USING NEUROTYPICAL SIBLINGS AS INTERVENTION AGENTS IN FAMILY-IMPLEMENTED MOTOR AND PHYSICAL ACTIVITY INTERVENTIONS FOR CHILDREN WITH AUTISM SPECTRUM DISORDER

By

Yuemei Lu

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PUBLIC ABSTRACT

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About one in 44 8-year-old children in the United States has an Autism Spectrum Disorder (ASD). Most of the existing programs for children with ASD focus on social-communication skills and language development, which are the core symptoms of ASD. However, research indicates that individuals with ASD may also experience delay or impairments in the development of motor skills and infrequently participate in regular daily physical activities (PA). Therefore, effective motor and PA interventions are needed for children with ASD. Neurotypical (NT) siblings are suggested as unique agents of interventions to support their brother/sister with ASD, yet our knowledge of their involvement in ASD motor and PA interventions is limited. This dissertation is comprised of three separate studies. The first study utilized a qualitative design to gain input from NT siblings and caregivers of children with ASD to inform sibling-guided motor intervention design. Then, during the COVID-19 pandemic, a cross-sectional study investigating PA patterns, parental perceived motor competence, and family dynamics in children with ASD with a NT sibling was conducted. As a continuation of the first two studies, an online PA intervention with parents and NT siblings serving as agents to deliver the activity sessions was conducted for children with ASD. Results showed that children with ASD spent significant time in sedentary activities during COVID-19, and their competence in only a few motor skills was perceived as pretty good by their parents. The online PA intervention effectively promoted parental perceived motor competence in object control skills, with the condition with both NT sibling and parent involved showing more significant improvements. The intervention also effectively increased parent-child interaction. The results of this dissertation advocate using the online format to deliver the motor or PA intervention at the family level by training parents and NT siblings to support PA participation and motor skill acquisition in children with ASD.

ABSTRACT

USING NEUROTYPICAL SIBLINGS AS INTERVENTION AGENTS IN FAMILY-IMPLEMENTED MOTOR AND PHYSICAL ACTIVITY INTERVENTIONS FOR CHILDREN WITH AUTISM SPECTRUM DISORDER

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There is a consensus that individuals with Autism Spectrum Disorder (ASD) fall short of the recommended 60-minute daily moderate-to-vigorous physical activity (MVPA), and some experience motor delays and abnormalities. Yet ASD interventions focusing on addressing these challenges are insufficient in the existing literature. Research evidence supports the effectiveness of neurotypical (NT) sibling involvement in ASD intervention, therefore, using NT siblings as intervention agents to promote PA and motor skills in their sister/brother with ASD may be a viable option. The three studies within this dissertation were conducted during the COVID-19 pandemic when free and unstructured physical activity (PA) was suggested to be achieved by playing with siblings. This dissertation's first investigation was a qualitative study investigating the perceptions of NT siblings and caregivers on prospective sibling-guided motor intervention in children with ASD. The principal investigator also gathered information that ball games, in-person format, once or twice per week frequency, weekend days, and 30-minute session duration were most preferred. Prior to designing and implementing the PA intervention, a cross-sectional study was conducted with 18 parent-ASD-NT triads (54 participants) to understand PA, parental perceived motor competence, and PA-related family dynamics in children with ASD during COVID-19. The findings from the PA questionnaire revealed that children with ASD spent a significantly greater amount of time in sedentary behaviors (mean = 2379.06 mins; SD = 1480.10) during an entire week than in leisure time activities (mean = 316.88 mins; SD =

301.48) and sports activities (mean = 183.00 mins; SD = 153.94). Also, parents perceived their children's competence on most skills listed in the parental proxy of the Pictorial Scale of Perceived Movement Skill Competence (PMSC-parent) as *not too good* or *sort of good*. In addition, it was indicated that NT siblings' self-efficacy in supporting children with ASD was lower than that of parents. By incorporating the findings from the first two studies, the third study within this dissertation provided an online family-implemented PA intervention for children with ASD to promote the variables that were measured in the cross-sectional study. The intervention used a randomized control trial with three intervention conditions: (a) Group A: PA intervention carried out by both a parent and a NT sibling, (b) Group B: PA intervention delivered by a parent only, and (c) Group C: control condition with only sedentary activities provided, rather than PA intervention. Among families who completed more than 60% of the intervention, significant differences were found in scores of object control skills [F (1,6) = 17.163, p = 0.006, ηp^2 = 0.741], fundamental motor skills [F (1,6) = 7.385, p = 0.035, ηp^2 = 0.552], and PMSC-parent total scores [F (1,6) = 6.914, p = 0.039, ηp^2 = 0.535] over time across the three groups [F (2,6) = 6.838, p = 0.028, ηp^2= 0.695], [F (2,6) = 13.507, p = 0.006, ηp^2 = 0.818], and [F (2,6) = 6.844, p = 0.028, ηp^2 = 0.695], with Group A showed more significant improvements. In addition, a significant within-group difference was found in parent-ASD interaction across time [F (1,6) = 6.964, p = 0.039, ηp^2 = 0.537]. Lastly, a process evaluation was conducted to examine the reach, dose, fidelity, and participant enjoyment. Results from this dissertation inform the design of future sibling-guided motor and PA interventions for children with ASD and encourage researchers to provide quality and enjoyable motor, PA intervention, and play-based services in an online format at the family level.

This dissertation is dedicated to the children and their families who participated in these research studies. This would not have been possible without your participation and insights. Thank you for your time, patience, and smiling faces!

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KEY TO ABBREVIATIONS

ADI-R	Autism Diagnostic Interview - Revised
ADOS-2	Autism Diagnostic Observation Schedule - Second Edition
ASD	Autism Spectrum Disorder
BCBA	Board-Certified Behavior Analyst
BMI	Body Mass Index
CDC	Centers for Disease Control
C-PAQ	Children’s Physical Activity Questionnaire
DSM-V	The Diagnostic Statistical Manual - Fifth Edition
FMS	Fundamental Movement Skills
MVPA	Moderate-to-Vigorous Physical Activity
NT	Neurotypical
PA	Physical Activity
PACES	Physical ACtivity Enjoyment Scale
PMSC-parent	Parental proxy of the Pictorial Scale of Perceived Movement Skill Competence
SB	Sedentary Behavior
TGMD-3	Test of Gross Motor Development - Third Edition

CHAPTER 1

Introduction and Literature Review

Autism Spectrum Disorder

Autism Spectrum Disorder (ASD), also known as autism, is a group of complex neurodevelopmental disorders. Individuals with ASD experience challenges in social interaction, communication, behavior, and often other developmental domains (American Psychiatric Association, 2013).

Prevalence

Based on 2018 medical and educational service records of children in the United States, the Autism and Developmental Disabilities Monitoring (ADDM) Network from the Centers for Disease Control and Prevention (CDC) reported the overall ASD prevalence was 23 per 1,000 (one in 44) children aged 8 years (Maenner et al., 2021). The prevalence has increased rapidly during the past two decades. It was 6.7 per 1,000 (one in 150) for 2000 data, 9.0 per 1,000 (one in 110) for 2006 data, 11.3 per 1,000 (one in 88) for 2008 data, 16.8 per 1,000 (one in 59) for 2014 data, and 18.5 per 1,000 (one in 54) for 2016 data (Baio et al., 2018; CDC, 2007; CDC, 2009; Maenner et al., 2020). Many hypotheses have been put forward to explain this dramatic growth, such as remarkably increased awareness of the disorder, broadening in diagnostic criteria, increased diagnosis in minority children, diagnostic recategorization from comorbid features (e.g., intellectual disability), and progress in diagnostic and screening tools (Matson & Kozlowski, 2011; Neggers, 2014; Nevison & Zahorodny, 2019; Polyak et al., 2015).

History

Scientists and clinicians have been studying ASD for hundreds of years (Lord et al., 2020). Although our knowledge about specific causes of ASD is still limited, people's beliefs about the causes of ASD have changed drastically over the past few decades (Cook & Willmerdinger, 2015). Individuals with ASD were previously described as being punished by God (Donvan & Zucker, 2016; Lord et al., 2020), being raised by wolves (i.e., the wild boy of Aveyron; Itard, 1932), avoiding unsatisfying realities and replacing them with fantasies (Bleuler, 1910), experiencing childhood schizophrenia (Kanner, 1949), and lacking maternal warmth/being raised by "refrigerator mothers" (i.e., emotionally cold mothers; Rimland, 1974). In 1998, a published report suggested that autism is caused by the Measles, Mumps, and Rubella (MMR) vaccine (Wakefield et al., 1998), which was later retracted by *Lancet* in 2010. Since 1998, numerous rigorously designed studies have disassociated vaccines and autism (Taylor et al., 2014). For instance, nationwide cohort studies were conducted in Denmark investigating the association between MMR vaccination and the development of autism. 537,303 children born from January 1991 through 1998 (Madsen et al., 2002) and 657,461 children born from 1999 through 2010 in Denmark (Hviid et al., 2019) were examined. Both studies provided strong evidence against the hypothesis that autism is caused by the MMR vaccine. Hviid et al. (2019) also indicated that MMR vaccination does not trigger autism in "genetically susceptible" children who have a sibling diagnosed with autism.

Symptoms, Screening, and Diagnosis

According to the Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition (DSM-V), ASD diagnostic criteria include: (a) persistent deficits in social communication and social interaction across multiple contexts, (b) restricted, repetitive patterns of behavior, interests, or activities, (c) symptoms must be present in the early developmental period, (d) symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning, and (e) these disturbances are not better explained by intellectual disability or global developmental delay (American Psychiatric Association, 2013).

An ASD diagnosis by an experienced professional can be provided reliably by 2 years of age (Lord et al., 2006). However, many children do not receive a diagnosis of ASD until they are much older. According to the report *Spotlight on: Delay between first concern to accessing services* from ADDM network, most children (85%) identified with ASD had concerns noted about their development in their records by 3 years of age, yet fewer than half (42%) of children with ASD received a developmental evaluation by 3 years of age (CDC, 2019). Given the lag between first concern and a formal developmental evaluation, the American Academy of Pediatrics (AAP) recommends that pediatricians ask parents about developmental concerns at each well-child visit and screen all children for autism twice by their second birthday. Some red flags of ASD, such as being less responsive to their name, illustrating fewer pointing and showing gestures, and poor eye contact, can be detected by parents as early as the first year of life (De Giacomo & Fombonne, 1998; Watson & Crais, 2013). If the parents do have developmental concerns for children, depending on the level of concern, an ASD-specific screener should be administered and/or the child should be referred for a diagnostic evaluation (Johnson & Myers, 2007).

Making an ASD diagnosis requires a comprehensive assessment, including detailed developmental history and description of current behaviors, assessment of cognitive and language abilities, clinical judgments, and observations of functioning across settings (Filipek et al., 1999; Le Couteur et al., 2008; Ozonoff et al., 2005). The widely used diagnostic instruments which are also considered “gold-standard” assessments include the Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003) and Autism Diagnostic Observation Schedule - Second

Edition (ADOS-2; Lord et al., 2012), both of which align with the specified diagnostic criteria outlined in the DSM-V. ADI-R is a well-established semi-structured interview conducted with parents. According to parents' descriptions of a child's current presentation and lifelong developmental history, ADI-R provides a systematic and standardized way to determine whether the child's development and behaviors meet the diagnostic criteria of ASD (Rutter et al., 2003). The ADOS-2 is a standardized diagnostic instrument based on semi-structured observations of the children. It consists of four modules for individuals across different stages of development and levels of language proficiency. The ADOS-2 is natural and play-based, which includes a variety of activities that provide interesting contexts, allowing for observation of social and communicative behaviors such as make-believe play, construction task, and joint interactive play. Also, ADOS-2 provides a measure of standardized calibrated severity that is independent of chronological age, developmental, and language levels (Lord et al., 2012).

Motor Competence in Individuals with ASD

In addition to the core features of ASD (i.e., challenges in social interaction, communication, and behavior), some co-occurring difficulties are also commonly observed in individuals with ASD (Lai et al., 2019). Deficits, delays, or impairments in motor competence are among these major concerns (Soke et al., 2018).

Fundamental motor skills (FMS) lay the foundation for complex sport-specific skills and can be classified into two categories - locomotor skills and objective control or ball skills (Goodway et al., 2019; Kokstejn et al., 2019). Locomotor skill refers to the physical act of moving from one place to another, such as running, hopping, galloping, skipping, etc. (Haywood & Getchell, 2019). Object control or ball skill refers to the manipulation and projection of objects such as throwing, catching, dribbling, kicking, striking, etc. (Stodden et al., 2008). The “mountain of motor development” metaphor was introduced by Clark and Metcalfe (2002). It indicated that the cumulative and sequential nature of developing motor skills is similar to climbing a mountain. An individual’s reflexive and pre-adapted periods occur in the first year of life. When a child is proficient in fundamental motor skills, they can start to learn and develop more complex skills that are context-specific, then eventually acquire skillfulness. During the process, the skills and experiences that are gained from each step serve as the basis for reaching the subsequent step.

However, researchers have found that some individuals with ASD experience delays or impairments in gross and fine motor skills (Chawarska et al., 2007; Davidovitch et al., 2015; Landa & Garrett-Mayer, 2006). The motor impairments can take the form of dyspraxia, impaired motor speed and coordination, gait abnormalities, and postural and balance disorder (Abu-Dahab et al., 2013; Dziuk et al., 2007; Rinehart et al., 2006; Siaperas et al., 2012). Previous research also compared the motor competence in children with ASD and neurotypical (NT) children within their studies. MacDonald et al. (2014) reported that for very young children with ASD within their sample (12-33 months), their gross and fine motor skill development levels were 6.4 and 9.5 months behind chronological age, respectively. Another study by Ketcheson et al. (2018) indicated that children with ASD ages 2 to 5 showed significantly lower levels in gross, fine, and total motor quotient than their peers without ASD. Additionally, a cross-sectional study by Pusponegoro et al. (2016) compared gross motor skills in 40 children with ASD aged from 18 months to 6 years and 40 age-matched typically developing children. The results showed that gross motor function in 20% of their ASD sample was below average, and gross motor skills in children with ASD were significantly lower than in the NT children, especially in ball throwing and catching, using stairs, jumping, and bicycling.

Some commonly used standardized assessments to evaluate children's gross motor performance include the Test of Gross Motor Development - Third Edition (TGMD-3; Webster & Ulrich, 2017), the Movement Assessment Battery for Children - Second Edition (MABC-2; Henderson et al., 2007), the Vineland Adaptive Behavior Scales - Second Edition (Vineland-II; Sparrow et al., 2005), the Bruininks-Oseretsky Test of Motor Proficiency - Second Edition (BOT-2; Bruininks, 2005), the Peabody Developmental Motor Scales - Second Edition (PDMS-2; Folio & Fewell, 2000), and the Mullen Scales of Early Learning (MSEL; Mullen, 1995), etc. Besides these standardized assessments that directly evaluate the child's performance in motor skills, there are also some instruments developed to assess children's self-perceived motor competence and parents' perceptions of their children's competence in FMS and active play. For example, the Pictorial Scale of Perceived Movement Skill Competence (PMSC) and the parent version of PMSC. Both instruments align with the TGMD-3 and have been shown to be valid and reliable (Barnett et al., 2015; Maher et al., 2018; Valentini et al., 2018).

Physical Activity in Individuals with ASD

Motor competence has been associated with many developmental domains, such as social skills, language skills, and cognitive skills. In addition, motor competence is also a possible determinant of an individual's physical activity (PA) levels (Bedford et al. 2016; Houwen et al., 2009; MacDonald et al., 2011; MacDonald et al., 2013; McCleery et al., 2013; Stodden et al., 2008).

PA refers to any bodily movement generated by skeletal muscles that result in energy expenditure (Caspersen et al., 1985). Based on the metabolic equivalent of task (MET), PA can be classified into light-intensity physical activity (LPA; < 3 METs; i.e., light housework), moderate-intensity physical activity (MPA; 3-6 METs; i.e. brisk walking), and vigorous-intensity physical activity (VPA; > 6 METs; i.e., jumping rope) where 1 MET is the rate of energy expenditure while sitting at rest (US Department of Health and Human Services, 2018). Stodden and colleagues (2018) provided the model of developmental mechanisms influencing the PA trajectories of children. It explains the dynamic and reciprocal relationship between motor competence and PA during childhood. That is, higher motor competence in childhood could lead to more time spent in PA (a positive spiral of continued engagement). A review by Robinson et al. (2015) examined published data that relate to the pathways noted in Stodden's (2008) conceptual model. It synthesized studies that investigated the correlation between motor competence and objectively measured PA (i.e., using accelerometers and pedometers) and emphasized the positive relationships between motor competence and PA illustrated in the conceptual model (Cliff et al., 2009; Fisher et al., 2015; Dubose et al., 2018; Morgan et al., 2008, Robinson et al., 2012). For example, Robinson et al. (2012) used the pedometer (Yamax SW-200 pedometer) to measure PA and Test of Gross Motor Development - Second Edition (TGMD-2; Ulrich, 2000) to assess motor skills in 34 preschool students. Their findings revealed that there was a significant relationship between PA and motor skills (locomotor skills: $r = 0.461$, $p < 0.01$; object control skills: $r = 0.435$, $p < 0.05$). In addition, the study by DuBose et al. (2018) used the accelerometer (ActiGraph GT1M) to measure PA and MABC-2 to assess motor skills in children aged 3 to 10 years. They found that MPA and MVPA (but not VPA) were positively related to motor skills (MPA: $\beta = 0.36$, $p = 0.05$; MVPA: $\beta = 0.25$, $p = 0.05$).

According to the Physical Activity Guidelines for Americans, Second Edition (2018) by the US Department of Health and Human Services, Preschool-aged children between 3 to 5 years of age should be physically active throughout the day to enhance their growth and development. For children at 6 years old and beyond, 60 minutes or more of moderate-to-vigorous physical activity (MVPA) per day is recommended. However, the National Survey of Children's Health (2016) reported that only 24% of children and youth meet the 60 minute-MVPA guideline and participate in enough daily physical activity. For children with disabilities age 6 years and beyond, merely 17% of them meet the PA guidelines (Child and Adolescent Health Measurement Initiative, 2018). Furthermore, data from the National Survey of Children's Health (NSCH) suggested that children and adolescents with ASD engage a lower percentage of time in MVPA than their NT peers (McCoy et al., 2016; McCoy & Morgan, 2020). Results from additional studies show similar findings. For example, a study by Stanish et al. (2018) investigated the level, frequency, and type of PA in adolescents with (n = 35) and without ASD (n = 60). Results indicated that adolescents with ASD spent less time in MVPA (29 vs 50 min/day) and participated in fewer activities (5.3 vs 7.1) than those without ASD.

There is a consensus that individuals with ASD fall short of the recommended PA levels (Menear & Neumeier, 2015). For example, in a study by Pan et al. (2016), among 35 secondary school-aged participants with ASD, only 13 (37%) of them accumulated at least 60 minutes of daily MVPA. Across another sample of 83 children with ASD aged 6 to 17, only 10 participants (12%) met the activity guidelines according to the parent-reported data (Memari et al., 2015). Similarly, a study by Bandini et al. (2013) with a sample of 53 children with ASD aged 3 to 11 found that only 23% of the participants with ASD met the criteria for MVPA. Additionally, declines in PA as children with ASD age were noted in the previous study (MacDonald et al., 2011). Moreover, within a sample of 72 children with ASD aged 9-18, compared to younger children (9-11 years), older children (12-18 years) are significantly less physically active with decreased MVPA as well as increased sedentary behaviors. Due to the disruption in physical education and other play-based services, the COVID-19 pandemic could have further affected

PA in children with ASD. Although our knowledge of PA and motor competence in children with ASD during the COVID-19 pandemic is limited, a preliminary qualitative investigation indicated reduced walking behavior and declining coordination and balance abilities in children with ASD were reported by their parents during the pandemic (Yarimkaya & Esenturk, 2020).

It is also important to notice that, given that individuals with ASD typically exhibit stereotyped behaviors such as hand flapping and body rocking (Bodfish et al., 2000), the meaningful MVPA in children with ASD may be even less than what is objectively measured using devices (e.g., accelerometers and pedometers) only. It is suggested that a comprehensive measurement of how young children with ASD are accumulating their PA is necessary. For example, including an observational period while stereotypic behavior is coded so that researchers can understand if the PA data is from meaningful movements/activities that improve motor competence or from the stereotyped behaviors (Ketcheson et al., 2017).

Interventions/Evidence-Based Practice

The rapidly growing prevalence of ASD increases the demand for behavioral treatments (Reichow et al., 2012). Although no treatment has been shown to cure ASD and no agreement exists as to how a “cure” may be defined (Bölte, 2014), many treatments and early interventions have been developed and investigated for children with ASD that contribute to long-term positive outcomes on later skills and address developmental difficulties (Koegel et al., 2013). Interventions/treatments supported by significant scientific evidence for individuals with ASD include Applied Behavior Analysis (e.g., discrete trial training, pivotal response training), early intensive behavioral interventions, cognitive-behavioral therapy, social skills training, use of assistive technology (e.g., picture exchange communication system, augmentative and alternative communication), visual supports, and parent-implemented intervention, etc. (Lindgren & Doobay, 2011; Peters-Scheffer et al., 2021; Reichow et al., 2012).

Family-Implemented Interventions

While most of the existing interventions for children with ASD are implemented by professionals/therapists, having family members serve as intervention agents (defined as individuals who receive training and then implemented learned strategies/skills to guide the target population in this dissertation) is also a viable option. According to the Social Learning Theory (Bandura, 1977), individuals learn new behaviors and modify existing behaviors via observation, imitation, and modeling; both environmental and cognitive factors interact to influence human learning and behavior. The time spent with significant others (e.g., parents, teachers, peers, and siblings) can provide countless opportunities for individuals to observe, imitate, and learn. In addition, Bronfenbrenner's Ecological Model (1977) considers the environment as a crucial mechanism in an individual's development and emphasizes that behavior is influenced at multiple levels (i.e., *microsystem, mesosystem, exosystem, and macrosystem*). Within the *microsystem,* which focuses on the relationship between individuals, people who have direct contact with the child in their immediate environment, such as parents, siblings, and peers, play important roles in shaping and supporting individuals' behaviors and development. Therefore, among the existing interventions for individuals with ASD, common partners have been used as intervention agents to carry out interventions.

Parents are included either directly or indirectly in many evidence-based interventions for ASD, also known as parent-mediated interventions (PMI; Bearss et al., 2015; Karst & Hecke, 2012). PMI can be further categized into primary and complementary intervention. In primary PMI, parents served as the primary intervention agents. The parent is trained by professionals to implement strategies and directly carry out the intervention to facilitate improvements in their child’s development. Complementary PMI, however, involves therapists as the primary intervention agents, while parents are coached to assist the therapist to enhance the outcomes (Bearss et al., 2015; Ratliff-Black & Therrien, 2021). Parents’ involvement and expectations are core components of the interventions and are associated with long-term outcomes for children with disabilities (Lindgren & Doobay, 2011; Ivey, 2004). Existing literature has indicated that parent-mediated interventions successfully improve the children's communication and social skills, adaptive behavior, and problem behavior (McConachie & Diggle, 2007; Oono et al., 2013; Siller et al., 2013). Additionally, such interventions can also help parents with decreasing parental stress and increase their self-efficacy and mental health (Singer et al., 2007).

Siblings also have the potential to serve as powerful intervention agents, given their unique and long-lasting relationship with individuals with ASD. It is also believed that involving siblings in treatment for ASD could strengthen the fabric of the whole family (Law, 2020). NT siblings’ involvement in the upbringing of an individual with a disability can lead to long-term positive developmental outcomes (Banda, 2015). Previous literature reviews indicate that sibling involvement and guidance as intervention agents, models, and/or co-recipients in interventions bring about positive outcomes for children with ASD across a variety of skills (Banda, 2015; Shivers and Plavnick, 2015; Lu et al., 2021). For example, a systematic review by Shivers and Plavnick (2015) found that sibling involvement brings about positive outcomes for children with ASD in terms of social skills (i.e., Ferraioli & Harris, 2011; Oppenheim-Leaf et al., 2012), play skills (i.e., Celiberti & Harris, 1993; Coe at al., 1991; Taylor et al., 1999), and academic skills (i.e., Jones and Schwartz, 2004; Schreibman et al., 1983). Their comparable age and family ties make NT siblings more likely to have intrinsic motivation to interact and play with their siblings with ASD (Celiberti & Harris, 1993; Cicirelli, 1994). Additionally, for similar reasons, individuals with ASD may be more likely to respond to their siblings than to other children (Knott et al., 1995). In a study by Clark (1989), NT siblings were provided with training (i.e., labelling, describing play, praising appropriate behavior, avoiding coercive strategies, and using signs) to enhance the social interactions between NT children and their siblings with ASD. Results showed an increase in positive interactions for all three of the sibling dyads, which was maintained up to six months after the intervention. In addition, training NT siblings as intervention agents may also benefit NT siblings themselves. Given parents usually prioritize the needs of the child with ASD, the NT children in the family are often described as the 'forgotten child' due to a lack of parental time and attention (Madan-Swain et al., 1993; Molinaro et al., 2020). A mother reported she tried to divide attention between the child in treatment and the child staying in the waiting room: "He (the sibling) came to check out the room, but he wasn't a part of it". Also, a sister to a child with ASD expressed her feelings of exclusion from her brother's treatment: "Everybody needs a turn" (Law, 2020). Therefore, getting NT siblings involved in the ASD interventions and helping them understand ASD can be helpful. In addition, it can provide opportunities for NT siblings to overcome the difficulties in communicating with their siblings with ASD and improving the quality of their interactions and relationship (Kryzak & Jones 2017; Tsao & Odom; 2006).

Some existing interventions include both parents and siblings in the intervention. For example, in a study by Stewart et al. (2007), a mother and a sister of a child with Asperger's syndrome were trained to teach the child social skills at home. The child's mother and sister were taught how to implement behavioral skills training (BST) to teach social skills. BST is a treatment package consisting of instructions, modeling, rehearsal, and feedback. In the intervention implementation, the mother provided instructions and rules to the child with Asperger's disorder. Then the sister modeled appropriate conversation skills (i.e., initiating and sustaining a conversation) several times with the research assistant. After that, the child with Asperger's disorder got the opportunity to rehearse the skills with the research assistant. Once a session was done, feedback was provided to the mother and the sister. The study results indicated that the child's mother and sister became proficient in BST and were able to correctly implement BST to teach the child with Asperger's syndrome social skills. Additionally, an increased frequency of use of the target social skill was found in the target child after the intervention.

Inviting Parents and Siblings to Support PA and Motor Competence in Children with ASD?

To our knowledge, very few existing motor/PA interventions involved parents and siblings. While there is emerging literature on PA and motor interventions developed for children with ASD with a variety of activities, including horseback riding/equine therapy (Bass et al., 2009; García-Gómez et al., 2014), stationary cycling or weightlifting (Lochbaum & Crews, 2003), swimming (Pan, 2010; Yilmaz et al., 2004), karate (Bahrami et al., 2016), and bicycle riding (Hauck et al., 2017; MacDonald et al., 2012; Reynolds et al., 2016), the majority of the existing motor/PA interventions are individual tasks completed by children with ASD themselves, with few including interactions and engagement of parents and siblings. One motor intervention (Chu & Pan, 2012) that involved family members was an aquatic program aimed at interaction behaviors and aquatic skills. It provided siblings and peers training about assisting physical and social interactions for children with ASD. Then the siblings and peers demonstrated learned aquatic skills, gave physical assistance, cues, feedback, and social assistance to siblings with ASD on their performance. The study results indicated that children with ASD improved both their social and physical interactions with siblings and peers. Improved aquatic skills were also found in children with ASD, NT siblings, and peers.

Given (a) benefits of using parents and NT siblings to serve as intervention agents for children with ASD, (b) the fact that children with ASD fall short of PA and experience motor delay and impairments, and (c) the lack of knowledge to the effectiveness and feasibility of PA/motor interventions for children with ASD with their family members involved, there is a need to design and implement PA/motor interventions to fill this literature gap and better support children with ASD and their family.

About this Dissertation

This dissertation consists of three studies and is organized into three separate manuscripts. First, we conducted a qualitative study to interview the key stakeholders (i.e., parents and NT siblings of children with ASD) about their insights into sibling-guided motor intervention in study 1 (Chapter 2). Then we gained an overall understanding of what levels of PA, parental perceived motor competence (we used a parental proxy to replace direct motor assessment due to the pandemic), and family dynamics in children with ASD looked like when they and their NT siblings were staying at home during COVID-19 pandemic in study 2 (Chapter 3). Lastly, we conducted an online family-implemented PA intervention (we incorporated what we learned from the qualitative study in the study design) to measure its effectiveness on the measurements we assessed in study 2. We also did a process evaluation to understand how well it was implemented, as it was a new intervention method and conducted during the pandemic (Chapter 4). A bit more information for each study is introduced below:

Manuscript 1 is a qualitative study aimed at gaining insights into NT siblings’ and their caregivers’ perceptions of prospective sibling-guided motor interventions. We aimed to use findings from this study to inform the design of feasible and effective motor interventions for children with ASD with NT siblings acting as intervention agents. Specifically, we investigated (a) their perceptions of having NT siblings guide children with ASD (e.g., NT siblings' willingness to teach, NT siblings' teaching skill, NT siblings' previous teaching experience) and (b) gathered their preferences for the design of future sibling-guided motor interventions (e.g., setting, format, time in a week, frequency, and intervention component/activity). This study provides meaningful direction for future sibling-guided motor interventions for children with ASD, and we incorporated many of our findings in the study outlined in manuscript 3.

Manuscript 2 took place during the COVID-19 pandemic schools for more than 168 million children globally were closed for almost a full year (UNICEF, 2021). Changes in daily routine, services, and many other aspects of life made it challenging for children with ASD and even their families to make adaptations at home, let alone get opportunities to keep physically active and gain motor skills. Therefore, Manuscript 2 focused on investigating levels of PA, motor competence, and PA-related family dynamics in children with ASD with a neurotypical sibling during the COVID -19 pandemic.

Manuscript 3 incorporated findings from both manuscript 1 and 2 to develop and test an online family-implemented physical activity intervention for children with ASD. We provided a 14-week online PA intervention with parents (and NT siblings) serving as intervention agents to deliver/implement the intervention. Given that it was a novel intervention approach that had never been conducted before and was provided during the COVID-19 pandemic, the study described manuscript 3 aimed at investigating the intervention's preliminary effectiveness and examining how well it was implemented amidst the COVID-19 context.

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CHAPTER 2

Insights of Caregivers and Neurotypical Siblings on Prospective Sibling-Guided Motor Interventions for Children with Autism Spectrum Disorder

Abstract

Motor delays and abnormalities are common in individuals with Autism Spectrum Disorder (ASD). Existing literature indicated neurotypical (NT) siblings can bring unique advantages in promoting skill acquisition in their brother/sister with ASD when they serve as intervention agents. However, NT siblings' involvement in motor interventions for individuals with ASD and their perceptions of teaching their siblings with ASD are limited to our knowledge. To inform the design of feasible and effective motor interventions for children with ASD with NT siblings acting as intervention agents, this qualitative study aimed to gain insights into NT siblings' and their caregivers' perceptions of prospective sibling-guided motor interventions. Semi-structured interviews were conducted online with ten NT siblings of children with ASD (9.00 ± 2.98 years) and their primary caregivers (36.00 ± 4.71 years) to elicit their perceptions. Data were analyzed using thematic content analysis. Most families reported NT children are willing to support and teach their siblings with ASD, but only about half of them were confident in teaching and had experience teaching their brothers/sisters with ASD. NT siblings indicated experiencing some difficulties interacting with children with ASD due to characteristics related to ASD. Also, NT siblings' knowledge about ASD and available recourses to understand how to interact and support children with ASD were limited. In addition, this study uncovered preferences of caregivers and NT siblings related to the design of sibling-guided motor interventions (e.g., setting, format, time in a week, frequency, and intervention

component/activity). This study provides meaningful direction for future sibling-guided motor interventions for children with ASD.

Introduction

Although social and communication challenges are core characteristics of individuals with ASD (American Psychiatric Association, 2013), delays or abnormalities in motor skills are commonly noted, especially in activities that demand complex, interceptive actions, or core balance ability (Chawarska et al., 2007; Davidovitch et al., 2015; Fulceri et al., 2019; Landa & Garrett-Mayer, 2006; Whyatt & Craig, 2012). For example, results from a large-scale study (Melissa et al., 2020) among 2,084 children with ASD aged 6 and younger from the Western Australian Register indicated 35.4% of their sample experienced motor difficulties. Additionally, in a study by Ketcheson and colleagues (2017), children with ASD aged 2 to 5 showed significantly lower levels in gross, fine, and total motor quotient than their peers without ASD.

Motor competence is critical in development as it is associated with many other developmental domains, such as social skills, language skills, cognitive skills, and adapted behavior skills (Bedford et al., 2016; MacDonald et al., 2013a; MacDonald et al., 2013b; McCleery et al., 2013). Moreover, inadequate motor skills may result in lower participation in physical activity (PA) given their dynamic and reciprocal relationship (Houwen et al., 2009; Stodden et al., 2008). According to the Physical Activity Guidelines for Americans, 2nd edition (2018), preschool-aged children should be physically active throughout the day to enhance their growth and development. And for children aged 6 and beyond, 60 minutes or more of moderate-to-vigorous physical activity (MVPA) per day is recommended. However, in children with disabilities age 6 and beyond, approximately 83% of them fall short of the daily 60-minute MVPA recommendation (Child and Adolescent Health Measurement Initiative, 2018). In addition, there is a general consensus that individuals with ASD fall short of the recommended PA levels (Menear & Neumeier, 2015). Inadequate PA can further lead to motor delay and the risk of being overweight or obese (Curtin et al., 2014; Stodden et al., 2008).

Although interventions for children with ASD aimed at addressing their motor skills are less common than those focused on social and communication skills (Colombo-Dougovito & Block, 2019; Ketcheson et al., 2018), there is emerging literature on motor skills interventions for children with ASD. A literature review by Colombo-Dougovito & Block (2019) identified five intervention studies focused on promoting motor skills for children with ASD. This review suggested some evidence of general positive effect of fundamental motor skill interventions. There is also an increasing number of motor and physical activity interventions for individuals with ASD, including bicycle training, horseback riding/equine-therapy, karate, etc. (Bahrami et al., 2016, Bass et al., 2009; García-Gómez et al., 2014; Hauck et al., 2017; MacDonald et al., 2012). However, there is still a lack of understanding on what are the most effective and practical intervention strategies that could support motor skills of children with ASD (Colombo-Dougovito & Block, 2019).

Sibling Involvement in ASD Interventions

It is the hope of most parents that their children will love each other, enjoy playing and interacting together, and develop warm and long-lasting relationships (Stoneman, 2001). Although researchers have found that relationships between individuals with disabilities and their siblings are usually positive (Kaminsky & Dewey, 2001; Roper et al., 2014; Zaidman-Zait et al., 2020), siblings of children with disabilities do experience difficulties (Guidotti et al., 2021; Hastings & Petalas, 2014; Moyson & Roeyers, 2011). The daily lives of children can be altered in significant ways when they grow up alongside a sibling who has disabilities (McHale &

Gamble, 1989). Neurotypical (NT) siblings often experience a decrease in positive parental attention and communication. Also, they are often asked to engage in caretaking for their brothers or sisters with disabilities (Meltzer & Kramer, 2016; Meltzer, 2017; Seltzer et al., 2005). Some NT siblings perceive themselves as a parent-surrogate sibling - “not a child, but a parent caretaker” (Avieli et al., 2019). NT siblings of children with ASD often express more frustration than siblings of children with other disabilities (Hastings, 2003). This may be caused by those characteristics unique to individuals with ASD, such as impairments in communication and social interaction, restricted behavior, oversensitivity, unusual mood or emotional reactions, and possible aggressive and disruptive behaviors (American Psychiatric Association, 2013).

Nevertheless, existing literature indicated neurotypical (NT) siblings can bring unique advantages in promoting skill acquisition in their siblings with ASD and can experience positive sibling interactions when they serve as intervention agents (Banda, 2015; Bene & Lapina, 2021; Lu et al., 2021; Shivers & Plavnick, 2015). Siblings play important roles as part of a family, such as playmates, social tutors, attachment figures, rivals, and role models (White & Hughes, 2017). These essential roles and the significant amount of time that siblings spend together can provide numerous opportunities for children with ASD to learn and practice new skills across multiple settings, as playing with siblings is a natural context (Ferraioli et al., 2012; McGee et al., 1985; White & Hughes, 2017; Wright & Benigno, 2019). It is also believed that NT siblings can develop social skills, gain senses of competence and self-esteem, and become mature through supporting and interacting with their siblings (McHale & Gamble, 1989; Tsao & Odom, 2006).

Knowing the effectiveness of sibling involvement in interventions, however, our current knowledge of the effectiveness specifically in motor intervention for individuals with ASD is limited. Most of the existing sibling intervention research for individuals with ASD is focused on promoting social and communicative skills (Clark et al., 1989; Dodd et al., 2008; Oppenheim-Leaf et al., 2012). Lu et al. (2020) synthesized the evidence on the influence of interventions with NT siblings and peers involved in motor behaviors in individuals with ASD. Though all studies included in that review administered motor behavior assessments for individuals with ASD, motor or play skills were not intervention priorities. The primary target behaviors were still social and communicative skills. In terms of sibling involvement, only two of the included studies recruited siblings (Chu & Pan, 2012; Kent, 2018). Clearly, there is a dearth of NT sibling-guided motor interventions for individuals with ASD. In order to develop high quality evidence-based sibling guided motor interventions that targets on motor skills of children with ASD, there is a need for an in-depth understanding on families' needs and preferences.

Some qualitative studies have investigated parents' perceptions, experiences, and perceived effectiveness of interventions after implementation (Alotaibi & Almalki, 2016; Iversen et al., 2003; Stahmer et al., 2017). However, we have limited knowledge related to the acceptability of sibling-guided motor interventions and the preferences of families related to these interventions. It is important for professionals to gain an understanding of the perceptions of key stakeholders (i.e., NT siblings and caregivers; Ayala & Elder, 2011) on the use of NT siblings to teach/guide individuals with ASD before they design and implement sibling-guided motor interventions, given NT siblings take primary responsibility in delivering interventions and caregivers play an important role in selecting and registering for programs for their children. Formative research methods, such as interviews and focus groups, can help with it by determining what characteristics might influence their acceptability and adoption of intervention strategies (Freimuth & Mettger, 1990). To meet this need, we conducted a qualitative study to gain insights into how to create and implement a feasible and effective motor intervention by asking caregivers and NT siblings for input in the development of appropriate sibling-guided motor interventions to meet the needs of children with ASD. More precisely, this study addressed the following two research questions:

1. What are caregivers' and NT siblings' perceptions of having NT siblings guide children with ASD?
2. For prospective sibling-guided motor interventions, what are caregivers' and NT siblings' preferences (e.g., setting, format, time in a week, frequency, and intervention component/activity)?

Method

Research Design and Sample Selection

A qualitative research design was utilized within this study. Ten NT siblings of children with ASD ($M_{age} = 9.00$, $SD = 2.98$) and their primary caregivers ($M_{age} = 36.00$, $SD = 4.71$) were interviewed. The research team recruited participants by (a) distributing information about the study through a university-wide email list for families of children with special needs, (b) emailing families who previously participated in ASD research in our laboratory and consented to be contacted for future research opportunities, and (c) posting details about the study within various social media groups related to ASD. Families were eligible to participate if they had (a) a child with ASD between the ages of 3 and 11, (b) an NT child aged 5 or older who consented to participate, and (c) a caregiver within the family who consented to participate. The NT sibling could be older or younger than the child with ASD, as long as they were able to understand the instructions given by the research team and correctly deliver instructions as prescribed. Caregivers of families who had more than two eligible NT children were asked to select one to participate in the study and provide a rationale of why they choose that NT sibling.

Data Collection

This study received approval from the university institutional review board before data collection began. Data collection, the semi-structured interview, was conducted entirely online to elicit the perceptions and experiences of caregivers and NT siblings. The study involved a virtual interview with two separate sessions (one for the caregivers and one for the NT sibling). Prior to the interviews, the interviewer (the first author) introduced herself, obtained consent, explained the rationale of the study, and described what we expect to learn. Then the interviewer informed the participants that the interview recording was activated. The length of the total interview ranged from 22 to 28 minutes. Specifically, the interview session with NT siblings ranged from 10 to 15 minutes, and the session with caregivers ranged from 8 to 16 minutes. NT siblings could have their caregiver present during their interview or leave for a while based on their preference. Six NT siblings (Mage = 11.00, SD = 1.90) chose to be interviewed without their caregivers present. The other four NT siblings (Mage = 6.00, SD = 0.82) had their caregivers present primarily because of their young ages; their caregivers repeated, further clarified, and prompted the answers for them when necessary. Interviews took place with nine families over Zoom and with one family via phone. All interviews were audiotaped and then transcribed for later analysis.

The semi-structured interviews for caregivers and NT siblings were guided by our interview protocol (see Appendix B and C: Semi-Structure Interview Guides). The interview protocol included 12 questions for caregivers and 14 questions for NT siblings. It was created to align with sibling-guided intervention development, including perceptions of having NT siblings serve as intervention agents (e.g., NT siblings’ barriers in interacting with children with ASD, NT siblings’ teaching experience and skills, and NT siblings’ willingness to teach) and preferences of future sibling-guided motor intervention (e.g., format, setting, dosage, frequency, activity). Most of the questions for NT siblings and caregivers were related and consistent, but questions for NT siblings were simplified to make them age appropriate. For example, we asked caregivers: *Have you ever talked with your NT child about Autism Spectrum Disorders? If yes, what did you say? In the interview for NT siblings, we asked: Tell me about Autism Spectrum Disorders. What makes your sister/brother different from others?* By gathering responses from both NT siblings and caregivers, we were able to identify their common and divergent perspectives and triangulate data from the two participant groups related to motor interventions. When data saturation was reached, a full understanding of the participants' perspectives was gained, we discontinued data collection and began data analysis.

Data Analysis

The first author (a doctoral student in Kinesiology) and the third author (a doctoral student in Human Development and Family Studies) performed data analysis. The first author conducted all interviews and had relevant experience related to motor interventions and ASD. The third author had experience working with families who have children with ASD but was not present during the interviews and had no experience related to motor interventions.

Data were analyzed using thematic analysis followed a guide consisting six phases (Braun & Clarke, 2006). Phase 1: Become familiar with the data. The coders carefully read the entire body of the transcripts and extracted significant statements sentence-by-sentence. Phase 2: Generate initial codes. With research questions in mind, codes that were relevant to or addressed the research questions were generated from the significant statements line-by-line. Phase 3: Search for themes. Coded data were categorized based on the conceptual phrases and their similarity. Then we explored how categories/themes and subcategories/subthemes related to each other. A preliminary codebook using the initial themes and subthemes identified was therefore developed. Phase 4: Review themes. Coders conducted a pilot testing on the preliminary codebook using an uncoded transcript and made adjustments accordingly. Phase 5: Define themes. In this phase, the main themes and how the subthemes related to the main themes were identified. Before the codebook and themes were finalized, several steps were taken in phase 1 to 5 to enhance trustworthiness. The first author and the third author independently followed procedures to code the interviews of three randomly selected families. Then they worked through the entire transcript coding by comparing coding and discussing any disagreements until an agreement was reached. When the coders reached a consistent agreement, the rest of the interviews were coded independently by a first coder and then reviewed and checked by a second coder. The two coders met weekly throughout the data analysis process to resolve disagreements and discuss categories. Lastly, in Phase 6, we finalized the coding book and wrote up our findings.

Results

Demographic information about children with ASD, NT siblings, and caregivers are described in **Table 1**. The age of NT siblings ranged from 5 to 14 years ($M_{age} = 9.00$, $SD = 2.98$), and age of siblings with ASD was from 3 to 11 years ($M_{age} = 7.70$, $SD = 2.45$). For families that have two or more NT siblings, primary reasons for why an NT sibling was chosen from others by the caregivers included: (a) specific characteristics of the NT sibling - caregivers gravitated toward selecting a sibling who was more patient and responsible, (b) age of the NT sibling - caregivers often selected older children who they thought were more mature and would take the study seriously, and to whom the sibling with ASD listened to better, and (3) relationship between the NT sibling and child with ASD - caregivers indicated a preference for NT siblings who had a better rapport with the child with ASD.

Five sibling dyads had older NT siblings, and the biggest age gap between these sibling dyads was 9 years (NT sibling aged 12 and child with ASD aged 3). The other five sibling dyads had younger NT siblings, and the biggest age gap between these sibling dyads was 4 years (NT sibling aged 7 and child with ASD aged 11). The combinations of the NT-ASD sibling dyads across all ten families included brother-brother (60%), sister-sister (10%), and sister-brother (30%). Caregivers were all mothers of the sibling dyads and 29 to 45 years in age ($M_{age} = 36.00$, $SD = 4.71$), although our study recruit was open to any caregiver with children in our age range.

All the questions in the interview guide were well-answered by the caregivers and most NT siblings. Two NT siblings (Noah, a 6-year-old NT brother to a 9-year-old boy with ASD; Charlotte, a 5-year-old sister to an 8-year-old boy with ASD) were not able to answer some of the questions, even though the interviewer and caregiver tried to clarify/simplify the questions. Given the questions for NT siblings and caregivers were closely related, the data analysis of the caregivers' and NT siblings' perceptions was grouped separately under each subtheme, making it easy and clear to compare any differences and similarities between their opinations. Themes aligned with the research questions of the study: (1) perceptions of having NT siblings guide children with ASD and (2) preferences in prospective sibling-guided interventions. We also had a theme named "additional findings related to Covid-19" to summarize the findings that were specific to the pandemic.

Perceptions of Having NT Siblings Guide Children with ASD

NT siblings' and caregivers' insights into having NT siblings guide children with ASD, yielded five subthemes: (a) NT siblings are willing to teach and learn how to teach, (b) NT siblings’ teaching skills, (c) NT siblings’ previous teaching experience, (d) ASD characteristics that frustrated NT siblings, and (e) NT siblings lack knowledge about ASD. We found that most families reported NT children are willing to support and teach their siblings with ASD, but only about half of them were confident in teaching and had experience teaching their brothers/sisters with ASD. Also, NT siblings were experiencing some difficulties interacting with children with ASD due to some characteristics of ASD. In addition, NT siblings’ knowledge about ASD and available recourses to understand how to interact and support children with ASD were limited.

NT Siblings Are Willing to Teach and Learn How to Better Teach. Most NT siblings indicated a willingness to teach their brothers/sisters with ASD and expressed that they would be happy to participate in a sibling-guided motor intervention to learn how to better support and teach their brothers/sisters with ASD motor skills. Similarly, all caregivers believed their NT children would be willing to engage in a prospective sibling-guided motor intervention with their sibling with ASD.

***Neurotypical Siblings*.** Most NT siblings were willing to teach and participate in a sibling-guided motor intervention to better support their brothers/sisters with ASD. The potential factors NT siblings mentioned that influenced their willingness to teach their sibling with ASD included: (a) patience of their siblings with ASD, (b) sibling with ASD’s need for instructions, (c) their own understanding of the target skills, and (d) their interest in the target skills. Additional factors that NT siblings identified as influencing their willingness specifically to participate in a sibling-guided motor intervention included (a) the motor intervention’s usefulness to support communication with their sibling with ASD, (b) interest in the intervention component/activity, and (c) their availability. For example, when being asked whether she would be willing to participate in programs to learn how to teach, Emma, a 14-year-old NT sister to a 7-

year-old boy with ASD, told us: “Well, if it would be useful to learn how to communicate better with him,” she also mentioned, “If it doesn’t take too much time, I think it would be awesome!” Logan, an 11-year-old NT brother to an 8-year-old boy with ASD, who made considerations for availability, stated: “Depending on how long it is and what the date is, because we're pretty busy this summer.”

Caregivers. Caregivers reported that they believed their NT children would be willing to teach and participate in the prospective sibling-guided motor intervention to learn how to help their siblings with ASD. The potential factors they perceived that influenced the willingness of NT siblings’ teaching included: (a) request from parents, (b) amount of help sibling with ASD needs, and (c) the amount of work required within the intervention. Additionally, parents indicated that the following factors would influence TD sibling’s willingness to participate in sibling-guided motor interventions: (a) usefulness of the intervention for the child with ASD, (b) incentive, and (c) interest in the intervention component/activity. For example, Ms. Thomas, mother to a 5-year-old NT girl and an 8-year-old boy with ASD, told us: “So, [Charlotte] is generally very open to do things that she knows are beneficial for [Matthew].” Ms. Thompson, mother to a 12-year-old NT boy and a 3-year-old boy with ASD, also said: “I think [Lucas] would be pretty excited to being able to do something to help his brother.” Another example, Ms. Lee, mother to a 7-year-old NT boy and an 11-year-old boy with ASD, believed her NT child would love to participate if the intervention involved activities: “I think just because it's an activity. He will be like ‘I want to go play basketball. Sounds good!’ (laughing)”.

NT Siblings’ Teaching Skills. Most caregivers believed their NT children have great teaching skills, but only half of the NT siblings thought they were good at teaching.

Neurotypical Siblings. Only about half of the NT siblings thought they were good at teaching their siblings with ASD, while the others were not confident teaching their siblings with ASD. Qualities they identified that made them good teachers included: (a) patience, (b) being able to deliver instructions clearly, and (c) being calm. For example, Logan told us: “I'm being calm when I tell him to do something when he says no”. Areas they felt they needed improvement to become better teachers included: (a) showing emotional control (e.g., not get annoyed when they have to repeat things), (b) gaining self-efficacy, and (c) increasing effective communication skills. In terms of emotional control, Olivia, a 9-year-old NT sister to an 11-year-old boy with ASD, believed she needed to do a better job controlling her emotions while interacting with her brother with ASD:

> Sometimes I get a little annoyed when I just have to keep on going, keep on repeating it over and over again. Because it's just it's very annoying when you keep on telling them over and over and over again.

Many NT siblings also expressed concerns about their communication skills. For example, Emma said: “I'm not great at communicating.” Also, Logan who had the same concerns mentioned: “Sometimes it's really hard for me to get my point across because I stumble with words.”

Caregivers. Most caregivers reported they think their NT children are good “little teachers” when they help their siblings with ASD. Positive qualities they identified in their NT children included: (a) sensitive (i.e., able to sense the emotions of the child with ASD), (b) emotional self-control, (c) supportive, (d) patient, (e) tolerant, (f) accommodating and understanding, and (g) able to understand their sibling’s ability level. Areas in which they identified their NT children could improve included: (a) better emotional control, (b) more patience, (c) using more verbal instructions, (d) helping and teaching more frequently, and (e) being more confident to overcoming their fear of failure. For example, Ms. Clark, mother to an 11-year-old NT boy and an 8-year-old boy with ASD, believes it’s important for her NT child Logan to boost his self-confidence and be more persistent regardless of failure: “So if you guys would be working with Logan, it would also be boosting his confidence that when something doesn't go successful that it doesn't mean he did a bad job.”

NT Siblings’ Previous Teaching Experience. In our sample, about half of the families reported that NT siblings didn’t have much experience showing or teaching their siblings things even though they were willing to support their sibling with ASD.

Neurotypical Siblings. About half of the NT siblings in our sample reported they didn’t have much experience showing or teaching their siblings things. For those who had that previous experience, things that they had taught their siblings with ASD include: (a) lip reading, (b) saying names (i.e., differentiate “you” and “I”), (c) playing video games, (d) shading with pencils, and (e) drawing. When teaching their sibling with ASD something new, they used strategies such as (a) verbal explanations, (b) providing demonstrations, (c) practice and testing new skills, and (d) delivering verbal prompts (e.g., good job). For example, Logan used some of these strategies when he taught Joseph how to do lip reading:

> I really like to test out his lip-reading skills. I just I tell him “Do you want to test out lip reading or something doing a lip read?” And then if he says yes, sometimes he says no, but if he does, I just say a sentence and then he repeats it. Like I say something without any sound. I just say it silently, and he says like “I like to play something.” And that's what I said, and I say, “good job!”

Caregivers. Some caregivers reported that often see NT siblings teaching or showing children with ASD how to do new things, while others reported that they didn't see this occur. Those caregivers who indicated seeing their NT children teach their child with ASD reported skills they observed: (a) cleaning the toothpaste out of the sink, (b) buttoning clothing, (c) grasping pencils, (d) tying shoes, and (e) playing games (both video games and outdoor play). In the process of teaching, caregivers observed that NT siblings used several strategies: (1) verbal instructions, (2) modeling, (3) practice and testing new skills, and (4) strategies learned from ABA therapy. For example, Ms. Anderson, mother to a 9-year-old NT daughter and a 5-year-old daughter with ASD, said: "Like we do sidewalk chalk, so there're a lot of like 'look what I made!' you know, 'let me trace your' or 'let's make this', that kind of thing. She [Ava] does do a lot of like 'now you try it!'" Similarly, Ms. Thompson also stated: "He [Lucas] is patient and he'll show him how to do it, and then he'll tell [Samuel] to try."

ASD Characteristics that Frustrated NT Siblings. It's important to understand potential barriers that NT siblings had in teaching or interacting with their brother/sister with ASD, so that future interventions can better support NT siblings. Although most NT siblings reported being willing to teach their brothers/sisters with ASD, they did experience some challenges teaching and interacting with their siblings with ASD due to the characteristics/symptoms of ASD.

Neurotypical Siblings. NT siblings shared the difficulties that they experience with their siblings with ASD. NT siblings often experienced difficulties when siblings with ASD exhibited behavioral or emotional challenges, including (a) resistance to change, (b) limited social-communicative skills, (c) problems with emotional control, (d) oversensitivity, (e) lack of acceptance when they lose, and (f) spending too much time on restricted interests (i.e., tablet). Illustrative quotes supporting these characteristics are provided in **Table 2**.

NT siblings also shared how they cope with the challenging behaviors that their sisters/brothers with ASD display. Logan told us that he learned to be very patient with people and try to be as nice as possible. He also tried to avoid his brother's triggers. For instance, Joseph disliked when others touch his belongings. As a result, Logan avoided touching Joseph's stuff: "He was very territorial. He doesn't like me touching any of his things. Yeah, I don't usually touch them."

Caregiver. Caregivers also believed there were some challenging behaviors in children with ASD that negatively influenced sibling interactions. The challenging behaviors in children with ASD that caregivers identified overlapped with those shared by NT siblings. Challenging behaviors included: (a) a preference to play alone, (b) limited social-communicative skills, (c) problems with emotional control, and (d) being overly sensitive. Illustrative quotes related to challenging behaviors are provided in **Table 3**.

NT Siblings Lack Knowledge about ASD. NT siblings' knowledge about ASD could shape the way they understand their siblings' challenging behaviors, and therefore influence their willingness to teach and the teaching strategies they may be willing to use. All the families in our sample indicated having conversations about ASD in their home. However, from the interviews, we found that NT siblings lacked comprehensive knowledge of ASD and were unsure about how they might obtain information about ASD.

Neurotypical Siblings. Most NT siblings mentioned some knowledge about ASD. When asked: "*Tell me something about Autism Spectrum Disorders. What makes your brother/sister different from others?*", three NT siblings (i.e., Olivia, aged 9 years old, Noah, aged 6 years old, and William, aged 7 years) indicated that they did not understand what ASD means, while the other seven NT siblings described the knowledge that they gained about ASD. Those that had knowledge of ASD knew that individuals with ASD: 1) process things differently, 2) have sensitive ears, 3) have different severity levels, and 4) should be treated with patience and kindness. Liam, a 6-year-old boy who has an 8-year-old brother with ASD, stated that “Well, all I know about autism … their brains are different and most of them might have sensitive ears. He has a different brain, and he has sensitive ears.” A 12-year-old boy, Lucas, who has a 3-year-old brother with ASD also described: “I know that like he processes things differently but like at my birthday party, he's like scared cause like you know, like so much noise and stuff.” In terms of the different severity levels of ASD, Emma age 14 told us that the function of individuals with ASD varies and that her brother is high functioning: “Well, here's one thing coming to my mind is that they are different, vary, like severity, I guess? Like there is high functioning, like [Dylan]. And there are kids that are not high functioning.” NT siblings also noted that individuals with ASD should be treated with patience and kindness. For example, Logan told us: “Sometimes you have to be very patient, and you can't really get mad at them, so I learned to be very patient with people and try to be as nice as possible.”

In terms of the available recourse to access to information about ASD, most NT siblings reported that they got information from their parents and their own observations on behaviors of their sibling with ASD. Only one child within our sample (a 12-year-old NT boy, Lucas, who has a 3-year-old brother with ASD) had an opportunity outside of their home to learn ASD: “Yeah, I know of kids with autism like I have a good friend named [Conner], he's autistic. We talk a lot.”

Some NT siblings also expressed hope that their siblings with ASD could make new friends and play with other kids. Moreover, they expressed hope not only for their siblings with

ASD, but also for all people with disabilities. That they can be respected and not be made fun of by others. “It just makes me feel good, someone that with a disability can find friends, and not be made fun of that much.”, Logan, age 11 said.

Caregivers. The caregivers in our study reported conversations with their NT children about ASD that were open and honest. Caregivers also mentioned other resources from which their NT children learned things about ASD including: (a) their own observation: direct observations of sibling with ASD and observations of home-based ABA therapy, (b) books, (c) school: peers with ASD and autism awareness activities at school, and (d) in the community: autism awareness flyers and posters. Caregivers indicated that conversations about ASD have been ongoing with their NT children. This included questions from their NT children such as: “Why doesn't my brother/sister talk to me?’; and “Why doesn't my brother/sister like it when I touch him?” The caregivers reported that they try their best to explain ASD to their NT child. The topics that they mentioned discussing included an understanding that individuals with ASD (a) process things differently, (b) have sensitive ears, (c) have difficulties with emotional control, and (d) need help and therapy. They also noted that NT siblings should protect their brother/sister with ASD, and that we should welcome difference and diversity.

Caregivers also utilized a variety of approaches when they explained ASD to their NT children. For example, they read picture books about ASD (e.g., *All My Stripes)* and being a sibling to someone with ASD. They had also engaged in dialogue about ASD with their NT children and used metaphors to make it easier for them to understand ASD and the difference between them and their siblings. For example, Ms. Martin, mother to an 11-year-old NT boy and a 7-year-old boy with ASD, said:

> When we first got the diagnosis, we sat down with him [James] and explained it to him. He understands computer programming. We were like: “Well, here is what it is. Daniel is on a Java computer system, and you are on Microsoft. They don’t communicate together, but we can build a bridge.”

In our sample, more than half of the caregivers reported it’s not easy for NT children to fully understand ASD. They also believed that NT siblings tend to forget what they have been taught about ASD. Thus, they must remind their NT children and repeat information they have shared about ASD. For example, Ms. Smith, mother to a 14-year-old NT daughter and a 7-year-old son with ASD, noted, “Won’t work that way, you will see that when I try to escalate the situation, you know if I try to explain why it’s different with his brain versus their brains. But it’s not that easy to really understand, I don’t think.” Ms. Brown, a mother who has a 6-year-old NT son and an 8-year-old son with ASD, also mentioned, “There's been a few times he's got really upset and wanted to know why he acts the way he does. And we just remind him to remember he has autism, and then we also remind him that means his brain just works differently than yours.”

Lastly, although all caregivers indicated that they have talked to their NT siblings about ASD, some NT siblings mentioned they don’t know what ASD means. When her daughter said she doesn’t know what ASD means, Mr. Thomas responded: “Yes, you do. He doesn't talk, he's got an aide at school. You know these things.” Similarly, Ms. Lee responded when her son told us he doesn’t know anything about ASD: “How I talked to you? I told you, because [Owen] has lots of therapy, right? And it's because he needs help, right?”

Preferences in Prospective Sibling-guided Interventions

Through this study also gained knowledge about the preferences of caregivers and NT siblings related to the design of sibling-guided motor interventions. We collected information about the setting and activity that NT siblings and caregivers would prefer in the prospective interventions. In addition, format, frequency, time in a week, and length of each session were asked to the caregivers, given their important role in managing the schedule and selecting programs for their children.

Neurotypical Siblings. NT siblings were asked about their preference in the prospective sibling-guided intervention in terms of setting and activity. A summary of results about their preferences and supporting quotes can be found in **Table 4**.

Setting. Most NT siblings indicated a preference for playing indoors than outdoors. They also noted that their preferred setting might depend on the specific activity.

Activity. The motor activities that NT siblings preferred and believed to be important for their siblings with ASD to learn included (listed in the order of popularity): (a) basketball, (b) soccer, (c) catching, (d) riding a bike, (e) jump roping, (f) drawing, and (g) fundamental motor skills (e.g., running, hopping, and kicking). The potential factors that determined preferred activities included: (a) personal enjoyment of the activity, (b) sibling with ASD's enjoyment of the activity, (c) NT siblings' comprehension of the skill/activity, (d) previous experience, (e) availability of equipment in their home, (f) lack of opportunity to engage in activity at school, and (g) potential benefits for the child with ASD.

Caregivers. Besides preferences on setting and motor activity for prospective sibling-guided motor interventions, given the critical role caregivers play in monitoring and coordinating schedules for their children, we also asked caregivers about their preference for the format, frequency, time in a week, and length of each intervention sessions. A summary of results about their preferences and supporting quotes can be found in **Table 4**.

Setting. Caregivers' preferences related to setting were polarized. Some caregivers preferred to let their children play indoors, mainly due to their concerns keeping track of children outdoors, their home environment, or their belief that children prefer and work better indoors. In contrast, other caregivers mentioned that their children prefer to play outside.

Activity. Caregivers consistently reported ball games (e.g., soccer, basketball, baseball) and fine motor activities such as activities of daily living (e.g., do a button on shirt) would be great for their children to learn, especially for the child with ASD. Caregivers also noted that they would appreciate activities that would provide children with ASD more opportunities to interact with others, take turns, and develop teamwork. For example, Ms. Clark told us: "When you were talking about improving motor skills, that is something that would be so nice for him because he can't participate in a regular sport team. So getting that teamwork, right? It would be something that is awesome to develop in him."

1Caregivers also expressed a desire that motor interventions involve various skills (e.g., basketball involves hand coordination, dribbling, and walking), not be restricted to location (e.g., can be easily played in the front yard), and be developmentally appropriate for their children. For example, Ms. Lee, who is concerned about the developmental appropriateness of the activities, mentioned: "Owen has done special needs baseball and he did enjoy that although I pull him out of it. Because he was so little and it goes up to 21, the kids. I just worried in the heart."

Besides gross motor activities, caregivers also emphasized an interest in fine motor skill activities of daily living (e.g., do a button on the shirt). Ms. Thomas stated:

> But there's also still deficits that kind of pop up, and a lot of it is the fine motor skills, like the fine motor, you know, "You're gonna do a button on the shirt or button your pants,"

> and instead of doing that, “We're just gonna stand here and we'll scream until somebody comes through and does it for us”.

Format. Most caregivers stated that they believe in-person interventions would be the most effective as it’s easier for kids to pay attention and for researchers to fully capture children's behaviors. Moreover, some caregivers indicated challenges with technology and dealing with lots of emails and materials. Nevertheless, a few caregivers mentioned virtual format (e.g., watching videos) would work better for them considering distance and availability. Ms. Clark also suggested that sibling-guided intervention be presented in a hybrid format, combining online communication and in-person visits:

> I don’t think I can get to [intervention location] once a week. I wonder if it could be a combination of the two, like couple of videos, or some videos, and then, maybe more like once a month, we go to [intervention location] or something like that? I wonder if it could be a combo of those two?

Frequency. Most caregivers preferred a frequency of once or twice a week, while a few caregivers stated that ongoing, intense interventions (e.g., 10-days consecutive program) are the best if they are held in summer. For example, Mr. Thomas, who preferred the idea of an ongoing intervention, told us:

> Yeah, I think that would honestly be my preferred method, but that's basically just because my schedule is just all over the place. It's never the same day to day. So, the high-intensity is normally my go-to just because it's easier to schedule around one event than, you know two, three, four of them.

Time in a Week. Caregivers preferred intervention sessions to be held during the weekend rather than after-school. The provided two major reasons: (a) children are often tired after school, and (b) they have limited availability after school because of children's schedules with homework and therapy.

"It will definitely be the weekend," Ms. Smith said, "I think they get tired after school every single day. They'll burn out." Similarly, Ms. Thompson reported: "After school is really crazy because you have all these activities, you have homework, all of those sorts of things going on."

Length of Each Session. The preferred length of each session varied among caregivers from fifteen minutes to two hours. Among those, 30-minutes and 15-minute sessions were most preferred. In general, all caregivers indicated that the length of the session should be worth the trip to campus, but not so long that children lose their attention. For example, Ms. Thompson noted: "I think it would be enough to like make it worth coming in for, but not so long that they lose their attention." Similarly, Ms. Johnson, mother to a 9-year-old NT daughter and an 11-year-old boy with ASD, said: "Probably at least a half an hour, make a trip worth it."

Additional Findings Related to COVID-19

This study was conducted during the COVID-19 pandemic. As such, we found some influence of the pandemic on the results of this study. Firstly, some families reported NT siblings and children with ASD get more time to spend together at home due to the quarantine. "They've obviously been around each other a lot more frequently than they normally are", stated Mr. Thomas. Secondly, with the experience of homeschooling and telehealth, caregivers stated they feel more comfortable participating in future studies remotely (e.g., watching training videos). Lastly, when we asked caregivers to evaluate their NT children's teaching skills, Ms. Anderson mentioned she thinks her NT child had improved her teaching skills to guide her sister with ASD during the quarantine, mainly because the NT child had the opportunity to see some direct examples of ABA therapy at home when her sister took online classes. “A five, for sure. Ahead of quarantine, it might’ve been a little bit lower. But, like I said, she [Ava] has seen so much direct example of ABA that it’s really rubbing off on her.”

Discussion

This qualitative study aimed to gain insights into how to create and implement a feasible and effective sibling-guided motor skills intervention for children with ASD by asking caregivers and NT siblings for input. Specifically, this study gained knowledge of (a) the perspectives of caregivers and NT siblings on prospective motor interventions that will have NT siblings act as the teachers/instructors to guide children with ASD, and (b) caregivers’ and NT siblings’ preferences (e.g., setting, format, intervention component/activity, frequency, time in a week, and length for each session) in future sibling-guided motor intervention.

In relation to the first research question, we found that most families reported NT siblings are willing to support and teach their siblings with ASD, which is consistent with the finding of a previous study that the NT sibling is willing to lend a helping hand to their sibling with disabilities (Dauz et al., 2010). Given the importance of NT siblings’ willingness to support, a study by Trent et al. (2005) used “the sibling indicated a willingness to participate in” as one of their inclusion criteria. However, only about half of NT siblings were confident in teaching and reported having previous experience teaching their brothers/sisters with ASD something. According to Bandura (1977)’s Social Learning Theory, an individual’s beliefs in their ability could influence how much effort they will put on a task (Bandura & Adams, 1977). Attention should be given to how to support NT siblings’ self-efficacy in designing in future sibling-guided intervention designs.

Additionally, this study found NT siblings were experiencing some difficulties interacting with children with ASD due to characteristics of ASD, such as resistance to change, limited social-communicative skills, problems with emotional control, oversensitivity, etc. In a study by Ross and Cuskelly (2009), 25 NT children and adolescents who has a sibling with ASD were asked to provide three examples of a problem that they had experienced with their brother/sister with ASD. When all the response were analyzed, the problems they had experienced were classified into three categories: aggressive behaviors (53%), social difficulties (16%), and syndrome-specific (16%). These similar findings emphasized that ASD-specific characteristics, specifically emotional control and limited social skills in children with ASD, negatively influenced the experience of sibling interactions. In addition, this study noticed that NT siblings' knowledge about ASD and available resourses to understand how to interact and support children with ASD are limited.

To respond to the second research question, we gained knowledge about the preferences of caregivers and NT siblings related to the characteristics of sibling-guided motor interventions. Most NT siblings preferred indoor settings and ball games. Both indoor and outdoor settings, ball games, in-person format, once or twice per week frequency, weekend days, and 30-minute session duration were preferred by most caregivers regarding future sibling-guided motor interventions. These findings of key stakeholders' opinions and preferences provide essential implications to and should be incorporated in future intervention design, given they may be less likely to participate in such interventions no matter how potentially effective it might be if participants do not like it (Wolf, 1978). By providing interventions with feasible and preferred characteristics (e.g., frequency, setting, and duration), it can potentially lower the burden of the intervention on the families as well as increase the participation and completion rate.

When we compared responses from NT siblings and caregivers, we found consistency in most areas, but conflicts in a few areas. For example, a few NT siblings mentioned they don't know what ASD means. Their caregivers, however, insisted that they had talked to their NT children about ASD and thought their NT children had some knowledge about ASD. Caregivers indicated that they think their NT children forget what they have had been told about ASD and fully understand ASD is hard for children. We also noticed that some NT siblings did not feel confident in their ability to teach, while their caregivers believed they did a great job teaching their siblings with ASD. Caregivers also reported that NT children can become easily discouraged even when they do a great job and may need to build self-efficacy to teach their siblings with ASD.

Implications for Future Research

A promising finding from this study is that NT siblings are willing to teach and learn how to better support their brother/sister with ASD. This may provide encouragement to researchers to include NT siblings as intervention agents in future studies, such as motor interventions and physical activity interventions for children with ASD. Given playing with a sibling is a natural context, sibling-mediated motor and/or physical activity interventions could be a viable option to help both children with ASD and NT siblings improve motor skills and come closer to meeting the 60-minutes MVPA guidelines on non-intervention days. However, we uncovered some important barriers that should be considered. For instance, NT siblings lacked a comprehensive knowledge about ASD, and ASD characteristics such as sensory sensitivities, difficulty losing during games, and difficulty controlling emotions could be challenging for NT siblings when interacting with their sibling with ASD. These findings could guide the development and content within future sibling-involved interventions. The literature shows the content of the NT sibling training in the existing sibling interventions were mostly focused on the strategies to better interact with siblings with ASD, such as Stay-Play-Talk (Kryzak & Jones, 2017; Tsao & Odom, 2016; Tsao, 2020), prompting, and reinforcement (Celiberti & Harris, 1993; Clark et al., 1989; Neff et al., 2017; Oppenheim-Leaf et al., 2012; Özen, 2015; Schreibman et al., 1983). In addition to these intervention strategies, our findings suggest that coping strategies when siblings with ASD have challenging behaviors may be necessary for NT siblings. For example, guiding NT siblings to explain the nature of the game to children with ASD could be helpful, especially if the target skill is a competitive activity and their siblings with ASD may get mad if they lose the game or fail. The skills that caregivers and NT children identified should be incorporated to ensure that interventions are effective.

Another important implication for future research was making considerations for intervention preferences (e.g., setting, duration, frequency, and activity, etc.) within intervention design. For instance, our study uncovered the need to consider convenience for families who might be willing to participate but may not be able to due to availability and distance. In these cases, a virtual or a hybrid intervention (i.e., video watching combined with in-person visits) may be a viable alternative to increase intervention accessibility. Additionally, within our results, most caregivers valued interactive play. Researchers could utilize this information and incorporate it into interventions by providing more opportunities for individuals with ASD to engage in developmentally appropriate motor activities that involve interaction and teamwork. A formative assessment could be used to develop a feasible and effective intervention that is flexible and will work well for each family.

Regarding the contradictions that we found between responses from NT siblings and caregivers, there are some implications for future studies. First, there is a need to include comprehensive information about understanding ASD within interventions, such as what ASD is, why challenging behaviors may occur, and the important roles of the NT sibling. Additionally, we discovered that some NT siblings have low self-efficacy in teaching their siblings with ASD even though caregivers believe they will do a great job. Therefore, in future studies, researchers may consider adding content within interventions to help NT siblings boost their self-efficacy, set self-efficacy as an intervention target to explore if NT siblings improve self-efficacy through sibling interventions, and examine if self-efficacy may impact the effectiveness of interventions.

Strengths and Limitations

Several major strengths are noted within this study. First, the study included interviews with both NT siblings and caregivers, separately. It is important to understand the perceptions of NT siblings on their barriers to interact with siblings with ASD, acting as a teacher to guide siblings with ASD, and their preferences for future sibling intervention studies. However, caregiver's options are also essential for interventions as they are often responsible for arranging schedules and monitoring progress as part of interventions. Second, the interviews were conducted remotely, given COVID-19 social distancing guidelines. Children and caregivers were interviewed in a familiar environment with familiar people surrounded, making them more relaxed and comfortable. This method also lowered the burden of the caregivers to travel and might be considered as an option even after the pandemic passes. Lastly, the some of the findings from this study (e.g., perceptions of using NT siblings to guide children with ASD, preferred intervention format and frequency) can also benefit broader types of sibling-guided interventions, beyond just motor interventions.

We also noted some limitations within this study. First, we recruited individuals for this study via a university-wide family list and the social media pages of the research labs at the same university. As such, our findings may not be representative of other individuals outside our locale. Second, within our semi-structured interviews, some of the youngest NT sibling participants were not able to answer all the questions. Perhaps they were nervous or shy, or perhaps their developmental level was such that they had difficulty understanding some questions asked by the interviewer. Lastly, typical assessments to identify ASD severity such as Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012) were not feasible given pandemic restrictions.

Conclusion

This study gathered information and gained insight into perceptions of NT siblings and caregivers of children with ASD. Further, this study posited having NT siblings acting as intervention agents to guide their siblings with ASD to acquire motor skills. The results provided meaningful direction for future studies which will guide the design of feasible and effective sibling interventions for children with ASD with NT siblings acting as intervention agents.

APPENDICES

APPENDIX A: Tables

Table 1

Sibling with ASD, Neurotypical Sibling, and Primary Caregiver Demographics

NT Pseudonym	NT Age* & gender	ASD age & gender	Race	Number of siblings	ASD birth order	Annual household income (in USD)	Caregiver Pseudonym	Caregiver age	Caregiver education level
Emma	14 F	7 M	White	3	3	> 100,000	Ms. Smith	45	Master’s
Olivia	9 F	11 M	White	2	1	50,000 - 99,999	Ms. Johnson	36	Bachelor’s
Liam	6 M	8 M	White	3	1	25,000 - 49,999	Ms. Brown	29	Bachelor’s
Noah	6 M	9 M	Asian	3	1	50,000 - 99,999	Ms. Chen	37	Bachelor’s
William	7 M	11 M	Asian	2	1	> 100,000	Ms. Lee	40	Master’s
Ava	9 F	5 F	White	2	2	50,000 to 99,999	Ms. Anderson	33	Bachelor’s
James	11 M	7 M	White	3	2	50,000 to 99,999	Ms. Martin	37	Bachelor’s
Charlotte	5 F	8 M	White	2	1	> 100,000	Ms. Thomas	31	Master’s
Lucas	12 M	3 M	White	4	3	25,000 - 49,999	Ms. Thompson	33	Associate’s
Logan	11 M	8 M	White	3	3	25,000 - 49,999	Ms. Clark	39	Associate’s

Note. *age reported in years; M=Male; F= Female; USD= United States Dollars

Table 2

Illustrative Quotes About NT Siblings' Perceived Characteristics of ASD that are Challenging

Perceived Characteristics of SWA with Supporting Quotes		NT Respondent (SWA) Age/Gender
Resistance to change	Sometimes I sit in a certain spot, then if I sit in a different spot, he blows up about like I should be sitting in the spot that I usually sit in; He does not like changes.	11 M (8 M)
	Like he has to do in his way. Otherwise, he is just not gonna do it; Yes, he has his own set rules, which can be pretty annoying sometimes.	14 F (7 M)
Compulsions	He was very territorial. He doesn't like me touching any of his things.	11 M (8 M)
Limited social communicative skills	Sometimes we're working on saying names like you say like "Lily, did you have a good day?" and she said "you have good day" because we know why she does that. It's because you say "did you" so she thinks "you" means her.	9 F (5 F)
	When he starts talking really, really fast it is very hard to understand him.	11 M (7 M)
Emotional control	He blows up about like I should be sitting in the spot that I usually sit in.	11 M (8 M)
	We get along quiet okay, but when things get a little messed up, my brother starts to get mad.	7 M (11 M)
	Like sometimes, she just wants to play alone. And sometimes, like if we're trying to get her to play with somebody, she yells at you	9 F (5 F)
Oversensitivity	Usually what makes me stop is when he starts overreacting.	14 F (7 F)
Lack of acceptance when they lose	He was like "we both lose!!" And I tried to explain. Because he doesn't want to be the only one that loses. That why he is fine if we both lose.	7 M (11 M)
	Levi can ride much faster. Even though he's faster than me, I kinda go around or go over stuff and he just get mad. That's how so I usually win. Even though he can run faster. Well on the end if I win once he gets really mad. Levi thinks he always if, I'm doing it next he should have the most of it. He thinks he has to (win).	6 M (8 M)
Spends too much time on restricted interests	A lot of times she's pretty much always on the tablet so I don't really get to spend that much time with her, and so like straight after school she goes, she just yells "I want the tablet" and like right in the morning if you get up, you try to ask her a question but she says: "I want tablet".	9 F (5 F)

Note. M=Male; F= Female; ASD = autism spectrum disorder; NT = neurotypical; SWA = sibling with ASD

Table 3

Illustrative Quotes About Caregivers' Perceived Challenging Behaviors in Children with ASD that May Influence Sibling Relationship

Perceived Challenging Behaviors in CWA with Supporting Quotes		**NT Child (CWA) Age/Gender**
Prefer to play alone	He would much rather just kind of do his own thing than to interact with other kids. So, I think that's really honestly the most critical component is that it's not really reinforcing for him, so unless she's specifically doing something that he enjoys and that he wants to do right now, he's not going to do it with her or any other kid for that matter.	5 F (8 M)
Limited social communicative skills	There's definitely a communication piece missing, which causes a lot of frustrations, aggravations, raised voices.	6 M (8 M)
	Lily has some pretty big social emotional deficits, especially in terms of like her school and community life.	9 F (5 F)
	He doesn't really care for socializing. He's not reinforced by social interaction in any capacity.	5 F (8 M)
Emotional control	Levi was getting frustrated and mad and just getting up and leaving	6 M (8 M)
Overreacting	I think it depends on my older son gets so overstimulated and gets a little bit nuts. And then, I think that does affect their relationship.	7 M (11 M)

Note. M=Male; F= Female; ASD = autism spectrum disorder; NT = neurotypical; CWA = child with ASD

APPENDIX B: Semi-Structure Interview Guide (Parent Version)

Section 1: Self Report

1. Are you the child's primary caregiver? _________
2. Your Biological Relationship to Child _________
3. Your age______
4. Your race______
5. What is your highest level of education completed? ________
6. What category best describes your annual household income?
   Less than $24,999 $50,000 to $99,999
   $25,000-$49,999 More than $100,000
7. How many children do you have? Please list their ages and gender with birth order:

	Age	Gender	ASD diagnosis
1st child	_______	_______	☐
2nd child	_______	_______	☐
3rd child	_______	_______	☐
4th child	_______	_______	☐
5th child	_______	_______	☐

Section 2: Interview

1. If there was an intervention project which gives your child some training on how to use teaching strategies to better teach your child with ASD some motor skills such as galloping, skipping, throwing, and dribbling, etc. Among all your children, who do you think would be the best person to teach? Why?
   (participants selection)
2. Some siblings get along very well, but some of them don't. How would you rate the relationship between your kids from 1 to 5 (5 means extremely well)? Why?
   1 2 3 4 5
   (sibling relationship)
3. What are the things/activities that your kids enjoy playing? How much interest do you think they have in common?
   (component and design of the intervention; how to maximize enjoyment and engagement in intervention)
4. Where do your children usually play?
   (settings of the intervention)

5. Some kids spend lots of time with their siblings, while others don't spend so much. How much free time do you think your kids spend together? How long do they actually play with each other each day? If _____ was teaching ____ how to ride a bike, how long before they would lose focus?
   (dosage of the intervention; sibling relationship)

6. If there was an intervention provided to your kids - training the sibling some teaching strategies and let them teach their sibling with ASD some motor skills, would you like to participate? If yes, when, where, how long do you prefer, and how long can a single session last? If no, what's the main barrier for you to participate this intervention?
   When:
    A. After school
    B. Weekends

   Where：
    A. At home only
    B. At home or at MSU
    C. At home and at MSU
    D. At MSU only

   How long for the project:
    A. Once a week for 4 months
    B. Twice a week for 2 months
    C. Every day for 1 month

   How long for each session:
    A. 15 mins
    B. 20 mins
    C. 30 mins

   (feasibility of the intervention)

7. How much do you see [child(T)] show [child(A)] how to do things he or she doesn't know how to do? How much does [child(T)] teach [child(A)] things that he or she doesn't know?
   (*previous teaching experience*)

8. What do you think about [child(T)]'s teaching skills (1 means extremely good and 5 means poor)? Can you give me an example?
   1 2 3 4 5
   (feasibility of the intervention; how pre-training for ND siblings can enhance)

9. How much do you think [child(T)]'s willingness to teach [child(A)] (1 means extremely much and 5 means hardly at all)?
   1 2 3 4 5
   (motivation of participation)

10. What skill(s) do you think is/are the most important for your child with ASD to learn (ex. run, jump, kick a soccer ball, ride a bike, dribble a basketball, etc.)?

(component and design of the intervention)





11. Have you ever talked with your child(T) about Autism Spectrum Disorders?
    (background knowledge about ASD; how pre-training for NT siblings can help)

12. Has your child (NT) ever learned anything from anywhere (home, school, or community, etc.) how to better play and help children with ASD? If yes, do you know what they've learned?
    (background knowledge about ASD; how pre-training for NT siblings can help)

APPENDIX C: Semi-Structure Interview Guide (Sibling Version)

1. Some siblings get along very well, but some of them don’t. How would you rate the relationship between you and____ from 1 to 5 (5 means extremely well)? Why?
   (sibling relationship)

2. What do you and ___ enjoy playing? How often do you and _____ do that?
   (component and design of the intervention; how to maximize enjoyment and engagement in intervention)

3. Where is your favorite place to play with _____?
   (settings of the intervention)

4. Some kids spend lots of time with their siblings, while others don’t spend so much. After school or on the weekends, what do you and ____do together? How long do you usually play with your sibling each day?
   (dosage of the intervention; sibling relationship)

5. What makes you stop? What do you think is the biggest barrier for you to play with ______ or teach them something new?
   (possible problems in the intervention process; how pre-training for NT siblings can help)

6. What do you like about playing with ____ or teach them something new?
   (how to maximize engagement in intervention; how pre-training for NT siblings can enhance)

7. You’re the big brother/sister, right? Do you ever show _____ how to do things he or she doesn’t know how to do? Like what? Do you show them every day or just once in a while?
   (*previous teaching experience*)

8. How good are you at teaching? Have you ever taught someone how to do something? What, tell me about it.

   

   (extremely good) ……………………..(poor)
   (feasibility of the intervention; how pre-training for NT siblings can enhance)

9. Do you feel confident to teach something new to ______?

   

(extremely much) ……………………..(hardly at all)

(self-esteem)

10. How much do you want to teach ____ how to do stuff?

(extremely much) ……………………..(hardly at all)

(motivation of participation)

11. What do you think about ______ playing with other kids? Would that be good or bad? Why?
(perception of benefits of motor and communicative skills for children with ASD)

12. What skill(s) do you think is/are the most important for _____ to learn (ex. run, jump rope, kick a soccer ball, ride a bike, dribble a basketball, etc.)?
(component and design of the intervention)

13. Tell me about Autism Spectrum Disorders. What makes _____ different from others?
(background knowledge about ASD; how pre-training for NT siblings can help)

14. Have you ever learned anything from anywhere (home, school, or community, etc.) how to better play and help children with ASD? If yes, could you tell me what you've learned?
(background knowledge about ASD; how pre-training for NT siblings can help)

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CHAPTER 3

An Investigation of Levels of Physical Activity, Parental Perceived Motor Competence, and Related Family Dynamics in Children with Autism Spectrum Disorder with A Neurotypical Sibling During the Covid-19 Pandemic

Abstract

The COVID-19 pandemic significantly impacted people's daily lives. Children with Autism Spectrum Disorders (ASD) experienced more challenges adapting to pandemic-related changes in their daily routines. Existing literature indicates that delays or impairments in gross motor and fine motor skills are common in children with ASD, and they do not engage in enough daily moderate-to-vigorous physical activity (MVPA). Due to the disruption in physical education and other play-based services, the COVID-19 pandemic could have further affected PA and motor skills in children with ASD. Some researchers suggested unstructured PA could be achieved by playing with siblings. Therefore, this cross-sectional study investigated levels of physical activity (PA), parental perceived motor competence, and related family dynamics in children with ASD with a neurotypical (NT) sibling during the COVID-19 pandemic. Eighteen parent-ASD-NT triads (54 participants) were recruited. Children's Physical Activity Questionnaire (C-PAQ) results indicated children with ASD in our sample spent a significantly greater amount of time in sedentary behaviors (mean = 2379.06 mins; SD = 1480.10) during an entire week than in leisure time activities (mean = 316.88 mins; SD = 301.48) and sports activities (mean = 183.00 mins; SD = 153.94). Besides duration, children with ASD also participated in sedentary activities more frequently and in more types than other levels of PA. Also, parents perceived their child with ASD as "not too good" or "sort of good" in many motor skills. For family dynamics, compared to NT siblings, parents reported higher self-efficacy in

supporting PA and greater interactions with children with ASD. This study highlights the importance of providing quality family-implemented PA and motor intervention for children with ASD.

Introduction

COVID-19 Pandemic and Autism Spectrum Disorder (ASD)

In response to the unprecedented global public health emergency caused by the coronavirus (COVID-19) outbreak, the government tightened protective measures to prevent further spreading of the virus, including limiting social gatherings, encouraging work from home, travel restrictions, and closures of schools, etc. Although these measures helped mitigate the public's exposure to the virus, many aspects of people's lives were significantly affected. For example, education services were altered worldwide. Schools for more than 168 million children globally were closed for almost a full year (UNICEF, 2021). For children with ASD, specifically, in-person school-based special education services such as speech and language, physical, and occupational therapy were disrupted (White et al., 2021). Although some services children with ASD had prior to the pandemic were adapted to telehealth formats, many families reported they did not receive services available pre-pandemic (White et al., 2021). For example, online programming was either not provided by many Applied Behavior Analysis (ABA) centers, or not covered by insurance even if it was offered (Cox et al., 2020). In addition to the disruption of services, given the difficulty children with ASD experience adapting to changes in their daily routines, the pandemic-related changes made it challenging for many children with ASD to make adaptations at home, which often resulted in more frequent negative emotions such as anxiety and stress (Genova et al., 2021; Wigham et al., 2015). Mutluer et al. (2020) indicated their sample of 87 individuals with ASD even had problems understanding what COVID-19 meant.

Additionally, parents of children with ASD reported an increase in behavioral problems in their children during the pandemic (Colizzi et al., 2020). Taken together, families of children with ASD were a vulnerable group to develop anxiety and other mental health concerns during the pandemic.

In addition to the impact on mental health, closure of active living areas such as schools, parks, and recreation centers occurred during the pandemic resulted in a reduction in levels of physical activity (PA) and an increase in sedentary behaviors (SB; Burhaein et al., 2021; Chen et al. 2020; Yarımkaya & Esentürk, 2020). Moreover, a preliminary investigation indicated that children with ASD showed reduced walking behavior and declining coordination and balance abilities during the pandemic (Yarımkaya & Esenturk, 2020). It was suggested that free and unstructured PA could be met by playing with siblings (Dunton et al., 2020). Existing literature shows siblings can bring unique advantages in prompting skill acquisition in children with ASD (Banda, 2015; Bene & Lapina, 2021; Lu et al., 2021; Shivers & Plavnick, 2015). However, given our knowledge of movement behaviors in children with ASD with a neurotypical (NT) sibling during the COVID-19 pandemic is limited, this study focused on quantitatively describing their levels of PA, motor competence (using a parental proxy), and PA-related family dynamics. Besides revealing movement behaviors in children with ASD during the pandemic, this study may also help with evolving our knowledge and strategies about influencing PA in children with ASD at the family level.

Physical Activity in Children with ASD

Children who are physically active tend to be healthier (National Physical Activity Plan Alliance, 2018). The health benefits of PA are well known and documented. Regular PA can help children improve cardiorespiratory fitness, build strong bones and muscles, reduce symptoms of anxiety and depression, lower the risk of developing health conditions, promote growth in a variety of developmental domains (e.g., motor competence, social functioning, cognitive performance), and maintain a healthy weight (Centers for Disease Control and Prevention, 2010; Dale et al., 2019; Loprinzi et al., 2015; Michael et al., 2015; Physical Activity Guidelines Advisory Committee, 2018; Pitukcheewanont et al., 2010; Reinders et al., 2019; Stodden, et al., 2008; Strong et al., 2005). Therefore, it is important to provide children with PA opportunities and encourage active participation in enjoyable physical activities that are developmentally appropriate (US Department of Health and Human Services, 2018).

According to the Physical Activity Guidelines for Americans, 2nd edition (2018) by the U.S. Department of Health and Human Services (USDHHS), preschool children ages between 3 to 5 years should be physically active throughout the day to enhance their growth and development. For children 6 years old and beyond, 60 minutes or more of moderate-to-vigorous physical activity (MVPA) per day is recommended. The World Health Organization (WHO) provided similar PA guidelines and recommendations (WHO, 2020), for children aged 5 years and beyond; at least 60 minutes of MVPA per day is required to enhance their growth and development. Also, vigorous physical activity (VPA) should be incorporated into their activities at least 3 days per week. Sedentary time, particularly recreational screen time, should be limited.

However, the findings by the National Survey of Children's Health (2016) reported that approximately 76% of children and youth are not getting enough daily PA and failed to meet the guidelines. Children and adolescents with ASD, furthermore, engaged in a lower percentage of time in MVPA than their neurotypical peers in many settings (McCoy et al., 2016; McCoy & Morgan, 2020; Sandt & Frey, 2005). National data have shown that approximately 83% of children with ASD aged 6 years and beyond fall short of the daily 60 minute-MVPA recommendation (Child and Adolescent Health Measurement Initiative, 2018). In a study by Pan et al. (2016), among 35 secondary school-aged participants with ASD, only 13 (37%) of them accumulated more than 60 minutes of daily MVPA. In a study by Memari et al. (2015) parent-reported data from Godin-Shephard Leisure Time Questionnaire (GLTEQ), with a sample of 83 children with ASD aged 6 to 17, showed only 10 participants (12%) were active. Similarly, in a study with 53 children with ASD aged 3 to 11, only 23% of the participants with ASD met the criteria for MVPA (Bandini et al., 2013). These existing investigations indicated a consensus that individuals with ASD fall short of the recommended PA levels (Menear & Neumeier, 2015).

The COVID-19 pandemic may have further affected PA in children with ASD, given school-based PA opportunities and interactive play-based therapies were disrupted. An online investigation on psychosocial and behavioral impact of COVID-19 reported that parents or guardians of individuals with ASD experienced increased difficulties in managing daily activities, especially free time and structured activities (Colizzi et al., 2020). A qualitative study conducted by Yarımkaya and Esentürk (2020) revealed that parents reported that their children with ASD exhibited increased sedentary behaviors such as frequent television watching and tablet use. However, our knowledge of the duration, frequency, and types of MVPA, LPA, and SB children with ASD participated in during the pandemic is still limited.

Motor Competence in Children with ASD

It is suggested that motor competence is developed gradually in children through various meaningful experiences of interacting with the environment, people, and objects in both structured and unstructured PA settings (Obergh, 2019; Tortella et al. 2016, Van Capelle et al., 2017). Fundamental motor skills (FMS) lay the foundation for complex sport-specific skills and can be classified into two categories which are locomotor skills and objective control skills

(Kokstejn et al., 2019). Locomotor skills refer to the physical act of moving from one place to another, such as running, hopping, galloping, skipping, etc. (Haywood & Getchell, 2019). Object control skills (or ballistic skills) refer to the manipulation and projection of objects such as throwing, catching, dribbling, kicking, striking, etc. (Stodden, et al., 2008). Clark and Metcalfe (2002) created the “mountain of motor development” metaphor to illustrate the development of motor skills. It showed the interactive, cumulative, and sequential nature of motor skill development which includes six phases: (1) reflexive, (2) pre-adapted, (3) fundamental motor skills, (4) more complex skills that are context-specific, and (5) skillfulness. With the metaphor of “climbing a mountain”, skills and experiences that human gained from each phase can lay the foundation for reaching the subsequent phase. Given this cumulative and sequential pattern, achieving fundamental motor skills is of great importance for the long-term motor development outcomes.

However, researchers have found that delays or impairments in gross motor and fine motor skills are common in individuals with ASD (Chawarska et al., 2007; Davidovitch et al., 2015; Landa & Garrett-Mayer, 2006). These motor impairments can take the form of dyspraxia, impaired motor speed and coordination, gait abnormalities, and postural and balance disorder (Abu-Dahab et al., 2013; Dziuk et al., 2007; Rinehart et al., 2006; Siaperas et al., 2012). Previous research also compared motor competence in children with ASD and typically developing children within their studies. MacDonald et al. (2014) reported that for very young children with ASD within their sample (12-33 months), their gross and fine motor skill deficits were 6.4 and 9.5 months behind chronological age, respectively. Another study by Ketcheson et al. (2018) indicated that children with ASD ages 2 to 5 showed significantly lower levels of gross, fine, and total motor quotient than their peers without ASD ($p < 0.001$). Additionally, a cross-sectional study by Pusponegoro et al. (2016) compared gross motor skills in 40 children with ASD aged from 18 months to 6 years and 40 age-matched typically developing children using the Vineland Adaptive Behavior Scales, 2nd edition (Vineland-II; Sparrow et al., 2005). The results showed that gross motor function in 20% of their ASD sample was below average, and gross motor skills in children with ASD were significantly lower than in the typically developing controls ($p = 0.0001$), especially in ball throwing and catching, using stairs, jumping, and bicycling. In addition to comparing motor competence to chronological age-matched NT peers, a study by Staples and Reid (2010) also investigated FMS in children with ASD (9 to 12 years) to the movement skill-matched NT children. Their findings indicated that NT children with similar levels of movement skills were only about half the age of children with ASD. Overall, this means delays and impairments in motor skills can be an issue in individuals with ASD, and actions need to be taken to address these difficulties and promote their motor skill development. Given the difficult time during the pandemic, children with ASD may have less opportunity to practice and learn motor skills, as services and projects aimed at promoting motor skill development in children with ASD might be even harder for educators and therapists to deliver. However, no literature reporting data on motor competence in children with ASD during the pandemic has been established yet.

Physical Activity-Related Family Dynamics

Families play a critical role in encouraging children with ASD to maintain a healthy physical activity lifestyle (Arnell et al., 2020). On theoretical grounds, Bronfenbrenner’s Ecological Model (1977) indicates that an individual’s development and behavior are influenced by many aspects in the environment as well as the dynamic interactions between the individual and the environment. The model introduced a set of nested structures: *microsystem* (the immediate setting), *mesosystem* (interrelations among major settings), *exosystem* (major institutions of the society), *and macrosystem* (culture or subculture). The interactions between parents and siblings are acknowledged as influential in the individual's behaviors in the immediate setting within *microsystem* - the most intimate level of interactions.

Existing studies indicated that parents' active participation is of great importance in effectively improving a variety of different skills in children with ASD (McConachie & Diggle, 2007). For that reason, parental involvement and initiation of PA for their children during the pandemic could potentially influence their children's success in participating in PA and meeting PA guidelines. Siblings, apart from the parents, are the most significant members of families in supporting their brothers/sisters with disabilities. They are usually the playmates of a child, and they spend a significant amount of time with each other (Mauthner, 2005). Additionally, according to the Social Learning Theory (Bandura,1977), an individual's expectation and beliefs about their capacity to execute behaviors can influence their persistence on a task in the face of obstacles, whether they can initiate coping behaviors, and how much effort they will put forth (Bandura & Adams, 1977). For instance, Diken (2009) studied interactional style and self-efficacy of mothers of children with language delays and found that mothers with high levels of self-efficacy performed more achievement-oriented behaviors during the interactions with their children. Therefore, evaluating parents' and NT siblings' self-efficacy in supporting PA in children with ASD and investigating interactions between siblings as well as parent and child could be helpful for (a) gaining an understanding of possible family factors that may influence PA in children with ASD and (b) informing future PA intervention design.

Specific Aims

Given the health benefits of regular PA and acquiring motor competence, the fact that children with ASD fall short of PA guidelines and can experience motor delay or impairments, as well as challenges during this unprecedented time, research needs to be established to understand PA and motor competence in children with ASD during the COVID-19 pandemic. Existing data revealing motor skills and physical activity in children with ASD during the COVID-19 pandemic were gathered from quantitative studies through interviews. And there is a dearth of quantitative investigations conducted to report motor skills and physical activity. In addition, understanding parent-child interactions, NT-ASD interactions, and parents' and NT siblings' self-efficacy in supporting PA in children with ASD that occurred during the unique circumstances brought on by the pandemic will be helpful to us as we evolve our knowledge and strategies about influencing PA in children with ASD at the family level.

Therefore, this study investigated levels of PA, parent perceived motor competence, and PA-related family dynamics (i.e., parent-child interactions, NT-ASD interactions, parents' and NT siblings' self-efficacy in supporting PA) in children with ASD with a neurotypical sibling during the COVID-19 pandemic.

Method

Study Design

This study was a cross-sectional investigation that descriptively reported levels of PA, parent perceived motor competence, and PA-related family dynamics in children with ASD with a NT sibling during the COVID-19 pandemic.

Participants

Groups of the parent, the child with ASD, and the NT sibling (parent-NT-ASD triads) from eighteen families (a total of 54 participants) were recruited. The research team recruited participants by distributing study information (i.e., recruitment flyer, parent letter, consent form) via (a) a university-wide email list for families of children with special needs, (b) a laboratory-wide family email list of whom previously participated in ASD research and consented to be contacted for future research opportunities, (c) social media groups related to ASD, and (d) local elementary schools.

Families were eligible to participate if they had (a) a child with ASD between the ages of 6 and 11 years without medical conditions other than ASD that could affect PA participation or motor competence (e.g., Down syndrome, epilepsy, intellectual disabilities), (b) a neurotypical child age 5 or older who consented to participate (we asked for verbal assent if they aged 5-7 years; a language appropriate assent form was obtained if they aged 8-12 years), (c) a caregiver within the family who consented to participate, and (d) access to the internet and compatible devices to complete online surveys. Caregivers of families who had more than two NT children were asked to select one NT child to participate in this study and fill out sibling-related surveys.

Data Collection

All the data collection procedures were conducted remotely. Demographic information, PA, parental perceived motor competence, and PA-related family dynamics were measured using electronic copies of assessment scales and online surveys (see appendices in Chapter 5). Objective PA data was measured using accelerometers (ActiGraph GT3X), and the devices were distributed and returned by mail.

Demographic Information. Demographic information was collected via an online survey (see Appendix B: Demographic Survey). Questions included the age, sex, weight and height of all participants (parents, children with ASD, and NT siblings), race, caregiver's highest level of education completed, annual household income, number of children in the family, birth order of the child with ASD, as well as whether the child with ASD had an intellectual disability and an individualized education plan.

Physical Activity. Physical activity in children with ASD was measured both subjectively and objectively. Subjective PA data was collected using the Children's Physical Activity Questionnaire (C-PAQ), which had parents to report on their child's physical activity. Objectively, PA data were collected using accelerometers for a seven-day period.

Questionnaire-Based Physical Activity. C-PAQ is a parent-reported, seven-day-recall questionnaire that consists of physical activities across four areas: (a) sports activities, (b) leisure time activities, (c) activities at school, and (b) sedentary activities. A number of activities are listed within each section. For example, the section on sedentary activities includes a variety of sitting activities such as doing homework, playing indoors with toys, reading, playing computer games, and playing music instruments. Parents are asked to report the frequency and duration their child did in each activity for both weekdays and weekend days. The C-PAQ has a validity of 0.42 ($p = 0.04$) and a reliability of 0.39 ($p < 0.05$) for MVPA (Anderson et al., 2017; Corder et al., 2009).

Although the questionnaire did not inquire about the intensity of participation in activities, for the purpose of this study, the *sports activities* category within the C-PAQ served as a proxy for MVPA, and the *leisure time activities* category served as a proxy for LPA, given the nature of those activities and the support of the Youth Compendium of Physical Activities (Butte et al., 2018). In addition, activities at school were not analyzed as the questionnaire was completed by the parents during school closure.

Accelerometry-Based Physical Activity. An accelerometer is a lightweight and compact device that can be used to capture PA (Santos-Lozano et al., 2013). It has been shown to be a feasible and valid method of assessing PA in children (Pate et al., 2006; Pfeiffer et al., 2006; Pulakka et al., 2013; O'Neil et al., 2014). Families were told to wear the accelerometer (ActiGraph GT3X) for seven consecutive days and record the periods of non-wear time in a PA log. Within this study, the accelerometer was worn on the right hip of the child with ASD and removed only for showers and aquatic activities. Accelerometers and PA logs were distributed by mail with detailed wearing instructions attached. We also decorated the devices with stickers to promote monitoring adherence in children with ASD, as suggested by Hauck et al. (2016). Once completed, families returned the accelerometers by mail with a prepaid return label the investigator provided. All accelerometer-measured PA data were downloaded and analyzed using ActiLife 6 software. To get a valid estimate of PA, a minimum of 10 hours/day for at least four days was necessary for inclusion in the final analysis (Troiano et al., 2008). Sixty minutes of continuous zero count was considered non-wear and was removed before data analysis. Evenson (2008) ActiGraph cut points, which was recommended by Trost et al. (2010) for predicting activity intensity in children and adolescents, were applied to demarcate sedentary (0-100 counts per minute (CPM), light (101-2295 CPM), moderate (2296-4011 CPM), and vigorous (>4012 CPM) physical activity.

Parental Perceived Motor Competence. Since this study was conducted while COVID-19 restrictions were in place, motor competence was reported by parents using the parental proxy of the Pictorial Scale of Perceived Movement Skill Competence (PMSC-parent; Barnett et al., 2015), which was developed to assess parents' perceptions of their children's competence in fundamental motor skills and active play. The measure consists of six active play skills (i.e., bike riding, scootering, board paddle, skating/blading, swimming, and rope climbing), six locomotor skills (i.e., running, galloping, skipping, leaping, jumping, and step & slide), and seven object control skills (i.e., hitting a ball, hitting a ball with one hand, bouncing a ball, catching a ball, kicking a ball, throwing underhand, and throwing overhand). Parents were asked to rate how good their child was at each skill. For skills/activities that their child had not tried or they were not sure about, parents were asked to rate based on their perceptions of how good their child would be at them. There are four options available for each skill: (a) not too good, (b) sort of good, (c) pretty good, and (d) really good, and they are scored as 4, 3, 2, 1, respectively. Therefore, possible scores for the active play, locomotor, and object control subtests are 6-24, 6-24, and 7-28, respectively. The total possible score for fundamental motor skills (FMS) is 13-52, and the possible score for the entire PMSC-parent is 19-76.

The PMSC-parent is aligned with the Test of Gross Motor Development - 3rd Edition (TGMD-3; Ulrich, 2017), which is a valid and reliable assessment of gross motor performance (Webster & Ulrich, 2017). A study by Maher et al. (2018) compared the parent proxy report on motor competence by PMSC and the actual motor competence measured by TGMD-3 in a sample of 100 children aged 7-9 years. The study results indicated the parent version of PMSC was moderately associated with the actual motor skill ($r = 0.36$, $P < 0.001$). In addition, excellent internal consistency (Cronbach's alpha) was found in the seven-object control (0.94), the six locomotor (0.90) items, and the 13 FMS items (0.92).

Physical Activity-Related Family Dynamics. Within this study, data on (a) parent-child interactions, (b) NT-ASD interactions, (c) parents' self-efficacy in supporting PA in children with ASD, and (d) NT siblings' self-efficacy in supporting physical activities in children with ASD were collected using self-administered online surveys. For each survey, participants used a 5-point rating scale to indicate how much they agree with the statements (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree). The parent-child interaction survey (designed for parents) and NT-ASD interaction survey (designed for NT siblings) each included 12 questions, making a possible total score of 12-60 points for both. For the self-efficacy survey, surveys designed for parents and NT siblings include 11 questions each, for a possible total score of 11-55 points for each. In addition, questions for parents and NT siblings were related and consistent, except questions for NT siblings were simplified, making them age-appropriate and easy for children to understand and answer. In addition, this study investigated how these interactions and self-efficacy variables were associated with each other.

Data Analysis

Descriptive analysis was used to analyze PA, parental perceived motor competence, and PA-related family dynamics data. Also, a Pearson's correlation was used to examine the associations among the PA-related family dynamics measures. All analyses were conducted via SPSS (version 27).

Results

Demographic Information

Demographic characteristics of the 18 parent-ASD-NT triads from midwestern US in our sample were analyzed and are provided in **Table 4**. Across the 18 parent-ASD-NT triads (African American = 5.6%, Asian = 11.1%, and White = 83.33%), parents/primary caregivers aged from 30 to 47 years (mean = 39.06; SD = 4.90), children with ASD aged from 6 to 12 years (mean = 9.22, SD = 1.66), and NT siblings aged from 5 to 23 years (mean = 11.06, SD = 5.46).

Parental Perceived Motor Competence

Results of parental perceived motor competence in children with ASD in our sample are presented in **Table 5**. The score for each skill/activity, each category (i.e., active play, locomotor, object control), fundamental motor skills (i.e., the sum of locomotor + object control), and total score were presented.

Within our sample, on average, parents perceived their children's competence on most skills as not too good (scored as 1) or sort of good (scored as 2), with a few skills as pretty good (scored as 3). Among all the skills in PMSC-parent, parents perceived relatively higher competence in their children's scootering skills (mean = 3.06; SD = 0.97), running (mean = 3.18; SD = 0.95), and galloping (mean = 3.00; SD = 1.00). Competence in skills/activities that were perceived relatively lower including board paddle (mean = 1.94; SD = 0.97), skating/blading (mean = 1.65; SD = 1.00), rope climbing (mean = 1.59; SD = 0.94), hitting a ball (mean = 1.82; SD = 0.95), and hitting a ball with one hand (mean = 1.82; SD = 1.02).

Physical Activity

Questionnaire-Based Physical Activity. Frequency, type (the number of different kinds of activities participated in), and duration (in minutes) spent in sports activities (proxy for MVPA), leisure time activities (proxy for LPA), and sedentary activities during a 7-day period are reported in **Table 6**.

First, the data show that children with ASD in our sample spent a significantly greater amount of time in sedentary behaviors (mean = 2379.06; SD = 1480.10) during an entire week than LPA (mean = 316.88; SD = 301.48) and MVPA (mean = 183.00; SD = 153.94). In addition, when we investigated the minutes of time spent in weekdays and weekend separately, SB was still greater [weekdays (mean = 1752.38; SD = 1019.27); weekend (mean = 682.19; SD =

742.58)] than LPA [weekdays (mean = 203.53; SD = 163.71); weekend (mean = 119.24; SD = 158.21)] and MVPA [weekdays (mean = 137.41; SD = 120.91); weekend (mean = 45.60; SD = 51.99)] in both time periods. In reference to the WHO PA guidelines (i.e., at least an average of 60 minutes MVPA per day), only two participants (11.11%) met the 60-minute MVPA guideline.

For each category of activities, participants engaged in more SB during both weekdays (mean = 7.76; SD = 2.02) and weekends (mean = 4.29; SD = 3.06) than that of LPA [weekdays (mean = 4.47; SD = 2.07); weekend (mean = 2.94; SD = 2.46)] and MVPA [weekdays (mean = 2.12; SD = 2.00); weekend (mean = 1.24; SD = 1.44)]. Frequency of participation in LPA and MVPA were also measured using the C-PAQ. Parents in our sample reported that, during both weekdays and weekend, children with ASD participated in LPA [weekdays (mean = 14.00; SD = 9.63); weekend (mean = 5.41; SD = 6.35)] more frequently than MVPA [weekdays (mean = 6.79; SD = 7.91); weekend (mean = 2.35; SD = 3.12)].

Accelerometry-Based Physical Activity. Valid accelerometry data were collected in 10 children with ASD within our sample, given some participants were not able to meet the minimum wear time (minimum wear time was 10 hours/day for at least four days, including one weekend day). It was mostly due to the sensory issues in children with ASD, which can make them feel uncomfortable wearing the accelerometer on their hip. Results indicated that a greater percentage of time was spent in SB (mean = 78.35; SD = 7.15) than LPA (mean = 13.65; SD = 2.80) and MVPA (mean = 8.00; SD = 5.21) during the time when the accelerometer was worn.

Physical Activity-Related Family Dynamics

The questions for parents and NT siblings about interactions and self-efficacy were related and consistent, except questions for NT siblings were simplified and age-appropriate.

Therefore, they were combined to make it easier to compare the perceptions of parents and NT siblings (see **Table 7** and **Table 8**).

Parent-Child and NT-ASD Interactions. In terms of interaction surveys, for parent-ASD interactions, on average, parents agreed with the following four statements: *my child and I talk to each other a lot* (mean = 4.00; SD = 1.09), *I enjoy helping my child to learn new things* (mean = 4.61; SD = 0.70), *my child and I enjoy playing together* (mean = 4.33; SD = 0.91), and *my child and I enjoy doing physical activities together* (mean = 4.11; SD = 0.83). However, they reported the least agreement on the statement *my child asks me to do physical activities with him/her a lot* (mean = 2.94; SD = 1.21). For NT-ASD interactions, NT siblings were neutral (i.e., neither agree nor disagree) for most of the statements. Statements with which they disagreed include *my sibling and I play together a lot* (mean = 2.83; SD = 1.10), *when my sibling looks at or touches a toy or object, I talk to him/her about the toy or object* (mean = 2.61; SD = 1.24), *I invite my sibling to play with me a lot* (mean = 2.89; SD = 1.32), *and my sibling asks me to do physical activities with him/her a lot* (mean = 2.89; SD = 1.49). When comparing the results from parents and NT siblings, parents reported higher than NT siblings in almost all the statements, except *my child asks me to play with him/her a lot* (mean = 3.28; SD = 1.32). NT siblings rated higher on the statement *my sibling asks me to play with him/her a lot* (mean = 3.44; SD = 1.54), indicating children with ASD could initiate play activities more frequently towards their NT siblings than their parents.

Parents' and NT Siblings' Self-Efficacy in Supporting Physical Activity in Children with ASD. Parents in our sample indicated that they agreed with most statements related to self-efficacy in supporting PA in children with ASD. Some aspects that they perceived relatively lower confidence in their capabilities include *I can bounce back after I tried my best and failed* (mean = 3.94; SD = 0.73), *I'm patient to deal with my child's challenging behaviors* (mean = 3.89; SD = 0.96), and *I'm involved a lot in my child's leisure activities* (mean = 3.83; SD = 1.10). On the contrary, NT siblings' belief in their capacity to support PA in their brother/sister with ASD was neutral. When comparing the results from the parents and NT siblings, parents (mean = 46.50; SD = 6.73) showed much higher self-efficacy than the NT siblings (mean = 36.94; SD = 9.29) in supporting PA in their children with ASD in all aspects.

Associations Among Physical Activity-Related Family Dynamics

There were some positive associations among the PA-related family dynamics that we measured in this study: (a) parent-ASD interaction & parent's self-efficacy in supporting their child with ASD (r = 0.537, p = 0.021), (b) parent-ASD interaction and NT-ASD interaction (r = 0.595, p = 0.009), and (c) parent's self-efficacy and NT sibling's self-efficacy in supporting the child with ASD (r = 0.739, p = 0.000).

Discussion

Summary of Findings

This study aimed at investigating levels of PA, parent perceived motor competence, and PA-related family dynamics in children with ASD with a NT sibling during the COVID-19 pandemic. Even though children with ASD spent much more time with their NT siblings and parents at home during the pandemic, both direct and indirect data collected (measured by accelerometry and questionnaire) within this study suggested that they engaged in more sedentary activities than MVPA and LPA. This finding is consistent with the results from a qualitative study conducted by Yarımkaya and Esentürk (2020) which indicated that parents reported their children with ASD exhibited increased sedentary behaviors during the COVID-19 outbreak. Our questionnaire-based data also revealed that, besides more minutes spent in SB than other levels of PA, children with ASD in our sample also participated in SB more frequently and engaged in more types of sedentary activities than MVPA and LPA. In addition, our study gathered information via the C-PAQ from all the recruited families. However, valid data via accelerometry were only collected from 11 out of the 18 children with ASD within our sample due to sensory issues related to device wearing. This issue of the adherence to accelerometer wearing echoed what was revealed by Hauck et al. (2016) and explained why researchers use self-reported and recall instruments in addition to objective measures of PA (Reilly, 2011).

For parental perceived motor competence in children with ASD, parents in our study perceived their children's competence on most skills in PMSC-parent as not too good or sort of good, with only a few skills as pretty good. This finding aligns with the results of a study by Phytanza and colleagues (2021) where they evaluated motor competence directly using the TGMD-2 in a sample of 25 children with ASD, aged 8 to 12 years. Their findings also showed that most of the participants in their sample had low levels of motor competence in both locomotor skills and object control skills. In addition, when we looked into the results of each activity/skill in PMSC-parent, motor competence of children with ASD in scootering, running, and galloping were perceived relatively higher than in other skills. Skills/activities that were perceived relatively lower included board paddle, skating/blading, rope climbing, hitting a ball, and hitting a ball with one hand, skills that require more practice and hand-eye coordination.

With the likelihood that more time was spent with family members during the COVID-19 pandemic, we also investigated PA-related family dynamics, including parent-child interaction, ASD-NT interaction, as well as parents' and NT siblings' self-efficacy in supporting PA in children with ASD. In general, parents perceived higher levels of interaction with their children with ASD than NT siblings did, except for one aspect - play initiation from children with ASD. Our results indicate that children with ASD initiate play activities more frequently towards their NT siblings than their parents. This finding is consistent with a classic study by El-Ghoroury & Romanczyk (1999). In the study, the authors observed play interactions within nine families that have a child with ASD. They noticed that children with ASD initiated more interactions towards their siblings than parents, even though parents exhibited more play behaviors towards them. In addition, although not compared with parents, other studies show that children may be more motivated to be physically active with siblings. For example, a systematic review by Kracht and Sission (2018) described the influence of siblings on children's PA and SB and found that children with siblings participated in more PA and less SB than those who are the only child in the family. Moreover, parents reported much higher self-efficacy than the NT siblings in their capability of supporting PA in children with ASD. We also found some interesting findings that parents' self-efficacy in supporting PA in their children with ASD was positively associated with many PA-related factors of the family dynamic, such as parent-ASD interaction and NT siblings' self-efficacy in supporting PA in their brother/sister with ASD. Also, a higher level of parent-child interaction was correlated to a higher level of NT-ASD interaction. This correlation could possibly be explained by the findings from the study by O'Brien et al. (2020), which suggested that older siblings can adopt a parental style in their play interactions with their younger siblings with ASD.

Strengths and Limitations

This study has some unique strengths. First, although there was emerging literature understanding the levels of physical activity and motor competence in children with ASD, this study specifically provided information on their motor behaviors during the COVID-19 pandemic. Second, given families played a critical role in encouraging children with ASD to maintain physical activity during stay-at-home and it was suggested that free and unstructured PA could be met by playing with siblings (Dunton et al., 2020), our sample specifically recruited children with ASD who have a NT sibling. Lastly, we included parents and NT siblings in our study, who are vulnerable but understudied groups. We evaluated interactions between (a) parents and children with ASD and (b) NT siblings and children with ASD, as well as their efficacy in supporting PA in children with ASD. This provided helpful information to (a) understand family dynamics that could potentially influence children's PA at home and (b) inform future studies to better support parents and NT siblings in overcoming barriers in interacting with children with ASD and boost their self-efficacy.

Some limitations were also noticed in this study. First, this study included a small sample size. Given the variability in the characteristics among individuals with ASD, studies with larger sample sizes are needed. Second, for the safety consideration due to the pandemic, this study collected indirect PA and motor competence data using a parent-reported questionnaire and scale. Compared to direct data collection, collecting self-reported data could be biased to some degree. Third, interactions and participants' self-efficacy were evaluated using newly developed surveys designed by the investigators, given the construct of interest was not readily available in the existing measures. The validity of these newly developed surveys serves as a limitation of this study. Lastly, there was some missing data in accelerometer-based PA, given many children with ASD experienced sensory issues and felt uncomfortable wearing the devices.

Implications for Future Studies

Our results found that children with ASD spend much more time in sedentary activities (e.g., watching TV, using computer, talking on the phone), participate in SB more frequently, and engage in more types of sedentary activities than MVPA and LPA (according to a parental proxy). This highlights the need for the development of high-quality play-based services and physical education online programs. Although pandemic restrictions have lifted and most students are back to school, online services and programs are still necessary given that (a) some parents of children with ASD may be reluctant to enroll their child in in-person PA opportunities given the continued risk associated with the pandemic and (b) some children with ASD have limited resources to access quality physical activities and play-based services.

Our findings also show that parental self-efficacy was associated with many factors such as parent-child interaction, NT-ASD interaction, and NT siblings' self-efficacy. As such, there is a need for future studies to evaluate programs to boost parents' self-efficacy. For example, given parents in our sample reported relatively lower confidence in their resilience when they failed (i.e., *I can bounce back after I tried my best and failed*) and their capability in dealing with the challenging behaviors in their children with ASD, programs that aimed to support parents by teaching them some behavioral strategies in coping with obstacles and ASD-specific characteristics may be beneficial for parents who have a child with ASD. Moreover, support groups could be organized for parents to share their experiences, ask for advice, and get affirmation from others.

Lastly, only 11 out of 18 children with ASD in this study agreed to wear an accelerometer and met the minimum wear time due to sensory issues. There is a need to identify, develop, and evaluate strategies to increase accelerometer wear time in young children with ASD. A study by Hauck et al. (2016) suggested several support strategies that can increase accelerometer adherence rates for youth with ASD (aged 9 to 18 years), including social stories, incentives, concealing techniques, and 24 hours/day wearing instructions. These options should be explored for younger children with ASD. Age-appropriate materials such as well-created cartoon videos introducing accelerometers, pictures, and scripts that parents can use may also be helpful and should be developed.

Conclusion

This study was the first study aimed at investigating levels of PA, parental perceived motor competence, and PA-related family dynamics in children with ASD with a neurotypical sibling during the COVID-19 pandemic. The findings of this study informed the importance of (a) providing quality home-based physical activity/education programs and/or play-based services with a variety of sports equipment for children with ASD to actively participate in MVPA and develop motor skills, (b) boosting parents' and NT siblings' self-efficacy in supporting PA in children with ASD, especially coping skills for challenging behaviors of ASD and behavioral strategies in positively interacting with children with ASD, and (c) creating effective methodology or strategies to accurately collect objective PA data.

APPENDICES

APPENDIX A: Tables

Table 4

Demographic Characteristics of Study Participants

	N	Percent	Mean	Std. Deviation
Age_ASD	18		9.22	1.66
Sex_ASD				
Male	12	66.7		
Female	6	33.3		
Anthropometric_ASD				
Height (cm)			139.34	14.70
Weight (kg)			38.28	15.84
BMI percentile			72.21	28.73
Age_NT	18		11.06	5.46
Sex_NT				
Male	4	22.2		
Female	14	77.8		
Anthropometric_NT				
Height (cm)			145.19	25.84
Weight (kg)			43.66	20.75
BMI percentile*			72.29	25.81
Age_Caregiver	18		39.06	4.90
Anthropometric_Caregiver				
Height (cm)			167.92	6.74
Weight (kg)			77.60	20.66
BMI			27.36	6.32
Race				
African American	1	5.6		
Asian	2	11.1		
White	15	83.3		
Caregiver relationship to the child				
Mother	17	94.4		
Father	1	5.6		
Caregiver's highest level of education completed				
High school	2	11.1		
Some college	4	22.2		
Bachelors	7	38.9		
Masters	5	27.8		
Annual household income				
Less than $24,999	1	5.6		
$25,000 to $ 49,999	4	22.2		
$50,000 to $ 99,999	5	27.8		
More than $ 100,000	8	44.4		
Child with ASD has intellectual disability (IQ<70)?				
Yes	4	22.2		
No	14	77.8		

Note. ASD = autism spectrum disorder; NT = neurotypical sibling; BMI = body mass index, IQ = intelligence quotient; IEP = individualized education plan.

* The 23-year-old NT sibling was not included in the mean and standard deviation of BMI percentile data

Table 4 (cont'd)

Child with ASD has IEP		
Yes	11	61.1
No	7	38.9
Birth Order_ASD		
1	9	50.0
2	4	22.2
3	3	16.7
4	2	11.1

Table 5

Measurements of Parent Version of the Perceived Movement Skill Competence (PMSC-parent)

Movement Skill	Mean	Std. Deviation
PMSC_Active play	**13.71**	**4.09**
Bike riding	2.65	1.27
Scootering	3.06	0.97
Board paddle	1.94	0.97
Skating/blading	1.65	1.00
Swimming	2.82	1.07
Rope climbing	1.59	0.94
PMSC_Locomotor	**17.27**	**4.66**
Running	3.18	0.95
Galloping	3.00	1.00
Skipping	2.65	1.12
Leaping	2.76	1.03
Jumping forwards	2.88	0.93
Step and slide	2.82	0.81
PMSC_Object control	**16.24**	**4.40**
Hitting a ball	1.82	0.95
Hitting a ball with one hand	1.82	1.02
Bouncing a ball	2.24	0.90
Catching a ball	2.53	0.94
Kicking a ball	2.65	0.70
Throwing underhand	2.59	1.00
Throwing overhand	2.59	0.87
PMSC_Fundamental motor skills *(locomotor + object control)*	**33.52**	**6.61**
PMSC_Total	**47.24**	**9.14**

Table 6

Frequency, Type, and Duration Spent in Different Levels of Physical Activity in Children with ASD

	Mean	**Std. Deviation**
C-PAQ (*a parental proxy*)		
Sports Activities (proxy for MVPA)		
Weekdays_MVPA_frequency (in number of times)	6.79	7.91
Weekend_MVPA_frequency (in number of times)	2.35	3.12
Weekdays_MVPA_type (in numbers)	2.12	2.00
Weekend_MVPA_type (in numbers)	1.24	1.44
Weekdays_MVPA_duration (in minutes)	137.41	120.91
Weekend_MVPA_duration (in minutes)	45.60	51.99
MVPA_total duration (in minutes)	183.00	153.94
Leisure Time Activities (proxy for LPA)		
Weekdays_LPA_frequency (in number of times)	14.00	9.63
Weekend_LPA_frequency (in number of times)	5.41	6.35
Weekdays_LPA_type (in numbers)	4.47	2.07
Weekend_LPA_type (in numbers)	2.94	2.46
Weekdays_LPA_duration (in minutes)	203.53	163.71
Weekend_LPA_duration (in minutes)	119.24	158.21
LPA_total duration (in minutes)	316.88	301.48
Sedentary Activities (proxy for SB)		
Weekdays_SB_type (in numbers)	7.76	2.02
Weekend_SB_type (in numbers)	4.29	3.06
Weekdays_SB_duration (in minutes)	1752.38	1019.27
Weekend_SB_duration (in minutes)	682.19	742.58
SB_total duration (in minutes)	2379.06	1480.10
Accelerometry		
% Of time spent in MVPA	8.00	5.21
% Of time spent in LPA	13.65	2.80
% Of time spent in SB	78.35	7.15

Note. MVPA = moderate-to-vigorous intensity of physical activity, LPA = light intensity of physical activity, SB = sedentary behavior.

Table 7

Results of Parent-Child and NT-ASD Interaction Surveys

Statements for parents	Mean	Std. Deviation	Statements for NT	Mean	Std. Deviation
1. My child and I play together a lot.	3.56	1.20	1. My sibling and I play together a lot.	2.83	1.10
2. My child and I talk to each other a lot.	4.00	1.09	2. My sibling and I talk to each other a lot.	3.28	1.27
3. My child and I do physical activities together a lot (e.g., running, dancing, ball games).	3.56	0.86	3. My sibling and I do physical activities together a lot (e.g., running, dancing, ball games).	3.00	1.41
4. I enjoy helping my child to learn new things.	4.61	0.70	4. I enjoy helping my sibling to learn new things.	3.39	1.38
5. I make up games or songs for my child.	3.72	1.18	5. I make up games or songs for my sibling.	3.11	1.23
6. When my child looks at or toughs a toy or object, I talk to him/her about the toy or object.	3.89	1.13	6. When my sibling looks at or toughs a toy or object, I talk to him/her about the toy or object.	2.61	1.24
7. My child and I enjoy playing together.	4.33	0.91	7. My sibling and I enjoy playing together.	3.44	0.92
8. My child and I enjoy doing physical activities together.	4.11	0.83	8. My sibling and I enjoy doing physical activities together.	3.61	1.15
9. My child asks me to play with him/her a lot.	3.28	1.32	9. My sibling asks me to play with him/her a lot.	3.44	1.54
10. I initiate play opportunities together with my child a lot.	3.67	1.03	10. I invite my sibling to play with me a lot.	2.89	1.32
11. My child asks me to do physical activities with him/her a lot.	2.94	1.21	11. My sibling asks me to do physical activities with him/her a lot.	2.89	1.49
12. I initiate physical activity opportunities together with my child a lot.	3.72	1.07	12. I invite my sibling to do physical activities with me a lot.	3.11	1.28
Total score	**45.39**	**8.27**	**Total score**	**37.61**	**10.80**

Note. Participants used a 5-point rating scale to indicate how much they agree with the statements (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).

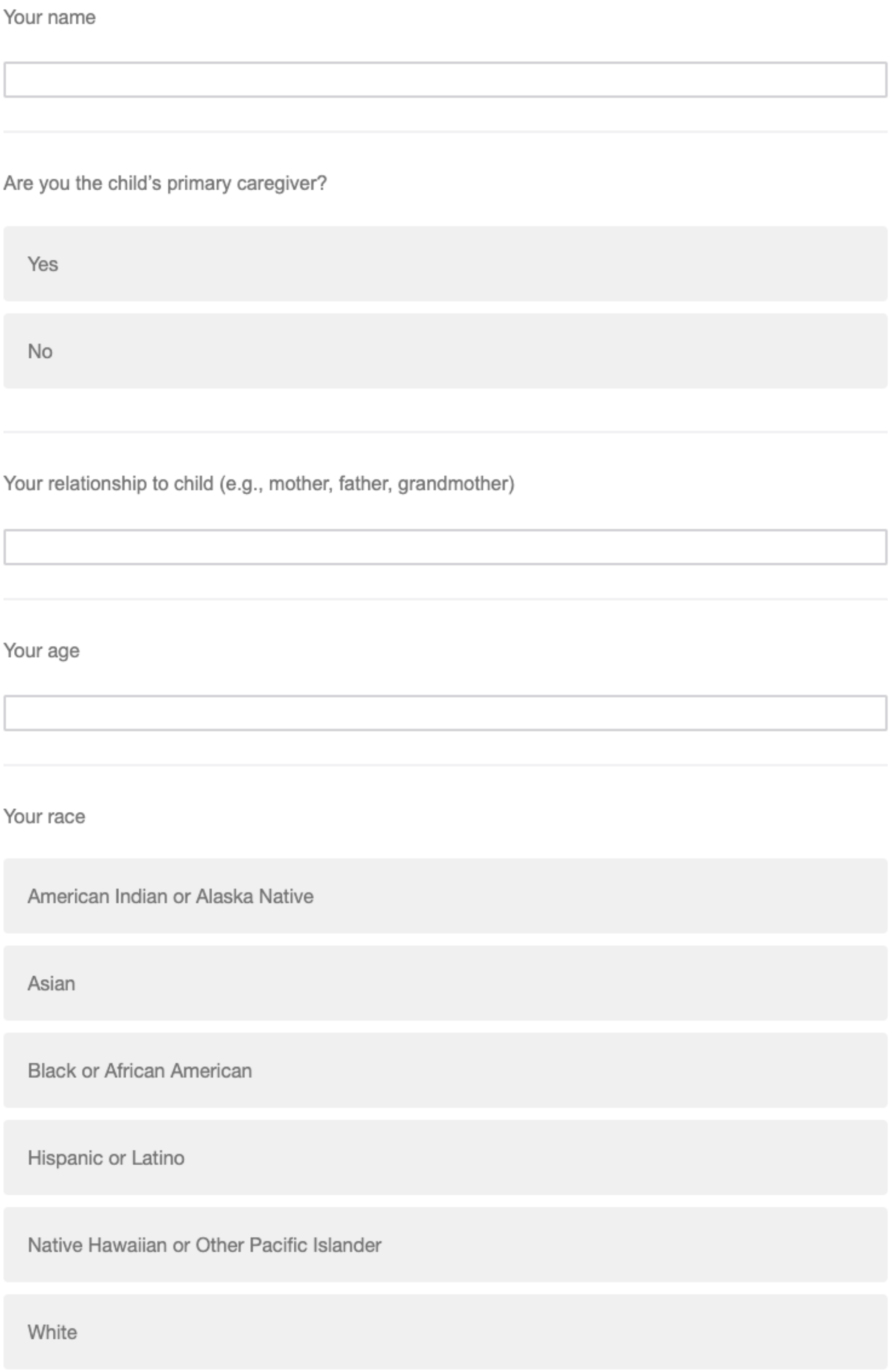
Table 8

Survey Results of Parents' and NT Siblings' Self-Efficacy in Supporting Physical Activity in Children with ASD

Statements for parents	**Mean**	**Std. Deviation**	**Statements for NT**	**Mean**	**Std. Deviation**
1. I share a good relationship with my child.	4.72	0.46	1. I share a good relationship with my sibling.	3.94	1.16
2. I can make an important difference to my child.	4.78	0.65	2. I can make an important difference to my sibling.	3.94	1.26
3. I know how to communicate with my child.	4.33	0.97	3. I know how to communicate with my sibling.	3.83	1.38
4. I'm able to do things that will improve my child's behavior.	4.06	1.06	4. I'm able to do things that will improve my sibling's behavior.	3.00	1.33
5. I'm able to teach my child new skills.	4.33	0.84	5. I'm able to teach my sibling new skills.	3.39	1.24
6. I'm confident in my ability to learn and exercise new parenting skills/strategies.	4.28	0.90	6. I'm confident in my ability to learn and exercise new skills/strategies to help my sibling.	3.28	1.18
7. I can bounce back after I tried my best and failed.	3.94	0.73	7. I can get myself to keep trying when things are going really badly.	3.22	1.44
8. I'm patient to deal with my child's challenging behaviors.	3.89	0.96	8. I'm patient to deal with my sibling's challenging behaviors.	3.17	1.20
9. I can help my child keep physically fit.	4.22	0.81	9. I can help my sibling keep physically fit.	3.11	1.23
10. I can get my child to actively participate in physical activities besides school-based activities.	4.11	0.90	10. I can get my sibling to actively participate in physical activities.	3.00	1.24
11. I involved a lot in my child's leisure activities.	3.83	1.10	11. I do a lot of physical activities together with my sibling.	3.06	1.35
Total score	**46.50**	**6.73**	**Total score**	**36.94**	**9.29**

Note. Participants used a 5-point rating scale to indicate how much they agree with the statements (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).

APPENDIX B: Demographic Survey



Your name

Are you the child's primary caregiver?

Yes

No

Your relationship to child (e.g., mother, father, grandmother)

Your age

Your race

American Indian or Alaska Native

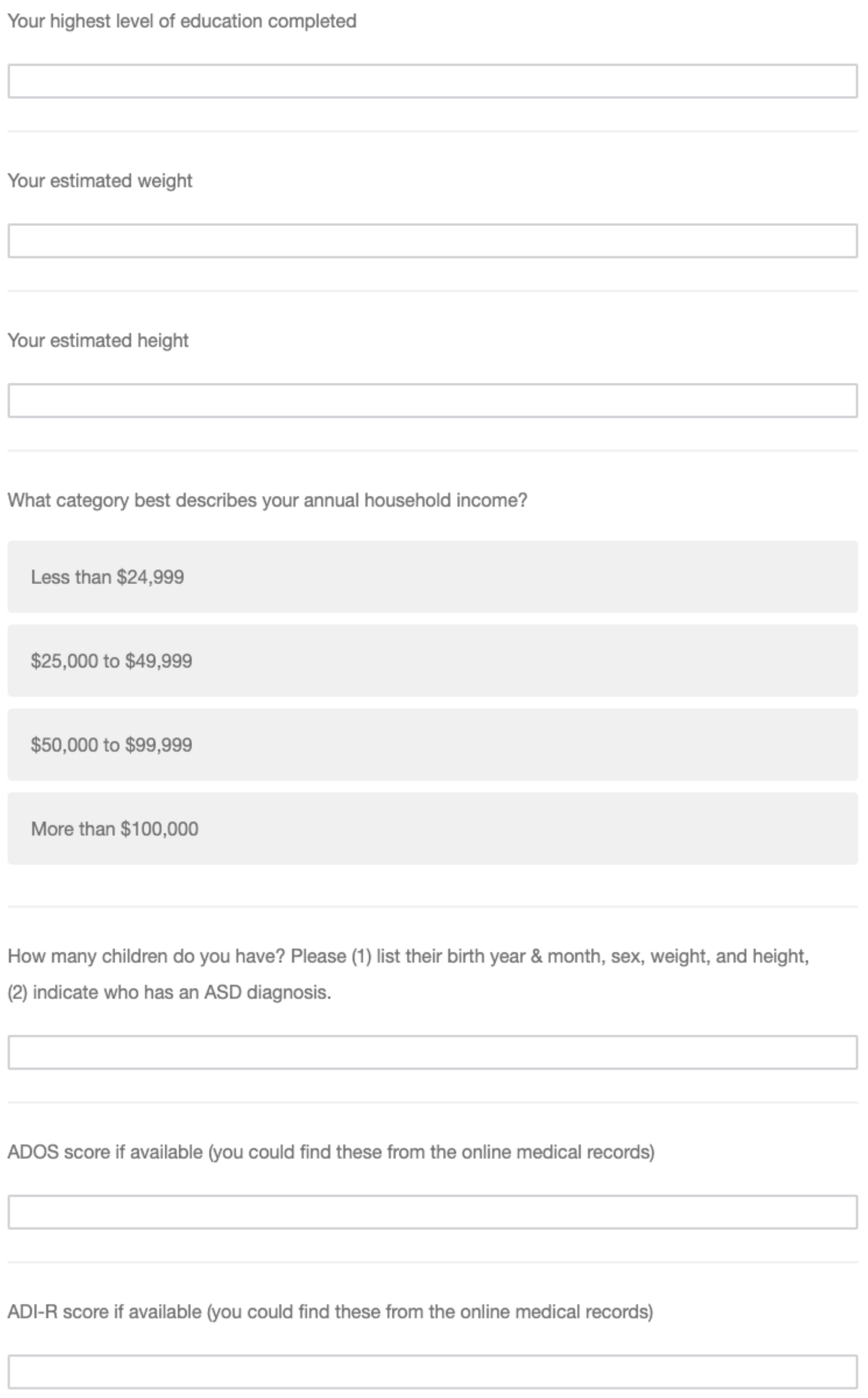
Asian

Black or African American

Hispanic or Latino

Native Hawaiian or Other Pacific Islander

White



Your highest level of education completed

Your estimated weight

Your estimated height

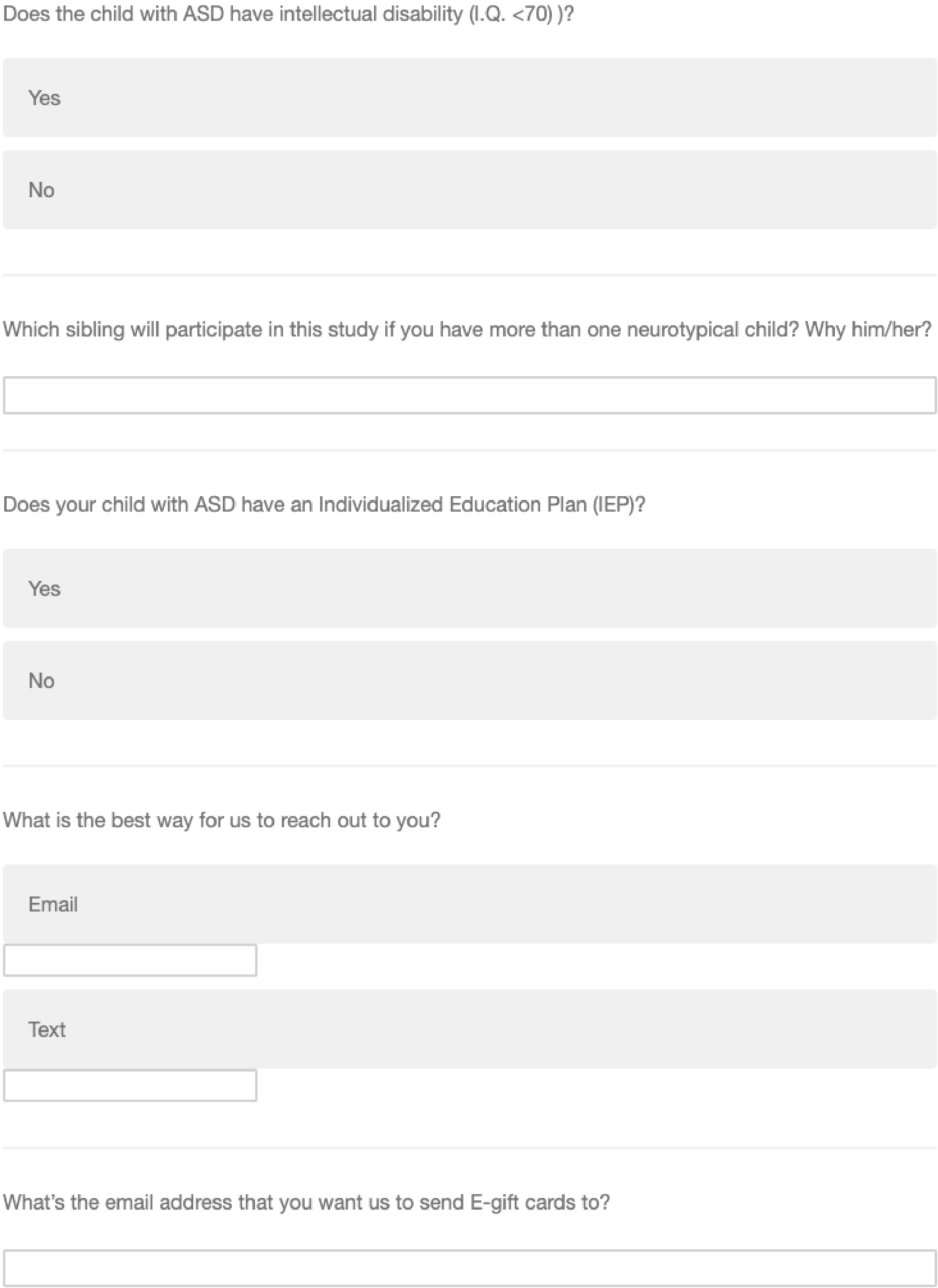
What category best describes your annual household income?

- Less than $24,999
- $25,000 to $49,999
- $50,000 to $99,999
- More than $100,000

How many children do you have? Please (1) list their birth year & month, sex, weight, and height, (2) indicate who has an ASD diagnosis.

ADOS score if available (you could find these from the online medical records)

ADI-R score if available (you could find these from the online medical records)



Does the child with ASD have intellectual disability (I.Q. <70))?

Yes

No

Which sibling will participate in this study if you have more than one neurotypical child? Why him/her?

Does your child with ASD have an Individualized Education Plan (IEP)?

Yes

No

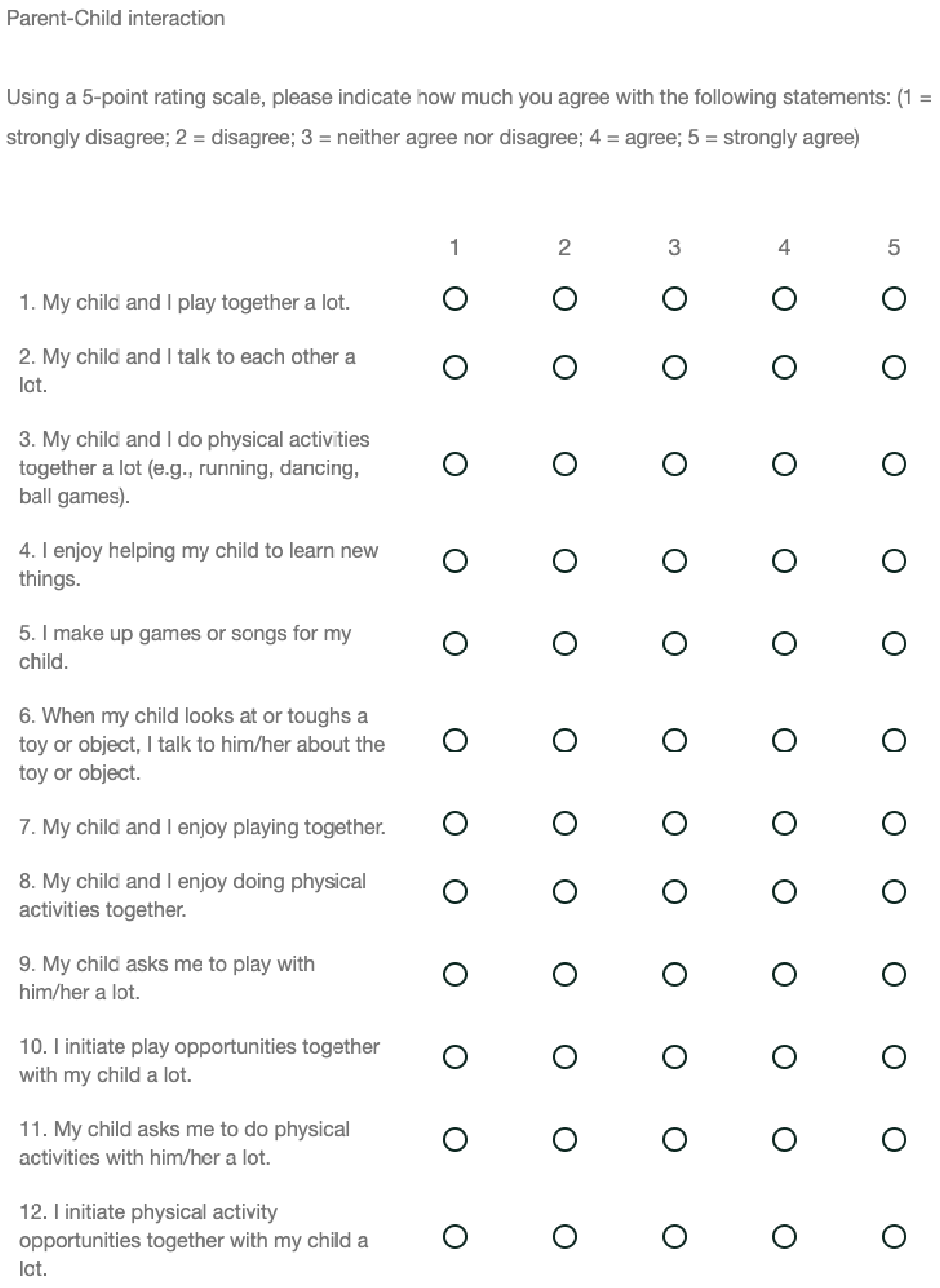
What is the best way for us to reach out to you?

Email

Text

What’s the email address that you want us to send E-gift cards to?

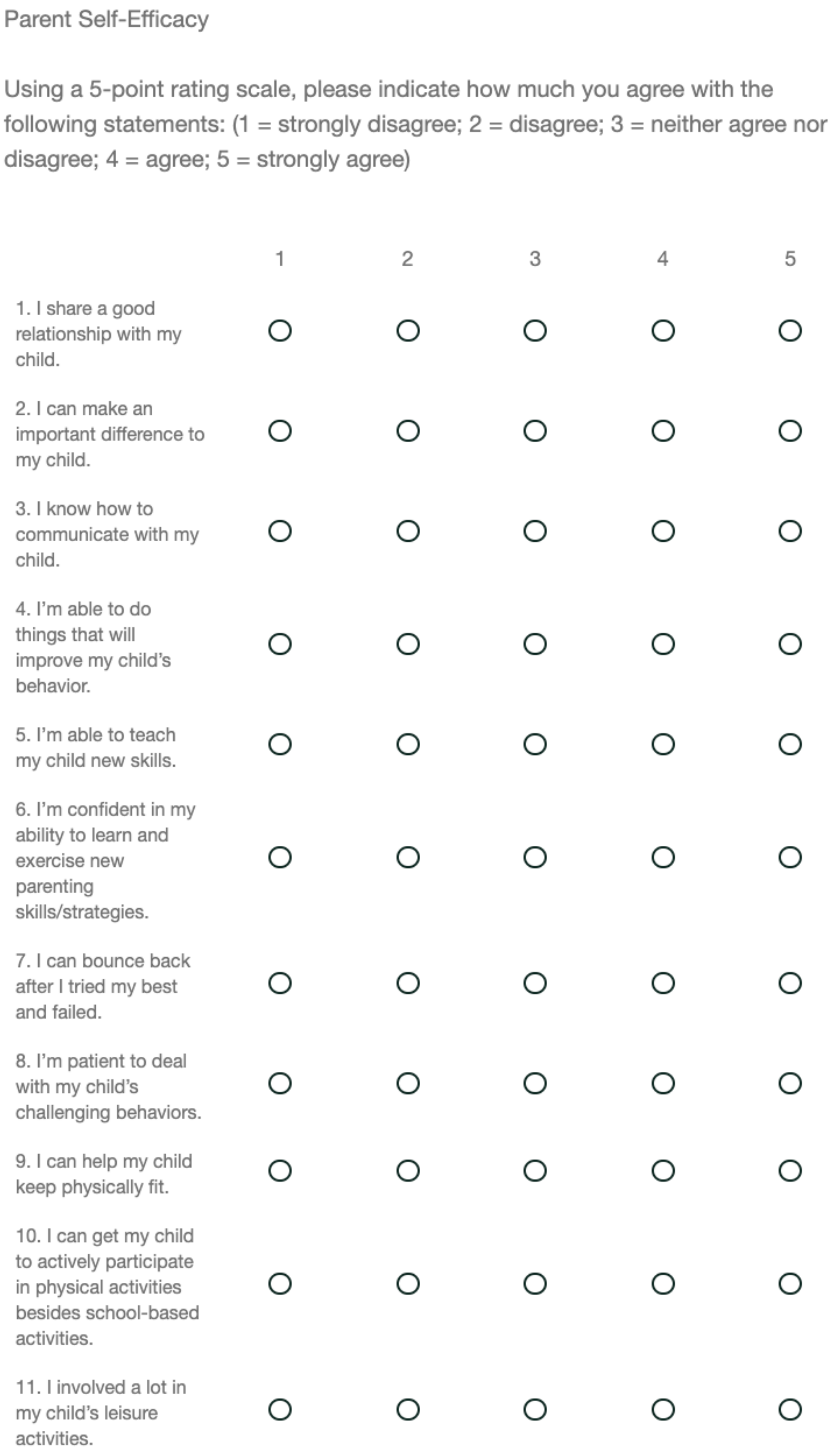
APPENDIX C: PA-Related Family Dynamics Survey (Parent Version)



Parent-Child interaction

Using a 5-point rating scale, please indicate how much you agree with the following statements: (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree)

	1	2	3	4	5
1. My child and I play together a lot.	○	○	○	○	○
2. My child and I talk to each other a lot.	○	○	○	○	○
3. My child and I do physical activities together a lot (e.g., running, dancing, ball games).	○	○	○	○	○
4. I enjoy helping my child to learn new things.	○	○	○	○	○
5. I make up games or songs for my child.	○	○	○	○	○
6. When my child looks at or toughs a toy or object, I talk to him/her about the toy or object.	○	○	○	○	○
7. My child and I enjoy playing together.	○	○	○	○	○
8. My child and I enjoy doing physical activities together.	○	○	○	○	○
9. My child asks me to play with him/her a lot.	○	○	○	○	○
10. I initiate play opportunities together with my child a lot.	○	○	○	○	○
11. My child asks me to do physical activities with him/her a lot.	○	○	○	○	○
12. I initiate physical activity opportunities together with my child a lot.	○	○	○	○	○

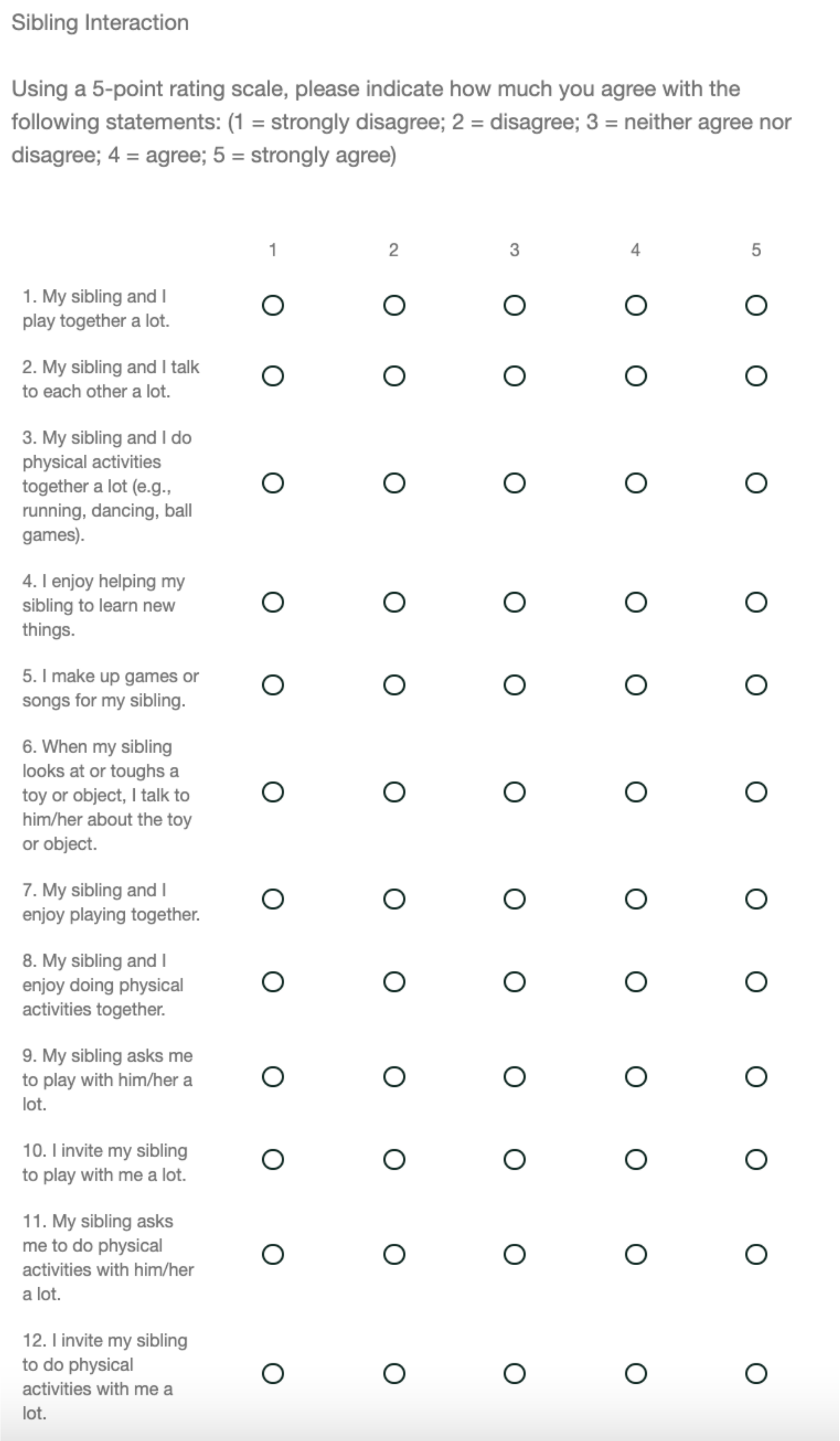


Parent Self-Efficacy

Using a 5-point rating scale, please indicate how much you agree with the following statements: (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree)

	1	2	3	4	5
1. I share a good relationship with my child.	○	○	○	○	○
2. I can make an important difference to my child.	○	○	○	○	○
3. I know how to communicate with my child.	○	○	○	○	○
4. I'm able to do things that will improve my child's behavior.	○	○	○	○	○
5. I'm able to teach my child new skills.	○	○	○	○	○
6. I'm confident in my ability to learn and exercise new parenting skills/strategies.	○	○	○	○	○
7. I can bounce back after I tried my best and failed.	○	○	○	○	○
8. I'm patient to deal with my child's challenging behaviors.	○	○	○	○	○
9. I can help my child keep physically fit.	○	○	○	○	○
10. I can get my child to actively participate in physical activities besides school-based activities.	○	○	○	○	○
11. I involved a lot in my child's leisure activities.	○	○	○	○	○

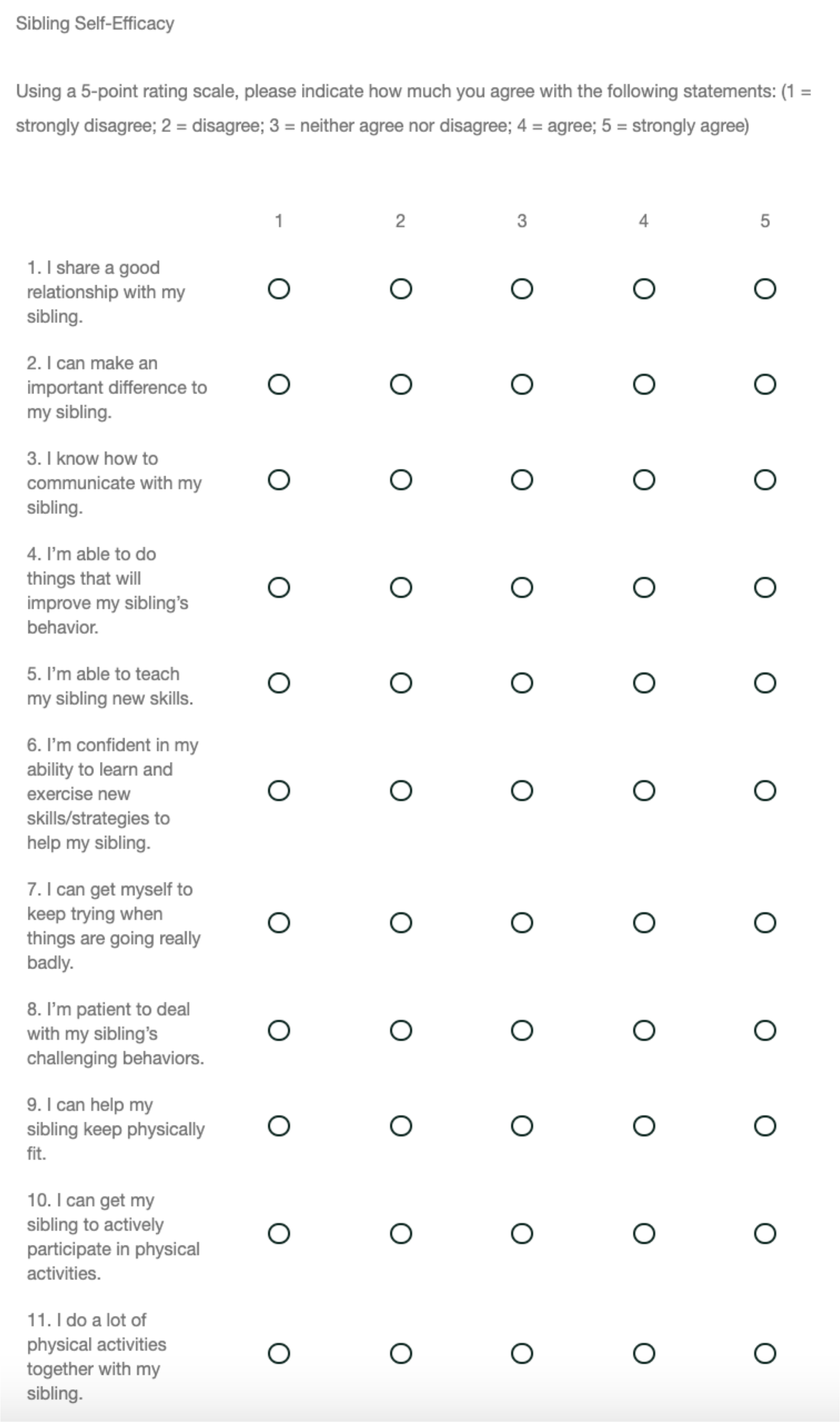
APPENDIX D: PA-Related Family Dynamics Survey (Sibling Version)



Sibling Interaction

Using a 5-point rating scale, please indicate how much you agree with the following statements: (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree)

	1	2	3	4	5
1. My sibling and I play together a lot.	○	○	○	○	○
2. My sibling and I talk to each other a lot.	○	○	○	○	○
3. My sibling and I do physical activities together a lot (e.g., running, dancing, ball games).	○	○	○	○	○
4. I enjoy helping my sibling to learn new things.	○	○	○	○	○
5. I make up games or songs for my sibling.	○	○	○	○	○
6. When my sibling looks at or toughs a toy or object, I talk to him/her about the toy or object.	○	○	○	○	○
7. My sibling and I enjoy playing together.	○	○	○	○	○
8. My sibling and I enjoy doing physical activities together.	○	○	○	○	○
9. My sibling asks me to play with him/her a lot.	○	○	○	○	○
10. I invite my sibling to play with me a lot.	○	○	○	○	○
11. My sibling asks me to do physical activities with him/her a lot.	○	○	○	○	○
12. I invite my sibling to do physical activities with me a lot.	○	○	○	○	○

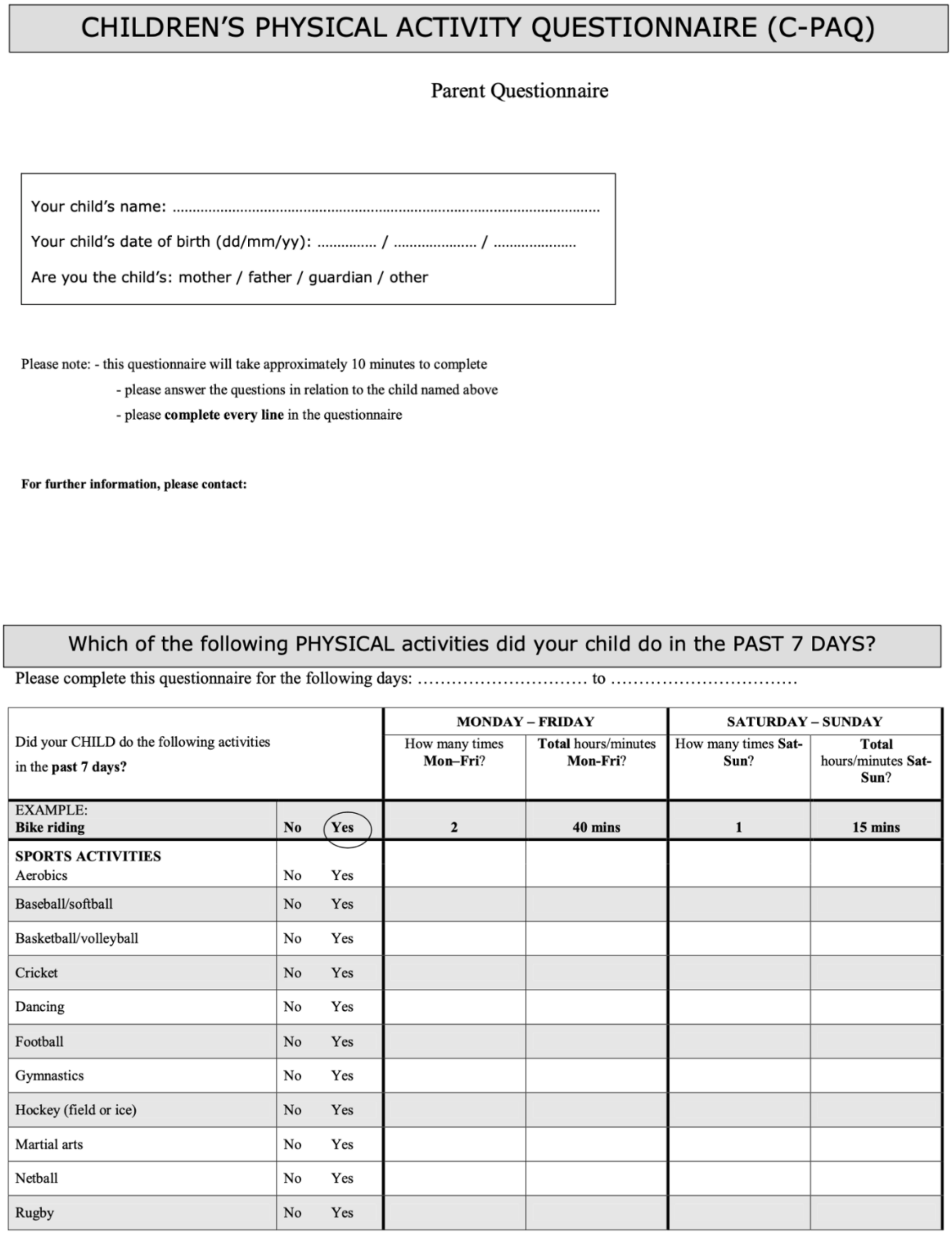


Sibling Self-Efficacy

Using a 5-point rating scale, please indicate how much you agree with the following statements: (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree)

	1	2	3	4	5
1. I share a good relationship with my sibling.	○	○	○	○	○
2. I can make an important difference to my sibling.	○	○	○	○	○
3. I know how to communicate with my sibling.	○	○	○	○	○
4. I'm able to do things that will improve my sibling's behavior.	○	○	○	○	○
5. I'm able to teach my sibling new skills.	○	○	○	○	○
6. I'm confident in my ability to learn and exercise new skills/strategies to help my sibling.	○	○	○	○	○
7. I can get myself to keep trying when things are going really badly.	○	○	○	○	○
8. I'm patient to deal with my sibling's challenging behaviors.	○	○	○	○	○
9. I can help my sibling keep physically fit.	○	○	○	○	○
10. I can get my sibling to actively participate in physical activities.	○	○	○	○	○
11. I do a lot of physical activities together with my sibling.	○	○	○	○	○

APPENDIX E: Children's Physical Activity Questionnaire (C-PAQ)



CHILDREN'S PHYSICAL ACTIVITY QUESTIONNAIRE (C-PAQ)

Parent Questionnaire

Your child's name: ....

Your child's date of birth (dd/mm/yy): .... / .... / ....

Are you the child's: mother / father / guardian / other

Please note: - this questionnaire will take approximately 10 minutes to complete

- please answer the questions in relation to the child named above
- please **complete every line** in the questionnaire

For further information, please contact:

Which of the following PHYSICAL activities did your child do in the PAST 7 DAYS?

Please complete this questionnaire for the following days: ………………………… to ……………………………

Did your CHILD do the following activities in the **past 7 days?**			**MONDAY – FRIDAY**		**SATURDAY – SUNDAY**	
			How many times **Mon–Fri**?	**Total** hours/minutes **Mon-Fri**?	How many times **Sat-Sun**?	**Total** hours/minutes **Sat-Sun**?
EXAMPLE: **Bike riding**	**No**	[✓ **Yes**]	**2**	**40 mins**	**1**	**15 mins**
SPORTS ACTIVITIES Aerobics	No	Yes				
Baseball/softball	No	Yes				
Basketball/volleyball	No	Yes				
Cricket	No	Yes				
Dancing	No	Yes				
Football	No	Yes				
Gymnastics	No	Yes				
Hockey (field or ice)	No	Yes				
Martial arts	No	Yes				
Netball	No	Yes				
Rugby	No	Yes				

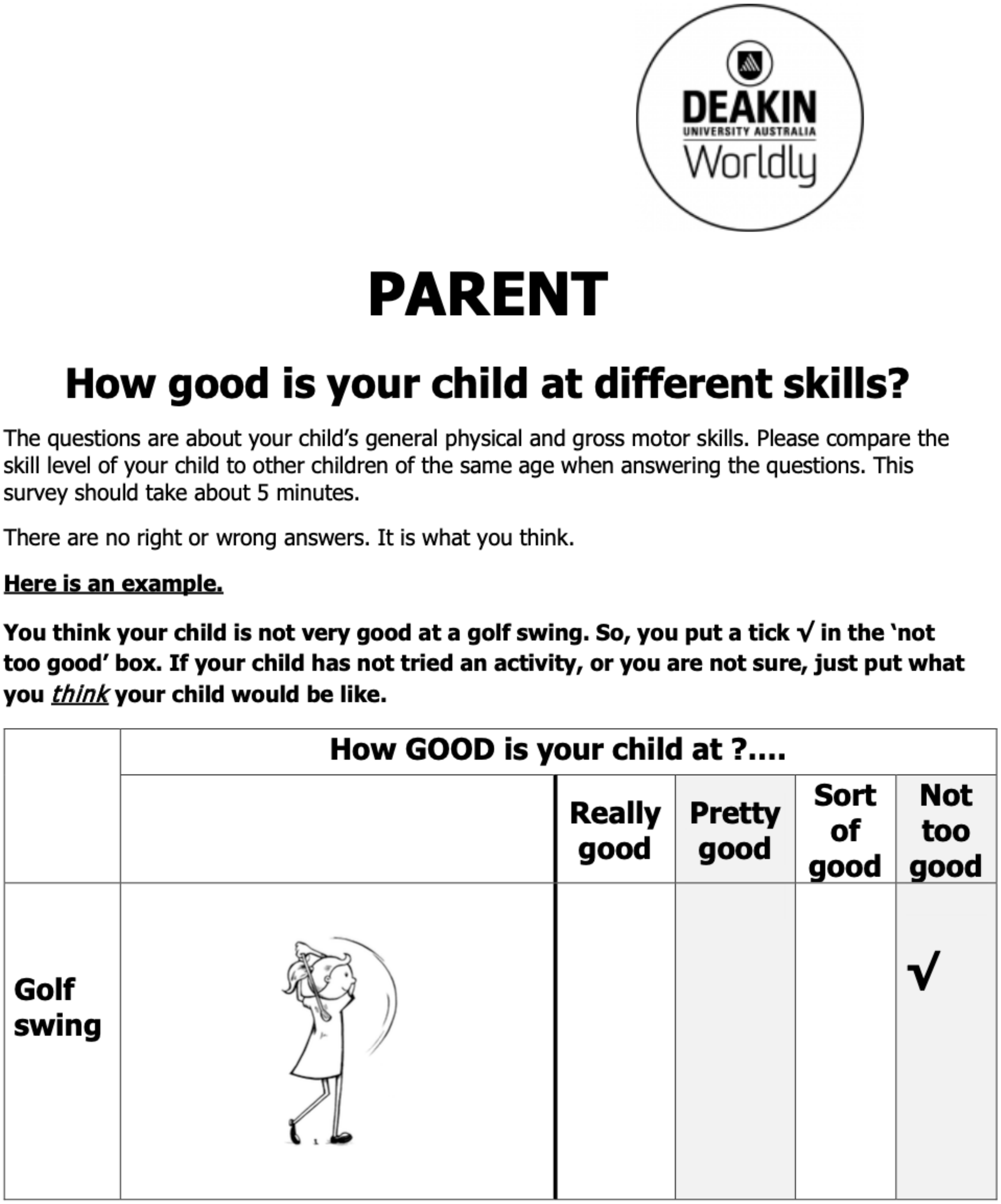
Did your CHILD do the following activities in the **past 7 days?**			MONDAY – FRIDAY		SATURDAY – SUNDAY	
			How many times **Mon–Fri**?	**Total** hours/minutes **Mon-Fri**?	How many times **Sat-Sun**?	**Total** hours/minutes **Sat-Sun**?
Running or jogging	No	Yes				
Swimming lessons	No	Yes				
Swimming for fun	No	Yes				
Tennis/badminton/squash/ other racquet sport	No	Yes				
LEISURE TIME ACTIVITIES Bike riding (not school travel)	No	Yes				
Bounce on the trampoline	No	Yes				
Bowling	No	Yes				
Household chores	No	Yes				
Play in a play house	No	Yes				
Play on playground equipment	No	Yes				
Play with pets	No	Yes				
Rollerblading/roller-skating	No	Yes				
Scooter	No	Yes				

Did your CHILD do the following activities in the **past 7 days?**			MONDAY – FRIDAY		SATURDAY – SUNDAY	
			How many times **Mon–Fri**?	**Total** hours/minutes **Mon-Fri**?	How many times **Sat-Sun**?	**Total** hours/minutes **Sat-Sun**?
Skateboarding	No	Yes				
Skiing, snowboarding, sledging	No	Yes				
Skipping rope	No	Yes				
Tag	No	Yes				
Walk the dog	No	Yes				
Walk for exercise/hiking	No	Yes				
ACTIVITIES AT SCHOOL Physical education class	No	Yes				
Travel by walking to school (to and from school = 2 times)	No	Yes				
Travel by cycling to school (to and from school = 2 times)	No	Yes				
OTHER please state:	No	Yes				

Did your CHILD do the following activities in the **past 7 days?**		**MONDAY-FRIDAY** **Total** hours/minutes	**SATURDAY-SUNDAY** **Total** hours/minutes
EXAMPLE: **Watching TV/videos**	**No** [✓ **Yes**]	**15hrs**	**6hrs 30mins**
Art & craft (eg. pottery, sewing, drawing, painting)	No Yes		
Doing homework	No Yes		
Imaginary play	No Yes		
Listen to music	No Yes		
Play indoors with toys	No Yes		
Playing board games / cards	No Yes		
Playing computer games (e.g. playstation / gameboy)	No Yes		
Playing musical instrument	No Yes		
Reading	No Yes		
Sitting talking	No Yes		
Talk on the phone	No Yes		
Travel by car / bus to school (to and from school)	No Yes		

Did your CHILD do the following activities in the **past 7 days?**		**MONDAY-FRIDAY** **Total** hours/minutes	**SATURDAY-SUNDAY** **Total** hours/minutes
Using computer / internet	No Yes		
Watching TV/videos	No Yes		
Other (please state):	No Yes		

APPENDIX F: Parental Proxy of the Pictorial Scale of Perceived Movement Skill Competence (PMSC-parent)



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PARENT

How good is your child at different skills?

The questions are about your child's general physical and gross motor skills. Please compare the skill level of your child to other children of the same age when answering the questions. This survey should take about 5 minutes.

There are no right or wrong answers. It is what you think.

Here is an example.

You think your child is not very good at a golf swing. So, you put a tick √ in the 'not too good' box. If your child has not tried an activity, or you are not sure, just put what you *think* your child would be like.

	How GOOD is your child at ?....				
		Really good	**Pretty good**	**Sort of good**	**Not too good**
Golf swing					√

HOW WELL CAN YOUR CHILD DO THESE SKILLS?

		How GOOD is your child at ?....			
		Really good	**Pretty good**	**Sort of good**	**Not too good**
Bike riding					
Scootering					
Board paddle					
Skating/ Blading					
Swimming					
Rope climbing					

HOW WELL CAN YOUR CHILD DO THESE SKILLS?

	How GOOD is your child at ?....				
		Really good	Pretty good	Sort of good	Not too good
Running					
Galloping (like a horse)					
Skipping					
Leaping					
Jumping forwards (jumping far)					
Step & Slide (step to one side and slide the other foot over)					

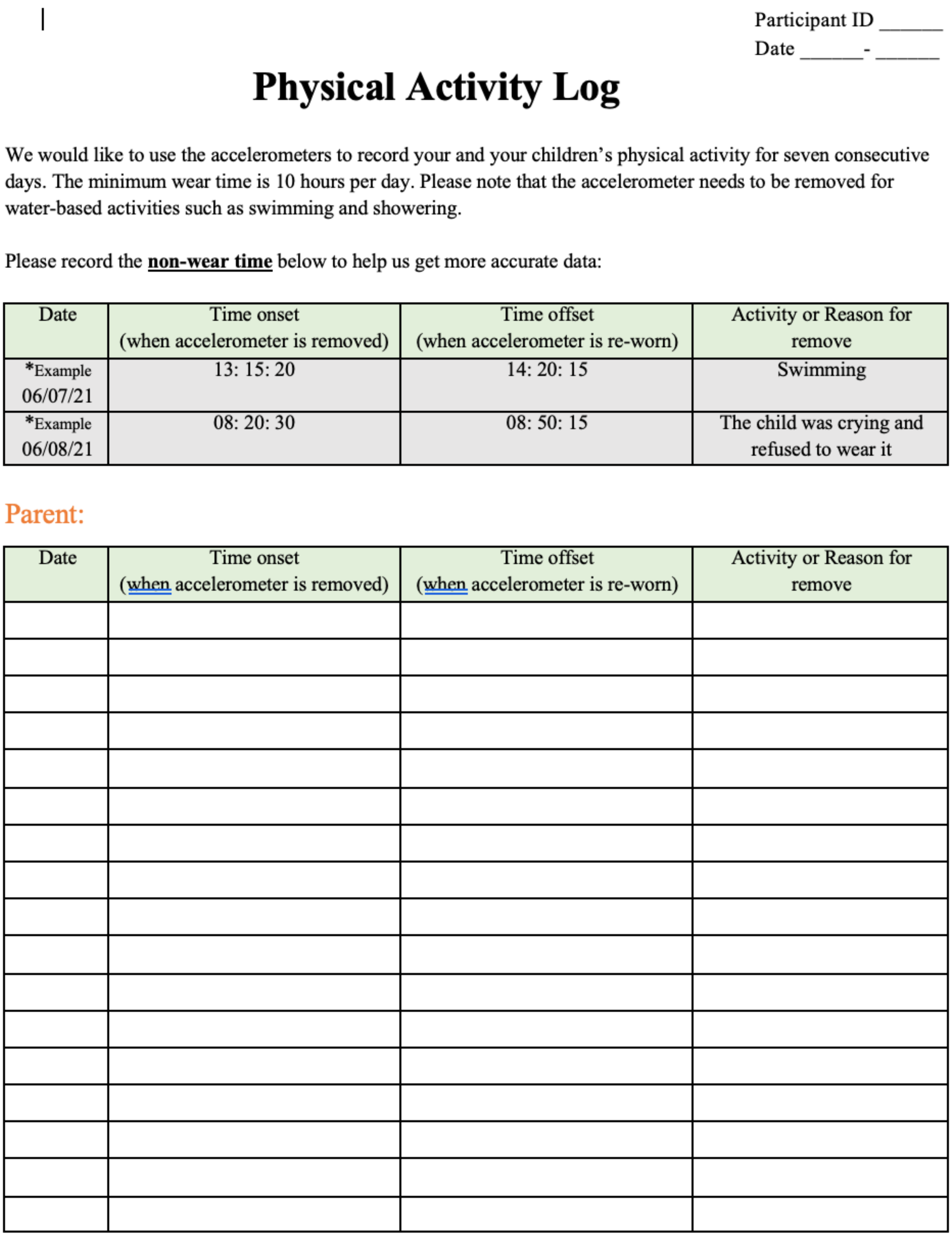
	How GOOD is your child at ?....				
		Really good	**Pretty good**	**Sort of good**	**Not too good**
Hitting a ball					
Hitting a ball with one hand					
Bouncing a ball					
Catching a ball					
Kicking a ball					
Throwing underhand					
Throwing overhand					

APPENDIX G: Physical ACtivity Enjoyment Scale (PACES)

When I'm physically active… (1 = "Disagree a lot" to 5 = "Agree a lot")

	1	2	3	4	5
1. I enjoy it	○	○	○	○	○
2. I feel bored	○	○	○	○	○
3. I dislike it	○	○	○	○	○
4. I found it pleasurable	○	○	○	○	○
5. It's no fun at all	○	○	○	○	○
6. It gives me energy	○	○	○	○	○
7. It makes me sad	○	○	○	○	○
8. It's very pleasant	○	○	○	○	○
9. My body feels good	○	○	○	○	○
10. I get something out of it	○	○	○	○	○
11. It's very exciting	○	○	○	○	○
12. It frustrates me	○	○	○	○	○
13. It's not at all interesting	○	○	○	○	○
14. It gives me a feeling of success	○	○	○	○	○

APPENDIX H: Physical Activity Log



Participant ID ______
Date ______- ______

Physical Activity Log

We would like to use the accelerometers to record your and your children's physical activity for seven consecutive days. The minimum wear time is 10 hours per day. Please note that the accelerometer needs to be removed for water-based activities such as swimming and showering.

Please record the **non-wear time** below to help us get more accurate data:

Date	Time onset (when accelerometer is removed)	Time offset (when accelerometer is re-worn)	Activity or Reason for remove
*Example 06/07/21	13: 15: 20	14: 20: 15	Swimming
*Example 06/08/21	08: 20: 30	08: 50: 15	The child was crying and refused to wear it

Parent:

Date	Time onset (when accelerometer is removed)	Time offset (when accelerometer is re-worn)	Activity or Reason for remove

Neurotypical child:

Date	Time onset (when accelerometer is removed)	Time offset (when accelerometer is re-worn)	Activity or Reason for remove

Child with ASD:

Date	Time onset (when accelerometer is removed)	Time offset (when accelerometer is re-worn)	Activity or Reason for remove

REFERENCES

REFERENCES

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CHAPTER 4

Exploration of An Online Family-Implemented Physical Activity Intervention for Children with Autism Spectrum Disorder: A Feasibility Study

Abstract

Low participation in daily moderate-to-vigorous physical activity (MVPA) and delays in motor skills are common in children with Autism Spectrum Disorder (ASD). Recent preliminary evidence indicates these issues may be worse during the COVID-19 pandemic, yet there is a dearth of online programs created to support physical activity (PA) and motor skills development in children with ASD. Thus, this study provided a family-implemented online PA intervention for children with ASD during the COVID-19 pandemic and investigated its preliminary effectiveness and the extent to which it was delivered as prescribed. Twenty-four families [the parent, the child with ASD, and the neurotypical (NT) sibling] were recruited and randomly assigned to three intervention conditions: (a) Group A; both the parent and the NT sibling served as intervention agents, (b) only the parent served as an intervention agent, and (c) no PA intervention was given (sedentary play activities were provided instead). Descriptive analysis and a repeated-measures ANOVA were used to investigate differences in PA, parental perceived motor competence, and social outcomes (i.e., interaction and self-efficacy) in the three groups over time. Results indicated, among families who completed more than 60% of the intervention, significant differences were found in scores of object control skills [$F\ (1,6) = 17.163$, $p = 0.006$, $\eta p^2 = 0.741$], fundamental motor skills [$F\ (1,6) = 7.385$, $p = 0.035$, $\eta p^2 = 0.552$], and PMSC-parent total scores [$F\ (1,6) = 6.914$, $p = 0.039$, $\eta p^2 = 0.535$] over time across the three groups [$F\ (2,6) = 6.838$, $p = 0.028$, $\eta p^2 = 0.695$], [$F\ (2,6) = 13.507$, $p = 0.006$, $\eta p^2 = 0.818$], and [$F\ (2,6) = 6.844$, $p=0.028$, $\eta p^2 = 0.695$], with Group A showing more significant improvements.

Moreover, participants in all three groups showed improvement in parent-ASD interaction across time [F (1,6) = 6.964, p = 0.039, $\eta p^2 = 0.537$]. The process evaluation indicated high fidelity and level of enjoyment, although some families were not able to complete the intervention sessions as prescribed. This study should provide new clues for the design of the future online sibling-guided motor and PA intervention for children with ASD.

Introduction

Compared to their neurotypical (NT) peers, children and adolescents with Autism Spectrum Disorder (ASD) spend less time in physical activity (PA) and participate in fewer types of activities (McCoy et al., 2016; McCoy & Morgan, 2020; Stanish et al.,2018). Most children with ASD fall short of the 60-minutes daily moderate-to-vigorous physical activity (MVPA) guideline (Menear & Neumeier, 2015; Pan et al., 2016; Memari et al., 2015; Bandini et al., 2013; US Department of Health and Human Services, 2018). Recent studies indicate that during the COVID-19 pandemic children with ASD spent more time in sedentary activities than MVPA and light physical activity (LPA), and exhibited increased sedentary behaviors (Lu et al., manuscript in preparation; Yarımkaya & Esentürk, 2020). Therefore, there is a need to provide children with ASD with more accessible PA opportunities, especially when restrictions are in place limiting their access to school, therapeutic, and recreational activities. We provided a family-implemented online PA intervention for children with ASD during the COVID-19 pandemic and investigated its preliminary effectiveness and how well it was implemented.

Barriers of Children with ASD in Participating in Physical Activity

Many physical activities have been introduced to children with ASD, such as horseback riding (Bass et al., 2009; García-Gómez et al., 2014), yoga (Koenig et al., 2012), bicycle riding (Hauck et al., 2017; MacDonald et al., 2012), and aquatic exercise (Fragala-Pinkham et al., 2011;

Pan, 2010; Yilmaz et al., 2004). A meta-analysis on the effect of PA intervention on youth with ASD indicated an overall moderate effect within a total of 29 studies that included 1,009 participants (Healy et al., 2018). However, individuals with ASD still face multiple barriers that interfere with their successful participation in PA (Sandt & Frey, 2005). For example, their social impairment (i.e., avoidance of eye contact, inability to play with others, and difficulties in understanding and expressing feelings) can act as a barrier as PA often takes place in social environments (Obrusnikova and Miccinello, 2012; Center for Disease Control and Prevention, 2018). Moreover, delays or abnormalities in gross and fine motor skills are also common in children with ASD (Chawarska et al., 2007; Davidovitch et al., 2015; Landa & Garrett-Mayer, 2006). Dyspraxia, gait abnormalities, impaired motor speed and coordination, and postural and balance issues are common forms of motor impairments in individuals with ASD (Abu-Dahab et al., 2013; Dziuk et al., 2007; Rinehart et al., 2006; Siaperas et al., 2012). Existing literature has suggested that motor competence in children with ASD is significantly lower than in their age-matched peers without ASD (Ketcheson et al., 2018; MacDonald et al., 2014; Pusponegoro et al., 2016). The Model of Developmental Mechanisms Influencing Physical Activity Trajectories of Children (Stodden et al., 2008) illustrated a dynamic and reciprocal relationship between motor competence and physical activity during childhood. That is, motor skill deficiencies in individuals with ASD can lead to low participation in PA. Many studies provide positive evidence to support Stodden’s conceptual model by investigating the associations between PA (using accelerometers and pedometers) and motor competence (Cliff et al., 2009; Fisher et al., 2015; Robinson et al., 2012).

Besides individual factors (e.g., social impairments and motor deficits) that impede PA participation, the Physical Activity Behavior Model (Van der Ploeg et al., 2004) environmental factors on PA should also be taken into consideration such as program availability, location, cost, expectations, and attitudes of family members towards PA can shape children's PA behavior (Van der Ploeg et al., 2004). In a study with 83 children with ASD aged 6 to 15 years, parents were asked to specify the barriers for their children to participate in physical activities. The results indicated that financial burden and lack of opportunities were the primary barriers (Memari et al., 2015).

An Online Family-Implemented Physical Activity Intervention is Needed

Environmental barriers proved more challenging during the COVID-19 pandemic when many schools were closed (UNESCO, 2020). To overcome the environmental barriers, there is a need to (a) make PA programs accessible with lower costs and reduced travel to more families so that they can easily participate in programs and (b) provide family members with enough support and education, as their behavior and attitude can greatly influence PA in children.

Considering many children were not able to play with peers during COVID-19 restrictions, some have recommended that the efforts for free and unstructured PA should be promoted through playing with siblings (Dunton et al., 2020). Previous literature indicates that siblings may have the potential to serve as powerful intervention agents given their unique relationship with individuals with ASD (Banda, 2015). In the language of Social Learning Theory (Bandura, 1977), individuals learn new skills via observation, imitation, and modeling. The considerable amount of time spent with family members can provide countless opportunities for individuals to observe, imitate, and learn new skills and behavior. The *microsystem* in Bronfenbrenner's Ecological Model (1977) also indicates that parents and siblings play an important role in shaping individuals' behavior. Sibling involvement could lead to long-term positive developmental outcomes in children with ASD (Banda, 2015). Some skills in children with ASD that NT siblings were able to effectively promote through participating in interventions include social skills (often a primary target for children with ASD), play skills, academic skills, etc. (Shivers & Plavnick, 2015). Also, individuals with ASD may be more likely to respond to their siblings than to other children (Knott et al., 1995). However, most existing physical activity interventions are individual tasks completed by children with ASD themselves, and very few include interactions and engagement with family members as instructors, models, or co-recipients (i.e., parents and siblings).

Given there is a dearth of online PA interventions that are accessible to families of children with ASD, and there is a lack of knowledge of the effectiveness of family members' involvement in PA interventions, we developed an online family-implemented PA intervention for children with ASD and explore its preliminary effectiveness.

A Process Evaluation is Critical

When examining the effectiveness of an intervention, it can be difficult to understand the reasons why the intervention worked (or not) without examining how the intervention was delivered since the lack of effect may be due to the weaknesses in the intervention design itself or inappropriate intervention implementation by the intervention agents (Craig et al., 2008; Steckler & Linnan, 2002). In other words, not being able to implement an intervention as intended can compromise the fidelity of the implementation and the effectiveness of the intervention (Brownson et al., 2015). On the other hand, positive outcomes can be achieved even if the intervention is not delivered sufficiently (Moore et al., 2013). Therefore, in addition to what was delivered, how the intervention was delivered should be examined (Montgomery et al., 2013).

A process evaluation can help evaluate the implementation of each component of the intervention thoroughly and critically, interpret its potential effects on the study outcomes, and identify potential implementation problems (Craig et al., 2008; de Meij et al., 2013; Grant et al., 2013). In addition, process evaluation can identify problems and correct them accordingly to ensure accurate outcomes (Durlak & DuPre, 2008; Moore et al., 2013). Previous reviews have identified eight dimensions of program implementation. These include fidelity, dose, quality, participant responsiveness, program differentiation, monitoring of control conditions, program reach, and adaptation (Dane and Schneider 1998; Durlak and DuPre 2008; Dusenbury et al. 2003). Given our knowledge of the effectiveness of online family-implemented physical activity intervention for children with ASD is limited, there is also a need to provide a comprehensive evaluation of this novel online PA intervention. Such an evaluation can help researchers identify potential problems, better interpret the potential effects of the implementation process on the study outcomes, and provide directions for future research.

Specific Aims

To summarize, the purposes of this feasibility study were to (a) investigate the preliminary effectiveness of an online family-implemented intervention and (b) conduct a process evaluation to understand the extent to which the intervention was implemented as prescribed. Specifically, the following aims were examined:

1. Evaluate the effectiveness of an online family-implemented physical activity intervention on physical activity, parental perceived motor competence, and social outcomes in children with ASD over time when (a) both NT sibling and parent serve as intervention agents and (b) parent serves as the only intervention agent (it is hypothesized that the

intervention condition with both parent and NT sibling involved will result in the greatest improvements).

2. Conduct a process evaluation to determine the extent to which the online family-implemented PA intervention for children with ASD was implemented as prescribed in terms of reach, dose, fidelity, and participant enjoyment.

Method

Study Design

Preliminary Effectiveness. A randomized controlled trial research design guided this 14-week online family-implemented physical activity intervention. The research team recruited participants by distributing study information via university and laboratory email lists for families of children with ASD and special needs in general, social media groups related to ASD, and local elementary schools that have ASD programs. Families were eligible to participate if they had (a) a child with ASD between the ages of 6 and 11 without medical conditions that could affect PA participation or motor competence (e.g., Down syndrome, epilepsy, intellectual disabilities), (b) a neurotypical sibling age 5 or older who consented to participate, (c) a caregiver within the family who consented to participate, and (d) access to the internet and compatible devices to open intervention materials and communicate with the research team. Caregivers of families who had more than two NT children were asked to select one NT sibling to participate in this study and provide a rationale of why that NT sibling was selected. A power analysis was conducted in G*Power with an α of 0.05, power of 80%, three measurement times (baseline, post-intervention, and follow-up), and three groups (parent-guided and sibling-assisted, parent-guided only, and control group). An f effect size of 0.4 was included, which indicates a medium difference between groups (Cohen, 1988). This power analysis suggested that 18 families (6 in each group) were needed to accurately detect moderate effect sizes. Eligible families were divided into three groups: Group A (parent-guided and sibling-assisted; n = 8), Group B (parent-guided only; n = 8), and Group C (control group; n = 8). We assigned a family into a group once we got consent from participants following the order Group A, B, C, A, B, C, and so forth.

Prior to the beginning of PA sessions (further explained below), the research team provided each family (including the control group) with a sports equipment kit that contained playground balls, jump ropes, a pair of rackets, tennis balls, spot markers, and cones. Components in the equipment kit were selected based on the items that need to be used in videos of PA sessions during the intervention. The PA intervention components (pre-training and refresher, PA sessions, and teleconferences with the investigators) were only provided to Group A and B. If a family was assigned to Group A, the parent, a NT sibling, and the child with ASD all needed to participate in the PA intervention. The intervention was delivered by both the parent and the NT sibling after they received training in using behavioral strategies in the PA sessions, with the parent playing the major role in carrying out the intervention and the NT sibling offering assistance. If a family was assigned to Group B, then the parent and the child with ASD needed to participate in the intervention without the NT sibling's involvement. The parent became the only intervention agent who received training on strategies for promoting PA participation and carried out the PA intervention.

Families in Group C were encouraged to utilize the provided equipment to actively participate in physical activity, but no physical activity intervention was given. Instead, the research team provided families assigned in Group C with weekly "quiet play" activities, such as drawing, paper crafting, and cooking, with the same duration and frequency (30 minutes/session, 2 sessions/week). Parents, NT siblings, and Children with ASD were all invited to participate.

Pre-training and Refresher. Prior to the family-implemented intervention, three training videos (i.e., Prompting, Reinforcement, and Behavioral Skills Training) about strategies to support and guide the child with ASD to actively engage in the PA sessions were provided to parents and neurotypical siblings in Group A, and parents in Group B.

Prompts refer to stimuli and cues presented to assist a learner to acquire a new skill or correctly respond to a task (Hayes, 2013). Five types of prompting were introduced in the video together with examples and pictures. They included physical prompting (e.g., hand-over-hand support), modeling prompting (e.g., give a demonstration of jumping jacks), gestural prompting (e.g., point to the screen or the sports equipment), position prompting (e.g., position the child facing towards the screen), and verbal prompting (e.g., “hey, look at me!” “jump!”). In addition, the principle of selecting appropriate prompting was introduced; that is always starting with the lowest level of prompt that a child required to be successful on a task based on their needs (Bryan & Gast, 2000). For example, if the child doesn’t know how to do the activity/movement at all, intervention agents should start with physical prompting, such as hand-over-hand support. If the child can complete the activity with gestural prompts, then the intervention agents should start with that level of prompting. Reinforcers are actions that increase the likelihood of a certain behavior occurring the next time (Michael, 2004), such as food, toys, praise, and physical touch. Similar to the training video on prompting, examples and principles were introduced in the video of reinforcement. It was clarified in the video that agents need to deliver the reinforcer immediately after a correct/desired response, keep an enthusiastic and involved manner, and use varied rewards. Lastly, Behavioral Skills Training, a training approach that utilizes instructions, modeling, rehearsal, and feedback in order to teach a new skill was provided. Again, explanations and examples were provided in the training video. For example, for the step of feedback, a script “Good job looking at the ball! Next time I want to see your hands spread nicely and underneath the ball. You also need to throw the ball up higher.” was provided. Additionally, considering that (a) NT siblings lack knowledge of ASD and their recourses to understand ASD is limited (Chapter 2) and (b) sibling-guided interventions are suggested to be encouraged through NT children’s intrinsic motivation, rather than a sense of obligation Lu et al. (2021), for NT siblings in Group A, a video about understanding ASD, why challenging behaviors may occur, and the importance of understanding and helping them were provided.

The caregivers of children with ASD in Chapter 2 indicated that (a) NT siblings sometimes forget what they had been taught about ASD and how to interact with someone with ASD, and (b) they believe their NT child is good at teaching their sister/brother with ASD, but many NT children reported low self-efficacy in supporting their siblings with ASD. Therefore, to ensure the intervention agents in experimental groups could implement the interventions as planned, there was a refresher/list of tips for intervention agents at the beginning of each week’s PA sessions highlighting how to correctly use the taught strategies. A positive affirmation (e.g., “Great work! Keep it up!”, “You’re amazing!”, “Thank you for the great work!”) in a format of a picture was also provided each week to help with boosting the self-efficacy in the intervention agents.

Asynchronous Physical Activity Sessions. The 14-week PA intervention consisted of 28 asynchronous PA sessions using interactive PA videos with instructions that are accessible online. That is, each week’s module included two PA sessions, given twice per week frequency is acceptable and preferred by caregivers of children with ASD (Chapter 2). PA session media and survey/questionnaire links were provided via an online learning management platform called Desire2Learn (D2L), which is commonly used in schools and institutes of higher education. With D2L, the investigators in this study developed an “online course” where the 14-week PA intervention was divided into 14 weekly PA modules for participants to follow. The participants were granted access to this online intervention platform once they were recruited. Materials for each week were available every Monday morning, and the assigned two PA sessions, PA session log, and any required survey(s) were expected to be completed by every Sunday night.

Each PA session was approximately 30 minutes long, given a 30-minute duration was preferred by most of the caregivers of children with ASD in a previous qualitative study (Chapter 2). And the sessions consisted of a variety of fun physical activities that were already produced and available online for free, including exercising with cartoon characters (e.g., “Easy Exercises for Kids at Home” by Little Sports), dancing (e.g., “Just Dance 2020: Baby Shark by Pinkfong”), and fundamental motor skills (e.g., “6 individual Throwing & Catching challenges”), etc. Once the parent logged into our intervention program on D2L, the video could be easily played on any device such as a laptop, mobile phone, and tablet. For the short videos that briefly introduce an activity, such as *6 individual Throwing & Catching challenges*, participants watched the video first and started the PA once they understood how to do it. For longer videos such as exercising with cartoon characters (e.g., *Easy Exercises for Kids at Home*), participants followed the videos throughout the PA sessions. Two to three videos were provided for each PA session. Moreover, in case the child lost interest or did not enjoy the provided videos in a specific PA session, a “video gallery” was also provided on D2L so that parents could easily select other videos/activities for their children when needed.

Throughout all the PA sessions, intervention agents (parents and NT siblings) were instructed to use the strategies they learned to support the child with ASD to actively engage in the activities. For Group A, the parent was taking the lead role in supporting PA in the child with ASD, while both the parent and the NT sibling were encouraged to provide prompts and reinforcement for appropriate behaviors throughout the PA sessions. For Group B, only the parent served as the intervention agent to support the child with ASD. The siblings in families assigned to Group B were not involved in the PA sessions, even as co-recipients of the intervention.

The families worked on the asynchronous PA sessions at their own pace as long but completed the two PA sessions assigned each week. PA sessions did not need to be recorded, but the parent filled out a PA session log indicating which video(s) they completed, the estimated time that they provided the PA session, the estimated time in minutes that the child with ASD was on task, and the estimated time in minutes that child was off task (e.g., not paying attention, running away, crying) for later process evaluation (dose).

Teleconferences with the Investigators. Each family in Group A and B also engaged in three teleconferences with the research investigator throughout the 14-week intervention period (week 1, week 7 or 8, and week 14). During the teleconference, the investigators observed a 30-min PA session via Zoom, Skype, or FaceTime. Right after the PA session, the investigators provided feedback to the intervention agents (parent and NT sibling) on their use of trained strategies and answered any questions. The teleconferences were recorded to evaluate intervention fidelity and understand changes in parent-ASD interactions and NT-ASD interactions.

Specifically, the first two teleconferences served to answer any questions or concerns the parent and/or NT sibling had and provided feedback to the parents and NT siblings based on the 30-minute observations to ensure their correct use of taught strategies. The last teleconference served as a wrap-up, and the investigator provided additional feedback and some strategies that the family could use to support the child with ASD in the future.

Discussion Board. A discussion board was provided on D2L for participants in each group to build connections with other participants and ask any clarifying questions to the research team. The investigators checked the discussion board daily to see if there were any questions that need to be answered.

Process Evaluation. We examined the extent to which the online family-implemented PA intervention was carried out as planned in terms of reach, dose, fidelity, and participant enjoyment. The investigator analyzed the video recording of PA sessions from teleconferences and PA session logs to collect a combination of quantitative and qualitative data.

Data Collection

Preliminary Effectiveness. Demographic information was collected once the family was recruited. Physical activity, parental perceived motor competence, and social outcomes were measured three times throughout the study period (baseline, post-intervention, and 4-week follow up).

Demographic Information. Demographic information, including age, biological sex, race, annual household income, parental education level, scores of the Autism Diagnostic Observation Schedule (ADOS), and whether the child had an intellectual disability (IQ<70) were collected via an online self-reported survey.

Physical Activity. Physical activity was measured using the Children's Physical Activity Questionnaire (C-PAQ). C-PAQ is a questionnaire that asks parents to report on their child's PA in the past seven days in terms of sport, leisure time, school, and sedentary activities. Under each category, the parent reported the frequency and duration of their child's participation in each activity for both weekdays and weekend days. Given the C-PAQ did not inquire about the intensity of participation in the listed activities, considering the nature of those activities and the Youth Compendium of Physical Activities (Butte et al., 2018), we reported the category of *sports activities* as a proxy for MVPA and the category of *leisure time activities* as a proxy for LPA in this study. In addition, activities at school were not analyzed as the questionnaire was completed by the parents during school closure.

Parental Perceived Motor Competence. Since this study was conducted while COVID-19 restrictions were still in place, motor competence was reported by parents using the parent version of the Pictorial Scale of Perceived Movement Skill Competence (PMSC-parent; Barnett et al., 2015), which was developed to assess parents' perceptions of their children's competence in fundamental motor skills and active play. The PMSC-parent aligns with the Test of Gross Motor Development - 3rd Edition (TGMD-3; Ulrich, 2017), which is a valid and reliable assessment of gross motor performance (Webster & Ulrich, 2017). A study by Maher et al. (2018) compared the parent proxy report on motor competence by PMSC and the actual motor competence measured by TGMD-3 in a sample of 100 children aged 7-9 years. The study results indicated the parent version of PMSC was moderately associated with the actual motor skill ($r = 0.36$, $P < 0.001$). And it showed excellent internal consistency (Cronbach's alpha) in the seven-object control (0.94), the six locomotor (0.90) items, and the 13 fundamental motor skill items (0.92).

Social Outcomes. Social outcomes, including parent-child interaction, NT-ASD sibling interaction, and parents' and NT siblings' self-efficacy in supporting the PA in children with ASD, were evaluated using self-administered surveys newly developed by the research team. For Group A and B, video coding using the recordings of the first and the last teleconferences examined the difference in participants' interactions before and after the intervention. An interval recording strategy was used in video coding. Recorded teleconferences (unrelated clips such as conversations between the investigator and the parent were cut) were broken down into 5-sec intervals. By observing whether a behavior occurred or did not occur during each 5-sec interval, (a) the percentage of intervals that had eye contact and conversation and (b) the numbers of eye contact and conversation per minute were calculated. The criterion for an eye contact is that two individuals look directly into each other's eyes. And the criterion for a conversation is that the two individuals had a talk with each other in which thoughts, feelings, and ideas were expressed. Percentage and counts/minute data, rather than counts only, were calculated because the length of the PA session recorded during the teleconference with each family was varied (ranged from 8.58 to 30.83 minutes). Parent-ASD and NT-ASD interactions (i.e., eye contact and conversation) were coded for Group A. Only parent-ASD interactions were coded for Group B.

Inter-rater reliability was achieved among the coders. Coders included a graduate student (the primary investigator of the study) and three undergraduate students studying Kinesiology. The coding manual was developed, and three undergraduate coders were trained by the primary investigator. Three 1-minute video examples (sixty 5s clips) were used to test the inter-rater reliability among all the coders. Following training and practice, all three undergraduate coders viewed and coded the first two video examples independently and compared their results with the results coded by the primary investigator. Example#1 achieved agreement of 83.20%, 85.00%, and 87.40%, and example#2 achieved agreement of 87.4%, 79.59%, and 83.50%. Then the primary investigator carefully reviewed the coding results and discussed the possible confusion that may have resulted in the disagreements (e.g., given sometimes the participants may be off-camera, coders need to put an “off” into the cell, as we can’t say no eye contact just because we didn’t capture it). Then all three undergraduate coders independently completed video example#3 and achieved inter-rater reliability of 94.78%, 90.00%, and 91.74% with the primary investigator. Given all coders achieved inter-rater reliability higher than 90.00%, they started to code the teleconferences.

Social Validity. Social validity refers to the social significance of intervention goals, social acceptability of intervention procedures, and social importance of intervention effects. Parents’ perceptions of social validation of goals and procedures were collected via parents’ notes left in PA session logs and informal conversations between the investigator and the parents (i.e., emails, text messages, conversations during teleconferences). Social validation of outcomes was assessed by two naïve observers (graduate students in the Department of Kinesiology). They viewed both two video recordings (teleconference#1 at the beginning of the intervention and teleconference#3 at the end of the intervention) from each family without knowing the ID or timepoint of the teleconference (#1 or #3). Based on their observation, they completed a survey developed by the investigator using a Likert-type scale (1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = very good) to rate PA participation of the child with ASD, motor performance of the child with ASD, quality of parent-ASD interactions (and NT-ASD interactions for Group A), and intervention agents’ ability to use behavioral strategies for both two videos.

Process Evaluation

***Reach*.** Reach in the current study was assessed by participants' attendance according to the PA session logs. Throughout the intervention period, once a PA session is finished, a PA session log was completed by the parent. With the log, the parent needed to record the date and time they completed each PA session. Families were encouraged to follow the provided instructions in the weekly module to participate in two PA sessions per week. Meanwhile, the research team made sure the participants knew that they had the freedom to skip a PA session if they were not able to complete it as planned due to illness, time conflicts, travel plans, etc. The research team gathered and analyzed the attendance data to report the number and the percentage of completed sessions for the total 28 asynchronous PA sessions.

***Dose*.** The dose was evaluated for dose delivered (completeness of intended amount of the intervention) and the dose received (the extent to which participants are actively engaged). Dose was assessed using the PA session logs completed by the parents after each PA session.

Dose Delivered**.** Dose delivered refers to the completeness of the intended amount of the intervention. As the current study is an online family-implemented intervention, we relied on questions from the PA session logs to evaluate the dose delivered: *What video(s) and or/activity(s) did you complete with your child(ren)? What is the estimated time in total that you actually provided in the PA session for your child(ren)?*

Dose Received**.** Dose received (exposure) refers to the extent to which participants are actively engaged with the intervention and provided resources (Saunders, 2015), which usually can be evaluated using objective measures, such as accelerometers, pedometers, PA trackers, and heart rate monitors (Robbins et al., 2016). We relied on the PA session log to evaluate the dose delivered. Besides the questions related to the dose delivered, a couple of questions were provided to understand the extent to which the child with ASD was actively engaged in the PA sessions: *How many times your child was off task during the PA session today (e.g., running away, not paying attention, crying)? What is the total estimated time that your child was on task (i.e., actively engaged) in the PA session?*

Fidelity. Fidelity refers to adherence or program integrity to describe the extent to which intervention components were delivered as prescribed (Durlak and DuPre 2008). To ensure the quality of the intervention implementation, we wanted to make sure the parents and NT siblings in the experimental groups implemented the interventions using trained strategies as intended. The 30-min asynchronous PA session during the teleconferences with the investigators was recorded and analyzed using the interval recording technique. This method of data analysis involved observing whether a behavior occurs or does not occur during a specific interval. The recorded videos were broken down into 5-sec intervals and evaluated by the research team to see if trained strategies were used (e.g., prompting, reinforcement) and if the child with ASD was on-task (i.e., actively engaging in PA) throughout the PA sessions. The percentages of intervention agents' use of trained strategies and the percentage of on-task behavior of the child with ASD (and NT sibling for Group A) were calculated.

Participant Enjoyment. Within the PA context, enjoyment is considered one of the most important correlates of PA participation. The positive association between enjoyment and increased PA was indicated in previous studies (Dishman et al., 2005; Jin et al., 2018). In the current study, we examined both NT siblings' and children with ASD's enjoyment in PA sessions at the end of the three teleconferences. The enjoyment of NT siblings and children with ASD in PA sessions was evaluated using a revised version of the Physical ACtivity Enjoyment Scale (PACES) designed for young children (Motl et al., 2001). It is revised from the original

PACES, which consists of 18 bipolar statements on a 7-point continuum (Kendzierski and DeCarlo, 1991). The revised version used a 5-point Likert-type scale instead and reduced redundancy which is more comprehensible for young children. The revised PACES demonstrate promising structural validity and internal consistency (Moore et al., 2009). In addition, parents' notes left in the PA session logs were reviewed as useful information about participant enjoyment in the PA sessions was sometimes recorded by the parents.

Data Analysis

A total of 24 families (parent-ASD-NT triads; 72 participants) were recruited in our study. The report of participants' intervention completion status can be found in **Table 9**. Given this study was conducted during the COVID-19 pandemic, many families within our study experienced unexpected situations which impeded their full participation in this study. For the purpose of understanding the preliminary effectiveness of the intervention, data from those participants who completed more than 60% of the intervention were analyzed (i.e., A1, A2, A3, B3, B5, B6, C3, C4, and C6). Demographic information of these nine families is shown in **Table 2**.

Descriptive statistics were used to describe the physical activity, parental perceived motor competence, and social outcomes. A repeated-measures analysis of variance (ANOVA) was used to determine if there were significant differences in the measures across time (pre-intervention, post-intervention, and follow-up) within three groups. Given the small sample due to families dropping out or failing to complete more than 60% of the intervention, the analysis had a lower power than expected. In addition, for Group A, a paired t-test was used to determine if there were any significant differences in parent-ASD and NT-ASD interactions before and after the intervention; Similarly, for Group B, a paired t-test was used to determine if there were any significant differences in parent-ASD interactions before and after the intervention.

Results

Preliminary Effectiveness

Physical Activity. Descriptive data of duration (in minutes) spent in sports activities (a proxy for MVPA), leisure time activities (a proxy for LPA), and SB in a seven-day recall period across three assessment times (pre-intervention, post-intervention, and follow-up) from PMSC-parent can be found in **Table 11**. No statistically significant difference was found in duration, frequency, and type of all levels of PA across time and/or within three groups.

Parental Perceived Motor Competence. Pre-intervention, post-intervention, and follow-up assessments on Parental Perceived Motor Competence, specifically in categories of active play, locomotor skills, objective control skills, fundamental motor skills (locomotor skills + objective control skills), and total scores, are shown in **Table 12**.

Significant differences were found in scores of object control skills [F (1,6) = 17.163, p = 0.006, $\eta p^2 = 0.741$], fundamental motor skills [F (1,6) = 7.385, p = 0.035, $\eta p^2 = 0.552$], and total scores [F (1,6) = 6.914, p = 0.039, $\eta p^2 = 0.535$] over time across the three groups [F (2,6) =6.838, p = 0.028, ηp^2= 0.695], [F (2,6) = 13.507, p = 0.006, $\eta p^2 = 0.818$], and [F (2,6) =6.844, p=0.028, $\eta p^2 = 0.695$]. With the pairwise comparisons, significant difference in scores of object control skills (p = 0.032, 95% C.I. = [-13.08, -0.70]) and total scores (p = 0.031, 95% C.I. = [-33.06, -1.83]) were found between Group A and Group C. In addition, significant differences in scores of fundamental motor skills were found between Group A and Group B (p=0.038, 95% C.I. = [-17.23, -0.54]), and between Group A and Group C (p=0.007, 95% C.I. = [-21.23, -4.54]).

Social Outcomes. Pre-intervention, post-intervention, and follow-up assessment outcomes in social outcomes (parent-ASD interaction, NT-ASD interaction, parents' self-efficacy, and NT siblings' self-efficacy) can be found in **Table 13**. A significant difference was found in parent-ASD interaction across time [F (1,6) = 6.964, p = 0.039, $\eta p^2 = 0.537$]. No statistically significant difference was found in NT-ASD interaction, parents' self-efficacy, or NT siblings' self-efficacy over time across the three groups.

Results of parent-ASD eye contact, parent-ASD conversation, NT-ASD eye contact, and NT-ASD conversation before and after the intervention from video coding can be found in **Table 14**. For participants in Group A, no significant difference was found in any of the interactions, although there was an increasing trend in parent-ASD eye contact before and after the intervention (A1 increased from 4.56% of intervals to 8.25%, and A3 increased 9.48% to 34.26%). Also, no significant difference was found in the interactions between the parents and children with ASD in Group B.

Social Validity. According to parent's notes left in the PA session logs and informal conversations between the investigator and the parents, six out of the eight families (75%) in the experimental groups that had participated in PA sessions expressed their need for a PA program like this and believed that having their children participate in enjoyable physical activities, gaining more motor skills, and increasing the quality of their interactions with their child (and sibling interactions) are important for their children's development. For the social acceptability of intervention procedures, most families reported the pace of the intervention was appropriate, except one parent reported that a 30-minutes PA session was too long for her child and indicated that 15 minutes is the most that her child with ASD can focus on a PA activity (family #B8). All families stated activities introduced in the PA sessions were fun and helpful. However, three parents reported the skills introduced in the PA sessions were a little advanced for their children, but they were able to modify the activities to continue playing (e.g., using a balloon to replace the playground ball in the video for throwing activities; family #A3, #B5, and #B6).

In terms of the social validation of outcomes, without knowing the ID of the teleconferences (#1 or #3), both naïve observers rated higher in the video teleconference#3 than teleconference#1 in all dimensions (PA participation of the child with ASD, motor performance of the child with ASD, quality of parent-ASD interactions, quality of NT-ASD interactions, and intervention agents' ability of to use behavioral strategies.

Process Evaluation

Reach. Across the 24 families originally recruited at the beginning of the intervention, 11 families never started any sessions in this intervention. Their reasons for withdrawing included: illness due to COVID-19, the disapprobation of Applied Behavior Analysis (ABA) after noticing the pre-training included ABA-related elements, and parental stress. Six of these 11 families did not provide any reason for not participating and had no response to the investigator's communication after consenting and receiving the intervention package.

Across the 13 families (Group A = 3, Group B = 5, Group C = 5) that participated in intervention sessions in our study (see **Table 9**), their total number of completed sessions was 18.62 ± 9.47. Three families (23.08%) completed all sessions, six families (46.15%) completed more than 80% of the total sessions, and nine families (69.23%) completed more than 60% of the total sessions. And four families (30.77%) completed less than 30% of the total sessions. For the eight participants in Group A and B who had participated in PA sessions, two families (25.00%) completed all the sessions, five families (62.50%) completed more than 80% of the total sessions, six families (75.00%) completed more than 60% of the total sessions. And two families (25.00%) completed less than 30% of the total sessions.

When the intervention ended, the 13 families who participated in intervention sessions were asked to report their reason(s) for not being able to complete all the sessions at the end of this intervention. Reasons reported include illness (36.36%), availability/schedule (45.45%), not being interested in the activities (45.45%), activities were too difficult (9.10%), and parental stress (9.10%).

Dose. Both dose delivered and dose received were measured in this study.

Dose Delivered. For all the 13 participants who had participated in the program, the total time that parents reported they provided intervention sessions for their children was 568.92 ± 426.75 minutes. Based on the number of sessions completed, the average time parents provided for each PA session was 27.49 ± 9.54 minutes. For the eight participants in Group A and B who had participated in PA sessions, the total time that parents reported they provided PA sessions for their children was 701.00 ± 447.65minutes, and the average time provided for each PA session was 30.71 ± 10.38 minutes.

Dose Received. Different from the dose delivered, data on the dose received were only collected in Group A and B. For the eight participants in Group A and B who participated in PA sessions, the reported number of times that the children with ASD were off task per PA session (e.g., running away, not paying attention, crying) was 1.79 ± 1.54. The total amount of time that the child with ASD was actively engaged in the PA session was 651.43 ± 439.04 minutes. Again, based on the number of sessions completed, the average time children with ASD actively engaged in each PA session was 28.45 ± 10.97 minutes.

Fidelity. According to the data from the interval recording analyses on the recorded PA sessions during teleconferences, children with ASD were on task actively engaging in the PA sessions in 75.77 ± 34.96 % of intervals. For intervention agents, parents in both experimental groups used behavioral strategies introduced at the beginning of the intervention throughout the PA sessions. Strategies that were used most frequently were verbal prompting (used in 51.36 ± 19.02 % of intervals), physical prompting (used in 26.94 ± 25.27 % of intervals), verbal praise (used in 14.49 ± 7.32 % of intervals), and modeling (used in 12.93 ± 12.66 % of intervals). For NT siblings in Group A, they were on-task doing activities together with their sibling with ASD for about 96.60 ± 2.95 % of intervals. They didn't use behavioral strategies frequently compared to the parent, as the parent was taking the leading role in supporting children with ASD. For example, verbal prompting was used in 3.98 ± 5.45% of intervals.

Participant Enjoyment. According to children's responses from the Physical Activity Enjoyment Scale, both children with ASD in Group A and B and NT siblings in Group A enjoyed the PA sessions provided in our intervention (see **Table 15**). Children with ASD in experimental groups agreed or strongly agreed that they enjoyed the intervention (4.43 ± 0.79), the intervention was pleasurable (4.00 ± 0.82), and their body felt good when they were participating in the PA session (4.57 ± 0.53). Similarly, NT siblings in Group A agreed or strongly agreed that they enjoyed the intervention (4.33 ± 0.58), the activities gave them energy (4.00 ± 0.00), the intervention was pleasant (4.33 ± 0.58) and exciting (4.33 ± 0.58), their body felt good when they were participating in the PA session (4.33 ± 0.58), and they got something out of the physical activities (4.33 ± 0.58).

Additionally, we found many parents indicated in their notes of PA sessions about how much their children enjoyed the activities: "PA session was really fun, and we actually had a lot of laughs! He usually does not willingly participate in physical activities, and he absolutely loved it!!!", "We kept playing and playing! Lots of new ideas! We did the video and then kept playing ball! He LOVES ball!!! We play anything with a ball! But these ideas were new and different! We had fun!", "She is getting more confident in the movements. She enjoys every minute of the workouts and never complains about doing them. Her smile is ear to ear!"

Discussion

This study provided an online family-implemented PA intervention for children with ASD during the COVID-19 pandemic. To further explore this novel intervention approach, we investigated the preliminary effectiveness of this intervention and the extent to which the intervention was implemented as prescribed using a process evaluation. We provided three intervention conditions in which (a) both the parent and the NT sibling were trained and served as intervention agents to deliver the PA session (Group A), (b) only the parent was trained and served as intervention agents to deliver the PA session (Group B), and (c) sedentary activity sessions (e.g., drawing and paper crafting) were provided, rather than PA sessions.

For the preliminary effectiveness, assessments on PA, parental perceived motor competence, and social outcomes were conducted before, after, and 4-week after the intervention. Although no significant differences were found in was found in duration, frequency, and type of all levels of PA across time and/or within three groups, significant differences were found in scores of object control skills, fundamental motor skills, and total scores over time across the three groups. More precisely, children with ASD in Group A showed more improvements in scores of object control skills, fundamental motor skills, and the overall motor competence in PMSC-parent than those in Group C. In addition, Group A had more improvements in fundamental motor skill scores than Group B. These outcomes suggested the effectiveness of involving both the parent and the NT sibling in the PA intervention. However, existing ASD motor and PA interventions rarely included NT siblings, let alone having both parents and the NT siblings engaged. Although no PA and motor intervention were found having parents and siblings involved, a motor intervention by Chu and Pan (2012) had NT siblings and peers serving as intervention agents. It was an aquatic program aimed at promoting social and physical interaction behaviors and aquatic skills. NT siblings and peers received training about assisting physical and social interactions and taught children with ASD aquatic skills by providing demonstration, assistance, cues, and feedback. And their findings indicated aquatic skills were improved in all children with ASD, NT siblings, and peers. Taken together, their study and ours indicated that siblings could support motor skill development in children with ASD when they're properly trained on how to interact and give instructions. Furthermore, results also suggested that sibling-mediated motor interventions could take place in both a home setting and an intervention center.

For the process evaluation, assessment results indicated good intervention fidelity and a high level of participant enjoyment in this online PA intervention. This finding of participant enjoyment is consistence with the feasibility trial of a 4-week-long, WhatsApp-based PA intervention for children with ASD, which was also conducted during the COVID-19 pandemic (Esenturk & Yarimkaya, 2021). The authors reported that all the 14 parents reported that they were very happy during the participation in the PA intervention. However, a high withdrawal rate and low completion rate were found in our study. Only 13 families out of the 24 recruited families had participated in intervention sessions in our study, with 18.62 ± 9.47 sessions completed. For the eight families in PA intervention groups (Group A = 3 and Group B = 5) who had participated in PA sessions, only two families completed all the sessions and six families

(75.00%) completed more than 60% of the total sessions. Reasons reported for skipping PA sessions include illness, availability/schedule, not being interested in the activities, activities being too difficult, and parental stress during the pandemic. These listed reasons aligned with what was revealed by a qualitative study conducted in Michigan aiming at understanding the perceptions of families of individuals with ASD during the COVID-19 pandemic (Manning et al., 2021). The study reported that the greatest areas of stress that families of children with ASD experienced were therapeutic service disruption, isolation, illness, and finance. In the future, to prevent dropout and support participants' program completion, researchers could (a) work with the parents first to provide them with coping strategies and recourses to reduce their stress, (b) work with the parents and the teachers/therapist to better fit the intervention activities into their weekly routines for better adherence, and (c) better understand children's interest and incorporate the elements into the physical activities.

This intervention has some unique strengths. First, this study provided a video explaining to NT siblings what ASD means, why individuals with ASD have challenging behaviors, and the importance of understanding and helping them, in addition to training on strategies to support PA. These elements were designed to increase NT siblings' intrinsic motivation in supporting their sister/brother with ASD. Second, affirmation such as "Great work! Keep it up!" in the format of a picture was provided every week to encourage and boost intervention agents' self-efficacy in supporting children with ASD throughout this intervention. Third, we made sure the families knew that they had the flexibility to carry out the PA sessions at their own pace. It can be hard to add a new activity into the weekly routine for children with ASD, and some may have problems paying attention to a task for 30 minutes. Therefore, flexibility with PA sessions can potentially increase the intervention feasibility and acceptability.

Some limitations of this intervention should be noticed as well. First, because of the difficulty recruiting and conducting interventions during the COVID-19 pandemic, we had a small sample size for this study. Future research should include larger-scale online family-implemented PA interventions for children with ASD to further explore its effectiveness. With most families having gone back to their normal lives after the public health emergency caused by COVID-19, recruitment for such interventions may be smoother. Researchers can also reach more families by recruiting nationwide at ABA centers, ASD-related social media groups, and elementary schools that have ASD programs. Second, videos introduced in the PA sessions were from exiting online recourses, rather than created by the research team. Additionally, they were not individualized based on the age or motor skill level of the child with ASD. Therefore, some activities may have been difficult for some participants in our study, especially activities that require motor coordination and balance. Future research should include an assessment of participants' level of motor skills and cognitive skills, grouping based on their levels, and the creation and use of videos that are developmentally appropriate for each group. Lastly, given this PA intervention was delivered online, some parents might experience technical problems accessing materials using a new online platform. Within future online interventions, a brief individual meeting with the parent showing them how to navigate the online platform and solving any problems that they may have about using the website should be provided prior to the start of the study.

Conclusion

This study was the first intervention designed for children with ASD in an online format at the family level. The findings from this study suggested the preliminary effectiveness of an online PA intervention that had both parent and NT sibling serving as intervention agents in promoting parental perceived object control skills, fundamental motor skills, the overall motor competence, and parent-ASD interactions in children with ASD. This study provides new insights for delivering PA intervention in an online format and using family members as intervention agents to carry out PA intervention.

APPENDICES

APPENDIX A: Tables

Table 9

A Report of Participants' Intervention Completion Status

ID	Sign-up	Baseline (A#1)	T#1	T#2	T#3	A#2	A#3	Reason(s) for Drop-out/No response	Sessions Completed (%)
A1	✓	✓	✓	✓	✓	✓	✓		26 (92.86%)
A2	✓	✓	✓	missed	missed	✓	✓		22 (78.57%)
A3	✓	✓	✓	✓	✓	✓	✓		28 (100.00%)
A4	✓							unknown	
A5	✓	✓						unknown	
A6	✓							COVID-19	
A7	✓							unknown	
A8	✓	✓						COVID-19 & parental stress	
B1	✓	✓	✓					COVID-19 & health issue	8 (28.57%)
B2	✓							unknown	
B3	✓	✓	✓	✓	✓	✓	✓		25 (89.29%)
B4	✓	✓						disapprobation of ABA	
B5	✓	✓	✓	✓	✓	✓	✓		24 (85.71%)
B6	✓	✓	✓	✓	✓	✓	✓		28 (100.00%)
B7	✓	✓						unknown	
B8	✓	✓	✓	missed	missed	✓	✓		6 (21.43%)
C1	✓	✓	-	-	-	✓	✓		6 (21.43%)
C2	✓	✓	-	-	-	✓	✓		3 (10.71%)
C3	✓	✓	-	-	-	✓	✓		28 (100.00%)
C4	✓	✓	-	-	-	✓	✓		20 (71.43%)
C5	✓	✓						COVID-19	
C6	✓	✓	-	-	-	✓	✓		18 (64.29%)
C7	✓							unknown	
C8	✓							health issue	

Note. A =assessment; T = teleconference.

Table 10

Demographic Information of Participants (Who Completed More than 60% of the Intervention)

ID	ASD Age	ASD Sex	NT Age	NT Sex	Parent Age	Race	Parental Education	House Annual Income	ADOS	ASD_IQ<70 (yes/no)
A1	11	Male	9	Female	35	White	Bachelors	>100k	14	No
A2	6	Female	10	Female	34	White	Bachelors	50-100k	23	Yes
A3	8	Male	6	Female	35	Asian	Masters	50-100k	NR	Yes
B3	7	Male	5	Female	35	Asian	High school	<25k	NR	No
B5	9	Female	5	Female	39	White	Bachelors	>100k	NR	No
B6	10	Male	19	Male	44	White	Some college	>100k	NR	Yes
C3	11	Male	18	Female	41	White	Some college	25-50k	17	No
C4	8	Male	6	Female	30	White	Some college	25-50k	NR	No
C6	12	Male	10	Female	44	White	Bachelors	>100k	NR	Yes

Note. ASD = autism spectrum disorder; NT = neurotypical; ADOS = Autism Diagnostic Observation Schedule; IQ = intelligence quotient.

Table 11

Pre-Intervention, Post-Intervention, and Follow-Up Assessments in Physical Activity

ID	Sports Activities (a proxy for MVPA) _Duration (mins)			Leisure Time Activities (a proxy for LPA) _Duration (mins)			Sedentary Activities (a proxy for SB) _Duration (mins)		
	pre	**post**	**follow**	**pre**	**post**	**follow**	**pre**	**post**	**follow**
A1	500	35	55	90	180	40	4740	4350	3770
A2	60	80	80	0	545	130	210	NR	NR
A3	80	495	330	85	250	10	1560	1320	1400
B3	375	55	210	202	95	40	1220	2100	3540
B5	45	210	110	1110	235	80	5410	4770	3870
B6	440	97	40	400	770	440	1820	4440	2330
C3	315	120	355	130	295	97	2147	2150	2998
C4	260	150	50	420	960	120	NR	3960	3780
C6	270	165	260	260	230	65	1505	2810	1910

Note. MVPA = moderate-to-vigorous physical activity; LPA = light physical activity; SB = sedentary behaviors; NR = not reported.

* Numbers above were total minutes over a 7-day period.

Table 12

Pre-Intervention, Post-Intervention, and Follow-Up Assessments on Parental Perceived Motor Competence

ID	**PMSC_Active play**			**PMSC_Locomotor**			**PMSC_Object control**			**PMSC_FMS**			**PMSC_Total**		
	pre	**post**	**follow**	**pre**	**post**	**follow**	**pre**	**post**	**follow**	**pre**	**post**	**follow**	**pre**	**post**	**follow**
A1	9	10	11	13	10	13	9	12	15	22	22	28	31	32	39
A2	11	9	9	15	16	16	13	12	12	28	28	28	39	37	37
A3	12	11	12	12	10	10	10	13	13	22	23	23	34	34	35
B3	13	14	13	23	21	20	14	16	17	37	37	37	50	51	50
B5	15	16	17	19	22	19	14	14	16	33	36	35	48	52	52
B6	7	7	7	10	11	11	16	21	20	26	32	31	33	39	38
C3	12	13	14	12	14	15	21	20	24	33	34	39	45	47	53
C4	12	14	14	23	22	21	12	16	18	35	38	39	47	52	53
C6	18	19	19	21	23	18	19	19	22	40	42	40	58	61	59

Note. PMSC = Perceived Movement Skill Competence; FMS = fundamental motor skills.

Table 13

Pre-Intervention, Post-Intervention, and Follow-Up Assessment Outcomes in Social Outcomes

ID	Parent-ASD Interaction			NT-ASD Interaction			Parent's Self-Efficacy			NT's Self-Efficacy		
	pre	**post**	**follow**	**pre**	**post**	**follow**	**pre**	**post**	**follow**	**pre**	**post**	**follow**
A1	45	55	47	38	43	38	49	52	45	44	38	32
A2	42	48	51	31	42	35	50	53	53	37	52	51
A3	34	44	43	34	39	39	34	40	38	33	35	41
B3	45	55	53	23	52	54	32	52	42	14	49	44
B5	46	41	38	45	37	35	49	45	44	30	30	35
B6	60	60	60	44	36	42	55	53	51	51	46	45
C3	43	50	45	47	46	49	47	51	51	39	41	45
C4	51	51	54	39	31	40	53	54	54	42	40	47
C6	53	59	54	39	41	52	53	53	50	42	37	45

Table 14

Interactions During Physical Activity Session Before and After Intervention

ID	Parent-ASD Eye contact				Parent-ASD Conversation				ASD-NT Eye contact				ASD-NT Conversation			
	%		#/minute		%		#/minute		%		#/minute		%		#/minute	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
A1	4.56	8.25	0.55	0.80	10.18	10.63	1.22	1.28	1.40	6.31	0.17	0.76	0.35	4.32	0.04	0.52
A2	NC	/	NC	/	31.63	/	3.79	/	NC	/	NC	/	0.00	/	0.00	/
A3	9.68	34.26	1.16	4.22	0.00	0.77	0.00	0.09	6.45	5.98	0.77	0.72	0.00	0.00	0.00	0.00
B3	9.52	20.00	1.23	2.63	17.19	23.58	2.25	3.40	-	-	-	-	-	-	-	-
B5	2.77	21.05	0.30	2.53	4.96	11.25	0.60	1.35	-	-	-	-	-	-	-	-
B6	54.50	47.12	12.00	6.92	6.56	4.27	0.84	0.51	-	-	-	-	-	-	-	-

Note. % = percentage of intervals that a behavior was observed; #/minute = number of times that a behavior was observed per minute; NC = the behavior was not captured in the video.

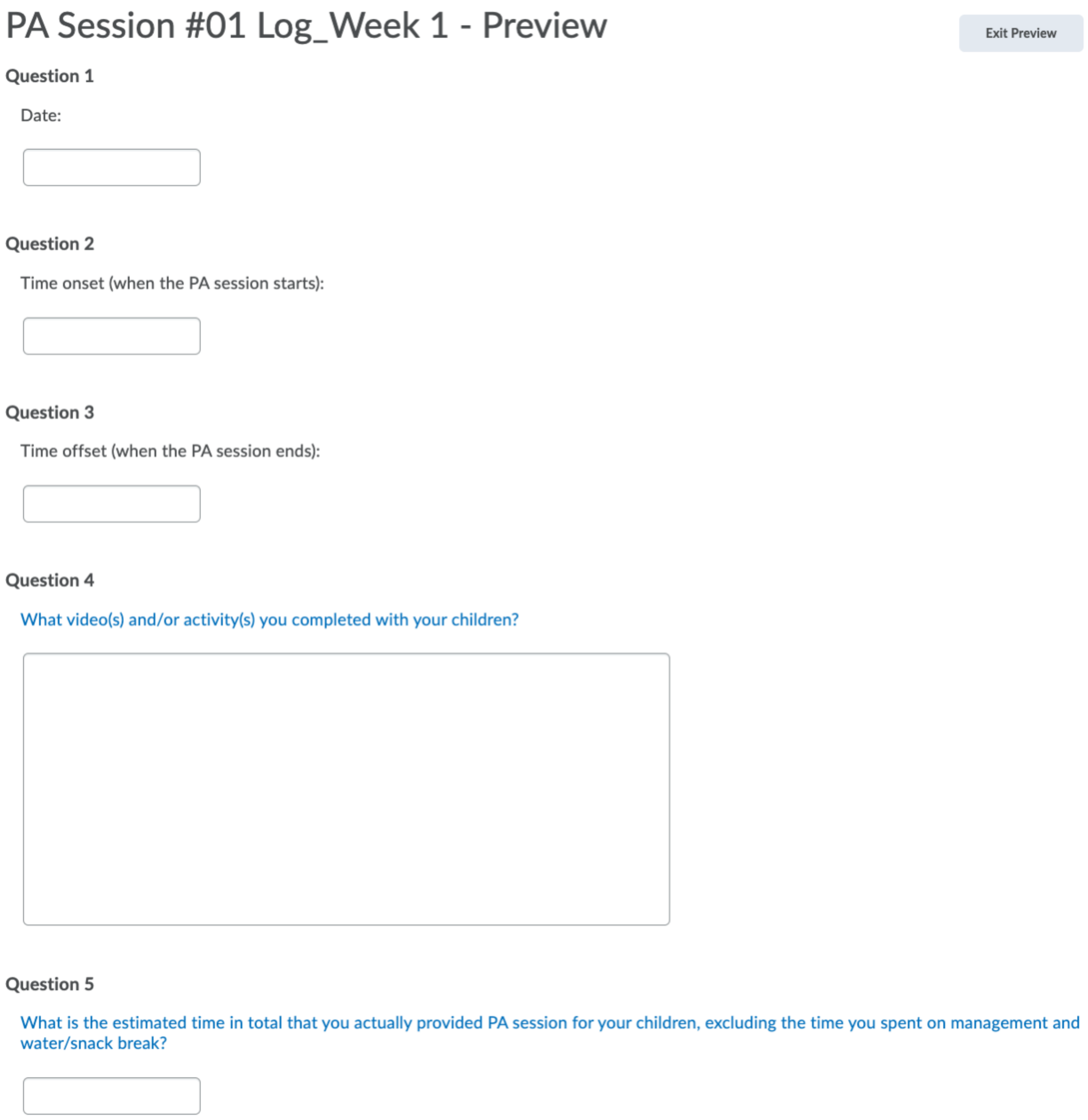
Table 15

Participants' Response to Physical Activity Enjoyment Scale

	Children with ASD (n = 7)		Neurotypical Siblings (n = 3)	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
1. I enjoy it	4.43	0.79	4.33	0.58
2. I feel bored	2.00	0.58	2.00	0.00
3. I dislike it	1.71	0.76	1.33	0.58
4. I found it pleasurable	4.00	0.82	3.67	0.58
5. It's no fun at all	1.71	0.49	1.33	0.58
6. It gives me energy	3.57	1.40	4.00	0.00
7. It makes me said	1.43	0.79	1.67	0.58
8. It's very pleasant	3.71	1.11	4.33	0.58
9. My body feels good	4.57	0.53	4.33	0.58
10. I get something out of it	3.86	0.90	4.33	0.58
11. It's very exciting	3.57	0.98	4.33	0.58
12. It frustrates me	1.43	0.79	2.00	1.00
13. It's not at all interesting	1.57	0.79	2.33	0.58
14. It gives me a feeling of success	3.86	1.07	3.67	0.58

Note. Participants used a 5-point rating scale to indicate how much they agree with the statements (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).

APPENDIX B: Physical Activity Session Log (Example)



PA Session #01 Log_Week 1 - Preview

Question 1

Date:

Question 2

Time onset (when the PA session starts):

Question 3

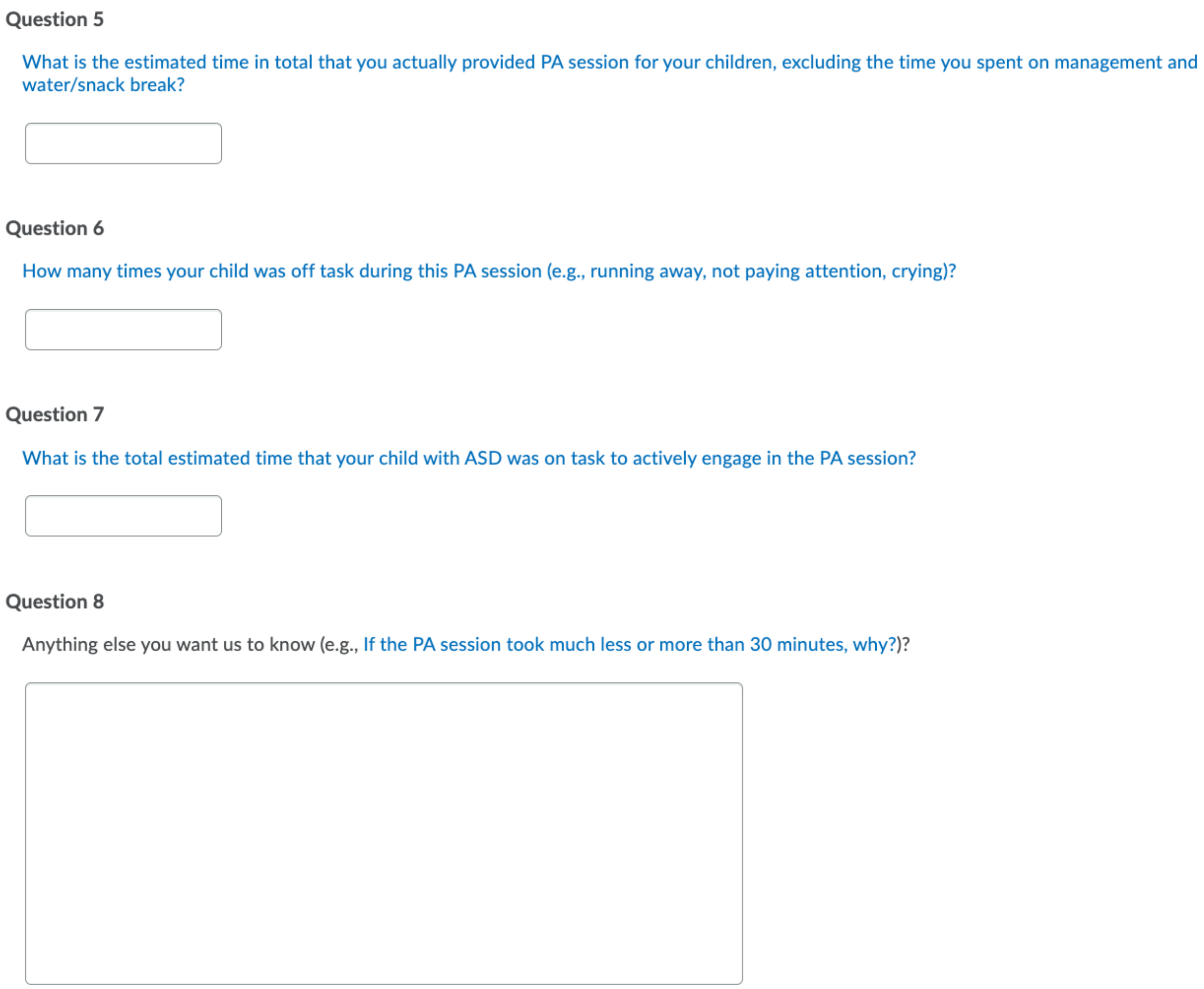
Time offset (when the PA session ends):

Question 4

What video(s) and/or activity(s) you completed with your children?

Question 5

What is the estimated time in total that you actually provided PA session for your children, excluding the time you spent on management and water/snack break?



Question 5

What is the estimated time in total that you actually provided PA session for your children, excluding the time you spent on management and water/snack break?

Question 6

How many times your child was off task during this PA session (e.g., running away, not paying attention, crying)?

Question 7

What is the total estimated time that your child with ASD was on task to actively engage in the PA session?

Question 8

Anything else you want us to know (e.g., If the PA session took much less or more than 30 minutes, why?)?

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CHAPTER 5

Conclusion

This dissertation addresses levels of physical activity (PA), parental perceived motor competence, and related family dynamics in children with Autism Spectrum Disorders (ASD) with a neurotypical (NT) sibling during the COVID-19 pandemic. It also advances our knowledge about influencing these aspects at the family level by involving NT siblings and caregivers in an online family-implemented PA intervention.

This dissertation presents original data from a set of three studies, and the related studies and chapters were conducted and arranged in an intentional order. First, a qualitative study was conducted to investigate NT siblings' and caregivers' perceptions of prospective sibling-guided motor interventions and their preferences on the design of such interventions, such as setting, format, time in a week, and frequency (Chapter 2). Second, we conducted a cross-sectional study examining levels of PA, parental perceived motor competence, and related family dynamics in children with ASD with a NT sibling during the COVID-19 pandemic (Chapter 3). Lastly, an online family implemented PA intervention with a randomized control design was conducted. Its preliminary outcomes and a process evaluation were also assessed (Chapter 4). Overall, the knowledge that we gained from the studies in Chapter 2 and 3 were incorporated into the research design of the study in Chapter 4.

Summary

A summary of each chapter and a brief discussion of each chapter's relevance within the context of the whole dissertation and larger literature are presented below.

Chapter 2: Insights of Caregivers and Neurotypical Siblings on Prospective Sibling-Guided Motor Interventions for Children with Autism Spectrum Disorder

The second chapter of this dissertation was a qualitative study that aimed to gain insights into NT siblings' and their caregivers' perceptions of prospective sibling-guided motor interventions for children with ASD. The study specifically addressed (a) NT siblings' and caregivers' perceptions of having NT siblings serve as intervention agents (defined as individuals who receive training and then implemented learned strategies/skills to guide the target population in this dissertation) to guide children with ASD (e.g., NT siblings' willingness to teach, NT siblings' teaching skills, NT siblings' previous teaching experience) and (b) NT siblings' and caregivers' preferences for prospective sibling-guided motor intervention (e.g., setting, format, time in a week, frequency, and intervention component/activity). Our findings from the semi-structured interviews with ten NT sibling-caregiver dyads indicated that only about half of the NT children within our sample were confident and had experience teaching their brothers/sisters with ASD, even though most of them were willing to support and teach their siblings with ASD. NT siblings also experienced some difficulties interacting with children with ASD due to some ASD-specific characteristics, such as resistance to change, limited social-communicative skills, problems with emotional control, and oversensitivity. Also, NT siblings' knowledge about ASD and available recourses to understand how to interact and support children with ASD are limited. In addition, in terms of the knowledge gained about participants' preferences related to the design of sibling-guided motor interventions, we found that most NT siblings preferred indoor settings and ball games. For caregivers, both indoor and outdoor settings, ball games, in-person format, once or twice per week frequency, weekend days, and 30-minute session duration were most preferred.

Overall, although strong evidence exists for motor interventions' effectiveness in promoting motor skills, the number of existing interventions aimed at addressing the motor skills of children with ASD is small (Colombo-Dougovito & Block, 2019). Furthermore, previous motor interventions for children with ASD were most often delivered by a research team without the involvement of siblings, even though siblings have been suggested as effective intervention agents to promote skill development (Banda, 2015; Shivers and Plavnick, 2015; Lu et al., 2021). With the long-term aim of designing and implementing this novel intervention approach to promote motor skills and PA in children with ASD, this qualitative study emphasized the usefulness of asking for stakeholders' input in the study design before starting a pilot or feasibility trial.

Chapter 2 of the dissertation provides meaningful direction to inform the design of feasible and effective motor interventions for children with ASD with NT siblings serving as intervention agents. Some of the findings from this study (i.e., NT siblings' willingness to teach, NT siblings' lack of knowledge about ASD, and participants' preferred intervention characteristics) may also be applied to broader types of sibling-guided programs beyond just motor interventions.

Chapter 3: An Investigation of Levels of Physical Activity, Parental Perceived Motor Competence, and Related Family Dynamics in Children with Autism Spectrum Disorder with A Neurotypical Sibling During the COVID-19 Pandemic

The third chapter of this dissertation was a cross-sectional investigation. To our knowledge, it was the first study aimed at understanding levels of PA, parent perceived motor competence, and PA-related family dynamics (i.e., parent-ASD interaction, NT-ASD interaction, NT siblings' and parents' self-efficacy) in children with ASD with a NT sibling during the COVID-19 pandemic.

PA data collected by the accelerometer and the questionnaire both suggested that children with ASD engaged in much more sedentary activities (e.g., watching TV, using a computer, talking on the phone) than sport (e.g., dancing, basketball, running) and leisure time activities (e.g., bike riding, skateboarding, walking the dog). In addition, according to the questionnaire, besides longer duration, children with ASD also participated in sedentary activities more frequently and engaged in more types of sedentary activities than sports and leisure time activities. Parental perceived motor competence data indicated that parents perceived their children's competence on most skills listed in parental proxy of the Pictorial Scale of Perceived Movement Skill Competence (PMSC-parent; Barnett et al., 2015) as not too good or sort of good, with only a few skills as pretty good (e.g., scootering, running, and galloping). In terms of PA-related family dynamics, when asked about levels of interactions with children with ASD, NT siblings' perceptions were lower than parents. In addition, compared to parents, NT siblings reported lower self-efficacy in their capability of supporting PA in children with ASD. Among the measures of family dynamics within this study, parents' self-efficacy in supporting PA in their children with ASD was positively correlated with many other variables, such as parent-ASD interaction, NT-ASD interaction, and NT siblings' self-efficacy in supporting PA in their brother/sister with ASD. Moreover, a positive correlation between the level of parent-child interaction and NT-ASD interaction was found.

Although previous literature on levels of PA and motor competence in children with ASD during the COVID-19 pandemic is limited, there is a consensus that children with ASD can experience motor delay/deficits and fall short of regular participation in moderate-to-vigorous physical activity (MVPA) prior to the outbreak of COVID-19 (Menear & Neumeier, 2015; Soke et al., 2018). The findings of relatively low participation in sports activities and the skills rated "not too good" (e.g., skating/blading and hitting a ball with one hand; skills that require coordination and balance) listed in parental perceived motor competence in our study are consistent to the findings of existing studies prior to the outbreak of COVID-19 (Abu-Dahab et al., 2013; Menear & Neumeier, 2015; Siaperas et al., 2019).

Chapter 3 of this dissertation informs researchers and special educators of the importance of providing quality play-based programs to promote active participation in physical activity and motor skill development for children with ASD at the family level. It also provides insights for future studies to consider family dynamics when designing interventions, especially parents' self-efficacy in supporting PA in their children with ASD.

Chapter 4: Exploration of An Online Family-Implemented Physical Activity Intervention for Children with Autism Spectrum Disorder: A Feasibility Study

The fourth chapter of this dissertation was an online family-implemented PA intervention for children with ASD during the COVID-19 pandemic. It firstly explored the preliminary outcomes of the intervention and included a process evaluation to examine to what degree the intervention was implemented as planned. It was in a randomized control trial, which allowed us to compare different intervention conditions when (a) both parent and NT sibling served as PA intervention agents (Group A), (b) only the parent served as PA intervention agent (Group B), and (c) a "quiet-play" condition (e.g., drawing and paper crafting) in which PA sessions were not provided (Group C). In terms of the first part of this chapter (preliminary effectiveness), outcome measures were identical to those presented in Chapter 3, with the addition of direct data collection of parent-ASD interactions and NT-ASD interactions (i.e., eye contact and conversation) from video recordings. Assessments were conducted three times (pre-intervention, post-intervention, and 4-week follow-up). For the second part of this chapter (process evaluation), reach, dose, fidelity, and participant enjoyment were evaluated and reported.

According to the results of PMSC-parent, significant differences were found in scores of perceived motor competence in object control skills, fundamental motor skills, and total scores over time across the three groups. More precisely, the results indicated participants in Group A (with both parent and NT sibling serving as PA intervention agents) improved perceived object control skill scores and total scores significantly higher in participants in Group C (the control group in which only quiet play activities were provided). In addition, participants in Group A showed significant improvements in parental perceived fundamental motor skills than participants in Group B (with only the parent serving as the PA intervention agent) and Group C. In terms of family dynamics measured via online surveys, a significant difference was found in parent-ASD interaction over time across all three groups. No statistically significant difference was found in PA (from both accelerometer-based and questionnaire-based PA data) and family interactions (analyzed from video recordings) across time and/or within three groups.

This novel online family-implemented PA intervention for children with ASD contributed to the body of the existing PA intervention literature that solely involved individuals with ASD and was delivered by the research team (Bahrami et al., 2016; García-Gómez et al., 2014; Hauck et al., 2017; MacDonald et al., 2012). It was the first online PA intervention for children with ASD with NT siblings and parents serving as intervention agents and also the first intervention that investigated PA-related family dynamics in children with ASD (i.e., interactions and self-efficacy in supporting PA). In addition, the process evaluation of this study should inform refinement in the study design for future online play-based programs that are aimed at influencing motor behaviors at the family level.

Implications and Future Directions

Understanding Stakeholder's Needs and Preferences is Helpful in Intervention Design

In this dissertation, we incorporated some of the findings that we gained from the stakeholders in Chapter 2 into the design of the intervention introduced in Chapter 4. For example, given NT siblings' knowledge about ASD and available resources to understand how to interact and support children with ASD are limited, we provided training sections prior to the intervention to educate what ASD is, why we should understand and help them, and some behavioral strategies (e.g., reinforcement, prompting) to interact with children with ASD and enhance their desired behaviors. Also, given we found that some NT siblings were not confident in teaching their sibling with ASD, throughout the intervention, positive affirmation in the format of pictures was provided in each week's intervention session to boost their self-efficacy in serving as intervention agents to support their sister/brother with ASD. In addition, considering NT siblings' and caregivers' preferences we learned, the sessions provided in the PA intervention were 30-minute long each session, delivered twice per week, and included a variety of ball games (e.g., throwing and catching and soccer games).

Stakeholder engagement refers to "*active involvement of public, patients, health professionals, and other decision makers throughout the research process*", which has been suggested as an approach to facilitate the intervention's quality, impact, and reach (Byrne, 2019). In a chapter of the book *The Handbook of Behavior Change* (Hudson et al., 2020), engagement of stakeholders in the design of complex behavior change interventions is also suggested to be of great importance. Having stakeholders involved in the design, evaluation, and implementation can help inform how to make necessary adjustments, increasing the likelihood of translating behavior interventions informed by theory into real-world practice. However, most of the research projects only focused on developing an intervention and testing its effectiveness by conducting pilot studies and feasibility trials. Investigators' knowledge of utility, usability, accessibility, and acceptability of the intervention are limited, which can potentially affect the desired outcomes of the intervention. Therefore, future study design should be tailored to address stakeholder context by asking for their input in the process of research development.

Adequate Attention Should be Paid to NT Siblings

Previous studies reported that NT children's psychological well-being might be affected due to living with a brother/sister with ASD (Angell et al., 2012; Benderix & Sivberg, 2007). With unequal parental time and attention paid to them and their sibling with ASD, the NT child is often described as the 'forgotten child' and feels they have an increased number of responsibilities in the family (Madan-Swain et al., 1993; Molinaro et al., 2020). Many NT siblings feel unsafe and anxious due to ASD-specific characteristics, especially aggressive behaviors in children with ASD (Angell et al., 2012). In the context outside of their homes, Petalas et al. (2012) revealed that NT siblings of children with ASD might also experience anxiety, embarrassment, and anger resulting from prejudice, rejection, and misunderstanding from their peers. Therefore, there is a need to provide resources and mental health support to those children who have a sibling with ASD. Additionally, although previous studies indicated that NT siblings can serve as unique intervention agents to effectively support skill development in children with ASD (Banda, 2015; Shivers and Plavnick, 2015; Lu et al., 2021), it is suggested by Lu et al. (2021) that sibling-guided intervention should be encouraged through NT children's intrinsic motivation, rather than a sense of obligation. Moreover, education on what ASD is and why their siblings with ASD exhibit challenging behaviors, such as oversensitivity and limited social-communication skills, should be provided to them.

Parents' Self-Efficacy is Important for the Entire Family Dynamics

From the findings in Chapter 3, we understand that parents' self-efficacy in supporting PA in their children with ASD was positively correlated with parent-ASD interaction. The Social Learning Theory (Bandura, 1977; Bandura & Adams, 1977) can help to explain the correlation. In that theory, it is believed that an individual's persistence on a task and the amount of effort they will put in are influenced by self-evaluation of their ability to execute that behavior. Besides parent-ASD interactions, this dissertation also found that parents' self-efficacy in supporting PA in children with ASD is also positively associated with NT siblings' self-efficacy and NT-ASD interaction. That is, through the observation and imitation of how parents positively interact with children with ASD, NT siblings can learn the interaction patterns and develop their confidence in supporting their sister/brother with ASD as well. Therefore, strategies to boost parental self-efficacy are needed, given it is a critical factor that is associated with many other elements within the entire family dynamics.

Flexibility of The Intervention is Critical for Families

According to the process evaluation in terms of reach in Chapter 4, across those families who participated in our intervention sessions (from all three groups), only two families (15.28%) completed all the intervention sessions. In addition, there were four families (30.77%) who completed less than 30% of the intervention sessions. Among all the reported reasons for not being able to complete all the sessions, availability/schedule was reported by most families (45.45%). It can be difficult for a family to add intervention sessions into a weekly routine, no matter how effective the intervention might be. Thus, it is necessary for the intervention providers to help participants incorporate new activities into their schedules with increased flexibility of intervention delivery.

Methodology to Accurately Measure PA in Children with ASD is Needed

Seven out of the 18 children with ASD within our sample in Chapter 3 were not able to meet the minimum wear time for the accelerometers because of their sensory issues. This result aligns with the fact that many researchers still choose self-reported and recall instruments to collect PA data in children, even though objective measure of PA is important (Reilly, 2011). Issues in adherence to accelerometer wearing were revealed by Hauck et al. (2016) in children with ASD aged 9-year-old and beyond, and some strategies such as social stories, concealing techniques, and incentives were recommended. Accelerometer wearing adherence can be even harder for younger children with ASD. Therefore, future studies should explore effective and age-appropriate strategies to increase the wearing adherence rate.

In addition, researchers need to come up with a more effective methodology to understand accurate PA patterns in individuals with ASD, given they typically exhibit stereotyped behaviors such as body rocking and hand flapping (Bodfish et al., 2000). That is, some of the movements captured by the devices such as accelerometers, pedometers, and Fitbit trackers may result from those stereotyped and repetitive behaviors, rather than meaningful and health-promoting movements. Ketcheson et al. (2017) suggested including an observational period while stereotypic behavior is coded. Moreover, cut points for activity intensity analysis in children with ASD can be an issue in accurately understanding their PA pattern. A study by Trost et al. (2011) compared multiple sets of intensity-related accelerometer cut points for children and adolescents and indicated Evenson and Freedson/Trost cut points exhibited significantly better classification accuracy than others. However, there is a dearth of knowledge of accelerometer cut points specifically for individuals with ASD. Studies that investigate cut points for activity intensity analysis in children with ASD are necessary for the future.

Online Family-Implemented Physical Activity Intervention Can be Enjoyable and Effective

This study is the first study to our knowledge that provided online PA intervention for children with ASD with parents (and NT siblings) engaged. By incorporating caregivers' and NT siblings' preferences in the intervention design, the online family-implemented PA intervention we provided has been shown to be enjoyable and effective. For the participant enjoyment measured by a revised version of the Physical ACtivity Enjoyment Scale (PACES) designed for young children (Motl et al., 2001), both children with ASD and NT siblings reported that they enjoyed the intervention, and their bodies felt good when they were participating in the PA session. For the effectiveness, preliminary data showed children with ASD in the PA intervention groups had greater improvements in parental perceived motor competence (locomotor skills, fundamental skills, and the general skills reflected by total scores of PMSC-parents). Participants in all the groups improved parent-ASD interaction. Therefore, with this first investigation of a novel intervention approach, more PA intervention in online format should be established at the family level for children with ASD and other developmental disabilities.

Dissertation Strengths and Limitations

The current dissertation has some strengths and limitations. In terms of strengths, first, the three studies were connected within the dissertation context. The findings from the qualitative study in Chapter 2 (a) provided insights for investigating children with ASD who has a NT sibling in Chapter 3 and (b) gathered information from the stakeholder for better intervention design in Chapter 4 to meet their preferences and needs. Also, after knowing the excessive sedentary behaviors and inadequate motor skills in children with ASD, Chapter 4 was a continuation of Chapter 3, conducting interventions to promote the variables that were measured in Chapter 3 (PA, parental perceived motor competence, parent-ASD and NT-ASD interactions, and parents' and NT siblings' self-efficacy in supporting PA in children with ASD). Second, regardless of all the difficulties during the COVID-19 pandemic, the set of three studies in this dissertation were able to be conducted and completed as planned by making appropriate adjustments (e.g., conducting online interviews in Chapter 2, using a parental proxy to measure perceived motor competence in Chapter 3 and 4, using video recordings via teleconferences to evaluate fidelity in Chapter 4). Lastly, this dissertation had a specific focus on NT siblings, an understudied and often ignored population. We heard their voices, asked for their input in the study design, provided them with resources and training, boosted their self-efficacy, and evaluated their enjoyment during the PA intervention.

This dissertation also has some limitations. First, participants in our studies were mostly midwestern families in the US. During the wintertime, children's PA (especially outdoor activities) can be impacted greatly because of the colder weather, which can affect the PA outcomes of the intervention. Second, given the studies were conducted during the pandemic, self-administered surveys, instead of direct data collection, were applied in both measures in the cross-sectional study in Chapter 3 and the online PA intervention in Chapter 4. Therefore, some of the outcomes in our study could be biased due to the self-report nature of the data. Third, information on the severity level of the participant with ASD within our studies was not well collected, given many participants had never received an evaluation of Autism Diagnostic Observation Schedule - Second Edition (ADOS-2; Lord et al., 2012) or Autism Diagnostic

Interview-Revised (ADI-R; Rutter et al., 2003), or they were not able to remember or find the scores from their medical history documents.

Conclusion

This dissertation focused on physical activity, parental perceived motor competence, and related family dynamics in children with ASD and conducted an online family-implemented PA intervention for children with ASD to promote these aspects. It suggests that having NT siblings serve as intervention agents is a viable option, based on both qualitative and quantitative findings from this dissertation. As supported by this dissertation, future PA intervention for children with ASD may use an online format to deliver the activity sessions at the family level, involving both parents and NT siblings as intervention agents to support the PA engagement and motor skill development in children with ASD.

Lessons Learned & Goals for the Continuation of Research Line

As the author and the investigator of all of the studies within this dissertation, I enjoyed this research journey working with children with ASD and their families. I am grateful for having the first-hand experience of getting to know more about the needs, happiness, and struggles of families who have a child with ASD. The major lesson that I have learned was the skillset for a researcher to conduct independent studies. The entire process of using a qualitative study to ask for stakeholders' input, collecting data on interested variables, and then designing and implementing the intervention to promote these target variables taught me how to develop research questions step-by-step and equipped me with skills to implement different study designs, which will be of great benefit for my future development as a scholar.

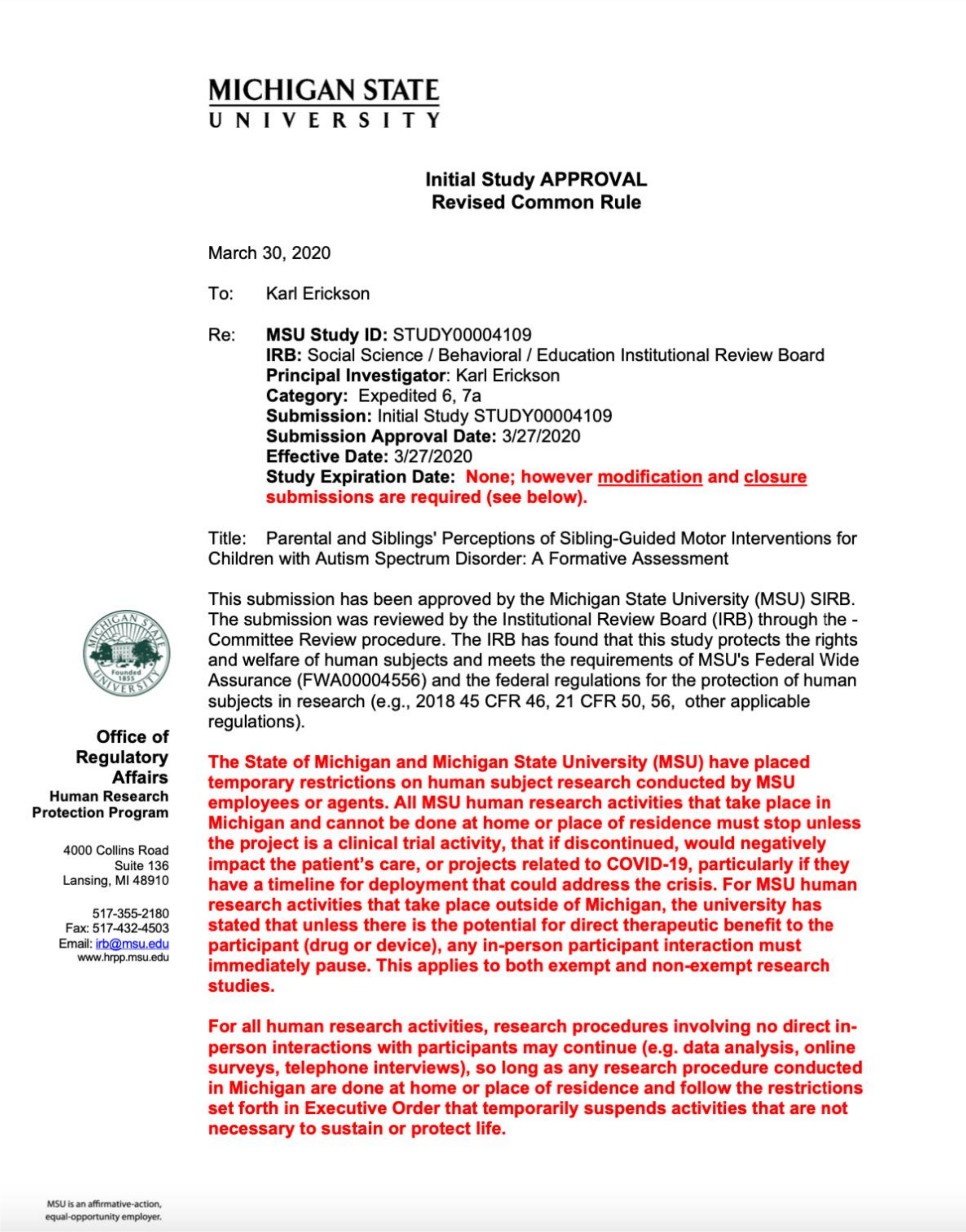
In addition, it taught me much more beyond research. For example, it educated me on the importance of hearing the family's voices about their philosophy in rearing their children. A family who was very interested in our PA intervention withdrew from our study after reviewing the study materials because they found the pre-training sessions involved elements of Applied Behavior Analysis (ABA), such as prompting and reinforcement. ABA is the most common behavioral therapy used in children with ASD. However, the parent stated, "*We do not believe that we have a responsibility to train our autistic daughter to appear 'less autistic', as ABA strives to do. We believe that those of us who are neurotypical have an obligation to understand and be comfortable in the autistic world, just like we ask autistic individuals to do in our neurotypical world*." Researchers in the field of ASD study should think about how to provide resources to families who do not accept behavioral approaches and help them select programs that will still meet their child's needs, as these families may be struggling with finding services for their children. Another helpful lesson that I learned from this dissertation was how important it is to give affirmation to the wonderful parents and siblings of children with ASD. They do a great job loving, caring, and supporting their child with ASD, unquestionably. Enjoyable and useful programs and services should be developed for them as well to help them solve problems that they may face living alongside a child with ASD.

I was fortunate to be able to complete these studies during the COVID-19 pandemic, the unprecedented difficult time, with the support from my mentor, dissertation committee, and the participated families. I believe that PA and motor interventions in the online format at the family level are an important and feasible approach that should be further developed for children with ASD and other developmental disabilities. To continue the research line, my goal is to conduct a larger-scale online PA intervention for children with ASD, nationwide or even worldwide. Regardless of the pandemic, an online approach can still be a viable option for those families who have difficulty traveling to the intervention centers and accessing PA resources.

APPENDIX

APPENDIX N: IRB Approval Letters

Chapter 1



MICHIGAN STATE
UNIVERSITY

Initial Study APPROVAL
Revised Common Rule

March 30, 2020

To: Karl Erickson

Re: **MSU Study ID:** STUDY00004109
IRB: Social Science / Behavioral / Education Institutional Review Board
Principal Investigator: Karl Erickson
Category: Expedited 6, 7a
Submission: Initial Study STUDY00004109
Submission Approval Date: 3/27/2020
Effective Date: 3/27/2020
Study Expiration Date: **None; however modification and closure submissions are required (see below).**

Title: Parental and Siblings' Perceptions of Sibling-Guided Motor Interventions for Children with Autism Spectrum Disorder: A Formative Assessment

This submission has been approved by the Michigan State University (MSU) SIRB. The submission was reviewed by the Institutional Review Board (IRB) through the - Committee Review procedure. The IRB has found that this study protects the rights and welfare of human subjects and meets the requirements of MSU's Federal Wide Assurance (FWA00004556) and the federal regulations for the protection of human subjects in research (e.g., 2018 45 CFR 46, 21 CFR 50, 56, other applicable regulations).

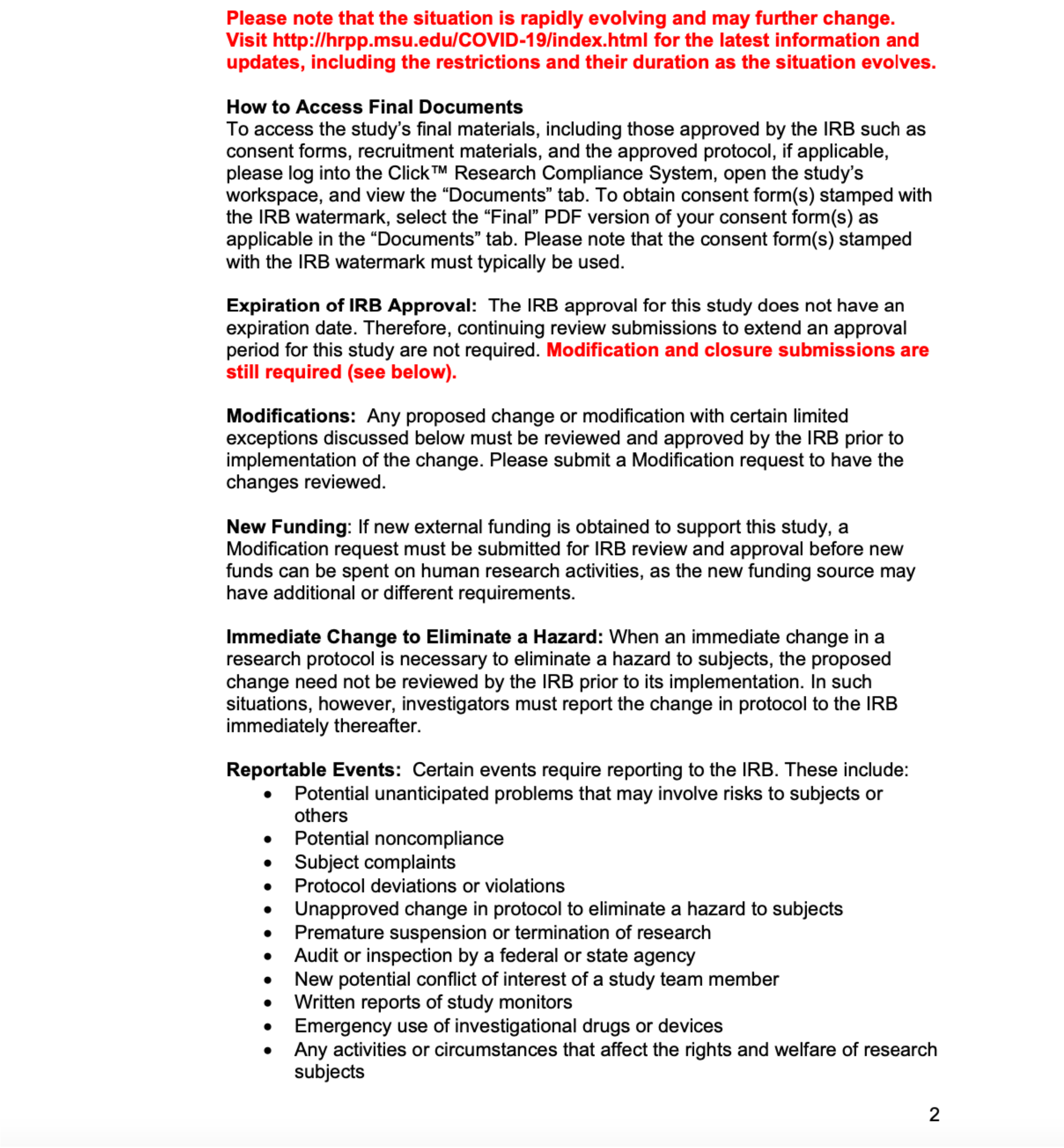
The State of Michigan and Michigan State University (MSU) have placed temporary restrictions on human subject research conducted by MSU employees or agents. All MSU human research activities that take place in Michigan and cannot be done at home or place of residence must stop unless the project is a clinical trial activity, that if discontinued, would negatively impact the patient's care, or projects related to COVID-19, particularly if they have a timeline for deployment that could address the crisis. For MSU human research activities that take place outside of Michigan, the university has stated that unless there is the potential for direct therapeutic benefit to the participant (drug or device), any in-person participant interaction must immediately pause. This applies to both exempt and non-exempt research studies.

For all human research activities, research procedures involving no direct in-person interactions with participants may continue (e.g. data analysis, online surveys, telephone interviews), so long as any research procedure conducted in Michigan are done at home or place of residence and follow the restrictions set forth in Executive Order that temporarily suspends activities that are not necessary to sustain or protect life.

Office of Regulatory Affairs
Human Research Protection Program

4000 Collins Road
Suite 136
Lansing, MI 48910

517-355-2180
Fax: 517-432-4503
Email: irb@msu.edu
www.hrpp.msu.edu



Please note that the situation is rapidly evolving and may further change. Visit http://hrpp.msu.edu/COVID-19/index.html for the latest information and updates, including the restrictions and their duration as the situation evolves.

How to Access Final Documents
To access the study's final materials, including those approved by the IRB such as consent forms, recruitment materials, and the approved protocol, if applicable, please log into the Click™ Research Compliance System, open the study's workspace, and view the "Documents" tab. To obtain consent form(s) stamped with the IRB watermark, select the "Final" PDF version of your consent form(s) as applicable in the "Documents" tab. Please note that the consent form(s) stamped with the IRB watermark must typically be used.

Expiration of IRB Approval: The IRB approval for this study does not have an expiration date. Therefore, continuing review submissions to extend an approval period for this study are not required. **Modification and closure submissions are still required (see below).**

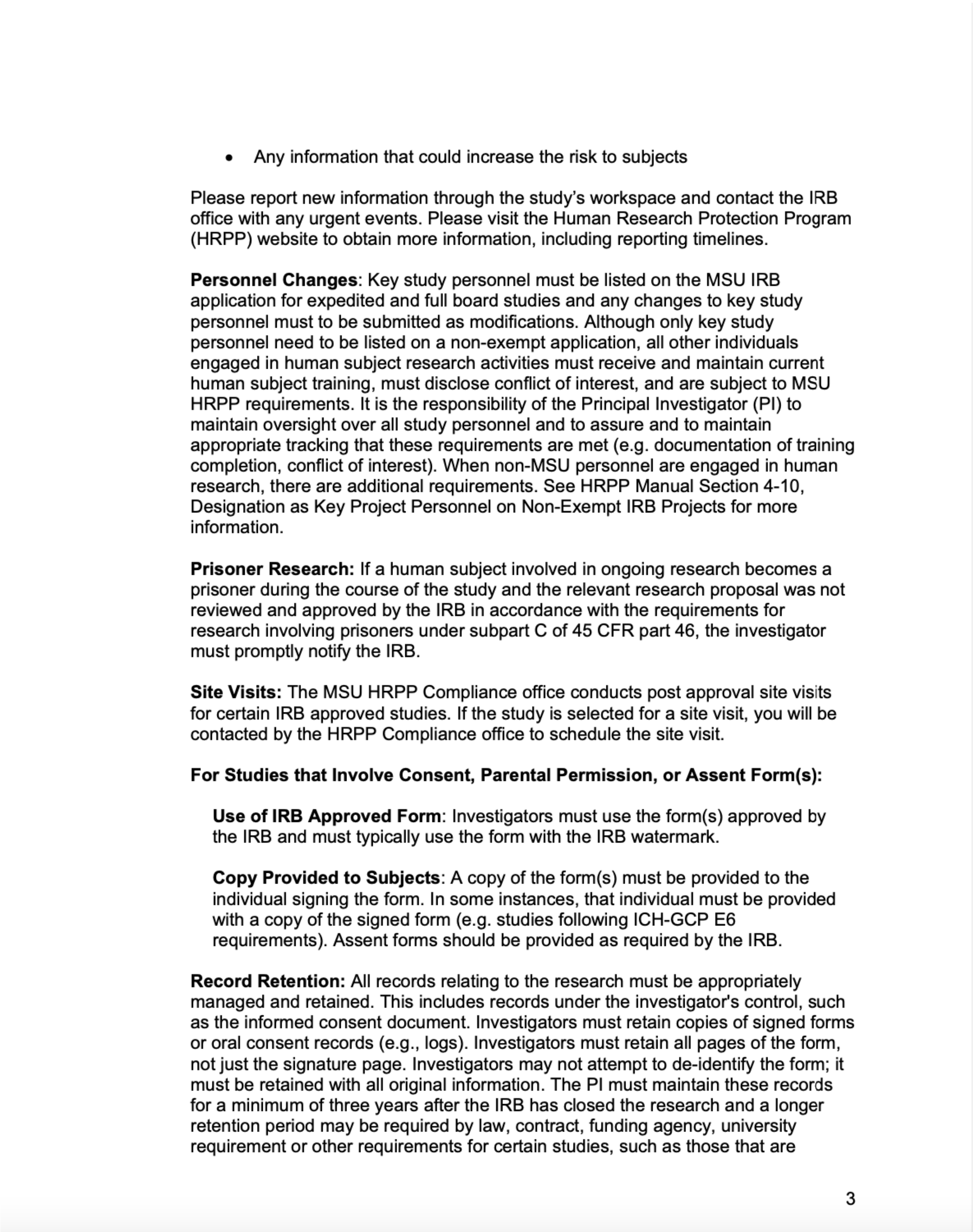
Modifications: Any proposed change or modification with certain limited exceptions discussed below must be reviewed and approved by the IRB prior to implementation of the change. Please submit a Modification request to have the changes reviewed.

New Funding: If new external funding is obtained to support this study, a Modification request must be submitted for IRB review and approval before new funds can be spent on human research activities, as the new funding source may have additional or different requirements.

Immediate Change to Eliminate a Hazard: When an immediate change in a research protocol is necessary to eliminate a hazard to subjects, the proposed change need not be reviewed by the IRB prior to its implementation. In such situations, however, investigators must report the change in protocol to the IRB immediately thereafter.

Reportable Events: Certain events require reporting to the IRB. These include:

- Potential unanticipated problems that may involve risks to subjects or others
- Potential noncompliance
- Subject complaints
- Protocol deviations or violations
- Unapproved change in protocol to eliminate a hazard to subjects
- Premature suspension or termination of research
- Audit or inspection by a federal or state agency
- New potential conflict of interest of a study team member
- Written reports of study monitors
- Emergency use of investigational drugs or devices
- Any activities or circumstances that affect the rights and welfare of research subjects



- Any information that could increase the risk to subjects

Please report new information through the study's workspace and contact the IRB office with any urgent events. Please visit the Human Research Protection Program (HRPP) website to obtain more information, including reporting timelines.

Personnel Changes: Key study personnel must be listed on the MSU IRB application for expedited and full board studies and any changes to key study personnel must to be submitted as modifications. Although only key study personnel need to be listed on a non-exempt application, all other individuals engaged in human subject research activities must receive and maintain current human subject training, must disclose conflict of interest, and are subject to MSU HRPP requirements. It is the responsibility of the Principal Investigator (PI) to maintain oversight over all study personnel and to assure and to maintain appropriate tracking that these requirements are met (e.g. documentation of training completion, conflict of interest). When non-MSU personnel are engaged in human research, there are additional requirements. See HRPP Manual Section 4-10, Designation as Key Project Personnel on Non-Exempt IRB Projects for more information.

Prisoner Research: If a human subject involved in ongoing research becomes a prisoner during the course of the study and the relevant research proposal was not reviewed and approved by the IRB in accordance with the requirements for research involving prisoners under subpart C of 45 CFR part 46, the investigator must promptly notify the IRB.

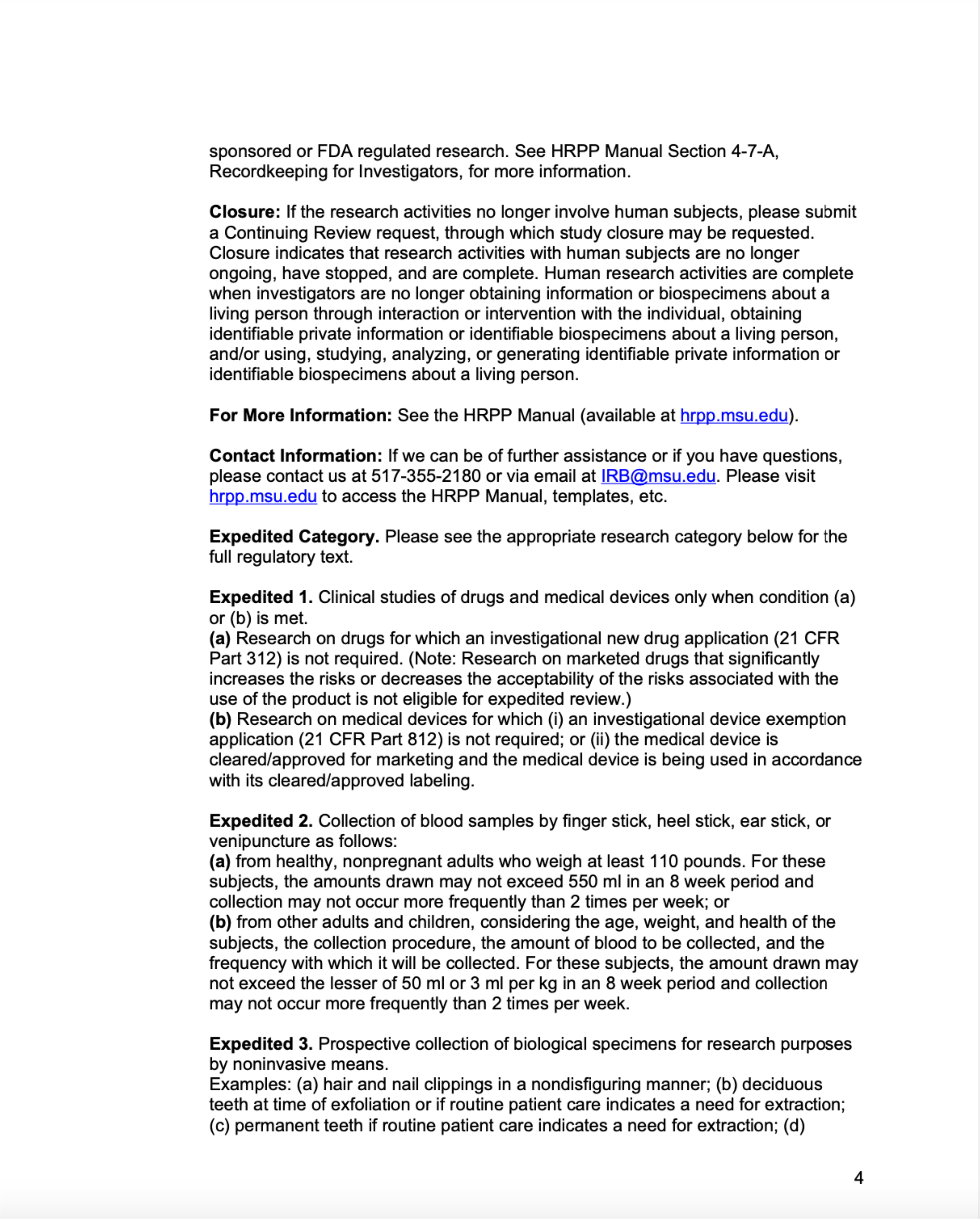
Site Visits: The MSU HRPP Compliance office conducts post approval site visits for certain IRB approved studies. If the study is selected for a site visit, you will be contacted by the HRPP Compliance office to schedule the site visit.

For Studies that Involve Consent, Parental Permission, or Assent Form(s):

Use of IRB Approved Form: Investigators must use the form(s) approved by the IRB and must typically use the form with the IRB watermark.

Copy Provided to Subjects: A copy of the form(s) must be provided to the individual signing the form. In some instances, that individual must be provided with a copy of the signed form (e.g. studies following ICH-GCP E6 requirements). Assent forms should be provided as required by the IRB.

Record Retention: All records relating to the research must be appropriately managed and retained. This includes records under the investigator's control, such as the informed consent document. Investigators must retain copies of signed forms or oral consent records (e.g., logs). Investigators must retain all pages of the form, not just the signature page. Investigators may not attempt to de-identify the form; it must be retained with all original information. The PI must maintain these records for a minimum of three years after the IRB has closed the research and a longer retention period may be required by law, contract, funding agency, university requirement or other requirements for certain studies, such as those that are



sponsored or FDA regulated research. See HRPP Manual Section 4-7-A, Recordkeeping for Investigators, for more information.

Closure: If the research activities no longer involve human subjects, please submit a Continuing Review request, through which study closure may be requested. Closure indicates that research activities with human subjects are no longer ongoing, have stopped, and are complete. Human research activities are complete when investigators are no longer obtaining information or biospecimens about a living person through interaction or intervention with the individual, obtaining identifiable private information or identifiable biospecimens about a living person, and/or using, studying, analyzing, or generating identifiable private information or identifiable biospecimens about a living person.

For More Information: See the HRPP Manual (available at hrpp.msu.edu).

Contact Information: If we can be of further assistance or if you have questions, please contact us at 517-355-2180 or via email at IRB@msu.edu. Please visit hrpp.msu.edu to access the HRPP Manual, templates, etc.

Expedited Category. Please see the appropriate research category below for the full regulatory text.

Expedited 1. Clinical studies of drugs and medical devices only when condition (a) or (b) is met.
(a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review.)
(b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

Expedited 2. Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows:
(a) from healthy, nonpregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or
(b) from other adults and children, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

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Examples: (a) hair and nail clippings in a nondisfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d)

excreta and external secretions (including sweat); (e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.

Expedited 4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.) Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

Expedited 5. Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis). (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.)

Expedited 6. Collection of data from voice, video, digital, or image recordings made for research purposes.

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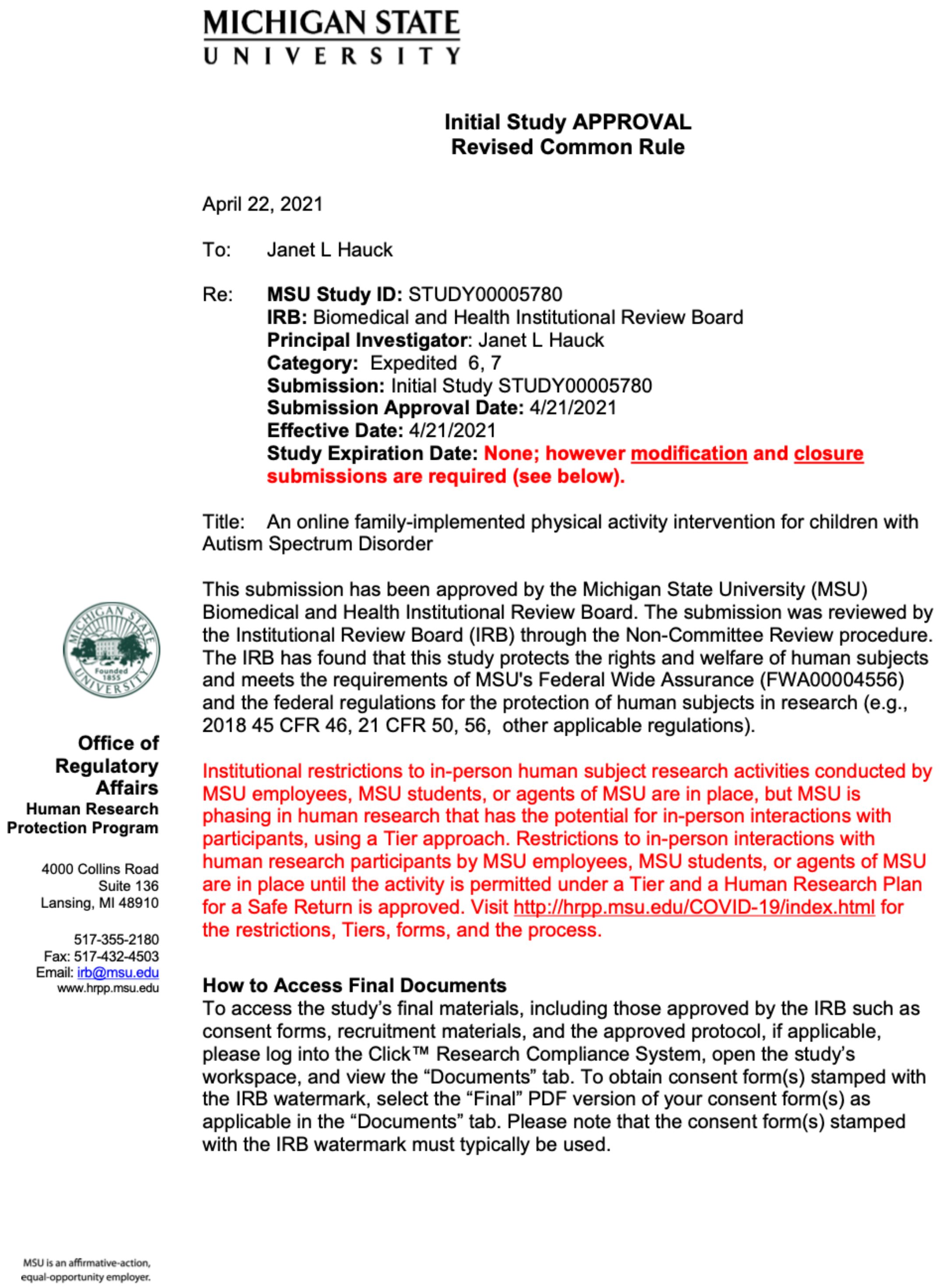
(a) where (i) the research is permanently closed to the enrollment of new subjects; (ii) all subjects have completed all research-related interventions; and (iii) the research remains active only for long-term follow-up of subjects; or
(b) where no subjects have been enrolled and no additional risks have been identified; or
(c) where the remaining research activities are limited to data analysis.

Expedited 9. Continuing review of research, not conducted under an investigational new drug application or investigational device exemption where categories two (2) through eight (8) do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified.

Chapter 2 and 3



MICHIGAN STATE
UNIVERSITY

Office of Regulatory Affairs
Human Research Protection Program

4000 Collins Road
Suite 136
Lansing, MI 48910

517-355-2180
Fax: 517-432-4503
Email: irb@msu.edu
www.hrpp.msu.edu

Initial Study APPROVAL
Revised Common Rule

April 22, 2021

To: Janet L Hauck

Re: **MSU Study ID:** STUDY00005780
IRB: Biomedical and Health Institutional Review Board
Principal Investigator: Janet L Hauck
Category: Expedited 6, 7
Submission: Initial Study STUDY00005780
Submission Approval Date: 4/21/2021
Effective Date: 4/21/2021
Study Expiration Date: None; however modification and closure submissions are required (see below).

Title: An online family-implemented physical activity intervention for children with Autism Spectrum Disorder

This submission has been approved by the Michigan State University (MSU) Biomedical and Health Institutional Review Board. The submission was reviewed by the Institutional Review Board (IRB) through the Non-Committee Review procedure. The IRB has found that this study protects the rights and welfare of human subjects and meets the requirements of MSU's Federal Wide Assurance (FWA00004556) and the federal regulations for the protection of human subjects in research (e.g., 2018 45 CFR 46, 21 CFR 50, 56, other applicable regulations).

Institutional restrictions to in-person human subject research activities conducted by MSU employees, MSU students, or agents of MSU are in place, but MSU is phasing in human research that has the potential for in-person interactions with participants, using a Tier approach. Restrictions to in-person interactions with human research participants by MSU employees, MSU students, or agents of MSU are in place until the activity is permitted under a Tier and a Human Research Plan for a Safe Return is approved. Visit http://hrpp.msu.edu/COVID-19/index.html for the restrictions, Tiers, forms, and the process.

How to Access Final Documents
To access the study's final materials, including those approved by the IRB such as consent forms, recruitment materials, and the approved protocol, if applicable, please log into the Click™ Research Compliance System, open the study's workspace, and view the "Documents" tab. To obtain consent form(s) stamped with the IRB watermark, select the "Final" PDF version of your consent form(s) as applicable in the "Documents" tab. Please note that the consent form(s) stamped with the IRB watermark must typically be used.

Expiration of IRB Approval: The IRB approval for this study does not have an expiration date. Therefore, continuing review submissions to extend an approval period for this study are not required. **Modification and closure submissions are still required (see below).**

Modifications: Any proposed change or modification with certain limited exceptions discussed below must be reviewed and approved by the IRB prior to implementation of the change. Please submit a Modification request to have the changes reviewed.

New Funding: If new external funding is obtained to support this study, a Modification request must be submitted for IRB review and approval before new funds can be spent on human research activities, as the new funding source may have additional or different requirements.

Immediate Change to Eliminate a Hazard: When an immediate change in a research protocol is necessary to eliminate a hazard to subjects, the proposed change need not be reviewed by the IRB prior to its implementation. In such situations, however, investigators must report the change in protocol to the IRB immediately thereafter.

Reportable Events: Certain events require reporting to the IRB. These include:

- Potential unanticipated problems that may involve risks to subjects or others
- Potential noncompliance
- Subject complaints
- Protocol deviations or violations
- Unapproved change in protocol to eliminate a hazard to subjects
- Premature suspension or termination of research
- Audit or inspection by a federal or state agency
- New potential conflict of interest of a study team member
- Written reports of study monitors
- Emergency use of investigational drugs or devices
- Any activities or circumstances that affect the rights and welfare of research subjects
- Any information that could increase the risk to subjects

Please report new information through the study's workspace and contact the IRB office with any urgent events. Please visit the Human Research Protection Program (HRPP) website to obtain more information, including reporting timelines.

Personnel Changes: Key study personnel must be listed on the MSU IRB application for expedited and full board studies and any changes to key study personnel must to be submitted as modifications. Although only key study personnel need to be listed on a non-exempt application, all other individuals engaged in human subject research activities must receive and maintain current human subject training, must disclose conflict of interest, and are subject to MSU HRPP requirements. It is the responsibility of the Principal Investigator (PI) to maintain oversight over all study personnel and to assure and to maintain appropriate tracking that these requirements are met (e.g. documentation of training completion, conflict of interest). When non-MSU personnel are engaged in human research, there are additional requirements. See HRPP Manual Section 4-10, Designation as Key Project Personnel on Non-Exempt IRB Projects for more information.

Prisoner Research: If a human subject involved in ongoing research becomes a prisoner during the course of the study and the relevant research proposal was not reviewed and approved by the IRB in accordance with the requirements for research involving prisoners under subpart C of 45 CFR part 46, the investigator must promptly notify the IRB.

Site Visits: The MSU HRPP Compliance office conducts post approval site visits for certain IRB approved studies. If the study is selected for a site visit, you will be contacted by the HRPP Compliance office to schedule the site visit.

For Studies that Involve Consent, Parental Permission, or Assent Form(s):

Use of IRB Approved Form: Investigators must use the form(s) approved by the IRB and must typically use the form with the IRB watermark.

Copy Provided to Subjects: A copy of the form(s) must be provided to the individual signing the form. In some instances, that individual must be provided with a copy of the signed form (e.g. studies following ICH-GCP E6 requirements). Assent forms should be provided as required by the IRB.

Record Retention: All records relating to the research must be appropriately managed and retained. This includes records under the investigator's control, such as the informed consent document. Investigators must retain copies of signed forms or oral consent records (e.g., logs). Investigators must retain all pages of the form, not just the signature page. Investigators may not attempt to de-identify the form; it must be retained with all original information. The PI must maintain these records for a minimum of three years after the IRB has closed the research and a longer retention period may be required by law, contract, funding agency, university requirement or other requirements for certain studies, such as those that are sponsored or FDA regulated research. See HRPP Manual Section 4-7-A, Recordkeeping for Investigators, for more information.

Closure: If the research activities no longer involve human subjects, please submit a Continuing Review request, through which study closure may be requested. Closure indicates that research activities with human subjects are no longer ongoing, have stopped, and are complete. Human research activities are complete when investigators are no longer obtaining information or biospecimens about a living person through interaction or intervention with the individual, obtaining identifiable private information or identifiable biospecimens about a living person, and/or using, studying, analyzing, or generating identifiable private information or identifiable biospecimens about a living person.

For More Information: See the HRPP Manual (available at hrpp.msu.edu).

Contact Information: If we can be of further assistance or if you have questions, please contact us at 517-355-2180 or via email at IRB@msu.edu. Please visit hrpp.msu.edu to access the HRPP Manual, templates, etc.

Expedited Category. Please see the appropriate research category below for the full regulatory text.

Expedited 1. Clinical studies of drugs and medical devices only when condition (a) or (b) is met.
(a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review.)
(b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

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