AN ABSTRACT OF THE DISSERTATION OF

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Abstract approved:

Megan MacDonald

Early childhood is a crucial time for the holistic development of a child's social, emotional, cognitive, and physical needs to build a solid and broad foundation for lifelong wellbeing and learning (Irwin et al., 2007). During this critical period, there is an increased demand for motor skills and executive function (EF) among young children as they move from preschool or home-based care into a more formal school setting like kindergarten (McClelland & Cameron, 2012). However, this transition can be challenging for children with autism spectrum disorder (ASD), who often experience deficits in motor skills and EF, in addition to their core characteristics (American Psychiatric Association, 2013; Demetriou et al., 2018; Staples & Reid, 2010). Recent evidence has indicated that motor skills and EF are interrelated among children without ASD (MacDonald et al., 2016; van der Fels et al., 2015). Since motor and EF development is influenced by the cultural context in which children grow up (Venetsanou & Kambas, 2010), a better understanding of cross-cultural similarities or differences in motor skills and EF might contribute to the

global perspective regarding the motor skill and EF of children with ASD from western and eastern countries. Yet, no research has been conducted to examine the cross-cultural comparison and relationship of motor skills and EF between children with ASD in the US and Taiwan. Thus, the purpose of this study was twofold: (1) to compare the parent ratings of motor skills and EF in children with ASD in the US and Taiwan and (2) to examine the relationships between parent ratings of motor skills and EF in children with ASD in the US and Taiwan.

One hundred and seventy-two parents/ legal guardians of children (4 to 6 years and 11 months old) with ASD were recruited from two countries, Taiwan (n = 100) and the US (n = 72). The parents or guardians of the child with ASD completed an internet-based survey including 66 questions anonymously, as a part of a cross-sectional survey-designed study. One-way multivariate analysis of covariance (MANCOVA) and a series of hierarchical multiple regressions were conducted to answer the research questions in the present study. The findings of the current study indicated that children with ASD from the US were rated as having better fine and gross motor skills than their peers from Taiwan, while there was no difference in EF ratings. Further, results of hierarchical regression analyses revealed that parental ratings of total motor skills, fine motor skills, and gross motor skills were significantly associated with parental ratings of EF in both working memory and inhibition of children with ASD from Taiwan and the US. In addition, these associations were similar between the two countries.

The present study represents an important first step in understanding the variability and relationship between parental perceptions of young children with

ASD's motor skills and EF cross-culturally. This study revealed parent ratings of motor skills differences observed in children with ASD from Taiwan and the US. Further, positive associations with specific aspects of parent ratings of fine motor and gross motor skills and working memory and inhibition were found in children with ASD from both countries. These findings have implications for future interventions and programs focused on improving early motor skills and EF development for young children with ASD from Taiwan and the US.

Cross-cultural Comparison and Relationship of Motor Skills and Executive Function in Children with Autism Spectrum Disorder in Taiwan and the United States

by
Ming-Chih Sung

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Ming-Chih Sung, Author

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CONTRIBUTION OF AUTHORS

This project is a production of the intellectual environment of a collaboration of researchers who have contributed in various degrees to the conceptualization of the research concept and study, the experimental design, and the analytical methodology. Ming-Chih Sung conceptualized this project, collected data, conducted data analyses, interpreted the findings, and drafted the manuscripts. Megan MacDonald, Ph.D., assisted in the conceptualization of the project, research design, and provided editorial comments and suggestions on the final draft.

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Chapter 1. General Introduction

The prevalence of autism spectrum disorder (ASD) has risen noticeably around the world. The updated estimate of prevalence in the United States suggested that the occurrence of ASD has increased from one in sixty-eight to one in fifty-four children (CDC, 2020; Maenner, 2020), making ASD one of the most frequently observed developmental disorders (Fombonne 2009). A similar trend of increasing prevalence has also been revealed in Taiwan, in which people identified having ASD increased from 10,160 to 15,750 between the years 2010 to 2020 (Ministry of Health and Welfare, 2020). ASD, a genetically based neurodevelopmental disorder, is a lifelong disorder experiencing challenges in social interactions and communication and exhibiting restricted and repetitive patterns of behaviors (American Psychiatric Association, 2013).

Although motor symptomatology is not included in the diagnostic criteria for ASD, motor skills impairments have been recognized as an early ASD-associated symptom in research (Bhat et al., 2011). A myriad of studies has indicated impaired or delayed motor skills among children with ASD, including gait and muscle tones, motor coordination, fine and gross motor skill (Fournier et al., 2010; Green et al., 2009; Kanner, 1943; Liu et al., 2021; Lloyd et al., 2013; Pan, 2014; Staples & Reid, 2010; Van Damme et al., 2021). Empirical research has revealed that up to 87% of children with ASD demonstrated significant motor impairment (Bhat, 2020). A hallmark study (Landa & Garrett-Mayer, 2006) indicated that motor skills deficits were evident in children at higher risk for ASD at 14 months of age compared to children with language delays and typical development. A recent meta-analysis revealed that infants with ASD aged 3 to 42 months demonstrated significantly impaired motor ability early on compared to infants without ASD. Further, the difference in motor ability between the two groups is amplified as infant and children age increases (Lloyd et al., 2013; Staples & Reid, 2010; West, 2019).

Another known developmental deficit common in children with ASD is executive function (EF) (Zhang et al., 2020). EF, under the broad category of cognitive functioning, is an umbrella term comprised of a set of higher-order cognitive processes, including inhibitory control, working memory, and cognitive flexibility, that are necessary for goal-directed behavior in a constantly changing environment (Diamond, 2013). EF deficits have consistently been reported in research of ASD population, including the performance of inhibition (Corbett et al., 2009), working memory (Wang et al., 2017), cognitive flexibility (Landry & Al-Taie, 2016), and planning (Olde Dubbelink & Geurts, 2017). A recent meta-analysis study by Demetriou et al. (2018) included 235 studies with 14,081 participants across different age groups examining EF performance of people with ASD. Their findings suggested that individuals with ASD performed overall significantly worse on EF compared to the neurotypical control group, and the impairments observed in the ASD group are relatively equivalent across different constructs of EF (Demetriou et al., 2018).

Early childhood is a crucial time for the holistic development of a child's social, emotional, cognitive, and physical needs to build a solid and broad foundation for lifelong wellbeing and learning (Irwin et al., 2007). Motor and EF skills are thought of as prerequisites skills for children's early learning (McClelland & Cameron, 2019). Young children above 4 years old experience considerable environmental changes as they move from preschool or home-based care into a more formal school setting like kindergarten. These changes include that young children interact with other peers and teachers and are introduced to structured activities and curriculum, which will increase demands on their social, motor, and EF skills, in addition to literacy, numeracy, and writing skills (McClelland & Cameron, 2012). For many young children, this transition goes well, but it can be quite challenging and stressful for others, especially those children with ASD (Hart & Whalon, 2013), as they experience difficulties of transitioning due to the by-product of deficits in motor skills and EF along with other developmental domains (MacDonald et al., 2013; Nuske et al., 2019; Ohara et al., 2020).

In the past, motor skills and EF were regarded as two different constructs developing independently and discussed separately (Hertzberg, 1929). Recent evidence, however, has indicated that these two constructs are interrelated (Becker et al., 2014; Houwen et al., 2017). For example, a systematic review of 21 studies suggested that complex motor skills, which were categorized to have a higher cognitive demand, demonstrated the strongest associations with higher-order cognitive skills (i.e., EF) among children without ASD (van der Fels et al., 2015). In the ASD population, evidence for the relationship between motor skills and EF has only been found in a couple of studies (Hilton et al., 2014; Schurink et al., 2012). Schurink et al. (2012) examined the relationship between motor skills and EF of 28 school-aged children diagnosed with pervasive developmental disorder-not otherwise specified (PDD-NOS). Their results indicated that fine motor skills and balance were significantly correlated with cognitive flexibility among children with PDD-NOS. Yet, these studies mentioned above were mainly conducted in western countries. How the relationships between motor skills and EF persist or differ in other countries remains unknown.

Since motor and EF development is influenced by the cultural context in which children grow up (Venetsanou & Kambas, 2010), a better understanding of cross-cultural similarity or differences in motor skills and EF might contribute to the global perspective regarding the motor skill and EF of children with ASD from western and eastern countries. Evidence has shown significant differences in motor skills and EF when comparing typically developing children living in western and eastern countries (Chow et al., 2001; Lan et al., 2011). For example, Chow et al. (2001) used a performance-based motor skills assessment and indicated that Chinese children performed better on fine motor skills, while American children had better performance in object control skills. Schmitt et al. (2019) indicated that Chinese children demonstrated better EF performance at the beginning of preschool compared to American children. Although evidence suggested differences in motor skills and EF between children without ASD who live in western and eastern countries, whether similar findings hold true is still relatively unknown in children with ASD, who have known deficits in these areas, across different cultures.

Theoretical frameworks provide the foundation for the association between motor skills and cognitive development. The perspective from a theoretical framework of learning to learn proposes that cognition develops due to a child's bodily interactions with their environments and surroundings (Adolph, 2005). For example, children develop the capacity for problem-solving through the interaction of their motor behaviors and exploration of the environment. In other words, early learning is centered around the motor systems and behaviors involving gripping, posture, and motor control coordinately. Therefore, early motor skills seem to lay the foundation for later cognitive development among children.

Examining motor skills and EF early in life is important as it could help educators, researchers, and policymakers to identify skills or programs that facilitate and enhance these critical developmental areas among children with ASD in different cultures. To the best of the author’s knowledge, no research has been conducted to examine the cross-cultural variability and relationships of motor skills and EF between children with ASD in the US and Taiwan. Therefore, the following specific aims and questions will be addressed by this study:

Aim 1: To compare the parent ratings of motor skills and EF in children with ASD in the US and Taiwan.

Questions 1: How do parent ratings of motor skills of children with ASD in Taiwan compare with parent ratings of motor skills of children with ASD in the US?

Question 2: How do parent ratings of EF of children with ASD in Taiwan compare with parent ratings of EF of children with ASD in the US?

Aim 2: To examine the relationships between parent ratings of motor skills and EF in children with ASD in the US and Taiwan.

Question 3: What is the relationship between parent ratings of motor skills and EF in children with ASD in Taiwan and the US, and how does this relationship between parent ratings of motor skills and EF of children with ASD in Taiwan compared to children in the US?

Assumptions

1. All participants completed the survey honestly.
2. Parents/legal guardians of children with ASD will rate their children's motor skills and EF behavior.
3. Survey measures used in this study are assumed to respectively measure motor skills and EF.

Delimitations

1. Parents/legal guardians who had children with ASD (4 – 6 years and 11 months old).
2. Parents/legal guardians had a device (e.g., computer, tablet, or smartphone) and internet access to participate in this study.
3. This study investigated two domains of motor skills and two domains of EF behaviors.
4. The cross-sectional nature of this study cannot allow us to draw any conclusions about the causality of the relationship.

Operational Definitions

1. Autism spectrum disorder – Autism spectrum disorders are neurodevelopmental disorders identified through developmental deficits in social interaction and communication, and demonstrated restricted interests or repetitive patterns of behaviors (American Psychiatric Association, 2013).
2. Motor skills – Motor skills are operationally defined as motor competence, which is a global term reflecting various terminologies (i.e., motor proficiency, motor performance, fundamental motor skill, fine and gross motor skills, and motor coordination) to describe goal-directed human movement (Robinson et al., 2015).
3. Executive function – Executive function (EF) refers to a set of higher-order cognitive processes necessary for goal-directed behavior, which include distinct yet highly interrelated components such as inhibitory control, cognitive flexibility, and working memory (Diamond, 2013).

Chapter 2. Manuscript 1

Cross-cultural Comparison of Motor Skill and Executive Function in Children with Autism Spectrum Disorder from Taiwan and the United States

Abstract

The purpose of this study was to examine cross-cultural differences in motor skill and executive function (EF) between children with autism spectrum disorder (ASD) from the US and Taiwan. One hundred and seventy-two parents/ legal guardians of children (4 to 6 years and 11 months old) with ASD were recruited from two countries, Taiwan (n = 100) and the United States (n = 72). The parents or guardians of the child with ASD completed a questionnaire that included demographic information, child's motor skills using the Children Activity Scale – Parents (ChAS-P), and child's EF using the Childhood Executive Functioning Inventory (CHEXI). One-way multivariate analysis of covariance (MACOVA) was conducted to examine the ChAS-P (i.e., fine motor skills, gross motor skills, and total motor score) and CHEXI (i.e., working memory, inhibition, and total EF score) measure between children with ASD from Taiwan and the US. The findings showed that there was a significant difference in parent ratings of motor skills, Wilk's $\Lambda = .956$, $F(2, 166) = 3.83$, $p = .024$, partial $\eta^2 = .044$, with children with ASD in the US rated as having better gross motor skills ($M = 15.50$) and fine motor skills ($M = 18.03$) compared to their peers in Taiwan ($M = 18.34$ & 21.78). However, parent ratings of EF were not significantly different between the two countries, Wilk's $\Lambda = .993$, $F(2, 167) = .55$, $p = .577$, partial $\eta^2 = .007$. The present study indicated that American children with ASD were rated as having better gross and fine motor skills than Taiwanese children with ASD, while the EF was comparable as rated by parents. Understanding the similarity and difference between motor skills and EF among young children with ASD from different countries might be an important first step for future interventions and programs to improve early motor skills and EF for young children with ASD.

Introduction

Autism Spectrum Disorder (ASD) is a type of neurodevelopmental disorder sharing similar impairments in social interaction, communication, and repetitive pattern of behaviors (American Psychiatric Association, 2013). According to the Center for Disease Control and Prevention (CDC), the estimated prevalence of ASD in 2016 increased from 1 in 68 to 1 in 54 children (CDC, 2020; Maenner, 2020). The increasing prevalence was also found in Taiwan, people who identified with ASD increased from 10,160 to 15,750 between the years 2010 to 2020 (Ministry of Health and Welfare, 2020). Such dramatic increases in autism prevalence worldwide underscore the increasing need for health, education, and social services for this group of people. While the core characteristics of ASD are considered to be pervasive, another common characteristic includes motor skill impairments (Green et al., 2009). In fact, research indicates that early motor deficits may emerge before communicative and social deficits, implying that motor skill difficulties may underlie an apparent ASD core characteristic (Leary & Hill, 1996; Nayate et al., 2005).

In the current study, the term "motor skills" refers to motor competence, which reflects various global terminologies (i.e., motor proficiency, motor performance, fundamental motor skill, and fine and gross motor skills) to describe goal-directed human movement (Robinson et al., 2015). Numerous studies have indicated that children with ASD demonstrated impaired or delayed motor skills (Bhat et al., 2011; Ketcheson et al., 2018; Lloyd et al., 2013; Pan, 2014; Staples et al., 2012). The International Classification of Functioning, Disability and Health also identifies motor skill deficits as an ASD-associated symptom (World Health Organization, 2001). Evidence has revealed that motor skills deficits among children with ASD range from 59% to 87%, depending on various motor skills assessments used in different studies (Bhat, 2020; Dewey et al., 2007; Green et al., 2009; Hilton et al., 2012). A meta-analysis consisting of 51 studies conducted by Fournier et al. (2010) showed pronounced deficits in motor behavior in the ASD population. Further, a hallmark research study by Landa & Garrett-Mayer (2006) reported that children at higher risk for ASD at 14 months of age demonstrated evident motor skills deficits compared to children with language delays and typical development. Therefore, it is imperative to examine the motor competence of children with ASD early on and find ways to improve this developmental area.

In addition to motor skills deficits, another common developmental deficit recognized in children with ASD is executive function (EF). EF consists of a set of higher-order cognitive processes necessary for goal-directed behavior, which include distinct yet highly interrelated components such as inhibitory control, cognitive flexibility, and working memory (Diamond, 2013). A myriad of studies have indicated that children with ASD demonstrated impairments in various aspects of EF in comparison with their peers without ASD (Hill, 2004; Kleinhans et al., 2005; Ozonoff & Jensen, 1999; Zhang et al., 2020). For instance, Robinson et al. (2009) found that children with ASD demonstrated EF deficits in the performance of planning and inhibition when compared with IQ and language level matched peers without ASD. Gardiner et al. (2017) suggested that young children with ASD aged 3 – 7 years demonstrated difficulties in day-to-day EF-related behavior compared with their peers without ASD matched on age, IQ, and maternal education. Further, deficits in EF among children with ASD can also lead to difficulties later in life, including independent behavior and ability to work (Hume et al., 2009; Woolard et al., 2021). Due to the importance of EF throughout the development of children with ASD, investigating and identifying means to hone-in on EF-related skills in early childhood is critical.

Motor and EF skills are thought of as prerequisite skills for children's early learning (McClelland & Cameron, 2019). For example, fine motor skills, which involve smaller movements of muscles in the hands, are essential for classroom settings such as handling materials, writing, and picking up objects with the thumb and fingers (Grissmer et al., 2010). Gross motor skills, which involve movement and coordination of larger muscles in the legs and torso, help children navigate the learning environment and participate in physical activities and sports (Lin et al., 2017). Similarly, children need to utilize EF skills in learning, for instance children need to pay attention and switch focus when needed (cognitive flexibility), remember instructions (working memory), and demonstrate self-control (inhibitory control) (McClelland & Cameron, 2019). Further, the theoretical framework of learning to learn suggests that motor skills demonstrated by young children play an important role in early learning (Adolph, 2005) and set the foundation for the higher order of cognitive process (i.e., EF). Taken together, motor and EF skills build the foundation for school readiness, academic performance, and physical and cognitive development (Best & Miller, 2010; Diamond, 2013). Thus, it is critical to examine motor skills and EF in young children with ASD, who have known deficits in these developmental areas.

Although deficits in motor skills and EF have been noted widely in children with ASD, motor skills and EF also differ as a function of geographical and cultural contexts (Chow et al., 2006; Sabbagh et al., 2006). It is of importance to understand cross-cultural similarities or differences in motor skills and EF, as this understanding may contribute to the global perspective regarding the motor skill and EF of children with ASD from western and eastern countries and provide more effective directions in which children with ASD's motor skills and EF could be developed. However, discussion of comparison cross-culturally has mainly been drawn from typically developing samples in western countries (Brian et al., 2018). Very few studies involved typically developing samples from eastern countries (e.g., China, Hong Kong) and showed differences in motor skills between Chinese children and their peers from the US and UK (Chow et al., 2001; Ma et al., 2022) and from Portugal and the US (Santos et al., 2016). Similarly, EF comparison between eastern and western countries has been conducted in a couple of studies (Lan et al., 2011; Sabbagh et al., 2006; Schmitt et al., 2019), with better EF observed in the eastern sample (i.e., China). Although evidence suggests differences in motor skills and EF between children who live in western and eastern countries, whether similar findings hold true in children with ASD is still relatively unknown.

Compared to the US and other western countries, Taiwan, a sovereign state located in East Asia, has distinctive geographical, cultural, and educational differences. It is worth noting that people in Taiwan speak Chinese and have some cultural and educational commonalities with people from China. Several factors may contribute to the differences in motor skill and EF in children from different countries. Most Chinese families live in tower blocks in urban cities where outdoor play is very limited, unlike their American counterparts, who might be able to play games involving ball skills in their backyard. In Chinese culture, for example, children are taught how to use chopsticks, an extremely dexterous task, from as early as two years of age. In addition, Chinese parents highly value self-control and impulse control in children as young as two years of age, as they teach their children to practice behavioral control and to be obedient early in life. In terms of the educational factors, Chinese kindergarten and preschools are academic-oriented; therefore, Chinese children seem to receive intensive training in writing/literacy and in inhibiting their behaviors and controlling their attention in a classroom. Overall, these factors might play a role in early childhood development in different countries.

To date, however, no study has compared the motor skill and EF between children with ASD from Taiwan and children with ASD from the US. By comparing motor skill and EF between Taiwan and the US, we may be able to understand cross-cultural variability in children with ASD's motor skills and EF, which might provide insights for future curriculum proposals about motor skill and EF improvement early on. Therefore, the purpose of this study was to examine cross-cultural differences in parent ratings of motor skill and EF between children with ASD from the US and Taiwan. It was hypothesized that 1) children with ASD from Taiwan will be rated as having better fine motor skills than children with ASD from the US, while children with ASD from the US will be rated as having better gross motor skills compared to children with ASD from Taiwan, and 2) children with ASD from Taiwan will be rated as having better EF on inhibition and working memory compared to children with ASD in the US.

Method

Sample

A total of 172 parents/ legal guardians of children with ASD (100 in Taiwan and 72 in the US) were recruited for this study. Inclusion criteria included being a parent/ guardian of a child with ASD and the child's: (1) current age between 4 – 6 years and 11 months, (2) parental report of their child having a diagnosis of ASD, Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), or Asperger syndrome. Participants were recruited through various strategies; social media was utilized to reach potential participants, including personal social media websites. In addition, ASD-organization and association websites and social media pages were used to advertise the study in Taiwan and the US, and the study was advertised through Facebook advertisements (e.g., paid based on geographic region). These identified websites were asked to post a pre-established flyer/ message to their social media page, which includes a link to the study survey. Second, flyers and bulletins with a QR code of the survey link were sent to targeted programs, ASD support groups, disability organizations, and pediatric services both in Taiwan and the US. Lastly, due to the difficulty of recruiting enough US samples, a research panel (n = 50) was purchased from a survey research form “Centiment” (http://centiment.co). Centiment was chosen because of their reputation and experience in surveying respondents that are difficult to reach, and Centiment has been used in previous studies (Chatterjee et al., 2021; D’Aniello et al., 2022). Statistical analyses were conducted to examine the differences between the panel sample and the other US sample. Results indicated that there were no statistically significant differences in demographic information (e.g., child age, gender, race, body mass index (BMI), whether children received physical activity or cognitive training, parental education level) and outcome variables (e.g., total motor score, fine motor skills, gross motor skills, total EF score, working memory, and inhibition); thus, the two US samples were combined.

Measures

An anonymous online survey distributed through the Qualtrics survey system (Provo, UT; https://www.qualtrics.com) was used in the current study and included three sections: (a) demographic information, (b) child motor skills, and (c) child executive function (EF). The English version of the survey was used by the American participants, and the Chinese version was used for participants in Taiwan.

Demographic Questionnaire

A demographic questionnaire was completed by the parent/ guardian of the child with ASD. The questions in the questionnaire included participant and family background information, such as child age, gender, race/ethnicity, height, and weight, whether they received physical activity (e.g., after-school physical activity program or exercise intervention) and cognitive interventions or programs, parent/guardian age, gender, race/ethnicity, living in urban/rural area, educational level, and annual income.

Motor Skill Questionnaire

The Children Activity Scale – Parents (ChAS-P) was utilized to assess motor skills in this study. ChAS-P is an efficient and appropriate parent-proxy questionnaire measuring the gross and fine motor skills and activities of daily living of children aged 4 – 8 years during everyday functional/play skills in a natural environment (Rosenblum, 2006). The time for parents/ guardians to complete ChAS-P is about 5 minutes. This questionnaire asks parents to evaluate their child's motor skills or activity of daily living by comparing their child's performance to another child. ChAS-P consists of 27 questions with a 5-point Likert scale ranging from 5 = "less adequately" to 1 = "very well." These 27 questions are grouped into four factors: gross motor skills (e.g., maintaining balance, playing in the playground), fine motor skills (e.g., writing/copying shapes, drawing), organization in space and time (representing the ability to organize movement in time and space, e.g., organizing self in preparation for going out), and activities of daily living (e.g., eating without getting dirty, self-dressing). Scores are summed for a total score ranging from 27 (lowest) to 135 (highest), with lower scores rated by parents reflecting better motor skills among children. Participants completed the entire questionnaire; however, only the subitems measuring fine motor skills (6 items) and gross motor skills (6 items) were used for the analyses of this study. The sum scores from motor skill subitems range from 12 (lowest) to 60 (highest).

The ChAS-P is selected for use because it is free and has also demonstrated good internal consistency, construct validity, and concurrent validity, with a significant moderate correlation between the Movement Assessment Battery (MABC) and ChAS-P (r = 0.51) (Rosenblum, 2006). Further, the ChAS-P has been used for measuring the motor skills of children with other developmental disorders, such as attention-deficit/hyperactivity disorder (ADHD) (Mimouni-Bloch et al., 2018) and developmental coordination disorder (DCD) (Asunta et al., 2019), and was recommended by Bardid et al. (2019) as an appropriate parent proxy for measurement of motor skills when direct individually administered measures are not feasible. The author translated English version of ChAS-P to Chinese version based on the cross-cultural adaptation of instruments.

Executive Function Questionnaire

EF was assessed by the Childhood Executive Functioning Inventory (CHEXI). The CHEXI (Thorell & Nyberg, 2008) is a 24-item parent-report inventory that assesses the behavioral manifestations of EF deficits in children aged 4 to 12 years. The CHEXI is an open-access tool with multiple language versions, including Chinese (http://www.chexi.se). The administration time of CHEXI is about 5 minutes for parents/ guardians to complete the form. CHEXI capitalizes on observations of children in their naturalistic settings to quantify their EF impairments during participation in regular life activities. The CHEXI is comprised of 24 questions with a 5-point Likert scale ranging from 1 being “Definitely not true” to 5 being “Definitely true.” From the working memory subscale example items include “Has difficulty with tasks or activities that involve several steps” and “Has difficulty remembering lengthy instructions.” An example item from the inhibition subscale includes “Has difficulty holding back his/her activity despite being told to do so.” Parents/ guardians will read such a statement and indicate how well that statement is true for the child. Although the CHEXI was designed to assess four EF subscales: working memory (11 items), planning (4 items), inhibition (6 items), and regulation (5 items), only two factors tapping working memory (working memory and planning subscales) and inhibition (regulation and inhibition subscales) provide a more parsimonious representation of the items in young children in the kindergarten (Thorell & Nyberg, 2008). Each question's scores are summed for a total score ranging from 24 (lowest) to 120 (highest), with higher scores indicating greater EF problems.

The reason for using the CHEXI to measure EF among children with ASD is because it provides the measurement of a child's EF deficits in the context of everyday demands as rated by parents. Research has indicated that neuropsychological tests administered in a lab may not be representative of the more complex daily lives of children (Blijd-Hoogewys et al., 2014). In addition, these lab-based EF tests have limits in their ecological validity and generalizability (Gioia et al., 2002). Research also revealed that CHEXI has higher discriminant validity than the one found in neuropsychological tests (Thorell et al., 2010). A recent meta-analysis study indicated that parent-reported ratings of EF had larger effect sizes compared to psychometric tests or experimental tasks (Demetriou et al., 2018). Thorell & Nyberg (2008). suggested that questionnaires reported by raters capture the child's behavior in the real world based on observations during an extended period. Also, evidence has shown that both the English and Taiwanese versions of CHEXI demonstrated good validity and reliability (Camerota et al., 2018; Tsai et al., 2020). Further, CHEXI has been used in children with developmental disorders such as ADHD (Thorell et al., 2010) and in typically developing young Taiwanese children (Tsai et al., 2020).

Procedure

Ethical approval for the study was obtained from the Institutional Review Board at Oregon State University. The current research was a cross-sectional study, which used comprehensive survey assessments, and the survey was administered through the Qualtrics survey system (Provo, UT; https://www.qualtrics.com). In both the US and Taiwan, participants were recruited from various ASD organizations, pediatric services and schools, social media websites and advertisements (e.g., Facebook). These identified websites were asked to post to their social media page with a link to the survey. The messages were preconstructed, minimizing the work for the organizations and maximizing consistency. The parents or guardians of the child with ASD filled out the Qualtrics surveys, including a demographic questionnaire, ChAS-P, and CHEXI. The time for completing the demographic questionnaire, ChAS-P, and CHEXI is about 5 minutes for each (total about 15 minutes). As much as possible, parents/ guardians were encouraged to complete the surveys in a non-distracting environment.

Data analysis

Descriptive statistical analysis (means and standard deviations) was used for demographic information (e.g., age, gender, race, BMI, whether children received physical activity or cognitive training, parental education level), ChAS-P, and CHEXI scores. The ChAS-P variables used for the analysis included (1) fine motor skills, (2) gross motor skills, and (3) total motor score. The following outcomes of EF: (1) working memory, (2) inhibition, and (3) total EF score in CHEXI were used for analysis.

To examine the difference in parent ratings of motor skills and EF between children with ASD in the US and Taiwan, one-way multivariate analysis of covariance (MANCOVA) tests were utilized to compare the ChAS-P (i.e., fine motor skills, gross motor skills, and total motor score) and CHEXI (i.e., working memory, inhibition, and total EF score) measure between two groups while controlling for covariates (i.e., BMI and whether children received physical activity or cognitive training). All statistical analyses were conducted using RStudio (version 3.6.1). An alpha level of 0.05 was used for all statistical tests.

Results

Descriptive analysis

Descriptive statistics for participants from Taiwan and the United States are presented in Table 1, including means, standard deviations, or proportions. Statistical differences were found in (1) whether children with ASD received cognitive training. Children with ASD from Taiwan had a higher percentage compared to their peers from the US; (2) parental education level. Parents from Taiwan generally had higher degrees compared to parents from the US; (3) BMI. Children with ASD had lower BMI compared to their peers from the US; (4) parents' age. Parents from Taiwan were older than parents from the US (see Table 1).

Table 1. Characteristics of Participants

	Taiwan (n = 100)	USA (n = 72)	
	Mean ± SD/ Proportion	Mean ± SD/ Proportion	*p*
Age	4.99 ± 0.80	5.00 ± 0.73	.405
4 years old	32.0% (n = 32)	26.4% (n = 19)	
5 years old	37.0% (n = 37)	47.2% (n = 34)	
6 years old	31.0% (n = 31)	26.4% (n = 19)	
Gender			.251
Boys	81.0% (n = 81)	73.6.% (n = 53)	
Girls	19.0% (n = 19)	26.4% (n = 19)	
Race			
Taiwanese	96% (n = 96)		
Taiwanese aborigines	4 % (n =4)		
White/Caucasian		52.8% (n = 39)	
Black/African American		12.5% (n = 9)	
Hispanic/Latino		16.7% (n = 12)	
Asian		11.1% (n = 8)	
Native American		2.8% (n = 2)	
Other		2.8 % (n = 2)	
Prefer not to say		1.4% (n = 1)	

BMI	15.89 ± 2.25	19.72 ± 6.61	< .001
IEP			.916
Yes	71.0% (n = 71)	69.4% (n = 50)	
No	27.0% (n = 27)	29.2% (n = 21)	
Prefer not to say	2.0% (n = 2)	1.4% (n = 1)	
(Adapted) Physical Activity			.063
Yes	51.0% (n = 51)	38.9% (n = 28)	
No	49.0% (n = 49)	58.3% (n = 42)	
Prefer not to say	0% (n = 0)	2.8% (n = 2)	
Cognitive Training			< .001
Yes	76.0% (n = 76)	43.1% (n = 31)	
No	24.0% (n =24)	52.8% (n = 38)	
Prefer not to say	0% (n = 0)	4.2% (n = 3)	
Living Area			.153
Rural	18.0% (n = 18)	27.8% (n = 20)	
City	77.0% (n = 77)	70.8% (n = 51)	
Prefer not to say	5.0% (n = 5)	1.4% (n = 1)	
Parents/guardians Age	38.79 ± 4.84	35.36 ± 6.14	< .001
Parental Education Level			< .001
Elementary school	1.0% (n = 1)	1.4% (n = 1)	
High school	8.0% (n = 8)	31.9% (n = 23)	
College (2 years)	6.0% (n = 6)	20.8% (n = 15)	
College (4 years)	53.0% (n = 53)	30.6% (n = 22)	
Master degree	31.0% (n = 31)	13.9% (n = 10)	
Ph.D. degree	1% (n = 1)	1.4% (n = 1)	
Annual Household Income			.198
Less than $20,000	7% (n = 7)	10.9% (n = 7)	
$20,000 to $34,999	20% (n = 20)	11.1% (n = 8)	
$35,000 to $49,999	13% (n = 13)	25.0% (n = 18)	
$50,000 to $74,999	21% (n = 21)	16.7% (n = 12)	
$75,000 to $99,999	12% (n = 12)	18.1% (n = 13)	
$100,000 or more	19% (n = 19)	15.3% (n = 11)	
Prefer not to say	8% (n = 8)	4.2% (n = 3)	

Note: BMI = body mass index; IEP = individualized education program

MANCOVA

Motor skills

MANCOVA results are presented in Table .2. There was a significant difference between children with ASD in Taiwan and the US when considered jointly on the variables total motor skills scores, fine motor skills, and gross motor skills while controlling for BMI and whether children received physical activity or cognitive training, Wilk's Λ = .956 (Pillai's Trace = .044), F (2, 166) = 3.83, p = .024, partial η^2 = .044. A separate ANCOVA was further conducted for each dependent variable while accounting for covariates mentioned above, with each ANCOVA evaluated at an alpha level of .025 (see Table 3). The results showed a significant difference between parent ratings of their child with ASD from Taiwan and from the US on total motor skills scores, F (4, 167) = 4.67, p = .001, partial η^2 = .101, with American children with ASD (M = 33.53) rated lower than Taiwanese (M = 40.12). The result of parent perceptions on their child's gross motor skills was also significant, F (4, 167) = 2.68, p = .019, partial η^2 = .060, with children with ASD from the US (M = 15.50) rated lower than children with ASD from Taiwan (M = 18.34). Further, there was also a significant difference between parent ratings of their child with ASD in Taiwan and in the US on fine motor skills, F (4, 167) = 4.83, p = .001, partial η^2 = .104, with ASD children in the US (M = 18.03) rated lower than ASD children in Taiwan (M = 21.78). It is worth noting that if a child with ASD was rated with low motor skill scores by parents, it reflects this child has better motor skills.

Executive Function

The MANCOVA results showed that parent ratings of EF between children with ASD from the US and Taiwan were not significantly different on total EF scores, working memory, and inhibition while controlling for whether children received physical activity and cognitive training, Wilk's Λ = .993 (Pillai's Trace = .007), F (2, 167) = .55, p = .577, partial η^2 = .007. ANCOVA also revealed that there was no significant difference between parent ratings of their child with ASD from the US and Taiwan on total EF scores, F (3, 168) = 1.67, p = .176, partial η^2 = .029, (M = 84.51 vs. M = 86.31), on working memory, F (3, 168) = 2.59, p = .055, partial η^2 = .044, (M = 44.67 vs. M = 45.42), and on inhibition, , F (3, 168) = .58, p = .632, partial η^2 = .010, (M = 39.85 vs. M = 40.89), respectively (see Table 2 & 3).

Table 2. One-way multivariate analysis of covariance of motor skills and executive function

Variables	Wilks' Lambda	F	Hypothesis df	Error df	p	Partial η^2
Motor skills	.956	3.83	2	166	.024	.044
Executive function	.995	.46	2	167	.577	.007

Table 3. One-way analysis of covariance of motor skills and executive function

	Taiwan (n = 100)		US (n = 72)				
Variables	M	SD	M	SD	F	P	Partial η^2
Total motor skills	40.12	11.12	33.53	12.54	4.67	.001	.101
Gross motor skills	18.34	6.58	15.50	6.60	2.68	.019	.060
Fine motor skills	21.78	6.35	18.03	6.96	4.83	.001	.104
Total EF	86.31	15.51	84.52	16.93	1.67	.176	.029
Working memory	45.42	9.92	44.67	10.16	2.59	.055	.044
Inhibition	40.89	6.66	39.85	8.12	.58	.632	.010

Note: EF = executive function

Discussion

The purpose of this study was to examine cross-cultural differences in motor skills and EF between children with ASD from the US and Taiwan. To the best of the author's knowledge, this is the first study to examine the differences of motor skills and EF in 4-6 years old children with ASD cross-culturally between Taiwan and the US. The findings of this study indicate that (1) children with ASD from the US were rated as having significantly better total motor skills, fine motor skills, and gross motor skills than their peers from Taiwan, and (2) parent ratings of total EF scores, working memory, and inhibition do not significantly differ between children with ASD from the two countries.

Consistent with our hypothesis, the findings indicated that children with ASD from the US were rated by parents as having better gross motor skills than children with ASD from Taiwan, which is commensurate with previous cross-cultural research investigating motor performance in typically developing children using performance-based motor skills assessment (Chow et al., 2001). Chow et al. (2001) suggested that 4 to 6 years old American children demonstrated better performance on tasks involving projection and reception of moving objects (e.g., balls skills) compared to Chinese children. One possible explanation for motor skills differences between countries might be related to physical activity opportunities. In general, American children are introduced to activities that require gross motor ability, such as ball games, much earlier than Chinese children (Chow et al., 2001). Research has indicated that motor skill development could also be influenced by popular sports in a given country (Wong & Cheung, 2006). For example, the high popularity of baseball and basketball in the US provided children with more opportunities to practice associated motor skills, including throwing, catching, and dribbling. In addition, previous evidence has revealed that Taiwanese preschoolers spent an average of 22 minutes/day in physical activity (Lin et al., 2017), while other studies reported that American preschool children spent approximately 320 minutes per day participating in PA (Pfeiffer et al., 2009). Stodden et al. (2008)'s theoretical perspective further supported the dynamic relationship between motor skills and physical activity. The theoretical perspective indicated that physical activity drives the development of motor skills, given that physical activity provides opportunities to promote and practice fundamental motor skills among children. Although 51% of Taiwanese parents reported that their child engaged in some physical activity programs or classes, this proportion was not statistically different from the reports of American parents. While the information on physical activity levels among children with ASD is in the current study unknown, physical activity engagement might affect children with ASD's motor skill acquisition profoundly. The findings of the present study suggest that it is vital to provide opportunities for young children with ASD in Taiwan to further promote their gross motor skills.

The difference in parental perception of gross motor skills between children with ASD from the US and Taiwan might also be attributed to the activities and curriculum and its quality in preschool programs. Evidence has indicated that motor skills should be taught, practiced, and reinforced by well-planned activities and programs (Logan et al., 2018). Such settings not only provide opportunities for children to be physically active but also for them to acquire and master motor skills (Wang, 2004). Morgan et al. (2013) also suggested that children are more likely to improve their fundamental motor skills if opportunities to learn and practice are maximized. The American curriculum states that children should master locomotor and manipulative skills, including hopping, running, catching, and throwing balls, by the end of kindergarten (SHAPE America, 2013). While preschools and kindergartens in Taiwan are required to offer 30 minutes activities involving "major muscle groups" per day, the curriculum does not emphasize ball skills (Lee, 2017). Our findings echoed a study by Santos et al. (2016) who found that children without ASD in Portugal, whose curriculum included more general (unspecific) goals, performed less mastery in fundamental motor skills compared to their American counterparts (a country with the most direct and specific goals towards the development of motor skills). Further, the 30 minutes activities involving major muscle groups in Taiwan's preschools and kindergartens are typically not taught by physical education specialists (Lee, 2017). Pesce (2012) suggested that the qualitative aspect of physical activity is crucial for physical and cognitive development. Therefore, providing more physical activity-related lessons or programs with better quality is imperative for the current preschool curriculum in Taiwan in order to set a foundation for young children's motor development and beyond.

Surprisingly, the finding of the present study revealed that children with ASD from the US were rated by parents as having better fine motor skills than their Taiwanese counterparts, which is inconsistent with previous evidence (Chow et al., 2001). Chow et al. (2001) used MABC to measure motor skills among children cross-culturally and indicated that Chinese children had better performance in manual dexterity than American children. Caregivers of children with ASD's priorities may explain the cross-cultural difference in the present study. In Taiwan, parents usually emphasize the importance of academic or cognitive development for their children; thus, facilitating children's motor skills may not be viewed as the top priority, resulting in overlooking motor development among children (Lin et al., 2017). Further, the medical model of disability deeply affects how people view their child with ASD in Taiwan (Ravindran & Myers, 2012), in which parents might spend more time in treatment and other therapies (e.g., occupational, physical, or speech therapy) for their children with ASD (Chiu & Turnbull, 2014), and might force parents to restrict the amount of time their child spent in physical activity participation (Lin et al., 2017). Indeed, a significant difference in whether children with ASD received a certain cognitive training was revealed in the demographic information of our sample, with more Taiwanese parents reporting that their children with ASD received training compared to their US counterparts. Although occupational or physical therapy might help improve children with ASD's motor behavior, the characteristics and information about those therapies are unknown. Recent research indicated that the factors of occupational therapy utilization service were only significantly associated with the improvement in gross motor development among children with developmental delay in Taiwan (Lin & Cherng, 2019). Further, the present study did not control whether children with ASD were exposed to intensive learning environments which required the usage of fine motor skills, such as writing, cutting, or using chopsticks. American children may, for instance, have encountered conditions that specifically promoted their motor behaviors using their hands. Future cross-cultural research should therefore take into account of characteristics of the therapies and the differences between learning environments.

Other contextual factors (i.e., personal and environmental factors) might also affect young children's motor development (Luo et al., 2007). Previous evidence has indicated that children with ASD with different levels of IQ have different motor performance (Yu et al., 2018). Yu et al. (2018) indicated that children with ASD with discrepantly higher intelligence quotient performance were associated with better fine motor skills than were children with even intelligence quotient discrepancy and those with discrepantly higher verbal intelligence quotient. Yet, the intelligence quotient information is unavailable within current samples. Thus, the impact of intelligence quotient levels on motor skills among young children with ASD cannot be drawn based on our current findings. With regard to environmental factors, a review conducted by Venetsanou & Kambas (2010) reported that preschool settings are one of the factors influencing children's motor skills. Chow & Louie (2013) indicated that better performance on locomotor skills was observed in children who attended private preschools, where it has a larger play area compared to public preschools. It might be the fact that the preschools in the US have a larger area allowing for young children to engage in a variety of activities involving movement, construction, sand and water, and dramatic play (Marr et al., 2003). The minimum space requirement of preschool in Taiwan is 3 m^2 per child for outdoor activity and 2 m^2 per child for indoor activity (Ministry of Education, 2012). Further, most Taiwanese families reside in small apartments in high-rise buildings (Pan et al., 2021). The areas for physical activity or movement participation in communities are also limited, which might contribute to limited opportunities for motor development. Further cross-cultural research is needed to look at the effect of other personal and environmental variables such as IQ level and types of preschool settings on motor skills development among children with ASD.

Of particular interest in the present study was to examine the EF on cross-cultural differences. Our results indicated that there was no difference in parent ratings of overall EF, including inhibition and working memory, in children with ASD from Taiwan and the US. This finding is consistent with the results of Zhou et al.'s (2009) cross-cultural research. Zhou et al. (2009) found that the parental rating of children without ASD's inhibitory control did not significantly differ between parents from China and the US. Interestingly, research using CHEXI examined the EF of children without ASD from four countries and reported that Chinese children were generally rated as having more EF deficits compared to other western countries (i.e., Sweden, Spain, and Iran) (Thorell et al., 2013). Our findings, nonetheless, are contrary to some previous studies (Sabbagh et al., 2006; Schmitt et al., 2018). Sabbagh et al. (2006) indicated that preschoolers from China demonstrated better performance on multiple behavioral EF assessments. The inconsistent findings may be the result of differences in methodological approaches (parental proxy report vs. performance-based tasks). In the present study, children with ASD's EF were measured by parental ratings. Parents/legal guardians responded to questions such as "Has difficulty remembering lengthy instructions." Parental proxy reports of

EF might capture other aspects of EF than performance-based assessment. Behavioral performance-based assessment is used to measure specific cognitive processes involved in EF, while parental reports reflect how these processes in their children manifest themselves in real-world contexts. Future research is warranted to further investigate the combination of both parent rating and performance-based EF measurement on EF among young children with ASD cross-culturally.

Our findings revealed that parent ratings of EF were not different between children with ASD in Taiwan and the US, which is contrary to our hypotheses and previous research (Sabbagh et al., 2006). Due to the cultural and educational aspects, it has been suggested that Chinese society, in general, has greater value on self-regulation and inhibitory control (Grabell et al., 2015; Lan et al., 2011). However, evidence has suggested that the rapid urbanization and modernization in Chinese society in recent years might have changed the values placed on specific social behaviors (Chen et al., 2005), which may partially explain the similarity of parent rating EF between children with ASD from Taiwan and the US. Further, Zhou et al. (2009) indicated that the shifting value of inhibitory control among children might be more manifest among Chinese parents than Chinese teachers because the traditional values of group harmony and obedience are probably still robust and influential in the Chinese school system. It is possible that a shift in cultural value influences the rating of parents toward their children with ASD in Taiwan. These factors, however, cannot be ruled out in the present study. More research is clearly needed to elucidate the nature of these findings, as exploring cross-cultural differences in EF is an emerging line of work that has the potential to inform practices to support the development of EF.

Overall, the findings on the similarities and differences of parent ratings of motor skills and EF between children with ASD in Taiwan and the US extend our understanding of the complex ways that cultural context may be affecting children with ASD's early development. The findings of lower motor skills rated by parents revealed in children with ASD from Taiwan have some practical implications for the identification of and intervention in motor skills development in Taiwanese children with ASD. The limited opportunities and competing priorities may hinder the motor skills development in children with ASD from Taiwan. Therefore, educators and practitioners should establish programs and interventions targeting both fine and gross motor skills, which leads by qualified professionals for young children with ASD in Taiwan to improve motor skills development. Children with ASD could also reap the benefits of physical activity participation and the development of physical fitness by improving their motor skills. While parent ratings of EF were comparable between children with ASD from two countries, identifying EF deficits and providing means to improve EF is critical for children with ASD to be successful in early childhood and beyond.

Although this study provides notable findings regarding the cross-cultural comparison of motor skills and EF between young children with ASD from Taiwan and the US, this study is not without limitations. First, the information on IQ, severity level, and comorbidity status of children with ASD from both countries were not assessed in the current study, given that these factors might influence motor skills and EF. Second, the motor skills and EF of children with ASD were measured through parental rating. This proxy report may be influenced by some biases, including personal and cultural beliefs and parents' prior experiences. Thus, the evaluation of motor skills and EF might vary based on different parental perceptions (Houwen et al., 2017). To be noted, parent rating and performance-based measurement should not be used interchangeably as they capture different aspects, preferably using these two types of assessment in combination in the best-case scenario. Future studies should utilize a combination of both parental rating and objective measurement of motor skills and EF to gain more holistic information among young children with ASD in different countries. Future research should also consider other additional factors when examining cross-cultural differences with regard to motor skills and EF (e.g., cultural values and preference for physical activity opportunities and parenting style). Therefore, our findings should be interpreted cautiously, and this study should be viewed as the first step toward evaluating cross-cultural differences in motor skills and EF of children with ASD between the two countries.

Conclusion

The current study was the first to examine the cross-cultural comparison of motor skills and EF among young children with ASD. The findings indicated that parent ratings of motor skills significantly differ in 4 – 6 years of children with ASD from Taiwan and the US, with both gross and fine motor skills rated better in American children with ASD compared to their Taiwanese peers. However, the results did not find any difference in parent ratings of EF in children with ASD between the two countries. This research suggests that understanding the similarity and difference of motor skills and EF among young children with ASD might be beneficial for designing early intervention programs to enhance early motor skills and EF and in developing policies to strengthen educational opportunities for young children with ASD.

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Chapter 3. Manuscript 2

Association between Motor Skills and Executive Function of Children with Autism Spectrum Disorder in Taiwan and the United States

Abstract

The purpose of this study was to examine the relationship between parent ratings of motor skills and executive function (EF) in children with autism spectrum disorder (ASD) in the US and Taiwan. One hundred and seventy-two parents/ legal guardians of children (4 to 6 years and 11 months old) with ASD were recruited from two countries, Taiwan (n = 100) and the US (n = 72). The parents or guardians of the child with ASD completed a questionnaire including demographic information, child's motor skills (using ChAS-P), and child's EF (using CHEXI). A series of hierarchical multiple regressions were conducted to determine whether ChAS-P (total motor score, fine motor skills, and gross motor skill) was associated with CHEXI (total EF score, working memory, and inhibition), after controlling for covariates (i.e., age, gender, race, BMI, whether children received physical activity or cognitive training, parental education level). Results indicated that total motor skills, fine motor skills, and gross motor skills were significantly associated with EF in both working memory and inhibition as rated by parents in both countries (β = .213 ~ .572, $p < .01$). In addition, the associations between parent ratings of motor skills (i.e., fine motor and gross motor skills) and EF (i.e., working memory and inhibition) were similar between the two countries. The present study represents an important first step in understanding the relationship between motor skills and EF among young children with ASD cross-culturally.

Introduction

Early childhood is a crucial period for the holistic development of a child's social, emotional, cognitive, and physical needs to build a solid and broad foundation for lifelong learning and wellbeing (Irwin et al., 2007). Young children above five years old experience considerable environmental changes as they move from preschool or home-based care into a more formal school setting like kindergarten. These changes include that young children interact with peers and teachers and are introduced to structured activities and curriculum, which will increase demands on their social, motor, and executive function (EF) skills (McClelland & Cameron, 2012). For many young children, this transition goes well, but it can be quite challenging and stressful for others, especially those children with autism spectrum disorder (Hart & Whalon, 2013).

Autism spectrum disorder (ASD), a neurodevelopmental disorder, is defined by deficits in social communication and the presence of restricted or repetitive behaviors (American Psychiatric Association, 2013). Based on the recently revealed estimate from the Center for Disease Control and Prevention (CDC), the prevalence of ASD in 2016 increased from 1 in 68 to 1 in 54 children (CDC, 2020; Maenner, 2020). Similarly, individuals who identified with ASD in Taiwan increased from 10,160 to 15,750 between the years of 2010 to 2020 (Ministry of Health and Welfare, 2020). Furthermore, the number of children aged 3 through 5 years served under the Individuals with Disabilities Education Improvement Act (IDEA) Part B services within the ASD category increased from 7.8 percent in 2012 to 10.8 percent in 2017 (U.S. Department of Education, 2020). The drastic increases in autism prevalence worldwide highlight the growing need for health, education, and social services for this population.

In addition to the core characteristics of ASD, deficits in motor skills have been consistently revealed in research on children with ASD (Staples & Reid, 2010; Whyatt & Craig, 2012). "Motor skills" in the present study are defined using the term motor competence, which reflects various global terminologies (i.e., motor proficiency, motor performance, fundamental motor skill, and fine and gross motor skills) to describe goal-directed human movement (Robinson et al., 2015). A myriad of studies have indicated that children with ASD demonstrate impaired or delayed motor skills, including postural control, motor coordination, and fine and gross motor skill (Green et al., 2009; Lloyd et al., 2013; Pan, 2014; Van Damme et al., 2021). Evidence has suggested that 87% of children with ASD demonstrated significant motor impairment (Bhat, 2020). Landa & Garrett-Mayer (2006) indicated that children at higher risk for ASD at 14 months of age demonstrated evident motor skills deficits compared with peers without ASD. A recent meta-analysis further echoed Landa & Garrett-Mayer's (2006) hallmark research and indicated that infants with ASD exhibited motor behavior deficits early on, compared to infants without ASD, and this difference between the two groups amplified as age increased (West, 2019). Thus, it is essential to evaluate motor skills among young children with ASD and identify approaches to mitigate this developmental deficit.

Another commonly impaired developmental area in children with ASD is EF (Chen et al., 2016; Hill, 2004). EF refers to a set of higher-order cognitive processes necessary for goal-directed behavior, including inhibitory control, cognitive flexibility, and working memory (Diamond, 2013). EF deficits have consistently been reported in children with ASD (Corbett et al., 2009; Demetriou et al., 2018; Ozonoff & Jensen, 1999; Zhang et al., 2020). Research has shown that children with ASD demonstrated EF deficits in the performance of planning, inhibition of responses, and self-monitoring compared with their peers without ASD matched on

IQ and language level (Robinson et al., 2009). EF is critical to everyday functioning in life (Best & Miller, 2010). If children with ASD experience deficits in EF, it might lead to difficulty in social interaction and quality of life. For example, inhibition, children may not be able to inhibit themselves and show aggressive behavior or distract easily in the class; cognitive flexibility, children may have problems shifting gears and thinking about things in different ways; working memory, children may not be able to hold on and visualize the numbers the teacher has called out. Further, EF deficits observed in individuals with ASD can also result in difficulties later in life, including independent behavior and work functioning (Hume et al., 2009; Woolard et al., 2021). Therefore, identifying and assessing EF impairments early in life to prevent long-term difficulties in children with ASD across a range of important functional domains is crucial.

In the past, motor skills and EF were regarded as two different constructs developing independently and discussed separately (Hertzberg, 1929). Recent evidence, however, has indicated that these two constructs are interrelated (Becker et al., 2014; Houwen et al., 2017). For example, one study found that visual-motor integration skills of preschoolers aged 3 to 5 years significantly predicted their EF skills seven months after (MacDonald et al., 2016). In addition, a systematic review of 21 studies suggested that complex motor skills, which were categorized to have a higher cognitive demand, demonstrated the strongest associations with higher-order cognitive skills (i.e., EF) among children without ASD (van der Fels et al., 2015). In the ASD population, evidence for the relationship between motor skills and EF has only been found in a couple of studies (Hilton et al., 2014; Schurink et al., 2012). Schurink et al. (2012) indicated that fine motor skills and balance were significantly correlated with cognitive flexibility among school-aged children with ASD. While the research mentioned above has indicated promising results, these studies have mainly focused on children in western countries such as Europe and the US. Thus, how these relationships persist or differ in other countries and regions is important to understand.

Theoretical frameworks and neurobiological evidence provide the fundamental viewpoint of the co-occurrence and relationship between motor skills and cognitive development (Gibbs, 2005; Piaget, 1952; Smith & Gasser, 2005). The theoretical framework of learning to learn proposes that motor behaviors play an essential role in early learning (Adolph, 2005). Within this framework, infants demonstrate their abilities to discover new solutions to solve novel problems through their motor flexibility when exploring and interacting with their surroundings. Thus, within this framework, early motor behaviors set the foundation for cognitive development and higher-order cognitive process (i.e., EF). In addition, research has shown that the pre-frontal cortex and cerebellum are co-activating while children are performing cognitive and motor tasks (Diamond, 2000). Furthermore, the peak developmental age of both motor and cognitive skills in early childhood is around the same timeframe between the ages of 5 to 10 years (Anderson, 2002). Therefore, examining the relationships between motor skills and EF early is critical given the evidence of theorized and the neurocognitive associations between the two domains.

The delineation of a particular motor cognitive relation has the potential to inform earlier identification and inform key intervention initiatives, especially for young children with ASD. Although there has been a surge of research on the link between motor skills and EF in children without ASD (Livesey et al., 2006; Ludyga et al., 2019; Piek et al., 2004), few researchers have examined the association between motor skills and executive functioning in young children with ASD (Hilton et al., 2014; Kim et al., 2016). Specifically, few if any studies have examined the cross-cultural similarities and differences in such relationships in young children with ASD. Therefore, the purpose of this study was to examine the relationship between parent ratings of motor skills and EF in children with ASD in the US and Taiwan. We wished to identify similarities and differences of associations between motor skills and EF among children with ASD across countries. Using a cross-cultural sample of young children with ASD from Taiwan and the US, the present study provided important insights into cross-cultural universality and cultural variation in the links between motor skills and EF, especially in the autism community. Because there are few existing cross-cultural studies of the association between motor skills and EF, especially no studies in ASD children, the specific hypotheses regarding cross-cultural similarities and differences were developed based on the broader literature, including cross-cultural studies on children without ASD. It was hypothesized that 1) there would be significant associations between parent ratings of motor skills and EF in children with ASD from Taiwan and the US, respectively, and 2) the relationship between parent ratings of motor skills and EF in children with ASD from Taiwan would be stronger than the US.

Method

Sample

One hundred and seventy-two parents/ legal guardians of children with ASD were recruited from two countries, Taiwan (n = 100) and the US (n = 72). Inclusion criteria of the present study included being a parent/ guardian of a child with ASD and the child's: (1) current aged between 4 – 6 years and 11 months, and (2) parental report of their child having a diagnosis of ASD, Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), or Asperger syndrome. Several strategies were employed to recruit parents/guardians of children with ASD. First, social media was used to reach potential participants, including personal social media websites (e.g., Facebook and Instagram), websites and social media pages of ASD-organization and associations in Taiwan and the US, and through Facebook advertisements (e.g., paid based on geographic region). These identified websites were asked to share a pre-established flyer/message to their social media page, which includes a link to the study survey. Second, flyers and bulletins with a QR code of the survey link were sent to targeted programs, ASD support groups, disability organizations, and pediatric services both in Taiwan and the US. Lastly, a research panel was purchased from “Centiment” due to the difficulty in recruiting enough US samples (http://centiment.co). Centiment was chosen because of their reputation and experience in surveying respondents that are difficult to reach, and Centiment has been used in previous studies (Chatterjee et al., 2021; D’Aniello et al., 2022). Statistical analyses were conducted to compare the differences between the panel sample and the other US sample. Results showed no statistically significant differences in demographic information (e.g., child age, gender, race, body mass index (BMI), whether children received physical activity or cognitive training, parental education level) and outcome variables (e.g., total motor score, fine motor skills, gross motor skills, total EF score, working memory, and inhibition). Therefore, the two US samples were combined for further analyses.

Measures

A comprehensive online survey distributed through the Qualtrics survey system (Provo, UT; https://www.qualtrics.com) was utilized in the present study and included three sections: (a) demographic information, (b) child motor skills, and (c) child executive function (EF). The English version of the survey was used by the American participants, and the Chinese version was used for participants in Taiwan.

Demographic Questionnaire

A demographic questionnaire was filled out by the parent/legal guardian of the child with ASD. The questions included participant and family background information, such as child age, gender, race/ethnicity, height, and weight, whether they received (adapted) physical activity (e.g., after school physical activity program, soccer, or Taekwondo) and cognitive interventions or programs (e.g., physical therapy or occupational therapy), parent/guardian age, gender, race/ethnicity, living in urban/rural area, educational level, and annual income.

Motor Skill Questionnaire

The motor skills were measured by the subitems of Children Activity Scale – Parents (ChAS-P) in this study. ChAS-P is an efficient and appropriate parent-proxy questionnaire measuring the gross and fine motor skills and activities of daily living of children aged 4 – 8 years during everyday functional/play skills in a natural environment (Rosenblum, 2006). The time for parents/ guardians to complete ChAS-P is about 5 minutes. The questionnaire asks parents to evaluate their child's motor skills or activity of daily living by comparing their child's performance to another child. ChAS-P consists of 27 questions with a 5-point Likert scale ranging from 5 = "less adequately" to 1 = "very well." These 27 questions are grouped into four factors: gross motor skills (e.g., maintaining balance, playing in the playground), fine motor skills (e.g., writing/copying shapes, drawing), organization in space and time (representing the ability to organize movement in time and space, e.g., organizing self in preparation for going out), and activities of daily living (e.g., eating without getting dirty, self-dressing). Scores are summed for a total score ranging from 27 (lowest) to 135 (highest), with lower scores rated by parents reflecting better motor skills among children. Participants completed the entire questionnaire. Yet, only the subitems measuring fine motor skills (6 items) and gross motor skills (6 items) were used for the analyses of this study. The summary scores from motor skill subitems range from 12 (lowest) to 60 (highest).

The ChAS-P was selected for use because it has demonstrated good internal consistency, construct validity, and concurrent validity, with a significant moderate correlation between the Movement Assessment Battery (MABC) and ChAS-P (r = 0.51) (Rosenblum, 2006); in addition this assessment was free for use. Further, the ChAS-P has been used for measuring the motor performance of children with other developmental disorders, such as attention-deficit/hyperactivity disorder (ADHD) (Mimouni-Bloch et al., 2018) and developmental coordination disorder (DCD) (Asunta et al., 2019), and was recommended by Bardid et al. (2019) as an appropriate parent proxy for measurement of motor skills when direct individually administered measures are not feasible. The author translated English version of ChAS-P to Chinese version based on the cross-cultural adaptation of instruments.

Executive Function Questionnaire

Childhood Executive Functioning Inventory (CHEXI) was employed to measure problems with executive function (EF). The CHEXI (Thorell & Nyberg, 2008) is a 24-item parent-report inventory that assesses the behavioral manifestations of EF abilities in children aged 4 to 12 years. The CHEXI is an open-access tool with multiple language versions, including Chinese (http://www.chexi.se). The administration time of CHEXI is about 5 minutes for parents/ guardians to complete the form. CHEXI capitalizes on observations of children in their naturalistic settings to quantify their EF impairments during participation in regular life activities. The CHEXI is comprised of 24 questions with a 5-point Likert scale ranging from 1 being “Definitely not true” to 5 being “Definitely true.” The example items for the working memory subscale include “Has difficulty with tasks or activities that involve several steps” and “Has difficulty remembering lengthy instructions.” An example item for the inhibition subscale includes “Has difficulty holding back his/her activity despite being told to do so.” Parents/

guardians will read such a statement and indicate how well that statement is true for the child. Although the CHEXI was designed to assess four EF subscales: working memory (11 items), planning (4 items), inhibition (6 items), and regulation (5 items), only two factors tapping working memory (working memory and planning subscales) and inhibition (regulation and inhibition subscales) provide a more parsimonious representation of the items in young children in the kindergarten (Thorell & Nyberg, 2008). Each question's scores are summed for a total score ranging from 24 being the lowest to 120 being the highest, with higher scores indicating greater EF problems.

The reason for using the CHEXI to measure EF among children with ASD was because it provides the measurement of a child's EF deficits in the context of everyday demands as rated by parents. Research has indicated that neuropsychological tests administered in a lab may not be representative of the more complex daily lives of children (Blijd-Hoogewys et al., 2014). In addition, many lab-based EF tests have limits in their ecological validity and generalizability (Gioia et al., 2002). Research also revealed that CHEXI has higher discriminant validity than the one found in neuropsychological tests (Thorell et al., 2010). A recent meta-analysis study indicated that parent-reported ratings of EF had larger effect sizes compared to psychometric tests or experimental tasks (Demetriou et al., 2018). Thorell & Nyberg (2008) suggested that questionnaires reported by raters capture the child's behavior in the real world based on observations during an extended period. Also, evidence has shown that both English and Taiwanese version of CHEXI demonstrated good validity and reliability (Camerota et al., 2018; Tsai et al., 2020). Further, CHEXI has been used in children with developmental disorders such as ADHD (Thorell et al., 2010), and in typically developing young Taiwanese children (Tsai et al., 2020).

Procedure

Ethical approval for the study was received from the Institutional Review Board at Oregon State University. In both the US and Taiwan, participants were recruited from various ASD organizations, pediatric services and schools, social media websites, and advertisements (e.g., Facebook). These identified websites were asked to post to their social media page with a link to the survey. The messages were preconstructed, minimizing the work for the organizations and maximizing consistency. The parents or guardians of the child with ASD were asked to fill out the Qualtrics surveys, including a demographic questionnaire, ChAS-P, and CHEXI. The time for completing the demographic questionnaire, ChAS-P, and CHEXI is usually 5 minutes for each (total about 15 minutes). As much as possible, parents/ guardians were encouraged to complete the surveys in a non-distracting environment.

Data Analysis

Descriptive analyses (means and standard deviations) were conducted for demographic information (e.g., age, gender, race, BMI, whether children received physical activity or cognitive training, parental education level), ChAS-P, and CHEXI scores. The following outcomes of ChAS-P were used for analysis: (1) fine motor skills, (2) gross motor skills, and (3) total motor score. For the variables in EF, (1) working memory, (2) inhibition, and (3) total EF score in CHEXI were used for analysis. The chi-square and t-tests were conducted to examine whether demographic and outcome variables differed between the two countries.

Previous research examining the associations between motor skills and EF in children with and without disabilities had mixed findings. While the majority of studies indicated that fine motor skills were associated with EF (Becker et al., 2014; van der Fels et al., 2015; Van Rooijen et al., 2016), some studies found associations between gross motor skills and EF (Fels et al., 2019; Piek et al., 2008; Wu et al., 2017). Therefore, a series of hierarchical linear regressions were conducted with total motor skill scores, fine motor skills, or gross motor skills as separate independent variables and working memory or inhibition as a dependent variable while controlling for the covariates for children with ASD from Taiwan and the US respectively.

To examine the individual association between parent ratings of motor skills and EF in children with ASD in the US and Taiwan, a series of hierarchical regressions were conducted to determine whether ChAS-P (total motor score, fine motor skills, and gross motor skill) was associated with CHEXI (working memory and inhibition). The dependent variable was EF, including working memory and inhibition. All covariates (i.e., age, gender, BMI, whether children received physical activity or cognitive training, and parental education level) were entered in step 1, and motor skills (i.e., total motor score, fine motor skills, and gross motor skills) were entered in step 2 of the hierarchical regression models. Hierarchical regressions provided information regarding if the independent variables (i.e., motor skills) explain a statistically significant amount of variance in the dependent variable (i.e., EF) after accounting for all other covariates.

To examine whether children with ASD from Taiwan and the US showed different relationships between motor skills and EF, another hierarchical regression analysis was employed, with EF as the dependent variable. All covariates were entered in step 1, and motor skills, country, and the interaction term of motor skills x country were entered in step 2. All statistical analyses were conducted using RStudio (version 3.6.1). An a-priori alpha level of 0.05 was used for all statistical tests.

Results

Descriptive Analysis

Descriptive statistics for participants from Taiwan and the US are presented in Table 1, including means, standard deviations for continuous variables, and proportions for categorical variables. Statistical differences were found in (1) whether children with ASD received cognitive training. Children with ASD from Taiwan had a higher percentage compared to their peers from the US; (2) parental education level. Parents from Taiwan generally had higher degrees compared to parents from the US; (3) BMI. Children with ASD had lower BMI compared to their peers from the US; (4) parents' age. Parents from Taiwan were older than parents from the US (see Table 1).

The descriptive statistics for motor skills (total motor skills scores, fine motor skills, and gross motor skills) and EF (total EF scores, working memory, and inhibition) were presented in Table 2. That stated, the focus of the analyses in the present study was not to make comparisons between countries in motor skills and EF. We wished to identify similarities and differences across countries in terms of associations between motor skills and EF.

Table 1. Characteristics of Participants

	Taiwan (n = 100)	USA (n = 72)	
	Mean ± SD/ Proportion	Mean ± SD/ Proportion	*p*
Age	4.99 ± 0.80	5.00 ± 0.73	.405
4 years old	32.0% (n = 32)	26.4% (n = 19)	
5 years old	37.0% (n = 37)	47.2% (n = 34)	
6 years old	31.0% (n = 31)	26.4% (n = 19)	
Gender			.251
Boys	81.0% (n = 81)	73.6.% (n = 53)	
Girls	19.0% (n = 19)	26.4% (n = 19)	
Race			
Taiwanese	96% (n = 96)		
Taiwanese aborigines	4 % (n =4)		
White/Caucasian		52.8% (n = 39)	
Black/African American		12.5% (n = 9)	
Hispanic/Latino		16.7% (n = 12)	
Asian		11.1% (n = 8)	

Native American		2.8% (n = 2)	
Other		2.8 % (n = 2)	
Prefer not to say		1.4% (n = 1)	
BMI	15.89 ± 2.25	19.72 ± 6.61	< .001
IEP			.916
Yes	71.0% (n = 71)	69.4% (n = 50)	
No	27.0% (n = 27)	29.2% (n = 21)	
Prefer not to say	2.0% (n = 2)	1.4% (n = 1)	
(Adapted) Physical Activity			.063
Yes	51.0% (n = 51)	38.9% (n = 28)	
No	49.0% (n = 49)	58.3% (n = 42)	
Prefer not to say	0% (n = 0)	2.8% (n = 2)	
Cognitive Training			< .001
Yes	76.0% (n = 76)	43.1% (n = 31)	
No	24.0% (n =24)	52.8% (n = 38)	
Prefer not to say	0% (n = 0)	4.2% (n = 3)	
Living Area			.153
Rural	18.0% (n = 18)	27.8% (n = 20)	
City	77.0% (n = 77)	70.8% (n = 51)	
Prefer not to say	5.0% (n = 5)	1.4% (n = 1)	
Parents/guardians Age	38.79 ± 4.84	35.36 ± 6.14	< .001
Parental Education Level			< .001
Elementary school	1.0% (n = 1)	1.4% (n = 1)	
High school	8.0% (n = 8)	31.9% (n = 23)	
College (2 years)	6.0% (n = 6)	20.8% (n = 15)	
College (4 years)	53.0% (n = 53)	30.6% (n = 22)	
Master degree	31.0% (n = 31)	13.9% (n = 10)	
Ph.D. degree	1% (n = 1)	1.4% (n = 1)	
Annual Household Income			.198
Less than $20,000	7% (n = 7)	10.9% (n = 7)	
$20,000 to $34,999	20% (n = 20)	11.1% (n = 8)	
$35,000 to $49,999	13% (n = 13)	25.0% (n = 18)	
$50,000 to $74,999	21% (n = 21)	16.7% (n = 12)	
$75,000 to $99,999	12% (n = 12)	18.1% (n = 13)	
$100,000 or more	19% (n = 19)	15.3% (n = 11)	
Prefer not to say	8% (n = 8)	4.2% (n = 3)	

Note: BMI = body mass index; IEP = individualized education program

Table 2. Mean and standard deviation of outcome variables

	Taiwan (n = 100)	USA (n = 72)
	Mean ± SD	Mean ± SD/
Motor skills		
Total motor skills	40.12 ± 11.12	33.53 ±12.54
Fine motor skills	21.78 ± 6.35	18.03 ± 6.96
Gross motor skills	18.34 ± 6.58	15.50 ± 6.60
Executive function		
Total executive function	86.31 ± 15.51	84.51 ± 16.93
Working memory	45.42 ± 9.92	44.67 ± 10.16
Inhibition	40.89 ± 6.66	39.85 ± 8.12

Note: higher the scores in motor skills and executive function mean more deficits

Bivariate Correlations

The correlations between the demographic and outcome variables are shown in Tables 3 & 4 for each country.

Table 3. Correlation matrix for demographic and outcome variables of participants from Taiwan.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	1											
2. Gender	.01	1										
3. BMI	.07	-.13	1									
4. PA	-.16	-.02	-.05	1								
5. Cognitive	.13	.15	-.01	.01	1							
6. Parental Edu	-.04	.02	-.05	-.35**	.08	1						
7. Gross motor	.16	-.12	.10	-.00	-.09	-.05	1					
8. Fine motor	.05	-.14	.15	-.06	-.31**	-.14	.48**	1				
9. Total MS	.12	-.15	.15	-.03	-.23*	-.11	.87**	.86**	1			
10. WM	.23*	-.10	.02	.11	-.24*	-.26**	.33**	.47**	.46**	1		
11. Inhibition	.22*	-.13	.03	-.01	-.20*	-.16	.28**	.29**	.33**	.74**	1	
12. Total EF	.24*	-.12	.03	.07	-.24*	-.24*	.33**	.43**	.44**	.96**	.90**	1

Note: BMI = Body mass index; PA = whether a child received a physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level; Total MS = total motor skills scores; Total EF = total executive function scores.
***p* < 0.01 (two-tailed), **p* < 0.05 (two-tailed).

Table 4. Correlation matrix for demographic and outcome variables of participants from the US.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	1											

2. Gender	.09	1										
3.BMI	-.01	-.05	1									
4. PA	.04	.17	-.00	1								
5. Cognitive	.10	.13	.10	.50**	1							
6. Parental Edu	.08	-.05	-.21	-.11	-.29*	1						
7. Gross motor	.05	-.04	-.01	.06	-.14	.06	1					
8. Fine motor	-.12	-.20	-.05	.12	-.03	.06	.71**	1				
9. Total MS	-.04	-.13	-.03	.10	-.09	.07	.92**	.93**	1			
10. WM	-.05	-.03	-.06	.20	.04	.11	.54**	.54**	.58**	1		
11. Inhibition	-.08	-.17	.05	.14	.13	.05	.33**	.42**	.41**	.71**	1	
12. Total EF	-.07	-.10	-.01	.18	.09	.09	.49**	.52**	.55**	.94**	.90**	1

Note: BMI = Body mass index; PA = whether a child received a physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level; Total MS = total motor skills scores; Total EF = total executive function scores.
***p* < 0.01 (two-tailed), **p* < 0.05 (two-tailed).

Regression

Working Memory

The hierarchical regression analysis indicated that Taiwanese children with ASD had parent ratings of total motor skills that were significantly related to ratings of working memory after controlling for covariates (β = .39, p < .001). Overall, the full model explained nearly 28% of the variance in working memory (i.e., adjusted R^2 = .276). American children with ASD had total motor skill ratings that were also significantly associated with ratings of working memory (β = .57, p < .001) after controlling for covariates. The full model accounted for nearly 31% of the variance in working memory (i.e., adjusted R^2 = .305) (See Table 6).

Table 5. Hierarchical multiple regression analyses for total motor skills predicting working memory

	Taiwan (n = 100)			US (n = 72)		
	ΔR^2	β	t	ΔR^2	β	t
Block 1	.141*			-.021		
Age		.272*	2.829		-.063	-.520
Gender		-.065	-.685		-.052	-.427
BMI		-.013	-.140		-.029	-.235
PA		.086	.841		.234	1.674
Cognitive		-.251*	-2.630		-.024	-.162
Parental Edu		-.202	-2.005		.128	.992
Block 2	.276**			.305**		

Age	$.221^{*}$	2.484		-.050	-.498
Gender	-.027	-.310		.029	.283
BMI	-.057	-.658		-.020	-.192
PA	.100	1.072		.116	.988
Cognitive	-.164	-1.828		.069	.569
Parental Edu	-.167	-1.802		.107	1.012
Total motor skills	$.388^{**}$	4.284		$.572^{**}$	5.614

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level.
$^{**}p < 0.01$, $^{*}p < 0.05$.

The association between parent ratings of fine motor skills and working memory of Taiwanese children with ASD was significant in step 2of hierarchical regression analysis after controlling for covariates ($\beta = .41$, $p < .001$). Overall, the full model explained nearly 29% of the variance in working memory (i.e., adjusted $R^2 = .287$). In addition, the association between fine motor skills and working memory ratings of American children was also significant after accounting for covariates ($\beta = .53$, $p < .001$). The full model accounted for 24% of the variance in working memory (i.e., adjusted $R^2 = .242$) as shown in Table 7.

Table 6. Hierarchical multiple regression analyses for fine motor skills predicting working memory

	Taiwan (n = 100)			US (n = 72)		
	ΔR^2	β	t	ΔR^2	β	t
Block 1	$.141^{*}$			-.021		
Age		$.272^{**}$	2.829		-.063	-.520
Gender		-.065	-.685		-.052	-.427
BMI		-.013	-.140		-.029	-.235
PA		.086	.841		.234	1.674
Cognitive		$-.251^{*}$	-2.630		-.024	-.162
Parental Edu		-.202	-2.005		.128	.992
Block 2	$.287^{**}$			$.242^{**}$		
Age		$.248^{**}$	2.835		-.007	-.064
Gender		-.033	-.385		.062	.573
BMI		-.063	-.729		-.006	-.055
PA		.122	1.307		.128	1.050
Cognitive		-.131	-1.436		.013	.106
Parental Edu		-.147	-1.588		.099	.896
Fine motor skills		$.411^{**}$	4.483		$.525^{**}$	4.852

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level.
$^{**}p < 0.01$, $^{*}p < 0.05$.

After controlling for covariates, parent ratings of gross motor skills were significantly associated with working memory ratings among children with ASD from Taiwan ($\beta = .26$, $p = .006$). Overall, the full model explained 20% of the variance in working memory (i.e., adjusted $R^2 = .200$). Further, children with ASD from the US had gross motor skill ratings that were significantly related to ratings of working memory after controlling for covariates ($\beta = .55$, $p < .001$). The full model accounted for nearly 28% of the variance in working memory (i.e., adjusted $R^2 = .279$) (See Table 8).

Table 7. Hierarchical multiple regression analyses for gross motor skills predicting working memory

	Taiwan (n = 100)			US (n = 72)		
	ΔR^2	β	*t*	ΔR^2	β	*t*
Block 1	.141*			-.021		
Age		.272**	2.829		-.063	-.520
Gender		-.065	-.685		-.052	-.427
BMI		-.013	-.140		-.029	-.235
PA		.086	.841		.234	1.674
Cognitive		-.251*	-2.630		-.024	-.162
Parental Edu		-.202	-2.005		.128	.992
Block 2	.200*			.279**		
Age		.229*	2.433		-.101	-.987
Gender		-.041	-.451		-.030	-.293
BMI		-.033	-.358		-.037	-.359
PA		.080	.817		.135	1.134
Cognitive		-.227*	-2.447		.104	.835
Parental Edu		-.196	-2.018		.122	1.127
Gross motor skills		.259**	2.805		.547**	5.294

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level.
**$p < 0.01$, *$p < 0.05$.

Inhibition

The hierarchical regression analysis showed that Taiwanese children with ASD had parent ratings of total motor skills that were significantly related to ratings of inhibition after controlling for covariates ($\beta = .26$, $p = .012$). Overall, the full model explained nearly 12% of the variance in inhibition (i.e., adjusted $R^2 = .122$). American children with ASD had total motor skill ratings that were also significantly associated with ratings of inhibition after accounting for covariates (β = .40, p < .001). The full model accounted for 14% of the variance in inhibition (i.e., adjusted R^2 = .143) as shown in Table 9.

Table 8. Hierarchical multiple regression analyses for total motor skills predicting inhibition

	Taiwan (n = 100)			US (n = 72)		
	ΔR^2	β	t	ΔR^2	β	t
Block 1	.070*			-.006		
Age		.231*	2.313		-.086	-.708
Gender		-.102	-1.027		-.186	-1.529
BMI		-.009	-.096		.053	.433
PA		-.026	-.241		.123	.888
Cognitive		-.201*	-2.025		.126	.872
Parental Edu		-.143	-1.360		.111	.871
Block 2	.122*			.143**		
Age		.198*	2.019		-.076	-.684
Gender		-.077	-.793		-.130	-1.143
BMI		-.039	-.401		.059	.526
PA		-.016	-.154		.041	.316
Cognitive		-.144	-1.455		.190	1.413
Parental Edu		-.120	-1.171		.097	.825
Total motor skills		.256*	2.563		.397**	3.509

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level.
**p < 0.01, *p < 0.05.

The association between parent ratings of fine motor skills and inhibition of Taiwanese children with ASD was significant in step 2of hierarchical regression analysis after controlling for covariates (β = .21, p = .042). Overall, the full model explained 10% of the variance in inhibition (i.e., adjusted R^2 = .101). In addition, the association between fine motor skills and inhibition ratings of American children with ASD was also significant after accounting for covariates (β = .39, p = .001). The full model accounted for nearly 13% of the variance in working memory (i.e., adjusted R^2 = .134) (See Table 10).

Table 9. Hierarchical multiple regression analyses for fine motor skills predicting inhibition

	Taiwan (n = 100)			US (n = 72)		
	ΔR^2	β	t	ΔR^2	β	t
Block 1	.070*			-.006		
Age		.231*	2.313		-.086	-.708
Gender		-.102	-1.027		-.186	-1.529
BMI		-.009	-.096		.053	.433
PA		-.026	-.241		.123	.888

Cognitive		-.201*	-2.025		.126	.872
Parental Edu		-.143	-1.360		.111	.871
Block 2	.101*			.134*		
Age		.219*	2.227		-.043	-.383
Gender		-.085	-.874		-.100	-.869
BMI		-.035	-.363		.070	.618
PA		-.007	-.066		.044	.339
Cognitive		-.139	-1.359		.153	1.144
Parental Edu		-.114	-1.098		.090	.760
Fine motor skills		.213*	2.067		.393*	3.396

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level.
$^{**}p < 0.01$, $^{*}p < 0.05$.

After controlling for covariates, parent ratings of gross motor skills were significantly associated with inhibition ratings among children with ASD from Taiwan (β = .22, p = .025). Overall, the full model explained nearly 11% of the variance in inhibition (i.e., adjusted R^2 = .109). Further, American children with ASD from the US had gross motor skills ratings that were significantly associated with ratings of inhibition after accounting for covariates (β = .35, p = .003). The full model accounted for nearly 11% of the variance in inhibition (i.e., adjusted R^2 = .108) (See Table 11).

Table 10. Hierarchical multiple regression analyses for gross motor skills predicting inhibition

	Taiwan (n = 100)			US (n = 72)		
	ΔR^2	β	t	ΔR^2	β	t
Block 1	.070*			-.006		
Age		.231*	2.313		-.086	-.708
Gender		-.102	-1.027		-.186	-1.529
BMI		-.009	-.096		.053	.433
PA		-.026	-.241		.123	.888
Cognitive		-.201*	-2.025		.126	.872
Parental Edu		-.143	-1.360		.111	.871
Block 2	.109*			.108*		
Age		.194	1.961		-.110	-.964
Gender		-.081	-.838		-.172	-1.499
BMI		-.026	-.271		.048	.413
PA		-.030	-.291		.059	.450
Cognitive		-.180	-1.845		.207	1.500
Parental Edu		-.138	-1.341		.108	.895
Gross motor skills		.221*	2.271		.351*	3.057

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level.
$^{**}p < 0.01$, $^{*}p < 0.05$.

The last regression model showed that the interaction term between motor skills and the country was not significant, indicating that the differences in associations between parent ratings of motor skills and EF did not vary as a function of the country (β = .061 ~ .086, p = .647 ~ .829) (see Table 5). In other words, the relation between motor skills and EF ratings was not different in children with ASD from Taiwan compared to the children with ASD from the US.

Table 11. Hierarchical multiple regression analyses for motor skills predicting EF (n = 172).

	Total EF			Working memory			Inhibition		
	ΔR^2	β	t	ΔR^2	β	t	ΔR^2	β	t
Block 1	.027			.043*			.005		
Age		.144	1.89		.157*	2.04		.103	1.34
Gender		-.113	-1.48		-.070	-.92		-.154*	-1.99
BMI		-.019	-.24		-.037	-.47		.009	.11
PA		.158	1.94		.194*	2.40		.082	1.00
Cognitive		-.139	-1.69		-.178*	-2.18		-.063	-.76
Parental Edu		-.052	-.64		-.070	-.86		-.020	-.24
Block 2	.230**			.269**			.165**		
Age		.110	1.61		.120	1.80		.078	1.07
Gender		-.053	-.78		-.008	-.12		-.107	-1.45
BMI		-.014	-.18		-.042	-.58		.027	.34
PA		.115	1.59		.150*	2.12		.049	.63
Cognitive		-.046	-.60		-.087	-1.16		.017	.21
Parental Edu		-.057	-.75		-.065	-.89		-.036	-.45
Country		.066	.82		.104	1.33		.003	.04
Total motor skills		.428**	4.32		.468**	4.85		.303*	2.86
Total motor skills*Country		.077	.79		.061	.65		.086	.83

Note: BMI = Body mass index; PA = whether a child received physical activity program/intervention; Cognitive = whether a child received a cognitive training; Parental Edu = parental education level; EF = executive function.
**p < 0.01, *p < 0.05.

Discussion

The purpose of this study was to examine the relationships between parent ratings of motor skills and EF in children with ASD from the US and Taiwan. Specifically, this study aimed to answer (1) what is the relationship between motor skills and EF ratings in young children with ASD from Taiwan and the US and (2) how do such relationships in children with ASD in Taiwan differ from the children with ASD in the US? Results indicated that parent ratings of total motor skills, fine motor skills, and gross motor skills were significantly associated with EF in both working memory and inhibition in both countries. Another important finding was that considerable similarities were revealed between Taiwan and the US children with ASD in the relationships between ratings of motor skills and EF. This is one of the first studies, to the authors' knowledge, investigating the associations between motor skills, including both fine and gross motor skills, and EF, including working memory and inhibition, in young children with ASD across two countries.

Our findings indicated that the significant associations between ratings of motor skills and EF in children with ASD did not depend on country, suggesting that these relationships are culturally comparable, with significant and positive correlations of magnitude in both countries. No research, to date, has explored the link between motor skills and EF in young children with ASD cross-culturally. It might be possible that the relation between motor skills and EF follow the same developmental timeframe and trajectory, regardless of the different contextual influences, such as geographical, cultural, and educational factors. While the exploratory nature of this study warrants future cross-cultural research, the current findings partially corroborate evidence from previous research on children with ASD in western countries (Hellendoorn et al., 2015; Kim et al., 2016; Schurink et al., 2012). Schurink et al. (2012) found significant relationships between manual dexterity, balance, and planning ability measured by objective assessments among children with pervasive developmental disorder-not otherwise specified, a type of ASD, indicating that inferior motor skills performance is associated with poorer EF. Such a relationship may be explained by considering that substantial comorbidity between deficits in motor skills and cognitive functioning was observed in children with neurodevelopmental disorders. Indeed, several studies have suggested that the relations between motor skills and cognitive development were manifested in children with intellectual disabilities (Hartman et al., 2010; Houwen et al., 2016; Wuang et al., 2008), Down syndrome (Schott & Holfelder, 2015), developmental coordination disorder (Leonard et al., 2015) and attention-deficit hyperactivity disorder (Ziereis & Jansen, 2016). The present study contributes to a greater magnitude of existing literature in the field of disability, indicating the relationship between motor skills and two domains of EF (i.e., working memory and inhibition) among young children with ASD from different countries.

The current findings are in accordance with the theoretical framework of learning to learn (Adolph, 2005) and embodied cognition theory (Smith & Gasser, 2005), which suggests that cognition develops as a result of an agent's bodily interactions with their surroundings. For instance, children develop the capacity for problem-solving through the interaction of their motor behavior and exploring and interacting with the environment. With this, early motor skills seem to lay the foundation for later cognitive development among children. The theoretical perspective was further supported by neuroimaging research (Diamond, 2000). Empirical evidence has revealed that the rostral premotor cortex connects between motor and cognitive networks and that brain regions previously thought to be involved only in motor activities (i.e., cerebellum and basal ganglia) or cognitive activities (i.e., the prefrontal cortex) are co-activating while people engage in certain cognitive and motor tasks. (Diamond, 2000; Hanakawa, 2011). Moreover, previous evidence has revealed that motor and cognitive development are highly associated and further suggested that motor behaviors that facilitate interaction with the environment during early childhood are critical for cognitive growth (Campos et al., 2000). Our findings further reinforce the theorized and neuroimaging evidence on the associations between motor skills and EF in the ASD population.

Motor Skills and Working Memory

Consistent with our hypothesis, the findings of the present study showed that both parent ratings of fine and gross motor skills were significantly related to working memory ratings in children with ASD from Taiwan and the US. Our results corroborate previous studies revealing that fine motor skills are associated with working memory in children at-risk/with ASD (Rosenblum et al. 2019; St. John et al., 2016) and preschool-aged children without ASD (Houwen et al., 2017). Rosenblum et al. (2019) suggested a significant relationship between handwriting and working memory among school-aged children with ASD. Authors assumed that handwriting, especially in the context of story-writing, might be difficult and particularly affected by even minor distractions for children with ASD, who are known to have deficits in working memory. Another plausible explanation might be the fact that working memory is needed for various activities involving fine motor skills, especially visual-motor integration (MacDonald et al., 2016). The items evaluating fine motor skills in the current study consisted of how well a child does in using scissors for cutting, in the constructive play and creative activities (e.g., Lego). These complex motor tasks, such as building blocks or manipulating scissors to cut along a line, likely involve the processes of working memory to control the coordination necessary to complete the activity/task successfully (van der Fels et al., 2015). Indeed, children spend a significant amount of time engaged in fine motor skills such as drawing, cutting, folding, and manipulating objects in preschool settings (Cameron et al., 2012; Pitchford et al., 2016). These activities have certain demand on fine motor skills and visuomotor integration, which are necessary for executive functioning, including working memory among young children.

In line with previous studies in typically developing children (Lehmann et al., 2014; Rigoli et al., 2012; Wassenberg et al., 2005) and children with intellectual disabilities (Hartman et al., 2010), our findings showed that gross motor skills ratings are associated with ratings of working memory in young children with ASD. While speculative in nature, a possible explanation for such findings might be the underlying cerebellar processes. The lateral zone of the cerebellum is intricately involved in regulating the motor activity of the whole body, namely the gross motor skills (Grodd et al., 2001). Neuroimaging research has indicated the activation of the cerebellum during working memory tasks (Marvel & Desmond, 2010). Collectively, the present study differs from earlier research on children with ASD by offering a more nuanced understanding of the associations between fine and gross motor skills and working memory in both western and eastern countries.

Motor Skills and Inhibition

The findings of this study indicated that both parent ratings of fine and gross motor skills were significantly associated with inhibition ratings in children with ASD from Taiwan and the US. This result mimics previous research on young children without ASD (Livesey et al., 2006). Livesey et al. (2006) utilized objective motor skill assessment (i.e., MABC) and Stroop test and indicated a significant association between motor skills and inhibitory control among 5 – 6 years old children without ASD. In addition to the explanation of co-activation of brain areas, this association between motor skills and inhibition might be posited from a behavioral learning perspective (Sung et al., 2021). For example, when children with ASD are in a learning environment, such as in preschool settings, they must pay attention and inhibit unrelated behaviors to properly demonstrate a fine motor task, such as writing, stringing beads, and manipulating objects. Inhibition is especially critical for young children, who may be more susceptible to environmental distractions in their surroundings. Evidence has suggested that inhibition emerges first during development in order for young children to ignore irrelevant stimuli and solve the problem (Best et al., 2009). The ability to inhibit pre-potent responses might be an important first step in learning among young children.

While gross motor skills are generally considered to be associated with social skills or physical well-being (Holloway et al., 2018), our results revealed that children with ASD's gross motor skills ratings were significantly related to ratings of inhibition. This finding is consistent with previous cross-sectional (Livesey et al., 2006) and longitudinal research (Wu et al., 2017). Wu et al. (2017) have indicated that the early gross motor ability of 2-year-old infants predicts their inhibitory control at three years. In addition, evidence has suggested that the motor planning ability among children was associated with the capacity to inhibit a potent but irrelevant response (Pennequin et al., 2010). The item measured gross motor skills in ChAS-P included not only movement skills and ball skills but also included the item of maintaining balance while performing various activities (i.e., moving through obstacle courses), which likely involves certain aspects of motor planning. Further, this finding is aligned with the results of physical activity intervention studies. Research has revealed that physical activity involving gross motor exercise positively facilitates the processes of inhibitory control (Pan et al., 2017; Tsai et al., 2012). Our results highlight the importance of engaging in gross motor opportunities for children with ASD, given its association with inhibition.

The findings of the present study also revealed that ratings of fine motor skills had higher associations with EF ratings than gross motor skills. This result is aligned with research on children without ASD (Maurer & Roebers, 2019) as well as children with disabilities (Houwen et al., 2016; Wuang et al., 2008). The difference observed in the link between gross motor skills and fine motor skills with EF may be attributable to the fact that fine motor skills exert a greater demand on the integrity of the cortical nervous system, specifically the frontoparietal network

(Davare et al., 2006). Additionally, while the relationships between parent ratings of motor skills and EF were not significantly different in children with ASD from Taiwan and the US, the lower standardized beta coefficients were observed in Taiwanese children. This finding might be partially due to other influences of contextual factors. Evidence has indicated that both personal (e.g., comorbidity) and environmental factors (e.g., parenting practice) might affect motor and cognitive development (Houwen et al., 2017; Luo et al., 2007). However, information such as ADHD symptoms or parenting style is unavailable in this study. Thus, it is essential to acknowledge the influence of these factors on the association between ratings of motor skills and EF among young children with ASD.

Children with ASD often experience deficits in various domains that have long-term consequences. Motor skills difficulty puts an additional burden on the child and could impact their daily life and social interactions considerably. Therefore, assessing and knowing the roles of fine and gross motor skills might help parents and professionals identify skills and programs that can be intervened early on in improvements of EF, which might also help provide these young children with ASD to reach their full potential in their developmental trajectory. The present findings provide some critical practical implications for parents and practitioners working with young children with ASD. Parents and practitioners should be aware of the specific relationship between both motor skills (i.e., fine and gross motor skills) and EF (i.e., working memory and inhibition). Such specific associations might indicate that early measurement of motor skills may be particularly beneficial for a child’s higher-order cognitive development, given the observed links between motor skills and EF. Neuroimaging evidence has indicated that the areas of the brain linked with more basic functions, including motor skills, mature first (Casey et al., 2005). Therefore, the development of early motor skills should be a priority.

Parents and practitioners should provide and highlight both fine and gross motor opportunities in order to facilitate the EF of young children with ASD.

While this study has yielded meaningful findings with regard to the cross-cultural associations between parental rating of motor skills and EF of young children with ASD from Taiwan and the US, several limitations need to be considered. First, the severity level, IQ, and comorbidity status of the children with ASD from both countries were not reported in this study. Although various confounding variables were included in our analyses, it is important to mention that other variables that did not account for in the present study might have played a role, given that multiple systems would influence child development (Thelen & Smith, 2007). Second, the motor skills and EF measurement of children with ASD were assessed via parental proxy report. Such subjective rating may be influenced by personal and cultural biases or beliefs, as well as prior experiences. In order words, parental perceptions might result in different bars in evaluating their child's daily performance of motor skills and EF (Houwen et al., 2017). It is worth noting that parent rating and performance-based measurement should not be used interchangeably as they capture different aspects; preferably using these two types of assessment in combination in the best-case scenario. Therefore, future research should utilize a combination of both parental reports and objective performance-based assessments of motor skills and EF to obtain more comprehensive and detailed information regarding the relationship between motor skills and EF among young children with ASD. Lastly, the cross-sectional nature of the current study limits causal implications. Future studies should examine the motor and cognitive development of children with ASD using longitudinal design and assessments to gain more insight regarding how the relationship between motor skills and EF changes over time in the ASD population.

Conclusion

This research is one of the first study to explore cross-cultural relationships between motor skills and EF of young children with ASD from Taiwan and the US. Overall results revealed that parent ratings of fine motor skills and gross motor skills were significantly associated with EF ratings in both working memory and inhibition among 4 – 6 years children with ASD from Taiwan and the US. Further, these associations between motor skills (i.e., fine motor and gross motor skills) and EF (i.e., working memory and inhibition) ratings were similar between the two countries. The present study is the important first step in understanding the relationships between motor skills and EF development. This study also sheds light on the importance of developing relevant initiatives and programs to create motor skills and EF intervention to build the early foundation for success later in school and in life among children with ASD.

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Chapter 4. General Conclusion

This study investigated cross-cultural comparisons and relationships of parent ratings of motor skills and EF in children with ASD from Taiwan and the US. The purpose of this study was twofold: (1) to compare the parent ratings of motor skills and EF in children with ASD in the US and Taiwan and (2) to examine the relationships between parent ratings of motor skills and EF in children with ASD in the US and Taiwan. One hundred seventy-two parents of children with ASD aged 4 – 6 years and 11 months completed an internet-based survey including 66 questions anonymously, as a part of a cross-sectional survey-designed study. One-way MANCOVA and a series of hierarchical multiple regressions were conducted to answer the research questions in the present study. Overall, the current study revealed that children with ASD from the US were rated as having better fine and gross motor skills than their peers from Taiwan, while there was no difference in EF ratings. Further, parent ratings of total motor skills, fine motor skills, and gross motor skills were significantly associated with EF ratings in both working memory and inhibition of children with ASD from Taiwan and the US. In addition, these associations were similar between the two countries.

A hypothesis of study 1 was that children with ASD from Taiwan would be rated as having better fine motor skills than children with ASD from the US, while children with ASD from the US would be rated as having better gross motor skills compared to children with ASD from Taiwan. However, our results indicated that the hypotheses were partially met. The findings indicated that children with ASD in the US were rated by parents as having better gross motor skills (M = 15.50) and fine motor skills (M = 18.03) compared to their peers in Taiwan (M = 18.34 & 21.78), Wilk's Λ = .956, F (2, 166) = 3.83, p = .024, partial η^2 = .044. It is noteworthy that if a child with ASD was rated with low motor skill scores by parents, it reflects this child has better motor skills. The cross-cultural motor skill differences found may be related to aspects such as physical activity opportunities, curriculum and educational priorities, and other contextual factors (e.g., personal and environmental). The findings provided cross-cultural differences in motor skills of ASD in Taiwan and the US.

Another hypothesis of study 1 was that children with ASD from Taiwan would be rated as having better EF on inhibition and working memory compared to children with ASD in the US. Contrary to the hypothesis, our results showed that children with ASD from the US and Taiwan's total EF scores (M = 84.51 vs. M = 86.31), working memory (M = 44.67 vs. M = 45.42), and inhibition (M = 39.85 vs. M = 40.89) rated by parents were not significantly different between the two countries, Wilk's Λ = .993, F (2, 167) = .55, p = .577, partial η^2 = .007. While speculative in nature, no differences found in EF of children with ASD from Taiwan and the US might be explained by a shift in cultural value in Chinese society, which influences the rating of parents toward their children with ASD in Taiwan (Chen et al., 2005). Also, the results might be influenced by the differences in methodological approaches used in different studies (i.e., parental proxy report vs. performance-based tasks). While this study did not find any difference in EF ratings, it provided initial evidence of the EF of young children with ASD measured by parent reports in different countries.

In study 2, a hypothesis was that the relationship between parent ratings of motor skills and EF would be statistically different across countries, with children with ASD from Taiwan would have stronger associations of motor skills and EF ratings than their peers from the US. In contrast to the hypothesis, our findings indicated that the differences in associations between motor skills and EF did not vary by country (β = .061 ~ .086, p = .647 ~ .829). In other words, the relationship between parent ratings of motor skills and EF were not different in children with ASD from Taiwan compared to their peers from the US. No research, to date, has explored the link between motor skills and EF in young children with ASD cross-culturally. It might be possible that the relations between motor skills and EF follow the same developmental timeframe and trajectory across countries among ASD population, regardless of the different contextual influences (e.g., geographical, cultural, and educational factors).

Another hypothesis of study 2 was that there would be significant associations between parent ratings of motor skills and EF in children with ASD from Taiwan and the US, respectively. As expected, our results revealed that children with ASD's total motor skills, fine motor skills, and gross motor skills were significantly associated with working memory ratings in both countries after controlling for covariates ($\beta = .259 \sim .572$, $p < .01$). Overall, the full models of total motor skills, fine motor skills, and gross motor skills explained nearly 20% to 31% of the variance in working memory. In addition, parent ratings of total motor skills, fine motor skills, and gross motor skills were significantly associated with ratings of inhibition of children with ASD from Taiwan and the US, respectively, after accounting for covariates ($\beta = .213 \sim .397$, $p < .01$). The overall models of total motor skills, fine motor skills, and gross motor skills explained 10% to 14% of the variance in inhibition. Our findings supported previous research and further reinforced the theorized and neuroimaging evidence on the associations between motor skills and executive functioning in the ASD population.

While the present study represents an important first step in understanding the comparison and relationship of motor skills and EF among young children with ASD cross-culturally, it is noteworthy to suggest future directions based on the current study. Given that multiple systems could influence child development (Thelen & Smith, 2007), future studies should take into account both personal factors (e.g., IQ, ASD severity level, and comorbidity status) and environmental factors (e.g., cultural values, preference for physical activity opportunities, and parenting style) when examining comparison and association of motor skills and EF of children with ASD from different countries. Furthermore, future research is warranted to utilize a combination of both parental reports and objective performance-based assessments of motor skills and EF to obtain more comprehensive and detailed information regarding the variations and relationships between motor skills and EF among young children with ASD cross-culturally.

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Appendix

Appendix A: Literature Review

The purpose of this chapter is to synthesize existing literature on introduction of autism spectrum disorder (ASD), introduction of motor skills and executive function (EF) in ASD population, the association between motor skills and EF in typically developing children and the relationship between motor skills and EF in children with ASD, and cross-cultural aspects of motor skills and EF.

Autism spectrum disorders

Autism Spectrum Disorders (ASD), a genetically based neurodevelopmental disorder, is a lifelong disorder experiencing challenges in social interactions and communication and exhibiting restricted and repetitive patterns of behaviors (American Psychiatric Association [APA], 2013). ASD is typically diagnosed in early childhood around 3 years old. Based on the latest report from the Center for Disease Control and Prevention (CDC), the estimated autism prevalence in 2016 increased from one in sixty-eight to one in fifty-four children (CDC, 2020; Maenner, 2020). The prevalence of ASD in Taiwan was also increasing; people who identified with ASD increased from 10,160 to 15,750 between 2010 to 2020 (Ministry of Health and Welfare, 2020). In addition, the number of children aged 3 through 5 years served under Individuals with Disabilities Education Improvement Act (IDEA) Part B services within the ASD category increased from 7.8 percent in 2012 to 10.8 percent in 2017 (U.S. Department of Education, 2020). These increasing numbers highlight the need for health, education, and social services for the ASD population. The sex ratio for ASD is estimated at least 4:1 with the rate of more commonly diagnosed in males (Werling & Geschwind, 2013). While the core characteristics of ASD are considered to be pervasive, another common characteristic includes motor skill impairments (Green et al., 2009), which is lacking as an identifiers in the Diagnostic and Statistical Manual of Mental Disorders (APA, 2013). Nonetheless, the International Classification of Functioning, Disability and Health classifies motor skill deficits as an ASD-associated symptom (World Health Organization, 2001).

Motor skill development

In this study, the term “motor skills” refers to motor competence, which reflects various global terminologies (i.e., motor proficiency, motor performance, fundamental motor skill, fine and gross motor skills, and motor coordination) to describe goal-directed human movement (Robinson et al., 2015). Dynamic systems theory is frequently used in the field of motor development to understand how movement develops and changes from the interaction of multiple subsystems within the person, task, and environment (Thelen, 2005). It highlights a new movement skill emerges from the self-organization of cooperative interactions among multiple subsystems in a nonlinear, interactive, and bidirectional fashion (Thelen, 2005). *Self-organization* represents the pattern and order emerge from the interactions of the components of a complex system without explicit instructions, either in the organism itself or from the environment (Thelen & Smith, 2007). *Nonlinearity* means that development is a continuous but nonlinear pattern of development. (e.g., it's not uncommon for an infant to triple their weight from birth to 6 months old. If this trend continued, in a linear way, he/she would weigh over 17 billion pounds by age 10) (Thelen, 2005). Furthermore, motor development contributes to the dynamic interaction of *multiple systems*, cooperating with many subsystems. (e.g., movement involves muscular, postural, sensory, cardiovascular). This dynamic interaction explains that the behavioral outcome is a product of system interaction (Thelen & Smith, 2007).

Importance of motor skills

Motor skills play a crucial role in early childhood development (Robinson et al., 2015), and it is also considered as a building block for early learning (Adolph & Hoch, 2019). For example, fine motor skills involve small muscles of hands, fingers, and forearms movement needed for reaching, grasping, manipulating objects, and handwriting, which are essential for performing activities of daily living such as eating, playing, dressing, and engaging in academic activities (Grissmer et al., 2010). Gross motor skills involve movement and coordination of larger muscles in the legs and torso for walking, running, and jumping, which help children navigate the surroundings and participate in physical activities and sports (Lin et al., 2017).

Motor skills are the prerequisite skills and steppingstone to be physically active. Stodden and his colleagues (2008) proposed a conceptualized model to discuss the relationship between physical activity, motor competence, perceived motor skills competence, health-related physical fitness, and obesity. They stated that fundamental motor skills, such as locomotor and objective control, build the foundation for future movement and physical activity. This model provides a reciprocal and dynamic relationship between motor skills competence and physical activity. They describe fundamental motor skills as alphabets in the world of physical activity; if children don't have these fundamental skills, they will have limited opportunities to engage in physical activity later in their lives because they don't have the prerequisite skills to be active. Especially in young children, physical activity drives the development of their motor skills competence in ways that increased physical activity provides more opportunities to promote fundamental motor skills. Related, having better fundamental motor skills might increase their willingness to be physically active. Further, such relationships will be strengthened over time and have compound effects. In this model, other factors will also interact with the relationship between fundamental motor skills and physical activity, such as perceived motor skills competence, health-related physical fitness, and obesity, which, taken together, will promote or demote the dynamic relationship between motor skills and physical activity.

The positive trajectory of motor skills could also impact various fundamental aspects of child development. Numerous studies have indicated that fine motor skills are associated with school readiness (Cameron et al., 2015; Tepfer, 2015), emergent academic skills (Fischer et al., 2020; Suggate et al., 2018), and later academic achievement (Cameron et al., 2016; Fernandes et al., 2016; Greenburg et al., 2020; Macdonald et al., 2018). Evidence has also suggested that gross motor skills are related to social interaction (Leonard & Hill, 2014), physical well-being (Barnett et al., 2016; Lin et al., 2017), and academic performance (Lopes et al., 2013). Furthermore, motor skills are linked to language development from infancy to early childhood (Gonzalez et al., 2019; Libertus & Violi, 2016). In sum, the evidence illuminates the important association between motor skills and other developmental domains, which highlights the need to foster motor skills development in early childhood.

Motor skill of children with ASD

Children with ASD demonstrate motor skills delay and deficits (Green et al., 2009; Staples & Reid, 2010). Evidence has indicated that the motor delay among children with ASD was observed within the first two years of age (Harris, 2017). Research also revealed that motor skills impairments were related to their clinical features of repetitive behaviors, social skills, and expressive language in preschool children with ASD (Fulceri et al., 2019). Children with ASD demonstrating motor skills deficits range from 59% to 83%, depending on various motor skills assessments used in different studies (Dewey et al., 2007; Green et al., 2009; Hilton et al., 2012). The gender difference in motor skills performance was also observed in children with ASD.

Evidence showed that significant differences in object control skills with boys outperformed girls with ASD aged 6-8 years (Berkeley et al., 2001).

Recent neuroanatomical and neurophysiologic studies revealed cortical and subcortical areas including the motor cortex, supplementary motor area, basal ganglia, and cerebellar dysfunction as contributory to the observed deficits of individuals with ASD in motor planning, integration, and execution (Suzumura et al., 2021). A systematic review and meta-analysis reported that total brain volume, cerebral hemispheres, cerebellum, and caudate nucleus were increased, while the corpus callosum area was reduced among individuals with ASD (Stanfield et al., 2008). Evidence indicated that abnormal movement-related potentials, including increased post-movement cortically activity over the supplementary motor area and abnormal peak time, were observed in people with ASD, which likely contributes to motor dysfunction in ASD (Enticott et al., 2009). Taken together, these neurobiological studies elucidate the possible mechanistic findings of the difference in motor behaviors observed in children with ASD.

Numerous studies comparing children with ASD and their typically developing peers revealed that motor impairments are evident in the ASD group (Kaur et al., 2018; Ketcheson et al., 2018; Landa & Garrett-Mayer, 2006; Liu et al., 2021; Pan, 2014; West, 2019; Whyatt & Craig, 2012). Green et al. (2009) examined the motor skills impairment in a group of children with ASD with a wide range of IQ by using Movement Assessment Battery for Children (MABC) (n = 101, 89 males, 12 females, age range 10 to 14 years). They found that 79.2% of children with ASD had motor problems, and motor skills deficits are more common and more severe in children with ASD with the comorbidity of intellectual disability (IQ < 70). They also indicated that motor impairment was not associated with everyday adaptive behaviors once the IQ of children with ASD was accounted for. A meta-analysis conducted by Fournier et al. (2010)

reported a large and significant overall standardized difference effect 1.20 ($SE = 0.114$; $p < 0.0001$) in comparison of motor coordination between people with ASD and typically developing group, suggesting pronounced deficits in motor coordination and postural stability in ASD population. Staple & Reid (2010) 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. This 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 (perform similarly to TD children approximately half their age), reflecting both deficits and delays in motor skills among children with ASD (Staples & Reid, 2010).

Motor skills are related to other developmental areas among children with ASD, including social skills (Bhat et al., 2011; Holloway et al., 2018; MacDonald et al., 2013b), language development (Bedford et al., 2016; Mody et al., 2017), and daily living skills (Jasmin et al., 2009). A systematic review conducted by Ohara et al. (2020) indicated that motor and social skills are highly associated among children with ASD, with fine motor skills demonstrating a stronger relationship with social skills than gross motor skills. MacDonald et al. (2013a) examined the relationship of motor skills on daily living and adaptive behavior skills among 159 young children with ASD aged between 12-33 months. Their results showed that the fine motor skills were significantly associated with adaptive social and communicative skills, while gross motor skills were significantly predictive of daily living skills performance in young children with ASD. In sum, identifying the delay or deficits of motor skills among young children with ASD should be viewed as the top priority because motor impairment might not only exacerbate other core symptoms by limiting their social interaction with others and surroundings but also hinder their willingness to be physically active during early childhood development.

Executive function development

Executive function (EF), an umbrella term, comprises a set of higher-order cognitive processes that include distinct but highly intercorrelated components necessary for goal-directed behavior (Diamond, 2013). Miyake et al. (2000) proposed a prominent theoretical framework to describe the “unity and diversity of EF,” suggesting that the EF construct encompass interrelated but distinct components. In this seminal study, they used confirmatory factor analysis (CFA) to examine this framework. Three correlated latent variables were extracted by the CFA model, namely inhibitory control, working memory, and cognitive flexibility – that contributed differentially to complex EF performance (Miyake et al., 2000).

Inhibitory control refers to the ability to control impulsive responses to more appropriate or needed ones adapted to the situation (McClelland & Cameron, 2012). Working memory refers to the ability to hold certain information in a mentally accessible state and manipulate it for ongoing processing (Garon et al., 2008). Individuals use working memory to identify and maintain information in order to perform a task successfully. Cognitive flexibility refers to the ability to switch perspectives and approaches between different mental tasks or strategies (Diamond, 2013). The interaction of these three core EF components builds higher-level EF behaviors, such as planning and reasoning (Collins & Koechlin, 2012).

EF is mainly coordinated by the prefrontal cortex (Durston & Casey, 2006), and the timeframe for the development of EF is from childhood to early adulthood (Best, Miller, & Jones, 2009). While EF development continually improves across the first two decades of life, early childhood has been recognized as a critical period of changes for EF skills. The development of executive functioning starts in infancy; nonetheless, preschool years is the time period for the rapid increases of brain maturation in EF skills (Garon et al., 2008). Specifically, inhibition and working memory have been identified to be the fundamental and necessary skills for higher-order EF operations such as task-switching and planning (Chevalier et al., 2012). Evidence has indicated that inhibitory control emerges first in the EF construct in order to disregard irrelevant stimuli due to the nature of environmental distractions; thus, inhibitory control plays a vital role for young children (Best et al., 2009). After young children have developed the inhibitory control to a certain level, they could benefit more from other components of EF such as working memory and cognitive flexibility (Garon et al., 2008).

Importance of executive function

Executive functioning is positioned as a foundational ability with the potential to affect developmental trajectories (Best & Miller, 2010). Evidence has indicated that EF plays a crucial role in physical and mental health (Robson et al., 2020), school readiness (Becker et al., 2014; McClelland et al., 2007; McClelland & Cameron, 2012), social interaction (Hirshfeld-Becker et al., 2007; Smithers et al., 2018), academic performance (Allan et al., 2014), and quality of life (de Ridder et al., 2012). EF not only enables individuals to initiate and organize tasks but also allows people to inhibit inappropriate behaviors and make alternative plans quickly in unpredictable settings (Tsai et al., 2017). In addition, EF provides a foundation to success in school and work and allows people to manage stress and overcome the barriers to daily life activities (Diamond, 2013). Without well-developed EF, children and adults might say or do things that are considered to be bizarre or offensive, which therefore impeding positive social interaction and everyday functioning in life. Indeed, a recent meta-analysis study revealed that higher EF in preschool was positively correlated with social skills, school participation, and academic performance in early school years. Better EF performance in early school years was associated with a lower incidence of depressive symptoms, obesity, cigarette smoking, and illicit drug use in later school years. Further, EF performance in childhood was negatively linked to a greater likelihood of unemployment, criminal behavior, and symptoms of physical illness in adulthood (Robson et al., 2020).

Executive function of children with ASD

While the theory of mind and weak central coherence can explain some deficits related to ASD, the executive dysfunction serves as complementation in explaining the repetitive behaviors and restricts interests, such as a need for sameness or difficulty switching between tasks, in addition to the core symptoms of individuals with ASD (Hill, 2004; Jones et al., 2018). Impairment of various EF has been consistently reported in children with ASD (Hill, 2004; Kleinhans et al., 2005; Ozonoff & Jensen, 1999; Zhang et al., 2020). Further, the EF impairments of ASD are not only demonstrated in childhood but are persistent through development to adulthood (Fossum et al., 2021; Luna et al., 2007; Rosenthal et al., 2013). Deficits in EF among autism are supported by brain abnormalities that compromise complex information processing (Minshew et al., 2002). Research has indicated structural and functional abnormalities in brain areas, such as the prefrontal cortex, in individuals with ASD (O'Hearn et al., 2008; Zhang et al., 2020). Evidence has also suggested that the difficulties in communicative skills might implicate the EF of children with ASD since the acquisition of language skills in young children may associate with EF development (Pellicano, 2012; Zelazo et al., 2003).

A myriad of studies has indicated that children with ASD demonstrated EF impairments in various aspects of EF in comparison with their typically developing peers, including inhibition (Luna et al., 2007; Sinzig et al., 2014; Tsai et al., 2011), working memory (Barendse et al., 2013;

Chen et al., 2016; Kercood et al., 2014), cognitive flexibility (Corbett et al., 2009; Geurts et al., 2004), and planning (Hill, 2004; Kimhi et al., 2014). A recent meta-analysis conducted by Demetriou et al. (2018) included 235 studies with 14,081 participants across different age groups examining EF performance of people with ASD. Their findings suggested that individuals with ASD performed overall significantly worse EF compared to the neurotypical control group, and the impairments observed in the ASD group are relatively equivalenced across different constructs of EF. In a study conducted by Robinson et al. (2009), they found that children with ASD demonstrated EF deficits in the performance of planning, inhibition of responses, and self-monitoring when compared with IQ and language level matched typically developing children. Gardiner et al. (2017) examined the EF in young children (aged three to seven years) with and without ASD matched on age, IQ and, maternal education using both computerized measures and behavioral rating EF scale via parental report. Their findings showed no differences between young children with and without ASD on computerized tasks of working memory, inhibitory control, flexibility, and planning. However, a significant group difference on the EF behavior rating scale was observed, indicating young children with ASD demonstrated difficulties in day-to-day EF-related behavior (Gardiner et al., 2017). Although studies provided some evidence of EF impairments in the ASD population, the results have not all reached the consensus on which areas of EF are impaired in children with ASD.

EF deficits have also been posited to affect other developmental domains of children with ASD, including social interaction (Leung et al., 2016), adaptive behaviors (Kenny et al., 2019; Pugliese et al., 2016), and academic achievement (Kim et al., 2020). Evidence has indicated that poor EF performance in initiation, working memory, and planning demonstrated by children with ASD was related to increased playground isolation and less engagement with peers (Freeman et al., 2017). Research also revealed that the initiation and working memory in children with ASD were significantly associated with communication and socialization skills (Gilotty et al., 2002) and adaptive social skills (Pugliese et al., 2015). John et al. (2018) found that better EF performance at age 6 of children with ASD was associated with higher math achievement at age 9. Further, evidence has indicated that EF deficits among individuals with ASD lead to difficulties later in life during adulthood (Hume et al., 2009). Woolard et al. (2021) suggested that 62 individuals with ASD aged between 16 to 46 years who reported having more EF difficulties also perceived themselves as having poorer social and work functioning. Altogether, examining the EF skills of children with ASD is crucial as the impairments of EF may aggravate other aspects throughout the development.

The association between motor skills and executive function

Theoretical frameworks and neurobiological evidence

Theoretical frameworks provide the fundamental viewpoint of the co-occurrence and relationship of motor skills and cognitive development (Gibbs, 2005; Piaget, 1952; Smith & Gasser, 2005). The theoretical framework of learning to learn proposes that motor behaviors play an essential role in early learning (Adolph, 2005). In other words, early learning is centered around the motor systems involving gripping, posture, and motor control coordinately. As children adapt to a constantly changing environment, they need to use motor behaviors, such as reaching, crawling, and gripping, to produce novel solutions to solve any locomotor challenge they encounter while exploring and interacting with the surroundings. The novel solutions as a result of motor behaviors seem to drive cognitive development by requiring children to use mental flexibility and other cognitive functioning. Thus, early motor behaviors may set the foundation for cognitive development and higher-order cognitive process (i.e., EF).

Neurobiological evidence also shows underlying mechanisms of association between motor skills and EF. Functioning neuroimaging research found that the co-activation of the cerebellum, an area in charge of motor coordination, and the pre-frontal cortex, an area responsible for planning complex cognitive behavior, was observed when individuals with developmental disorders performed cognitive tasks (Diamond, 2000). Also, evidence shows that motor and cognitive skills appear to develop rapidly around the same timeframe, between 5 to 10 years old (Anderson, 2002). Moreover, several common underlying processes were revealed in both motor and cognitive skills, such as monitoring, sequencing, and planning (Roebers & Kauer, 2009). Therefore, examining the relationships between motor skills and EF during early childhood is critical given the evidence of theorized and the neurocognitive association between the two domains.

Relation of motor skills and executive function in typically developing children

Research has shown that motor skills are positively associated with EF in the population of typically developing (TD) children (Becker et al., 2014; Geertsen et al., 2016; McClelland & Cameron, 2019). While a majority of studies actively investigated the relations between fine motor skills and EF (Cameron et al., 2012; Fang et al., 2017; Maurer & Roebers, 2020; Rule & Smith, 2018), a few studies examining the association between gross motor skills and EF revealed promising results (Cook et al., 2019; Piek et al., 2008). In addition, EF performance seems to be selectively correlated with motor skills; namely, not every facet of EF is linked to different domains of motor skills (Ludyga et al., 2019). A systematic review included 21 studies examining the relationship between motor skills and cognitive skills among 4-16 years TD children indicated that complex motor skills show stronger associations with higher-order cognitive skills (i.e., EF) among TD children (van der Fels et al., 2015). This specific motor-cognitive link was proved by a recent study indicating that difficult motor tasks involve more EF than easy motor tasks among 124 TD preschoolers (Maurer & Roebers, 2019). MacDonald et al. (2016) investigated motor skills and EF performance in 92 children aged 3 to 5 years old. Their results revealed that the visual-motor integration skills of preschoolers significantly predicted their EF seven months after. Evidence also showed that motor skills performance and working memory index in a parent-rating EF scale were correlated in 153 young TD children aged 3 to 6 years (Houwen et al., 2017). All in all, these studies suggested different aspects of motor skills and EF have some degree of association and development simultaneously during early childhood.

Relation of motor skills and executive function in children with ASD

Evidence for the association between motor skills and EF in children with ASD has been found in only a small number of studies. Liu and Paulo (2021) investigated the association between motor competence and EF of 15 children with ASD aged 8 to 14 years. Their result showed that total score and aiming and catching subscales of MABC-2 were significantly correlated with EF performance measured by the Conner Continuous Performance Test-3. An exergaming intervention conducted by Hill et al. (2014) indicated that there was a strong correlation between EF metacognition index and motor skills in 7 school-aged children with ASD. Schurink et al. (2012) examined the motor and executive functioning in 28 children with pervasive developmental disorder not otherwise specified (PDD-NOS; a type of ASD) aged 7 – 12 years. The motor skills were measured with MABC, whereas EF was evaluated by the Tower of London (TOL) task. Findings revealed that manual dexterity, balance, and total MABC scores were significant correlated with the TOL scores (Schurink et al., 2012). Recently evidence indicated that there are strong positive correlations between manual dexterity, ball skills, balance, and cognitive flexibility among 18 children and adolescents with ASD aged 9 to13 years (Ramello de Carvalho et al., 2020). Research also suggested that handwriting performance, considered a type of fine motor skills, was correlated with working memory and shifting indices measured by the Behavior Rating Inventory of Executive Function questionnaire in 30 school-aged children with ASD (Rosenblum et al., 2019). While the evidence of correlations between motor skills and EF in children with ASD is promising, the studies mentioned above only focus on school-aged children with a limited sample size. Thus, further investigation is warranted.

Cross-cultural aspects of motor skills and executive function

Comparative research focusing on motor skills between children from distinct regions is scarce and has been only targeting children without disabilities. Brain et al. (2018) examined the motor competence of 4–5-year young children from Belgium and the US using the Test of Gross Motor Development, Second Edition (TGMD-2). Results showed that Belgian children demonstrated significantly higher performance on object control and locomotor skills compared to the US children. The authors indicated that preschool physical education programs in Belgium might play a key role in facilitating young children’s motor development. Chow et al. (2001) compared the motor skills between 255 Chinese TD children aged 4 – 6 years and 493 American counterparts using the MABC. Their findings showed that Chinese children demonstrated significantly better manual dexterity, while American children performed better on tasks involving projection and the reception of moving objects.

Research has indicated significant differences in EF performance between children in the eastern and western countries (Lan et al., 2011; Sabbagh et al., 2006; Schmitt et al., 2019). Some studies indicated that better EF performance (e.g., inhibition control) are frequently observed in the eastern sample (i.e., China) compared to their counterpart in the western sample (i.e., the US)

(Lan et al., 2011; Sabbagh et al., 2006), while other studies reported different findings (Schmitt et al., 2019; Thorell et al., 2013). Lan et al. (2011) examined the EF between 119 Chinese and 139 American TD children aged 4-5 years using Head-Toes-Knee-Shoulders (HTKS, inhibition), Sentence Completion task (working memory), and Woodcock-Johnson Pair Cancellation task (attentional control). Their findings showed that young Chinese children outperformed American children in inhibition and attentional control tasks while working memory performance in both samples was comparable. Similarly, Sabbagh et al. (2006) investigated the EF performance of 109 preschoolers in China and 107 in the United States using a series of EF batteries. Results revealed that the Chinese preschoolers outperformed their American counterparts on all EF tasks. Further, Schmitt et al. (2019) conducted a longitudinal study examining the growth of EF development across preschool periods for children in the US and China. Results revealed that Chinese children received more significant gains in EF, specifically in cognitive flexibility and behavioral regulation, during the preschool year compared to their US counterparts.

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Appendix B: Research Flyer

You're invited to complete an online survey to help improve our understanding of motor skills and executive function of young children with autism spectrum disorder (ASD).

To participate in this study, you should:

- Be a parent/legal guardian of a child with ASD ages 4 to 6 years 11 months
- Be 18 years old or above
- Live with your child with ASD over 1 year

Participation in this study involves:

- Completing an online survey, which takes approximately 10 - 15 minutes

Survey link: https://rb.gy/elrsrx or Scan the QR code

To learn more information for this study, please contact an assistant investigator, Ming-Chih (Darren) Sung at sungmin@oregonstate.edu

Principal Investigator: Dr. Megan MacDonald

Appendix C: Online Survey

EXPLANATION OF RESEARCH

Project Title: Cross-cultural Comparison and Relationship of Motor Skills and Executive Function in Children with Autism Spectrum Disorder in Taiwan and the United States

Principal Investigator: Megan MacDonald
Student Researcher: Ming-Chih (Darren) Sung
Version Date: 02/17/2022

Purpose:
The purpose of this study is twofold: (1) to compare the motor skills and executive function in children with autism spectrum disorder in the US and Taiwan, and (2) to examine the relationship between motor skills and executive function in children with autism spectrum disorder in the US and Taiwan. This research project will be used for a Ph.D. dissertation.

Activities: You will be asked questions about your child's motor skills and executive function and demographic information collected about the parent/guardian in an online Qualtrics survey.

Time: This survey takes approximately 15 minutes to complete.

Risks: There are no known risks associated with completing this questionnaire. Note: if you are affiliated with OSU community (e.g., students and employees), your academic or employment status will not be affected by participating in this study.

Confidentiality: The information you provide during this research study will be kept confidential. Research records will be stored securely. The security and confidentiality of information collected online cannot be guaranteed. Confidentiality will be kept to the extent permitted by the technology being used. Information collected online can be intercepted, corrupted, lost, destroyed, arrive late or incomplete, or contain viruses.

Potential Benefits: Your involvement in this study is important in understanding the cross-cultural variability in motor skills and executive function between children with autism spectrum disorder in the US and Taiwan.

Payment: You will not be paid for being in this research study.

Voluntary: Participation in this study is voluntary. The participant is free to skip any questions that they would prefer not to answer. The participants may discontinue participation at any time without penalty.

Study contacts: The researcher conducting this study is Megan MacDonald. For questions or more information concerning this research you may contact her at 541-737-6928 (phone) or megan.macdonald@oregonstate.edu (email) or her research assistant, Ming-Chih (Darren) Sung at sungmin@oregonstate.edu. If you have questions about your rights or welfare as a participant, please contact the Oregon State University Human Research Protection Program (HRPP) office, at 541-77-8008 or by email at IRB@oregonstate.edu

I understand the activities and conditions of my participation described above. My questions have been answered to my satisfaction. I agree to participate in this study and provide both informed consent for my participation (by completing the questionnaires about the child and providing demographic data) and permission for my child's data to be used in the research study by selecting 'I agree to participate in this study.'

Informed consent

○ I agree to participate in this study

○ I do not agree to participate in this study

You can print or take a screenshot of this consent/permission form for your records if you wish.

→

Oregon State University

Thank you for your interest in completing our survey. Your participation as a caregiver of a child with autism spectrum disorder is greatly appreciated to help gain a better understanding of motor skills and executive function and their association in children with autism spectrum disorders. Please read the following information carefully to help you complete the survey.

Questions have been separated into different categories with separate instructions for each different category. Please carefully read the instructions before starting each section. Please read each question carefully and mark one response for each question and/or sub-question. There are no right or wrong answers. **Once again, thank you for your time and contribution.**

By checking the box below, you are indicating that you are at least 18 years old and have at least one **child between the ages of 4 - 6 and 11 months with autism spectrum disorder,** and you have lived with the child for at least one year.

- ○ Yes
- ○ No

← →

Oregon State University

1) What is your **child's** age and year of birth (Example: 5 years old, 2017)

Years old	
Year of birth	

2) What is your **child's** gender?

- ○ Male
- ○ Female
- ○ Other

3) What is your **child's** race?

- ○ White/Caucasian
- ○ Black/African American
- ○ Hispanic/Latino
- ○ Asian
- ○ Native American
- ○ Pacific Islander
- ○ Other (Please identify) ________
- ○ Prefer not to say

4) What is your **child's** height? (Example: 3 feet 5 inches)

5) What is your **child's** weight? (Example: 45 pounds)

6) Does your **child** have an Individualized Education Program (IEP)?

- ○ Yes
- ○ No
- ○ Prefer not to say

7) Does your child attend any programs or interventions related to (adapted) physical activity/education?

- ○ Yes (Please describe only the type of program/intervention, e.g., after-school physical activity program or exercise intervention)
- ○ No
- ○ Prefer not to say

8) Does your child receive any cognitive training programs or interventions?

- ○ Yes (Please describe only the type of program/intervention, e.g., cognitive training program or intervention) [ ]
- ○ No
- ○ Prefer not to say

9) What is **your** relationship with your child?

- ○ Mother
- ○ Father
- ○ Other legal guardian

10) What is **your** gender?

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Prefer not to say

11) What is **your** age? ______years old (Example: 40 years old)

Years old [ ]

12) How would you classify the area where **you and your child** currently live in?

- ○ Rural
- ○ Urban
- ○ Prefer not to say

← →

Oregon State University

13) What is **your** highest level of education?

- ○ No school at all
- ○ Elementary school
- ○ Middle school
- ○ High school
- ○ College (2 years)
- ○ College (4 years)
- ○ Master degree
- ○ Ph.D. degree
- ○ Prefer not to say

14) What is **your** race?

- ○ White/Caucasian
- ○ Black/African American
- ○ Hispanic/Latino
- ○ Asian
- ○ Native American
- ○ Pacific Islander
- ○ Other (Please identify)
- ○ Prefer not to say

15) What is **your** annual household income?

- ○ Less than $20,000
- ○ $20,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 or more
- ○ Prefer not to say

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This section is composed of questions regarding your *child's movement skills and activity of daily living*. **Please mark your responses by checking one circle for each question.** (Please compare the degree of movement skills or activities your child has with other children of the same age when answering the questions.)

	Very well	Well	Almost well	Adequately	Less adequately
16) Maintaining balance while performing various activities (i.e., standing on one foot, moving through obstacle courses)	○	○	○	◉	○
17) Walking about without bumping into objects or falling	○	○	○	○	○
18) Movement skills (i.e., running, skipping, jumping)	○	○	○	○	○
19) Playing in the playground (i.e., climbing, swinging, sliding, etc.)	○	○	○	○	○
20) Learning new movement skills (moving through space or performing movement sequences that accompany songs (e.g., The Itsy Bitsy Spider)	○	○	○	○	○
21) Playing ball (i.e., throwing, catching, kicking)	○	○	○	○	○
22) Organizing self in preparation for playing a board game	○	○	○	○	○
23) Organization during social play (i.e., following rules, etc.)	○	○	○	○	○
24) Constructive play (i.e., Duplo, Lego)	○	○	○	○	○
25) Creative activities with Play Doh, clay, stickers	○	○	○	○	○
26) Drawing	○	○	○	○	○
27) Coloring	○	○	○	○	○
28) Writing/copying shapes	○	○	○	○	○
29) Using scissors for cutting	○	○	○	○	○

30) Bathroom skills/washing hands	○	○	○	○	○
31) Dressing self in a reasonable amount of time (including shoes, coat)	○	○	○	○	○
32) Zippering zippers	○	○	○	○	○
33) Buttoning buttons	○	○	○	○	○
34) Organization in time and space in preparation for eating	○	○	○	○	○
35) Using eating utensils, cutting food	○	○	○	○	○
36) Transferring food to the plate or pouring without spilling	○	○	○	○	○
37) Eating without getting dirty	○	○	○	○	○
38) Opening a snack bag without spilling the contents out	○	○	○	○	○
39) Persevering and completing a task that he/she initiates	○	○	○	○	○
40) Transitioning easily from activity to activity	○	○	○	○	○
41) Orientation and organization in space within the classroom (i.e., desk, replacing supplies appropriately, etc.)	○	○	○	○	○
42) Organizing self in preparation for going out of home	○	○	○	○	○

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This section is composed of questions regarding your _child's executive function_. Below, you will find a number of statements. Please read each statement carefully and thereafter indicate how well that statement is true for the child. You will mark your responses by checking one circle for each question.

	Definitely not true	Not true	Partially true	True	Definitely true
43) Has difficulty remembering lengthy instructions	○	○	○	○	○
44) Seldom seems to be able to motivate him/herself to do something that he/she doesn't want to do	○	○	○	○	○
45) Has difficulty remembering what he/she is doing, in the middle of an activity	○	○	○	○	○
46) Has difficulty following through on less appealing tasks unless he/she is promised some type of reward for doing so	○	○	○	○	○
47) Has a tendency to do things without first thinking about what could happen	○	○	○	○	○
48) When asked to do several things, he/she only remembers the first or last	○	○	○	○	○
49) Has difficulty coming up with a different way of solving a problem when he/she gets stuck	○	○	○	○	○
50) When something needs to be done, he/she is often distracted by something more appealing	○	○	○	○	○
51) Easily forgets what he/she is asked to fetch	○	○	○	○	○
52) Gets overly excited when something special is going to happen (e.g., going on a field trip, going to a party)	○	○	○	○	○

53) Has clear difficulties doing things he/she finds boring	○	○	○	○	○
54) Has difficulty planning for an activity (e.g., remembering to bring everything necessary for a field trip or things needed for school)	○	○	○	○	○
55) Has difficulty holding back his/her activity despite being told to do so	○	○	○	○	○
56) Has difficulty carrying out activities that require several steps (e.g., for younger children, getting completely dressed without reminders; for older children, doing all homework independently)	○	○	○	○	○
57) In order to be able to concentrate, he/she must find the task appealing	○	○	○	○	○
58) Has difficulty refraining from smiling or laughing in situations where it is inappropriate	○	○	○	○	○
59) Has difficulty telling a story about something that has happened so that others may easily understand	○	○	○	○	○

60) Has difficulty stopping an activity immediately upon being told to do so. For example, he/she needs to jump a couple of extra times or play on the computer a little bit longer after being asked to stop	○	○	○	○	○
61) Has difficulty understanding verbal instructions unless he/she is also shown how to do something	○	○	○	○	○
62) Has difficulty with tasks or activities that involve several steps	○	○	○	○	○
63) Has difficulty thinking ahead or learning from experience	○	○	○	○	○
64) Acts in a wilder way compared to other children in a group (e.g., at a birthday party or during a group activity)	○	○	○	○	○
65) Has difficulty doing things that require mental effort, such as counting backwards	○	○	○	○	○
66) Has difficulty keeping things in mind while he/she is doing something else	○	○	○	○	○

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Appendix D: IRB Approval

Oregon State University
Research Office

Human Research Protection Program
& Institutional Review Board
B308 Kerr Administration Bldg, Corvallis OR 97331
(541) 737-8008
IRB@oregonstate.edu
http://research.oregonstate.edu/irb

Date of Notification	January 25, 2022		
Notification Type	Determination of Exemption		
Submission Type	Initial Application	Study Number	IRB-2021-1290
Principal Investigator	Megan MacDonald		
Study Team Members	Sung, Ming-Chih		
Study Title	Cross-cultural Comparison and Relationship of Motor Skills and Executive Function in Children with Autism Spectrum Disorder in Taiwan and the United States		
Review Level	Exempt		
Exempt Category	Category 2: Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: i. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; ii. Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or iii. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by .111(a)(7).		
Waiver(s)	Documentation of Informed Consent		
Risk Level for Adults	Minimal Risk		
Risk Level for Children	Study does not involve children		
Funding Source	Internal	Cayuse Number	N/A

DATE ACKNOWLEDGED: 01/25/2022 **EXPIRATION DATE:** 01/24/2027

A new application will be required in order to extend the study beyond this expiration date.

Comments:

The above referenced study was acknowledged by the OSU Institutional Review Board (IRB). The IRB has determined that the protocol meets the minimum criteria for approval under the applicable regulations pertaining to human research protections. The Principal Investigator is responsible for ensuring compliance with any additional applicable laws, University or site-specific policies, and sponsor requirements.

Study design and scientific merit have been evaluated to the extent required to determine that the

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regulatory criteria for approval have been met [45CFR46.111(a)(1)(i), 45CFR46.111(a)(2)].

Principal Investigator responsibilities:

- Keep study team members informed of the status of the research.
- Obtain IRB approval for project revisions prior to implementing changes as required by section 8.6 of the Policy Manual.
- Report all unanticipated problems involving risks to participants or others within three calendar days.
- Use only approved consent document(s).

Making changes to exempt studies

With a few exceptions, changes to the research must be submitted for review. Failure to adhere to the approved protocol can result in study suspension or termination and data stemming from protocol deviations cannot be represented as having IRB approval. Refer to the HRPP website (Project Revision Guidance) for a list of revisions to exempt studies that do not require prior approval.