The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder

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Abstract
This study examined the effects of a 12-week physical activity intervention on the motor skill proficiency and executive function of 22 boys (aged 9.08 ± 1.75 years) with autism spectrum disorder. In Phase I of the 12 weeks, 11 boys with autism spectrum disorder (Group A) received the intervention, whereas the other 11 boys with autism spectrum disorder (Group B) did not (true control, no intervention). The arrangement was reversed in Phase II, which lasted an additional 12 weeks. The Bruininks–Oseretsky Test of Motor Proficiency, Second Edition, and the Wisconsin Card Sorting Test were conducted three times for each participant (Group A, primary grouping: baseline (T1), post-assessment (T2), and follow-up assessment (T3); Group B, control grouping: T1−T2; intervention condition, T2−T3). The main findings were that both groups of children with autism spectrum disorder significantly exhibited improvements in motor skill proficiency (the total motor composite and two motor-area composites) and executive function (three indices of the Wisconsin Card Sorting Test) after 12 weeks of physical activity intervention. In addition, the effectiveness appeared to have been sustained for at least 12 weeks in Group A. The findings provide supporting evidence that physical activity interventions involving table tennis training may be a viable therapeutic option for treating children with autism spectrum disorder.

Keywords
autism spectrum disorder, executive function, motor skill proficiency, physical activity intervention

Introduction
Children with autism spectrum disorder (ASD) experience challenges in social communication and interactions and exhibit a restricted pattern of behavior and interests (American Psychiatric Association (APA), 2013). Identifiers for ASD-related motor skill impairment are lacking in the Diagnostic and Statistical Manual of Mental Disorders (APA, 2013); however, the International Classification of Functioning, Disability and Health lists motor skill deficits as an ASD-associated symptom (World Health Organization, 2001). Impaired or delayed motor skills (e.g. movement skills, motor coordination, and gross and fine motor skills) have been reported in numerous studies on children with ASD (Fournier et al., 2010; Green et al., 2009; Lloyd et al., 2013; Staples and Reid, 2010). Traditional interventions are primarily focused on core challenges in the social, communicative, and behavioral domains. However, a frequently overlooked area in the early intervention literature for children with ASD is motor skills. Motor skills, including locomotor (e.g. running, hopping, and jumping), object control (e.g. catching, throwing, and striking), gross motor (e.g. coordination, balance, and agility), and fine motor skills (e.g. precision, integration, and manual dexterity), are necessary for engaging in physical activities related to the development
of healthy lifestyles; however, participation in physical activities is necessary for promoting the development of these skills as well. Therefore, developing proficient motor skills may be even more critical for children with ASD because it empowers them with the opportunity to engage in physically active activities with peers, enabling them to derive the developmental benefits of physical activities.

A range of motor skill impairments has been identified in studies on people with ASD, and these include gross motor, fine motor, postural control, and imitation or praxis impairments (Bhat et al., 2011). There is no one-size-fits-all approach to motor skill assessment (Staples et al., 2012); however, researchers and pediatric clinicians commonly assess gross and fine motor skill performance using standardized measures such as the Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOS-2; Pan, 2014; Wuang et al., 2010), the Movement Assessment Battery for Children (Ament et al., 2015; Whyatt and Craig, 2012), or the Test of Gross Motor Development (MacDonald et al., 2013; Staples and Reid, 2010) in children with ASD. The most comprehensive study directly measured the motor skills of 25 school-aged children with ASD compared with three typically developing (TD) comparison groups, each individually matched according to (1) chronological age, (2) movement skill performance, and (3) mental age (Staples and Reid, 2010). That cross-sectional study found that children with ASD exhibited significantly poorer locomotor and object control scores compared with TD children in the chronological- and mental-age-matched groups; however, no significant differences emerged between the children with ASD with a mean age of 11.15 years and TD children with a mean age of 5.87 years. The significant motor delays experienced by school-age children with ASD indicate the need for creating motor skill interventions in order to minimize motor delays and promote optimal overall development.

In addition to the motor skill deficits reported in numerous studies on children with ASD, executive dysfunction has consistently been observed in people diagnosed with ASD (Robinson et al., 2009; Sachse et al., 2013). Executive function constitutes a set of cognitive processes that comprise distinct yet highly interrelated components such as cognitive flexibility, inhibitory control, and working memory (McClelland et al., 2014). Because executive function is involved in the regulation of both thought and action, the behavioral manifestations of executive function can be assessed (Becker et al., 2014), including difficulty switching between tasks, difficulty initiating new nonroutine actions, and a lack of impulse control (Rajendran and Mitchell, 2007). Low cognitive and behavioral flexibility is a specific executive function impairment in many children with ASD (Reed et al., 2013), and this difficulty is correlated with core symptom presentation (Reed et al., 2013) and adaptive behaviors in ASD (Pugliese et al., 2015). Problems with flexibility and initiation are linked to decreased independence and poor outcomes in adulthood (Hume et al., 2009). Other long-term effects of executive function deficits have been found in middle-childhood girls with attention-deficit hyperactivity disorder; specifically, impaired global executive function predicted a higher number of suspensions and expulsions from school. Because executive function contributes to success in school and employment and enables people to inhibit inappropriate behaviors as well as manage stress and barriers related to activities in daily life, assessing and developing interventions that target executive function impairments early in life to prevent long-term difficulties across a range of important functional domains is critical.

Evidence supports the beneficial effects of physical activity on executive function and suggests that effects might be particularly large for children (Gapin et al., 2011). The rationale is that exercise-induced neural plasticity is not merely restricted to areas of the brain serving motor function and may therefore translate into enhanced executive function (Verburgh et al., 2014). However, few studies have explored physical activity as a means of improving executive function of children with ASD. To date, data on the effects of physical activity intervention addressing executive function for children with ASD are promising. Hilton et al. (2014) conducted a single-group pretest–posttest design in a group of seven children diagnosed with ASD (aged 6–14 years) and reported improved motor skill proficiency and executive function following 10 weeks of an exergaming program; significant improvements were noted in working memory, metacognition, and the motor skill areas of strength and agility. Because motor skill and executive function deficits, in addition to core symptoms in children with ASD, may contribute to low rates of physical activity participation by presenting a greater challenge for such children, interventions directly targeting motor skill proficiency and executive function in children with ASD may be helpful.

Studies have indicated that physical activity interventions can be effective for improving motor skills in children with ASD (aged 4–18 years) (Bremer et al., 2015; MacDonald et al., 2012; Wuang et al., 2010). A recent study on optimal outcomes for young children with ASD aged 14–33 months indicated that motor skills were a significant predictor of calibrated autism severity (i.e. a severity marker less influenced by verbal intelligent quotient (IQ; Gotham et al., 2009)) at that age, implying that young children with superior motor skills demonstrated fewer social communicative skill deficits (MacDonald et al., 2014). Therefore, physical activity interventions can potentially improve the overall development of young children with ASD, in addition to their motor skills. Bass et al. (2009) indicated that 12-week therapeutic horseback riding was effective in improving sensory skills and social responsiveness in children with ASD ranging from 5 to 10 years. Pan (2010) reported that a 10-week aquatic exercise regimen
improved aquatic skills and has social improvement potential for children with ASD (aged 6–9 years). Anderson-Hanley et al. (2011) found significant improvements in the measures of attention and working memory and significant decreases in repetitive behaviors in 12 children aged 10–18 years with a diagnosis of an ASD immediately after they participated in a 20-min exergaming intervention. Chan et al. (2013) investigated the efficacy of a 4-week (60 min per session, twice per week) mind–body exercise, nei yang gong, in 20 children with ASD aged 6–17 years, and found positive enhancements in self-control and reductions in typical autistic symptoms and daily emotional and behavioral problems. Although the mentioned data support the positive effects of these novel interventions, whether the treatment efficacies can be sustained or cumulate remains largely inconclusive.

Numerous studies have been published on the value of employing moderate to vigorous aerobic exercise in executive function improvement in TD children (Crova et al., 2014; Diamond and Lee, 2011; Verburgh et al., 2014); however, the effects of using alternative forms of physical activity intervention have only begun to be studied. Pesce (2012) indicated that whether and how the qualitative aspects of physical activity intervention (e.g. open-skill exercise or a combination of complex skills) affect short- and long-term physical and cognitive performance must be examined. Recent evidence suggests that ASD-associated motor skill deficits may not be pervasive, but are apparent in activities requiring complex, interceptive actions or core balance abilities (Whyatt and Craig, 2012), or in skills necessitating the coupling of visual and temporal feedback (Ament et al., 2015). Therefore, the purpose of this study was twofold: (1) to evaluate the effects of a 12-week physical activity intervention through table tennis exercise on motor skill proficiency and executive function in two groups (A and B) of children with ASD and (2) to examine the possible sustained intervention effects in improving motor skill proficiency and executive function of primary-grouping (i.e. Group A) children with ASD. We employed a physical activity intervention through table tennis exercise because it merges motor skill training (i.e. locomotor and object control skills) with executive function training (more details are in physical activity intervention session), and the characteristics of this type of exercise are expected to affect response selection and execution in children with ASD (e.g. the training of visual information in a table tennis task as perceived by the player, and the manipulation of the temporal and spatial characteristics of ball flight). The research questions asked were as follows:

1. Does motor skill proficiency assessed using the BOT-2 (Bruininks and Bruininks, 2005) improve after participation in the physical activity intervention through table tennis exercise in two groups of children with ASD?

2. Does executive function measured using the computer version of the Wisconsin Card Sorting Test (WCST; Heaton and PAR Staff, 2003) improve after participation in the physical activity intervention through table tennis exercise in two groups of children with ASD?

3. Does the intervention effect sustained for at least 12 weeks in primary-grouping children with ASD (i.e. Group A)?

We hypothesized that (1) physical activity intervention through table tennis exercise would improve both motor skill proficiency and executive function in both groups of children with ASD, and (2) the intervention effect would sustain for at least 12 weeks in primary-grouping children with ASD. To date, no study has examined these physical and cognitive measures concurrently in a realistic and dynamic environment (i.e. table tennis setting) in ASD; therefore, our study was partly exploratory.

**Method**

**Study design**

Ethical approval was received from a university research ethics committee for human behavioral sciences. All parents and children provided informed consent before the study began. Before intervention, all children were screened for eligibility and paired on the basis of age, disability type, and comorbidity and then they were randomly split into Group A (n = 11; primary grouping: baseline (T1), post-assessment (T2), and follow-up assessment (T3)) and Group B (n = 11; control grouping: T1–T2; intervention condition, T2–T3). This enabled testing the effectiveness of the intervention (Group A children with ASD receiving the first phase of a 12-week intervention, and Group B children with ASD acting as the control) in addition to the effectiveness of a second phase of a 12-week intervention in Group B children with ASD as well as the potential sustainment of treatment effectiveness in Group A children with ASD.

Regardless of group assignment, all participants received the intervention for the same number of sessions and hours. Each participant also attended three assessments, where we assessed motor skill proficiency and executive function: once at study enrollment to serve as the baseline (T1), a second time after 12 weeks of physical activity intervention or regular treatment (T2), and a third time after another 12 weeks (T3). Assessments 1 and 2 represented the pre- and post-assessment, respectively, of the experimental (Group A) and control (Group B) groups. Assessment 3 served as the 12-week follow-up for Group A and the posttest for Group B following the intervention. The progression of the participants throughout the trial is depicted in Figure 1.