Summer 2022

Physical Activity as a Predictor of Obesity in Autistic Children

Cody A. Mullins
Missouri State University, Cody1898@live.missouristate.edu

PHYSICAL ACTIVITY AS A PREDICTOR OF OBESITY IN AUTISTIC CHILDREN

A Master's Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Kinesiology

By

Cody Mullins

August 2022

PHYSICAL ACTIVITY AS A PREDICTOR OF OBESITY IN AUTISTIC CHILDREN

Kinesiology

Missouri State University, August 2022

Master of Science

Cody Mullins

ABSTRACT

Research has found autistic children to be 40% more likely to be obese compared to their non-autistic peers. Reduced physical activity (PA) is thought to be a contributing factor to the increased prevalence of obesity in autistic children. This was one of the first studies to investigate the PA behaviors of autistic children during an adapted physical education (APE) class using accelerometry. The purpose of this study was to examine the PA of autistic children and determine the relationship between PA and obesity. Participants were recruited from a school for students with disabilities who participate in a once-weekly APE class at a large Midwest university and grouped by weight classification (overweight or obese). PA was measured by wearing an accelerometer during the one-hour visit. Height and weight data were provided by participants' teachers. Independent sample t-tests were used to compare group differences. A correlation analysis was used to determine the relationship between PA and BMI score. A simple linear regression analysis was used to determine the predictability of BMI score based on PA. No significant differences were observed between groups and no relationship between PA and BMI were observed.

KEYWORDS: autism, physical activity, accelerometry, adapted physical education, body mass index

PHYSICAL ACTIVITY AS A PREDICTOR OF OBESITY IN AUTISTIC CHILDREN

By

Cody Mullins

A Master's Thesis
Submitted to the Graduate College
Of Missouri State University
In Partial Fulfillment of the Requirements
For the Degree of Master of Science, Kinesiology

August 2022

Approved:

Rebecca Woodard, Ph.D., Thesis Committee Chair

Stacy Goddard, D.H.Ed., Committee Member

Cody Smith, Ph.D., Committee Member

Julie Masterson, Ph.D., Dean of the Graduate College

ACKNOWLEDGEMENTS

I am deeply indebted to my supervisor, Dr. Rebecca Woodard, for her unending support and optimistic attitude. Her constant reassurance that “everything will be okay” was comforting, even though I did not always believe her. I would also like to express my deepest appreciation to the other members of my committee, Dr. Cody Smith and Dr. Stacy Goddard, for their invaluable patience and feedback. Their plentiful knowledge made me a better writer and made this process significantly easier. This endeavor would not have been possible without the support of Rivendale Institute of Learning and Center for Autism. My gratitude extends to the faculty and staff and Rivendale, whose support and patience were critical helped make this process a reality.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Autistic children tend to have more health complications than non-autistic children, but it is not known why. Studies on the differences in physical activity (PA) of autistic and non-autistic children have shown few, if any, differences (Ketcheson et al., 2018, Bandini et al., 2013; Stanish et al., 2017). However, the designs of those studies excluded a large portion of the autism community. This research aims to assess the PA behaviors of autistic children, as well as to determine whether PA can be used to predict weight classification in autistic children. This chapter will provide an introduction to the study by first discussing the background and context, followed by the purpose of the study, and finally, the significance of the study.

Autism

Autism is characterized by a differential profile of social communication skills and repetititive behaviors that vary in presentation (Lord, et al., 2018). In 2013, the American Psychiatric Association (APA) updated its Diagnostic and Statistical Manual of Mental Disorders. Included in the update was a change to the diagnostic criteria for autism spectrum disorder, combining the diagnoses of autism, Asperger's, and pervasive developmental disorder-not otherwise specificed into the singular diagnosis of autism (American Psychiatric Association [APA], 2013). According to the APA (2013), to receive a diagnosis of autism, a person must show evidence of behaviors that differ from what is considered typical in each of the three subdomains of social communication and deficits in at least two of the four subdomains of restricted, repetitive patterns of behavior. Examples of deficits in social communication and interaction include failure to initiate or respond to social interactions, lack of understanding and use of gestures, and difficulty adjusting behavior to fit various social contexts. Examples of deficits in restricted, repetitive patterns of behavior, interests, or activities include rocking back and forth, ritualized patterns and extreme distress at small changes, strong attachment to unusual objects, and adverse responses to specific sounds or textures (APA, 2013). The social and motor differences, combined with co-occurring conditions, can make participation in physical activities difficult for autistic people. As more information about autism has become known in recent years, the diagnostic rate for autism has increased.

Diagnostic Rate of Autism

Two different methods have been used to estimate the diagnostic rate of autism in the United States and both reached a similar conclusion. Maenner et al. (2021) used documented diagnoses of 8-year-old children collected from 11 selected sites across the United States and found a diagnostic rate of 1 in 44 children. An increase of 18.5% compared to the diagnostic rate of 1 in 54 in 2016 (Maenner et al., 2021). In contrast, Xu et al. (2018) used parent-reported data and a nationally representative sample that included children and adolescents aged 3–17 years and found a diagnostic rate of 1 in 43 children (Xu et al., 2018). Although the true prevalence rate of autism cannot be determined, it is known that autism is found in all populations.

The diagnosis of autism is seen in both males and females and across all racial, ethnic, and socioeconomic backgrounds (Xu et al., 2018; Maenner et al., 2021). Currently, males are four times as likely as females to be diagnosed with autism, and Caucasian children are more likely to be diagnosed with autism compared to non-Hispanic Black, Asian/Pacific Islander, and Hispanic children (Maenner et al., 2021). The discrepancies in diagnostic rates between males and females and across racial, ethnic, and socieconomic backgrounds may be due to diagnostic bias, biases held by healthcare professionals, social stigma, access to healthcare, or having a primary language other than English (Hodges et al., 2020; Lumes et al., 2017). As more information is learned about autism, diagnostic tools are improved, and access to evaluations increases, it is expected that the diagnostic rate will increase, but it is not known by how much. One area of autism research that may shed light on the prevalence rate of autism is the cause(s) of autism.

Causes of Autism

Although significant advancements in research have been made, a direct or single cause for autism has yet to be found. The leading hypothesis is that autism is influenced primarily by genetic factors, with environmental factors being secondary (Hodges et al., 2020). Copy number variants (CNVs) have been found to be significantly associated with autism, with approximately 5 to 15% of autistic people receiving autism genetically due to de novo CNVs (Pinto et al., 2010; Sebat et al., 2007). CNVs are variations in the number of copies of a particular gene or DNA sequence that can be found from one person to another, and a de novo CNV is a newly occuring genetic mutation that was not passed from parent to child (Eichler, 2019). These variations include duplications, an increase in number of copies, and deletions, or a decrease in number of copies (Eichler, 2019). CNVs are much larger and four times more likely to disrupt genes in autistic individuals compared to non-autistic individuals (Brandler et al., 2016). So far, a total of 226 validated CNVs have been observed in autistic individuals (Pinto et al., 2010), with autistic females having a higher frequency of de novo CNVs compared to males (Levy et al., 2011). Common CNVs associated with autism include deletions at the 16p11.2 locus, mutations of the FMR1 gene (fragile X syndrome), and mutations of the MECP2 gene (Rett syndrome) (Zufferey et al., 2012; Hatton, et al., 2006; Amir et al., 1999). With known genetic mutations making up a small proportion of autism cases, researchers have turned to environmental factors for futher information.

While there is no conclusive evidence that environmental factors cause autism, some environmental factors have been shown to be associated with an increased risk of autism (Gardener et al., 2009). Prenatal (before birth) environmental factors significantly associated with autism include either parent being 30 years old or older, gestational diabetes or hypertension, maternal bleeding during pregnancy, maternal medication, and high levels of stress in the mother (Gardener et al., 2009). Perinatal (during and immediately after childbirth) environmental factors associated with autism include gestation age of less than 37 weeks, spontaneous labor, no labor, breech presentation, preeclampsia, and fetal distress (Wang et al., 2017). Postnatal (after birth) environmental factors associated with autism include low birth weight (less than 5 lbs, 8 oz.), postpartum hemorrhage, male gender, and brain anomaly. However, despite the significant associations between prenatal, perinatal, and postnatal environmental factors and autism, evidence necessary to establish causal relationships is still lacking (Wang et al., 2017). Regardless of its causes, of perhaps greater concern to autistic individuals are the conditions associated with autism, one of which is being overweight or having obesity.

Overweight and Obesity in Children

One method of measuring health and identifying individuals at risk of developing health conditions is body mass index (BMI), which has been widely used due to its convenience and ease of use (Gutin, 2019). BMI was first conceptualized in 1842 by Belgian mathematician, Adolph Quetelet, and defined as mass in kilograms divided by height in meters squared, kg/m^2 (Quetelet, 1842). Because children have different growth rates during different periods of childhood, and growth rates differ between sexes, BMI classifications for children in the United States are based on the 2000 Centers for Disease Control and Prevention's growth charts (Kuczmarski et al., 2002). Children and adolescents (ages 2–18 years) are considered overweight when they have a BMI-for-age that is greater than or equal to the 85th percentile and less than the 95th percentile, or $30kg/m^2$, whichever is smaller. Children and adolescents are considered to have obesity when they have a BMI-for-age equal to or greater than the 95th percentile, or greater than $30kg/m^2$, whichever is smaller (Krebs et al., 2007). The prevalence rates of children that are overweight or have obesity have been increasing in recent decades, with the prevalence rate of childhood obesity doubling in the past 30 years (Sanyaolu et al., 2019). Currently, an estimated 16.1% of all children are overweight and 19.3% have obesity (Hales et al., 2018). Although the trend for the general population is troubling, an even more troubling trend has been found amongst autistic children.

Prevalence of Overweight and Obesity in Autistic Children

Studies have used various methods to examine the prevalence rates of overweight and obesity in autistic children (Curtin et al., 2005; Curtin et al., 2010; Egan et al., 2013; Evans et al., 2012). Using patient records of autistic children pulled from a tertiary clinic, a clinic specializing in the evaluation and treatment of children with development disorders, researchers found that 19% of the children were overweight (Curtin et al., 2005). A second study using patient records of autistic children pulled from a tertiary clinic found that 15.38% of the children were overweight and 17.58% of the children had obesity (Egan et al., 2013). Using a sample from the local community, researchers found that 17% of the autistic children were obese and 9% of the non-autistic children were obese (Evans et al., 2012). Using a nationally representative survey conducted by phone interview, researchers found the prevalence rate of obesity to be 30.4% in autistic children and 23.6% for non-autistic children. Additionally, the researchers found that autistic children are 40% more likely to have obesity than their non-autistic peers (Curtin et al., 2010).

The prevalence rate of obesity in autistic children ranges from 17% (Evans et al., 2012) to 30.4% (Curtin et al., 2010). The differences may be explained by the use of different methods (objective measures vs. parental report) and/or that all three studies used a different sample pool (clinic vs. local community vs. national survey). Further study in this area is needed to identify the most valid and reliable method(s) to assess prevalence rates of overweight and obesity in autistic children. Data collected through observational and cross-sectional studies suggests that decreased participation in physical activity (PA) and increased sedentary behavior are two factors that can be used to predict weight status (Must & Tybor, 2005), making PA a top priority not just for autistic children, but all children.

Physical Activity

PA is defined as body movement produced as the result of skeletal muscle contractions and is characterized by frequency (how often), intensity (energy expenditure), time, and type (Must & Tybor, 2005). Measuring PA is typically achieved through objective measurements, such as accelerometry, or self- or proxy-report using questionnaires (Jones et al., 2017). Accelerometers detect and measure changes in direction and the data is stored as activity counts. Intensity level of PA is determined by the number of activity counts per minute (cpm) or “cut points." Many sets of cut points have been developed and published in peer-reviewed literature; however, the cut points for sedentary physical activity (SPA), light physical activity (LPA), moderate physical activity (MPA), vigorous physical activity (VPA), and moderate-to-vigorous physical activity (MVPA) vary across all of them (Trost et al, 2011). Although no standard set of cut points has been established, the set of cut points developed by Evenson et al. (2008) has been shown to have the greatest validity for children of all ages (Trost et al., 2011). The value of accelerometers is that they provide an objective measurement of PA, both in terms of amount and intensity level, removing the need to use subjective reporting methods or observations.

Despite the value of objective measurement that accelerometers provide, they have limitations that could potentially impact results, especially for a population such as autistic children. It is common for autistic children to engage in self-stimulating behaviors such as rocking back and forth, hand flapping, or leg bouncing (Kapp et al., 2019). While all of these behaviors require the contraction of skeletal muscles, and therefore constitute PA, they may not be accurately captured by accelerometry (Must & Tybor, 2005). This could lead to an overestimation of SPA and underestimation of LPA, obscurring the true PA behaviors of autistic children. This becomes particularly relevant when determining whether or not autistic children are being physically active enough to receive the benefits of PA and reduce their risk of developing further health complications.

Guidelines and Benefits of Physical Activity

The physical activity guidelines (PAG) for children ages 6–17 years includes 60 minutes of MVPA every day, muscle-strengthening exercise at least three days per week, and bone-strengthening exercise at least three days per week (Bushman, 2019). PA can provide many benefits to children, with and without complex needs. Positive health outcomes include weight management, improved cardiorespiratory fitness, improved muscular fitness, and a reduction in risk of developing chronic diseases (Piercy et al., 2020). PA has also been shown to improve motor skills and cognition (Lang et al., 2010). In addition to the health benefits experienced by all, PA has been shown to decrease stereotypies, aggression, and off-task behavior, and improve sleep in autistic children (Alhowikan, 2016). Despite strong evidence that supports the importance of PA for the health and wellbeing of all people, data from across the world indicate that approximately half of non-autistic children and less than half of autisitc children are meeting the PAG of 60 minutes of MVPA every day (Liang et al., 2020). The discrepancy between the two groups can be explained by barriers autistic children experience that non-autistic children do not experience.

Barriers to Physical Activity for Autistic Children

Barriers to exercise can be grouped into three categories: child/family barriers, social barriers, and community barriers. Child/family barriers include a child's motor skills, co-occuring conditions, and family time constraints. Social barriers include a child's social skills, feelings of exclusion, amd having few friends. Community barriers include inadequate opportunities, costs, and transportation (Must et al., 2015). In a study investigating the barriers to PA experienced by autistic children, researchers found that 51% of the autistic children experienced six or more barriers and 81% of the autistic children experienced two or more barriers. In contrast, the average number of barriers reported by parents of non-autistic children was less than one (Must et al., 2015). Of particular relevance to the performance of PA are motor performance and motor skills.

Dewey et al. (2007) examined the motor performance of autistic children in comparison to non-autistic children in the age range of 5–18 years. The autistic children demonstrated significantly lower scores in both the motor performance skills assessment and the gestural performance assessment compared to the non-autistic children. The lower scores on the motor performance assessment can be attributed to differences in motor functioning; however, motor functioning cannot explain the lower scores on the gestural performance assessment. Lower scores in gestural performance are likely attributed to social communication, sensory, and/or behavioral differences experienced by the autistic group that are not experienced by the non-autistic group (Dewey et al., 2007). The social and motor differences, co-occurring conditions, and other barriers can make participation in physical activities difficult for autistic people.

Subjective Assessments of Physical Activity Behaviors

Subjective assessments (e.g., questionnaires) have been used to assess the PA behaviors of autistic children. Using a sample pulled from the 2011–2012 National Survey of Children's Health, researchers found that autistic adolescents were 60% less likely to participate in regular PA (≥ three days per week) and 74% less likely to have participated in a sport in the past 12 months compared to non-autistic adolescents (McCoy et al., 2016). Studies using self-developed questionnaires to investigate PA behaviors have found similar results. Bandini et al. (2013) found that autistic children participated in significantly fewer types of activities and spent significantly less time doing those activities in the previous year compared to non-autistic children (Bandini et al., 2013). Stanish et al. (2017) grouped participants by age (<16 years, ≥16 years) and observed that austistic adolescents younger than 16 years participated in significantly fewer regular activities (defined as ≥ 12 times per year) compared to their non-autistic peers during the previous year (Stanish et al., 2017). The results of these studies suggests that there are behavioral differences when it comes to PA for autistic and non-autistic children. Unfortunately, the questionnaire format of the assessments do not provide the data necessary to determine how big or small the differences are. There is also the problem of studies using different questionnaires, preventing direct comparisons across studies.

It is important to note that, to date, there are no validated questionnaires for PA for autistic children (López-Valverde et al., 2021). Therefore, researchers must carefully consider the designs of the questionnaires they use. While asking parents to reflect back on just the previous week can reduce bias and reporting error, it also limits the interpretation and application of the results. On the other hand, while asking parents to reflect back on the previous year makes the data more vulnerable to error, it allows for broader interpretation and application of the results. Until a validated questionnaire is established, using a direct, objective method of measurement, such as an accelerometer, is the only validated method to asses the PA behaviors of autistic children (Trost et al., 2011).

Adapted Physical Education

Physical education (PE) is an academic subject designed to develop motor skills and promote PA and physical fitness. Adapted physical education (APE) has the same objectives as PE, but is modified and designed for students with disabilities (Block, 2016). Approximately 90% of students with disabilities in the United States participate in PE/APE classes alongside students without disabilities (Hodge et al., 2012). Traditionally, research on APE has focused on the perceived experiences of parents, teachers, and peers, giving little consideration to those that are most affected—the students with disabilities. Although more recent literature has placed greater emphasis on the experiences of students with disabilities—as opposed to the experiences of caregivers and teachers—the focus is still on how people perceive experiences, rather than the experiences themselves (Block et al., 2021). When trying to identify the needs and supports of students with disabilities, their perception of their experiences—while extremely valuable—cannot provide all of the necessary information. Of perhaps equal importance are the PA behaviors that students engage in during PE/APA classes. Unfortunately, literature describing the PA behaviors of autistic children specifically during PE/APE is scant. Future research focusing specifically on the PA behaviors of autistic children during PE may be helpful in determining their needs and supports.

Purpose Statement

The purpose of this study was to analyze the PA behaviors of autistic children and determine if PA can be used as a predictor of BMI score in autistic adolescents. It was expected that the participants would engage in more LPA than MVPA and that lower levels of PA would be associated with higher BMI scores.

Significance of the Study

Two common themes in the research of PA behaviors of autistic children have been observed. First, the exclusion of participants who are prescribed medications or diagnosed with conditions that affect their dietary or PA patterns (Pan, 2008; Stanish et al., 2017, Bandini et al., 2013, Rosser-Sandt & Frey, 2005). Second, including only autistic people without intellectual disability (ID) and less complex needs (Pan et al., 2016; Pan et al., 2011; Pan, 2008; Rosser-Sandt & Frey, 2005). While these exclusions make for neater data and easier conclusions, the results represent only a small portion of the autism community. Approximately one-third to one-half of autistic children are prescribed at least one medication that affects appetite (Siegel, 2012) and almost half of autistic children have one or more medical conditions that could impact dietary or PA patterns (Williams et al., 2004). To correct for the lack of representation in autism studies, participants of the current study were not excluded on the basis of medication, medical condition, or co-occuring disability, allowing for a more inclusive and more accurate assessment of the PA behaviors of the autism population.

LITERATURE REVIEW

Accelerometers are commonly used to measure PA because they provide objective data that could not be obtained through subjective assessment methods. This synoptic literature review will provide an overview of the relevant existing literature pertaining to accelerometry-measured PA behaviors of autistic children in comparison to their non-autistic peeers, PE-specific PA behaviors, and the relationship between PA and BMI. Each study discussed below is described and evaluated in terms of methodological approach, limitations, and implications. There are more studies investigating the PA behaviors of autistic children than just those discussed below. However, since the focus of this research is PA behaviors during PE, these will not be reviewed in detail and will only be referred to when appropriate.

Physical Activity Behaviors of Autistic Children

Ketcheson et al. (2018) investigated the PA behaviors of 53 children (ages 2–5 years) using an ActiGraph GT3X+ accelerometer. The accelerometers were set to record data in 15-second intervals (known as epoch length) and cut points established by Cliff et al. (2009) were used to establish PA intensity levels. Participants were required to wear the acclerometer for 600 minutes/day for five days, including one weekend day. All 53 participants (34 autistic, 19 non-autistic) met the inclusion criteria for accelerometry analysis. IQ scores, determined using the Mullen Scales of Early Learning (Mullen, 1995) ranged from 4.44 to 67.10 for the autistic children and from 75.69 to 162.03 for the non-autistic children. However, no diagnosis of ID was reported for either group.

Compared to the non-autistic children, the autistic children engaged in significantly greater amounts of PA at all levels of intensity except for SPA. The autistic children also spent a greater percentage of time engaged in LPA, MPA, and MVPA compared to the non-autistic children (Ketcheson et al., 2018). The differences in percentage of time each group engaged in LPA, MPA, and MVPA were statistically significant; however, the average difference was only 3.32%, with an average effect size of 0.53. However, wear time was not equal between groups, with the non-autistic children averaging approximately 38 more minutes of wear time per day compared to the autistic children. This would obviously affect the absolute amount and percentage of time spent at each intensity level, but wear time alone cannot explain all differences. Another likely contributor is the set of cut points chosen by the researchers. The threshold of 800 cpm for LPA have been shown to be less accurate than the typical 101 cpm for LPA, and is likely to underestimate LPA (Trost et al., 2011). The findings of this study contrast the findings of studies using older children, but it is not known if these results represent a true age-related difference between younger and older children, or are simply the result of the study design.

Bandini et al. (2013) examined the PA behaviors of autstic and non-autistic children (ages 3–11 years) using an Actical accelerometer. The epoch length set to 30 seconds and cut points established by Puyau et al. (2004) were used to define PA intensity levels. Participants were required to wear the accelerometer for a minimum of 600 min/day for three weekdays and one weekend day. A total of 46 autistic and 54 non-autistic children wore the accelerometer, but only 35 autistic and 47 non-autistic children met the criteria to be included in the accelerometry analyses. After controlling for age and sex, the researchers found that the non-autistic children participated in significantly more MPA (1500–6499 cpm in this study) and for longer periods of time compared to the autistic children, but only during weekdays. BMI-z score was not found to be significantly related to total activity counts or time spent in MVPA; however, data regarding the relationship between PA and BMI was not reported (Bandini et al., 2013). The fact that a significant difference was only found during weekdays and not weekend days could be attributable to non-autistic children being more likely to participate in after-school programs such as sports (McCoy et al., 2016; Must et al., 2015). The non-autistic group averaged 21,118 more counts in MVPA and 23,568 more total activity counts compared to the autistic group, but the mean differences in minutes and percentage of time spent in LPA and MVPA were neglibible. The researchers did not provide either total or average wear time, nor did they provide data for SPA, making the reason for the large difference in activity counts impossible to determine. On the surface, the results of this study would indicate that autistic and non-autistic children are quite similar.

The remarkable similarity between the two groups in this study can easily lead to the conclusion that there are no differences in the PA behaviors of autistic and non-autistic children, at least not between the ages of 3 and 11 years old. However, it could be reasoned that the remarkable similarities found in this study are due to the remarkably similar sample, a direct result of the inclusion criteria. By excluding participants with diseases or disorders that could affect dietary and/or PA habits, combined with excluding participants taking medications known to affect appetite, the researchers included only autistic children that are most similar to non-autistic children. It should be no surprise that two similar groups of people would have similar PA behaviors. For an article that is treated as foundational in this area of research, having been cited more than 100 times, its application is severly limited. More inclusive studies provide more information and have a greater generalizability.

Stanish et al. (2017) also used the Actical accelerometer, a minimum of 600 min/day for three weekdays and one weekend day, and the cut points established by Puyau et al. (2004). However, they used an epoch length of 15 seconds. A total of 35 autistic and 60 non-autistic adolescents (ages 13–21 years) participated in the study, but only 29 autistic and 55 non-autistic adolescents met the criteria to be included in the accelerometry analyses. Analysis of the accelerometry data revealed that total activity counts and time spent in MVPA for autistic adolescents were significantly lower than the activity counts for non-autistic adolescents. In addition to the statistical significance, the mean differences between the two groups were also large. The non-autistic group averaged 69,009 more activity counts and 20.9 more minutes in MVPA (defined as ≥1500 cpm in this study) compared to non-autistic adolescents (Stanish et al., 2017). Although this study used a similar protocol as Bandini et al. (2013), the use of two different epoch lengths prevents us from knowing if the differences in outcome variables were due to age, the epoch length, or a combination of factors. A strength of this study is that 18 of the autistic participants also had an ID. Unfortunately, no comparisons were made between autistic children with and without an ID, or between autistic children with an ID and non-autistic children.

The three studies discussed thus far assessed the daily PA behaviors of children. While data on total daily PA behaviors is valuable, all children are not afforded the same opportunities to be physically active. Choosing to be inactive or to engage in SPA is different from not having an opportunity to be physically active. One method of determining if measurable differences in PA behaviors exist between autistic and non-autistic children is to measure their PA behaviors in a controlled environment in which all participants are provided the same opportunities to be physically active.

Physical Activity Behaviors of Autistic Children During Physical Education

Few studies have looked at the PA behaviors of autistic children during PE, a controlled environment in which all, or nearly all, children are provided the same opportunities to be physically active. Rosser-Sandt and Frey (2005) conducted one of the first studies to investigate PA behaviors of autistic children during PE using accelerometry. The researchers used the MTI 7164 accelerometer with an epoch length of 60 seconds. PA intensity level was determined by metabolic equivalants (METs): LPA (<3.0 METs), MPA (3.0–5.9 METs), VPA (6.0–8.9 METs), and very VPA (≥9.0 METs). The study included 15 autistic children and 13 non-autistic children and assessed PA using both accelerometry and direct observation (Rosser-Sandt & Frey, 2005). Although the differences were non-significant, autistic children engaged in 3.9 fewer minutes of MVPA during PE compared to non-autistic children (Rosser-Sandt & Frey, 2005). This difference may be attributable to autistic children averaging 2.58 fewer minutes of PE compared to their non-autistic peers. PE attendance also was not equal across groups, with 77% of the autistic children and 69% of the non-autistic children attending PE classes four days a week. The researchers did not provide data for any other level of PA. Although the amount of data reported in this study was minimal, the researchers did provide several observations regarding PA behaviors. The autistic children frequently sat down or stood around while waiting for activities to begin, they required additional verbal and physical prompts to complete activities, and several received instruction from special education teachers that were not certified to teach that content area (Rosser-Sandt & Frey, 2005). These observations, while not measurable, provide valuable context for data that are measurable. Although this study provided a mostly equal environment in which to compare PA behaviors, further controlling for frequency and duration of PE would allow for more accurate comparisons.

Pan et al. (2011) used the GT1M ActiGraph accelerometer with an epoch length of 10 seconds. PA intensity level was determined by METs: MPA (3.0–5.99 METs), VPA (6.0–8.99 METs), and very VPA (≥9.0 METs). A total of 19 autistic and 76 non-autistic adolescents with a mean age of 14 years participated in the study. Participants wore the accelerometer for two 45-minute inclusive PE classes during the same week. The only statistically significant finding was that non-autistic adolescents averaged 9.62 more steps per minute compared to their autistic peers. Other notable findings were that non-autistic adolescents averaged 485 more cpm and spent 8% more time engaged in MVPA compared to the autistic group (Pan et al., 2011). Two limitations of this study should be noted. All participants were male and none had an ID or co-occuring conditions. Although the generalizability of the results are reduced due to the limitations of the study, this is one of the few studies to find measurable differences between autistic children without complex needs and non-autistic children. These findings seem to suggest that even during PE, when equality of opportunity to be physically active is given, that autistic children are less active than their non-autistic peers. This would suggest that decreased PA is not simply a choice or matter of opportunity—although those two factors certainly play a role—but is part of being autistic. This aspect of autism may help explain the increased prevalence rate of overweight and obesity in the autism community.

Relationship Between Physical Activity and Body Mass Index

Garcia-Pastor et al. (2019) compared weight classification to PA for 29 autistic children (ages 7–12 years) and 15 autistic adolescents (ages 13–18 years). PA was assessed using the

GT1M ActiGraph accelerometer with an epoch length of 60 seconds. A minimum weartime of 600 minutes/day for four consecutive days, including one weekend day were required to be included in the analysis. The set of cut points established by Evenson et al. (2008) were used to establish PA intensity levels. The researchers found that autistic children and adolescents that are overweight or have obesity engaged in significantly lower levels of MVPA, fewer steps, and higher levels of SPA during weekends compared to autistic children and adolescents of normal weight (Garcia-Pastor et al., 2019). The results were the same for weekdays, but they did not reach significance. Unfortunately, the researchers presented the data in the form of bar graphs and the exact values for each variable and each weight classification cannot be determined. Other studies have investigated the relationship between PA and BMI with mixed results.

MacDonald et al. (2011) split autistic children into two age groups, 9–11 years (n = 42) and 12–18 years (n = 30). Both groups met the PAG of 60 minutes of MVPA and none were considered overweight or to have obesity (MacDonald et al., 2011). Pan et al. (2016) compared 35 autistic children to 35 non-autistic children ages 12–17 years. No correlation between PA and BMI was observed, but the researchers found that those who met the PAG of 60 minutes of MVPA had higher BMIs than those that did not meet the PAG (Pan et al., 2016). Considering the participants who met the PAG also scored higher on the physical fitness assessments than those who did not met the PAG, it may be presumed that higher BMI was a consequence of greater physical fitness, not just amount of PA. It should be noted this study included only males and none of the participants had an ID, a co-occuring condition that could interfere with PA, or received treatment with psychotropic medications. It is not known if these findings would hold true for females and/or autistic children with more complex needs.

The reviewed literature suggests that autistic children are less physically active overall and engage in more low-intensity PA than their non-autistic peers. This difference is observed when looking at total daily activity, which may be skewed due to decreased opportunity for autistic children, as well as during PE, where opportunity to be physically active is equal for both groups. It also suggests that there is a relationship between PA and BMI. A major limitation of this literature review is that most studies excluded autistic people with complex needs. The current study seeks to remedy that and to investigate whether the conclusions reached in the reviewed literature hold true for a wider segment of the autism community.

METHODS

Participants

The researchers obtained approval from the Missouri State University IRB (IRB-FY2022-189, 12/20/2021) prior to recruiting participants (see, Appendix: IRB Approval Notice).The participants were recruited from a school for students with disabilities in the Midwest region of the United States. Participants were included if they had a diagnosis of autism from a qualified professional and could tolerate wearing an accelerometer. Approximately 14 students who received services at the school and participated in an once-weekly APE class at a local university were invited to participate in the study. A parental consent form was distributed to parents through the school's teachers. The parental consent form included information about the proposed study, a description of its protocols, any risks or benefits, as well as the contact information for the primary researcher. Child assent was not required for this study.

The parents of all 14 students returned parental consent forms. The participants were a mix of males (n = 10) and females (n = 4), ranging in age from 12 to 18 years, and have received a diagnosis of autism by a qualified healthcare professional.

Measures

Age, height, and weight data were provided by students' teachers. BMI was determined by dividing body mass in kilograms by height in meters squared (kg/m^2). PA data was recorded using an accelerometer (ActiGraph GT9X, ActiGraph Corporation, Pensacola, FL). The accelerometer was set to record activity counts every 15 seconds and cutoff points for PA levels were <100 cpm for SPA, 101–2,295 cpm LPA, 2,296–4,011 cpm for MPA, and >4,011 cpm for VPA (Evenson et al., 2008).

Procedures

Participants were asked to wear an accelerometer in an elastic belt on their right hip during their weekly one-hour PA session on the university campus. The accelerometer was worn for four 1-hour sessions over the course of six weeks. At the start of each session, the accelerometers were attached by aides that work with the students. The researchers monitored the placement of the accelerometers throughout the session to ensure they were in the proper location and adjustments were made when necessary. The accelerometers were removed at the end of each session and the data were downloaded immediately. All data were stored within the ActiLife software on a password protected computer inside of a locked office. Only the researcher and the researcher's supervisor had access to the data. Participants were not asked to perform specific tasks or exercises by the researchers. Typical activities the participants chose to engage in were walking, riding a tricycle, playing catch, kicking a ball, and shooting a basketball. Calculated BMI classified all participants as either overweight or having obesity. None of the participants were classified as either normal or underweight. Thefore, for the purpose of data analysis, all participants were grouped according to their weight classification, overweight or obese.

Data Analysis

Demographic characteristics (age, height, weight, and BMI) were compared using independent sample *t*-tests. Independent sample *t* tests were used to determine group (overweight and obese) differences for each level of PA. The Pearson correlation coefficient (*r)* was computed to examine the bivariate relationships between accelerometry-measured activity levels and BMI. Significance for all statistical analyses was set at $p < .05$. Values are reported as mean (standard deviation).

RESULTS

All participants completed the study. Participants were grouped based on weight classification as either being overweight or having obesity. None of the demographic variables differed significantly between the overweight adolescents and the adolescents with obesity (Table 1).

Table 1. Demographic characteristics of overweight and obese autistic adolescents.

	Overweight (n = 4)	Obese (n = 5)		
	Mean (SD)	Mean (SD)	*p*	MD
Age (years)	16 (2.71)	14.20 (1.79)	.268	1.80
Height (m)	1.69 (.15)	1.62 (.091)	.413	.068
Weight (kg)	74.50 (14.98)	96.25 (33.01)	.266	21.750
BMI (kg/m^2)	25.95 (2.38)	36.42 (11.97)	.133	10.47

Note. SD: standard deviation; MD: mean difference.

Accelerometry

PA level was measured directly by accelerometry. Overall, nine (64%) participants wore an accelerometer during at least one session, three (21%) wore an accelerometer during two sessions, three (21%) wore an accelerometer during three sessions, and four (28%) wore an accelerometer during all four sessions. The absolute amount of time and the percentage of time that participants spent in SPA, LPA, MPA, and VPA are presented in Table 2. No significant differences in absolute time or percentage of time spent in any level of PA between the two groups were observed.

Table 2. Physical activity levels among overweight and obese autistic adolescents.

	Overweight (n = 4)	Obese (n = 5)		
	Mean (SD)	Mean (SD)	*p*	MD
Total Minutes				
SPA	28.13 (24.24)	38.80 (19.30)	.48	10.68
LPA	75.50 (64.19)	59.05 (24.08)	.66	16.45
MPA	19.44 (9.28)	18.60 (9.01)	.90	.84
VPA	2.63 (2.50)	6.40 (6.30)	.30	3.78
MVPA	22.06 (9.31)	25.00 (14.50)	.74	2.94
Percentage of Total Time				
%SPA	20.76 (5.10)	32.30 (11.97)	.10	11.54
%LPA	54.19 (16.13)	47.10 (13.17)	.49	7.09
%MPA	23.11 (19.61)	16.05 (7.38)	.48	7.06
%VPA	1.94 (.91)	4.55 (3.36)	.18	2.62
%MVPA	25.05 (18.94)	20.60 (91.21)	.65	4.44
Wear Time	125.69	122.85	.96	2.84

Note. SD: standard deviation; MD: mean difference; SPA: sedentary physical activity; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; MVPA: moderate-to-vigorous physical activity.

Physical Activity and Body Mass Index

For either group, BMI was not found to be significantly related to total activity counts, absolute time, or percent time spent in any activity level (Table 3).

Table 3. Correlations between physical activity and BMI for Overweight and Obese Autistic Adolescents.

Parameter	BMI	
	r	*p*
SPA	.020	.960
LPA	-.242	.530
MVPA	-.182	.639
%SPA	.224	.562
%LPA	-.084	.831
%MVPA	-.095	.807
Total Counts	-.344	.364
CPM	-.268	.486

Note. SPA: sedentary physical activity; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; MVPA: moderate-to-vigorous physical activity; CPM: counts per minute.

DISCUSSION

This study was one of the first attempts to examine the PA behaviors of, and the association between PA and BMI in, autistic children that participate in an APE class. The hypothesis that autistic adolescents would engage in more LPA than MVPA was supported, with an average of 66.36 minutes spent in LPA and 18.97 minutes spent in MVPA (Table 2). This may be partially explained by the activities the participants chose to engage in. Most participants chose to walk laps as their warm-up activity, followed by a motor skill activity that did not require a lot of movement, such as catching or kicking. While there are no studies that allow for direct comparison, previous research in this area has also observed autistic children engaging in more LPA than MVPA (Bandini et al., 2013; Boddy et al., 2015). However, other studies have observed contrasting results, with autistic children engaging in more MVPA than LPA (Ketcheson et al., 2018; Tyler et al., 2014; Pan et al., 2021). All six studies, including the current study, used different sample populations and different methodologies, which could explain the lack of consensus. Unfortunately, few published studies report data about LPA, limiting the ability to draw conclusions. To get a better understanding of what intensity levels of PA autistic children engage in the most, future studies should report their data on SPA and LPA, not just MVPA.

The second hypothesis that lower levels of PA would be associated with higher BMI scores was only partially supported. Negative associations between total activity counts and counts per minute and BMI and BMI z-score were observed, but the associations were weak and failed to reach significance (Table 3). Previous studies have suggested that low levels of PA are associated with obesity in non-autistic children (Must & Tybor, 2005) and autistic children and adolescents (McCoy et al., 2016; McCoy & Morgan, 2019), whereas other studies have found no correlation (Bandini et al., 2013; Pan et al., 2016). The increased prevalence of overweight and obesity in autistic children may be explained by factors other than, or in addition to, PA.

Selective eating behaviors, also known as “picky eating,” is commonly observed in autistic children. Selective eating behaviors include restricted food acceptance (based on type, taste, smell, and texture), food refusal, and requiring specific utensils (e.g., a favorite spoon or plate). Approximately 72% of autistic children exhibit restricted food acceptance and 57% exhibit food refusal (Schreck & Williams, 2006). Studies show that autistic children prefer energy-dense foods (e.g., donuts, chicken nuggets) (Ahearn et al., 2001; Schreck et al., 2004), are more likely to consume sugar-sweetened beverages, such as juice or soda (Evans et al., 2012), and less likely to consume fruits and vegetables (Bandini et al., 2010). In addition, medications that are commonly prescribed to autistic children, such as atypical antipsychotics, have been associated with increases in weight gain (McPheeters et al., 2011). Selective eating behaviors, medications, and PA may all contribute to the increased prevalence of overweight and obesity, but the degree to which each factor impacts weight is unknown. Future research investigating all three factors within the same study would allow for a better understanding of each variable’s impact on weight.

Although none of the results of the independent *t*-tests reached significance, the mean difference between the two groups for several variables are worth mentioning. The autistic adolescents with obesity averaged 10.68 more minutes and 11.54% more percent of total time in SPA compared to the autistic adolescents that were overweight, 38.80 minutes and 32.30% compared to 28.13 minutes and 20.76%, respectively. Additionally, the autistic adolescents that were overweight engaged in 16.45 more minutes of LPA compared to the autistic adolescents with obesity, 75.50 minutes and 59.05 minutes, respectively (Table 2). The lack of significance is likely attributable to the small sample size and insufficient data points but does not invalidate the absolute differences that were observed.

When placed in a controlled environment, in which opportunities to be physically active are equal for both groups, there does appear to be measurable differences in PA behaviors between autistic and non-autistic children. Statistically significant differences may be few and far between, but differences in PA behaviors can impact weight and overall health, even if not statistically significant. An average of 21 fewer minutes spent in MVPA every day (Stanish et al., 2017) adds up to 147 fewer minutes (2.45 hours) spent in MVPA every week, 9.8 fewer hours each month, and 117.6 fewer hours (4.9 days) each year. It is imperative that researchers place less focus on what is or is not statistically significant and place greater focus on absolute differences when comparing autistic and non-autistic children. If the goal is to help autistic children improve their health outcomes and quality of life, all differences matter, not just those that are staticistally significant.

Several limitations in this study are worth mentioning. The sample size for this study was small, limiting the generalizability of the results. As this was a small-scaled exploratory study, practicalities inhibited data collection in larger numbers and including a wider range of variables. Data were collected during only four APE classes over the course of six weeks during the spring season. The cross-sectional design of the study prevent causality or the direction of relations from being determined. The placement of the accelerometer may have led to an over/under-estimation of activity levels. An activity that most participants enjoyed and engaged in often was riding a large tricycle, a light-to-moderate intensity activity for most participants. With the accelerometer placed on the right hip, it is not known how accurately the accelerometer was able to measure this activity. A seated version of an exercise is a common adaptation used by older adults and those with disabilities. Future research investigating the abilitiy of a waist-worn accelerometer to measure PA during seated activities would be valuable information to researchers across populations and specialties. Additionally, upper body movements, such as moving the arms, are not detected by accelerometers when worn on the hip. Therefore, we cannot know the impact of stereotypic behaviors (e.g., arm flapping, waving) or upper-body motor skills (e.g., catching, throwing) on the results. Wrist-worn accelerometers are available and would be more suitable for studying these specific movements. Finally, the epoch length and cutoff points used to determine PA intensities in this study may differ compared to those used in other studies. In the absence of a standardized procedure, choices were made based on the population being studied and best-practice recommendations.

In spite of the limitations, this study has several strengths. First, the use of accelerometers allowed for direct, objective measurement of PA levels that may not otherwise be obtained through self-report questionnaires or observations. The use of an objective measurement removes the posibility of recall bias affecting the results and removes the subjectivity inherrrent to researcher observations. A second strength was the diversity of the study sample. All participants had at least one co-occurring condition, the age range of participants represented most of the adolescent period of development (10–18-years-old), and the sample consisted of a male-to-female ratio of 2:1. The diversity of the sample used in the current study is more representative of the autism community than samples used in previous studies. This allows for a greater understanding of autistic people, which will in turn allow for better help and supports to be developed for autistic people to improve their health outcomes.

These findings using accelerometers suggest that autistic adolescents with obesity have similar PA behaviors as autistic adolescents that are overweight. Significant differences in PA intensity levels were not observed, but absolute differences in SPA and LPA were observed between the two groups. However, due to the small sample size, the possibility that these differences occurred due to chance cannot excluded. Future studies with larger sample sizes and more covariates are required to increase the knowledge base of the PA behaviors of autistic children and adolescents during APE classes.

REFERENCES

Ahearn, W. H., Castine, T., Nault, K., & Green, G. (2001). An assessment of food acceptance in children with autism or pervasive developmental disorder-not otherwise specified. *Journal of Autism and Developmental Disorders, 31*(*5*), 505–511. https://doi.org/10.1023/A:1012221026124

Alhowikan, A. M. (2016). Benefits of physical activity for autism spectrum disorders: A systematic review. *Saudi Journal of Sports Medicine, 16*(3), 163–167. American Psychiatric Association. (2013). Autism spectrum disorder. In *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890125596

Amir, R. E., Van den Veyver, I. B., Wan, M., Tran, C. Q., Francke, U., & Zoghbi, H. Y. (1999). Rett syndrome is caused by mutations in X-linked MECP2, encoding methyl-CpG-binding protein 2. *Nature Genetics, 23*(2), 185–188. https://doi.org/10.1038/13810

Bandini, L. G., Anderson, S. E., Curtin, C., et al. (2010). Food selectivity in children with autism spectrum disorders and typically developing children. *The Journal of Pediatrics, 157*(2), 259– 264. https://doi.org/10.1016/j.jpeds.2010.02.013

Bandini, L. G., Gleason, J., Curtin, C., Lividini, K., Anderson, S. E., Cermak, S. A., Maslin, M., & Must, A. (2013). Comparison of physical activity between children with autism spectrum disorders and typically developing children. *Autism: the international journal of research and practice, 17*(1), 44–54. https://doi.org/10.1177/1362361312437416

Block, M. (2016). *A teacher's guide to adapted physical education: Including students with disabilities in sports and recreation* (4th ed.). Brookes Publishing.

Block, M., Haegele, J., Kelly, L., & Obrusnikova, I. (2021). Exploring future research in adapted physical education. *Research Quarterly for Exercise and Sport, 92*(3), 429–442. https://doi.org/10.1080/02701367.2020.1741500

Boddy, L. M., Downs, S. J., Knowles, Z. R., Fairclough, S. J. (2015). Physical activity and play behaviors in children and young people with intellectual disabilities: A cross-sectional observational study. *School Psychology International, 36(2)*, 154–171. https://doi.org/10.1177/0143034314564242

Brandler, W. M., Antaki, D., Gujral, M., Noor, A., Rosanio, G., Chapman, T. R., Barrera, D. J., Lin, G. N., Malhotra, D., Watts, A. C., Wong, L. C., Estabillo, J. A., Gadomski, T. E., Hong, O., Fuentes Fajardo, K. V., Bhandari, A., Owen, R., Baughn, M., Yuan, J., … Sebat, J. (2016). Frequency and complexity of de novo structural mutation in autism. *American Journal of Human Genetics, 98*(4), 667–679. https://doi.org/10.1016/j.ajhg.2016.02.018

Bushman, B. (2019). Physical activity guidelines for americans: the relationship between physical activity and health. *ACSM's Health & Fitness Journal, 23*(3), 5–9. https://doi.org/10.1249/FIT.0000000000000472

Cliff, D. P., Reilly, J. J., & Okely, A. D. (2009). Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0–5 years. *Journal of Science and Medicine in Sport, 12*(5), 557–567. https://doi.org/10.1016/j.jsams.2008.10.008

Curtin, C., Anderson, S. E., Must, A., & Bandini, L. (2010). The prevalence of obesity in children with autism: a secondary data analysis using nationally representative data from the National Survey of Children's Health. *BMC pediatrics, 10*(11). https://doi.org/10.1186/1471-2431-10-11

Curtin, C., Bandini, L. G., Perrin, E. C., Tybor, D. J., & Must A. (2005). Prevalence of overweight in children and adolescents with attention deficit hyperactivity disorder and autism spectrum disorders: a chart review. *BMC pediatrics, 5*(48). https://doi.org/10.1186/1471-2431/5/48

Dewey, D., Cantell, M., & Crawford, S. G. (2007). Motor and gestural performance in children with autism spectrum disorders, developmental coordination disorder, and/or attention deficit hyperactivity disorder. *Journal of the International Neuropsychological Society, 13*(2), 246–256. https://doi.org/10.1017/51355617707070270

Egan, A. M., Dreyer, M. L., Odar, C. C., Beckwith, M., & Garrison, C. B. (2013). Obesity in Young Children with Autism Spectrum Disorders: Prevalence and Associated Factors. *Childhood Obesity, 9*(2), 125–131. https://doi.org/10.1089/chi.2012.0028

Eichler, E. E. (2019). Genetic variation, comparative genomics, and the diagnosis of disease. *New England Journal of Medicine, 381*(1), 64–74.

Evans, E. W., Must, A., Anderson, S. E., Curtin, C., Scampini, R., Maslin, M., & Bandini, L. (2012). Dietary Patterns and Body Mass Index in Children with Autism and Typically Developing Children. *Research in autism spectrum disorders, 6*(1), 399–405. https://doi.org/10.1016/j.rasd.2011.06.014

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008. Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences, 26*(14), 1557–1565. https://doi.org/10.1080/02640410802334196

Garcia-Pastor, T., Salinero, J. J., Theirs, C. I., & Riuz-Vicente, D. (2019). Obesity status and physical activity level in children and adults with autism spectrum disorders: A pilot study. *Journal of Autism and Developmental Disorders, 49,* 165–172. https://doi.org/10.1007/s10803-018-3692-2.

Gardener, H., Spiegelman, D., & Buka, S. L. (2009). Prenatal risk factors for autism: comprehensive meta-analysis. *The British Journal of Psychiatry, 195*(1), 7–14. https://doi.org/10.1192/bjp.bp.108.051672

Gutin, I. (2019). In BMI we trust: reframing the body mass index as a measure of health. *Social Theory & Health, 16*(3), 256–271. https://doi.org/10.1057/s41285-017-0055-0

Hales, C. M., Fryar, C. D., Carroll, M. D., Freedman, D. S., & Ogden, C. L. (2018). Trends in obesity and severe obesity prevalence in US Youth and adults by sex and age, 2007–2008 to 2015–2016. *JAMA, 319*(16), 1723–1725. https://doi.org/10.1001/jama.2018.3060

Hatton, D. D., Sideris, J., Skinner, M., Mankowski, J., Bailey D. B., Roberts, J., & Mirrett, P. (2006). Autistic behavior in children with fragile X syndrome: prevalence, stability, and the impact of FMRP. *American Journal of Medical Genetics, 140A*(17), 1804–1813. https://doi.org/10.1002/ajmg.a.31286

Hodge, S. R., Lieberman, L. J., & Murata, N. M. (2012). *Essentials of teaching adapted physical education.* Holcomb Hathaway.

Hodges, H., Fealko, C., & Soares, N. (2020). Autism spectrum disorder: definition, epidemiology, causes, and clinical evaluation. *Translational Pediatrics, 9*(Supple 1), S55–S65. https://doi.org/10.21037/tp.2019.09.09

Jones, R. A., Downing, K., Rinehart, N. J., Barnett, L. M., May, T., McGillivray, J. A., Papadopoulos, N. V., Skouteris, H., Timperio, A., Hinkley, T. (2017). Physical activity, sedentary behavior and their correlates in children with autism spectrum disorder: A systematic review. *Public Library of Science ONE, 12*(2), e0172482. https://doi.org/10.1371/journal.pone.0172482

Kapp, S. K., Steward, R., Crane, L., Elliot, D., Elphick, C., Pellicano, E., & Russell, G. (2019). 'People should be allowed to do what they like': Autistic adults' views and experiences of stimming. *Autism, 23*(7), 1782–1792. https://doi.org/10.1177/1362361319829628

Ketcheson, L., Hauck, J. L., & Ulrich, D. (2018). The levels of physical activity and motor skills in young children with and without autism spectrum disorder, aged 2–5 years. *Autism, 22*(4), 414–423. https://doi.org/10.1177/1362361316683889

Krebs, N. F., Himes, J. H., Jacobson, D., Nicklas T. A., Guilday P., & Styne, D. (2007). Assessment of child and adolescent overweight and obesity. *Pediatrics, 120*(Suppl),193–228. https://doi.org/10.1542/peds.2007-2329D

Kuczmarski, R. J., Ogden, C. L., Guo, S. S., Grummer-Strawn, L. M., Flegal, K. M., Mei, Z., Wie, R., Curtin, L., Roche, A. F., & Johnson, C. L. (2002). 2000 CDC Growth Charts for the United States: methods and development. National Center for Health Statistics. *Vital and Health Statistics (11),* 246. https://www.cdc.gov/nchs/data/series/sr_11/sr11_246.pdf

Lang, R., Koegel, L. K., Ashbaugh, K., Regester, A., Ence, W., & Smith, W. (2010). Physical exercise and individuals with autism spectrum disorders: A systematic review. *Research in Autism Spectrum Disorders,* 4, 565–576. https://doi.org/10.1016/j.rasd.2010.01.006

Levy, D., Ronemus, M., Yamrom, B., Lee, Y. H., Leotta, A., Kendall, J., Marks, S., Lakshmi, B., Pai, D., Ye, K., Buja, A., Krieger, A., Yoon, S., Troge, J., Rodgers, L., Iossifov, I., & Wigler, M. (2011). Rare de novo and transmitted copy-number variation in autistic spectrum disorder. *Neuron, 70*(5), 886–897. https://doi.org/10.1016/j.neuron.2011.05.015

Liang, X., Li, R., Wong, S. H. S., Sum, R. K. W., Sit, C. H. P. (2020). Accelerometer-measured physical activity levels in children and adolescents with autism spectrum disorder: A systematic review. *Preventative Medicine Reports, 19*, 101147. https://doi.org/10.1016/j.pmedr.2020.101147

López-Valverde, P., Rico-Díaz, J., Barcala-Furelos, M., Martí-González, M., Martín, J. L., & López-García, S. (2021). Instruments to assess physical activity in primary education students with autism spectrum disorder: A systematic review. *International Journal of Environmental Research and Public Health, 18*(9), 4913. https://doi.org/10.3390/ijerph18094913

Lord, C., Elsabbagh, M., Baird, G., & Veenstra-Vanderweele, J. (2018). Autism spectrum disorder. *The Lancet, 392*(10146), 508–520. https://doi.org/10.1016/S0140-6736(18)31129-2

Lumes, R., Hull, L., & Mandy, W. P. L. (2017). What is the male-to-female ratio in autism spectrum disorder? A systematic review and meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry, 56*(6), 466–474. https://doi.org/10.1016/j.jaac.2017.03.013

MacDonald, M., Esposito, P., & Ulrich, D. (2011). The physical activity patterns of children with autism. *BMC Research Notes, 4*, 442. https://doi.org/10.1186/1756-0500-4-422

Maenner, M. J., Shaw, K. A., Bakian, A. V., Bilder, D. A., Durkin, M. S., Esler, A., Furnier, S. M., Hallas, L., Hall-Lande, J., Hudson, A., Hughes, M. M., Patrick, M., Pierce, K., Poynter, J. N., Salinas, A., Shenouda, J., Vehorn, A., Warren, Z., Constantino, J. N., . . . Cogswell, M. E. (2021). Prevalence of autism spectrum disorder among children aged 8 years – Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2018. *Morbidity and mortality weekly report. Surveillance summaries, 70*(SS11), 1–16. http://dx.doi.org/10.15585/mmwr.ss7011a1

McCoy S., & Morgan, K. (2019). Obesity, physical activity, and sedentary behaviors in adolescents with autism spectrum disorder compared with typically developing peers. *Autism,24*(2), 387–399. https://doi.org/10.1177/1362361319861579

McCoy, S., Jakicic, J., & Gibbs, B. B. (2016). Comparison of obesity, physical activity, and sedentary behaviors between adolescents with autism spectrum disorder and without.

*Journal of Autism and Developmental Disorders, 46,*2317–2326. https://doi.org/10.1007/s10803-016-2762-0

McPheeters, M. L., Warren, Z., Sathe, N., Bruzek, J. L., Krishnaswami, S., Jerome, R. N., & Veenstra-Vanderweele, J. (2011). A systematic review of medical treatments for children with autism spectrum disorders. *Pediatrics, 127*(5), e1312–e1321. https://doi.org/10.1542/peds.2011-0427

Mullen, E. (1995). *Mullen Scales of Early Learning*. AGS ed. American Guidance Services, Inc.

Must, A., Phillips, S. M., Curtin, C., & Bandini, L. G. (2015). Barriers to physical activity in children with autism spectrum disorders: relationship to physical activity and screen time. *Journal of Physical Activity and Health, 12*(4), 529–534. https://doi.org/10.1123/jpah.2013-0271

Must, A. & Tybor, D. J. (2005). Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *International Journal of Obesity, 29*(Suppl 2), 84–96. https://doi.org/10.1038/sj.ijo.08030674

Pan, C. Y. (2008). Objectively measured physical activity between children with autism spectrum disorders and children without disabilities during inclusive recess settings in Taiwan. *Journal of Autism and Developmental Disorders, 38,*1292–1301. https://doi.org/10.1007/s10803-007-0518-6

Pan, C. Y., & Tsai, C. L. (2011). Physical activity correlates for children with autism spectrum disorders in middle school physical education. *Research Quarterly for Exercise and Sport, 82*(3), 491–498. https://doi.org/10.1080/02701367.2011.10599782

Pan, C. Y., Tsai, C. L., Chen, F. C., Chow, B. C., Chen, C. C., & Chu, C. H. (2021). Physical and sedentary activity patterns in youths with autism spectrum disorder. *International Journal of Environmental Research and Public Health, 18*(4), 1739. https://doi.org/10.3390/ijerph18041739

Pan, C.Y., Tsai, C. L., Chu, C. H., Sung, M. C., Ma, W. Y., & Huang, C. Y. (2016). Objectively measured physical activity and health-related physical fitness in secondary school-aged male students with autism spectrum disorder. *Physical Therapy, 96*(4) 511–520. https://doi.org/10.2522/ptj.20140353

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., & Olson, R. D. (2020). The physical activity guidelines for Americans. *Journal of the American Medical Association, 320*(19), 2020–2028. https://doi.org/10.1001/jama.2018.14854

Pinto, D., Pagnamenta, A. T., Klei, L., Anney, R., Merico, D., Regan, R., Conroy, J., Magalhaes, T. R., Correia, C., Abrahams, B. S., Almeida, J., Bacchelli, E., Bader, G. D., Bailey, A. J., Baird, G., Battaglia, A., Berney, T., Bolshakova, N., Bolte, S., … Betancur, C. (2010).

Functional impact of global rare copy number variation in autism spectrum disorders. *Nature, 466*(7304), 368–372. https://doi.org/10.1038/nature09146

Puyau, M., Adolph, A., Vohra, F., Zakeri, I., & Butte, N. (2004). Prediction of activity energy expenditure using accelerometers in children. *Medicine & Science in Sports & Exercise, 36*(9), 1625–1631. https://doi.org/10.1249/01.MSS.0000139898.30804.60

Quetelet, A. (1842). *On Man and the Development of his Faculties, or Essays on Social Physics*.

Rosser-Sandt, D. D., & Frey, G. C. (2005). Comparison of physical activity levels between children with and without autism spectrum disorders. *Adapted Physical Education Quarterly, 22*(2), 146–159.

Sanyaolu, A., Okorie, C., Qi, X., Locke, J., & Rehman, S. (2019). Childhood and adolescent obesity in the United States: A public health concern. *Global Pediatric Health, 6*, 1–11. https://doi.org/10.1177/2333794X19891305

Schreck, K. A. & Williams, K. (2006). Food preferences and factors influencing food selectivity for children with autism spectrum disorders. *Research in Developmental Disabilities, 27*(4), 353–363. https://doi.org/10.1016/j.ridd.2005.03.005

Schreck, K. A., Williams, K., & Smith, A. F. (2004). A comparison of eating behaviors between children with and without autism. *Journal of Autism and Developmental Disorders, 34*(4), 433–438. https://doi.org/10.1023/b:jadd.0000037419.78531.86

Sebat, J., Lakshmi, B., Malhotra, D., Troge, J., Lese-Martin, C., Walsh, T., Yamrom, B., Yoon, S., Krasnitz, A., Kendall, J., Leotta, A., Pai, D., Zhang, R., Lee, Y. H., Hicks, J., Spence, S. J., Lee, A. T., Puura, K., Lehtimaki, T., … Wigler, M. (2007). Strong association of de novo copy number mutations with autism. *Science, 316*, 445–449. https://doi.org/10.1126/science.1138659

Siegel, M. (2012). Psychopharmacology of autism spectrum disorder: evidence and practice. *Child and Adolescent Psychiatric Clinics of North America, 21*(4), 957–973. https://doi.org/10.1016/j.chc.2012.07.006

Stanish, H. I., Curtin, C., Must, A., Phillips, S., Maslin, M., & Bandini, L. (2017). Physical activity levels, frequency, and type among adolescents with and without autism spectrum disorder. *Journal of Autism and Developmental Disorders, 47,*785–794. https://doi.org/10.1007/s10803-016-3001-4

Trost, S. G., Loprinzi, P. D., Moore, R., & Pfeiffer, K. A. (2011). Comparison of accelerometer cut points for predicting activity intensity in youth. *Medicine and Science in Sports and Exercise, 43*(7), 1360–1368. https://doi.org/10.1249/MSS.0b013e31820647e

Tyler, K., MacDonald, M., & Menear, K. (2014). Physical activity and physical fitness of school-aged children and youth with autism spectrum disorders. *Autism Research and Treatment, 2014*, 312163. https://doi.org/10.1155/2014/312163

Wang, C., Geng, H., Liu, W., & Zhang, G. (2017). Prenatal, perinatal, and postnatal factors associated with autism: A meta-analysis. *Medicine, 96*(18), e6696. https://doi.org/10.1097/MD.0000000000006696

Williams, H. G., Whiten, A., & Singh, T. (2004). A systematic review of action imitation in autistic spectrum disorder. *Journal of Autism and Developmental Disorders, 34*, 285–299. https://doi.org/10.1023/B:JADD.0000029551.56735.3A

Xu, G., Strathearn, L., & Liu, B. (2018). Prevalence of autism spectrum disorder among US children and adolescents. *JAMA, 319*(1), 81–82. http://doi.org/10.1001/jama.2017.17812

Zufferey, F., Sherr, E. H., Beckmann, N. D., Hanson, E., Maillard, A. M., Hippolyte, L., Mace, A., Ferrari, C., Kutalik, Z., Andrieux, J., Aylward, E., Barker, M., Bernier, R., Bouquillon, S., Conus, P., Delobel, B., Faucett, W. W., Goin-Kochel, R. P., Grant, E. … Jacquemont, S. (2012). A 600 kb deletion syndrome at 16p11.2 leads to energy imbalance and neuropsychiatric disorders. *Journal of Medical Genetics, 49*(10), 660–668. https://doi.org/10.1136/jmedgenet-2012-101203

APPENDIX: IRB APPROVAL NOTICE

IRB-FY2022-189 - Initial: Initial Approval

do-not-reply@cayuse.com <do-not-reply@cayuse.com>

Mon 12/20/2021 3:37 PM

To: Mullins, Cody A <Cody1898@live.missouristate.edu>;Smith, Cody R <CodySmith@MissouriState.edu>;Woodard, Rebecca J <RebeccaWoodard@MissouriState.edu>;Goddard, Stacy E <SGoddard@MissouriState.edu>

Missouri State UNIVERSITY

To:
Rebecca Woodard
Kinesiology
Stacy Goddard, Cody Smith

RE: Notice of IRB Approval
Submission Type: Initial
Study #: IRB-FY2022-189
Study Title: Physical Activity as a Predictor of Obesity in Children with Autism Spectrum Disorder
Decision: Approved

Approval Date: December 20, 2021

This submission has been approved by the Missouri State University Institutional Review Board (IRB). You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented. Should any adverse event or unanticipated problem involving risks to subjects or others occur it must be reported immediately to the IRB.

This study was reviewed in accordance with federal regulations governing human subjects research, including those found at 45 CFR 46 (Common Rule), 45 CFR 164 (HIPAA), 21 CFR 50 & 56 (FDA), and 40 CFR 26 (EPA), where applicable.

Researchers Associated with this Project:
PI: Rebecca Woodard
Co-PI: Stacy Goddard, Cody Smith
Primary Contact: Cody Mullins
Other Investigators: