OBJECTIVELY MEASURED PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR IN CHILDREN WITH AUTISM SPECTRUM DISORDER

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Low levels of physical activity and high levels of sedentary behavior are of public health concern in children. However, little is known about the patterns of physical activity and sedentary behavior in 6-11-year-old children with autism spectrum disorder (ASD). PURPOSE: To examine patterns of physical activity and sedentary behavior in children with ASD. To examine relationships between moderate-to-vigorous physical activity (MVPA) and sedentary behavior and potential determinants of these behaviors. METHODS: Nineteen children 6-11-year-olds with ASD were recruited. Height and weight were objectively measured and used to determine BMI for age, and participants wore an ActiGraph GT3X activity monitor for 7 consecutive days to measure physical activity and sedentary time. Parents answered questions on demographics, perceptions of physical activity, barriers to child's physical activity, child's autism severity, and functional disability. RESULTS: Fifty percent of children achieved the guidelines for physical activity in children. Participants spent on average 76 ± 48 minutes per day engaged in MVPA, and 332 ± 65 minutes per day sedentary. There no differences between weekday and weekend MVPA, nor weekday and weekend sedentary time. Twelve participants were classified as normal weight, 4 participants were classified as overweight, and 3 participants were classified as obese.

There were no differences between prevalence rates of overweight or obesity in our sample compared to national averages. No relationships were found between MVPA and sedentary time and any independent variables examined. However, qualitatively, the most common parent-reported barriers to children's physical activity were child's lack of interest, inadequate community physical activity programs, behavioral problems, not being able to find a community program that accommodates their child's physical disability, and child is too developmentally disabled. CONCLUSIONS: Findings suggest that barriers commonly reported by parents of children with ASD may serve as targets for creating physical activity programs adapted for this population. Further, over 90% of participants wore the monitor over 12 hours on 7 days. Thus, these findings suggest that an activity monitor worn around the waist for one week is a feasible option for the measurement of physical activity and sedentary behavior in this population.

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PREFACE

I would first like to thank my advisors, Dr. John Jakicic, and Dr. Bethany Gibbs for their teaching, support, guidance, and encouragement over the past several years. Both have selflessly invested their time and energy to make me into a better scientist and teacher. I have been offered countless opportunities to grow and learn over the years and they have believed in me when sometimes I had no belief in myself. I can only hope to be able to one day continue to follow in their example with students of my own.

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1.0 INTRODUCTION

Autism Spectrum Disorders (ASD) are a range of complex developmental/neurological disorders which affect the function of the brain and have a prevalence of 1 in 68 children [1]. The diagnostic characteristics for ASD include impaired social interaction, communication deficits, and stereotypic behaviors [1]. In addition to these characteristics, individuals with ASD may display deficits in motor proficiency, lack of engagement in daily living activities, and lack of motivation for engaging in beneficial physical activity [2-4]. Despite the low engagement and barriers, physical activity has been shown to be beneficial to those with ASD. Specifically, physical activity has been shown to decrease negative behaviors such as stereotypy, aggression, and self-stimulatory behavior [5-8]. In addition to the benefits to these behaviors, regular physical activity is also positively associated with health benefits throughout life including decreased risk of developing cardiovascular disease, type 2 diabetes, obesity, and premature death [9]. Cross-sectional research has shown that there are significant disparities in obesity and physical activity levels in children and adolescents with ASD compared to their typically developing peers [10-15]. Thus, a greater understanding of physical activity patterns and obesity is needed to inform future research and programs in this population.

1.1 AUTISM SPECTRUM DISORDERS

ASDs consist of a group of developmental disorders with symptoms seen on a continuum ranging from mild to severe. Though ASD has an onset early in life, ASD may not be diagnosed until later in life due to compensation of deficits by parents or caregivers, delay in acknowledgement by parents or caregivers of symptoms, or that the presentation of symptoms may become more readily apparent later in childhood and adolescence when social interaction becomes more demanding [16]. Little is known about the causes of ASD, though some risk factors for the development of ASD include genetics, gender, and advanced age of parents [17, 18]. It is estimated that the cost to families of children with ASD is $3-5 million dollars more than the average lifetime cost of raising a typically developing child, and the estimated societal cost has been estimated at $90 billion per year [18, 19]. A child with ASD can incur 2.5 times more outpatient costs, 2.9 times more inpatient costs, and 7.6 times more in medication costs compared to a typically developing child [19]. Physiologically, children and adolescents with ASD display lower levels of physical fitness such as cardiovascular endurance, upper-body muscular strength and endurance, and lower-body flexibility. Children and adolescents with ASD also perform significantly poorer on tests of motor proficiency compared to those without ASD [20, 21].

1.1.1 Current Treatments for ASD

There are currently no disease-modifying treatments for ASD. Instead, treatments for ASD center on the management of symptoms. There are currently two pharmacotherapies for children and adolescents with ASD: risperidone and aripiprazole [17]. Both of these medications are atypical antipsychotics and used for the management of irritability symptoms present in children and adolescents aged 5-17 years in the United States with ASD. These medications are also used for the treatment of schizophrenia in those aged 13 years and older and bipolar disorder in those aged 10 years and older [17, 22, 23]. These atypical antipsychotics are dopamine D_2 and serotonin 5-HT (5-hydroxytryptamine)2_A receptor antagonists, that work by significantly inhibiting dopamine and serotonin [24]. Levels of serotonin have been shown to be increased in individuals with ASD, and atypical antipsychotics routinely prescribed have been shown to help manage some of the behaviors associated with ASD [25].

However, pharmacotherapies are not the foundation of ASD management but are usually used in conjunction with behavioral counseling. These interventions typically include behavioral strategies and are used to address communication, social skills, daily-living skills, play and leisure skills, academic achievement, and maladaptive behaviors [26]. Common educational interventions include specific strategies such as Applied Behavior Analysis (ABA), structured teaching, developmental models, speech and language therapy, social skills instruction, occupational therapy, and sensory integration therapy [26].

1.1.2 Physical Activity Interventions in ASD

Physical activity has been gaining popularity as an intervention to improve outcomes for children and adolescents with ASD [8, 27, 28]. Regulation of serotonin and dopamine via exercise may be possible, however, the mechanism of action for the effect of physical activity on children and adolescents with ASD is unknown. Intervention studies including walking, jogging, aquatics, horseback riding, bicycle riding, and outdoor activities in children and adolescents with ASD have reported improved outcomes. Improved outcomes include reduced stereotypy, reduced self-stimulatory behavior, reduced aggression and self-injury, and reduced classroom disruptive behaviors [5-7, 29-31]. Also, improvements in academics have been reported such as increased responses to academic demands and questions and increased accuracy when performing academic tasks [32]. Additionally, physical activity has yielded improvements in health parameters such as body mass index (BMI) and cardiorespiratory fitness in children with ASD [33-36].

1.2 PHYSICAL ACTIVITY, OBESITY, AND HEALTH

There is a positive association between physical activity and health outcomes throughout life [37]. In adults, regular physical activity has been shown to decrease the risk of developing chronic diseases such as cardiovascular disease, obesity, type II diabetes, certain types of cancer (breast and colon), and depression [9, 38]. For example, large prospective investigations have shown that inactive women have almost double the risk of developing risk factors such as hypertension, hypercholesterolemia, and obesity. In addition, inactive women have approximately double the relative risk for all-cause mortality and cardiovascular mortality, as well as a 29% increase in cancer-related mortality [38, 39]. In children and adolescents, the benefits of moderate-to-vigorous physical activity (MVPA) include improvements in cardiovascular health, improved fitness, improved metabolic health, and decreased obesity [40, 41].

1.2.1 Physical Activity in Children and Adolescents

The recommendation for physical activity in children and adolescents is 60 minutes or more of moderate-to-vigorous physical activity (MVPA) each day, with at least 3 days with 30 minutes of vigorous aerobic activity incorporated into the 60 minutes or more, and at least 3 days with 30 minutes of bone- and muscle-strengthening activities incorporated into the 60 minutes or more [40, 42]. Nationwide, approximately one quarter of children and adolescents aged 5-15 years met the recommendation of 60 minutes or more of physical activity on at least 5 days per week [43, 44].

The prevalence of meeting the physical activity guidelines varies by demographic characteristics such as gender, age, race, and socioeconomic status [44-50]. There is a significant inverse relationship between age and physical activity; the prevalence of meeting the recommendation is lower in adolescents aged 12-19 than in children aged 6-11 years [43, 44, 46-48, 51, 52]. Nationally, among 6-11 year olds, 42% meet current recommendations while, among 12-15 year olds, only 8% meet the recommendation [44]. More boys than girls meet the recommendation for physical activity [44, 45, 48, 49, 51, 53, 54]. Even children as young as 6-11 years show gender differences with 48% of boys meeting the current recommendation vs. 35% of girls [44]. Though the gender differences in physical activity are slightly smaller when looking at accelerometer data vs. self-reported data [48], studies employing objective measures still show that boys are more active during the school day, in the evening, and on weekend days [48, 53, 55, 56]. Differences in physical activity have also been observed by race, but these differences are inconsistent. Some studies show that nonwhite children and adolescents are more physically active than their white counterparts [43, 57], while others show that non-Hispanic whites are more active than their black and Hispanic counterparts [45-47, 55].

There are limited studies on physical activity in children and adolescents with ASD, though a handful of cross-sectional studies suggest that children and adolescents with ASD engage in significantly less MVPA than their typically developing peers and a smaller percentage meet the current recommendation [13, 15, 58]. The inverse associations between physical activity and age has also been seen in this population [14, 59, 60]. Also, as ASD severity increases, the odds of engaging in regular physical activity by parent-report significantly decreases [61]. Limitations exist in the current published studies including small sample sizes, use of self-reported physical activity, the exclusion of children and adolescents with ASD due to the use of medications, and decreased generalizability of studies conducted outside of the United States.

1.2.2 Sedentary Behavior in Children and Adolescents

Sedentary behavior is linked to reduced overall physical activity, decreased cardiovascular health profiles, and higher levels of obesity [41]. However, there are no guidelines for total sedentary behavior in children and adolescents. The American Academy of Pediatrics recommends that children and adolescents limit leisure "screen time" (television viewing, computer and video game usage) to less than 2 hours per day [62]. A little over half (53.5%) of American children meet this recommendation for screen time. More Hispanic children (61.7%) met the recommendation than non-Hispanic white children (55.4%), and only 36.7% of non-Hispanic black children met the recommendation [43, 50]. There are also age disparities in meeting the recommendation for daily screen time. Children aged 6-8 (via parent-report) meet the guideline more frequently compared to those aged 9-11 as well as high school students 14-17 years of age [47, 50].

Research on sedentary behaviors in youth with ASD is extremely limited. Cross-sectional studies using parent-reported “screen time” show that children 3-11 with ASD engage in an additional hour of screen time compared to their typically developing peers [63]. Objectively measured sedentary behavior has not been reported in the literature in children aged 6-11 with ASD.

1.2.3 Obesity in Children and Adolescents

In 2011-2012, it was estimated that 31.8% of youth were either overweight or obese, with 16.9% of youth obese. Among 6-11 year olds specifically, 34.2% were overweight or obese and 17.7% were obese [64]. The prevalence of obesity was higher among Hispanic and non-Hispanic black youth, compared to non-Hispanic whites. In addition, obesity is higher among children and adolescents aged 6-19 years of age compared to those aged 2-5 years [64]. Children and adolescents with ASD are at increased risk for obesity compared to their typically developing peers; children with ASD are 40% more likely to be obese [10, 12, 65].

Childhood obesity is associated with increased risk for developing cardiovascular risk factors, type II diabetes, and orthopedic problems [66]. Children who are overweight or obese throughout childhood are more likely to remain obese throughout adulthood [67], resulting in an increased risk for developing chronic conditions. In addition to the physiological consequences of obesity, there are also psychological consequences of childhood obesity including social stigmatization, poor body image, poor self-esteem, social isolation, and peer victimization [68-72]. Children are more likely to discriminate against children with social handicaps such as obesity compared to physical handicaps [72]. This social stigmatization may start at an early age, with evidence showing that children as young as preschool have negative views of their overweight peers [73].

1.3 PARENT-REPORTED BARRIERS TO PHYSICAL ACTIVITY

Parents play an important role in the development of children's health behaviors and, therefore, can play an important role in encouraging children to engage in physical activity. This is done by establishing or eliminating barriers or by providing resources to engage in the behavior [74, 75]. A review of parental perceptions regarding healthy behaviors for young children by Pocock, et al., (2010) [76] found that common barriers identified by parents for encouraging healthy behaviors include: parent tiredness leading to lack of motivation for physical activity, cost of physical activities, society encourages sedentary behaviors, lack of parent awareness about how much sedentary behavior is occurring, parents not acting as good role models, difficultly giving attention to one child in multiple children households, and environmental factors such as neighborhood safety or lack of access. In addition, parents also report that their child's own resistance to engaging in physical activity and preference for sedentary behaviors makes it more difficult to get their child active [76].

Child illness or disability which prevents physical activity has also been listed as a barrier to engagement in physical activity in the general population [76], and lack of time, lack of programs designed for physical disability, and child lack of interest/motivation have been reported by parents of children with special needs [77]. However, there is a lack of research on the perceived barriers for child engagement on physical activity specific to the parents of children and adolescents with ASD.

In the general population, perceived importance of physical activity is associated with parental support of physical activity, and parental support is in turn positively associated with physical activity in children [75] In addition, parental beliefs regarding physical activity are associated with children's participation in MVPA [78, 79]. However, it is unclear if parents of children with ASD perceive physical activity to be of benefit to their child or if parents know the recommendations for physical activity and leisure screen time.

1.4 PHYSICAL ACTIVITY MEASUREMENT IN CHILDREN

Objective methods for measuring physical activity in youth include direct observation, doubly labeled water, indirect calorimetry, heart rate monitors, and motion sensors (pedometers, accelerometers). Participantive methods include self-report questionnaires, interviewer-administered questionnaires, proxy reports, and diaries [80]. Criterion standards for the measurement of physical activity in youth are direct observation, doubly labeled water, and indirect calorimetry, though the most practical approach to measurement of physical activity in youth is direct observation [80].

Accelerometers, a type of motion sensor, are a commonly used and accurate objective measurement tool for physical activity in children and adolescents. Accelerometers are small, lightweight, and able to provide time-stamped, minute-by-minute data on the frequency, intensity and duration of free-living physical activity. Acceleration signals from the accelerometer are digitized and a "count" value per pre-set time interval (epoch) is obtained which corresponds to the magnitude of the acceleration [81].

The use of accelerometers has been validated in numerous studies in children and adolescents against criterion measures such as direct observation and indirect calorimetry [82-93]. However, different count cut-point values have been suggested to define intensity ranges for physical activity (sedentary, light, moderate, vigorous), which can make it hard to quantify physical activity behavior and compare across studies [81, 83, 87, 88, 94, 95].

1.5 GAPS IN THE LITERATURE

Although there have been some cross-sectional studies with nationally representative samples on physical activity and sedentary behaviors in children and adolescents with ASD, there are gaps in the literature that we will address with this dissertation. Studies of physical activity using nationally representative data in children and adolescents with ASD use self- or parent-report of physical activity [96]. Only three studies in the United States have used objective physical activity monitoring [13, 58, 59]. No published studies have examined total sedentary behavior using accelerometry in children aged 6-11 with ASD, with the current literature only reporting parent-reported screen time (which is a proxy for sedentary behavior) [63, 96]. Studies using accelerometers have not measured other potential determinants of physical activity and sedentary behavior such as objective height and weight, barriers to physical activity, ASD severity, and physical function [13, 58, 59].

As shown in Figure 1, this study is designed to objectively measure physical activity and sedentary behavior in children with ASD. Further, relationships between physical activity and sedentary behavior and BMI will be explored. Lastly, the associations between objectively measured physical activity and sedentary behavior and demographic characteristics, ASD severity, perceived barriers for engaging in physical activity, and functional disability will be examined.

This dissertation will add to the literature by informing researchers, decision makers, clinicians, and care-givers of objectively measured physical activity and sedentary behaviors in children with ASD. In addition, we will explore the determinants of physical activity and sedentary behaviors specific for children with ASD. This information could inform the development of physical activity programs for children with ASD. Additionally, identifying barriers for engaging in physical activity may help clinicians and researchers develop programs for these children to improve physical activity and decrease sedentary behaviors.

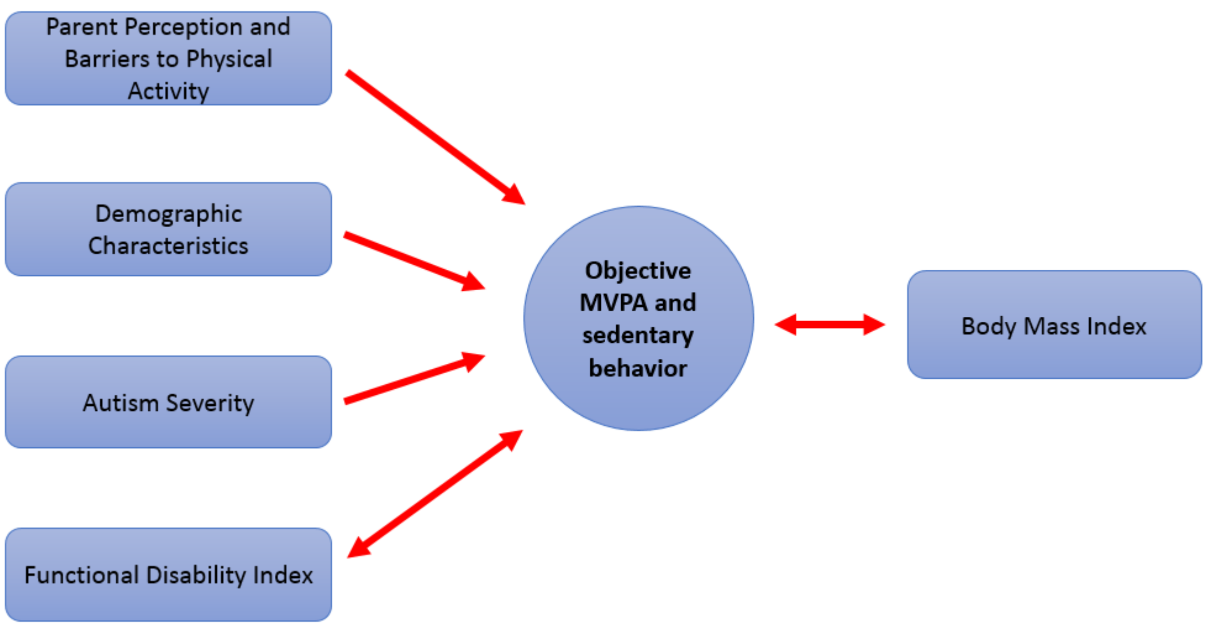

Figure 1. Theoretical Rationale

1.6 SPECIFIC AIMS

1. To examine objectively measured MVPA and sedentary behaviors in children aged 6-11 with ASD.
    a. To quantify time spent in MVPA and sedentary behavior overall and during weekdays, and weekends.
    b. To examine if children aged 6-11 years with ASD meet current recommendations for aerobic physical activity for children and adolescents.
2. To examine body mass index in children aged 6-11 years with ASD.
    a. To describe the prevalence of overweight and obesity in our sample.
    b. To compare MVPA and sedentary behavior across BMI categories.
3. To examine whether the following factors are associated with MVPA and sedentary behavior in children 6-11 years with ASD.
    a. Demographic characteristics: age, gender, and socioeconomic status (highest reported parental education, household income, and educational setting).
    b. ASD severity
    c. Parent-reported barriers to their child engaging in physical activity.
    d. Parent perceptions of physical activity
    e. Functional Disability Index Score

1.7 HYPOTHESES

- Descriptive analyses will report time spent in MVPA and sedentary behavior in children aged 6-11 with ASD (no hypotheses).
  - o A lower percentage of children in our sample (6-11 year olds with ASD) will meet the current Federal recommendation of 60 minutes or more of daily physical activity compared to the population estimate of 42% from the United States' 2014 Report Card on Physical Activity [43].
  - o Children aged 6-11 years with ASD will display lower MVPA and higher sedentary behavior on weekdays compared to weekend days.
- Describe the prevalence of overweight and obesity in our sample of children aged 6-11 years with ASD.
  - o Prevalence of overweight and obesity will be higher in our sample compared to population estimates for 6-11 year olds (34.2% overweight, and 17.7% obese) from 2011-2012 National Health and Nutrition Examination Survey (NHANES) [64].
  - o MVPA will be lower across increasing categories of BMI.
  - o Sedentary behavior will be higher across increasing categories of BMI.
- We hypothesize that the following variables will be associated with MVPA and sedentary behavior in children aged 6-11 with ASD.
  - o Higher age will be related to less MVPA and more sedentary behavior.
  - o Higher socioeconomic status will be related to higher MVPA and lower sedentary behavior.
  - o Higher ASD severity will be associated with lower MVPA and higher sedentary behavior.

- Lower MVPA and higher sedentary behavior will be related to individual parent-reported barriers to physical activity.
- Higher MVPA and lower sedentary behavior will be related to parent perceptions of physical activity.
- Higher Functional Disability Inventory Score will be associated with lower MVPA and higher sedentary behavior.

2.0 REVIEW OF THE LITERATURE

2.1 AUTISM SPECTRUM DISORDERS

ASDs consist of a group of developmental disorders with symptoms seen on a continuum ranging from mild to severe. ASDs are typically defined by symptoms such as communication deficits and social interaction, as well as restricted interests and repetitive behaviors [17]. The diagnostic characteristics for ASD are shown in Table 1. The exact causes of ASD are unknown, however some risk factors that make a child more likely to have ASD include genetics, siblings with an ASD, gender, advanced age of parents, as well as problems during birth such as oxygen deprivation [17, 18, 97-100]. However, there is currently no clinical biomarker or biological test to diagnose [17, 18].

Table 1. DSM-V Criteria for 299.0 Autism Spectrum Disorder

A. Persistent deficits in social communication and social interaction across multiple contexts, as manifested by the following, currently or by history (examples are illustrative, not exhaustive). 1. Deficits in social-emotional reciprocity, ranging, for example, from abnormal social approach and failure of normal back-and-forth conversation; to reduced sharing of interests, emotions, or affect; to failure to initiate or respond to social interactions. 2. Deficits in nonverbal communicative behaviors used for social interaction, ranging, for example, from poorly integrated verbal and nonverbal communication; to abnormalities in eye contact and body language or deficits in understanding and use of gestures; to a total lack of facial expressions and nonverbal communication. 3. Deficits in developing, maintaining, and understanding relationships, ranging, for example, from difficulties adjusting behavior to suit various social contexts; to difficulties in sharing imaginative play or in making friends; to absence of interest in peers. **Severity is based on social communication impairments and restricted repetitive patterns of behavior**
B. Restricted, repetitive patterns of behavior, interests, or activities, as manifested by at least two of the following, currently or by history (examples are illustrative, not exhaustive) 1. Stereotyped or repetitive motor movements, use of objects, or speech (e.g., simple motor stereotypies, lining up toys or flipping objects, echolalia, idiosyncratic phrases). 2. Insistence on sameness, inflexible adherence to routines, or ritualized patterns or verbal nonverbal behavior (e.g., extreme distress at small changes, difficulties with transitions, rigid thinking patterns, greeting rituals, need to take same route or eat food every day). 3. Highly restricted, fixated interests that are abnormal in intensity or focus (e.g, strong attachment to or preoccupation with unusual objects, excessively circumscribed or perseverative interest). 4. Hyper- or hyporeactivity to sensory input or unusual interests in sensory aspects of the environment (e.g., apparent indifference to pain/temperature, adverse response to specific sounds or textures, excessive smelling or touching of objects, visual fascination with lights or movement). **Severity is based on social communication impairments and restricted, repetitive patterns of behavior**
C. Symptoms must be present in the early developmental period (but may not become fully manifest until social demands exceed limited capacities, or may be masked by learned strategies in later life).
D. Symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning.
E. These disturbances are not better explained by intellectual disability (intellectual developmental disorder) or global developmental delay. Intellectual disability and autism spectrum disorder frequently co-occur; to make comorbid diagnoses of autism spectrum disorder and intellectual disability, social communication should be below that expected for general developmental level.

Currently, 1 in 68 children and adolescents are affected by ASD. This is a 10-fold increase in the past 40 years, which is only partially explained by recent changes in diagnostic criteria and increased awareness of the disorder [1]. A study examining ASD prevalence in seven major countries (United States, Japan, France, Germany, Italy, Spain, and the United Kingdom) by Nightengale et al. (2012) stated that there were 6.6 million cases of ASD in 2011, and that the prevalence is estimated to increase to 6.8 million cases by 2021 [17]. ASD is considered a lifelong condition that begins in childhood and affects an individual into adulthood [101]. Though the onset of ASD is early in life, it may not be diagnosed until later in life due to compensation of deficits by parents or caregivers, delay in acknowledgement by parents or caregivers of symptoms, or because the presentation of symptoms may become more readily apparent later in childhood and adolescence when social interaction becomes more demanding [16].

Individuals with ASD may also have comorbidities such as seizures, gastrointestinal problems, and sleep disturbances [26]. Comorbid severe mental retardation and motor deficits are associated with a high prevalence of seizures, though the prevalence is low in those without severe mental retardation and motor deficits. Gastrointestinal problems are common in those with ASD, though the reasons for the relationship in unclear. Cross-sectional research show that children with ASD exhibit gastrointestinal problems such as chronic constipation or diarrhea in 46% to 85% of cases [26].

It is estimated that the cost to families of children with ASD is $3-5 million dollars more than the average lifetime cost of raising a child. This is due to costs over the lifespan including adult care and lost productivity of not only the individual with ASD but also their parents or caregivers. The societal cost associated with ASD has been estimated at $90 billion per year [18, 19].

2.1.2 Treatments for ASD

There is currently no cure or disease-modifying treatment for ASD. The main goals of the current treatments for ASD are to manage symptoms, such as minimizing maladaptive behaviors and increasing functional independence. Two pharmacological treatments currently exist for the management of symptoms in children and adolescents with ASD: risperidone and aripiprazole [17, 26]. These medications are both atypical antipsychotics used for the management of symptoms such as irritability in children and adolescents aged 5-17 years with ASD. Additionally, these medications are used for the treatment of schizophrenia in those aged 13 years and older and bipolar disorder in those aged 10 years and older [17, 22, 23]. These atypical antipsychotics are dopamine D_2 and serotonin 5-HT (5-hydroxytryptamine)2_A receptor antagonists, which results in significant inhibition of dopamine and serotonin [24]. Levels of serotonin have been shown to be increased in individuals with ASD, and atypical antipsychotics routinely prescribed have been shown to help manage some of the behaviors associated with ASD [25].

However, pharmacotherapies are not the primary mode of treatment for ASD. Guidelines for the treatment of ASD indicate that pharmacological approaches should only be used to decrease maladaptive behaviors as a supplement to behavioral interventions [17]. Interventions typically include behavioral strategies and are used to address communication, social skills, daily-living skills, play and leisure skills, academic achievement, and maladaptive behaviors [26].

Common educational interventions include specific strategies such as Applied Behavior Analysis (ABA), structured teaching, developmental models, speech and language therapy, social skills instruction, occupational therapy, and sensory integration therapy [26]. ABA focuses on maintaining and increasing positive behavior and decreasing maladaptive behaviors or the conditions in which they occur. ABA is also used to teach new skills, and introduce behaviors in new environments. Children who receive ABA have improved IQ, language, academic performance, and positive behaviors [26]. Structured teaching focuses on improving skills as well as modifying the environment. Developmental models are based on developmental theory focusing on communication skills. For example, the Denver model uses play, activities, and interpersonal relationships to address deficits in emotion sharing and social perceptions [26]. Another theory, developed by Greenspan and Weider and called the developmental, individual-difference, relationship-based (DIR) model, uses play time to facilitate relationships and emotional and social interactions and uses other therapies to improve auditory processing [26], language, motor planning, and visual-spatial processing. Children and adolescents with ASD also have unique responses to sensory stimuli in the environment, and sensory integration therapies are used to help individuals with ASD adapt to the sensory information in the environment [26].

2.2 PHYSICAL ACTIVITY AND HEALTH IN CHILDREN

Regular physical activity has been shown to be a significant contributor to decreased morbidity and mortality in adulthood [102, 103]. In addition, regular physical activity and physical fitness have been shown to decrease the risk of developing chronic conditions such as obesity [104], cardiovascular disease [37, 105-107], metabolic syndrome [108-110], and type 2 diabetes [111-

113] later in life. Being physically active throughout childhood may help reduce the risk of developing these chronic conditions [40, 104]. As physical activity level in childhood is a significant predictor of physical activity levels in adulthood, being physically active throughout childhood may positively impact health status as an adult [114].

Physical activity levels have also been related to health status during childhood. There is strong evidence supporting the benefits of physical activity on musculoskeletal health, cardiovascular health, adiposity in overweight and obese youth, as well as blood pressure in mildly hypertensive youth [40].

2.2.1 Benefits of Regular Physical Activity

Benefits of physical activity in adults include improvements in cardiovascular and respiratory function, reduction in cardiovascular disease risk factors, and decreased morbidity and mortality [9]. Reductions in cardiovascular disease risk factors include decreased resting systolic and diastolic blood pressure, increased high-density lipoprotein cholesterol, reductions in serum triglycerides, reduced body total body fat as well as intra-abdominal fat, and increased insulin sensitivity [9]. Increased fitness and higher activity levels are further associated with decreased coronary artery disease mortality and, lower incidence of cardiovascular disease, coronary artery disease, stroke, type II diabetes, metabolic syndrome, injuries, and some forms of cancer such as breast and colon [9]. The relationship between physical activity and health outcomes is typically dose-repose such that greater physical activity participation leads to greater improvements in risk for all-cause mortality, cardiorespiratory health, metabolic health, weight loss, musculoskeletal health, colon and breast cancer, and mental health (depression) [9].

2.2.2 Cardiovascular Health in Children

There is an association with physical activity and cardiovascular health in children [40, 104]. A 6-year longitudinal study by Raitakan, et al., (1994) showed that youth who remained physically active over the 6-year period had more favorable cardiometabolic risk factors than those youths that remained inactive. Active boys had significantly lower insulin and triglyceride concentrations, adiposity, and increased HDL-to total-cholesterol ratio vs. inactive boys. Active girls had lower triglyceride concentrations and adiposity compared to inactive girls [115].

Most studies examine the association between physical activity and cardiovascular risk factors such as lipoprotein levels, blood pressure, and metabolic syndrome in children as cardiovascular disease is rare in children. The research on physical activity and lipid levels are inconsistent. In observational studies, the relationship between physical activity and total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides are mostly weak, however there is a positive, though weak relationship between HDL-C and triglycerides [40]. One cross-sectional study by Carnethon et al., showed that 12-19 year-old girls below the 20th percentile for fitness were 89% more likely to have hypercholesterolemia compared to moderately and highly fit girls. Adolescent boys of the same age in the lowest fitness quintile were 3.68 times more likely to have hypercholesterolemia than the moderately and highly fit boys [106]. However, most experimental studies of physical activity interventions evaluating changes in lipoprotein levels among youth are small and limited to children and adolescents with high cholesterol or obesity [40]. Thus, the dose-response relationship between exercise and lipid levels in children is unclear.

Several studies have assessed the relationship between physical activity and blood pressure in kids [116-118]. Though cross-sectional studies have shown either a weak association or no association, four randomized control trials found beneficial effects of a physical activity intervention on blood pressure. Studies of aerobic exercise interventions showed large reductions in systolic blood pressure (ES= -1.39) and small changes in diastolic blood pressure (ES= 0.39) [104]. Thus, it appears physical activity improves blood pressure in kids.

2.2.3 Relationship Between Physical Activity and Obesity

An inverse relationship between physical activity and overweight has been observed in most [119-121], but not all, studies [122, 123]. Several cross-sectional studies examining physical activity and varied measurements of obesity (BMI, waist circumference, skinfold thickness) found inverse relationships between overweight/obesity and physical activity levels [119-121]. For example, Ara, et al., (2007) examined physical activity levels and skinfold thickness on 1,068 children aged 7-12 years old. Though not statistically significant, those in the active group had lower skinfold thickness compared to those in the sedentary group. Additionally, while the proportion of boys who were classified as overweight and obese was not statistically different (p=0.09) in physically active and sedentary groups (overweight: 32% vs. 25%; obesity: 6% vs. 2%), physically active girls had lower obesity prevalence compared to their sedentary peers (6% vs. 10%, p<0.05) [120]. In another study, Haerens, et al., (2007) found significant negative associations between weight status and physical activity in 11-13-year-old children. Overweight children reported significantly less physical activity (-18 minutes) compared to normal weight children. For MVPA, overweight and obese children spent on average 12 minutes a day less in MVPA compared to normal weight children [121]. In a similar study, Gonzales-Suarez, et al.,

(2011) found an inverse association between BMI and physical activity. Those with lower physical activity had higher odds for being overweight (OR=4.6) or obese (OR=10.8) [119].

In contrast, Ng, et al., (2006), examined BMI and objective physical activity via pedometer in 82 children 9-12 years old, but found no significant differences in physical activity levels among BMI groups [122]. In a similar study, Aires, et al., (2010) observed no significant associations between BMI and total amount of physical activity or physical activity intensity, however, low cardiorespiratory fitness was significantly associated with obesity (OR=0.968).

Though this relationship is unclear, the body of literature suggests that there is an inverse relationship between physical activity and BMI status, with those children classified as overweight or obese having lower physical activity levels compared to normal weight peers. This inverse relationship has been observed in most [119-121], but not all, studies [122, 123].

2.2.4 Metabolic Syndrome and Physical Activity

Metabolic syndrome is a cluster of metabolic risk factors that can affect youth as well as adults. Youth are considered to have metabolic syndrome if their waist circumference is >90th percentile, triglycerides ≥110 mg/dL, blood pressure >90th percentile for age, sex, and height, fasting glucose ≥110 mg/dL, and reduced (HDL-C) level ≤40 mg/dL [124]. A cross-sectional study by Ekelund et al., (2007) showed that, among 1,706 children aged 9-10 or 15-16 years, physical activity and cardiorespiratory fitness were independently associated with indicators of insulin resistance, hyperglycemia, hyperlipidemia, and metabolic syndrome. Cardiorespiratory fitness was inversely associated with waist circumference, fasting glucose, and insulin, and positively correlated with systolic and diastolic blood pressure. Despite controlling for age, sex, study location, and cardiorespiratory fitness, total physical activity, time spent in sedentary behavior, all intensities of physical activity (light, moderate, vigorous) were still significantly and independently associated with metabolic risk factors. However, the greatest magnitude of association was seen for total physical activity levels [125].

In another study by Brage, et al., (2004), greater physical activity was significantly associated with decreased metabolic risk among children. However in this study, there was a significant interaction between physical activity and fitness such that the association between physical activity and metabolic risk was stronger among children with low fitness versus high fitness [126].

2.2.5 Bone Health and Physical Activity

Physical activity is positively associated with bone mineral density in children and adolescents [40, 104]. Elgan, et al., (2002) examined associations between lifestyle factors and bone mineral density in 218 females aged 16-24 years. Bone mineral density was positively associated with a physically active lifestyle [127]. Specifically, at least 10 minutes of moderate-to-high impact activities performed 2 or 3 days per week in combination with weight-bearing aerobic activities had a beneficial impact on bone mineral density [40, 104]. This suggests that physical activity has a beneficial effect on bone mineral density in children.

2.3 PHYSICAL ACTIVITY GUIDELINES

The current recommendation for children and adolescents (**Table 2**) aged 6-17 years is 60 minutes or more of physical activity on most days, if not all days of the week. Moderate- or vigorous-intensity aerobic activity should make up the majority of the 60 minutes each day. Vigorous-intensity aerobic activity should occur on at least three days per week as part of the total 60 minutes; muscle-strengthening physical activity should occur at least three times per week as part of the 60 minutes; bone-strengthening physical activity should occur on at least three days per week as a part of the 60 minutes [128, 129]. This physical activity can be accumulated throughout the day in school, during physical education class, and recess, as well as before- and after-school or during weekends [40].

In addition to the 60 minutes or more of physical activity on most if not all days of the week, a review on the benefits of physical activity in children and adolescents showed that as physical inactivity is a significantly contributor to overweight and obesity. Children and adolescents should limit their sedentary behaviors such as excessive television viewing, computer use, and video games should be limited to < 2 hours per day [40].

Table 2. Physical Activity Guidelines for Children and Adolescents

Guideline	Recommendation
2008 Physical Activity Guidelines for Americans [129]	Children and adolescents should engage in at least 60 minutes per day of moderate-to-vigorous intensity, physical activity and to include vigorous intensity, muscle-strengthening activity, and bone-strengthening activity on at least 3 days per week
Centers for Disease Control and Prevention [128]	Children and adolescents should do 60 minutes or more of physical activity on most if not all days of the week Age-appropriate aerobic activity should make up the majority of the 60 minutes or more each day, and can include moderate-intensity activity such as brisk walking, but vigorous activity should be included on at least 3 days per week Age-appropriate muscle-strengthening activities on at least 3 days per week as part of the 60 minutes or more per day Age-appropriate bone-strengthening activities should be included on at least 3 days per week as part of the 60 minutes or more
Strong et al. [40]	Children and adolescent should engage in sedentary behaviors <2 hours per day
Healthy People 2020 [130]	PA-3: Increase the proportion of adolescents who meet current Federal physical activity guidelines for aerobic and muscle-strengthening activity PA-4: Increase the proportion of the Nation’s schools that require daily physical education PA-6: Increase regularly scheduled elementary school recess PA-8: Increase the proportion of children and adolescents that do not exceed 2 hours of screen time per day

2.4 PHYSICAL ACTIVITY IN TYPICALLY DEVELOPING CHILDREN

National estimates of physical activity indicate that a minority of children and adolescents meet current physical activity recommendations. Elementary-aged students (6-11 years) report higher levels of physical activity as compared to adolescents. NHANES data from 2003-04 using accelerometry indicate that approximately 42% of 6-11 year olds meet current federal recommendations. However, the prevalence of meeting the physical activity guidelines varies by demographic characteristics such as age, gender, race, and socioeconomic status [44-50].

2.4.1 Age Differences in Physical Activity

A significant inverse relationship exists between age and physical activity levels [46-48, 51, 52]. Physical activity declines as children transition from childhood (6-11 years) into adolescence (12-19 years) [46]. Elementary students are significantly more active than their middle and high school counterparts [48]. Most studies have found a difference in the amount of physical activity in the transition from childhood to adolescence beginning in the teens, however, some studies have found that the age-related decline can begin as early as 4th grade (approximately 9-10 years of age) [48].

Trost, et al., (2002) objectively measured physical activity in children in grades 1-12 and found that daily MVPA and VPA were significantly lower with increasing grade level. In males, for each grade higher, MVPA was on average 35% lower with the largest difference between grades 1-3 and 4-6 (-40%). For VPA, the average difference associated with each additional grade in school was a 31% decrease in VPA, however the largest difference was between grades 4-6 and 7-9 (-45%). In females, MVPA was on average 35% lower for each additional grade in school, with the largest difference between grades 1-3 and 4-6 (49%). VPA was on average 38% lower with each additional grade in school, with the largest differences between grades 1-3 and 4-6 (-56%) [48].

Compared to boys, girls have a greater decline in physical activity from childhood into adolescence [46, 52]. Pate, et al., (2009) found that, in a sample of 2,331 adolescent girls, MVPA and VPA on average declined 11% and 13% with each additional year respectively, based on self-report. In the sample of girls measured objectively, the decline was 3% for MVPA and 4% for VPA. Overall, total physical activity, regardless of intensity, declined by 5.4% per year [52]. We can conclude that there is a significant inverse relationship with physical activity levels and age in children and adolescents, with physical activity levels declining in the transition from childhood to adolescence.

2.4.2 Gender Differences in Physical Activity

Gender disparities exist in physical activity levels in children and adolescents. More boys than girls meet the recommendation for physical activity [44, 45, 48, 49, 51, 53, 54]. In a cross-sectional study of 1,110 students, boys in all grades engaged in more MVPA than girls. On average, boys had 11% more MVPA and 45% more VPA compared to girls. Gender differences ranged from 8.4% in grades 10-12, and 19% in grades 1-3. In addition, boys exhibited more continuous bouts of physical activity than girls [48]. In the NHANES data from 2003-04, even children as young as 6-11 years old show gender differences, with 48% of boys meeting the current recommendation vs. 35% of girls [44]. Gender differences persisted through adolescence with 12% of boys vs. 3% of girls 12-15 years old meeting physical activity recommendations, and 10% of boys vs. 5% of girls aged 16-19 meeting physical activity recommendations [44].

Butcher, et al., (2008), examined physical activity guideline compliance in adolescents aged 14-17 years across 100 large cities throughout the United States (n=6,125). For both males and females, 47.9% met the guideline of 60 minutes or more of physical activity each day. However, gender was strongly associated with compliance; 57% of male students complied with federal guidelines vs. 40% of females [45].

The gender differences in physical activity are slightly smaller with objective vs. self-reported data [48], however, studies of physical activity using objective measures still find that boys are more active [48, 53, 55, 56]. In a study by Jago, et al., (2005) using accelerometers in 100 adolescents in the U.S, boys were less sedentary than girls, had higher levels of MVPA, as well as higher levels of low-intensity activity on week nights, weekend days, and weekend nights [53].

In studies with objectively measured physical activity during the school day, boys spend more time in MVPA during class time, physical education class, and recess [47, 56, 131, 132]. Nettlefold, et. al., (2011) found that among 380 school-aged children (8-11 years), girls accumulated only 3.8 minutes of MVPA during recess while boys accumulated 5.3 minutes of MVPA. In the same study, girls accumulated approximately 33.8 minutes of MVPA and boys accumulated 39.9 minutes in MVPA across the school day [133]. Thus, it can be concluded that in general, boys are more active that girls. However, when looking at objective vs. self-reported data, the differences are more modest.

2.4.3 Racial Differences in Physical Activity

Racial differences in physical activity have been observed in some, but not all, studies. Particularly among girls, studies show that physical activity is particularly lower in African

American and Hispanic youth compared to non-Hispanic white youth [45-47, 55, 134]. Two studies from NHANES observed that non-Hispanic white youth had significantly lower MVPA than non-Hispanic black youth [44, 57]. Interestingly, Gortmaker, et al., (2012), using combined data from NHANES 2003-04 and 2005-06 found that though non-Hispanic black youth were more active than non-Hispanic whites. Yet, in the same study, accelerometer counts among 6-11 year olds increased between 2003-04 and 2005-06, among non-Hispanic white, but decreased among non-Hispanic black and Hispanic youth [51].

Racial disparities in physical activity are particularly evident in girls, with physical activity levels being particularly low in black and Hispanic girls [46, 52]. Pate, et al., (2009) examined physical activity in 501 sixth and eighth grade girls and found that, though not statistically significant, the age decline in physical activity per year was higher in African American girls compared to non-Hispanic white girls. The annual percent decrease in physical activity was approximately 4% each year (-1.76 minutes of MVPA/day) using accelerometer data, and 6% to 13% based on self-report [52].

It can be concluded that racial differences exist in physical activity levels in children and adolescents. Some, but not all studies, suggest that physical activity levels are higher in non-Hispanic black youth compared to their non-Hispanic white and Hispanic peers, especially in boys, however this pattern is not seen among girls. Among girls, studies suggest that African American girls have lower levels of physical activity compared to non-Hispanic white girls.

2.4.4 Differences on Physical Activity by Socioeconomic Status

Similar to the research on the racial disparities in physical activity among children and adolescents, the relationship between socioeconomic status and physical activity is unclear. In a systematic review conducted by Sallis, et al., (2000) among 54 published studies between 1976 and 1999, indicators of socioeconomic status were not related to physical activity levels in children 4-12 years old. In adolescents aged 13-18 years, indicators of socioeconomic status were also unrelated to physical activity [135].

However, when examining compliance with the federal physical activity guidelines, Butcher, at al., (2008) found that compliance with guidelines was associated with having higher household income. This is also consistent with other research studies. Data from the National Longitudinal Study of Adolescent Health suggests that adolescents from higher income households were significantly more likely to comply with guidelines, and household income was related to inactivity [45, 136].

It can be concluded that although socioeconomic status may not be related to overall physical activity levels in children, socioeconomic status is related to compliance with national physical activity guidelines.

2.5 SEDENTARY BEHAVIOR IN TYPICALLY DEVELOPING CHILDREN

Current research suggests that only one quarter of children and adolescents aged 5-15 years meet the recommendation of 60 minutes or more of physical activity on at least 5 days per week [43, 44]. However, even for those children and adolescents that meet current recommendations for physical activity, there remains 23 hours of the day for school, sleep, work, and discretionary time. The American Academy of Pediatrics recommends that children and adolescents limit leisure “screen time” (television viewing, and computer and video game usage) to less than 2 hours per day [62]. A little over half (53.5%) of American children meet this recommendation for screen time as assessed by parental self-report. More Hispanic children (61.7%) met the recommendation than non-Hispanic white children (55.4%), and only 36.7% of non-Hispanic black children met the recommendation [43, 50]. There are also age disparities in meeting the recommendation for daily screen time. Children aged 6-8 report (via parent-report) meeting the guideline more frequently compared to those aged 9-11 as well as high school students 14-17 years of age [47, 50].

Independent of physical activity levels, sedentary behavior has been associated with increased risk for cardio-metabolic disease, all-cause mortality, and other physiological and psychological problems [95, 137, 138]. A review conducted by Tremblay, et al., (2011) of 232 studies on sedentary behavior and health indicators showed that increased sedentary behavior (assessed primarily through television viewing time) for more than 2 hours per day is associated with unfavorable body composition, decreased fitness, lower self-esteem, and decreased academic achievement in school-aged children and adolescents aged 5-17. These associations were observed across all types of studies, countries, both self-report and objective measurements, and sample sizes [139]. Thus, it can be concluded that sedentary behavior is associated with adverse health outcomes.

2.6 OBESITY IN TYPICALLY DEVELOPING CHILDREN

Though the prevalence of obesity in children and adolescents increased by 23% and the prevalence off overweight increased by 19% between 1999 and 2004, prevalences have been stable between 2004 and 2012 [64, 140]. In 2011-2012 NHANES data an estimated 34.2% of youth aged 6-11 were either overweight or obese, with 17.7% of youth aged 6-11 classified as obese. The prevalence of obesity was higher among Hispanic (22.4%) and non-Hispanic black youth (20.2%) compared to non-Hispanic white (14.1%). Obesity prevalence also was higher with older age. Approximately 8.4% of 2- to 5-year-olds were obese compared to 17.7% of 6- to 11- year olds and 20.5% of 12- to 19-year olds. However, there were no differences in obesity prevalence by gender [64].

2.6.1 Consequences of Obesity

Childhood obesity is associated with increased risk for developing cardiovascular risk factors, type II diabetes, and orthopedic problems [66]. Children who are overweight or obese throughout childhood are more likely to continue that obesity throughout adulthood, resulting in an increased risk for developing chronic conditions such as cardiovascular disease, diabetes, and certain cancers such as colon and breast [1]. Though the consequences of obesity usually manifest in adulthood, some are evident even in children and adolescence. Atherosclerotic changes can be detected in the aorta in children as young as 3, and changes in the coronary arteries can be seen by ages 8 to 13 [66]. In the Bogalusa Heart Study, which was conducted in Louisiana and examined cardiovascular risk factors in individuals from birth until 38 years of age, autopsies on 204 young adults (who died from any cause) showed atherosclerotic lesions that were associated with BMI, hypertension, and dyslipidemia. Also in this study, those individuals who had adolescent-onset overweight had higher systolic and diastolic blood pressure during young adulthood [141].

The prevalence of insulin resistance and type II diabetes is also increased in children and adolescents who are obese. Though once considered “adult-onset” diabetes, type II diabetes is becoming the more prevalent form of diabetes among children and adolescents [142]. There are long-term complications of type II diabetes including vascular disease, which can lead to other complications such as heart attacks, stroke, and kidney disease as well as microvascular complications such as blindness and amputation of limbs [142].

In addition to the physiological consequences of obesity mentioned, there are also psychological consequences of childhood obesity which include social stigmatization, poor body image, poor self-esteem, social isolation, and peer victimization [68-72]. Children who are obese are more likely to experience psychological problems compared to their normal weight peers [69]. This social stigmatization may start at an early age; children as young as preschool have negative views of their overweight peers [73]. Additionally, this social stigmatization occurs across childhood and adolescence, as even high school teachers have negative views of overweight and obese adolescents [142].

2.7 PHYSICAL ACTIVITY AND OBESITY IN CHILDREN WITH ASD

In addition to the benefits of physical activity for children and adolescents mentioned previously, there are additional benefits of regular physical activity for children and adolescents with ASD. Bouts of regular physical activity have been shown to improve negative behaviors associated with ASD such as stereotypy, aggression, and self-stimulatory behavior [5-8]. However, few studies examine physical activity levels, physical activity interventions, and obesity in children and adolescents with ASD. Children and adolescents with ASD are more likely to be overweight and obese and less likely to engage in regular physical activity compared to their typically developing peers based on parental self-report [10, 11, 14]. Few studies have measured physical activity in children with ASD objectively [13-15, 58-60], however these studies do not evaluate potential determinants of health such as parent-reported barriers, ASD severity, or parental perceptions of physical activity. However, from the small studies available, valuable information can be gained for a better understanding of physical activity patterns in this population and the benefits of physical activity for children with ASD. In the following sections we will describe previous studies examining physical activity in child with ASD.

2.7.1 Physical Activity Levels in Children with ASD

Though the benefits of physical activity are well documented in children and adolescents [40, 104], few studies have looked at physical activity levels in children and adolescents with ASD [13-15, 58-60]. These studies are summarized in Table 3. Like typically developing children, physical activity levels in children with ASD decline with age, and a majority of this population do not meet the federal guidelines for physical activity. However, the differences in physical activity levels and meeting the guidelines for physical activity between children with ASD and typically developing children is unclear.

Table 3. Summary of Research Findings of Physical Activity Levels in Children and Adolescents with ASD

Reference	Control Group	n	Age range (years)	PA measure	Outcome Variable	Findings
Bandini et al. [13]	yes	111 ASD=53 TD=58	3-11	Accelerometer	Time spent in light, moderate, vigorous PA	TD children more active on weekdays than children with ASD
MacDonald et al. [59]	no	72 M=55 F=17	9-18	Accelerometer	Time spent in sedentary behavior, MVPA	MVPA decreased in 12-18 year olds compared to 9-11 year olds
Memari et al. [14]	no	90 M=55 F=35	7-14	Accelerometer	Total PA, weekday PA, weekend PA, school PA, and after-school PA	All PA variables decreased with age, girls significantly less active than boys
Pan and Frey [60]	no	35 M=27 F=3	10-19	Accelerometer	Total PA, MVPA, 5-min bouts, 10-min bouts, 20-min bouts	Elementary students were more active than middle and high school students, 47% of participants met recommendation
Pan et al. [15]	yes	70 ASD=35 TD=35	12-17	Accelerometer	MVPA, physical fitness	Those with ASD less active than TD adolescents, lower physical fitness than TD
Rosser Sandt [58]	yes	28 ASD=15 TD=13	5-12	Accelerometer	Total MVPA, weekday MVPA, weekend MVPA, after school MVPA, PE MVPA, recess MVPA	Children with ASD spent less time engaging in MVPA than children without ASD across all time periods of the day (all day, after school, physical education, and recess), though the differences were not significant

2.7.1.1 Age-related Declines in Physical Activity

There is a similar age-related decline in physical activity seen in children with ASD compared to typically developing children. Pan and Frey (2006) investigated physical activity patterns in adolescents aged 10-19 with ASD and found that physical activity was lower with higher age. More students in elementary school (78%) met the recommendation for physical activity than middle (67%) and high school (<1%) students. Children in elementary school were more active overall that those in high school (+309 minutes) and spent more time in MVPA than both middle school aged children (+54 minutes) and high school students (+93 minutes) [60].

MacDonald, et al., (2011) examined physical activity levels in children aged 9-18 years with ASD, and also found that physical activity levels decline as children age with adolescents aged 12-18 engaging in significantly less MVPA than children 9-11 years of age. Younger children engaged in 132 ± 84 minutes of MVPA compared to older children who engaged in 90 ± 98 minutes of MVPA. Higher MVPA in younger children was observed in total MVPA, in-school MVPA (~13 minute difference), after-school MVPA (~7 minutes), and evening MVPA (~10 minutes) [59].

Memari, et al., (2012), found that (all measured in counts-per-minute) total physical activity levels, physical activity during weekdays, physical activity during weekends, school time physical activity, and after-school physical activity in children aged 7-14 years with ASD was significantly lower as children transitioned from childhood into adolescence. Children in the 7-8-year age group got, on average, 1763 ± 576 counts per minute, 9-10 year olds got 1657 ± 580 counts per minute, and 11-12 year olds got 1763 ± 576. The lowest amount of total physical activity was seen in adolescents aged 13-14 years old (1146 ± 445 counts per minute.) [14]. It can be concluded that children with ASD experience similar age-related declines in physical activity compared to typically developing children.

2.7.1.2 Meeting Physical Activity Guidelines

Whether children with ASD meet the federal recommendation for physical activity is unclear. Rosser Sandt, et al., (2005) observed physical activity patterns in 15 children with ASD and 13 typically developing children aged 5-12 years of age. Within this sample, 67% of children (n=10) met the federal recommendation of 60 minutes or more of physical activity compared to compared to 92% of typically developing children [58]. Pan and Frey (2006) found that 78% of elementary-aged children got at least 60 minutes of physical activity each day [60].

However, this high prevalence of meeting the recommendation for physical activity in children with ASD is not observed in all studies. Bandini, et al., (2013) found that, in children aged 3-11 with ASD, only 23% of the sample met the federal recommendation of 60 minutes or more of MVPA each day compared to 43% of typically developing children [13]. Also, Pan, et al. (2015) examined physical activity and physical fitness in secondary school aged males with ASD and found that only 47% of adolescents with ASD met the 60 minute-per-day recommendation of physical activity [15].

As these prevalences of meeting the recommendation are varied, it is unclear what percentage of children with ASD meet the current federal recommendations.

2.7.1.3 Physical Activity Levels in Children with ASD Compared to Typically Developing Children

Children with ASD have lower levels of physical activity compared to their typically developing peers. Rosser Sandt, et al., (2005) found that children spent less time engaging in MVPA than children without ASD across all time periods of the day (all day, after school, physical education, and recess), though the differences were not significant. However, the accelerometer was placed in a pouch that was tied to the participants pants or shorts, which may have decreased the sensitivity of the activity monitor to detect vertical movement [58]. Bandini, et al., (2013) found that 3-11-year-old children with ASD engaged in similar activity counts, and time spent in light, moderate, and vigorous physical activity over 7 consecutive days compared to typically developing children. However, after controlling for age and sex, children with ASD spent significantly less time in moderate activity compared to their typically developing counterparts. Typically developing children achieved a total of 58 minutes/day and autistic children achieving 47 minutes per day [13]. Similarly, Pan, et al., (2015) found that those with ASD were less physically active than typically developing adolescents (~106,000 count difference) and spent less time in MVPA (~30-minute difference over the school day). Typically developing children engaged in 97 minutes of MVPA compared to autistic children who got 70 minutes of MVPA. It can be concluded that children with ASD engage in significantly less MVPA and total physical activity compared to their typically developing peers.

2.7.2 Obesity in Children with ASD Compared to Typically Developing Children

Few studies have assessed the prevalence of overweight and obesity in children and adolescents with ASD [10, 11, 96, 143-145], but these few studies suggest that children with ASD have higher levels of overweight and obesity compared to their typically developing peers. These studies are summarized in Table 4.

Curtain, et al., (2010), using 2003-2004 National Survey of Children's Health, found that children and adolescents aged 3-17 with ASD were 40% more likely to be obese than their typically developing peers. The prevalence of obesity in those with ASD was 30% compared to 24% among typically developing children [10]. More recently, results from the 2010-2011 National Survey of Children's Health suggest that adolescents aged 10-17 with ASD are 27% more likely to be overweight and 72% more likely to be obese vs. typically developing children. Within this sample, only 53% of adolescents with ASD were normal weight compared to 66% of typically developing adolescents. In addition, 22% of adolescents were obese as opposed to 14% of typically developing adolescents [61]. Phillips, et al., (2014) found that among children with developmental disabilities in the 2008-2010 National Health Interview Survey, 20% were obese compared to 13% of adolescents without developmental disabilities. Within the category of developmental disabilities, adolescents with ASD had the highest obesity prevalence (32%), more than twice the prevalence for obesity in adolescents without ASD [12]. Thus, these studies using nationally-representative data suggest that children with ASD are more likely to be overweight and obese compared to their typically developing peers.

Table 4. Summary of Research Findings of Overweight and Obesity in Children and Adolescents with ASD

Reference	Control Group	n	Age range (years)	Weight Measure	Findings
Curtin et al. (2005) [143]	no	140	3-18	Chart Review: BMI	The prevalence of at-risk-for-overweight was 35.7% and the prevalence of overweight was 19%.
Curtain et al. (2010) [10]	yes	102,353 ASD= 454	3-17	Parent-reported height & weight (BMI)	The prevalence of obesity in children with ASD was 30.4% compared to 23.6% TD children.
Hyman et al. [11]	yes	ASD=252	2-11	BMI	Children with ASD under the age of 5 were more likely to be obese than age-matched controls from NHANES.
McCoy et al. [61]	yes	ASD=915	10-17	Parent-report height & weight (BMI)	Children with ASD were more likely to be overweight and obese compared to TD peers.
Phillips et al. [12]	yes	9,619	12-17	Parent-report height & weight (BMI)	Adolescents with developmental delays were more likely to be obese than TD adolescents.
Xiong et al. [145]	no	429	5-12	BMI	Among 6-11 year olds with ASD, 38% were at-risk for overweight, and 22% were in the overweight category.

2.7.2.1 Age-Related Differences in Weight Status in Children with ASD

Similar to patterns observed among typically developing children, younger children with ASD are less likely to be overweight or obese compared to older children. Using age-matched controls from NHANES, Curtain, et al., (2005) found that the prevalence of risk for overweight was 36% and the prevalence of those in the overweight category was 19% in children with ASD. These rates were highest in the eldest age group, 12-19 year olds. The prevalence for at-risk for overweight was 80% among 12-19 year olds with ASD vs. 31% for age-matched controls. The prevalence of overweight in 12-19 year olds with ASD was 50% compared to 16% in age-matched controls [143]. Xiong, et al., (2009), found that the prevalence for at-risk for overweight among 2-5 year olds with ASD was 32%, and 17% were in the overweight category. Among 6-11 year olds with ASD, 38% were at-risk for overweight, and 22% were in the overweight category which was consistent with results reported by Curtain, et al., (2005) [145].

In contrast, a study by Hyman, et al., (2012) examined obesity in 362 2-11-year-old children with ASD and found that children with ASD under the age of 5 were more likely to be obese than age-matched controls from NHANES (14 children with ASD compared to 9 age-matched controls). However, in the same study, children aged 6-11 with ASD were more likely to be in the underweight BMI category compared to age-matched controls (7 children with ASD compared to 2 age-matched controls) and were not actually more likely to be obese [11].

Though not all studies have found consistent results, studies suggesting older children with ASD are more likely to be obese compared to younger children are from nationally-representative samples, and thus it can be concluded that older children are more likely to be of higher weight status than younger children.

2.7.3 Sedentary Behavior in Children with ASD

Only a few studies have reported data on sedentary behavior in children and adolescents with ASD. Of the studies that do exist, most studies rely on parent-reported child television viewing time. To the author's knowledge, only one study exists examining sedentary behavior using an accelerometer. Though unclear, it suggests that children with ASD spend more time sedentary compared to their typically developing peers, and that younger children engage in less sedentary time compared to their older peers.

Orsmond, et al., (2011) examined the daily lives of adolescents with ASD using time use diaries and found that adolescents with ASD spent an average of 8.3 hours engaged in discretionary activities per day. This included approximately 2.3 hours watching television and 1.7 hours on the computer [146]. Must, et al., (2013) examined discretionary sedentary behavior in children aged 3-11 years with ASD using parent-reported television viewing, computer usage, video games, etc. as proxies for sedentary time. Children with ASD spent an hour more in sedentary behaviors on weekdays compared to typically developing children (5.2 vs. 4.2 hours). Additionally, total sedentary time on weekends was related to BMI z-score in children with ASD, but not typically developing children [63]. MacDonald, et al., (2011) in 9-18 year olds with ASD found significant differences in sedentary behavior between 9-11 year olds and 12-18 year olds (with older children spending more time sedentary) in-school (+40 minute difference), after school (+12 minute difference), and evening hours (+40 minute difference), though there was no typically developing comparison group [59].

In contrast, McCoy, et al., (2016) also examined sedentary behaviors using parent-reported television viewing, computer usage, video games, etc. as proxies for sedentary time among 42,747 children and adolescents (915 with ASD) from the National Survey of Children's

Health. Children and adolescents with ASD were not less likely to meet recommendations for sedentary behaviors (<2 hours per day television viewing and computer usage) compared to their typically developing peers [61].

Though inconsistent, smaller studies using objective monitoring for sedentary behavior suggest that children with ASD are more likely to be sedentary compared to their typically developing peers. However, in studies using parent-report as a proxy measure for sedentary behavior, children with ASD are not more likely to be sedentary.

2.7.4 Benefits of Physical Activity for Children with ASD

Though the research is limited, physical activity is associated with improved health in children and adolescents with ASD. A meta-analysis conducted by Sibley and Etnier (2003) showed that physical activity is just as beneficial for health for children and adolescents with learning disabilities [8]. In addition to the benefits of physical activity such as improvements in health parameters such as BMI and cardiorespiratory fitness [33-36], there are also improvements in the symptoms present in those with ASD. Improved outcomes include reduced stereotypy, reduced self-stimulatory behavior, reduced aggression and self-injury, and reduced classroom disruptive behaviors [5-7, 29-31]. In a meta-analysis of 16 studies and a total sample size of 133, an overall behavior improvement score of 37.5% was found with a small-to-medium effect size of -0.32 [8]. Also, improvements in academics have been reported such as increased responses to academic demands and questions, and increased correctness and accuracy to academic demands [32].

2.7.5 Physical Activity Interventions in Children with ASD

Physical activity interventions for children and adolescents with ASD have been conducted in the past few decades, though with very small sample sizes [5-7, 29-36, 147, 148]. Intervention studies including walking, jogging, aquatics, horseback riding, bicycle riding, and outdoor activities in children and adolescents with ASD have reported improved outcomes. Improved outcomes include reduced stereotypy, reduced self-stimulatory behavior, reduced aggression and self-injury, and reduced classroom disruptive behaviors [5-7, 29-31]. Also, improvements in academics have been reported such as increased responses to academic demands and questions, and increased correctness and accuracy to academic demands [32]. Additionally, improvements in health parameters have improved such as BMI, and cardiorespiratory fitness [33-36].

Allison, et al., (1991) found that 20 minutes of daily jogging for two weeks significantly reduced aggressive behavior in one 24 year old individual with ASD [29]. A study conducted by Celberti, et al., (1997) found that one child aged 5 years with ASD had significant improvements in self-stimulation and disruptive behaviors following 6-minute jog sessions for three weeks. [5]. Nicholson, et al., (2011) found that, in four 9 year old children with ASD, a 2-week intervention of 12 minutes of jogging 3 times per week significantly increased academic engagement [32]. Pan, et al., have conducted two studies (2010 and 2011) in children with ASD using aquatic physical activity. Varying levels of aquatic exercise significantly reduced antisocial behavior as well as significantly improved cardiorespiratory fitness [33, 149]. Two additional studies by Rogers, et al., (2010) and Yilmaz, et al., (2004) also found that aquatic exercise significantly decreased stereotypic behaviors and increased cardiorespiratory fitness [31, 35]. Also, Pitetti, et al., (2009) found that 9 months of treadmill walking significantly improved BMI [34]. Rosenthal, et al., (1997) also found that self-stimulatory behavior was decreased with 20-minutes of jogging. Thus, these small studies suggest that physical activity interventions can help improve health and ASD symptoms in children and adolescents with ASD.

2.8 PARENT-REPORTED PERCEPTIONS AND BARRIERS TO PHYSICAL ACTIVITY

Parents play an important role in the development of children's health behaviors. Therefore, parents can play an important role in encouraging children to engage in physical activity by either eliminating barriers that they or their children may face towards engaging in physical activity, or by creating barriers that can prevent their children from being physically active [74, 75]. For example, this could be providing resources such as equipment or transportation. Pocock, et al., (2010) conducted a review of parental perceptions of healthy behaviors for young children and found that the most common barriers that parents reported for encouraging healthy behaviors in their children include: parent tiredness leading to lack of motivation for physical activity, cost of physical activities, society encourages sedentary behaviors, lack of parent awareness about how much sedentary behavior is occurring, parents not acting as good role models, difficult for parents to give attention to one child in multiple children households, and environmental factors such as neighborhood safety or lack of access. In addition, parents also report that their child's own resistance to engaging in physical activity and preference for sedentary behaviors makes it more difficult to get their child active [76]. Additionally, in the review by Pocock, illness or disability in the child was listed as a barrier to preventing physical activity in the general population [76]. In a study conducted by Yazdani, et al., (2013) examining parental barriers to physical activity in children with disabilities, parents reported that lack of time, lack of programs designed for physical disability, and child lack of interest/motivation were the most significant barriers reported by parents of children with special needs [77]. However, we are unaware of research on the perceived barriers specific to the parents of children and adolescents with ASD for child engagement in physical activity.

In the general population, perceived importance of physical activity is associated with parental support of physical activity, and parental support is in turn positively associated with physical activity in children [75]. In addition, parental beliefs such as the importance of physical activity for their child are associated with children's participation in MVPA [78, 79]. However, it is unclear if parents of children with ASD perceive physical activity to be of benefit or importance to their child, or if parents know the recommendations for physical activity and leisure screen time.

2.9 PHYSICAL ACTIVITY ASSESSMENT

Measurement of physical activity can be classified as objective or participantive. Objective methods for measuring physical activity in youth include direct observation, doubly labeled water, indirect calorimetry, heart rate monitors, and motion sensors (pedometers, and accelerometers). Participantive methods include self-report questionnaires, interviewer-administered questionnaires, proxy reports, and diaries [81]. Criterion standards for the measurement of physical activity in youth are direct observation, doubly labeled water, and indirect calorimetry [81].

Direct observation is considered the most practical criterion method of measuring physical activity in children and adolescents [80]. Direct observation can be used in a variety of settings, including field settings. Correlations between directly observed physical activity and heart rate or oxygen consumption range from 0.61 to 0.91. However, there are drawbacks to direct observation including observer burden and reactivity of the observed participant [80].

Doubly-labeled water is another criterion measure for measuring physical activity. With doubly-labeled water, a dose of radio-labelled isotope ($^2H_2 18O$) is administered orally to the study participant. In the days following, ^2H is eliminated as water and 18O is eliminated as CO_2 and water. The difference between the rates of elimination is then used to calculate energy expenditure. This method has advantages such as the ability to be used in normal daily living conditions, however it is very expensive and physical activity cannot be broken down into the different components such as duration, intensity, and frequency [80].

Indirect calorimetry is the third criterion method for measuring physical activity in children and adolescents. Using gas analysis, O_2 consumption and CO_2 production is measured and converted to energy expenditure. This method is considered an accurate and valid method of measuring physical activity, but limitations include that the equipment is less feasible in a field setting and can result in participant reactivity to wearing the equipment [80].

Other ways of objectively measuring physical activity include heart rate monitors and motion sensors. Heart rate monitors rely on the linear relationship between heart rate and oxygen consumption to estimate energy expenditure and may be less accurate at low intensities because of the hemodynamics of standing, for example [80].

Accelerometers, a type of motion sensor, are a common and accurate way of objectively measuring physical activity in children and adolescents. Accelerometers are small, lightweight, and able to provide time-stamped minute-by-minute data on the frequency, intensity and duration of free-living physical activity. Acceleration signals from the accelerometer are digitized and a “count” value per pre-set time interval (epoch) is obtained, which corresponds to the magnitude of the acceleration [82].

The use of accelerometers has been validated in numerous studies in children and adolescents against criterion measures such as direct observation and indirect calorimetry [83-94]. However, different count cut-point values have been suggested to define intensity ranges for physical activity (sedentary, light, moderate, vigorous), which can make it hard to quantify physical activity behavior and can make comparison across studies difficult (specific cut points discussed in Chapter 3.4.3) [82, 84, 88, 89, 95, 96].

Participantive methods for measuring physical activity include self-report questionnaires, interviewer-administered questionnaires, proxy reports, and diaries. Self-report questionnaires, where the individual report’s their physical activity, can be an easy and inexpensive way for measuring physical activity in children and adolescents. However, recall bias may become a factor if the individual is unable to correctly recall the exact amount of physical activity they engaged in. For example, MVPA estimated from the Previous Day Physical Activity Recall (PDPAR) created by Weston, et al., (1997) is positively associated with MVPA as estimated by motion sensors (r=0.77 for pedometers and r=0.88 for accelerometers) [80, 150]. Proxy reports, which is the method that most studies on physical activity in children and adolescents with ASD have employed, are where a third party (i.e., teacher or parent) report the amount of physical activity that the child engages in. However, the correlations between proxy reports and criterion measures are inconsistent, with some studies showing that there is no correlation between proxy reports and criterion measures [151], and some studies showing a high, positive correlation [152, 153].

2.10 SUMMARY

Although there have been some cross-sectional studies with nationally representative samples on physical activity and sedentary behaviors in children with ASD, gaps existing in the literature are addressed with this dissertation. Studies of physical activity using nationally representative data in children and adolescents with ASD use self- or parent-report of physical activity [96]. Additionally, only three small studies in the United States have used objective physical activity monitoring [13, 58, 59], though none have examined total sedentary behavior, only parent-reported child screen time, which is a proxy for sedentary behavior [63, 96]. Furthermore, studies using accelerometers have not measured other potential determinants of physical activity and sedentary behavior such as objective height and weight, barriers to physical activity, ASD severity, and physical function [13, 58, 59].

This dissertation adds to the literature by informing researchers, decision makers, clinicians, and care-givers of objectively measured physical activity and sedentary behaviors in children with ASD. Moreover, this dissertation sought to identify barriers for the parent for their child engaging in physical activity to help clinicians and researchers develop programs for these children to improve physical activity and decrease sedentary behaviors.

3.0 METHODS

3.1 PARTICIPANTS

Nineteen male and female children (17 males, 2 females) with ASD were recruited from the Greater Pittsburgh community (within 70 miles) to participate in our study. The parent primarily responsible for providing or coordinating care for their child accompanied the children to answer questionnaires. Inclusion and exclusion criteria used for this study are displayed in Table 5.

Table 5. Study Inclusion and Exclusion Criteria

Inclusion Criteria: • Aged 6-11 years • Male or female • Diagnosed with autism spectrum disorder by a doctor or other health care provider • Residing in the Greater Pittsburgh Community
Exclusion Criteria: • Presence of any condition that may limit one's ability to engage in physical activity   • Because objectively measured MVPA and sedentary behavior are outcomes of this study, a physical disability preventing one from engaging in physical activity could act as a confounding factor • Lack of parent/guardian informed consent or child assent • Current participation in another research study that could impact physical activity

3.2 RECRUITMENT AND SCREENING PROCEDURES

Participants were recruited through several mechanisms. The majority of participates were recruited from the University of Pittsburgh's Clinical and Translational Science Institute's Research Participant Registry. Information about the study was sent (by letter and electronically) to parents of children 6-11 years old who had ICD-9/10 codes consistent with ASD and who were enrolled to receive information on potential research studies. Clinicians from the University of Pittsburgh Medical Center (UPMC) Children's Hospital, Western Psychiatric Institute and Clinic of UPMC's Center for Autism and Developmental Disorders provided flyers (**Appendix A, Figure 11**) containing information about the study to parents of children diagnosed with ASD. Further, flyers were handed out, placed at local organizations for ASD services, and posted online (Craigslist). Potential participants' parents/guardians completed an initial telephone screening process for eligibility (**Appendix B, Figure 12**). Parents first heard a description of the study, study protocol, compensation, and the risks of participation. If the parent was still interested in having their child participate, they provided verbal consent for the screening. Parents were asked to give information on their child's age, ASD diagnosis, physical disability and other eligibility criteria. Eligible individuals provided contact information and scheduled a single assessment visit

3.3 STUDY DESIGN

This study employed a cross-sectional study design. At the end of the screening call, initially eligible participant's parents scheduled as assessment visit. The assessment visit occurred at either the Physical Activity and Weight Management Research Center or the participant's home.

Upon arrival, the study was explained in detail and participants and parents were given the opportunity to ask questions. Once all questions were answered to the participant's and the participant's parent's satisfaction, the parent provided written consent in accordance with IRB approved procedures. Participants developmentally able to sign provided written assent in accordance with IRB approved procedures.

Participants then underwent assessment of height and weight. ActiGraph monitor instructions were given to the participant and parent verbally and in writing, and the ActiGraph was placed on the participant. The parent was given a prepaid envelope to mail back the ActiGraph to the study investigator. Finally, parents were asked to complete questionnaires to assess demographic characteristics, medical history, ASD severity, barriers to physical activity, perceptions of physical activity, and functional disability. Child participants were then given a small toy (connector toys, wiffle ball set, inflatable bowling set, door basketball hoop, etc.) valued at approximately $10 for participating in the assessment session. After the seven-day monitoring period, parents were asked to mail back the accelerometer. Once all assessments were completed, parents were compensated $25 for participation in the study.

3.4 ASSESSMENT COMPONENTS

3.4.1 Height and Weight

Child participants were instructed to remove their shoes and any accessories that may affect results. Height was measured in duplicate using a portable stadiometer to the nearest 0.1 cm. Body-weight was assessed in duplicate using a portable digital scale to the nearest 0.1 kg.

3.4.2 Body Mass Index

Height (cm) and weight (kg) were used to calculate BMI, BMI percentile, and BMI z-score. BMI was classified into percentiles using the CDC growth charts for boys and girls aged 2-20. Percentiles drawn were from the Expert Committee Recommendations which have been adopted by the Centers for Disease Control: underweight (BMI $<5^{th}$ percentile), normal weight (BMI $>5^{th}$ percentile and $<85^{th}$ percentile), overweight (BMI $\geq 85^{th}$ percentile and $< 95^{th}$ percentile), and obese (BMI $\geq 95^{th}$ percentile) [154].

3.4.3 Physical Activity

Children were fitted with an accelerometer, ActiGraph model GT3X (Pensacola, FL), that was attached to an elastic belt wrapped around the hip. The ActiGraph GT3X is a triaxial accelerometer designed to measure normal human movement and activities in a free-living environment. It is lightweight and small. A piezoelectric beam inside the monitor detects body acceleration and generates a signal proportional to the acceleration magnitude. The acceleration signal is then digitized and a “count” value per pre-set time interval (epoch) is obtained which corresponds to the magnitude of the acceleration [81].

Accelerometers have been previously reported as both reliable and valid for the assessment of objective physical activity in children [87, 92]. Participants were instructed to wear the accelerometer all waking hours except during water activities such as swimming and showering. For children that seemed hesitant in wearing the monitor, a method found to increase wear time in children with disabilities was used. This method includes providing a social story with the monitor to the participants about a superhero character who wears a magic belt [155].

Before distribution to each participant, the ActiGraph was calibrated and initialized according to the manufacturers recommendations using a customized ActiGraph calibration unit and software. The ActiGraph was initialized to collect 1 minute epochs during the wear period. Finally, parents were given a log to record the time of the day that the monitor was put on and taken off such as showing or swimming (**Appendix D, Figure 17**). Additionally, children were given a set of instructions for wearing the monitor (**Appendix E, Figure 19**). Parents were contacted on the 2nd day to make sure the monitor was working correctly, and on the 6th day as a reminder to continue wearing the monitor. Once received via mail back to the research center, raw data was downloaded from the monitor and stored for further analyses.

Accelerometry data for an individual day were considered valid if the participant had ≥ 8 hours of monitoring. As cut points vary widely in the literature, and multiple sets of cut points are available with ActiGraph software three cut points were initially explored in this study for the magnitude of physical activity (see Table 6). These three separate cut point sets were chosen based on previous validation and use in the objective measurement of physical activity and sedentary behavior in previous studies of children and youth within the age range of the current study. Magnitude of physical activity in each intensity (sedentary, light, moderate, vigorous, MVPA) was explored with the three sets of cut points, and is presented in Section 4.2.1.1. All further analyses are presented using the cut points described below, as examining associations with all cut points separately is beyond the scope of this study.

Table 6. Activity Cut points

Cut-Point		Activity Counts (c.p.m)
Freedson Children (2005)		
	Sedentary	**0-149**
	Light	**150-499**
	Moderate	**500-3999**
	Vigorous	**4000-7599**
	Very Vigorous	**7600 +**
Puyau Children (2002)		
	Sedentary	**0-799**
	Light	**800-3199**
	Moderate	**3200-8199**
	Vigorous	**8200 +**
Evenson (2008)/Troiano (2008)		
	Sedentary	**0- 100**
	Light[a]	**101- (1399-2058)**
	Moderate[a]	**(1400-2059) – (3757-4831)**
	Vigorous[a]	**(3758-4832) +**

[a] Moderate and vigorous cut points are age-specific

A multitude of validated cut points have been established for ActiGraph, and the choice of cut points results in different quantification of time spent in each activity category (sedentary, light, moderate, vigorous, and MVPA). Activity cut points derived from Puyau, et al., (2002) were developed with children aged 6 to 16 years old performing a variety of play activities which included: Nintendo, arts and crafts, aerobic warm-up, Tae Bo, treadmill walking and running, and games. These cut points were calculated from regression of count values and active energy expenditure in kcal/kg/min to take into account age-related resting metabolic rates in children. From this study, the following cut points were established: <800 (sedentary), 800- <3200 (light), 3200-8200 (moderate), and >8200 (vigorous) [87]. These cut points are by far the most conservative, and result in a large proportion of activity being classified as sedentary and light compared to other cut points values.

Freedson, et al., (2005) developed cut points with 80 children ages 6-17 years performing treadmill walking. The cut points are based on the age-specific prediction equation to predict MET level from the cut points which corresponded to the formula METs = 2.757 + (0.0015*counts per minute) - (0.08957*age) - (0.000038*counts per minute*age) with assumed MET thresholds of 3, 6, and 9 METs. This prediction equation translates to cut points of: <149 (sedentary), 150- <500 (light), 500-3999 (moderate), and >4000 (vigorous) [94]. These cut points are the lowest for MVPA of those considered, and therefore result in a higher percentage of activity classified as both moderate and vigorous physical activity.

Cut points used in the current study are a mix of two separate cut points, those by Evenson, et al., (2008) [156], and Troiano, et al., (2008) [44]. A validation study comparing ActiGraph to activPAL, the gold standard for objectively measuring sedentary time, found that the lowest mean bias (~5.2 minutes) between ActiGraph sedentary time and activPAL was observed when using a sedentary cut point of ≤ 100 counts per minute. The ROC curve analysis for sitting time provided an optimal cut-point of 96 counts [157]. Based upon this, the sedentary cut points of ≤ 100 counts was chosen for this study, which are in agreement with the cut-point for sedentary behavior established by Evenson, et al., (2008) [156] and the cut point typically used in adults for sedentary behavior [158]. NHANES age-specific cut points established by Troiano, et al., (2008) [44] were used to classify moderate [(1400-2059) – (3758-4832)] and vigorous activity (3758 +). These cut-points were chosen based on their moderate cut points for MVPA (in the middle of commonly used cut points) and for comparison purposes as an aim of this study was to compare physical activity levels in children with ASD to national averages.

To inform the average intensity level of each activity category (light, moderate, vigorous, and MVPA), average counts per minute in each activity intensity category using age-specific cut points was calculated within participants and then averaged across participants.

3.4.4 Parent Questionnaires

Parents answered questionnaires for further examination on potential determinants of physical activity and sedentary behavior in our sample, described in detail below (see **Appendix F**).

3.4.4.1 Demographics

Parents answered descriptive questions regarding basic demographic characteristics on the following topics. These questions were adapted from a previous questionnaire used in our laboratory; no psychometric properties are available (see **Appendix F, Figure 20**).

1. <u>Gender of the child</u>: The parent reported their child's gender as male or female.
2. <u>Ethnicity/race of the child</u>: The parent reported their child's ethnicity from: Latino, non-Latino. The parent reported their child's race from the following categories: a) white or Caucasian, b) black or African American, c) American Indian/Native American, d) Native Hawaiian or Pacific Islander, e) Asian, f) other.
3. <u>Highest household education</u>: The parent reported the highest level of education in the household from the following responses: a) elementary school, b) finished middle school (8^{th} grade), c) finished some high school, d) high school graduate or G.E.D., e) vocational or training school after high school, f) some college of Associates degree, g) college graduate or Baccalaureate degree, h) Masters of Doctoral degree (PhD, MD, JD, etc.).

4. Household income: The parent reported their household income as one of the following responses: a) less than $5,000, b) $5,000 through $11,999, c) $12,000 through $15,999, d) $16,000 through $24,999, e) $25,000 through $34,999, f) $35,000 through $49,999, g) $50,000 through $74,999, h) $75,000 through $99,999, i) $100,000 and greater, j) no response.
5. Type of school: The parent reported what type of school their child attends as one of the following responses: a) private, b) public, c) home-schooled, d) other.

3.4.4.2 ASD Severity

ASD severity was assessed using parent-proxy (see **Appendix F, Figure 21**). Parents reported via questionnaire their child's ASD severity as "mild, moderate, or severe." This method has been previously used in the National Survey of Children's Health [159]. Parents were asked to provide the child's IQ and severity score from the child's Individualized Education Plan (IEP) if available.

3.4.4.3 Parent Perception and Self-Report of Physical Activity and Sedentary Behavior

Parental perception of child physical activity was measured via questionnaire (**Appendix F, Figure 23**) adapted from White, et al., (2016) [160], though no psychometric properties are available. Parents were asked questions about their beliefs of the benefits of physical activity for their child, and how much they prioritize physical activity for their child. Additionally, parents were asked using open-ended questions if they knew the current recommendations for physical activity and "screen time" for children. Parents were then asked "on average, how many minutes of physical activity did your child accumulate daily by exercising, playing a sport, or participating in other physical activity that made them sweat and breathe hard?" and "outside of school, how much time each day did your child accumulate sitting or reclining?"

3.4.4.4 Parent-reported Barriers to Physical Activity

Parent-reported barriers to their child's physical activity were assessed using a questionnaire adapted by Yazdani, et al., (2013). This questionnaire was created for children and adolescents with disabilities, based on expertise and previous literature. The questionnaire was piloted by 30 parents to receive feedback on format, clarity, and types of questions, then administered to the parents of 171 children with special needs in kindergarten-12th grade [77]. This questionnaire evaluated the presence of eleven barriers, some specific to children with special needs, with "yes" or "no" responses. An additional open-ended question was added to capture additional barriers not listed in the questionnaire (**Appendix F, Figure 22**).

3.4.4.5 Functional Disability Index

Level of disability was measured with the Functional Disability Index (FDI). The FDI is a parent report questionnaire used for children with varying levels of disability and has been previously validated [161]. For use in this study, parents/guardians were asked to fill out the FDI which asks on a 5- point Likert scale ("no trouble" to "impossible") their child's ability to perform 15 activities of daily living. Activities included walking to the bathroom, doing chores at home, and doing activities in gym class, running, and walking, etc (**Appendix F, Figure 24**).

3.5 STATISTICAL ANAYSIS

Data were analyzed using Stata version 14 and statistical significance was set at p<0.05. All variables were checked for normality and, in cases of violation, were log transformed or analyzed using non-parametric methods. Dependent variables that were log transformed (i.e. MVPA) are presented as % difference in the dependent variable with a 1-unit increase in the independent variable to improve interpretability. All linear regression models were adjusted for average wear time. Descriptive statistics examined age, gender, ethnicity, height, weight, BMI, ASD severity, functional disability, educational setting, highest parental education, and household income. Each aim was analyzed using the statistical approach described below.

1. To objectively measure physical activity and sedentary behavior in children aged 6-11 with ASD.
    a. MVPA and sedentary behavior is presented as minutes per day of MVPA and sedentary behavior, as well as stratified by weekday, and weekend. In addition, the proportion of children meeting the federal recommendation for daily activity is presented. Dependent t-tests were used to detect differences in MVPA and sedentary behavior on weekdays compared to weekends. One-sample tests of proportions were used to detect differences in the proportion children meeting the federal guideline in our sample compared to the national rate of 42% [43].
2. To examine body mass index in children aged 6-11 with ASD.
    a. BMI is presented as the proportion of children in each clinical category. Linear regression was used to evaluate associations between MVPA and sedentary behavior across BMI categories (underweight, normal, overweight, obese). One-sample tests of proportions were used to detect differences in the proportion children $\geq 85^{th}$ percentile

for BMI in our sample compared to national rates as well as the proportion of children $\geq 95^{th}$ percentile for BMI in our sample compared to national estimates of overweight and obesity in children aged 6-11 (34.2% $\geq 85^{th}$ percentile and 17.7% $\geq 95^{th}$ percentile) [64].

3. To examine associations between potential determinants MVPA and sedentary behavior in children 6-11 years with ASD.
    a. Linear regression was used to evaluate associations between MVPA and sedentary behavior and the following variables: age, gender, race, ethnicity, educational setting, parent education, parent income, ASD severity, functional disability, barriers to physical activity, and parent perceptions of physical activity.

4.0 RESULTS

The primary aim of this study was to examine objective physical activity, sedentary behavior, and BMI, and potential determinants of physical activity and sedentary behavior in children aged 6-11 with ASD. The study was a cross-sectional study with one assessment visit. The results of this study are presented below:

4.1 PARTICIPANTS

Screenings were conducted on 22 individuals. Of these individuals, 20 were deemed eligible, and 2 were deemed ineligible based on the screening criteria. Of the ineligible participants, 2 parents reported their age outside of range for inclusion in this study. A third participant failed to come for the scheduled assessment after the phone screen. The consort diagram is displayed in Figure 2.

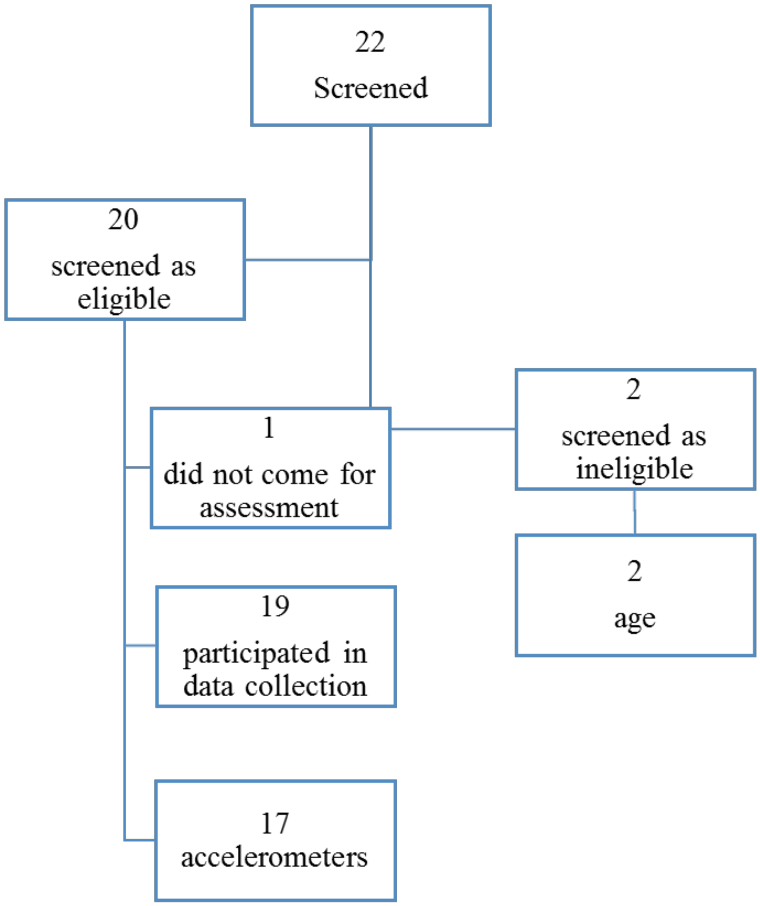

Figure 2. Consort Diagram

Of the 20 eligible participants, data was collected from 19 participants, and accelerometry data was available from 17 participants. One participant withdrew from the study, and one accelerometer was not returned by study close. Demographic characteristics of the study participants are presented in Table 7. All parents had a minimum of a high school education.

Two parents reported having a high school diploma or GED (11%), 1 parent (5%) reported vocational or training school after high school, 5 parents (26%) reported completing some college, and 11 participants (58%) were college graduates. One parent (5%) reported a household income of less than $5,000 per year, 2 parents (11%) reported $16,000 through $24,999, 3 parents (16%) reported $25,000 through $34,999, 4 parents (21%) reported $35,000 through $49,999, 4 parents (21%) reported $50,000 through $74,999, and 5 (26%) parents reported $100,000 and greater.

Children were 6-11 years old (mean age 8.4 ± 1.6 years) and were both males (n=17, 89%) and females (n=2, 11%). Children had an average BMI of 18.8 ± 2.8 kg/m^2 and a median BMI percentile of 82nd (55th, 88th) (**Table 9**). The sample was distributed across all ages. Sixteen percent of the sample was 6 years old (n=3), 21% of the sample 7 was years old (n=4), 5% of the sample was 8 years old (n=1), 26% of the sample was 9 years old (n=5), 26% of the sample was 10 years old (n=4), and 5% of the sample was 11 years old (n=1). The majority of participants were non-Hispanic (n=17, 89%) and white (n=16, 84%), and most participants attended public school (n=13, 68%) (**Table 7**). Approximately 50% of participants were on at least one prescription medication, including Methylin, Risperidol, Concerta, Abilify, Prozac, etc.

Table 7. Descriptive Characteristics (N=19)

Descriptive Variable		N	Percentage
Gender			
	Male	**17**	**89.5**
Age (years)			
	6	**3**	**15.8**
	7	**4**	**21.1**
	8	**1**	**5.3**
	9	**5**	**26.3**
	10	**5**	**26.3**
	11	**1**	**5.3**
Race, Ethnicity			
	White, non-Latino	**14**	**73.7**
	Latino Heritage	**2**	**10.5**
	Black	**3**	**15.8**
	Other	**0**	**0**
Type of School			
	Private	**4**	**21.1**
	Public	**13**	**68.4**
	Home-schooled	**1**	**5.3**
	Other	**1**	**5.3**
Parent Education			
	Less than High School	**0**	**0**
	High School Graduate	**2**	**10.5**
	Vocation of Training School	**1**	**5.3**
	Some College/Associate's Degree	**5**	**26.3**
	College Graduate	**11**	**57.9**
	Post-graduate work	**0**	**0**
Parent Income			
	Less than $5,000	**1**	**5.3**
	$5,000 through $11,999	**0**	**0**
	$12,000 through $15,999	**0**	**0**
	$16,000 through $24,999	**2**	**10.5**
	$25,000 through $34,999	**3**	**15.8**
	$35,000 through $49,999	**4**	**21.1**
	$50,000 through $74,999	**4**	**21.1**
	$75,000 through $99,999	**0**	**0**
	$100,000 and greater	**5**	**26.3**

4.2 ANALYSIS OF DATA BY SPECIFIC AIM

4.2.1 Specific Aim I

Specific Aim I examined objectively measured MVPA and sedentary behaviors in children aged 6-11 with ASD. Specifically, we aimed to quantify time spent in MVPA and sedentary behavior overall and during weekdays and weekends. Furthermore, we sought to examine if children aged 6-11 years with ASD met current recommendations for aerobic physical activity in children and adolescents.

4.2.1.1 Comparison of ActiGraph Cut points and the Influence of Wear Time

Participants were asked to wear the accelerometer during all waking hours for seven consecutive days, with removal only for water activities and sleep. Accelerometry data was excluded from our analysis if wear time was less than 8 hours for the day. Including only days of at least 8 hours (480 minutes), participants had on average 6.6 ± 1.5 valid days (2-8 days), and on average wore the accelerometer for 740 ± 72 minutes/day. Although it is standard practice to include only participants with at least 4 days of valid data [92], we kept one participant with only 2 days of data with respect for our small sample size and because excluding this participant did not change our results (data not shown). Average wear time across participants ranged from 10 to 14 hours per day.

To understand if wear time influenced our outcomes of interest, we calculated Spearman correlations between wear time and outcomes (MVPA and sedentary behavior). Wear time was not significantly associated with MVPA (rho=-0.15, p=0.571), but was positively and significantly associated with sedentary behavior (rho=0.70, p=0.003). Thus, because it is standard practice to adjust for wear time [162], and wear time was significantly associated with one of our outcome variables, all analyses are adjusted for wear time.

All variables were checked for normality, and MVPA was log transformed to achieve an approximately normal distribution. For easy interpretation, results from regression models where MVPA is the dependent variable are back transformed and presented as the % difference in MVPA that would be expected with a 1-unit increase in the independent variable.

All activity data is presented as least square means of minutes per day (overall, weekday, and weekend averages), normalized to the overall average wear time (747 minutes per day). Activity data were also reduced into time spent in modified “bouted” physical activity (activity accumulated in continuous bouts of 10 minutes or more allowing for 2 minutes of less than the cut-point) and presented by daily average, weekday average, and weekend average, normalized to average wear time. Lastly, minutes/day spent in sedentary behavior accumulated in continuous bouts of at least 10 minutes were also averaged across days and normalized to wear time.

The current study initially proposed to examine physical activity during the school day vs. after school, however, due to timing of data collection, this was not possible (see Section 5.7.13).

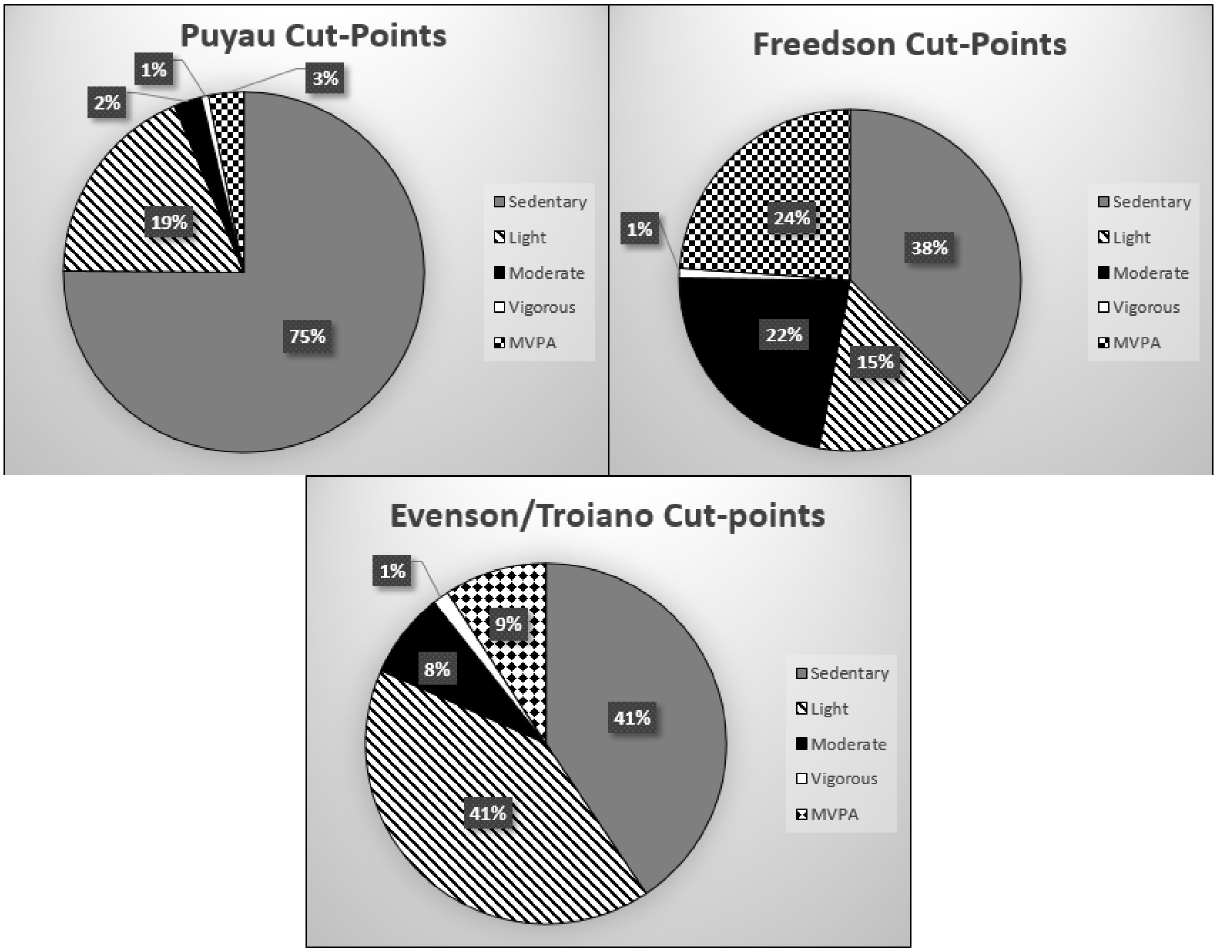

Figure 3. Cut-Point Comparison

To demonstrate the influence of cut point choice for reduction of accelerometry data into sedentary, light, moderate, or vigorous activity in children with ASD when using an ActiGraph GT3X monitor, we initially explored three sets of cut points (see **Table 6**) to observe differences in classification of physical activity intensities from our data.

Using the Puyau, et al., (2002) cut points (the most conservative cut points for MVPA) [87], the majority of time was classified as sedentary (75%), with 19% classified as light activity, and only 3% classified as MVPA. These percentages correspond to 579 ± 57 minutes sedentary, 143 ± 46 minutes in light activity, 19 ± 14 minutes in moderate activity, 5 ± 5 minutes in vigorous activity, and 24 ±16 minutes in MVPA. In comparison, using the Freedson, et al.,

(2005) cut points (least conservative for MVPA) [94], 38% of wear time was classified as sedentary, 15% classified as light activity, 22% classified as moderate activity, 1% classified as vigorous, and 24% classified as MVPA. These percentages correspond to 366 ± 59 minutes sedentary, 148 ± 28 minutes in light activity, 217 ± 55 minutes moderate, 9 ± 8 minutes vigorous, and 232 ± 62 minutes of MVPA. Between these two sets of cut points, there is a difference of +213 minutes classified as sedentary using the Puyau, et al., (2002) cut points, and +208 minutes of MVPA for the Freedson et al. cut points (see **Figure 3**).

This study analyzed ActiGraph data using a combination of Evenson, et al., (2008) cut points (for sedentary behavior) [156], and Troiano, et al., (2008) cut points (for moderate and vigorous activity) [44]. Using these age-specific cut-points also employed by NHANES, 40% of wear time was classified as sedentary, 41% was classified as light activity, 8% was classified as moderate activity, 2% was classified as vigorous activity, and 9% was classified as MVPA. These cut points are used hereafter because the sedentary cut points have been validated as the most accurate in children [157] and the MVPA cut points allow the most direct comparison to national data estimates, which is one of our aims.

4.2.1.2 Counts per Minute

Although categories of activity are helpful for interpretation, it is also of interest for investigators to evaluate average counts per minute within each category of physical activity intensity (light, moderate, vigorous, MVPA) to understand whether activity is typically accumulated in the lower, middle, or higher counts per minute values of each range. On average, participants got 571 ± 62 counts per minute while engaged in light intensity activity. Light intensity activity counts per minute ranged from 484 to 708 across participants. On average, participants got 2489 ± 281 counts per minute while engaged in moderate intensity activity, and moderate intensity activity counts per minute ranged from 2087 to 2954 across participants. Participants got 7261 ± 2805 counts per minute on average while engaged in vigorous intensity activity. Vigorous intensity activity counts per minute ranged from 4204 to 12582. Participants got 3521 ± 1483 counts per minute on average while engaged in the combined category of MVPA, which are higher on the spectrum of MVPA counts per minute, bordering on vigorous intensity counts per minute. MVPA counts per minute ranged from 2151 to 6958 (**Figure 4**).

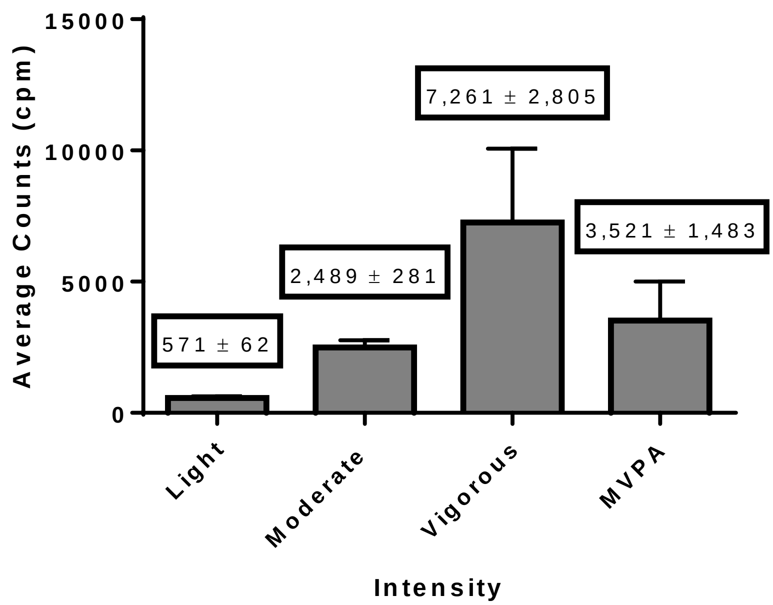

Figure 4. Counts per Minute in Different Intensities (N=17)

4.2.1.3 MVPA

Participants spent on average 76 ± 48 minutes per day engaged in MVPA. MVPA ranged from 11 minutes to 209 minutes. This was approximately 64 ± 41 minutes per day of moderate activity on average, and 12 ±12 minutes per day of vigorous activity, on average (**Table 8**). Moderate activity ranged from 11 minutes to 162 minutes, and vigorous activity ranged from less than 1 minute to 47 minutes per day across participants in our sample. When examined by MVPA accumulated in bouts, participants engaged in approximately 28 ± 20 minutes per day in bouted MVPA. MVPA accumulated in bouts ranged from 4 minutes to 68 minutes per day.

Table 8. Daily, Weekday, and Weekend Accelerometry Data (N=17)

	Daily Average	Weekday Average	Weekend Average
Average wear time (hours) per day	**12.3 ± 1.2**	**12.5 ± 1.0**	**12.1 ± 1.7**
Total time (minutes) per day[a]			
Sedentary	**332 ± 65**	**329 ± 73**	**332 ± 58**
Light Activity	**335 ± 53**	**333 ± 49**	**346 ± 65**
Moderate Activity	**63 ± 40**	**63 ± 43**	**56 ± 41**
Vigorous Activity	**12 ± 12**	**15 ± 15**	**6 ± 6**
MVPA	**75 ± 48**	**78 ± 53**	**62 ± 45**
Bouted time (minutes) per day[a]			
Sedentary	**135 ± 59**	**134 ± 66**	**131 ± 70**
MVPA	**26 ± 20**	**27 ± 22**	**18 ± 25**
Percentage of total time			
Sedentary	**45 ± 9**	**44 ± 10**	**45 ± 8**
Light activity	**45 ± 7**	**45 ± 7**	**47 ± 9**
Moderate activity	**9 ± 5**	**9 ± 6**	**8 ± 6**
Vigorous activity	**2 ± 2**	**2 ± 2**	**0.7 ± 0.7**
MVPA	**10 ± 6**	**11 ± 7**	**8 ± 6**

[a]Adjusted for average wear time

The weekday average for wear time was 752 ± 61 minutes per day. Wear time on weekdays ranged from 622 minutes to 852 minutes. On weekdays, participants spent approximately 11% ± 7% of their time engaged in MVPA (range less than 1% to 31%), corresponding to an average of 73 ± 53 minutes per day of MVPA (range: 9 to 231 minutes). Separated by intensity, this was approximately 63 ± 43 minutes per day of moderate activity and 15 ± 15 minutes per day of vigorous activity. Moderate intensity ranged from 9 minutes to 176 minutes on the weekdays, and vigorous intensity ranged from less than 1 minute to 55 minutes. Bouted MVPA was 27 ± 22 minutes per day on average on weekdays, and ranged from 0 minutes to 80 minutes.

The weekend average for wear time was 727 ± 104 minutes per day, and ranged from 528 to 893 minutes. On weekend days, participants spent on approximately 8% ± 6% of their time engaged in MVPA, corresponding to an average of 62 ± 45 minutes per day of MVPA. MVPA ranged from 8 minutes to 157 minutes on weekends, with moderate intensity activity ranging from 8 minutes to 143 minutes, and vigorous intensity activity ranging from 0 to 15 minutes. Separated by intensity, this was approximately 56 ± 41 minutes of moderate activity and 6 ± 6 minutes per day of vigorous activity. Bouted MVPA was 18 ± 24 minutes per day on weekends, and ranged from 0 to 68 minutes.

A dependent t-test was conducted to evaluate differences in MVPA between weekday and weekend days, with no difference found between weekday and weekend MVPA (p=0.124). Additionally, no significant difference was found between MVPA accumulated in bouts between weekdays and weekends (p=0.126).

Fifty percent (50%) of participants met the federal guideline for physical activity, meaning that they accumulated 60 minutes or more of physical activity (MVPA) on 5 or more days of the observed week (range 0-6 days per week). Two participants (13%) achieved 60 minutes per day none of the days of the week, 2 participants (13%) on 1 day per week, 2 participants (13%) on 2 days per week, 1 participant (6%) on 3 days per week, 1 participant (6%) on 4 days per week, 6 participants (38%) on 5 days per week, and 2 participants (13%) on 6 days per week. Among those individuals that met the federal guideline, MVPA was on average 99 ± 38 minutes per day. Among those individuals that did not meet the federal guideline for physical activity, MVPA was on average 48 ± 29 minutes per day (**Figure 5**).

A t-test of proportions was conducted to determine if the proportion of our sample meeting the guideline was significantly different from the national average of 42%. No significant difference was found (p=0.517).

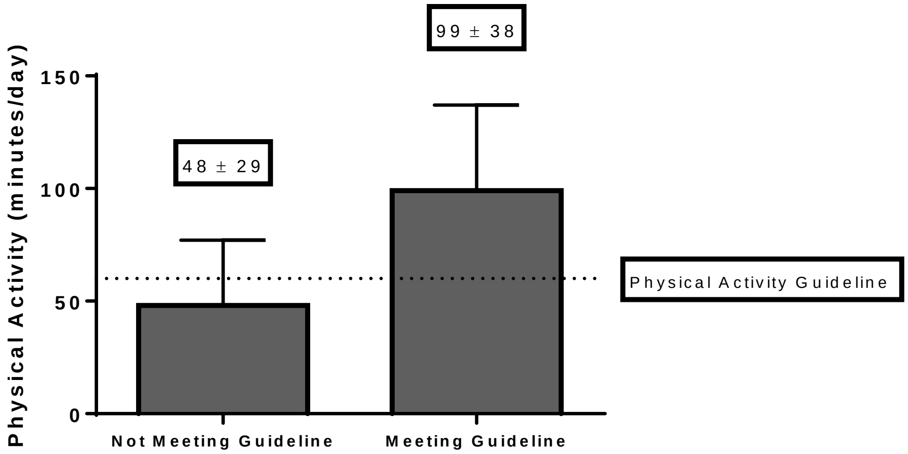

Figure 5. Differences in Physical Activity by Meeting and Not Meeting Physical Activity Guidelines (N=17)

4.2.1.4 Sedentary Behavior

Participants spent on average 332 ± 65 minutes per day sedentary (Table 8). Sedentary time ranged from 220 minutes to 448 minutes per day. When examined as sedentary time accumulated in bouts, participants spent 135 ± 59 minutes per day in prolonged (bouted) sedentary time. Bouted sedentary time ranged from 46 minutes to 279 minutes per day. Participants spent approximately 45% ± 9% of their time sedentary, on average. Percent sedentary time ranged from 3% to 61%.

On weekdays, participants spent approximately 44% ± 10% of their time engaged in sedentary behavior (range 27% to 62%), corresponding to an average of 329 ± 73 minutes per day of sedentary time (range: 199 to 458 minutes). Bouted sedentary time was 134 ± 66 minutes per day on average on weekdays, and ranged from 48 minutes to 294 minutes.

On weekend days, participants spent on approximately 44% ± 10% of their time engaged in sedentary behavior, corresponding to an average of 332 ± 58 minutes per day of sedentary behavior. When examined by sedentary behavior in bouts, sedentary behavior was 131 ± 70 minutes per day on weekends, and ranged from 14 to 242 minutes.

A dependent t-test was conducted to evaluate differences in sedentary behavior between weekday and weekend days. There was no difference found between sedentary behavior on weekdays compared to weekend days (p=0.924). Participants spent approximately the same amount of time engaged in sedentary behaviors across the week.

4.2.2 Specific Aim II

Specific Aim II examined BMI in children aged 6-11 years with ASD, to describe the prevalence of overweight and obesity in our sample, and to compare MVPA and sedentary behavior across BMI categories.

Participants were classified as either underweight ($<5^{th}$ percentile), normal weight ($>5^{th}$ percentile to $<85^{th}$ percentile), overweight ($\geq 85^{th}$ percentile to $< 95^{th}$ percentile), or obese ($\geq 95^{th}$ percentile) based on their objectively measured BMI percentile (age-and-gender specific). No participants were classified as underweight, 12 participants (63%) were classified as normal weight, 4 participants (21%) were classified as overweight, and 3 participants (16%) were classified as obese (**Figure 6**).

The national prevalences of overweight and obesity in children aged 6-11 year olds are 34.2% overweight and obese and, among these, 17.7% obese from 2011-2012 NHANES [64]. Prevalences of children with ASD in our sample were similar to the national average. In our sample, 36.8% of children were classified as overweight or obese. A t-test of proportions was conducted to determine if the proportion of children classified as overweight/obese (≥85th percentile) in our sample was different from national averages, but no significant difference was found (p=0.808). Additionally, a t-test of proportions was conducted to determine if the proportion of children classified as obese (≥95th percentile) in our sample was different from national averages, but no significant difference was found (p=0.827).

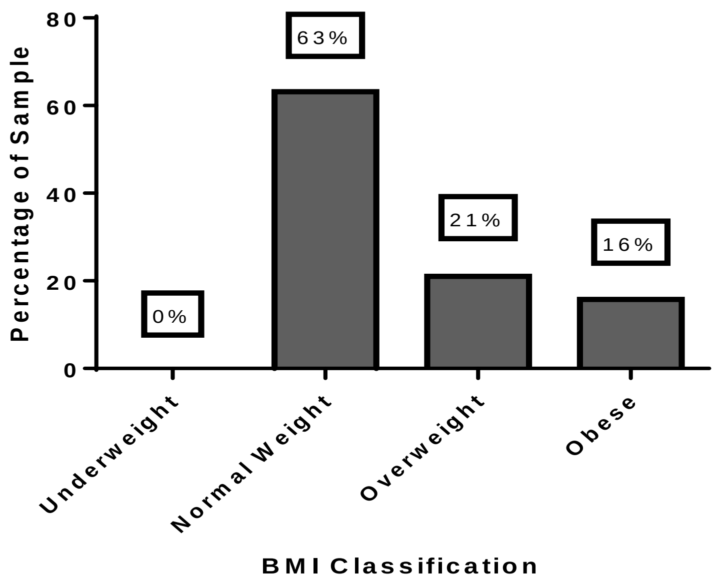

Figure 6. Percentage of Sample by BMI Classification (N=19)

BMI was on average 18.8 kg/m^2 ± 2.8 kg/m^2, and ranged from 15 kg/m^2 to 24.3 kg/m^2. Median BMI percentile was the 82nd percentile (55th, 88th). BMI z-score was on average 0.85 ± 0.83 and ranged from -0.36 to 2.54 (**Table 9**).

Table 9. Child BMI (N=19)

Descriptive Variable	
BMI (mean ± s.d.)	**18.8 ± 2.8 kg/m^2**
BMI Percentile (median, 25%, 75%)	**82nd (55th, 88th)**
BMI z-score	**0.85 ± 0.83**

Linear regression was used to evaluate associations between BMI z-score and MVPA as well as BMI z-score and sedentary behavior. BMI z-score was not related to MVPA (*p*=0.851) or sedentary behavior (*p*=0.480) (**Table 10**).

Table 10. Associations between BMI Z-score and MVPA and Sedentary Behavior[a,b] (N=17)

	MVPA % Difference	β Coeff.	*P* value	R^2
MVPA	**-4.1**		**0.851**	**0.3%**
Sedentary Behavior		**14.0**	**0.480**	**1.9%**

[a] Results are adjusted for wear time
[b] R^2 presented as the additional R^2 variability explained by BMI z-score after subtracting variability explained by wear time

4.2.3 Specific Aim III

Specific Aim III sought to examine whether demographic characteristics such as age, gender, race, ethnicity, parent income, parent education, and educational setting were associated with MVPA and sedentary behavior in children 6-11 years with ASD. Additionally, we aimed to determine if factors such as ASD severity, parent-reported barriers to child's physical activity, parental perceptions to physical activity, and functional disability index were related to MVPA and sedentary behavior.

4.2.3.1 Demographic Characteristics

Linear regression was used to determine relationships between demographic characteristics and MVPA as well as demographic characteristics and sedentary behavior.

Of the demographic variables examined (age, gender, race, ethnicity, parent income, parent education, and educational setting), only the relationship between age and MVPA approached significance (*p*=0.065) and none were associated with sedentary behavior (see **Table**

11). Though the relationship between age and MVPA was not statistically significant, MVPA decreased by 18.5% with each additional year, and age explained a meaningful 23% of the variability in MVPA.

Table 11. Associations Between Demographic Characteristics and Physical Activity[a, b] (N=17)

	MVPA			Sedentary Behavior		
	MVPA % Difference	*P* value	R^2	β Coeff.	*P* value	R^2
Age	**-18.5**	**0.065**	**22.7%**	**-8.4**	**0.404**	**2.8%**
Female (vs. Male)	**-26.0**	**0.325**	**8.5%**	**-18.1**	**0.693**	**0.7%**
Black (vs. White)	**9.5**	**0.853**	**0.3%**	**48.6**	**0.219**	**5.9%**
Parent Income	**-0.6**	**0.951**	**0.03%**	**-8.6**	**0.308**	**4.2%**
Parent Education	**-20.7**	**0.308**	**7.6%**	**24.35**	**0.198**	**6.5%**
Private School (vs. Public)	**-5.1**	**0.915**	**0.1%**	**-9.32**	**0.818**	**2.3%**
Other (vs. Public School)	**5.0**	**0.953**	**0.1%**	**45.2**	**0.515**	**10.2%**

[a] Results are adjusted for wear time
[b] R^2 presented is the additional R^2 variability explained by each demographic variable after subtracting variability explained by wear time

4.2.3.2 ASD Severity

ASD severity was coded as either mild, moderate, or severe based on parent report. Thirteen participants (68%) were classified by their parents as having “mild” ASD, 5 participants (26%) were classified as having “moderate” ASD, and 1 participant (5%) was classified as having “severe” ASD (**Figure 7**).

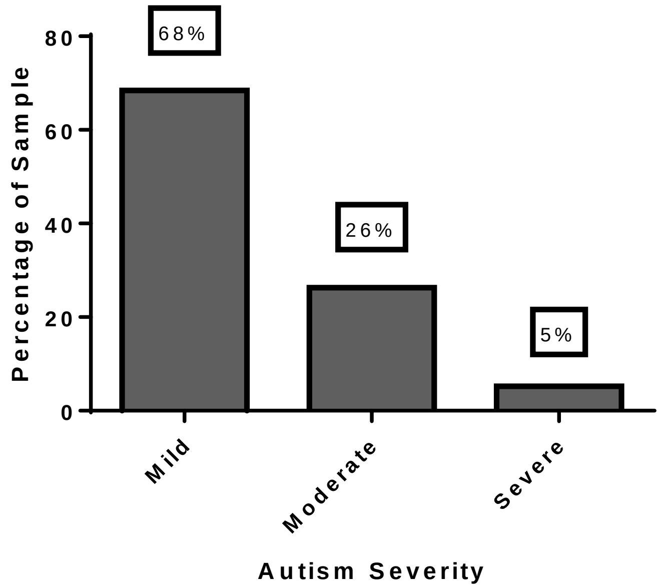

Figure 7. Parent Perception of ASD Severity (N=19)

Linear regression was used to evaluate whether ASD severity was associated with either MVPA or sedentary behavior. ASD severity was not significantly associated with MVPA or sedentary behavior (**Table 12**), though sedentary behavior was more than an hour less for children with parent-rated moderate or severe ASD and parent-rated severity explained a meaningful 17.4% of the additional variance.

Table 12. Associations Between ASD Severity and Physical Activity[a, b] (N=17)

	MVPA % Difference	β Coeff.	*P* value	R^2
MVPA				
Moderate	**10.3**		**0.844**	**0.7%**
Severe	**19.5**		**0.829**	
Sedentary Behavior				
Moderate		**-68.5**	**0075**	**17.4%**
Severe		**-93.4**	**0.132**	

[a] Results are adjusted for wear time
[b] R^2 presented is the additional R^2 variability explained by ASD severity after subtracting variability explained by wear time

4.2.3.3 Parent-reported Barriers to Physical Activity

The most common barriers to child physical activity reported by the parents were the child's lack of interest/motivation in physical activity (32%) inadequate community physical activity programs, (26%), child has too many behavioral problems (21%), not being able to find a community program that accommodates their child's physical disability (16%), and child is too developmentally disabled (16%), (**Table 13**).

Table 13. Parent-reported Barriers to Child's Physical Activity (N=19)

Barrier	N	Percentage
Child lacks interest/motivation	**6**	**31.6**
Inadequate community physical activity programs	**5**	**26.3**
Child has too many behavioral problems	**4**	**21.0**
Cannot find program that accommodates child's disability	**3**	**15.8**
Child is too developmentally delayed	**3**	**15.8**
Cannot afford the cost of exercise/sports	**2**	**10.5**
Child does not have enough time	**2**	**10.5**
Parent's lack of time	**1**	**5.3**
Lacks reliable transportation	**1**	**5.3**
Unsafe neighborhood	**1**	**5.3**
Child is too physically sick/frail	**0**	**0**

Linear regression was then used to determine relationships between outcome variables and those parent-reported barriers to child's physical activity reported by at least 3 parents in our sample (inadequate community physical activity programs, not being able to find a community program that accommodates their child's physical disability, child's lack of interest/motivation in physical activity, child is too developmentally disabled, and child has too many behavioral problems). Relationships between parent-reported barriers reported by less than 3 parents were not assessed.

Of the parent-reported barriers considered (listed above), only the relationship between behavioral problems and MVPA (r^2=22.8%, p=0.060) approached significance, and a meaningful 22.8% of the variability in MVPA levels between participants can be explained by the parent-reported barrier that their child has too many behavioral problems. Additionally, if parents reported that their child's behavioral problems were a barrier to their child engaging in physical activity, there was a 124% difference in MVPA. Barriers to physical activity were not associated with objectively measured sedentary behavior.

Table 14. Associations Between Parent-reported Barriers to Physical Activity[a, b] (N=17)

	MVPA			Sedentary Behavior		
	MVPA % Difference	*P* value	R^2	β Coeff.	*P* value	R^2
Inadequate community PA programs	**71.6**	**0.251**	**9.5%**	**-33.5**	**0.429**	**2.4%**
Program cannot accommodate child's disability	**87.0**	**0.263**	**9.1%**	**8.6**	**0.865**	**0.1%**
Child lack's interest/motivation	**-32.9**	**0.285**	**8.3%**	**11.4**	**0.737**	**0.4%**
Child is too developmentally delayed	**18.0**	**0.777**	**0.6%**	**7.1**	**0.891**	**0.1%**
Child has too many behavioral problems	**124.0**	**0.060**	**22.8%**	**-43.7**	**0.279**	**4.4%**

[a] Results are adjusted for wear time
[b] R^2 presented is the additional R^2 variability explained by each barrier after subtracting variability explained by wear time

4.2.3.4 Parent Perceptions of Physical Activity

Parent Perceptions of Physical Activity and Screen Time Guideline

Thirteen parent participants (68%) knew that the current recommendation for physical activity is 60 minutes or more each day, and 14 parent participants (74%) knew that the recommendation is to limit leisure screen time to less than 2 hours each day. On average, parents thought that the recommendation was 93 ± 61 minutes per day (range 20-240 minutes/day), and 2 ± 1 hours/day for sedentary behavior (range .5-4 hours/day).

Linear regression was used to evaluate the relationship between parental perception of the physical activity guideline and MVPA. Linear regression also evaluated the relationship between parent's knowing the screen time guideline and sedentary behavior. No relationship was found between parent's knowing the physical activity guideline and MVPA (*p*=0.615), nor parents knowing the screen time guideline and sedentary behavior (*p*=0.586) (Table 17).

Table 15. Associations Between Parent Perception of Recommendation and Physical Activity[a, b] (N=17)

	MVPA % Difference	β Coeff.	*P* value	R^2
Parent perception of physical activity recommendation[c]	**0.3**		**0.615**	**1.5%**
Parent perception of screen time recommendation[d]		**7.4**	**0.586**	**1.2%**

[a] Results are adjusted for wear time
[b] R^2 presented is the additional R^2 variability explained by each barrier after subtracting variability explained by wear time
[c] Parent perception of physical activity recommendation regressed with average MVPA
[d] Parent perception of screen time recommendation regressed with average sedentary behavior

Physical Activity Priority and Perception of Meeting the Guidelines

Fifty-three percent of parents (n=10) reported that considering their familial demands, physical activity was of moderate priority, 37% (n=7) stated it was of high priority, and 11% (n=2) reported physical activity being of low priority (**Figure 8**). Twenty-six percent (n=5) of parents reported that their child meets the recommendation of 60 minutes or more of physical activity on all days of the week, 26% (n=5) reported their child meets the recommendation more than half the days, 16% (n=3) reported about half of the days, 21% (n=4) reported less than half the days, and 11% (n=2) reported their child meets the physical activity recommendation almost none of the days (Figure 7).

Eleven percent (n=2) of parents reported that their child meets the recommendation of less than 2 hours each day of leisure screen time on all days of the week, 26% (n=5) reported their child meets the recommendation more than half the days, 26% (n=5) reported about half of the days, 11% (n=2) reported less than half the days, and 26% (n=5) reported their child meets recommendation for leisure screen time almost none of the days (**Figure 9**).

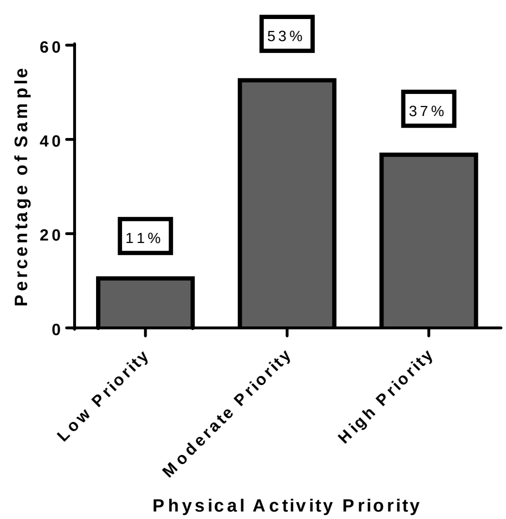

Figure 8. Parent Perception of Physical Activity Priority

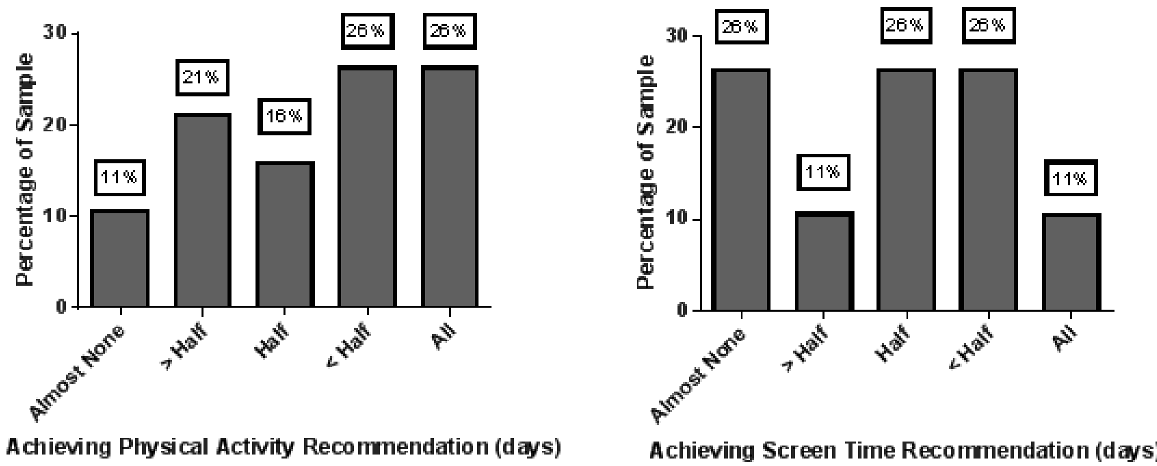

Figure 9. Parent Perception of Child Meeting Recommendations

Linear regression was used to evaluate the relationship between physical activity priority (moderate and high) and MVPA, and physical activity priority and sedentary behavior. Linear regressions also evaluated the relationship between parent's perception of their child meeting the physical activity guideline and MVPA as well as parent's perception of their child meeting the screen time guideline and sedentary behavior. No relationships were found between moderate physical activity priority and MVPA (p=0.181) or high physical activity priority and MVPA (p=0.423). Additionally, no relationships were found between parent's perception of their child meeting the physical activity recommendation and MVPA (see Table 16 for p-values) or parent's perception of their child meeting the screen time recommendation and sedentary behavior (see **Table 16** for p-values).

Table 16. Associations Between Parent Perceptions of Physical Activity Priority, Meeting Guidelines, and Physical Activity[a, b] (N=17)

	MVPA			Sedentary Behavior		
	MVPA % Difference	***P* value**	**R^2**	**β Coeff.**	***P* value**	**R^2**
Physical activity priority	**10.2**	**0.768**	**0.7%**	**-23.7**	**0.409**	**2.6%**
Achieving physical activity recommendation[c]	**10.4**	**0.484**	**3.7%**			
Achieving screen time recommendation[d]				**6.9**	**0.560**	**1.3%**

[a] Results are adjusted for wear time
[b] R^2 presented is the additional R^2 variability explained by independent variable after subtracting variability explained by wear time
[a] Parent-reported achieving the physical activity recommendation regressed with average MVPA
[b] Parent-reported achieving the screen time recommendation regressed with average sedentary behavior

4.2.3.5 Functional Disability Index

The majority (89%) of participants' parents reported that their child had no/minimal functional disability, and a small proportion (11%) reported that their child had moderate functional disability. On average, the total score for the Functional Disability Index was 5.6 ± 6.1, and ranged from 0 to 20 (**Figure 10**).

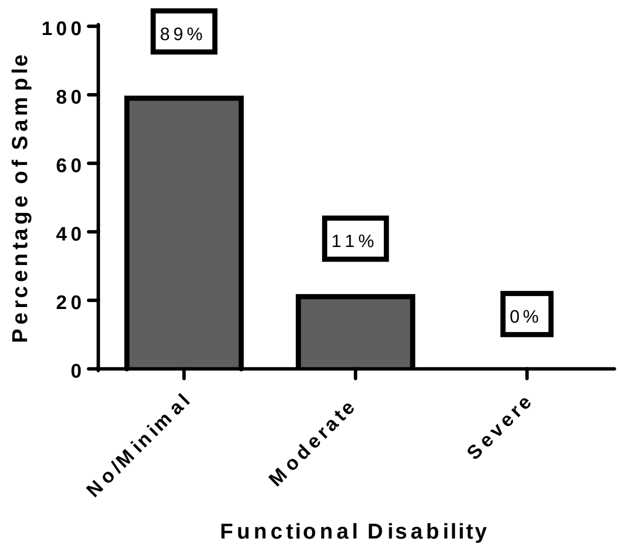

Figure 10. Functional Disability Index

Linear regression was used to evaluate associations between FDI score and MVPA and FDI score and sedentary behavior. No relationship was found between FDI score and MVPA (*p*=0.751) or FDI score and sedentary behavior (*p*=0.154) (**Table 17**).

Table 17. Associations Between Functional Disability Index and Physical Activity[a, b]

	MVPA			Sedentary Behavior		
	MVPA % Difference	*P* value	R^2	β Coeff.	*P* value	R^2
FDI score	**-1.1**	**0.751**	**0.7%**	**4.3**	**0.154**	**12.6%**

[a] Results are adjusted for wear time
[b] R^2 presented is the additional R^2 variability explained by FDI score after subtracting variability explained by wear time

4.2.4 Summary

The study found that 50% of children aged 6-11 years with ASD in our study achieved at least 60 minutes or more on at least 5 days per week, which is similar to population estimates. The children in our sample meeting the guidelines for physical activity achieved almost double the amount of MVPA compared to those individuals not meeting the federal guidelines. Children in our sample also engaged in similar amount of total and bouted MVPA on both weekdays and weekends. Children with ASD spent the same amount of time in sedentary behavior on weekdays and weekends. Further, the prevalence of children with ASD ≥ 85^{th} percentile (overweight) and ≥ 95^{th} percentile (obese) in our sample was similar to national estimates of children of the same age.

There were no significant relationships found between our dependent variables, MVPA and sedentary behavior, and any of the independent variables examined in this study (demographics, BMI, ASD severity, parent-reported barriers to child physical activity, parental perceptions of physical activity, and functional disability). Though not statistically significant, higher age and the parent reported barrier of behavioral problems were most strongly associated with lower MVPA, and increased severity of ASD was associated with less sedentary behavior (all with R^2 >15%).

5.0 DISCUSSION

5.1 SUMMARY OF MAIN FINDINGS

The primary aims of this investigation were to examine objective physical activity and sedentary behavior, BMI, and potential determinants of physical activity and sedentary behaviors in children with ASD. Specifically, this investigation sought to determine: 1) daily durations of physical activity and sedentary behavior; 2) BMI, and the relationship between BMI and levels of physical activity and sedentary behavior; 3) potential determinants of physical activity and sedentary behaviors such as demographics, ASD severity, parent-reported barriers to child's physical activity, parental perceptions of physical activity, and functional disability.

Half of the participants met the federal recommendation of 60 minutes or more of physical activity on most (at least 5), if not all days of the week [40, 42, 128]. Those children meeting the guidelines for physical activity engaged in daily physical activity well above the current guidelines and more than double the amount of MVPA compared to study participants who did not meet the guidelines (**Figure 5**). Interestingly, two-thirds of the parents knew the current recommendations for both physical activity and leisure time sedentary behavior. Also of interest, two-thirds of parents perceived that their child met the recommendation for physical activity more than half of the days of the week or all of the week (**Figure 9**), and almost two-thirds of parents perceived their child met the recommendation for sedentary behavior more than half of the days or all days of the week (**Figure 9**). However, knowing guidelines or perceived child adherence to the guidelines was not associated objectively measured physical activity or sedentary behavior in our sample.

Though it has been suggested in the literature [10, 61, 143, 163], the percentage of children in our sample ≥ 85^{th} percentile, and ≥95^{th} percentile for BMI was not different from national estimates in children of the same age. It was hypothesized that children with ASD would have higher levels of both overweight and obesity, though this was not observed.

Contrary to the study hypotheses, MVPA was not related to BMI classification, gender, race, parent income, parent education, educational setting, ASD severity, parental perceptions of physical activity, or functional disability. However, the relationship between MVPA and age approached significance (higher age associated with lower MVPA). Additionally, the relationship between behavioral problems and MVPA approached significance, with almost 124% higher MVPA in those with behavioral problems as a barrier to physical activity compared to those without.

Also, contrary to study hypotheses, sedentary behavior was not related to BMI classification, age, gender, race, parent income, educational setting, parental perceptions of physical activity, or functional disability. An interesting finding was that children with moderate or severe ASD by parent report had more than one hour less sedentary behavior each day, on average, when compared to those rated as having mild ASD.

The following sections will discuss the interpretation and practical significance of these findings, as well as strengths, limitations, and future directions. Results and interpretation of these results should be interpreted with caution for a number of reasons. Recruitment methods employed during this study may have yielded a sample of participants not representative of the general population of children with ASD, which may limit generalizability. Furthermore, this study is limited in sample size. Thus it is recognized that this study has limited statistical power to examine associations, which will be discussed further in the limitations section.

5.2 PHYSICAL ACTIVITY IN CHILDREN WITH ASD

5.2.1 Meeting the Federal Guideline

Physiologically, children and adolescents with ASD display lower levels of physical fitness such as cardiovascular endurance, upper-body muscular strength and endurance, and lower-body flexibility. Children and adolescents with ASD also perform significantly poorer on tests of motor proficiency compared to those without ASD [20, 21]. Additionally, nationally-representative data suggest that children with ASD are less likely to participate in regular physical activity [61]. Based on the body of literature, it was hypothesized that a lower percentage of children in our sample (6-11 year olds with ASD spectrum disorder) would meet the current Federal recommendation of 60 minutes or more of daily physical activity compared to the population estimate of 42% from the United States' 2014 Report Card on Physical Activity [43]. Approximately 50% of participants in this study met the current federal guidelines of 60 minutes or more of physical activity on most if not all (at least 5) days of the week. Our results were similar to the proportion of all children (potentially including those with disabilities) within the United States meeting the current recommendation for physical activity. These results conflict with the results of a few studies examining objective physical activity in children with ASD [13, 58, 60], but are in agreement with one other [164].

Rosser Sandt, el al., (2005) observed 67% meeting the current guideline among children with ASD aged 5-12 years old [58], and Pan & Frey (2006) found that 78% of elementary-aged students with ASD engaged in at least 60 minutes of daily MVPA [60]. However, these studies were published in 2005 and 2006, respectively, and trends in physical activity patterns may have changed over time. Additionally, cut points used in these studies differ from cut points used in the current study. Pan & Frey used age-specific cut points from Freedson, et al., (1998) [165]. For example, physical activity classified as MVPA was ≥1,017 counts per minute for 10 year olds, whereas in the current study, physical activity classified as MVPA for 10 year olds was ≥1,910 counts per minute. Based upon the more conservative nature of cut points employed in the current study, differences found between the current study and Pan & Frey are reasonable. Rosser Sandt, et al., (2005) did not report the activity count cut points used.

More recently in 2013, Bandini, et al., observed only 23% of children with ASD 3-11 years old achieving the guidelines. Within this study, cut points by Puyau, et al., (2004) were used: cut points for light, moderate, and vigorous activity were 100–1499, 1500–6499 and ≥ 6500 counts per minute, respectively, regardless of age. Though these cut-points are similar to the range of age-specific cut points for MVPA used in the current study, Bandini, et al.'s age range is 3-11 years (mean=6.7, SD=2.4), and these cut points may be conservative for the younger participants in the study, resulting in more activity classified as light activity [13]. Pan, et al., (2015) observed 47% of secondary-aged school children meeting the guideline [164]. However, participants in the Pan, et al., study were older (12-17 years) compared to the current study, and therefore may not be comparable to our sample.

Although we did not find that children with ASD had a lower prevalence of meeting the physical activity guidelines compared to national averages using the same cut points, the lack of difference may be partially explained by our sample. Consistent with the higher risk of ASD in males vs. females, our sample was primarily composed of males (90%). Males have consistently higher levels of physical activity compared to girls, and boys are more likely to meet the guidelines for physical activity [44, 45, 47-49, 51, 53-56, 133]. In NHANES from 2003-04 which used objective monitoring, even among children as young as 6-11 years old (the same age as this sample), almost half of boys (48%) meet the recommendation compared to only 35% of girls [44]. Though this study sought to determine if physical activity levels were different between children with ASD and typically developing children, future research including a true comparison group of typically developing children matched for all demographic characteristics except ASD diagnosis to detect differences in physical activity levels would improve the internal validity of the comparison.

5.2.2 Weekday vs. Weekend Physical Activity

We hypothesized that children in our sample would display lower MVPA on weekdays compared to weekend days; however, no significant differences were found between weekday and weekend physical activity. Relatedly, we initially also hypothesized that children would have lower MVPA during school hours vs. after school, though we were not able to investigate this hypothesis since data was collected during the summer break from school.

Few studies have examined weekday vs. weekend physical activity in children with ASD, though our results are in agreement with previous investigations. Rosser Sandt, et al., (2005) found no differences between weekday and weekend MVPA between the hours of 10am and 7pm among 5-12 year olds [58]. Additionally, Pan and Frey (2006) found no differences in overall physical activity of MVPA between weekdays and weekend among 10-19 year olds with

ASD. However, participants acquired more bouts of continuous MVPA (10 minutes) on weekends compared to weekdays [60]. Though not statistically significant, our findings contrasted these with slightly higher total and bouted MVPA on weekdays vs. weekends. Furthermore, Memari, et al., (2013) observed no differences between overall physical activity levels during the weekdays and weekends among children with ASD aged 7-14 years [14].

The lack of differences in our study between weekday and weekend MVPA may be explained by some limitations in our study (see Section 5.7.1). Data was collected during the summer months when children were not in school. Children spend a majority of time in school during the school year. As many younger children are provided with opportunities to engage in physical activity during the school day such as physical education and recess, physical activity during the weekday may be different in our study compared to physical activity levels that would be observed at other times during the year. Though differences in physical activity between the school year and summer months are not clear in children with ASD, nationally-representative data suggest typically developing children accumulate close to half of their physical activity each day at school. A study by Long, et al., (2013) using accelerometer data from 2003–2004/2005–2006 NHANES broken down into a segmented day (before school, during school, after school, and evening), found that the school day from 8:00am-2:59pm accounted for the largest proportion (45%) of daily MVPA on weekdays in 6-19 year olds [132].

5.3 SEDENTARY BEHAVIOR IN CHILDREN WITH ASD

Only a few studies have reported data on sedentary behavior in children and adolescents with ASD [59, 61, 63, 146]. Of the studies that do exist, most studies rely on parent-reported behavior of television viewing time. Though unclear, some literature suggests that children with ASD spend more time sedentary compared to their typically developing peers, and that younger children engage in less sedentary time compared to their older peers. Our study hypothesized that sedentary behavior would be higher on weekends compared to weekdays. However, no significant differences in sedentary time were observed between the weekdays and weekends.

In one study, Must, et al., (2013) examined discretionary sedentary behavior in children aged 3-11 years with ASD using parent-reported television viewing, computer usage, video games, etc. as proxies for sedentary time. Children with ASD spent an hour more watching TV, on the computer, and playing video games on weekdays compared to typically developing children (5.2 vs. 4.2 hours) [63]. Orsmond, et al., (2011) examined the daily lives of adolescents with ASD using time use diaries and found that adolescents with ASD spent on average, 2.3 hours watching television and 1.7 hours on the computer [146]. In another study, MacDonald, et al, (2011) found significant differences in sedentary behavior between 9-11 year olds and 12-18 year olds (with older children spending more time sedentary) during in school (+40 minute difference), after school (+12 minute difference), and evening hours (+40 minute difference), though there was no typically developing comparison group [59].

In contrast, McCoy et al. (2016) also examined sedentary behaviors using parent-reported television viewing, computer usage, video games, etc. as proxies for sedentary time among 42,747 children and adolescents (915 with ASD) from the National Survey of Children’s Health. Children and adolescents with ASD had similar rates of meeting recommendations for sedentary behaviors (<2 hours per day television viewing and computer usage) compared to their typically developing peers [61].

Of interest in our study, there were no differences in sedentary behavior between weekdays and weekend days. This was contrary to our study hypothesis, but, again, this may be explained by time of year (summer) during which data collection occurred. This will be discussed further in the limitations Section 5.7.1.

5.4 OBESITY IN CHILDREN WITH ASD

Nationally-representative data suggest that children and adolescents with ASD have higher levels of overweight and obesity compared to their typically developing peers [61, 163]. Based on other studies of weight status in children with ASD, we hypothesized that the prevalence of overweight and obesity would be higher in our sample compared to population estimates (31.8% overweight and obese, and 16.9% obese) from 2011-2012 NHANES [64]. Further, we expected that MVPA would be lower across increasing categories of BMI and that sedentary behavior would be higher across increasing categories of BMI. In contrast with available literature on weight status in children with ASD, the current study observed no differences in overweight or obesity compared to national prevalences and no associations with MVPA or sedentary behavior.

For example, Egan, et al., (2013) evaluated weight status in 273 2-5-year-old children with ASD using retrospective chart reviews. Rates of overweight and obesity were then compared to rates of overweight and obesity in 2007-08 NHANES (21.2% overweight and obese, and 10.4% obese). Within this study, rates of overweight and obesity in children with ASD were found to be above nationally representative prevalence estimates for children. Among children with ASD, 22% had a BMI percentile in the obese range (≥ 95th percentile). These differences we independent of both psychotropic medications prescribed and adaptive functioning [65]. Another study by Curtin, et al., (2010) using nationally-representative data from the National Survey of Children's Health (n=85,272) found that the weighted prevalence of obesity was 30.4% in children and adolescents with ASD and 23.6% in children without ASD. Additionally, the odds of obesity in this sample were 42% higher than in children without ASD [10]. Lastly, in a smaller study (n=53 with ASD, n=558 typically developing), Evans, et al., (2013) found that 17% of their sample met obesity criteria compared to only 9% of typically developing children. However, this difference was not significant [166].

In contrast, Curtin, et al., (2005) found that, when compared to age-matched controls, children with ASD had a prevalence of obesity that was similar to children in the general population using a retrospective chart review of 140 children aged 3-18 years with ASD or attention deficit hyperactivity disorder. For children 6-11 years old with ASD, the overall prevalence of overweight and obesity was 37.8% and the prevalence of obesity was 18.8% [143]. Similarly, Xiong, et al., (2009) observed a prevalence of 37.9% overweight and obese and a prevalence of 21.8% obese in a sample of 429 6-11-year-old children with ASD in China. Though these rates of overweight and obesity are among children in China, not American children, these rates are similar to the rates of overweight and obesity seen in Curtin, et al., (2005) (American children) [145].

It has been suggested that overweight and obesity levels are higher in children with ASD compared to their typically developing peers for a number of reasons. Factors such as psychopharmacological treatment, genetics, disordered sleep, atypical eating patterns, and lower levels of physical activity may be associated with the development of obesity in children with ASD [163]. Genetics, disordered sleep, and atypical eating patterns were not examined in the current study, however prescription medication information was collected. Over 50% of our sample was on prescription medications, some of which may cause weight gain in this population. Nationally representative data suggest that 30%-60% of children with ASD are prescribed at least one psychotropic medication, and 10% are prescribed more than three; stimulants, antidepressants, and antipsychotics are the most commonly prescribed [163]. These rates are similar to the current study. Atypical antipsychotics (especially risperidone and aripiprazole) are likely to cause weight gain in individuals [167]. Additionally, metabolic syndrome is of particular concern in individuals prescribed these medications, and children are more likely to develop obesity due to these second generation antipsychotics [168] which are a first-line treatment for behaviors associated with ASD [169].

While the rates of overweight and obesity in the current study are not statistically different, this may be due to the limitations in our sample size as well as our sample itself, which will be discussed more in the limitations and future directions section of this chapter.

5.4.1 Relationship Between Obesity, MVPA, and Sedentary Behavior

The relationships between weight status and MVPA has not been evaluated in children with ASD. In the general population, an inverse relationship between physical activity and overweight has been observed in some [119-121], but not all, studies [122, 123] examining this relationship in typically developing children.

Several cross-sectional studies examining physical activity and varied measurements of adiposity (BMI, waist circumference, skinfold thickness) have found inverse relationships between overweight/obesity and physical activity levels [119-121]. For example, Ara, et al., (2007) examined physical activity levels and skinfold thickness in 1,068 children aged 7-12 years old. Though not significant, those in the active groups had lower skinfold thickness compared to those in the inactive group. The proportion of boys who were classified as overweight and obese was not statistically different (*p*=0.09) comparing physically active and sedentary groups (overweight: 32% vs. 25%; obesity: 6% vs. 2%); however, physically active girls had a lower obesity prevalence compared to their sedentary peers (6% vs. 10%, *p*<0.05) [120]. Haerens, et al., (2007) found significant associations between weight status and physical activity in 222 11-13 year olds. Overweight children reported significantly less physical activity (~18 minutes) compared to normal weight children. Among boys, normal weight boys spent on average 21 minutes more in MVPA per day. Overall, overweight and obese children spent on average 12 minutes a day less in MVPA compared to normal weight children [121]. In a similar study, Gonzales-Suarez, et al., (2011) found an inverse association between BMI and physical activity. Those with lower physical activity had higher odds of being overweight (OR=4.6) or obese (OR=10.8) [119].

In contrast, Ng, et al., (2006), examined BMI and objective physical activity via pedometer in 82 children 9-12 years old, but found no significant differences in physical activity levels among BMI groups [122]. In a similar study, Aires, et al., (2010) observed no significant associations between BMI and total amount of physical activity or physical activity intensity; however, low cardiorespiratory fitness was significantly associated with obesity (OR=0.968).

The relationship between weight status and sedentary behavior has been evaluated in one study among children with ASD to this author's knowledge. Must, et al., (2013) examined sedentary behavior in 3-11-year-old children with ASD compared to typically developing children. Total sedentary time on weekends, measured by parent-reported TV viewing, computer usage, screen time etc. was directly related to BMI z-score (r=0.39, *p*=0.005) in children with ASD but not typically developing children. Additionally, TV time was associated with BMI z-score (r=0.35, *p*=0.01), and total screen time (television, computers, and video games) was associated with BMI z-score (r=0.42, *p*=0.003) in children with ASD, but not typically developing children [63].

Although BMI was not associated with MVPA or sedentary behavior in the current study, the body of literature suggests that there is an inverse relationship between BMI and physical activity, and future study of higher physical activity and lower sedentary behavior as means of improving BMI and weight status in children with ASD is warranted.

5.5 DETERMINANTS OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR

5.5.1 Demographic Variables

Associations between MVPA and sedentary behavior and demographic variables (age, gender, race, ethnicity, parent income, parent education, and educational setting) were evaluated, but only age was found to be approaching significance with MVPA. For each additional year of age, MVPA decreased by 18.5%. Our findings are consistent with age-related declines that have been observed in previous studies examining physical activity in children with ASD as well as typically developing children [14, 59, 60].

Pan and Frey (2006) investigated physical activity patterns in adolescents aged 10-19 with ASD and found that physical activity was lower with higher age. More students in elementary school (78%) met the recommendation for physical activity than middle (67%) and high school (<1%) students. Children in elementary school spent more time in MVPA than both middle school aged children (+54 minutes) and high school students (+93 minutes) [60]. In another study, MacDonald, et al., (2011) found that younger children engaged in 132 ± 84 minutes of MVPA compared to older children who engaged in 90 ± 98 minutes of MVPA per day. This difference was observed in total MVPA, in-school MVPA (~13 minute difference), after-school MVPA (~7 minutes), and evening MVPA (~10 minutes) [59]. Furthermore, Memari, et al., (2012), found that total physical activity levels, physical activity during weekdays, physical activity during weekends, school time physical activity, and after-school physical activity in children aged 7-14 years with ASD were significantly lower in increasing age categories from childhood to adolescence. Children in the 7-8-year age group got on average 1763 ± 576 counts per minute, 9-10 year olds got 1657 ± 580 counts per minute, and 11-12 year olds got 1763 ± 576. The lowest amount of total physical activity was seen in adolescents aged 13-14 years old (1146 ± 445 counts per minute) [14].

5.5.2 ASD Severity

Associations between physical activity and sedentary behavior and ASD severity were not found to be statistically significant. This is in contrast to a previous study examining physical activity and ASD severity. McCoy, et al., (2016) found that, as ASD severity increased from "mild" to "moderate" to "severe," the odds of engaging in regular physical activity as well as organized clubs and sports significantly decreased [61]. Though the association was not significant in our study, sedentary behavior was more than an hour less for children with parent-reported moderate or severe ASD and severity explained more than 20% of the variability in sedentary behavior. The lack of associations may be explained by the method this question was asked to parents, or the wording of the question. Based on a question from the National Survey of Children's Health, parents were asked to rate their child's ASD severity in their opinion. This may in fact underestimate ASD severity if parents feel that their child's severity is different than how a heath care provider would rate the child's ASD severity. Additionally, a high percentage of children in our sample were classified as mild ASD and this limited variability may have further reduce our ability to detect significant associations. The low prevalence of parent-rated moderate and severe ASD may have been due to selection, as it is possible that parents of children with mild ASD are more likely to participate in a research study involving wearing the activity monitor compared to parents of children with severe ASD. If future research does confirm that children with milder ASD engage in more sedentary behavior, this could inform intervention targets to decrease sedentary behavior in mild ASD more so than severe cases.

5.5.3 Parent-reported Barriers to Physical Activity

Parents play a pivotal role in the development of children's health behaviors. Thus, parents can play an important role in encouraging or discouraging their child's engagement in physical activity. This encouragement can be in the form of either eliminating barriers that they or their children may face towards engaging in physical activity or by creating barriers that can prevent their children from being physically active [74, 75]. Examples of facilitating physical activity include providing resources such as paying for sports programs, providing transportation, or purchasing equipment. Our study hypothesized that parent reported barriers such as child's lack of interest/motivation, inadequate community physical activity programs, behavioral problems, trouble finding programs to accommodate the child's disability, developmental delays, cost, and time would be negatively related to MVPA and positively related to sedentary behavior. Of the parent-reported barriers considered, only behavioral problems explained a meaningful amount of the variability in MVPA and approached significance.

To date, there have been no studies examining parent-reported barriers to child's physical activity in children with ASD alone. Yazdani, at al., (2013) examined factors predicting physical activity among children with special needs (ASD, attention deficit hyperactivity disorder, and learning disabilities) and found that 43% of parents reported their child lacked interest in physical activity, 33% reported lack of developmentally appropriate programs, 32% reported too many behavioral problems, and 29% reported parent's lack of time. Similar to our study, the most commonly reported barrier was child's lack of interest/motivation [77].

Pocock, et al., (2010) conducted a review of parental perceptions of healthy behaviors for young children (typically developing) and found that the most common barriers that parents reported for encouraging healthy behaviors in their children included: parent tiredness leading to lack of motivation for physical activity, cost of physical activities, society encourages sedentary behaviors, lack of parent awareness about how much sedentary behavior is occurring, parents not acting as good role models, difficult for parents to give attention to one child in multiple children households, and environmental factors such as neighborhood safety or lack of access. In addition, parents also reported that their child's own resistance to engaging in physical activity and preference for sedentary behaviors made it more difficult to get their child active. Some parents acknowledged that prolonged TV viewing might increase sedentary time, and in others, TV was not seen as a detrimental. Of note, most parents were unaware of the quantity of TV watched by their children. Additionally, in the review by Pocock, illness or disability in the child was listed as a barrier to preventing physical activity in the general population [76].

Although the current study did not find associations between parent-reported barriers to physical activity and MVPA other than approaching significance with behavioral problems, nor any relationships between sedentary behavior and parent-reported barriers, parent barriers to child physical activity may still be important. Qualitatively, the barriers reported most commonly were lack of interest/motivation for their child to engage in physical activity, inadequacy of community programs, behavioral problems in the child, child is too developmentally delayed, and community programs do not address the needs for their child's disability. Barriers most commonly reported in the current study differ from those reported for typically developing children [76] and this is important for designing interventions that meet the needs of children with ASD and their families. For example, most commonly reported barriers in the general population are lack of time, cost, and society encourages sedentary behaviors [76]. Though parental lack of time and cost were among those barriers asked in the current study, parents did not commonly report these barriers to physical activity for their child with ASD. Thus, the current study suggests that potential targets for increasing physical activity and decreasing sedentary behavior in children with ASD may be the child's lack of interest in physical activity, adequacy of physical activity programs in adapting to the child's disability and needs, and adapting interventions to accommodate children with and without behavioral problems.

Also, the lack of relationships between physical activity and barriers may be due to the wording of some of the questions asked for barriers. It is possible that the wording of the questions could have confused parents, and they may have answered "no" due to lack of understanding of the question rather than the barrier not applying to the parent and child in question.

5.5.4 Parent Perceptions of Physical Activity

Parental perceptions of child physical activity have not been previously studied in children with ASD. In the general population, perceived importance of child physical activity is associated with parental support of physical activity, and parental support is in turn positively associated with physical activity in children [75]. In addition, parental beliefs such as the importance of physical activity is associated with children's participation in MVPA [78, 79].

In the current study, the majority of parents knew the current guidelines for both MVPA and leisure screen time, however, these perceptions were not related to either MVPA or sedentary behavior, and for MVPA, the majority of parents perceived their children met the guidelines more than half of the days of the week. This is similar to previous studies examining parental perceptions of physical activity for their child (in typically developing children). A qualitative study conducted by Bentley, et al., in typically developing children found that most parents described their child as being active or very active and did not believe their child needed to increase physical activity. Though parents were not sure of the exact amount of physical activity that their child engaged in, some parents believed that because their child "seemed" physically fit, they were sufficiently active, and, because their child was "slim," they were sufficiently active [170].

In another study, Dempsey, et al., (1993) examined parental beliefs regarding physical activity on children's participation in MVPA among 71 fourth- and fifth- grade typically developing children and their parents. Within this study, parents' perception of their child's physical activity competence was significantly related to the amount of MVPA their child engaged in. Children whose parents had high perceptions of their child's competence for participating in MVPA were more likely to be physically active than children whose parents had low perceptions of their competence ($p < 0.05$) [78]. In a similar study conducted by Kimiecik and Horn (1998), parental beliefs regarding their child's physical activity did predict their child's MVPA. Particularly, parental beliefs regarding their child's physical activity accounted for 27%

of the variance in children's MVPA [79]. In another study by Trost, et al., (2003) examining parent perception of the importance of physical activity and MVPA among 380 children and their parents, physical activity was an important predictor of physical activity levels in the child. Also, higher parental perception of the importance of physical activity was positively associated with parental support (p <0.05), and parental support was positively associated with child physical activity both directly and indirectly through the positive association with child self-efficacy (p <0.05) [75].

Though parental perceptions for physical activity were not related to MVPA or sedentary behavior in our study, other studies with typically developing children suggest that parental beliefs about physical activity are an important predictor for physical activity levels in the general population. As small sample size is a limitation of the current study, larger, prospective, and experimental studies in children with ASD will add further clarity to the importance of parental beliefs about physical activity in this population.

5.6 IMPLICATIONS FOR ACTIVITY PROGRAMMING IN CHILDREN WITH ASD

Although this study did not find statistically significant associations between parental perceptions of physical activity or parent-reported barriers to their child's physical activity and MVPA or sedentary behavior, these factors may still be important for informing future physical activity intervention studies in this population.

While barriers such as lack of time, parent lack of motivation for physical activity, cost, societal norms, and neighborhood safety are commonly reported (parent) as barriers for child participation in physical activity in the general population (also measured in our study) [76], that is not the case in the current investigation. Within the current study, barriers associated with ASD such as inadequate community activity programs, behavioral problems, developmental delays, and lack of community activity programs for the child's disability, were commonly reported by parents. As these barriers for physical activity participation differ from the general population, our findings suggest that standardized physical activity interventions usually employed in typically developing children may not be effective for increasing physical activity in children with ASD.

Moreover, it should be noted that all barriers reported in this study were parent-reported. Though parent barriers are of importance for physical activity in children, this study did not evaluate barriers the children felt they faced for engaging in physical activity. Additionally, as some participants in the study were classified as "severely" autistic, evaluating barriers from the child participants themselves may have been difficult, and in some cases, impossible. Future research should evaluate effective ways to determine and seek to identify barriers in the children themselves.

One unofficial aim of this study was the feasibility of objectively measuring physical activity and sedentary behavior in 6-11-year-old children with ASD. Qualitatively, all parents expressed concerns for their child wearing the activity monitor for various reasons such as tightness of the band and displeasure wearing anything around the waist. However, only one participant wore the monitor less than 8 hours per day at least 4 days during the wear period. This suggests that an activity monitor around the waist is a feasible method for measuring physical activity in this population.

Overall, though no statistically significant associations were found between independent and dependent variables, this study provides valuable insight into the feasibility of physical activity research and the potential determinants of physical activity and sedentary behavior in children with ASD.

5.7 LIMITATIONS AND FUTURE DIRECTIONS

This study had a number of strengths that included: 1) objective measurement of physical activity, sedentary behavior, height and weight, and 2) examination of a broad array of potential determinants not previously studied in this population that included ASD severity, functional disability, parental perception of physical activity, and parent-reported barriers to child's physical activity. The assessment of these constructs may allow this study to better understand the potential patterns of physical activity and sedentary behavior in children with ASD to inform future studies and interventions in the population. However, this study did have a number of limitations that may influence the findings of this study, and therefore results should be interpreted with caution. The limitations are discussed below.

5.7.1 Study Limitations

This study was limited in several factors: 1) study recruitment and sample size; 3) different cut points available for Actigraph analysis; 4) time of data collection; 5) physical activity not measured by accelerometer; 6) measurement of sedentary behavior by accelerometry.

5.7.1.1 Study Recruitment and Sample Size

Participants for this study were mostly recruited using letters and emails sent to parents of children aged 6-11 years with ASD who signed up to be contacted about studies for children with ASD that they may be eligible for. As this was a convenience sample, it may have resulted in significant bias in regards to physical activity, sedentary behavior, and overall health behaviors. Parents were interested in research studies that may benefit the management of their child's ASD, or to help with understanding behaviors in this population. Beliefs about the course of ASD may also influence participation in research studies. Children with ASD from families that believe ASD is a curable disorder are, on average, concurrently involved in three treatments, with frequent switching or adding of treatments. One the other end of the spectrum, parents who believe ASD cannot be cured or improved may do little to try to manage their child's ASD [152]. Additionally, parents were involved and engaged in this research study, and very interested in learning how much physical activity their child engages in, which may have influenced results. Therefore, though participants were from all areas of the Greater Pittsburgh Community, this sample may not have been a generalizable sample of children with ASD in this area.

Also, this study originally planned to enroll 50 children aged 6-11 years with ASD. By the close of study recruitment, only 19 children with ASD provided data. Study recruitment is a limitation of this current study. Recruitment methods included 128 emails and 490 flyers sent through the University of Pittsburgh's Clinical and Translational Science Registry to potential interested participants. From this recruitment source, 14 interested participants called the principal investigator for more information and 12 completed the study. Flyers were posted on social media and advertisement websites including Craigslist and Facebook. From this recruitment method, 3 participants called for more information and participated in the study.

Furthermore, emails were sent to local organizations supporting ASD services, as well as through University of Pittsburgh contacts. Investigators thought that snow-ball recruitment would be an effective source of new participants, however, though flyers were given to each participant assessed to be passed along to friends and acquaintances with children with ASD, only one participant was recruited through this method. Finally, flyers were distributed at the Autism Speaks annual walk for ASD in Pittsburgh, PA. From this recruitment method, 3 potential participants called for more information, and 2 completed the study.

Future Directions: Based on this limitation, future studies should implement a recruitment/screening plan that recruits a larger portion of the participants from other sources to increase generalizability of the findings. Though a challenge in the current study due to time constraints, a future recruitment plan could include recruiting from support groups for parents of children with ASD, recruitment for programs and centers specializing in ASD, and medical centers specializing in the treatment of ASD. Additionally, in future studies, recruitment efforts should include relationship building within the community to enhance future study recruitment. For example, this could include local ASD networks (local/regional chapters of Autism Speaks, Autism Society, National Autism Association, etc.), health care professionals specializing in ASD, as well as teachers and parents in the community.

5.7.1.2 Different Cut points for ActiGraph

A multitude of cut points for ActiGraph accelerometers are available for data analysis. All cut points available to choose from have been previously validated in children against indirect calorimetry with a variety of activities [44, 87, 94, 156]. Based on the scope of this study, only one set of cut-points was chosen for analysis, physical activity may have been over- or under-reported based upon the cut points chosen.

Future Directions: Based upon this limitation, future research is needed to determine if existing cut points are sufficient for children with ASD. If cut points are sufficient, future research should employ a standardized set of cut points for this population. If existing cut points are not sufficient for children with ASD, new cut points should be established.

5.7.1.3 Time of Data Collection

Data collection occurred during the summer months when children were no longer in school. This may have introduced significant bias into the results of this study as children were not in the routine that they have for nine months (the majority) of the year. Schools provide opportunities for students to engage in physical activity such as physical education class and recess, which were not captured in this study. Also, levels of physical activity can vary with seasonality, and summer provides weather conducive to engaging in activities outside, which may have resulted in higher amounts of physical activity in our sample. It is possible the time of data collection for this study limits the studies' generalizability.

Future Directions: Based on this limitation, future studies should implement data collection during the school year and during the summer months for comparison purposes.

5.7.1.4 Limitations of Accelerometry

Children were required to wear the activity monitor for all waking hours and for 7 consecutive days. However, as ActiGraphs are not waterproof, participants were required to remove these activity monitors when engaged in water activities such as swimming. More than half of participants reported taking the activity monitor off for swimming. As even recreational swimming may be considered MVPA, activity monitors may be underestimating the amount of physical activity children in the current study children engaged in.

Future Directions: Based on this limitation, future studies may be able to implement a questionnaire of physical activity log to evaluate activities such as swimming that are not captured by the activity monitor. Challenges for implementing questionnaires in this population may include the administration of the questionnaire itself as well as children understanding the questionnaire. For example, in the current study, some participants were non-verbal and unable to give detailed answers to questions. Additionally, some participants in the current study had comorbid intellectual disability and developmental delays, which would make questionnaire administration challenging. Future studies should also include more standardized measured of IQ, adaptive functioning, and autism severity.

5.7.1.5 Measurement of Sedentary Behavior by Accelerometer

Sedentary time was measured by accelerometer in the current study. Accelerometers provide an estimate of the amount of time (minutes) participants spend at <100 counts per minute. While this can be considered an estimate of the participant not moving, there is no specific measurement of the participant's position (sitting, standing, reclining), which is included in a commonly used definition of sedentary behavior in the literature [171].

Future Directions: An activPAL, which includes a postural component, is considered the gold standard for the measurement of sedentary time [157]. Future studies could employ an activPAL for the measurement of sedentary behavior, though the feasibility of this method in children with ASD is unknown.

5.8 CONCLUSION

Although there have been investigations examining objective physical activity and sedentary behavior (self-report), as well as overweight and obesity in children with ASD, no studies to date have examined potential determinants of physical activity and objective sedentary behavior in this population. Without understanding the potential determinants of physical activity and sedentary behavior in this population, effective physical activity interventions cannot be created to combat potential lower levels of physical activity, higher levels of sedentary behavior, and increased obesity in children with ASD. Though this study did not find statistically significant findings, the findings from this study suggest that inherent characteristics of ASD such as ASD severity (targeting children with more mild severity) may be related to physical activity levels in this population. Findings suggest that barriers commonly reported by parents of children with ASD may serve as targets for creating targeted physical activity programs adapted for this population. Further, findings suggest that an activity monitor worn around the waist for one week is a feasible option for the measurement of physical activity and sedentary behavior in this population. Future studies are needed to further investigate these relationships in children with ASD to create and implement effective programs, as well as the feasibility of implementing physical activity programming in this population.

APPENDIX A: ADVERTISEMENT

Needed: Children aged 6-11 with Autism Spectrum Disorder for a Research Study on Physical Activity

Participation Requires:

- A 30 minute in-person visit, where height and weight will be measured.
- Parent will complete a Study Questionnaire.
- Children will be asked to wear a small activity monitor around their waist for 7 days.

Participants will be compensated for their time and effort. For more information, contact Stephanie McCoy at 412-383-4022.

Figure 11. Advertisement

APPENDIX B: SCREENING FORM

CONTACT TRACKING FORM

"Thank you for calling to find out more about our research study. My name is ______________ and I would briefly like to tell you about this research study."

Procedure for Describing the Study and Obtaining Verbal Consent to Conduct the Phone Screen: A description of the study will be read to participants, and this description includes important components of the informed consent (see script below). Individuals who express an interest in participating in this study will be told the following to obtain verbal consent:

Investigators component of Informed Consent: *"This study is being conducted by Stephanie McCoy at the University of Pittsburgh."*

Description Component of Informed Consent: *"The purpose of this study is to examine how much time children with autism spectrum disorder spend sitting and being active. In addition, we want to know if the amount of time your child is active is affected by your child's autism symptoms, ability to do everyday tasks or even your feelings towards being physically active. As a part of our study, we will be asking children to wear an activity monitor around their waist for one week. We will also ask parents to answers some questions about their child's autism symptoms, ability to do everyday tasks, and your feelings towards being physically active. We will also measure your child's height and weight. This study will involve either a trip to the University of Pittsburgh, partnering organization, or your home if you so choose. This visit should last no longer than 30 minutes, and there will be a small gift for your child to participate. If your child completes the study, they will receive an additional $20 for participation. All of the information will be coded and any identifying information will be kept in a separate locked location away from the collected study data.*

Before enrolling you in this study, we need to determine if your child is eligible. So, what I would like to do know is ask you a few questions about you and your family such as your age, your child's age, autism diagnosis, ability to participate in PE at school, and prescription medications. It will take approximately 5 minutes to ask you all of the questions. If your answer to a particular question tells me clearly your child will not be eligible, I will stop the interview and not ask you any more personal questions. If we complete the interview, I will ask you for your name, address, and telephone number so that we can contact you regarding your child's participation in this study. I will then schedule you for a study visit."

"Do you have any questions related to any of the information that I have provided to you?"

Staff member will answer any questions prior to proceeding. If the individual would like to think about their child's participation prior to proceeding with the Phone Screen, they will be provided with the telephone number that they can call if they decide to participate in the future.

Figure 12. Contract Tracking Form

Voluntary Consent Component of Informed Consent: *"Do you agree that the procedures that will be used to conduct this phone screen have been answered, and do you give me permission to ask you questions as part of the initial Phone Screen?"*

If the caller response is *"YES"*, indicate the participant's agreement with this statement on the top of the next page, sign your name and date the form, and then complete the Phone Screen.

If the caller response is *"NO"*, thank the individual for calling and <u>DO NOT</u> complete the Phone Screen.

<u>Phone Screening Consent:</u>

The caller gives verbal permission to conduct the Phone Screening: YES NO

Staff member signature: ________________________ Date consent was given: ____/____/____

Figure 12 cont'd

PHONE SCREENING FORM

Eligibility:

"*Are you at least 18 years old and the primary guardian for the child?*
YES NO (If no, ineligible)

** NOTE: If the adult calling is the primary guardian, but not the parent, they will need to provide the proper paperwork to the PI prior to data collection prove guardianship.

"*How old is your child?*": ____________________ (Must be between 6-11 years old)

"*What is your child's date of birth?*": _____/_____/_____

"*Has your child been diagnosed with Autism Spectrum Disorder by a health care provider?*"
YES NO (If the child does not have Autism Spectrum Disorder they are ineligible)

"*Is your child participating in any other research study?*"
YES NO If yes, specify: ______________________
(Any study that would affect physical activity habits would be an exclusion)

"*Is your child able to do the following activities without the use of an assistive device?*"

Walking the length of a football field:	YES	NO (If no, ineligible)
Participating in physical education class at school:	YES	NO (if no, ineligible)

"*Is your child currently receiving treatment for any cardiovascular, orthopedic, or other medical condition that could impact physical activity?*"
YES NO (If yes, ineligible)

"*Has your child had any medication changes in the past 2 months?*"
YES NO
If YES, please describe: ____ (Ineligible if medications for the treatment of autism symptoms/behaviors changed).

"*Do you expect there to be any changes to your child's medications for the management of their autism in the next month?*"
YES NO (If yes, ineligible)

"*All of the information you provided about your child meets our study criteria and we can proceed to collecting contact information and schedule an appointment date, time, and location.*"

Figure 13. Phone Screening Form

APPOINTMENT TRACKING

Appointment Date: ______/______/______ Appointment Time: ______________

Appointment Location: ____

Contact Information:

Parent Name: ____________________________

Child Name: _____________________________

Phone number: ___________________________

Address: _______________________________

City: _______________________ State: __________ Zip code: ___________.

Figure 14. Appointment Tracking Form

APPENDIX C: DATA COLLECTION FORM

PARTICIPANT VISIT CHECKLIST

☐ Informed Consent
☐ Contact Screening Form
☐ Needs to Meet with Principal Investigator

The assessments must be completed in the following order by the individuals listed. Under no circumstances is this protocol to be altered unless approved by the Principal Investigator for this participant.

☐ Greet Participant	Initial: ______
☐ Height and Weight	Initial: ______
☐ Fitting of Accelerometer	
☐ Accelerometer instructions/tracking given to parent	Initial: ______
☐ Accelerometer instructions given to child	Initial: ______
☐ Questionnaires	
☐ First check at assessment visit	Initial: ______
☐ Second check after assessment visit	Initial: ______
☐ Gift given	Initial: ______

Figure 15. Data Collection Coversheet

SECTION I: DEMOGRAPHIC INFORMATION

1. Age and Birthday

Child Birthday (m/d/yr)	
Child Age (years/months)	

SECTION II: HEIGHT AND WEIGHT ASSESSMENTS

1. Body Height: measured to the nearest 0.1 cm

Child Height (cm)		

2. Body Weight: measured to the nearest 0.1 kg

Child Weight (kg)		

3. Body Mass Index (BMI): BMI measured kg/m^2

Child BMI (kg/m^2)	

4. Child BMI Percentile:

- ☐ Underweight
- ☐ Normal Weight
- ☐ Overweight
- ☐ Obese

Figure 16. Data Collection Form

APPENDIX D: ACTIVITY MONITOR INSTRUCTIONS AND TRACKING FOR PARENTS

ACTIVITY MONITOR WEAR INSTRUCTION SHEET FOR PARENTS

TO: Parents/Guardians
FROM: Stephanie M. McCoy   Name: ______________________

Your child will be wearing the activity monitor for seven (7) consecutive days.

Day and Date to Start Wearing Activity Monitor: Day: __________ Date: __________

Last Day to Wear the Activity Monitor: Day: __________ Date: __________

Day and Date to Return the **Activity Monitor** and **Tracking Sheet** to Investigators: Day: __________ Date: __________

PLEASE remind your child to put his/her monitor on upon waking in the morning, and to remove it before bed at night. ***It is crucial to the integrity of the study that the monitor is worn as instructed, for the next 7 days.***

Placement of the activity monitor: The monitor should always be worn on the right hip. Securely fasten the monitor using the elastic belt. Check to make sure that the monitor is snug against the right hip so it won't move throughout the day. It is very important that the monitor placement be consistent from day to day.

Daily wear of the activity monitor: Put on the monitor right after getting out of bed. Record in the attached chart the time the monitor was put on. Remove the monitor for bathing, or any other water activities only (swimming, etc.). Remove the monitor before you go to bed. Record in the attached graph the time the monitor was taken off at night. Also record the time the monitor was taken off for any water activities (i.e. 7:00pm-7:20 pm).

Care for your activity monitor: The monitor is water resistant but not waterproof. Care must be taken to not immerse the monitor in water. If necessary, the monitor can be cleaned using a damp rag with soap and water.

If you have any questions, please call (412) 383-4022. Please leave a message and a number and time you can be reached if there is no answer. Your call will be returned as soon as possible.

Additional Instructions: Please answer the questions at the end of the tracking sheet about your child's physical activity and sedentary behavior for the week that they wore the activity monitor.

Figure 17. Activity Monitor Tracking Sheet for Parents

Please call 412-383-4022 if you have any questions regarding the wearing of the activity monitor or the completion of this form.

Date Given	Day of the Week Given	Time Put "ON" Body	Time Taken "OFF" for the Day Prior to Going to Bed for the Night	Additional Information		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		
Date	**Day of the Week Worn**	**Time Put "ON" Body**	**Time Taken "OFF" for the Day Prior to Going to Bed for the Night**	**Additional Information**		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		

Date	Day of the Week Worn	Time Put "ON" Body	Time Taken "OFF" for the Day Prior to Going to Bed for the Night	Additional Information		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		
		_______: ______ AM/PM	_______: ______ AM/PM	Did you take the monitor off at any time of the day?	NO ☐	YES ☐
				If "Yes," Time Taken Off:		AM/PM
				If "Yes," Time Put Back On:		AM/PM
				If "Yes," Reason the monitor was taken off:		

Figure 17 cont'd

Additional Questions:

1. During the past week, how many minutes of physical activity did your child accumulate daily by exercising, playing a sport, or participating in other activity that made them sweat and breathe hard? ___________ (minutes/day)

2. During the past week, outside of school, how much time each day did your child accumulate sitting or reclining? ____________ (hours/day)

Figure 18. Additional Questions on Tracking Sheet

APPENDIX E: ACTIVITY MONITOR INSTRUCTIONS FOR KIDS

Activity Monitor Instructions

Wear the monitor **ALL DAY- EVERY DAY FOR ONE WEEK**

From when you wake up until the time you go to bed

Take the monitor off **ONLY** for:

Swimming Showering Bathing Sleeping

The monitor should always be worn against your **right hip bone**; ☆ star sticker facing up; ID sticker facing your body.

DO NOT take the monitor apart; that will ruin the data and we won't be able to use it.

Please remember to put your monitor on when you wake up and make sure it's worn all day, everyday.

If you have any questions, please contact Stephanie McCoy at 412-383-4022

Figure 19. Activity Monitor Instructions for Kids

APPENDIX F: PARENT QUESTIONNAIRE

DEMOGRAPHIC CHARACTERISTICS

Instructions:
Please answer the following questions about yourself and your household.

1. Are you of Hispanic or Latino origin?

   _____ Yes
   _____ No

2. How would you best describe your ethnic background? (Check all that apply)

   _____ White or Caucasian
   _____ Black or African American
   _____ American Indian/ Native American
   _____ Native Hawaiian or Pacific Islander
   _____ Asian
   _____ Other: ______________________

3. What is the highest grade in school you finished? (Check one)

   _____ Did not finish elementary school
   _____ Finished middle school (8th grade)
   _____ Finished some high school
   _____ High school graduate or G. E. D.
   _____ Vocational or training school after high school
   _____ Some College or Associate degree
   _____ College graduate or Baccalaureate degree
   _____ Masters or Doctoral degree (PhD, MD, JD, etc.)

4. Which of these categories best describes your household income?

   _____ Less than $5,000
   _____ $5,000 through $11,999
   _____ $12,000 through $15,999
   _____ $16,000 through $24,999
   _____ $25,000 through $34,999
   _____ $35,000 through $49,999
   _____ $50,000 through $74,999
   _____ $75,000 through $99,999
   _____ $100,000 and greater
   _____ No Response

5. What is your child's gender? □ Male □ Female

6. What type of school does your child attend?
   _____ Private
   _____ Public
   _____ Home-Schooled
   _____ Other: ________________________

Figure 20. Demographics

HEALTH HISTORY

Instructions

Please answer the following questions.

1. If your child has an Individualized Education Plan (IEP) through his/her school, what is your child's IQ as listed on the IEP? ____________ ☐ Don't Know
2. How would you rate your child's autism severity?

   Mild Moderate Severe
3. Does your child have any other medical conditions?

4. Please list the medications your child is taking:

Medication	Used for:

Figure 21. Health History

BARRIERS TO PHYSICAL ACTIVITY

Instructions: In answering the following questions, I want you to think about the current barriers that you have that may or may not prevent your children from engaging in physical activity or playing sports. Please answer "yes" if you feel this is a barrier to your child engaging in physical activity or playing sports, and answer "no" if you feel this is not a barrier to your children engaging in physical activity or playing sports.

1. I do not have enough time to have my child play sports of exercise

   a. Yes   b. No   c. Not applicable

2. There are no adequate community physical activity programs

   a. Yes   b. No   c. Not applicable

3. I cannot afford the cost of my child playing sports or exercise

   a. Yes   b. No   c. Not applicable

4. We do not have reliable transportation

   a. Yes   b. No   c. Not applicable

5. I cannot find a program that accommodates my child's disability

   a. Yes   b. No   c. Not applicable

6. I live in an unsafe neighborhood, or the neighborhood where the programs are is unsafe

   a. Yes   b. No   c. Not applicable

7. My child does not have enough time

   a. Yes   b. No   c. Not applicable

8. My child lacks interest/motivation

   a. Yes   b. No   c. Not applicable

9. My child is too developmentally delayed

   a. Yes   b. No   c. Not applicable

10. My child has too many behavioral problems

   a. Yes   b. No   c. Not applicable

11. My child is too physically sick/frail to play sports or exercise

   a. Yes   b. No   c. Not applicable

12. Any other barriers not listed above:

1.
2.
3.
4.

Figure 22. Barriers

PARENT PERCEPTION OF PHYSICAL ACTIVITY

Instructions

Please answer the following questions.

1. How many minutes of physical activity do you believe your child get each day? __________ minutes

2. In your opinion, your child's leisure screen time (watching TV, playing on the computer) should be limited to _______ hours each day.

3. Do you think that physical activity for your child could benefit the following (Please circle one)?

   a. Maintaining a healthy weight YES NO

   b. Preventing the development of cardiovascular disease and type 2 diabetes YES NO

   c. Help to manage behaviors characterized by ASD such as stereotypy, and self-stimulatory behaviors? YES NO

4. Considering the familial demands you have raising a child, would you consider physical activity for your child to be of (please circle one):

   Low priority Moderate priority High priority

5. The current recommendation for physical activity for children is **60 minutes each day**. Do you think that your child achieves this recommendation on (please circle one):

   Almost None of the Days Less than Half the Days Half of the Days

   More than Half the Days All Days

6. The current recommendation for "screen time" (television watching, playing video games) for children is **less than 2 hours each day**. Do you think that your child achieves this recommendation on (please circle one):

   Almost None of the Days Less than Half the Days Half of the Days

   More than Half the Days All Days

7. On average, how many minutes of physical activity does your child accumulate daily by exercising, playing a sport, or participating in other activity that made them sweat and breathe hard? ____________ (minutes/day)

8. Outside of school, how much time each day does your child accumulate sitting or reclining? ______________ (hours/day)

Figure 23. Perceptions of Physical Activity

FUNCTIONAL DISABILITY INDEX

Instructions:
In answering the following questions, I want you to think about your child's current physical health (Please cł the box that is the most appropriate response).

In the last few days, has your child had any physical trouble or difficulty doing these activities?

Activity	No Trouble	A Little Trouble	Some Trouble	A Lot of Trouble	Impossible
1. Walking to the bathroom					
2. Walking upstairs					
3. Doing something with a friend (for example, playing a game)					
5. Eating regular meals					
6. Being up all day without a rest or nap					
7. Riding the school bus or traveling in the car					
Remember, you are being asked about difficulty due to physical health					
8. Being at school all day					
9. Doing the activities in gym class (or playing sports)					
10. Reading or doing homework					
11. Watching TV					
12. Walking the length of a football field					
13. Running the length of a football field					
14. Going shopping					
15. Getting to sleep at night and staying asleep					

For office use only:					
Totals:					
	X 0	X 1	X 2	X 3	X 4
Overall points:					

Figure 24. Functional Disability Index

APPENDIX G: DATA ANALYSIS USING PUYAU CUTPOINTS

Table 18. Accelerometry Data- Puyau et al. (2002) (N=17)

	Daily Average	Weekday Average	Weekend Average
Average weartime	**740 ± 72**	**752 ± 61**	**727 ± 104**
Total time (minutes) per day			
Sedentary	**574 ± 60**	**567 ± 65**	**593 ± 46**
Light Activity	**142 ± 45**	**145 ± 50**	**133 ± 39**
Moderate Activity	**19 ± 14**	**22 ± 17**	**12 ± 11**
Vigorous Activity	**5 ± 5**	**7 ± 7**	**1 ± 1**
MVPA	**24 ± 16**	**29 ± 20**	**13 ± 11**
Bouted time (minutes) per day			
Sedentary	**342 ± 93**	**441 ± 110**	**444 ± 98**
MVPA	**6 ± 4**	**7 ± 5**	**2 ± 3**
Percentage of total time			
Sedentary	**78 ± 8**	**76 ± 9**	**80 ± 6**
Light activity	**19 ± 6**	**20 ± 7**	**18 ± 5**
Moderate activity	**3 ± 2**	**3 ± 2**	**2 ± 2**
Vigorous activity	**0.7 ± 0.7**	**0.9 ± 1**	**0.1 ± 0.1**
MVPA	**3 ± 2**	**0.9 ± 1**	**2 ± 2**

APPENDIX H: DATA ANALYSIS USING FREEDSON CUTPOINTS

Table 19. Acceleromtetry Data- Freedson et al., (2005) (N=17)

	Daily Average	Weekday Average	Weekend Average
Average weartime	**740 ± 72**	**752 ± 61**	**727 ± 104**
Total time (minutes) per day			
Sedentary	**363 ± 59.00**	**360 ± 69**	**370 ± 57**
Light Activity	**147 ± 30**	**143 ± 26**	**157 ± 43**
Moderate Activity	**215 ± 55**	**219 ± 61**	**207 ± 48**
Vigorous Activity	**9 ± 8**	**11 ± 9**	**5 ± 6**
MVPA	**230 ± 61**	**237 ± 70**	**213 ± 51**
Bouted time (minutes) per day			
Sedentary	**165 ± 64**	**168 ± 73**	**159 ± 85**
MVPA	**126 ± 62**	**137 ± 65**	**101 ± 69**
Percentage of total time			
Sedentary	**49 ± 8**	**49 ± 9**	**50 ± 8**
Light activity	**20 ± 4**	**19 ± 3**	**21 ± 8**
Moderate activity	**29 ± 7**	**30 ± 8**	**28 ± 7**
Vigorous activity	**1 ± 1**	**1 ± 1**	**0.7 ± 0.7**
MVPA	**31 ± 8**	**32 ± 9**	**29 ± 7**

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