular Wii or Xbox Kinect user
- Additional physical complication that would prevent them from participating in moderate to vigorous physical activity
- Unable to follow instructions
- Any plan to participate in a new structured physical activity program that conflicts with the duration of the study, not including school-based physical activity

Time Commitment

This study will involve total of 19 hours of your child's time over the 12 weeks (3 months), including 16 hours of physical activity intervention (50minutes/ 2times/ 8weeks) and 3 hours of balance assessments (60 minutes for pre and 40 minutes for mid, post, and follow-up).

PROCEDURES

<u>Data collection procedures</u>
Your child will be randomly selected into either Taekwondo group, Nintendo Wii group, or control group. You and your child will visit CSU Northridge 4 times during the study. When you come for initial meeting, we will collect your child's information form, assent form, medical release form, and this parent/guardian consent form. Then, your child will be randomly selected into either Wii activities group or control group. Lastly, we will take your child's height and weight and then we will ask your child to stand on a special platform that measures how still people stand. Each child will be asked to stand on the platform with their eyes open, eyes closed for up to 20 seconds. This will be repeated three times. We will then ask your child to do some balance activities such as standing up from chair, moving from one chair to another, stand on one foot, turn in a circle, step-up onto a box. This will take about 40 minutes. Each child will be assessed before Taekwondo or Wii activities begin, during the 5th week and after the activities end on the 9th week and 12th week. All balance assessments will be videotaped (audio will be turned off) for reference when scoring the assessments. We will give you appointment dates for all the rest of the visits.

<u>Intervention procedures</u>
Yumi Kim will lead the Taekwondo program and Jae Lim will conduct the Nintendo Wii activity program. The physical activity programs, Taekwondo or Nintendo Wii activities will be held at in several locations; All Nations Church, Kyu Martial Arts

Studio (Taekwondo only), CSU Northridge (Wii activities only), or participant's home (Wii activities only). The program will run two days per week for 50 minutes. Times and dates will be provided at the initial data collection meeting.

If your child is chosen for the control group, he/she will continue regular daily routines for the duration of the study. Following the 12 weeks of the study, your child will be invited to participate in either Taekwondo or Nintendo Wii program for 8 weeks.

RISKS AND DISCOMFORTS

As in all Physical activities including Taekwondo and Nintendo Wii activities, there are possible risks such as falling, sprains or bruises, physical fatigue, muscle cramps, dehydration, and cardiovascular distress. We will minimize these risks by having foam flooring, research assistants to spot and help children as well as monitor children for fatigue, having water available at all times, and encourage children to take breaks as needed. All venues have telephone service, should an emergency arise emergency services will be contacted, all medical and emergency services are at your own cost. Should your child experience emotional stress or anxiety we will provide a list of local counseling services, these services are at your own cost.

BENEFITS

The possible benefits your child may experience from this study may include: overall fitness improvement, balance improvement, participation in a new organized exercise program, and preparation for community- and school-based physical activity programs. This study will contribute to community by expanding the knowledge of Taekwondo and Nintendo Wii activities for individuals with ASD. This study's finding may expand the use of Nintendo Wii in homes or clinics, and Taekwondo in group exercise classes to improve balance for individuals who have poor balance.

ALTERNATIVES TO PARTICIPATION

The only alternative to participation in this study is not to participate.

COMPENSATION, COSTS AND REIMBURSEMENT

Your child will not be paid for his or her participation in this research study.

You will not be reimbursed for any out of pocket expenses such as parking, traveling, and medical fees.

WITHDRAWAL OR TERMINATION FROM THE STUDY AND

CONSEQUENCES

You are free to withdraw your child from this study at any time. If you decide to withdraw your child from this study, you should notify the research team immediately. The research team may also end your child's participation in this study if he/she does not follow instructions, misses scheduled visits, or if his/her safety and welfare are at risk.

CONFIDENTIALITY

Subject Identifiable Data

All identifiable information that will be collected about your child will be removed and replaced with a code. A list of linking the code and your child's identifiable information will be kept separate from the research data in a locked office at the University.

Data Storage

All research data will be stored electronically on a secure computer with password protection. The video recordings will also be transcribed to the computer.

Date Access

Only the researcher (Yumi Kim and Jae Chun Lim) and faculty advisor (Dr. Teri Todd) named on the first page of this form will have access to your child's study records. Any information derived from this research project that personally identifies your child will not be voluntarily released or disclosed without your separate consent, except as specifically required by law. Publications and/or presentations that result from this study will not include identifiable information about your child.

Data Retention

The research data will be kept for approximately three years following completion of study (final presentation/defense of the research) and then it will be destroyed.

MANDATED REPORTING

Under California law, the researchers are required to report known or reasonably suspected incidents of abuse or neglect of a child, dependent adult or elder, including, but not limited to, physical, sexual, emotional, and financial abuse or neglect. If any researcher has or is given such information, he or she may be required to report it to the authorities.

IF YOU HAVE QUESTIONS

If you have any comments, concerns, or questions regarding the conduct of this research please contact the research team listed on the first page of this form.

If you have concerns or complaints about the research study, research team, or questions about your child's rights as a research participant, please contacts Research and Sponsored Projects, California State University, Northridge.

VOLUNTARY PARTICIPATION STATEMENT

You should not sign this form unless you have read it and been given a copy of it to keep. Participation in this study is voluntary. Your child may refuse to answer any question or discontinue his/her involvement at any time without penalty or loss of benefits to which you and your child might otherwise be entitled. Your decision will not affect your relationship with California State University, Northridge. Your signature below indicates that you have read the information in this consent form and have had a chance to ask any questions that you have about the study.

If your child is 9 years of age or older he/she will be provided with an assent form that explains the study in language understandable to a child. A member of the research team will also read the form to your child and answer any questions your child may have. Your child will be asked to sign the form only if he/she agrees to be in the study. If your child does not wish to be in the study he/she will not be asked to sign the form. In addition, if after signing the assent form your child changes his/her mind your child is free to discontinue his/her participation at any time.

If your child is younger than 9 years then an assent form will not be provided, but a member of the research team will explain the study to your child and ask your child whether or not he/she wishes to participate. If your child declines to participate then your child will not be included in the study. Additionally, if your child says yes and declines later your child will be withdrawn from the study at his/her request.

_____ I agree to allow my child to participate in the study.

_____ My child may be video recorded

_____ I do not wish my child to be video recorded

____

Parent or Guardian Signature   Date

____

Printed Name of Parent or Guardian

C2. Adolescent Assent Form

California State University, Northridge

ADOLESCENT ASSENT TO BE IN A HUMAN RESEARCH PROJECT

Effects of Taekwondo and Nintendo Wii Training on Balance

in Youth with Autism Spectrum Diagnosis

We would like to invite you to participate in a research project. Participating in this project is your choice. Please read about the project below. Feel free to ask questions about anything that you do not understand before deciding if you want to participate.

What is this project about?
This project studies how Taekwondo and Nintendo Wii training can help and improve balance in adolescents with autism spectrum diagnosis. We want to know if you would like to participate in our study.

What will happen if you take part in the project?

These things will happen if you want to be in the project:

First, you will be randomly selected into one of the following groups: Taekwondo training group, Nintendo Wii group, or control group. If you are selected into a Taekwondo training group, you will be asked to participate in a Taekwondo training program 2 times per week for 8 weeks. Each training session will be 50 minutes consisting of warm-up (10 minutes), Taekwondo training (30 minutes), and cool-down (10 minutes). If you are selected into a Wii group, you will be asked to participate in Wii game activities 2 times per week for 8 weeks. Each training session will be 50 minutes consisting of warm-up and cool down for 10 minutes and play Wii exercise games for 40 minutes. You may choose a game that you would like to play from our list of games for first 30 minutes, and then you will be asked to play "Just Dance," a dance exercise game for 10 minutes. If you are selected into the control group, you will be asked to continue your daily routine for the duration (12 weeks) of the study but you will still come for balance measurements. After 12 weeks of the study, you will be invited to participate in Taekwondo or Wii programs for 8 weeks.

If you agree to participate in this study, you will be required come to the Center of Achievement at California State University, Northridge to measure your balance throughout this study. Your balance will be measured before intervention, middle of intervention (5th week), and after intervention (9th week), and 4 weeks following the intervention (12th week). Follow-up balance measurements will only be measured if you get selected into Taekwondo and Wii activities groups. You will be provided with the dates and times of your testing appointments before the study begins.

When you get measured for your balance, you will be asked to do the following:

- Standing on a raised platform on one foot, two feet, eyes open/closed, for 10 seconds. Each stance will be repeated 3 times.
- Functional balance tasks on and off a raised platform such as sit to stance, turning, transfer from one chair to another, stepping on a box, and reaching.

**Foam mattress will be provided for your safety.

**Water will be provided to make sure you do not get dehydrated during the study.

**You will be video recorded during the balance testing.

How long will your part in this project last?

You will be expected to part in the project for 12 weeks (3 months).

Who will be told the things we learn about you in this project?

The information we collect about you will be kept private. Only the lead and co-investigator working on this project will be able to look at the information we collect. We will not tell anyone what you tell us without your permission. But, if you tell us that someone has been hurting you or another person, we may have to tell someone else. We may have to talk to people whose job it is to protect children. They can make sure you are safe.

What are the possible risks or discomforts from being in this project?

Taekwondo training and Nintendo Wii activities involve basic physical movements and do not involve any movement that will harm you in any way. If you experience any discomfort during the intervention, please let the researchers know right away.

What are the benefits from being in this project?

You will not receive any money or gifts for participating in this study. However, your participation might help doctors and researchers understand the benefits and importance of taekwondo training and Nintendo Wii Fit activities for adolescents with autism spectrum disorder. The potential benefits to you from being in this project might be improving your balance.

What if you have questions about this project?

You can ask questions any time. You can talk to the researchers, your family or someone else in charge, before you decide if you want to participate. If you do agree to participate, you can change your mind and end your participation without penalty. If you have questions about the study please contact a member of the research team listed on the first page of this form.

If you have any concerns or complaints about this project or questions about your rights as a research participant, please contact: Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, Northridge, CA 91330-8232, or call 818-677-2901.

If you want to be in the study sign your name below.

____

Participant’s Signature Date

____

Printed Name of Participants

C3. Child Assent Form

California State University, Northridge

CHILD ASSENT TO BE IN A HUMAN RESEARCH PROJECT

Taekwondo vs. Nintendo Wii activities,

Which one can help my balance?

This paper explains a research project. The people doing the research would like your help, but they want you to know exactly what this means. This paper describes this research project. Participating in this project is your choice. Please read about the project below. Before you choose if you want to be a part of this study, please feel free to ask questions.

What is this project about?
This project studies how Taekwondo and Wii game activities can help and improve balance in children with autism spectrum. We want to know if you would like to participate in our study.

What will happen if you take part in the project?

These things will happen if you want to be in the project:

First, you will be picked into one of the groups: Taekwondo training group, Nintendo Wii group, or control group. If you are selected into a Taekwondo training group, you will be asked to participate in a Taekwondo training program 2 times per week for 8 weeks. Each training session will be 50 minutes consisting of warm-up (10 minutes), Taekwondo training (30 minutes), and cool-down (10 minutes). If you are selected into a Wii group, you will be asked to participate in Wii game activities 2 times per week for 8 weeks. Each training session will be 50 minutes consisting of warm-up and cool down for 10 minutes and play Wii exercise games for 40 minuets. You may choose a game that you would like to play from our list of games for first 30 minutes, and then you will be asked to play "Just Dance," a dance exercise game for 10 minutes. If you are selected into the control group, you will be asked to continue your daily routine for the duration (12 weeks) of the study but you will still come for balance measurements. After 12 weeks of the study, you will be invited to participate in Taekwondo or Wii programs for 8 weeks.

If you agree to participate in this study, you will be required come to the Center of

Achievement at California State University, Northridge to measure your balance throughout this study. Your balance will be measured before intervention, middle of intervention (5^{th} week), and after intervention (9^{th} week), and 4 weeks following the intervention (12^{th} week). Follow-up balance measurements will only be measured if you get selected into Taekwondo and Wii activities groups. You will be provided with the dates and times of your testing appointments before the study begins.

When you get measured for your balance, you will be asked to do the following:

- Standing on a raised platform on one foot, two feet, eyes open/closed, for 10 seconds. Each stance will be repeated 3 times.
- Functional balance tasks on and off a raised platform such as sit to stance, turning, transfer from one chair to another, stepping on a box, and reaching.

**Foam mattress will be provided for your safety.

**Water will be provided to make sure you do not get dehydrated during the study.

**You will be video recorded during the balance testing.

How long will your part in this project last?

You will be expected to part in the project for 12 weeks (3 months).

Who will be told the things we learn about you in this project?

The information we collect about you will be kept private. Only the researcher and co-investigator who are working on this project will be able to look at the information we collect. We will not tell anyone what you tell us without your permission. But, if you tell us that someone has been hurting you or another person, we may have to tell someone else. We may have to talk to people whose job it is to protect children. They can make sure you are safe.

What are the possible risks or discomforts from being in this project?

These exercise interventions (Taekwondo training and Nintendo Wii activities) involve basic physical movements and do not involve any movement that will harm you in any way. If you experience any discomfort during the intervention, please let the researchers know right away.

What are the benefits from being in this project?

You will not receive any money or gifts for participating in this study. However, your participation might help doctors and researchers understand the benefits and importance of Taekwondo training and Nintendo Wii activities for children with autism spectrum disorder. The potential benefits to you from being in this project might be improving your balance.

What if you have questions about this project?

You can ask questions any time. You can ask now or you can ask later. You can talk to the researchers, your family or someone else in charge. It is important that you know what is going on.

Do you want to be in the project?

You do not have to be in the study. No one will be upset with you if you don't want to do this. If you don't want to be in this study, or if you want to skip a question that is hard or confusing, that's fine. Just tell the researchers and they won't get upset.

If you want to be in the study sign your name below. You can say yes now and say no later. It is up to you to decide.

____

Participant's Signature Date

____

Printed Name of Participants

C4. Medical Release Form

MEDICAL RELEASE FORM

RESEARCH TEAM:

Yumi Kim and Jae Chun Lim

Department of Kinesiology at California State University, Northridge

18111 Nordhoff St.

Northridge, CA 91330- 8287

Phone: 818-677-2182

Fax: 818-677-3246

Name of participant: ____________________________ DOB: ____________

To Attending Physician:

The student researchers at the California State University, Northridge would like to conduct a study titled “Effects of Taekwondo and Nintendo Wii Intervention on Postural Control in Youth with Autism Spectrum Disorder.” The purpose of this study is to evaluate balance improvement through Taekwondo and Wii programs. Both exercise programs will meet for 50 minutes, 2 times per week, for 12 weeks and perform moderate to vigorous physical activities composed of flexibility, muscular strength, cardiovascular endurance, and balance exercises.

The California State University, Northridge and Center of Achievement through Physical Activity would like to request any medical information for your patient, which would affect your patient and exercise programs designed by the student researchers. All medical records will be handled in strict confidence. Thank you for your assistance.

<u>Please complete items #1, 2, & 3 below as applicable:</u>

1. Primary Disability:

   ____

   Secondary Medical Diagnosis (If any):

____

2. Please circle one of the following:

    - YES, this patient is medically cleared to participate in Taekwondo or Wii program for the study titled "Effects of Taekwondo and Nintendo Wii Intervention on Postural Control in Youth with Autism Spectrum Disorder."
    - NO, this patient is not medically cleared to participate in Taekwondo or Wii program for the study titled "Effects of Taekwondo and Nintendo Wii Intervention on Postural Control in Youth with Autism Spectrum Disorder."

3. Please provide a brief explanation if there is any recommendation or concern regarding this patient.

    ____

    ____

    ____

    ____

Physician's Signature: ______________________________ **Date:** ___________

Print Name: ______________________________________

Phone #: _______________________________________

Fax: ____

C5. Bill of Rights

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

EXPERIMENTAL SUBJECTS

BILL OF RIGHTS

The rights below are the rights of every person who is asked to be in a research study. As an experimental subject I have the following rights:

1) To be told what the study is trying to find out,
2) To be told what will happen to me and whether any of the procedures, drugs, or devices is different from what would be used in standard practice,
3) To be told about the frequent and/or important risks, side effects or discomforts of the things that will happen to me for research purposes,
4) To be told if I can expect any benefit from participating, and, if so, what the benefit might be,
5) To be told the other choices I have and how they may be better or worse than being in the study,
6) To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study,
7) To be told what sort of medical treatment (if needed) is available if any complications arise,
8) To refuse to participate at all or to change my mind about participation after the study is started. This decision will not affect my right to receive the care I would receive if I were not in the study.
9) To receive a copy of the signed and dated consent form.
10) To be free of pressure when considering whether I wish to agree to be in the study.

If I have other questions I should ask the researcher or the research assistant, or contact Research and Sponsored Projects, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA 91330-8232, or phone (818) 677-2901.

X ____

Signature of Subject　　　　　　　　　　Date

Appendix D

Raw Data in SPSS Coding Format

Table D1. Abbreviations

Double Leg Stance	
A1V1	Stable EO Sway Velocity Pre
A1V2	Stable EO Sway Velocity Post
A2V1	Stable EC Sway Velocity Pre
A2V2	Stable EC Sway Velocity Post
A3V1	Unstable EO Sway Velocity Pre
A3V2	Unstable EO Sway Velocity Post
A4V1	Unstable EC Sway Velocity Pre
A4V2	Unstable EC Sway Velocity Post
Single Leg Stance	
R1V1	Right EO Sway Velocity Pre
R1V2	Right EO Sway Velocity Post
R2V1	Right EC Sway Velocity Pre
R2V2	Right EC Sway Velocity Post
L1V1	Left EO Sway Velocity Pre
L1V2	Left EO Sway Velocity Post
L2V1	Left EC Sway Velocity Pre
L2V2	Left EC Sway Velocity Post
Sit-to-Stand	
ST1	Standing Time Pre
ST2	Standing Time Post
Step-Quick-Turn	
RT1	Right Turning Time Pre
RT2	Right Turning Time Post
LT1	Left Turning Time Pre
LT2	Left Turning Time Post

Table D2. Mixed Model ANOVA (Both Groups)

A1V1	A1V2	A2V1	A2V2	A3V1	A3V2	A4V1	A4V2
0.40	0.43	0.53	0.77	0.77	0.73	1.33	1.30
0.67	0.57	0.90	0.73	0.93	1.07	2.03	0.93
0.60	0.67	0.97	0.87	1.40	1.43	1.67	1.57
0.70	0.53	1.20	0.80	1.30	1.07	3.30	2.60
0.73	0.73	0.97	1.07	1.17	1.30	1.53	2.13
0.47	0.47	0.43	0.47	1.97	1.00	3.03	1.73
0.43	0.53	1.43	0.73	0.63	0.70	1.53	1.03
1.00	0.80	0.57	0.97	1.50	1.30	2.93	1.57
0.57	0.63	0.70	1.13	0.97	0.97	2.20	1.97
0.80	1.13	1.23	1.07	1.87	2.33	3.13	2.67
0.83	0.93	1.43	0.90	1.60	1.23	2.83	1.97
0.33	0.37	0.47	0.63	0.73	0.87	1.43	1.67
0.77	0.57	0.77	0.73	1.60	0.90	1.87	1.77
0.33	1.03	0.63	0.63	1.10	1.27	2.47	2.00

R1V1	R1V2	R2V1	R2V2	L1V1	L1V2	L2V1	L2V2
4.90	1.60	12.00	12.00	0.93	1.20	5.43	5.80
12.00	1.13	8.93	5.80	5.47	1.57	8.93	5.53
1.67	5.07	8.83	12.00	5.00	2.50	12.00	12.00
1.50	1.27	5.63	5.47	1.17	1.07	8.67	12.00
1.60	2.37	12.00	3.37	4.97	1.63	8.93	2.47
8.53	1.67	12.00	12.00	12.00	8.47	12.00	12.00
8.40	1.53	12.00	12.00	4.63	1.17	12.00	8.87
1.37	2.50	8.87	3.43	2.27	2.27	6.40	6.47
1.30	1.47	12.00	12.00	4.90	1.60	12.00	3.53
8.47	5.30	12.00	12.00	12.00	12.00	12.00	12.00
1.93	5.03	12.00	12.00	5.93	5.00	12.00	12.00
1.53	1.87	12.00	8.80	1.40	1.67	8.93	5.57
5.33	1.97	12.00	12.00	2.13	5.23	12.00	12.00
12.00	12.00	12.00	12.00	12.00	8.93	12.00	12.00

ST1	ST2	RT1	RT2	LT1	LT2
0.32	0.13	2.46	1.20	2.28	2.54
0.24	0.41	1.39	2.07	1.50	1.69
0.12	0.26	1.82	1.50	1.07	0.85
0.33	0.19	3.60	1.77	2.73	1.81
0.33	0.67	0.48	0.42	0.58	0.49
0.69	0.18	2.31	1.42	1.98	2.00
0.31	0.64	3.23	2.38	1.95	2.69
0.59	0.2	1.50	1.36	1.62	1.33
0.13	0.17	1.26	1.54	1.51	1.49
0.64	0.29	1.89	1.88	1.24	2.22
0.66	0.25	2.72	1.17	3.86	3.06
0.15	0.33	1.16	1.32	1.80	0.85
0.31	0.24	4.39	2.91	3.93	2.79
0.29	0.52	1.19	0.99	0.87	0.73

Appendix E

Mixed Model ANOVA Summary Tables

Table E1. Tests of Between-Subjects Effects (Double Leg Stance)

Measure: STABLEEO

Source	SS	df	MS	F	Sig.
Intercept	5.785	1	5.785	169.455	.000
Group * Time	.023	1	.023	.687	.423
Error	.410	12	.034		

Measure: STABLEC

Source	SS	df	MS	F	Sig.
Intercept	9.887	1	9.887	180.594	.000
Group * Time	.002	1	.002	.030	.865
Error	.657	12	.055		

Measure: UNSTABLEO

Source	SS	df	MS	F	Sig.
Intercept	20.221	1	20.221	142.957	.000
Group * Time	.072	1	.072	.508	.490
Error	1.697	12	.141		

Measure: UNSTABLEO

Source	SS	df	MS	F	Sig.
Intercept	20.221	1	20.221	142.957	.000
Group * Time	.072	1	.072	.508	.490
Error	1.697	12	.141		

Table E2. Tests of Between-Subjects Effects (Single Leg Stance)

Measure: RIGHTEO

Source	SS	df	MS	F	Sig.
Intercept	243.037	1	243.037	28.078	.000
Group * Time	5.623	1	5.623	.650	.436
Error	103.868	12	8.656		

Measure: RIGHTEC

Source	SS	df	MS	F	Sig.
Intercept	1494.620	1	1494.620	323.783	.000
Group * Time	22.959	1	22.959	4.974	.046
Error	55.393	12	4.616		

Measure: LEFTEO

Source	SS	df	MS	F	Sig.
Intercept	315.045	1	315.045	25.544	.000
Group * Time	22.221	1	22.221	1.802	.204
Error	148.004	12	12.334		

Measure: LEFTEC

Source	SS	df	MS	F	Sig.
Intercept	1266.708	1	1266.708	189.269	.000
Group * Time	10.909	1	10.909	1.630	.226
Error	80.312	12	6.693		

Table E3. Tests of Between-Subjects Effects (Sit-to-Stand)

Measure: ST

Source	SS	df	MS	F	Sig.
Intercept	1.596	1	1.596	106.225	.000
Group * Time	.001	1	.001	.082	.779
Error	.180	12	.015		

Table E4. Tests of Between-Subjects Effects (Step-Quick-Turn)

Measure: RIGHTTURN

Source	SS	df	MS	F	Sig.
Intercept	46.310	1	46.310	67.917	.000
Group * Time	.013	1	.013	.019	.893
Error	8.182	12	.682		

Measure: LEFTTURN

Source	SS	df	MS	F	Sig.
Intercept	47.536	1	47.536	60.310	.000
Group * Time	.384	1	.384	.488	.498
Error	9.458	12	.788		