Investigating the Effectiveness of an Exercise Intervention on Sleep Behaviour and Problem Behaviour in Children Ages 6-10 with Autism Spectrum Disorder

by

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Chair of Examining Committee	Dr. Manon Lemonde
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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Children with Autism Spectrum Disorder (ASD) often experience problematic sleep behaviour and demonstrate low levels of participation in physical activity (PA) and exercise. There is a bidirectional relationship between sleep and exercise in children with typical development (TD), however, it is not well understood in children with ASD. Therefore, the purpose of this study was to explore the effectiveness of a 4-week exercise intervention on sleep behaviour of 6-10-year-old children with ASD in comparison to controls. Sleep, problem behaviour, and the feasibility of a rating of perceived exertion scale were assessed before and after the intervention. The results showed that subjectively reported sleep behaviour improved following participation in the exercise intervention. Problem behaviour improved in both groups and the ratings of perceived exertion fell within the expected ranges. Overall, the results indicate that exercise is a feasible, non-pharmacological option for children with ASD who experience problematic sleep behaviours, but further investigation is warranted.

Keywords: Autism Spectrum Disorder; sleep behaviour; exercise; problem behaviour; rating of perceived exertion; children

Tayler M. Runge (2020)

AUTHOR'S DECLARATION

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Tayler M. Runge

STATEMENT OF CONTRIBUTIONS

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

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LIST OF ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
ASD	Autism Spectrum Disorder
CBCL	Child Behaviour Checklist
CSHQ	Children's Sleep Habits Questionnaire
MET	Metabolic Equivalent
PA	Physical Activity
PAQ-C	Physical Activity Questionnaire for Older Children
RPE	Rating of Perceived Exertion
SDP	Sleep Disturbance Pediatric questionnaire
SDPP	Sleep Disturbance Parent Proxy questionnaire
TD	Typical Development
WASO	Waking After Sleep Onset
WHO-ICF	World Health Organization International Classification of Functioning, Disability and Health

OVERVIEW

This thesis is divided into five sections:

1. Introduction
2. Literature Review
3. Manuscript
4. Conclusion
5. Appendices

CHAPTER 1: INTRODUCTION

Introduction to Thesis

Overview of Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by challenges with social, behavioural, and communication skills (American Psychiatric Association, 2013). Individuals with ASD may exhibit verbal or nonverbal communication, strong fixated interests, repetitive movements, and/or difficulty with social relationships as well as back-and-forth conversation (American Psychiatric Association, 2013). In Canada, approximately 1 in every 66 children are diagnosed, with males four times more likely to be affected than females (Public Health Agency of Canada, 2018). The core characteristics are presented differently in every individual which contributes to the diversity within individuals with ASD. Additional delays and/or co-occurring conditions are common in individuals with ASD, such as motor skill delays, psychological disorders and/or medical conditions (e.g. epilepsy) (Bauman, 2010; Leyfer et al., 2006; Matson, 2016; Staples & Reid, 2010). Furthermore, low levels of participation in physical activity (PA) and sleep problems are more prominent in children with ASD than children with typical development (TD) (Case, Ross, & Yun, 2020; Hodge, Carollo, Lewin, Hoffman, & Sweeney, 2014; Tyler, MacDonald, & Menear, 2014). Further exploration of the relationship between these two variables in a bidirectional manner is necessary, but emphasis on PA and exercise programs to positively effect sleep behaviour could be an initial step to better understanding the relationship in children with ASD.

Sleep Problems

Sleep is a reversible behavioural state that is critical for one's psychological and physiological health with increasing recognition as a contributor to disease when sleep is insufficient (Carskadon & Dement, 2011). Two interacting and natural processes, known

as *Process C* (circadian rhythm) and *Process S* (homeostatic process), govern sleep and are regulated on a 24-hour cycle. Adequate sleep is important for development, memory, learning, and behaviour regulation in all children (Chaput et al., 2016; Cohen, Conduit, Lockley, Rajaratnam, & Cornish, 2014; Stores & Wiggs, 1998). However, more than half of children diagnosed with ASD experience sleep problems compared to a third of children with TD (Hodge et al., 2014; Richdale & Prior, 1995), and these problems are less likely to diminish with age in children with ASD compared to their peers (Goldman, Richdale, Clemons, & Malow, 2012; Richdale & Schreck, 2009). Poor sleep behaviour not only affects the children, but the health of their families as well (Richdale & Schreck, 2009), therefore, prompt attention is necessary.

Some of the most commonly reported sleep problems pertain to initiating and maintaining sleep which includes bedtime resistance, delayed sleep onset, prolonged waking after sleep onset (WASO), and/or early waking (Goldman et al., 2012; Souders et al., 2009; Veatch, Maxwell-Horn, & Malow, 2015). The poor sleep behaviours have been associated with neurobiological, medical and/or behavioural aetiologies, such as hormonal irregularities, anxiety and/or sensory reactivity (Cortesi, Giannotti, Ivanenko, & Johnson, 2010; Goldman et al., 2009; Richdale & Schreck, 2009). Currently, medication and behavioural intervention are some of the strategies that exist to manage sleep behaviour in children with ASD (Cortesi et al., 2010; Stores & Wiggs, 1998; Veatch et al., 2015). With the high prevalence of sleep challenges in children with ASD, we hope to explore whether an alternate form of intervention can have a positive impact on sleep. Exercise programs may be easier to implement than other management strategies in addition to having positive

effects on multiple health domains in children with ASD, one of which could be sleep, but further investigation is warranted.

Movement and Activity Levels

Movement is considered to be the combination of PA, sleep and sedentary behaviour in reference to an entire 24-hour period which was outlined in the release of the new Canadian 24-hour movement guidelines in 2016 (Tremblay et al., 2016). In support of leading a healthier lifestyle, the national guidelines recommend that children attain 9-11 hours of sleep, less than two hours of sedentary behaviour, several hours of light PA, and one hour of moderate to vigorous PA daily (Tremblay et al., 2016). Children that meet more guidelines have better physiological and psychological health compared to those that do not, yet less than 20% of children and youth are meeting all of these guidelines (Carson, Chaput, Janssen, & Tremblay, 2017; Janssen & Leblanc, 2010). Conversely, Carson et al. (2017) found that meeting the PA recommendations alone is not as beneficial as meeting the PA, and sleep recommendations. Individuals with ASD do not engage in the levels of activity represented in their peers with TD placing them at a greater risk for not meeting these guidelines (Case et al., 2020; Jones et al., 2017; Tyler et al., 2014). In individuals with ASD, most of the previous literature discusses sleep, PA, and sedentary activity independently, however, some preliminary research investigated the relationship between these activities in which further exploration is still needed (Benson et al., 2018; Wachob & Lorenzi, 2015).

Physical Activity and Exercise

Individuals with ASD tend to engage in less PA as well as fewer variations of activities than their peers with TD and other developmental disabilities (Bandini et al.,

2013; Case et al., 2020; Must et al., 2014; Tyler et al., 2014), with this pattern continuing into adolescence and adulthood (MacDonald, Esposito, & Ulrich, 2011). PA is described as any movement of the skeletal muscle that requires energy whereas exercise is a subcategory of PA that is purposeful and structured with the intention of maintaining or improving physical fitness (Caspersen, Powell, & Christenson, 1985). PA and exercise are an essential part of maintaining mental and physical health in addition to preventing the development of disease in all children (Janssen & Leblanc, 2010), while children with ASD also experience benefits with some of the core challenges in ASD, such as social interaction, on-task behaviour, stereotypical behaviours, and emotional regulation (Bremer, Crozier, & Lloyd, 2016; Lang et al., 2010; Sowa & Meulenbroek, 2012). It has been demonstrated that PA and exercise have numerous benefits in children with ASD (Lang et al., 2010; Sowa & Meulenbroek, 2012) although it is still unclear whether it contributes to improved sleep behaviour. We were interested in exploring this relationship by conducting an exercise intervention and evaluating the effects on sleep behaviour.

Relationship between Sleep and Exercise

In children with TD, there is a positive bidirectional relationship between sleep and PA (Kline, 2014; Lang et al., 2013; Lin et al., 2018). In other words, regular participation in PA leads to improved sleep, and better sleep results in more participation in PA (Baldursdottir, Taehtinen, Sigfusdottir, Krettek, & Valdimarsdottir, 2017; Kline, 2014). It has been recognized that children with ASD demonstrate sleep problems and insufficient levels of PA (Richdale & Prior, 1995; Stanish et al., 2017), but the relationship between the two variables is not well understood. The high prevalence of sleep problems in ASD emphasizes the need for more attention to sleep management through which multiple

strategies have been proven to be effective based on the type of sleep problem. Some approaches include medication, sleep hygiene education, behavioural intervention, and/or environmental adjustments (Richdale, 1999). However, PA and exercise could be a feasible, and non-pharmacological, method to managing sleep in which promising results have been demonstrated (Brand, Jossen, Holsboer-Trachsler, Puhse, & Gerber, 2015; Oriel, Kanupka, DeLong, & Noel, 2016). These studies offered aquatic, aerobic and motor skill programs over approximately one month and following the interventions, objective and subjective improvements in sleep were reported (Brand et al., 2015; Oriel et al., 2016).

The success of exercise interventions at improving sleep behaviour suggests that two issues can be managed through one intervention strategy, that is increasing exercise participation and improving sleep. Conversely, better sleep also increases the probability of engaging in exercise or other PA. Managing these two issues has also been shown to improve the quality of life in children with ASD (Delahaye et al., 2014; Toscano, Carvalho, & Ferreira, 2018). Previous studies have demonstrated an association between PA and sleep (Benson et al., 2018; Wachob & Lorenzi, 2015), however, more research is necessary for a better understanding of this relationship in children with ASD; in particular, different modes of exercise and its effect on sleep should be explored. Furthermore, the studies that analyzed the effects between exercise and sleep in children with ASD did so in a unidirectional manner by increasing exercise to observe potential change in sleep which will also be applied in the current study since previous literature is preliminary. That being said, the inverse relationship and effects should also be investigated in future research to better understand exercise and sleep in children with ASD.

Summary

ASD is characterized by a broad range of symptoms associated with challenges in social and behavioural domains (American Psychiatric Association, 2013). In addition to their diagnosis, children experience a number of co-occurring conditions and symptoms including, a high prevalence of sleep problems and low levels of participation in exercise (Bauman, 2010; MacDonald et al., 2011; Richdale, 1999). In children with TD, there is a bidirectional relationship between sleep and PA, however, less is known about this relationship in children with ASD (Baldursdottir et al., 2017). Some recent studies have examined the associations, but few have intervened to measure the effects of exercise on sleep within individuals with ASD (Brand et al., 2015; Wachob & Lorenzi, 2015). More specifically, the current study will address the gaps of previous literature, such as the mode of exercise and a comparison between an experimental and a control group with ASD.

Proposed Theoretical Framework: World Health Organization – International Classification of Functioning, Disability and Health (WHO-ICF)

Model Overview

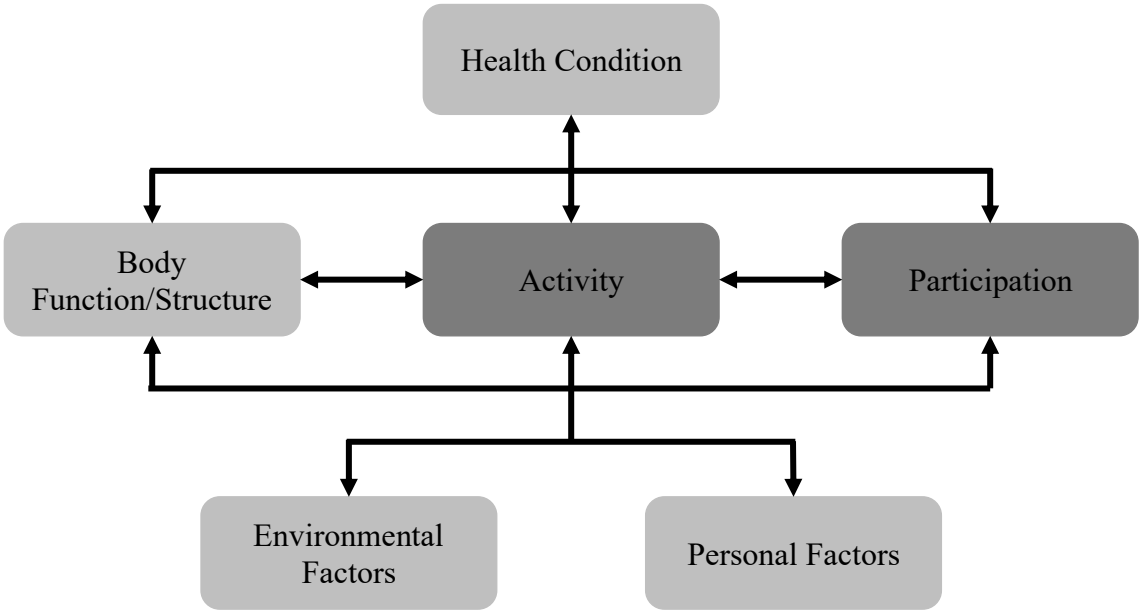
In 2001, the World Health Organization (WHO) Member States agreed to introduce a classification system with an underlying biopsychosocial approach to universally describe and better understand health and health-related states and functioning (World Health Organization, 2001). The purpose of this model is to improve communication of health states and care across various users and disciplines with the understanding that any individual can experience a health condition and/or some degree of disability (World Health Organization, 2001). The International Classification of Functioning, Disability and Health (ICF) defines functioning as body functions, activities, and participation, whereas disability refers to impairments, activity limitations, and participation restrictions (World Health Organization, 2001). It helps to describe health-related domains that affect functioning and disability including; body structure and function, activity, participation with the consideration of contextual factors (environmental and personal) that interact with each category (World Health Organization, 2001). The focus of the classification has shifted towards recognizing the constituents of health with a neutral position of the causes rather than the "consequences of disease" (World Health Organization, 2001). The ICF can be used as a tool to help organize information regarding human functioning across a broad spectrum (individual to population level) including personal health care, which involves prevention, promotion, and improvement of participation (World Health Organization, 2001). This can be done through the reflection of the social factors that positively or negatively affect health conditions or disability (World Health Organization, 2001).

Overall, the ICF provides a communal system to compare health states and care between various consumers (World Health Organization, 2001).

Children with ASD, Exercise Intervention and ICF

Figure 1 is an illustration of the WHO-ICF model that was used to discuss the classification of the population that will participate in the study. Each component of the model will be discussed with respect to children with ASD.

Figure 1. WHO-ICF model for the classification of health conditions and functioning



Health Condition

The participants in this study had a diagnosis of ASD in addition to parent-reported sleep problems. It was expected that the varying expressions of symptoms of ASD would contribute to a diverse sample in this study. An association has been reported between the symptom severity of ASD and sleep problems in individuals with ASD (Adams, Matson, Cervantes, & Goldin, 2014; Hollway & Aman, 2011). Moreover, difficulties with sleep are

understood to be a result of complex interactions between biological, psychological, behavioural, environmental, social, and family factors in individuals with ASD.

Body Function and Structure

The body structure and function category is defined as the physiological functions of body systems and anatomical parts of the body (World Health Organization, 2001). Sleep has functional properties as it is responsible for the regulation and function of many bodily systems including hormonal and metabolic regulation as well as immune and brain function (Zielinski, McKenna, & McCarley, 2016). Many individuals with ASD experience problems with their sleep, most commonly with initiating or maintaining sleep which are related to genetic abnormalities, circadian rhythm disruptions, sleep-wake cycle irregularities and/or hormonal imbalances (e.g. melatonin). As a result, it has also been recognized that children with ASD experience disruptions to sleep patterns and specific phases of sleep. Intellectual disability has also been found to increase the experience of sleep difficulties in individuals with ASD. Other common comorbid conditions such as, medical issues (e.g. gastrointestinal reflux), psychological conditions (e.g. anxiety) and/or neurodevelopmental disorders (e.g. attention deficit hyperactivity disorder and/or epilepsy) are known to have an affect on sleep, potentially exacerbating the sleep issues in individuals with ASD (Leyfer et al., 2006; Reynolds & Malow, 2011; Richdale & Schreck, 2009). However, this study did not directly target the body function and structure part of the model as the functions of sleep were not assessed.

Activity

The WHO-ICF describes activity as the execution of a task by an individual in addition to any difficulties experienced while performing the activities (World Health

Organization, 2001). Sleep is applicable to the activity component of the model in that poor sleep is a limitation of the activity. Children with ASD often experience problematic sleep, and these disruptions most frequently involve issues with initiating or maintaining sleep which results in inadequate sleep. A negative cycle is created as this leads to daytime sleepiness which ultimately impacts activity of daily living. Data on sleep and PA outcomes was collected pre- and post-intervention; it was hypothesized that by providing an opportunity to exercise, sleep behaviour will improve.

Participation

Participation refers to the involvement in a life situation or the problems an individual experiences during this involvement (World Health Organization, 2001). The primary focus of this study was to influence sleep behaviour in children with ASD by increasing participation in exercise in hopes of maximizing this important component of health. Children with ASD experience challenges with social and behavioural skills which could impede their ability to participate in daily activities or PA with their peers, but this research study provided an opportunity to do so. Additionally, children with ASD demonstrate low levels of participation in PA and exercise and this lack of participation has a detrimental affect on their physical, social, behavioural, and psychological health. By intervening to increase participation in exercise, there was potential to improve sleep behaviour in the participants. While the purpose of the intervention was to improve sleep behaviour in children with ASD, it could have also led to increased participation in exercise. If this hypothesis was supported, exercise could be promoted as an advantageous method to improving sleep in addition to the other benefits previously mentioned. It was

hopeful that regular participation in PA and exercise continued following the intervention and was incorporated into the daily routines of the participants.

Intensity of participation level can be estimated through objective and subjective measures. Based on the low levels of participation, it could be assumed that children with ASD do not frequently estimate their perceived exertion during PA and exercise. This opportunity was provided following each session during the intervention and could have assisted children with ASD in comprehending their efforts during activity which could ultimately facilitate participation in higher intensity activity. The participants also had an opportunity to answer questions in regards to their participation in PA using a questionnaire. Parents and instructors supported the intensity ratings by providing their perceptions of the effort demonstrated by each child during the intervention and assisted the participants with the PA questionnaire. Parents also completed all questionnaires regarding the child's sleep and behaviour. It was hypothesized that sleep, PA, and behaviour would improve after the intervention and children with ASD would accurately estimate their perceived exertion during exercise.

Environmental Factors

The environmental factors are related to the physical, social and attitudinal environment in which an individual lives and interacts within (World Health Organization, 2001). The participants in the experimental group engaged with one another and research assistants in a safe and enjoyable setting that promoted participation in exercise. The intervention was modified to suit the specific needs and preferences of the participants to maximize capacity to perform the activities. For example, the equipment used during the intervention was available in different sizes and colours which encouraged satisfaction and

adherence to the program. This all assisted with any sensory experiences of the children that altered their participation in the program. By providing opportunity for individualization and enjoyment, it was anticipated that the participants would maximize their participation in the intervention and exercise, and hopefully improve their sleep behaviour. Although not targeted in this study, it should be noted that the environment within the homes of the participants may have contributed to the sleep problems. Specifically, bedtime routines and schedules, the bedroom, natural and artificial light, room temperature, and/or sensory distractions should be considered in addition to exercise habits in children with ASD, but it was not discussed with the parents of the current study. The participation levels within the family could be a strong indicator of the emphasis on exercise and PA in the children. By focusing on the surrounding environment during the intervention, it was hoped that regardless of the other environmental influences, sleep behaviour improves.

Personal Factors

Personal factors consist of the individual background and profiles of individuals which are non-modifiable features or a part of the health condition, but they may influence the outcomes of various interventions (World Health Organization, 2001). Firstly, the age of the participants can have an affect on sleep; adolescence is a period in which sleep naturally changes. Furthermore, ASD is also four times more likely to affect males than females so it was expected that the recruited sample will be somewhat representative of this ratio. ASD is described by challenges in social and behavioural skills, however, the level of functioning varies in every individual with ASD. Specifically, the social functioning of the children could also contribute to issues with sleep in this population. The

behavioural assessment of the children, completed before and after the exercise intervention, was expected to vary and could potentially influence their capability to participate during the intervention. Participation levels prior to the intervention played a role in the capacity to participate in the exercises.

Summary

The movement activities (sleep and exercise) investigated in the current study were applied to the WHO-ICF framework to describe and better understand health and health-related functions. All components of the model were considered and described as they are interconnected; however, the activity and participation sections were the primary components related to the variables in the present study. The model was operationalized within the features and parameters of the current study.

Significance of the Study: Addressing the Gaps in the Literature

Sleep and PA have been independently researched in individuals with ASD which has contributed to the important recognition of sleep problems and low levels of PA and exercise in individuals with ASD. However, the relationship between exercise and sleep in children with ASD is not well understood. More specifically, few studies have explored the effectiveness of exercise as a management strategy to improve sleep; therefore, this study will address the gaps within the literature. The limitations and gaps outlined in previous research included small sample sizes, limited dosage of exercise, and lack of parent reflection. In addition, the current study was the first, to our knowledge, to offer organized play and circuits as the mode of exercise to attempt to improve sleep behaviour in children with ASD. Furthermore, this study also provided a comparison of children with ASD through an intervention and control group under different activity conditions which has not been done in previous research (Benson et al., 2018; Brand et al., 2015; Wachob & Lorenzi, 2015). We hoped the findings of the current study would determine the effectiveness of exercise on sleep behaviour in children with ASD to better understand the potential of exercise as a feasible and non-pharmacological approach to improving sleep behaviour.

Purpose and Overall Contributions

The purpose of this study was to explore the effectiveness of an exercise intervention on sleep behaviour in children with ASD in which it was hypothesized that improvements would be reported after participating in the exercise intervention. In addition to the primary objectives, we hoped to expand our understanding of exercise in relation to behavioural factors in that we expected to see improvements in problem behaviour

following the exercise intervention. Previous research has demonstrated that exercise can improve problem behaviour in children with ASD. Problem behaviour has also been shown to be associated with sleep problems in children with ASD, therefore, it could potentially affect the sleep results. The final objective was to explore the use of perceived exertion following an exercise intervention which has not been commonly used for children with ASD. The exploration of visual ratings of perceived exertion as a self-reported indicator of exercise intensity will be completed within the sample with a secondary purpose as a measure of fidelity for the interventions. This study was considered as pilot research as it tested the feasibility of the procedures, investigated the effect between exercise and sleep, and never intended to include a large sample.

Objectives & Hypotheses

Objectives of the Research

Primary Research Question:

1. What is the effectiveness of a 4-week exercise intervention on sleep behaviour in 6-10-year-old children with ASD compared to a control group?

Secondary Research Questions:

2. Does an exercise intervention affect problem behaviour in children with ASD?
3. Is a visual rating of perceived exertion scale a feasible method to determining relative intensity of exercise during an exercise intervention for children with ASD?

Specific Hypotheses of the Research

Hypothesis of Primary Objective:

1. The exercise intervention will result in improvements to the sleep behaviour of 6-10-year-old children with ASD in comparison to a control group.

Hypothesis of Secondary Objectives:

2. The exercise intervention will result in improvements to the problem behaviour of 6-10-year-old children with ASD.
3. The visual rating of perceived exertion scale will be a feasible tool to determine relative intensity of exercise for 6-10-year-old children with ASD.

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CHAPTER 2: LITERATURE REVIEW

Literature Review

Autism Spectrum Disorder

The Diagnostic and Statistical Manual of Mental Disorders – 5 (DSM-5) describes ASD as a neurodevelopmental disorder with challenges in social, communication, and behavioural skills (American Psychiatric Association, 2013). Every individual with ASD expresses the core symptoms differently which contributes to varying levels of functioning (American Psychiatric Association, 2013). In Canada, approximately, 1 in every 66 children are diagnosed with ASD and is more common in boys than girls (4 males:1 female) (Public Health Agency of Canada, 2018). In addition to the primary characteristics, children with ASD may also experience delays in motor skills, comorbidity of psychological and neuropsychiatric conditions, poor sleep or sleep disorders, medical conditions (e.g. epilepsy and gastrointestinal problems), and/or intellectual impairments (Bauman, 2010; Leyfer et al., 2006; Lloyd, MacDonald, & Lord, 2013; Matson, 2016).

Health risk factors, and the presence of comorbid conditions, can be accelerated or worsened with unhealthy lifestyle behaviours, especially a lifestyle with a lack of emphasis on physical activity (PA) and exercise as well as sleep (Itani, Jike, Watanabe, & Kaneita, 2017; Tremblay et al., 2016b). Some of these comorbid conditions may require medical and pharmacological intervention, although PA and exercise could be an affordable and easily accessible way to help manage some of the issues associated with the conditions such as poor sleep behaviour. The relationships between movement activities (PA, sleep, and sedentary behaviour) is well researched in individuals with typical development (TD) (Tremblay et al., 2016b); however, the movement activities are not as well understood in individuals with ASD. More specifically, we need to further understand the effects of

exercise on sleep behaviour in children with ASD (Wachob & Lorenzi, 2015). This literature review will synthesize evidence on the impact of exercise on sleep behaviour between children with TD and children with ASD in hopes of expanding our understanding of the relationship between these two movement activities within individuals with ASD.

Canada recently released a healthy movement guideline that describes the importance of obtaining appropriate levels of the movement activities within every 24-hour period (Tremblay et al., 2016b). These modes of activity include sedentary behaviour, light PA, moderate to vigorous PA, and sleep (Tremblay et al., 2016b). Research has shown that meeting the activity, but not meeting the sleep recommendations, is not as beneficial as being both physically active, and sleeping enough (Carson, Chaput, Janssen, & Tremblay, 2017a). Individuals with ASD can struggle to obtain optimal levels of both sleep and PA; therefore, more research is needed to further investigate the relationship between sleep and exercise in children with ASD.

Sleep in Children with Typical Development

Sleep is a naturally recurring and complex process which is ultimately organized and controlled by the body's primary biological clock called the suprachiasmatic nucleus (Borbély, 1999; Borbely, Daan, Wirz-Justice, & Deboer, 2016). This large group of nerve cells is located in the hypothalamus of the brain which governs the daily cycle known as the circadian rhythm or Process C (Borbély, 1999; Borbely et al., 2016). This repetitive 24-hour cycle is responsible for the coordination of external input (e.g. light or dark) and physiological changes associated with sleeping, waking and eating (e.g. metabolism, adjustments in body temperature, heart rate, blood pressure, brain activity, and hormones) (Borbely et al., 2016). Melatonin and cortisol are hormones that play vital roles in the

circadian rhythm. While the circadian rhythm, referred to as *Process C*, controls the timing of sleep, the homeostatic process, referred to as *Process S*, is the biochemical process that generates pressures to sleep (Borbély, 1999). These two processes were once thought to act independently but are now understood to have some interaction in regulating sleep (Borbely et al., 2016; Gruber, Carrey, Frappier, & Wise, 2014). The governing processes (Process C and S) regulate the sleep-wake cycle which describes the patterns of sleep and has been further categorized as two types of sleep; non-rapid eye movement sleep and rapid eye movement sleep (Colten & Altevogt, 2006). The two phases employ a cyclical pattern where the rapid eye movement phase occupies 20-28% of each cycle and the non-rapid eye movements consists of four stages that make up 72-80% of each cycle (Colten & Altevogt, 2006; Mindell & Owens, 2015). These phases repeat four to five times every 90-110 minutes, however, this changes slightly with age (Colten & Altevogt, 2006). Frequent interruptions to the sleep cycle leads to inadequate sleep and sleep insufficiency. Other factors such as stress, exercise, daily schedules or work, meal times and food intake may also influence sleep (Gruber et al., 2014).

Healthy sleep is associated with satisfaction, appropriate timing, adequate duration, high efficiency, and daytime alertness (Buysse, 2014). Children who experience poor quality or quantity of sleep experience negative effects on their cognitive and physical functioning (Gruber et al., 2014). More specifically, it can manifest to problems with memory, concentration, decision making, and mood regulation (Gruber et al., 2014; Mindell & Owens, 2015). Furthermore, inadequate sleep duration can interfere with neurohormonal and metabolic regulations (ex. decreased ghrelin and increased leptin or insulin resistance through increased production of cortisol) and is associated with increased

risk of being overweight or obese (Mindell & Owens, 2015). Therefore, exercise can help with these risk factors associated with insufficient sleep (ex. obesity). Severe disorders pertaining to sleep can be categorized as insomnia-related disorders, parasomnia-related disorders, hypersomnia-related disorders, sleep apnea disorders, circadian rhythm disorders, or sleep movement disorders (Gruber et al., 2014; Mindell & Owens, 2015; Reynolds & Malow, 2011; Richdale & Schreck, 2009; Verster, Pandi-Perumal, & Streiner, 2008). Insomnia-related sleep disorders are described by problems with initiating and maintaining sleep and are the most commonly reported sleep problems in individuals with ASD (Reynolds & Malow, 2011; Richdale, 1999; Verster et al., 2008). Behaviour-related sleep problems includes, but is not limited to, bedtime resistance, difficulty falling asleep, getting enough sleep, waking up during the night, waking up too early, and/or feeling unrested or experiencing daytime sleepiness (Owens, Spirito, & McGuinn, 2000), which was the focus of the current study, specifically in children with ASD.

The recommended hours of uninterrupted sleep for children between the ages of 5 and 13 years is 9-11 hours while 8-10 hours per night is recommended for 14-17-year-olds (Tremblay et al., 2016b). In a survey with 24, 896 Canadian children between the ages of 10-17 years old, approximately 70% were meeting the recommended guidelines every week (Chaput & Janssen, 2016). However, as participant age increased, shorter sleep durations were reported. Additionally, later bedtimes were reported by the older age groups (14-17-year-olds), yet they woke up at similar times as the younger age groups (10-13-year-olds) (Chaput & Janssen, 2016). The age of the participants should be considered since biological changes in sleep occur as children reach adolescence which naturally leads to later bedtimes (Mindell & Owens, 2015). Differences were also observed between the

weekdays and weekend in which sleep duration increased by approximately one hour on weekends in all age groups although the participants usually went to bed and woke up later (Chaput & Janssen, 2016). It was estimated that 28% of the participants in this sample were not meeting the appropriate sleep duration recommendations for their age especially throughout the week (Chaput & Janssen, 2016). More attention should be directed to the factors contributing to sleep behaviour in children, especially in children with ASD.

A systematic review by Chaput et al. (2016) focused on sleep duration in relation to the following health components in children and youth between the ages of 5-17 years; they specifically looked at adiposity, mental health, cognition, quality of life, injury, and cardio-metabolic biomarkers. A total of 141 studies were included, the majority of which used subjective measures of sleep duration while the remaining studies used objective measures or a combination of self-report and objective measures. Of these studies, 71 focused on the association between adiposity markers and sleep duration (Chaput et al., 2016). Similar findings were demonstrated across most studies (58 studies of 71) in which a significant association between shorter sleep duration and excess adiposity was reported. Additionally, sleep duration within the nationally recommended ranges (8-11 hours) was associated with better emotional regulation in 49 of the 62 studies (Chaput et al., 2016; Tremblay et al., 2016b). Other studies within the systematic review reported negative affects on academic performance, quality of life and injury with shorter sleep duration (Chaput et al., 2016).

Another study by Stein, Mendelsohn, Obermeyer, Amromin, and Benca (2001) surveyed the prevalence of sleep problems in 472 children between ages of 4-12 years by asking parents to complete the Sleep Behaviour Questionnaire, Health and the Family

Information, and the Child Behavior Checklist. The results demonstrated that 10.8% of the participants had had a sleep problem for longer than 2 weeks in the past 6 months. These problems were most commonly described by tiredness during the day, snoring, taking more than 30 minutes to fall asleep, waking frequently, grinding teeth, talking during sleep, and having too much energy to sleep (Stein et al., 2001). Based on the reported symptoms, parasomnia-related factors (25%) had the largest impact on overall sleep problems, whereas insomnia-related factors had the lowest impact (7.1%). These sleep disorders were strongly predicted by the Child Behavior Checklist scores, specifically, the thought problems, attention problems, social problems, somatic complaints, and anxious/depressed subscale scores (Stein et al., 2001). Children with symptoms of anxiety or attention and social difficulties were more likely to experience sleep disruption in addition to having trouble falling and staying sleep (Stein et al., 2001). Therefore, sleep quality and quantity play a key role in the overall health and development in children, yet they are often not getting enough of either. These relationships need further exploration in individuals with ASD as the prevalence of some of these sleep problems are higher and behavioural challenges can exacerbate sleep problems.

Sleep in Children with ASD

Children with ASD experience more problems with sleep compared to children with TD, and children with other developmental disorders (Krakowiak, Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008; Richdale & Prior, 1995; Souders et al., 2009). Approximately, 44-83% of children with ASD have poor sleep habits compared to 27% of children with TD (Richdale & Prior, 1995). Using questionnaires and sleep logs, Richdale and Prior (1995), compared three groups of children based on severity of diagnosis;

children with low-functioning ASD, high-functioning ASD, and children with TD. The group of children with high functioning ASD group experienced more disturbed sleep than the children with low-functioning ASD and children with TD, although both ASD groups still demonstrated more sleep problems than the controls (Richdale & Prior, 1995). More specifically, children with ASD experienced higher rates of delayed sleep onset, bedtime resistance, increased waking after sleep onset (WASO), daytime sleepiness, and early waking (Richdale & Prior, 1995; Richdale & Schreck, 2009). Richdale and Prior (1995) were one of the first to explore the prevalence of poor sleep in children with ASD indicating further attention was needed to understand the problem within individuals with ASD.

Wiggs and Stores (2004) presented similar findings to Richdale and Prior (1995) using questionnaires, sleep diaries, and actigraphy with 69 families of children with ASD. Parents reported that 83% of the children had sleep problems in the past, compared to 67% that had current problems (Wiggs & Stores, 2004). They further explored the frequency of underlying disorders causing sleeplessness and categorized the problems into behavioural sleep problems, circadian sleep-wake problems, anxiety-associated sleep disorder and unclassified sleeplessness (Wiggs & Stores, 2004). The researchers found that behavioural sleep issues such as, refusing to go to bed and feelings of sleeplessness, were the most frequent parent-reported symptoms of the sleep disorders (Wiggs & Stores, 2004). This study incorporated subjective and objective assessments of sleep and categorized the disorders based on their symptoms. These results were also consistent with Liu, Hubbard, Fabes, and Adam (2006) who recruited 167 participants with ASD between the ages of 2-18 years. Using a modified version of the Children's Sleep Habits Questionnaire, they found that 86% of children had at least one sleep problem, the most common being,

bedtime resistance (53.6%), insomnia (56.3%), and parasomnia (53.3%). After stratifying the groups by age, they found that younger age was significantly correlated with an increased risk for parasomnia. Furthermore, significant correlations were found between the sleep problems and the following factors; hypersensitivity, gastrointestinal problems, asthma, epilepsy, and allergies (Liu et al., 2006). Williams, Sears, and Allard (2004) asked parents of children with ASD between the ages of 2-16 years, a series of questions regarding the length of sleep and the specific symptoms relating to their child's sleep problems. The parents reported the most frequent sleep problems to be difficulty falling asleep, restless sleep, unwillingness to fall asleep in own bed, frequent night wakings, and difficulty arousing, while sleepwalking, morning headaches, crying during sleep, apnea, and nightmares were the least reported issues (Williams et al., 2004). Of the 210 participants, 70% were getting over eight hours of sleep and the remaining children were only getting six to seven hours (20%) and four to five hours (10%) (Williams et al., 2004). The studies presented above identify some of the common sleep problems and disorders presented in ASD, therefore, prompt intervention is necessary to alleviate these challenges.

Unlike individuals with TD, sleep problems often persist into adulthood for individuals with ASD (Goldman, Richdale, Clemons, & Malow, 2012; Hodge, Carollo, Lewin, Hoffman, & Sweeney, 2014). This was demonstrated in a study conducted by Hodge et al. (2014), who examined sleep across different ages in more than 200 children with ASD and TD. The mothers were asked to complete the 2nd edition of the Gilliam Autism Rating Scale as well as the Children's Sleep Habits Questionnaire which suggested that poor sleep habits were more likely to continue into adolescence in children with ASD than their peers with TD (Hodge et al., 2014). Furthermore, the sleep difficulties decreased

from 72% to 37.5% in children with TD based on the averages of the different age groups, however, the problems increased from 84% to 87.5% between the different age groups in children with ASD (Hodge et al., 2014). Therefore, sleep problems such as bedtime resistance, daytime sleepiness, and night wakings are more likely to continue into adulthood in individuals with ASD, whereas these problems subside in individuals with TD (Hodge et al., 2014). This study examined the sleep habits across different age groups discovering that sleep problems do not diminish with age implicating a need for further investigation of management strategies for individuals with ASD.

Sleep problems can also contribute to a lower subjective health-related quality of life in children with ASD (Delahaye et al., 2014). Delahaye et al. (2014) recruited 86 participants with ASD between the ages of 4-12 years to assess health-related quality of life, sleep, behaviour problems, autism severity, and cognitive ability. The participants scored significantly lower than the sample of children with TD across all subscale scores and the total score on the Children's Sleep Habits Questionnaire and the Pediatric Quality of Life Inventory (Delahaye et al., 2014). The total scores of these two assessments also presented significant negative correlations within the participants with ASD (Delahaye et al., 2014). The results indicated that the participants with insufficient amounts of sleep or feelings of anxiety in regards to sleep were more likely to exhibit a lower health related quality of life (Delahaye et al., 2014). Lack of sleep becomes familiar to the parents and caregivers as well because they are often up with the children when they are not sleeping (Meltzer, 2008), which can lead to heightened stress and a lower quality of life within the parents and caregivers (Meltzer & Mindell, 2007; Vasilopoulou & Nisbet, 2016). Overall, sleep problems can be associated with a lower quality of life in children with ASD and

their families, emphasizing the need for intervention to manage these issues and in turn, improving health related quality of life.

There are a number of potential factors that contribute to sleep problems within individuals with ASD (Reynolds & Malow, 2011). Firstly, biological factors may have an influence on sleep problems, specifically, circadian rhythm and clock gene abnormalities as well as abnormal melatonin secretions (Richdale & Schreck, 2009). Psychological factors such as anxiety and mood disorders often co-occur in individuals with ASD and can cause disruptions in sleep (Leyfer et al., 2006; Mazurek & Petroski, 2015; Simonoff et al., 2008). Sleep problems in children with ASD may also be caused by environmental factors including, bedtime routines and family-related influences (parental stress, family lifestyle and/or well-being) (Richdale & Schreck, 2009). Additionally, medical and neurodevelopmental conditions such as, epilepsy, attention deficit hyperactive disorder, and/or gastrointestinal issues can impact sleep (Reynolds & Malow, 2011; Veatch, Maxwell-Horn, & Malow, 2015). Lastly, ASD specific characteristics may also be associated with sleep disturbances including hypersensitivities, adaptive behaviour problems, repetitive behaviours, and challenges with communication and social skills (Goldman et al., 2011; Hollway & Aman, 2011; Reynolds & Malow, 2011; Richdale & Schreck, 2009). While some of these potential contributors to sleep problems have been addressed with behavioural management strategies (e.g. sleep hygiene) (Reynolds & Malow, 2011) and medication (Andersen, Kaczmarska, McGrew, & Malow, 2008), there has been very little research on exercise as an approach to manage sleep challenges in children with ASD. Children with ASD have high rates of comorbid conditions, many of which are supported with medication (Lake et al., 2017); however, certain medications can

have an affect on sleep. Approximately 5% of 4749 children with ASD between the ages of 2-11 years were estimated to be taking antipsychotic medication, but medication use or polypharmacy is more common in older individuals with ASD (Benson et al., 2018; Lake et al., 2017). Many stimulants, anticonvulsants, and antidepressants can negatively affect sleep (Benson et al., 2018; Liu et al., 2006; Mayes & Calhoun, 2009), therefore, medication should be considered when conducting research about sleep in children with ASD.

In summary, more than half of children with ASD experience sleep problems, most of which are related to difficulties with sleep onset and sleep maintenance (Richdale & Prior, 1995). These sleep disturbances are more likely to persist into adulthood than their peers with TD, therefore, early intervention is important to manage these symptoms and prevent the negative affects of sleep deprivation (Hodge et al., 2014). Behavioural challenges, biological factors as well as psychiatric, neurodevelopmental, and medical conditions are suggested to be potential aetiologies of sleep problems in individuals with ASD. Overall, more investigation on the effects of PA and exercise on sleep in children with ASD is warranted as a potential non-pharmacological and feasible management strategy.

Activity Levels and Exercise in Children with Typical Development

PA is described as any movement of the skeletal muscle system that requires energy expenditure in which there are multiple groupings including activities of daily living, active play, sport and exercise, as well as fitness training (Caspersen, Powell, & Christenson, 1985; Longmuir, Colley, Wherley, & Tremblay, 2014; World Health Organization, 2010). Exercise is a sub-category of PA that refers to the intentional and organized participation in PA to improve fitness and/or health (Caspersen et al., 1985; World Health Organization,

2010). Intensity of PA is commonly measured by metabolic equivalents or heart rate, but subjective measures such as a rating of perceived exertion scale can also be used. Different metabolic demands, also known as the metabolic equivalent (MET), are associated with varying intensities of PA including light, moderate and vigorous PA (Butte et al., 2018). Light PA is an exertion between one to three METs, moderate PA is an intensity of approximately three to six METs, and vigorous PA is an intensity above six METs. Common light physical activities include walking slowly, washing dishes, preparing food, arts and crafts, board games, playing instruments, and darts or croquet. Moderate activities usually consist of walking, cleaning, mowing the lawn, dancing, and recreational sport participation (e.g. basketball, badminton, or volleyball). Competitive sport participation (soccer, basketball, and/or volleyball game), bicycling, swimming, skiing, shoveling, jogging, running, and hiking are generally considered vigorous physical activities. Children around the world are consistently demonstrating low levels of participation in PA with less than 20% of children meeting all 24-hour movement recommendations with these patterns likely carrying into adolescence and adulthood (Carson et al., 2017a). In contrast, sedentary behaviour is commonly described as “screen time” and there is concern for the increasing sedentary behaviours demonstrated in children (Must et al., 2014). It is important to maintain a physically active lifestyle with a combination of light and moderate to vigorous activity, therefore, more emphasis should be placed on exercise in children.

Participation in PA and exercise is important for the physical and psychological health in all individuals (Longmuir et al., 2014). More specifically, PA can positively impact cholesterol and blood lipids, blood pressure, obesity, metabolic syndrome, depression, and bone density (Carson et al., 2017b; Janssen & Leblanc, 2010). That being

said, participation in PA has potential risks (e.g. injury), but it is far outweighed by the benefits (Longmuir et al., 2014). Colley et al. (2017) evaluated the adherence to the moderate to vigorous PA recommendations in 5,608 Canadian children, between the ages of 6-17 years and found that between 2007 and 2015 participation levels have not shown drastic change. On average, it was reported that younger children (6-11) were more active than the older children (12-17) (Colley et al., 2017). Approximately, 9% of children and youth participate in 60 minutes of moderate to vigorous PA everyday of the week compared to 70% once per week (Colley et al., 2017). On a global scale, PA has been rated as poor in children and youth in Canada demonstrating one of the lowest scores in the world (Tremblay et al., 2016a), therefore, immediate attention should be provided to the current rates of participation in PA and exercise as physical inactivity is a major contributor to chronic disease (Booth, Roberts, & Laye, 2012).

Activity Levels and Exercise in Children with ASD

Participation in PA and exercise as well as the outcomes following participation can differ in children with ASD from children with TD. For example, MacDonald, Esposito, and Ulrich (2011) found that children with ASD engage in less PA than their peers with TD and this worsens with age. Similarly, Tyler, MacDonald, and Menear (2014) compared the PA and fitness levels between children with TD and children with ASD. After a series of physical assessments, the results showed that children with ASD had lower strength and spent less time in light and moderate to vigorous PA (Tyler et al., 2014). Additionally, they spent more time in sedentary activities than children without ASD (Tyler et al., 2014). Interestingly, Bandini et al. (2013) found that both groups of children (TD and ASD) were not meeting the national recommendations of 60 minutes of moderate to

vigorous PA per day, but children with ASD participated in slightly less PA in addition to fewer types of activities than children with TD. A recent study by Case, Ross, and Yun (2020) compared the activity levels of 3010 children with ASD, cerebral palsy, Down syndrome, developmental disability, and intellectual disability between the ages of 6-17 years. The results were consistent with other research that suggests the children were not meeting the national guidelines with all groups of children under 20%; the participants with ASD demonstrated the lowest participation rates of 14% (Case et al., 2020).

The studies previously mentioned compared PA levels between children with ASD, TD, and other developmental disabilities; Pan and Frey (2006) observed the differences between PA patterns and age in 30 children and adolescents with ASD. The participants were stratified into three groups based on age (elementary, middle and high school), and were asked to complete the Child/Adolescent Activity Log questionnaire with parent assistance and wear accelerometers for at least eight hours for seven days (Pan & Frey, 2006). The accelerometer data was categorized into minutes spent in light, moderate, and vigorous PA as well as the time of day and week (Pan & Frey, 2006). The results demonstrated that 78% of elementary school participants, 67% of middle school participants, and 0.08% of high school participants obtained 60 minutes of moderate to vigorous PA (Pan & Frey, 2006). Data was also analyzed based on the duration spent in moderate to vigorous PA (5-, 10- and 20-minute bouts), and they found that elementary participants took part in higher intensity PA more often in all intervals and for longer periods of time than the older participants (Pan & Frey, 2006). Furthermore, the participants most commonly reported walking as their method of PA on the questionnaire followed by martial arts, weightlifting, swimming, skating, and running (Pan & Frey,

2006). Overall, participation in moderate to vigorous PA and the duration of participation declined as the individuals got older; however, all groups of children were not meeting the recommended duration and frequency (20-minute bouts three times per week) of higher intensity PA (Pan & Frey, 2006). This study provides insight on the patterns and choice of PA as children with ASD reach adolescence which emphasizes the need for exercise interventions in youth.

Children with ASD also demonstrate higher levels of sedentary behaviour than their peers with TD (Must, Phillips, Curtin, & Bandini, 2015). For example, a study conducted by Must et al. (2014) aimed to compare body mass index with sedentary behaviour between children with ASD and children with TD. They categorized sedentary behaviour based on the type of activity (TV, computer, video games, car time, crafts/board games, and reading) and found that the children with ASD spent most of their time watching TV and this behaviour was more frequent on weekends (Must et al., 2014). Also, the total time spent in sedentary behaviour was higher in children with ASD than children with TD and this continued with increasing age (Must et al., 2014). Lastly, there was a significant correlation between higher body mass index and higher sedentary behaviour demonstrated on the weekends in the ASD group (Must et al., 2014). Since children with ASD are more likely to maintain a sedentary lifestyle, there is a need for intervention to encourage healthy behaviour and lifestyle (Must et al., 2014). It is important to understand sedentary behaviour in individuals with ASD as it could potentially be a factor that impacts sleep behaviour; future studies that examine patterns of sedentary behaviour should consider the relationship to sleep.

The lower levels of participation in PA and exercise is problematic as there are a number of benefits associated with increased participation in PA and exercise specifically, for children with ASD including; improvements in motor skills, decreases in negative stereotypical and self-stimulatory behaviours, improvements in social skills, and positive influences on mental illness and psychiatric symptoms (Lang et al., 2010; Sowa & Meulenbroek, 2012). Other findings suggest exercise was beneficial for physical fitness, on-task behaviour, academic performance, and quality of life (Bedard, St John, Bremer, Graham, & Cairney, 2019; Bremer, Crozier, & Lloyd, 2016; Lang et al., 2010; Toscano, Carvalho, & Ferreira, 2018). For example, a 48-week PA program was initiated by Toscano et al. (2018) to evaluate the effects on the metabolic profile, quality of life, and characteristics of ASD. Participants in the intervention group that attended 90% of the sessions were included in the analysis and positive changes were observed across all measures (Toscano et al., 2018). More specifically, the parent-perceived quality of life improved significantly more in the intervention group compared to the control group (Toscano et al., 2018) which suggests that regular participation in exercise can lead to improved quality of life in children with ASD.

Many of the comorbid conditions or challenges associated with ASD can interfere or cause the children with ASD to experience difficulty with initiating or maintaining sleep. Often times, PA and exercise can positively impact some of the difficulties individuals with ASD experience. For instance, psychiatric conditions or symptoms, stereotypical or self-stimulatory behaviours, as well as off-task and maladaptive behaviours can have a negative affect on sleep behaviours in children with ASD, however, exercise positively influences many of these variables (Lang et al., 2010). Therefore, exercise may indirectly affect sleep

by reducing the symptoms which often contribute to sleep problems in addition to the direct changes in sleep from exercise.

Activity Levels, Exercise and Sleep in Children with Typical Development

A positive cyclical relationship between PA and sleep in children and youth with TD has been demonstrated in multiple studies (Baldursdottir, Taehtinen, Sigfusdottir, Krettek, & Valdimarsdottir, 2017; Dolezal, Neufeld, Boland, Martin, & Cooper, 2017; Kline, 2014; Nixon et al., 2009). For example, Baldursdottir et al. (2017) examined the impact of an exercise intervention on sleep quality in youth by using pedometers and communication devices to promote activity for a three-week period and compared the results to a control group. They found that the intervention group demonstrated higher step-count than the controls and sleep quality improved over time, whereas the control group showed a decline in subjective sleep quality (Baldursdottir et al., 2017). In other words, those that attained higher step counts also demonstrated improved quality of sleep (Baldursdottir et al., 2017). They found the intervention was effective in adjusting self-reported sleep quality, but also noted that higher intensity activity should be explored to test larger effects on sleep within individuals with ASD.

A follow-up study, Nixon et al. (2009) focused on sleep latency (difference between the time in bed and the time of sleep onset) in relation to daytime activity levels in 591 children. Mothers were initially recruited following the birth of their child, upon which they agreed to complete three questionnaires in addition to their child wearing an accelerometer for 24 hours once their child reached the age of 7 (Nixon et al., 2009). Overall, 16% of parents reported that their children had difficulties falling asleep (Nixon et al., 2009). The accelerometer data showed that the children who spent more time in

vigorous PA had shorter sleep latency, whereas those who spent more time in sedentary activity had longer sleep latency (Nixon et al., 2009). These findings demonstrate the importance of PA and exercise to enable children to fall asleep quicker; however, it is not well understood in individuals with ASD.

Another study by Stone, Stevens, and Faulkner (2013) investigated the difference between weekday and weekend sleep duration and the impact on PA in 856 children between the ages of 10-12 years. The results showed that children who slept fewer hours on weekdays had lower total activity in addition to lower moderate to vigorous PA and overall intensity compared to children getting more sleep, whereas mixed results were demonstrated on the weekend (Stone et al., 2013). PA levels were still lower in children who slept fewer hours throughout the week and more on the weekend compared to children that demonstrated a consistent schedule and slept more hours throughout the entire week (Stone et al., 2013). Therefore, getting consistent and adequate amounts of sleep is predictive of participation in PA with varying intensities.

Furthermore, a study by Lang et al. (2013) explored the relationship between sleep and PA in 37 adolescents with TD between the ages of 16-25 years. They employed the use of subjective and objective measures including, the International Physical Activity Questionnaire, the Pittsburgh Sleep Quality Index, the Insomnia Severity Index, an accelerometer, and a sleep electroencephalogram (Lang et al., 2013). The general findings suggested that the individuals who had higher PA levels presented better sleep (Lang et al., 2013). The research team also compared gender and found that females participated in less PA and reported more sleep complaints than males (Lang et al., 2013). Additionally, more active individuals, according to self-reported measures, experienced longer sleep duration,

less WASO, fewer insomnia-related symptoms, and greater sleep quality (Lang et al., 2013). Overall, children with TD demonstrate a bidirectional relationship between PA and sleep, however, further exploration of this relationship in children with ASD is needed.

Activity Levels, Exercise and Sleep in Individuals with ASD

Few experimental studies exist to show whether exercise interventions have an impact on sleep in children with ASD; nevertheless, positive results have already been demonstrated in the research that does exist. For example, Benson et al. (2018) recruited 15 adult participants between the ages of 18-27 years to understand the relationship between PA and sleep within adults with ASD. Ten of the participants were previously taking medication for psychiatric conditions that had a known effect on sleep (drowsiness and insomnia). The following measurements were used in the study; Godin-Shepard Leisure-Time Physical Activity Questionnaire, Pittsburgh Sleep Quality Index, STOP-Bang sleep apnea risk assessment questionnaire, Karolinska Sleepiness Scale, and actigraphy. The results were compared to 17 controls with TD where they discovered sleep onset latency was significantly longer in individuals with ASD and the adults with ASD also went to bed significantly earlier than adults with TD (Benson et al., 2018). Furthermore, the adults with TD spent more time in moderate to vigorous PA in comparison to only six participants from the ASD group that were meeting the American College of Sports Medicine PA recommendations. Overall, they found that there was a significant correlation between earlier bedtime and wake time with more moderate to vigorous PA minutes. Improved sleep behaviours such as, fewer wakings after sleep onset (WASO) and higher sleep efficiency (percentage of time spent asleep by time spent in bed), had a positive influence on participation in higher intensity PA the following day (Benson

et al., 2018). Therefore, individuals participating in more exercise may feel more tired and go to bed earlier, while those experiencing improvements in sleep behaviour are more likely to participate in exercise the following day (Benson et al., 2018). This is representative of a bidirectional relationship between sleep and PA in adults with ASD which should be further explored in children with ASD.

The first study that investigated whether PA has an influence on sleep quality in children with ASD was completed by Wachob and Lorenzi (2015). The participants were between the ages of 9-16 years and wore accelerometers for seven days to observe time spent in sedentary and moderate to vigorous PA as well as sleep efficiency and WASO. Additionally, the parents completed the Children's Sleep Habits Questionnaire along with a sleep log. The results revealed that older participants were significantly more sedentary and demonstrated more WASO which they found to be consistent with previous research with children with ASD (Wachob & Lorenzi, 2015). It was noted that four of the ten participants were taking medication to manage sleep and more than half the participants scored higher than 41 on the Children's Sleep Habits Questionnaire indicating poor sleep habits. Significant relationships were found between average time spent in moderate to vigorous PA (%) and average WASO time where more time in PA was associated with decreased waking time (Wachob & Lorenzi, 2015). Furthermore, it was reported that higher sedentary time was significantly correlated with lower sleep efficiency. This was the first study to examine the relationship in a small sample of children with ASD which demonstrated positive findings, although more investigation is warranted, particularly on the effects between exercise and sleep.

Impact of Exercise Interventions on Sleep in ASD

There is research to suggest that children with ASD experience a bidirectional relationship between exercise and sleep, however, it is preliminary and we must first understand the effects under unidirectional circumstances. Three studies were identified which examined the effect of exercise on sleep in children with ASD. The first study piloted an aquatic exercise intervention to examine the effects on sleep behaviours in eight, 6-11 year-old children with ASD (Oriel, Kanupka, DeLong, & Noel, 2016). The Children's Sleep Habits Questionnaire was used to measure the sleeping habits at baseline prior to the four-week intervention (Oriel et al., 2016). The design of the study ensured that exercise was the controlling factor for change in sleep behaviour because baseline testing was conducted for four weeks (phase A1), followed by the intervention (phase B – two 60-minute sessions per week for four weeks) with additional observation for four weeks under controlled conditions (phase A2) (Oriel et al., 2016). Sleep outcomes were collected through parent report and included total sleep, sleep latency, and night wakings (Oriel et al., 2016). Significant differences in total sleep (A1=493.59 minutes, B=576.91 minutes, and A2 =549.05 minutes) and sleep latency (A1=38.95 minutes, B=21.76 minutes, and A2=25.91) were demonstrated between the initial control phase and the intervention (A1 and B; $p<0.001$ for total sleep and sleep latency) as well as between both control phases (A1 and A2; $p<0.001$ for total sleep and $p<0.004$ for sleep latency) (Oriel et al., 2016). The exercise was confirmed as moderate PA through heart rate pulse oximetry measures throughout the study (Oriel et al., 2016). This study demonstrated promising results of increased participation in exercise that lead to improved sleep in children with ASD. However, the small sample size, extraneous variables (ex. participant activity level or bedroom environment), and the use of subjective measures were presented as limitations

of the study (Oriel et al., 2016). Furthermore, familial reflection on the intervention in addition to the restrictions of swim programs (ex. cost and availability of programs within the community or proximity to a swim facility) could be considered as gaps that should be addressed in future research.

A study by Mische Lawson and Little (2017) assessed the feasibility and effectiveness of an eight-week swimming intervention on sleep behaviours in children between the ages of 5-13 years with ASD. The Sensory Enhanced Aquatics intervention provided modifications based on the specific needs and sensitivities of the children (Mische Lawson & Little, 2017). Parents completed a number of questionnaires at baseline and post-intervention including the Social Responsiveness Scale, the Sensory Profile Caregiver Scale and the Children's Sleep Habits Questionnaire (Mische Lawson & Little, 2017). Each of the ten boys received eight 30-minute private lessons focused on swim skill development and safety (Mische Lawson & Little, 2017). The results showed that all participants had sleep disturbances prior to the intervention and 40% (n=4) of the participants showed improvements following the intervention; however, 50% (n=5) experienced more sleep disturbance (Mische Lawson & Little, 2017). With further analysis, they found that the sensory profiles, age, and attendance record of the individual children that did not respond to the intervention may have contributed to the degree of sleep response following the intervention (Mische Lawson & Little, 2017). This study addressed the feasibility and acceptability of the swimming intervention in which most parents were very satisfied, however, the study also had a number of limitations. The lack of assessment of participant activity level, the low intervention dosage, and the small sample size were considered to

be gaps that future research should explore. Additionally, different modes of exercise and its effects on sleep behaviour in children with ASD should be investigated.

Brand, Jossen, Holsboer-Trachsler, Puhse, and Gerber (2015) evaluated ten children between the ages of 7-13 years with ASD before and after an aerobic and motor skill training intervention. Each session consisted of 30 minutes of cycling and 30 minutes of coordination and object control skills, which occurred three times per week for three weeks. A sleep-encephalography device was applied before, throughout and after the 3-week intervention period to assess sleep duration, sleep onset latency, sleep efficiency, sleep stages, rapid eye movement sleep, and WASO (Brand et al., 2015). In addition, the Insomnia Severity Index, a custom questionnaire, and mood log were completed by parents. Brand et al. (2015) found medium to large effect sizes for increased sleep efficiency as well as decreased WASO and sleep onset latency on nights following PA. Subjective measures of sleep quality and mood also improved over time (Brand et al., 2015). As with all research, this study had limitations that future research should consider including a small sample size and short intervention length (three weeks). Furthermore, the variability within the intervention prohibits the distinction of whether the aerobic exercise, motor skill training or the combination led to the favourable effect(s) on sleep. It would have also been valuable to compare the participants to a control group which is suggested for future research. To our knowledge, this is the only study to look at the effects of a land-based exercise intervention on sleep behaviour in children with ASD, however, future research should consider alternative modes of exercise.

Conclusion

In Canada, recommendations for each movement behaviour has been provided in reference to every 24-hour period which signifies the lack of adherence to the suggested levels in the previous guideline and ultimately, could lead to poor physiological and psychological health. It has been recognized that individuals with ASD often experience poorer sleep behaviour and demonstrate lower levels of participation in PA compared to their peers with TD. Furthermore, children with TD demonstrate a positive bidirectional relationship between participation in PA and sleep behaviour, however, the relationship is not well understood in individuals with ASD. Promising results have been demonstrated to suggest that regular participation in PA and exercise can lead to improved sleep behaviour in children with ASD, but further exploration is needed to better understand this effect.

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CHAPTER 3: MANUSCRIPT

Abstract

Introduction: More than half of children with Autism Spectrum Disorder (ASD) experience sleep challenges. Children with ASD also present low levels of participation in physical activity (PA) and exercise. The objective of the study was to explore the effectiveness of an exercise intervention on sleep behaviour in children with ASD in addition to determining the effect of exercise on problem behaviour and the feasibility of a rating of perceived exertion scale. **Methods:** Five children with ASD between the ages of 6-10 were assigned to an experimental (exercise intervention) or control (arts and crafts intervention) group. The children participated in the interventions two times per week for four weeks. Subjective measures of sleep, behaviour, and PA were collected at pre- and post-test in addition to a rating of perceived exertion (RPE) scale which was used at the end of each session. **Results:** Four out of five participants had problematic sleep scores at baseline. The experimental group demonstrated improvements on all sleep measures at the post-test. A significant improvement was reported on the Sleep Disturbance Parent Proxy questionnaire from pre- to post-test ($p=0.02$) and in comparison to the control group ($p=0.03$). Problem behaviour improved in both groups at the post-test, however, the experimental demonstrated a greater improvement. The average RPE was within the moderate to vigorous range for the experimental group and very light to light range for the control group. **Conclusion:** The exercise intervention was shown to be effective at improving sleep behaviour for the participants in the experimental group, however, research with larger samples is needed. Additionally, problem behaviour improved more in the experimental group and the mean ratings from the RPE scale fell within the expected ranges for each group demonstrating feasibility in this population.

Introduction

Autism Spectrum Disorder

The Diagnostic and Statistical Manual of Mental Disorders describes the primary characteristics of Autism Spectrum Disorder (ASD) as persistent challenges with social skills, communication, as well as restricted and/or repetitive patterns of behaviour (American Psychiatric Association, 2013). Approximately 1-2% (1 in every 66 children) of Canadian children and youth have ASD with more cases in males than females (American Psychiatric Association, 2013; Public Health Agency of Canada, 2018). The diagnosis is based on challenges with the social, communication, and behavioural domains; however, it is not uncommon for other areas of development to also present challenges (Leyfer et al., 2006; Lloyd, MacDonald, & Lord, 2013; Matson, 2016). Every individual with ASD expresses these characteristics in different ways which contributes to the varying levels of functioning within individuals with ASD. In addition to the core characteristics of ASD, children with ASD often experience problems with their sleep and engage in low levels of physical activity (PA) and exercise (Case, Ross, & Yun, 2020; Richdale & Prior, 1995; Stanish et al., 2017). Individuals with typical development (TD) demonstrate a positive bidirectional relationship between sleep and exercise when optimal levels of each are achieved, but this relationship is not well understood in individuals with ASD (Kline, 2014; Lin et al., 2018; Stone, Stevens, & Faulkner, 2013).

Behavioural Sleep Problems

Sleep is a reversible behavioural state of alternative consciousness that is typically described by postural recumbence, closed eyes, and reduced movement (Carskadon & Dement, 2011; Mindell & Owens, 2015). Furthermore, sleep is regulated by complex

interactions between physiological and behavioural processes and is essential for its involvement in almost all bodily systems and functions (Carskadon & Dement, 2011; Mindell & Owens, 2015). It is recommended that children between the ages of 5-13 years sleep 9-11 hours per night (Tremblay et al., 2016) since chronic sleep loss can have a negative effect on physical and mental health, daytime functioning, and overall quality of life (Chaput et al., 2016; Mindell & Owens, 2015). More specifically, adiposity, memory, cognition, emotional regulation, and academic functioning could be compromised as a result of consistent sleep insufficiency (Baum et al., 2014; Chaput et al., 2016; Vriend et al., 2013). Approximately 10% of children with TD experience sleep challenges (Stein, Mendelsohn, Obermeyer, Amromin, & Benca, 2001), but sleep problems are more prominent in children with ASD, therefore, improving sleep should be prioritized in children with ASD who experience problematic sleep behaviour.

Sleep problems are more common in children with ASD than children with TD and other developmental disabilities, affecting approximately 44-83% of the population (Hodge, Carollo, Lewin, Hoffman, & Sweeney, 2014; Krakowiak, Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008; Richdale & Prior, 1995). When sleep challenges occur in children with ASD it can also have a negative impact on parental and familial sleep, stress, and well-being (Richdale & Schreck, 2009; Wiggs & Stores, 2004). The underlying cause of sleep difficulties within individuals with ASD is thought to be a combination of behavioural, biological, environmental, and medical factors (Cohen, Conduit, Lockley, Rajaratnam, & Cornish, 2014; Krakowiak et al., 2008; Richdale & Schreck, 2009). Sleep challenges have been shown to be predictive of problem behaviour and symptom severity in ASD (e.g. stereotypical behaviour), but recent studies suggest that the relationship

between these two variables is bidirectional (Adams, Matson, Cervantes, & Goldin, 2014a; Adams, Matson, & Jang, 2014b; Hollway, Aman, & Butter, 2013; Mayes & Calhoun, 2009; Schreck, Mulick, & Smith, 2004). Traditionally, the initial approach to manage problematic sleep in children with ASD is behavioural modification such as changes in sleep hygiene (ex. bedroom temperature or reducing the use of electronic devices before bed), followed by pharmacological intervention (Cortesi, Giannotti, Ivanenko, & Johnson, 2010; Veatch, Maxwell-Horn, & Malow, 2015). Exercise could be an enjoyable, feasible, and non-pharmacological method to managing sleep problems within individuals with ASD. It is well documented that children with ASD experience difficulty with their sleep, however, further investigation is needed on the effect of exercise on sleep behaviour for individuals with ASD.

Participation in Exercise

Regular exercise has numerous benefits that contribute to improved physical and mental health in all individuals (Carson, Chaput, Janssen, & Tremblay, 2017). The Canadian 24-hour Movement Guidelines recommend one hour of moderate to vigorous PA and several hours of light PA per day for 5-17-year-old children and youth (Tremblay et al., 2016). A large proportion of children between the ages of 5-17 are not meeting the current guidelines (Tremblay, 2018), however, children with ASD demonstrate even lower participation in exercise and PA than children with TD and other developmental disabilities (Bandini et al., 2013; Case et al., 2020; Stanish et al., 2017; Tyler, MacDonald, & Menear, 2014). Studies have shown that exercise leads to improved metabolic markers (ex. cholesterol), physical fitness, and motor performance in children with ASD (Healy, Nacario, Braithwaite, & Hopper, 2018; Sowa & Meulenbroek, 2012; Toscano, Carvalho,

& Ferreira, 2018). Additionally, PA positively influences some of the core challenges experienced by children with ASD such as social functioning, and in some cases, stereotypical behaviour, and aggression (Bremer, Crozier, & Lloyd, 2016; Healy et al., 2018; Lang et al., 2010; Sowa & Meulenbroek, 2012). It has also been recognized that exercise is beneficial for some aspects of cognition (ex. on-task behaviour and simple learning tasks) as well as quality of life (Tan, Pooley, & Speelman, 2016; Toscano et al., 2018) in children with ASD. However, the impact of exercise in improving the sleep behaviour of children with ASD is not well understood.

Exercise and Sleep in Children with ASD

There is substantial evidence to suggest that exercise and sleep present a bidirectional relationship in children with TD (Baldursdottir, Taehtinen, Sigfusdottir, Krettek, & Valdimarsdottir, 2017; Kline, 2014; Lin et al., 2018; Williams, Farmer, Taylor, & Taylor, 2014); yet research that involves direct intervention to better understand the effect of exercise on sleep in children with ASD is scarce. Of the few studies that have explored the issue in recent years, promising results have been demonstrated with the use of swim, aerobic, and motor skill programs to improve sleep (Brand, Jossen, Holsboer-Trachsler, Puhse, & Gerber, 2015; Mische Lawson & Little, 2017; Oriel, Kanupka, DeLong, & Noel, 2016; Wachob & Lorenzi, 2015). For example, Brand et al. (2015) offered an aerobic training and motor skill intervention three times per week for three weeks and documented improvements in sleep onset latency and waking after sleep onset (WASO). Similarly, Oriel et al. (2016) implemented an aquatic program two times per week for four weeks which lead to improvements in sleep latency and total sleep duration. These two pilot studies demonstrated a positive change in sleep behaviour within a short

amount of time and exercising only a few times per week. Therefore, more research is needed to explore the effect of exercise on sleep behaviour in children with ASD using different forms of exercise since the investigation of alternative modes of exercise provides variety for parents and their children. For example, the exercise intervention from the current study was multimodal and consisted of activities that could be implemented in various settings (school, community, or at home) so this type of program may be more easily accessible.

Purpose

The primary objective of this preliminary study was to determine whether a 4-week exercise intervention improved sleep behaviour in 6-10-year-old children with ASD. Behavioural characteristics were also assessed in relation to the intervention conditions. Additionally, the use of a rating of perceived exertion scale with visual cues was investigated for its effectiveness for children with ASD.

Methods

Study Design

This study followed an experimental pre-test, post-test design and participants were assigned to an experimental (exercise) or control group (arts and crafts). Each participant attended one of the two four-week interventions, two-times per week, for 45 minutes. Before and after the intervention, participants completed all assessments with their parents or caregivers.

Eligibility

To be included in the study, participants were required to meet the following criteria;

1. Participants had a diagnosis of ASD.
2. Participants were between the ages of 6-10 years.
3. All participants had parent-reported sleep problems; however, proof of a formal diagnosis was not necessary.
4. Participants were able to follow 2-step instructions (i.e. get a drink of water, then sit down on your circle).

Participants were excluded if the child experienced one or more of the following criteria;

1. Had an uncontrolled seizure disorder.
2. Displayed aggressive or self-injurious behaviour to self or others.
3. Had any additional health condition(s) that could be negatively affected by exercise.
4. Child was taking medication where exercise was contraindicated.

Recruitment

Ethics approval from the Ontario Tech University Research Ethics Board (REB #15482) and the research committee at Grandview Children's Centre was obtained prior to beginning the study (Appendix 1 and 2). This study was advertised on social media sites to encourage parents of children with ASD between the ages of 8-10 years, to contact the research team via email or phone if interested. The age range was initially determined based on it being a prepubescent period since sleep naturally changes during early adolescence (Mindell & Owens, 2015), in addition to promoting healthy behaviour in childhood. Originally, recruitment was low, therefore, a REB amendment was submitted and approved to recruit participants between the ages of 6-10 years (Appendix 1). Updated information was posted to the social media sites (Appendix 5) and parents of children previously

enrolled in studies in the Motor Behaviour and Physical Activity Lab at Ontario Tech that met the adjusted inclusion criteria were also contacted via email (ten families in total). All families who contacted the research team met the eligibility criteria. An appointment was scheduled with interested families to discuss the study design and assessment measures, and to allow the children to become familiar with the location. Written parental consent (Appendix 3) and child assent (Appendix 4) were obtained at the initial assessment where the participants were also assigned to the experimental or control group based on their availability. Randomization of the participants was the initial intention; however, group assignment was dictated by the availability of the families.

Participants

Five children with Autism Spectrum Disorder (ASD) between the ages of 6-10 years were recruited for this study and assigned to the exercise (n=3) or arts and crafts group (n=2). The participants were between the ages of 6-10 years for the purpose of encouraging healthy behaviour at an early age in addition to it being a prepubescent age range; adolescence is a period in which sleep naturally changes. Initially, we intended to randomly assign the participants to a group, however, low enrollment and the availability of the families dictated the group assignment. Participants who were able to attend both sessions every week were assigned to the experimental group, two of which were siblings (participant 3 and 4). Two of the families were only available for one session per week and for that reason they were assigned to the control group.

Measures

All assessments and interventions took place at the Motor Behaviour and Physical Activity Lab at the Ontario Tech with the research team, child, and their parent(s) and/or

caregiver(s). Following parental consent and child assent, parents were asked to complete a form to provide demographic information of each participant and their families (Appendix 6). Each of the measures listed below were completed prior to and following the intervention which were used to answer the three research questions. In addition to the standardized tools, parents were asked to complete a feedback form at the end of the study (Appendix 11).

Sleep Behaviour

The original Children's Sleep Habits Questionnaire (CSHQ) was created by Owens, Spirito and McGuinn in 2000 to assess sleep behaviours in children between the ages of 4-12 years. A study by Goldman, Richdale, Clemons, and Malow (2012) found that parent report is an accurate indication of sleep problems in which the CSHQ is the most commonly used parent report questionnaire for sleep in individuals with ASD (Hodge, Parnell, Hoffman, & Sweeney, 2012; Moore, Evans, Hanvey, & Johnson, 2017). This measure is used to describe the behavioural aspects of a child's sleep and contains 45-items, 33 of which are included in the total score. These questions are further categorized into eight subscales; bedtime resistance, sleep duration, parasomnia, sleep disordered breathing, night wakings, daytime sleepiness, sleep anxiety and sleep onset delay (Owens, Spirito, & McGuinn, 2000). Johnson et al. (2016) used the abbreviated version of the CSHQ and found children with ASD commonly reported behaviours within the bedtime resistance subscale and had few responses relating to sleep disordered breathing and parasomnia subscales which is consistent with other findings (Reynolds & Malow, 2011; Souders et al., 2009). Katz et al. (2018) recently modified the CSHQ to capture the challenges reported in individuals with ASD more appropriately, though more research was encouraged to test

the validity and reliability of this version. This version does not include some of the questions pertaining to sleep disordered breathing and parasomnia-related problems (Katz et al., 2018) and has a cut-off score of 30 to indicate sleep that is problematic (Bonuck, Goodlin-Jones, Schechter, & Owens, 2017), therefore, the modified version of the CSHQ was used for this study (Appendix 7).

Additionally, we employed the Patient-Reported Outcomes Measurement Information System (PROMIS) Sleep Disturbance Parent Proxy short form questionnaire for children between the ages of 5-17 years (Forrest et al., 2018) (Appendix 8). This parent report questionnaire consists of eight questions that address concerns around sleep characteristics, such as staying asleep and sleep satisfaction, in reference to the past seven days. The participants were also provided with an opportunity to self-report using the Sleep Disturbance Pediatric short form questionnaire which is recommended for children between the ages of 8-17 years and consists of the same eight questions (Forrest et al., 2018) (Appendix 8). To our knowledge, the questionnaires have not been previously used in studies with children with ASD.

Child Behaviour Checklist

The Child Behaviour Checklist (CBCL) is a commonly used parent report checklist that identifies behavioural and emotional problems present in children between the ages of 6-18 years (Achenbach & Rescorla, 2001). The tool contains a series of questions pertaining to aggressive behaviour, anxious or depressed behaviour, attention problems, rule-breaking behaviour, somatic complaints, social problems, thought problems, and withdrawn or depressed behaviour (Achenbach & Rescorla, 2001). The initial questions are related to activities, hobbies, social engagement and academic performance while the

remaining questions contribute to a total score as well as internalizing and externalizing problem scores. This questionnaire has been previously used for children with ASD (Malow et al., 2014; Moore et al., 2017) and assisted the current researchers with identifying potential behaviours that may have had an influence on sleep (Appendix 9).

Physical Activity Measures

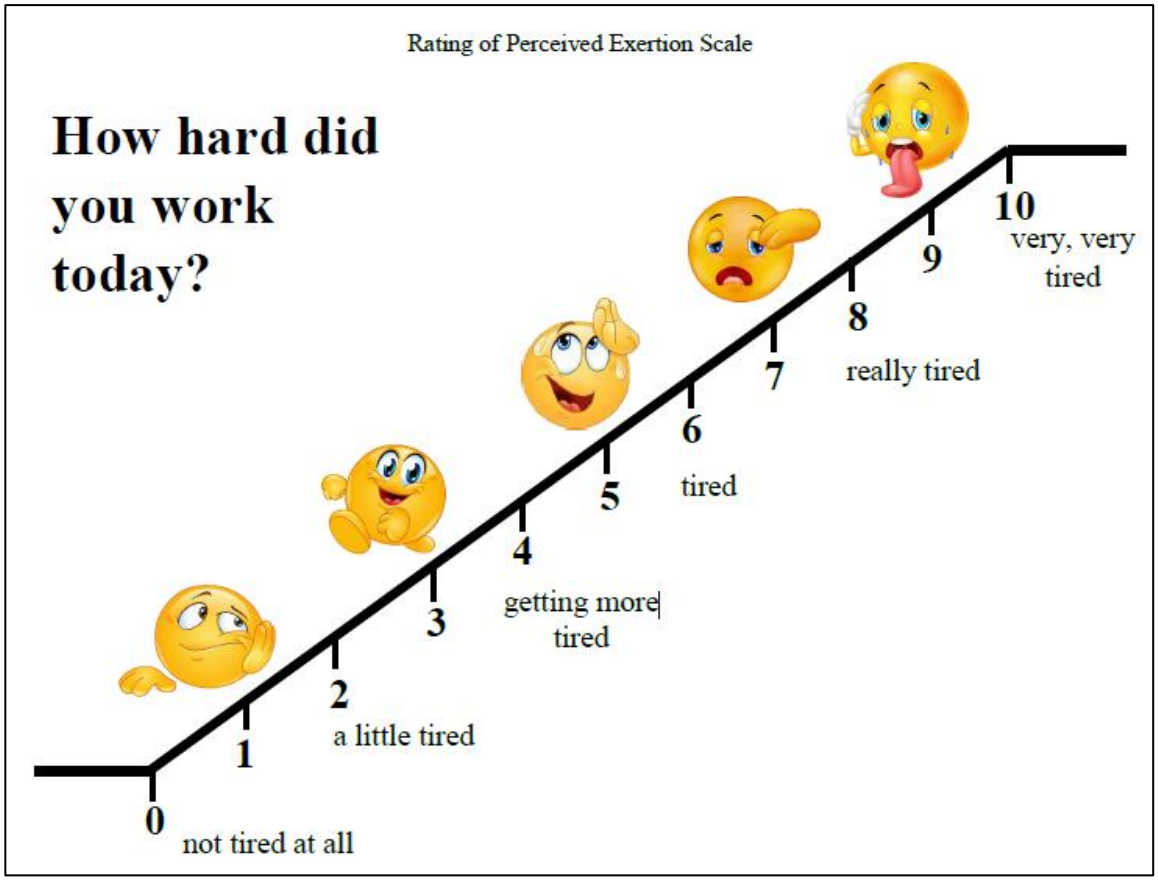
The Physical Activity Questionnaire for Older Children (PAQ-C) is a self-report questionnaire that was used to gauge the general PA levels of the participants based on their activity in the previous seven days (Kowalski, Crocker, & Donen, 2004) (Appendix 10). This measure contains nine questions that use a 5-point scale where the answers contribute to an overall PA score and rating; a score of one indicates low levels of PA and a score of five represents high levels of PA. This assessment is designed for children between the ages of 8-14 years although the age range of the participants in this study was 6-10 years, so parental assistance and review was welcomed when needed. To our knowledge, this questionnaire has been used in one study with children with ASD (Kamal Nor, Ghozali, & Ismail, 2019).

Rating of Perceived Exertion

A visual rating of perceived exertion (RPE) scale, similar to a children's omnibus picture scale (Utter, Robertson, Nieman, & Kang, 2002), was used at the end of each session to measure the relative intensity of the interventions. Ratings were collected from the perspective of the participant, parents, and instructor to note the daily effort during the sessions in order to triangulate the perceived exertion. The purpose of conducting RPE was to ensure the demand of the activities were within the moderate to vigorous range and the effort demonstrated by the child met this expectation (Figure 2). This scale allowed

participants to rate their perceived intensity on scale from zero to ten; a score of zero indicates a very light intensity such as laying down or sitting and a rating of ten specifies very vigorous intensity or maximal effort during an activity such as running (Department of Health and Human Services, 2018). Rating of perceived exertion scales have been shown to be effective in measuring the self-perceived level of exertion in children with TD and disabilities (Fragala-Pinkham, O'Neil, Trost, Lennon, & Forman, 2015; Robertson et al., 2005; Utter et al., 2002); pictorial scales have been recommended as an alternative for children with ASD who may have tactile sensitivities that prohibit the use of devices such as heart rate monitors (Srinivasan, Pescatello, & Bhat, 2014). The exercise intervention was designed to be of moderate to vigorous intensity, therefore, a score of five or higher would have been an accurate rating that supported the targeted intensity (Department of Health and Human Services, 2018). Alternatively, the control intervention was designed to be light intensity meaning a score below two would have been appropriate.

Figure 2. Rating of Perceived (RPE) Scale



Interventions

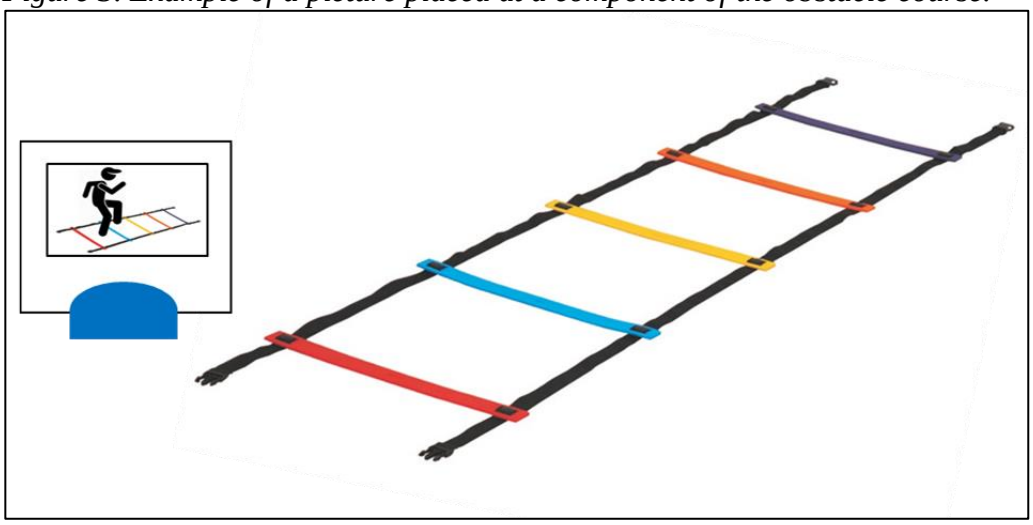
The interventions took place at the Motor Behaviour and Physical Activity Lab at Ontario Tech and parking was free of charge at this satellite location. Attendance was taken at the beginning of each session.

Experimental Group: Exercise Intervention

Children assigned to the experimental group participated in an exercise program two times per week for four weeks and each session was 45 minutes in length. The intervention was considered to be exercise as it is purposeful activity (Caspersen, Powell, & Christenson, 1985). The dose was determined based on the national recommendations that children should attain an accumulation of 60 minutes of moderate to vigorous PA daily,

therefore, the intervention was designed to fill majority of the daily recommendation. However, the weekly dosage was limited based on what was feasible for the families, but research has demonstrated that improvements can be seen with one to two days of intervention per week (Mische Lawson & Little, 2017; Oriel et al., 2016). Previous experience led us to believe that more than two days per week was not manageable for families with children with ASD which was demonstrated through the availability of the participants. All sessions began with a five-minute warm-up and a five-minute fun run, followed by 30-minutes of an obstacle course, circuit-oriented activities, and group game with the last five minutes dedicated to a cool-down period (Appendix 11). Each of the activity items were presented in order on a visual schedule for the participants to follow along and help ease the transition from one activity to the next. The general structure of the sessions remained consistent, but the activities varied within each session. Previous research has implemented exercise and PA interventions, however, to our knowledge, there were no studies that implemented a program of this specific design for children with ASD and in respect to sleep (Brand et al., 2015; Bremer et al., 2016; Dillon, Adams, Goudy, Bittner, & McNamara, 2016; Mische Lawson & Little, 2017; Oriel et al., 2016). Participating in an exercise program immediately after school would provide enough time for the body temperature to drop before bedtime which promotes sleep. All activities were demonstrated by the instructor and pictures were posted at each station of the obstacle course and circuit activities to provide a reminder of the expectation of each station (Figure 3).

Figure 3. Example of a picture placed at a component of the obstacle course.



Control Group: Arts & Crafts Intervention

Participants in the control group were scheduled to attend two 45-minute sessions which began immediately after the experimental group over the same four weeks of intervention. The program consisted of art and craft activities using a number of different materials (Appendix 11). Prior to the start of each session, an example of the craft was shown to the group along with step-by-step instructions and any additional directions or demonstrations were provided when necessary. Challenges with social interaction and communication is one of the core characteristics of ASD although, they also present delays in gross and fine motor skills (Liu & Breslin, 2013; Lloyd et al., 2013). Therefore, an arts and crafts intervention is an avenue that can promote the use of these skills and abilities (D'Amico & Lalonde, 2017) by incorporating activities that focus on fine motor skills, social skills, as well as self-expression and creativity without any physically demanding components. Social skills such as cooperation and communication were promoted by sharing the materials and encouraging the use of names and general discussion of the activity whereas fine motor skills and motor control were encouraged by manipulating the

different art mediums and materials (e.g. modelling clay). Art therapy has been found to be effective in improving social skills and fine motor skills in children with ASD when the program is tailored to do so (D'Amico & Lalonde, 2017). For example, D'Amico and Lalonde (2017) conducted an art program once per week for 21 weeks with six, 10-12 year old children with ASD. Social assessments were conducted prior to and following the intervention and improvements were seen in relation to assertion, cooperation and communication as well as inattention and hyperactivity (D'Amico & Lalonde, 2017). It was imperative to provide an intervention for the control group that targeted other challenging areas of development for individuals with ASD so it was still beneficial for the participants to be assigned to the control group. The control group had an opportunity to participate in the exercise intervention after the four-week control intervention and assessments were completed.

Statistical Analysis

This pilot study provides the results of the group analysis for each assessment and allowed the researchers to compare the experimental and control group. Descriptive characteristics (mean and standard deviation) were computed for all variables including the Sleep Disturbance Parent Proxy and Pediatric questionnaires, the Children's Sleep Habits Questionnaire, the Child Behaviour Checklist, the Physical Activity Questionnaire for Older Children, and rating of perceived exertion. Additionally, independent t-test and repeated measures analysis of variance were calculated across all variables using to better understand the interactions between the variables before and after the intervention.

Results

Descriptive Characteristics

The demographic information of the participants in their respective groups (experimental n=3, control n= 2) is summarized in Table 1. Two males and one female were assigned to the experimental group and the control group consisted of one male and one female. The baseline Physical Activity Summary score indicates the rounded mean activity level of each group; a score of one indicates low participation in PA whereas a score of five is indicative of high participation in PA (Kowalski et al., 2004). All participants in the experimental group attended every session, however, the participants in the control group were only available to attend one session per week. This was due to the prior commitments of the family which was discussed with the researcher ahead of time and was deemed acceptable based on their group assignment (control group) and necessary for the study to proceed. A more detailed case analysis for each participant are provided in Appendix 12. The participants were identified with a number; participants 1, 3, and 4 were assigned to the experimental group and participants 2 and 5 were assigned to the control group.

Table 1. Participant demographic information

Variable	Experimental Group	Control Group
n	3	2
Sex (Male, Female)*	2M, 1F	1M, 1F
Age (years) (mean ± SD)	8 ±2	9.5 ±0.71
Additional Diagnosis (Yes, No)**		
Attention deficit hyperactivity disorder and/or attention deficit disorder	2Y, 1N	1Y, 1N

Other (anxiety, intellectual disability, learning disability, sensory integration disorder, and/or Ehlers-Danlos syndrome)	2Y, 1N	1Y, 1N
Medications (Yes, No)**		
Sleep Medication	3N	1Y, 1N
Other Medication(s)	1Y, 2N	1Y, 1N
Physical Activity Score at Baseline (mean ± SD)	3 (±0)	3.5 (±1.41)
Diagnosed Sleep Problem (Yes, No)**	3N	1Y, 1N

*F=female, M=male; **Y=yes, N=no

Primary Objective

Sleep Disturbance Parent Proxy Short Form (parent report)

According to the parental responses, four out of five participants were classified as having sleep problems that were worse than average with the other participant presenting borderline scores at baseline (Figure 4). The raw scores are presented in Table 2 while the standard scores for each group are displayed in Figure 4 and the individual results are provided in Figure 5. The parents of both groups provided a score calculated as higher than 50 at both time points, which indicates their sleep disturbance was worse than average. There was no significant difference (t=0.87, p=0.45) between the experimental and control group at baseline. The repeated measures analysis of variance computed a significant interaction from pre- to post-test for time (F=18.33, p=0.02) and group by time (F=14.80, p=0.03) using the standard scores (T scores). This demonstrates that the exercise intervention had a statistically significant positive effect on sleep disturbance (scores went down) in the participants in the experimental group compared to the control group. Although the experimental group demonstrated an improvement, the sleep disturbances were still considered to be problematic and worse than average. At the pre-and post-test,

the control group had at a T score that was considered to be one standard deviation worse than average. Individually, each participant in the experimental group demonstrated pre-test scores that were considered to be worse than average, whereas the participants in the control group demonstrated mixed ranges of sleep disturbance. Overall, all participants in the experimental group showed positive change, however, the post-test scores demonstrated that the sleep challenges were not resolved completely.

Table 2. Raw score group means on the Sleep Disturbance Parent Proxy (SDPP) short form for the experimental and control groups at pre-test and post-test.

	Experimental Group	Control Group
SDPP Pre-Test Score (mean ± SD)	28 ± 7.55	21 ± 12.73
SDPP Post-Test Score (mean ± SD)	21.3 ± 7.57	21 ± 14.14
Pre to Post Change	-6.7	0
Pre to Post Change (%)	-23.93%	0%

Figure 4. T score group means on the SDPP short form for the experimental and control groups at pre-test and post-test.

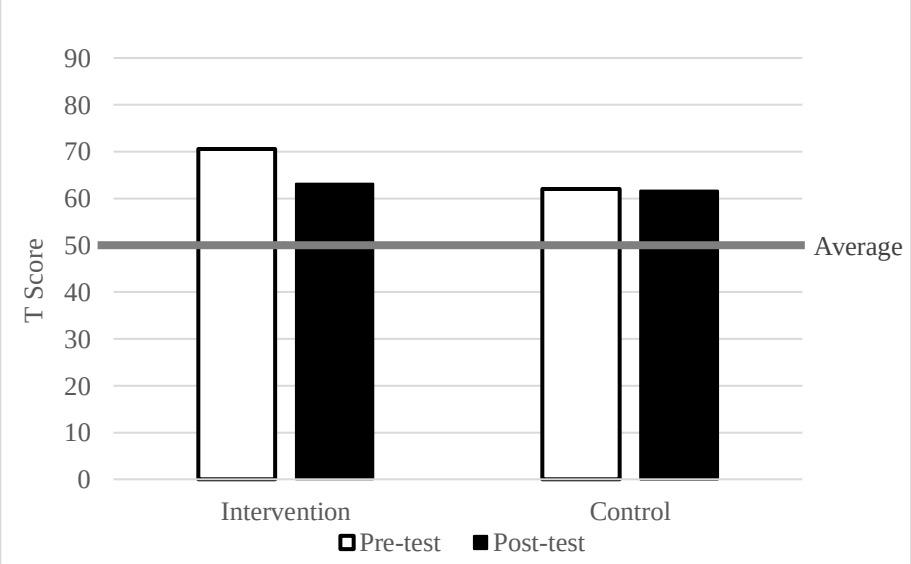
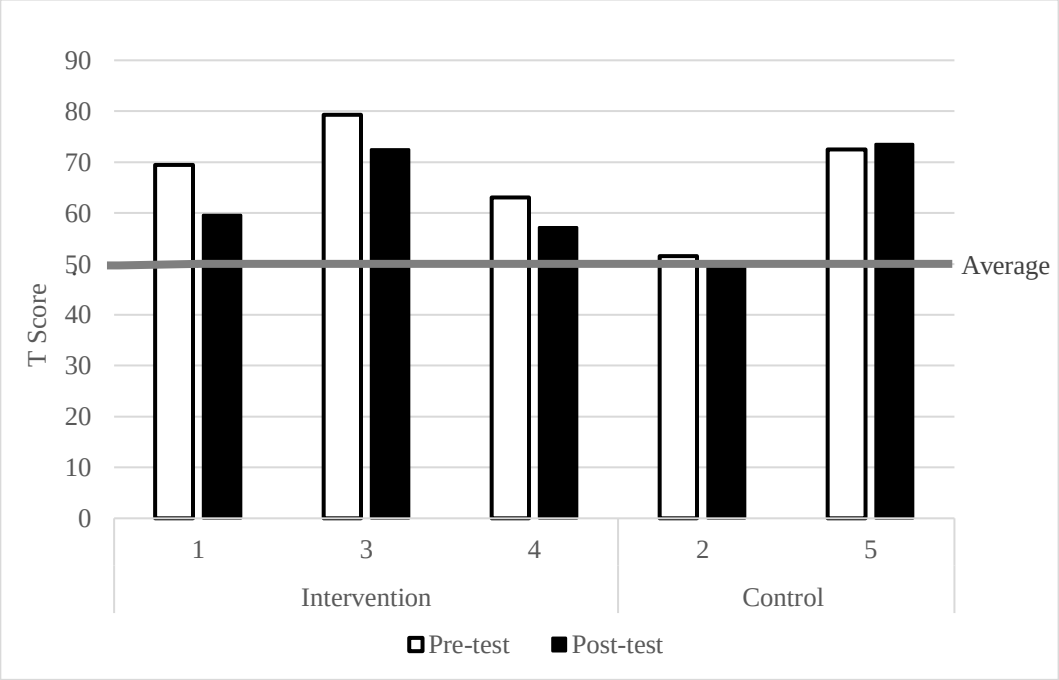


Figure 5. Individual T scores on the SDPP short form within the respective groups at pre-test and post-test.



Sleep Disturbance Pediatric Short Form (child report)

The raw scores from the child-report version of the Sleep Disturbance short form are presented in Table 3. Using the standard score, it was determined that both groups demonstrated sleep disturbance that was considered to be worse than average at pre- and post-test (Figure 6). The group means at the pre- and post-test are displayed in Figure 6 while the individual results are shown in Figure 7. There was no significant difference (t=-0.51, p=0.76*)* between the groups at baseline and the repeated measures analysis of variance yielded no significant time (F=0.45, p=0.55) or group by time interactions (F=0.004, p=0.95) between the groups from the pre- to post-assessment. Overall, a lower score was demonstrated in both groups at the post-test indicating a positive change in sleep disturbance. In other words, there were fewer sleep disturbances after the intervention. Moreover, all participants presented individual T scores that were considered to be worse

than average at the pre- and post-test. Two of the participants in the experimental group reported that their sleep disturbance was slightly worse after the exercise intervention and the other reported an improvement. Mixed results were also present in the control participants; one reported more sleep disturbance and the other reported less disturbance from pre- to post-test.

Table 3. Raw score group means on the Sleep Disturbance Pediatric (SDP) short form for the experimental and control groups at pre-test and post-test.

	Experimental Group	Control Group
SDP Pre-Test Score (mean ± SD)	27 ± 4.36	30 ± 14.14
SDP Post-Test Score (mean ± SD)	25 ± 6.56	29 ± 14.14
Pre to Post Change	-2	-1
Pre to Post Change (%)	-7.41%	-3.33%

Figure 6. T score group means on the SDP short form for the experimental and control groups at pre-test and post-test.

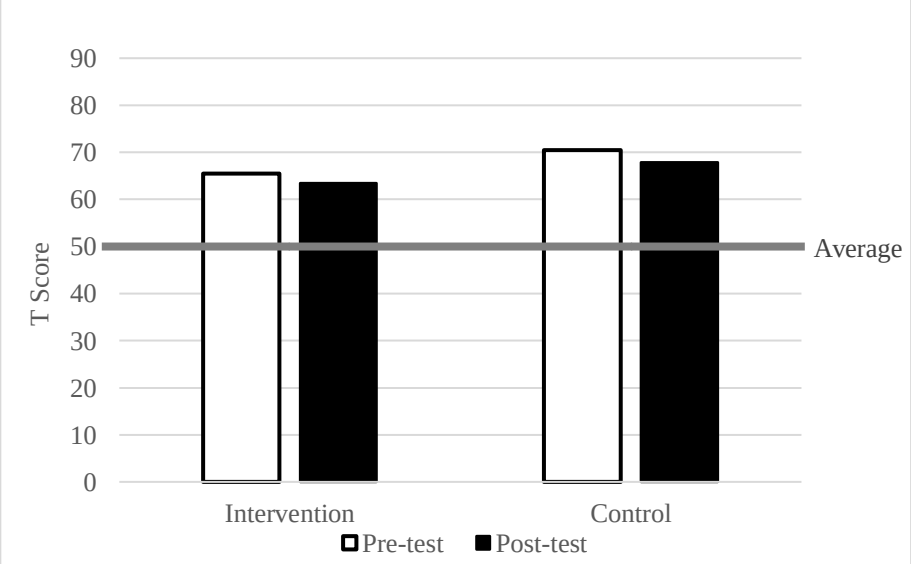
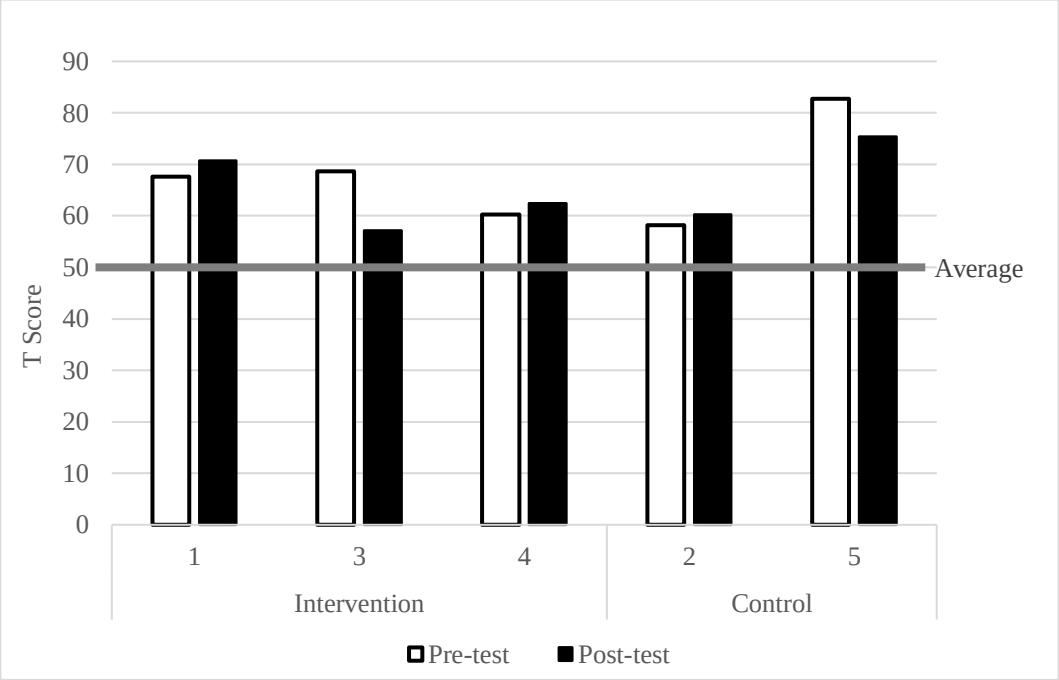


Figure 7. Individual T scores on the SDP short form within the respective groups at pre-test and post-test.



Children's Sleep Habits Questionnaire (Modified)

The raw score group means from the Children's Sleep Habits Questionnaire (CSHQ) are presented in Table 4. At baseline, there were no significant differences (t=1.843, p=0.16) between the two groups and the repeated measure analysis of variance did not produce any significant results (F=7.30, p=0.33 and F=4.68, p=0.12). An overall improvement in sleep behaviour was demonstrated in the experimental group from pre- to post-test by 11.63% whereas the control group displayed a higher raw score at the post-test than the pre-test, increasing by 4.55%. Therefore, the parents reported fewer sleep problems in the experimental participants after the exercise intervention and more sleep challenges in the control participants. Furthermore, both groups demonstrated average raw scores above 30 which is consistent at both time points, meaning, they are still classified

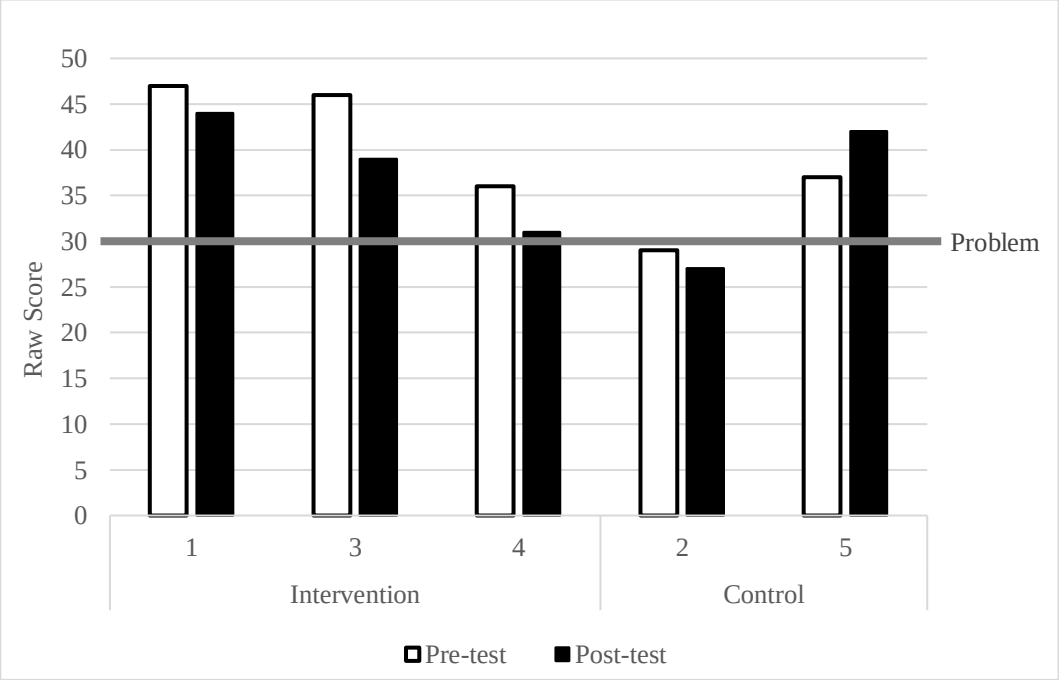
as having problematic sleep despite the improvements that were demonstrated by the experimental group (Bonuck et al., 2017).

Table 4. Raw score group means on the CSHQ for the experimental and control groups at pre-test and post-test.

	Experimental Group	Control Group
CSHQ Pre-Test Score (mean ± SD)	43 ± 6.08	33 ± 5.66
CSHQ Post-Test Score (mean ± SD)	38 ± 6.56	34.5 ± 10.61
Pre to Post Change	-5	1.5
Pre to Post Change (%)	-11.63%	4.55%

The individual results are displayed in Figure 8 which shows that all of the participants in the experimental group demonstrated improvements in their sleep behaviour. Furthermore, each of their scores at the pre- and post-test were above 30 suggesting they had parent-reported sleep problems (Bonuck et al., 2017). Mixed results were reported about the participants in the control group; one participant had a lower raw score from pre- to post-test with both scores below 30, while the other participant demonstrated a higher score from pre- to post-test and had scores greater than 30 at both time points. Overall, four out of five participants had parent-reported sleep problems based on the CSHQ results.

Figure 8. Individual raw scores on the CSHQ within the respective groups at pre-test and post-test.



Secondary Objectives

Child Behavior Checklist (School-Age, 6-18)

The results for the Total Problems score from the Child Behaviour Checklist (CBCL) are recorded in Table 5. The independent t-test test did not produce a significant outcome with the standard scores indicating there was no significant difference between the group means at baseline (t=0.67, p=0.55). The repeated measures analysis of variance also yielded no significant results between the two groups and over time (F=1.58, p=0.3 and F=0.05, p=0.83). Overall, the experimental group demonstrated a greater positive change than the control group from pre- to post-test. Despite the decrease in the Total Problems score from pre- to post-assessment, both groups fell within the clinical range for problem behaviour (Figure 9). On the other hand, Figure 10 displays the individual T scores of the participants within their respective groups. All of the participants were considered

to be within the clinical range for problem behaviour at the start. Following the exercise program, two of the participants remained within the clinical range and the other scored within the borderline range. In the control group, one of the participants presented a score within the borderline range at the post-test while the other sustained a score within the clinical range at the post-test.

Table 5. Raw and T score group means of Total Problems from the CBCL for the intervention and control groups at pre-test and post-test.

	Experimental Group		Control Group	
	Raw Score	T Score	Raw Score	T Score
CBCL Pre-Test Score (mean ± SD)	82 ± 25.63	72.33 ± 5.69	62.5 ± 3.54	69.5 ± 0.71
CBCL Post-Test Score (mean ± SD)	65.33 ± 27.47	68 ± 7.55	56.5 ± 17.68	66.5 ± 6.36
Pre to Post Change	-16.67	-4.33	-6	-3
Pre to Post Change (%)	-20.33%	-5.99%	-9.6%	-4.32%

Figure 9. T score group means on the Total Problems of the CBCL for the intervention and control groups at pre-test and post-test.

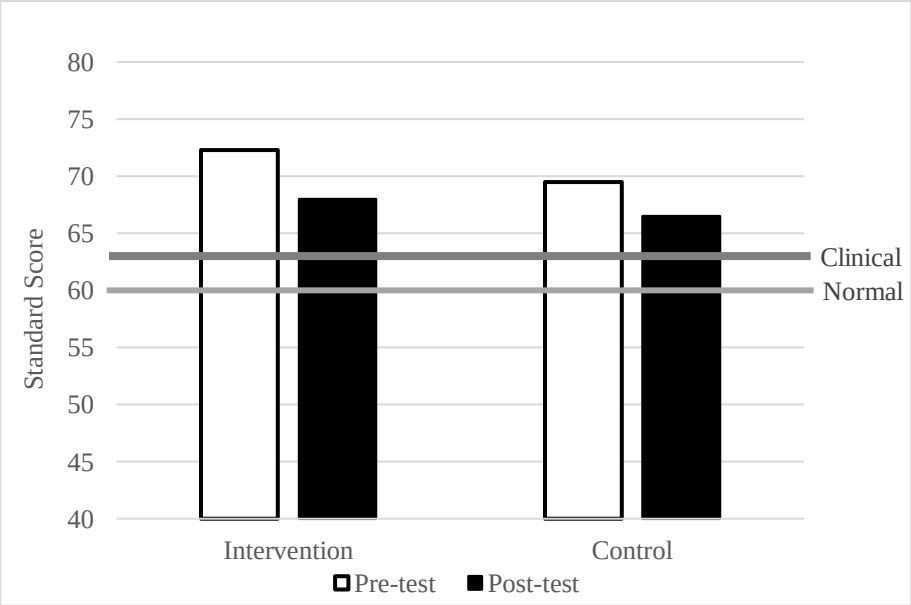
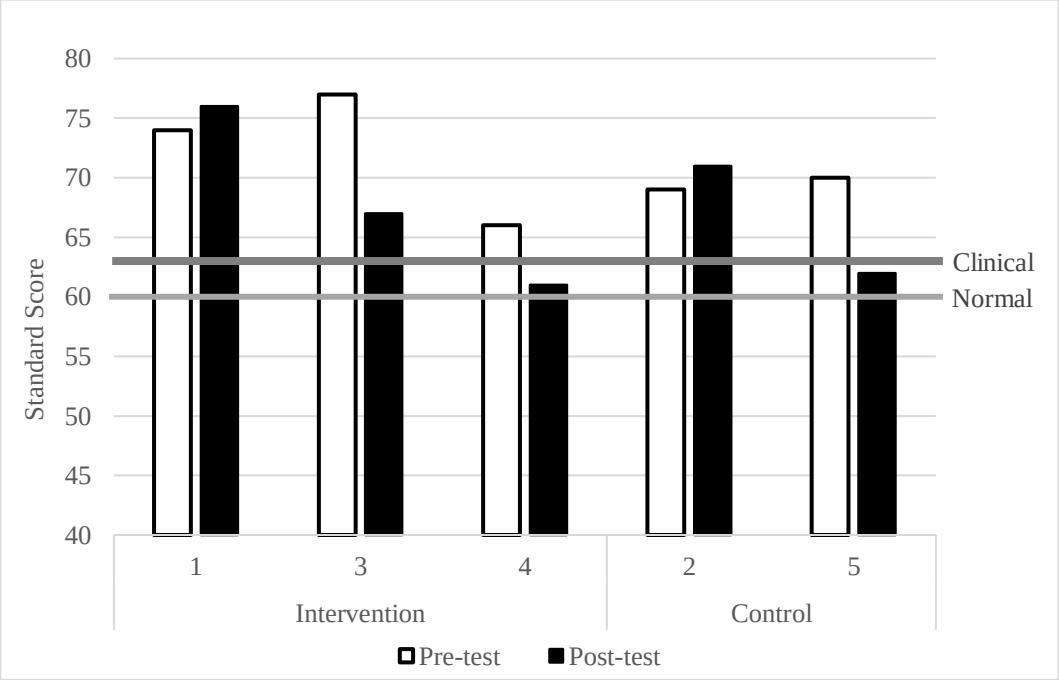


Figure 10. Individual T scores on the Total Problems of the CBCL for the intervention and control groups at pre-test and post-test.

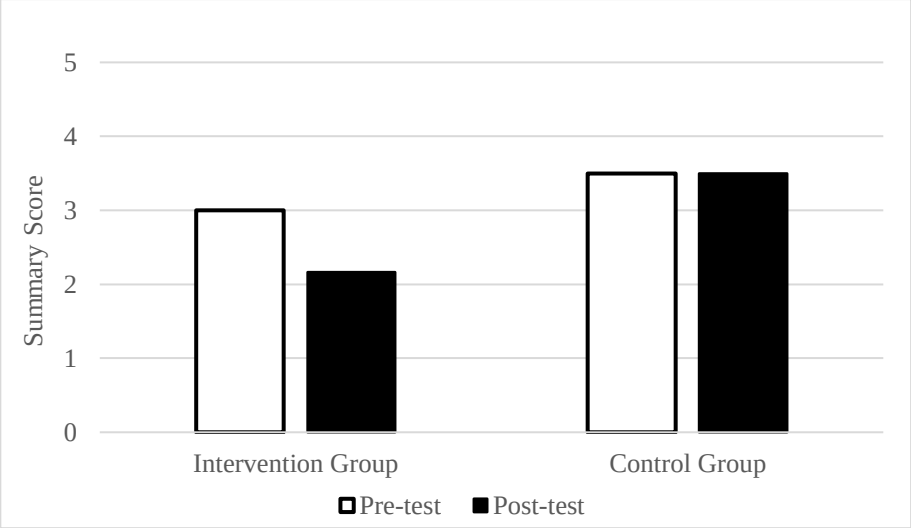


Physical Activity Questionnaire for Older Children

The independent t-test at baseline was not significant (t=-0.671, p=0.55), yet the repeated measures analysis of variance calculated significant results for time (F=15, p=0.03) and group by time (F=15, p=0.03). The experimental group demonstrated a significant change in comparison to the control group, but not in the direction that was expected; the PA score declined after the exercise intervention. As a whole, the experimental group rated their level of participation in PA as three, out of five, at the initial assessment (Figure 11). Therefore, their level of PA was considered to be moderate which suggests they participated in sports, dance, or active games 2-3 times per day on 3-4 days throughout the week based on the questions from the Physical Activity Questionnaire for Older Children (PAQ-C). This score decreased from pre- to post-test; their overall score was rated as 2.16 following the intervention which is reflected as moderately low. The

control group had a rating of 3.5 at both time points, indicating a moderately high level of PA (Figure 11).

Figure 11. Raw score group means for the PAQ-C from the experimental and control groups at the pre-test and post-test.



Rating of Perceived Exertion

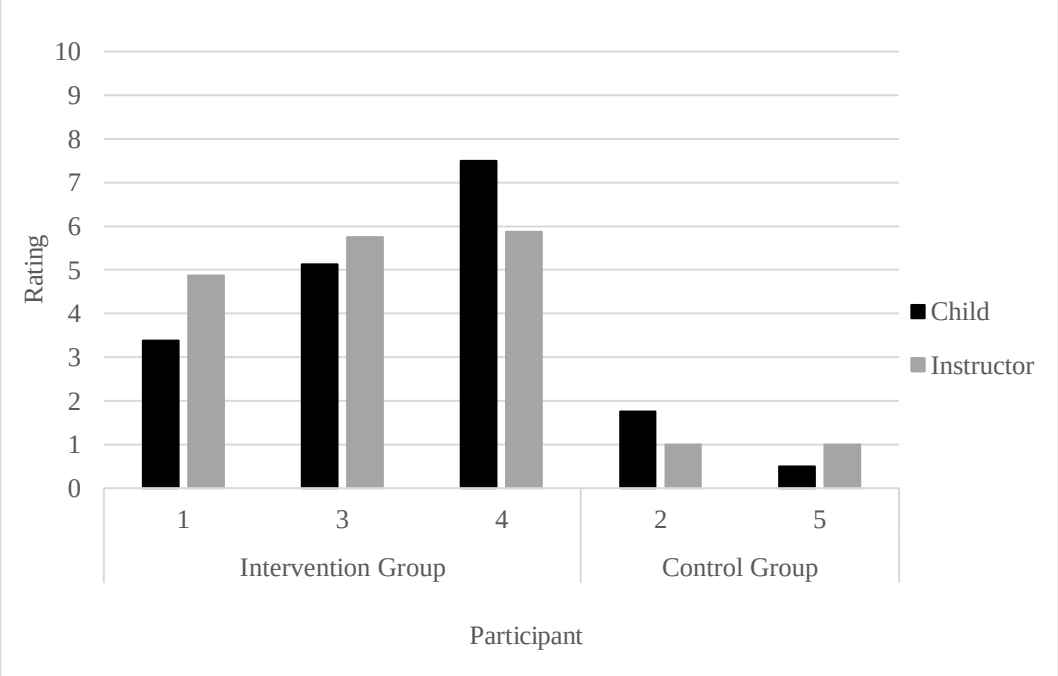
The experimental group reported ratings between 3.38-7.5 out of 10 whereas the instructor rated their exertion between 4.88-5.88 (Table 6). The control group demonstrated exertions that were lower than the experimental group; the participants reported ratings between 0.5-1.75 and the instructor rated their exertion as 1 (Table 6). Furthermore, the individual ratings of perceived exertion from each group are displayed in Figure 12. On average, two of the three participants in the experimental group rated their exertion lower than the instructor. In the control group, one participant rated their exertion lower than the instructor whereas the other participant rated their exertion higher than the instructor. The ratings of perceived exertion were collected from the parents as well, but they were excluded from the group analysis due to the limited availability of some parents to observe the entire sessions. For the control group, the researchers believed it would be

advantageous for the participants if the parents waited in the hallway which meant they were unable to watch their children for the entirety of each session.

Table 6. Mean ratings of perceived exertion of all participants and the instructor.

RPE	Intervention Group			Control Group	
	101	103	104	102	105
Child Rating (mean)	3.38	5.13	7.5	1.75	0.5
Instructor Rating (mean)	4.88	5.75	5.88	1	1
Group Averages		5.34		1.13	

Figure 12. Mean ratings of perceived exertion from the participants in their respective groups and the instructor.



Other Outcomes

Parent Feedback Form

Table 7. Written responses on the parent feedback form

Question 1: Do you think this intervention helped your child make improvements in their sleep behaviour? Please explain your answer.	
P1	"Yes, I notice that [P1] took less time between going to bed and falling sleep."
P3	"No, the 2 classes per week, she still had trouble getting to sleep."
P4	"No, the 2 classes per week, he still had trouble getting to sleep."
P2	"No, but he loved the activities."
P5	"Yes, gets her tired faster. Yes, brain work at night and play."
Question 2: What did you expect that you or your child would gain from participating in the intervention?	
P1	"It's a little bit hard during winter to get active but I will definitely make the effort to keep him more active."
P3	"I was expecting it would tire her out to help her get to sleep."
P4	"I was expecting it would tire him out to help him get to sleep."
P2	"No expectations."
P5	"Lots of active play and mental thinking (brain work)."
Question 3: Did the outcomes that you/your child experienced actually match what you expected? Why, or why not?	
P1	"Yes, it was better than he and I thought because he enjoyed the exercise."
P3	"No, it didn't help her get to sleep any faster."
P4	"No, it didn't help him get to sleep any faster."
P2	"There were no expectations based on the weekly activities."
P5	"Yes, so far, they loved it."
Question 4: What was your motivation for selecting this type of program?	
P1	"Try different alternatives, sleep is a struggle with [P1]. Help to find more knowledge about ASD. Have an activity to keep him active."

P3	“We like to help out with [Ontario Tech] and to see if the study would help out.”
P4	“We like to help out with [Ontario Tech] and to see if the study would help out.”
P2	“To help collect data that could potentially help kids on the autism spectrum.”
P5	“Grandview, Sleep”
Question 5: Did you feel the rating of perceived exertion scale was an effective tool to estimate your child's effort during the intervention?	
P1	“Yes, but maybe take signs like heart rate and recovered after exercise or took the time that the kid spent between time to go to bed and fell sleep [and] compare with the usual time that they took on it. The measures can help because you can show graphically the findings.”
P3	“Yes, I thought it was an interesting tool to see 3 people's opinions.”
P4	“Yes, I thought it was an interesting tool to see 3 people's opinions.”
P2	“I'm not sure. I wasn't watching him so I didn't witness how active he was.”
P5	“Yes, wish there were more days. Wish they both did the Wednesday night.”

Discussion

Children with TD demonstrate a positive bidirectional relationship between sleep and exercise (Lang et al., 2013; Lin et al., 2018); however, this relationship is not well understood in individuals with ASD. Research indicates that more than half of children with ASD experience sleep problems (Richdale & Prior, 1995; Richdale & Schreck, 2009) in addition to less participation in PA and exercise than their peers with TD (Pan, 2008; Stanish et al., 2017; Tyler et al., 2014). The present study investigated the effectiveness of exercise on sleep behaviour in children with ASD to in comparison with a control group.

To be involved in the current study, all participants were required to have parent-reported sleep problems. Each of the parents expressed that there was potential for their child's sleep to be improved during the initial discussion with the researcher and the baseline results from the sleep questionnaires supported these statements. Results from both parent-report questionnaires, the Sleep Disturbance Parent Proxy short form and the Children's Sleep Habits Questionnaire, suggested that four out of five participants had problematic sleep behaviour with the other participant demonstrating borderline scores. Other literature has reported rates of parent-reported sleep challenges between 44-83% in children with ASD, therefore, our findings are consistent with previous research (Allik, Larsson, & Smedje, 2006; Liu, Hubbard, Fabes, & Adam, 2006; Richdale & Prior, 1995; Wiggs & Stores, 2004). Overall, the high prevalence of sleep difficulties in the participants indicates a clear problem and the need for intervention. Moreover, all participants from the current study recognized their own sleep disturbances (Figure 7) on the self-report Sleep Disturbance Pediatric questionnaire; and in some cases, the child scored their sleep as more problematic than their parent. Earlier studies have demonstrated that children with high-

functioning ASD and Asperger syndrome between the ages of 5-17 years have been shown to reliably self-report their sleep problems and could offer more insight since parents may not be present for all sleep behaviour (Paavonen et al., 2008; Richdale & Baglin, 2015). Additionally, Paavonen et al. (2008) reported that 70% of parents and children were in agreement about the child's problematic sleep which is consistent with the findings of the current study that found four out of five parents and children in agreement. Therefore, the preliminary findings from the current study suggest that children with ASD as young as six might be able to accurately report their own sleep challenges, and while the results are encouraging, more research is needed. While no specific measures were taken to identify the precise level of functioning in the current study, the children were highly verbal, able to follow multiple instructions, rate their perceived exertion, and could self-report on the Sleep Disturbance Pediatric questionnaire and the Physical Activity Questionnaire for Older Children. The participants in the present study likely represent a sub-sample of individuals with ASD that were able to participate in the self-report procedures; however, this may not be true for all children with ASD. The varying level of functioning within individuals with ASD may affect their ability to self-report, consequently, more research incorporating self-assessments is needed for children across the entire autism spectrum.

Further analysis of the demographic information revealed that one participant (participant 5) experienced more challenges than the others since she was the only child prescribed medication specifically for her sleep problems (Clonidine) in addition to medication for anxiety (Zoloft) and attention deficit hyperactivity disorder (ADHD) (Vyvanse). Participant 5 could be considered an outlier due to the fact that she is the only child with a medically recognized sleep problem as per her prescribed sleep medication.

Mayes and Calhoun (2009) found that children with ASD on sleep and/or stimulant medication presented more sleep disturbance than those who were not on medication. Future studies should continue to include medication in data collection and control for these in the analysis since antidepressant and stimulant medications can have an effect on sleep (Giblin & Strobel, 2011; Graham et al., 2011; Stein, Weiss, & Hlavaty, 2012).

Three participants (participant 1, 3, and 5) from the present study were also diagnosed with ADHD and demonstrated more sleep disturbance than the other participants which was consistent on all sleep measures (Figure 5, 7, and 8). Two participants with co-morbid ADHD were in the experimental group and the other was in the control group. The literature indicates that children with ADHD experience similar challenges with their sleep such as, sleep disordered breathing, bedtime resistance, delayed sleep onset, and difficulty getting out of bed in the morning (Cortese, Faraone, Konofal, & Lecendreux, 2009; van der Heijden, Stoffelsen, Popma, & Swaab, 2018). Children with ADHD and ASD demonstrate an increased risk of sleep problems (Reynolds, Patriquin, Alfano, Loveland, & Pearson, 2017) which could be the reason the three participants with a dual diagnosis had higher scores. More specifically, the behavioural profile (internalizing and externalizing problems) of children with both disorders may be the primary predictor of problematic sleep (Reynolds et al., 2017; Richdale & Schreck, 2009), emphasizing the need for this data to be collected to determine which condition, and/or behaviour, is the precursor to poor sleep. Two participants from the present study were diagnosed with other conditions as well; the female (participant 5) in the control group had anxiety, an intellectual disability, and a learning disability, and the other female participant (participant 3) in the experimental group was diagnosed with sensory integration disorder. Children

with these conditions commonly experience more sleep challenges than children with TD, and comorbidity of these conditions could contribute to the higher magnitude of sleep problems (Kose, Yilmaz, Ocakoglu, & Ozbaran, 2017; Mazurek & Petroski, 2015). Being diagnosed with multiple conditions could exacerbate the sleep problems experienced by children with ASD as well as further complicate distinguishing the cause(s) of the sleep problems (Liu et al., 2006), therefore, other researchers are encouraged to investigate this complex interaction between comorbid conditions.

The parents also reported more challenging sleep behaviour in the female participants (participants 3 and 5) than all male participants on the Sleep Disturbance Parent Proxy questionnaire (Figure 5), and two of three males on the Children's Sleep Habits Questionnaire (Figure 8). The girls also reported more problems than the boys on the self-report sleep measure (Figure 7). These results are similar to a study by Hartley and Sikora (2009) who analyzed the sex differences in toddlers with ASD and found that girls with ASD experience significantly more sleep problems than boys. Additionally, females scored slightly higher than males on the Sleep Problem subscale of a parent report computerized interview (The Developmental, Dimensional and Diagnostic Interview) in a study with older children with ASD (Mandy et al., 2012). A study by Liu, Uchiyama, Okawa, and Kurita (2000) found no significant differences between sex in adolescents (12-18 years of age) with TD while Mindell and Owens (2015) specified that insomnia is more prevalent in females than males with TD. The current study had a small sample of participants, but the results suggest that the females experienced more sleep disturbance than the males; future studies should consider sex as a factor when analyzing sleep in children with ASD to better understand this trend. Overall, medication, comorbid

condition(s), and personal characteristics should be taken into consideration when understanding the results. Despite these factors, it has been clearly demonstrated that children with ASD experience problematic sleep, therefore, action should be taken to help alleviate the issue.

The primary objective of the current study was to evaluate the effects of an exercise intervention on sleep behaviour in children with ASD. Previous research has lacked the comparison of an experimental group to a control group (Brand et al., 2015; Oriel et al., 2016) so our study aimed to assess two groups of children with ASD under two different movement conditions. The results of the current study indicated there were no significant differences between the groups at baseline on any of the measures. Following the intervention, the experimental group demonstrated improvements on the Children's Sleep Habits Questionnaire and the child-reported Sleep Disturbance Pediatric questionnaire, as well as, a positive significant change on the Sleep Disturbance Parent Proxy questionnaire in comparison to the control group (Table 2). Therefore, despite the small sample size, the exercise intervention had a positive impact on sleep for the participants in the experimental group. Other studies that implemented exercise interventions of comparable weekly dosage also reported sleep improvements in individuals with ASD (Brand et al., 2015; Oriel et al., 2016). The control group in this study engaged in arts and crafts-based lessons and demonstrated slight changes (-3% to +4.5%) in sleep behaviour after participating. Despite the small number of participants enrolled in the study, we were able to observe positive significant changes in sleep as a result of the exercise intervention without the need for pharmacological support. Similar outcomes have been previously documented in children with TD in support of a robust bidirectional relationship between exercise and sleep, which

enticed our research team to investigate the relationship in children with ASD (Dolezal, Neufeld, Boland, Martin, & Cooper, 2017; Kline, 2014; Lin et al., 2018). In the current study, the strength of the findings is unclear given the small sample size, thus more research is needed with larger samples of children with ASD. Additionally, future studies should consider implementing longer interventions since continued participation in exercise may allow for steady change or even greater improvements in sleep.

The Canadian 24-hour movement guidelines recommend that children between the ages of 5-17 years participate in one hour of moderate to vigorous PA daily and obtain 8-11 hours of sleep per day (Tremblay et al., 2016). Currently, only 14% of children with ASD are meeting national PA guidelines and demonstrate the lowest participation in comparison to children with other developmental disabilities (Case et al., 2020). The exercise intervention from the current study only accounted for 20% of the recommended PA that children should obtain each week (Tremblay et al., 2016), yet the impact on sleep was statistically significant which speaks to the potential magnitude that exercise could have on sleep. That being said, the participants continued to experience problematic sleep at the post-test which indicates that the exercise intervention did not completely eliminate sleep challenges, however, if the participants actually met the daily PA guideline it is possible a more robust effect would be found. Oriel et al. (2016) conducted a study that included a follow-up assessment, 4 weeks after an aquatic exercise intervention, and found that sleep returned to similar patterns as before the intervention, which emphasizes the importance of regular and consistent participation in exercise.

Even though the benefits of exercise are well known, exercise may not be the primary concern for parents of children with ASD as other challenges (social, behavioural,

or communication) may take precedence, but exercise has been shown to benefit many children who experience challenging behaviours associated with ASD (Lang et al., 2010; Sowa & Meulenbroek, 2012). Specifically, research has demonstrated improved social interaction, behaviour, self-regulation, motor skills, physical fitness and quality of life after participation in exercise (Bremer et al., 2016; Healy et al., 2018; Lang et al., 2010; Sorensen & Zarrett, 2014; Sowa & Meulenbroek, 2012; Toscano et al., 2018). Sufficient sleep is also beneficial for children, particularly, brain structure and function, attention, working memory, academic performance, emotional regulation, adiposity, and quality of life (Chaput et al., 2016; Dutil et al., 2018; Vriend et al., 2013). In children with ASD, daytime behaviour (Mazurek & Sohl, 2016), adaptive functioning (Taylor, Schreck, & Mulick, 2012), and social skills (Malow et al., 2006) can be positively affected with sufficient sleep. Overall, sleep and exercise share similar health and behavioural outcomes, therefore, children with ASD who have sleep challenges may not experience many of the benefits associated with healthy sleep, but participation in exercise could counteract the impairments caused by poor sleep which the results of the current study have demonstrated.

The underlying cause of problematic sleep in children with ASD is unknown, but it is understood to be multi-faceted with connections to the core features of ASD as well as biological, neurodevelopmental, medical, and psychological factors (Mazzone, Postorino, Siracusano, Riccioni, & Curatolo, 2018; Richdale & Baker, 2014; Richdale & Schreck, 2009; Singh & Zimmerman, 2015). Some of the specific hypotheses include, circadian rhythm dysregulation, genetic factors (e.g. GABAergic system), hormonal (e.g. melatonin) and serum ferritin levels, problem behaviour (e.g. hyperactivity, and internalizing and externalizing problems), medical issues (e.g. gastrointestinal issues) as well as stress,

anxiety, and depressive symptoms (Richdale & Baker, 2014; Richdale & Schreck, 2009; Veatch et al., 2015). Exercise could potentially affect several of these poor sleep aetiologies, therefore, more research is needed on the effect of exercise on sleep in children and youth with ASD.

Problem behaviour was the only outcome assessed in the current study and has been well researched in relation to sleep challenges in children with ASD (Mayes & Calhoun, 2009; Mazurek & Sohl, 2016). For instance, Adams et al. (2014b) categorized 311 children with ASD based on the degree of their sleep problems and observed more challenging behaviour in the group that experienced more severe sleep difficulties. Similarly, 1784 children with ASD participated in a study by Goldman et al. (2011) who found a significant difference in problem behaviour between "poor sleepers" and "good sleepers". Furthermore, more than 50% of "poor sleepers" experienced problems with hyperactivity, anxiety, sensory issues, attention span, social interactions, and self-stimulatory behaviour (Goldman et al., 2011). Meanwhile, exercise has been shown to improve behaviour in children with ASD (Bremer et al., 2016; Lang et al., 2010), therefore, it is possible that the change in behaviour following the exercise intervention may be the primary reason for the improvement in sleep. In other words, exercise may indirectly affect sleep by improving behaviour, but a detailed analysis of this complex relationship is needed in future research.

In addition to the standardized tools, parents answered questions on the post-intervention feedback form (Table 7) where the results presented mixed responses from both groups when asked if the intervention improved their child's sleep. In the experimental group, one parent shared that it took their child (participant 1) less time to fall asleep, whereas the parent of participants 3 and 4 thought both of their children continued to have

trouble getting to sleep. The parents from the control group also reported different observations; one parent did not see any improvement in their child's (participant 2) sleep and the other parent said that the intervention helped to make their child (participant 5) tired faster. The responses from the parents may have differed from the results on the sleep measures due to the detailed questions on the standardized tools as opposed to the generalized inquiry from the post-intervention feedback form. Parents have been shown to accurately report their child's sleep problems on standardized questionnaires (Goldman et al., 2012) although asking whether the parents noticed a difference may have indicated if they actually observed an improvement which could be more meaningful for parents. It is important to consider parental well-being since research has shown that parental mood, stress, sleep, and daytime functioning can be negatively affected when their children with ASD have problematic sleep (Hoffman et al., 2008; Meltzer, 2008; Meltzer & Mindell, 2007). Ultimately, the goal of the present study was to positively impact the lives of children with ASD and their families so the fact that one parent noticed a difference after the exercise intervention amongst this small sample demonstrates potential value for exercise. Three parents perceived that their children enjoyed the exercises and activities from the interventions on the parent feedback form although more elaborate assessments are necessary to determine the satisfaction, feasibility, facilitators, and barriers of these specific programs.

The second objective of the study was to determine the effect of a 4-week exercise intervention on problem behaviour in children with ASD. Improvements in behaviour were see in both groups post-intervention; the experimental group had a 20% decrease in raw score whereas the control group had a 10% decrease in raw score (Table 5). The group

averages were considered to be within the clinical range at the pre- and post-test, but further analysis of the results at the post-test revealed that two participants, one from each group, had demonstrated problem behaviour within the borderline clinical range (Figure 9 and 10). Therefore, the results are consistent with previous research that suggests exercise can positively influence behaviour in children with ASD (Bremer et al., 2016; Lang et al., 2010; Sowa & Meulenbroek, 2012). Even though the results were not statistically significant, it is important that both groups from the current study demonstrated large (10-20%) improvements in problem behaviour as this change can be clinically meaningful for parents and families. Previous literature has demonstrated problem behaviour as a predictor of maternal and paternal stress as well as family quality of life (McStay, Trembath, & Dissanayake, 2014; Tehee, Honan, & Hevey, 2009). Future research should explore the effectiveness of exercise interventions on behavioural outcomes as it can positively affect the parents and families. Interestingly, the results also presented a connection between the arts and crafts program and behaviour given that the control group showed reductions in problem behaviour from pre- to post-assessment (D'Amico & Lalonde, 2017; Epp, 2008). Overall, the arts and crafts program proved to fulfil its purpose by improving other challenging areas for children with ASD and allowing the researchers to compare sleep in children under different activity intensities.

It was not within the scope of the present study to understand how exercise could have impacted sleep physiologically, however, the inclusion of behavioural assessments in the methods allowed us to explore potential connections to sleep based on the literature in this area. Research has shown that the behavioural profile of children with ASD is considered to be one of the etiological explanations for problematic sleep (Richdale &

Schreck, 2009). More specifically, previous studies have reported associations between internalizing and externalizing behaviour and sleep problems in children with ASD (Mayes & Calhoun, 2009; Mazurek & Sohl, 2016; Reynolds et al., 2017; Richdale & Schreck, 2009) where some researchers have proposed a potential bidirectional relationship (Adams et al., 2014b; Hollway & Aman, 2011). The baseline results from the current study appear to be consistent with the trends of previous literature. The Child Behaviour Checklist yielded scores that were considered to be within the clinical range for all participants in addition to the parent-reported sleep measures that classified four out of five participants as having problematic sleep. In other words, sleep difficulties and problem behaviour appear to co-occur in the participants at clinical levels suggesting there may be an association (Hollway & Aman, 2011), but more research is needed to better understand the relationship. Consideration of the post-test results of the experimental group further supports the potential for an association between behaviour and sleep since they improved in both areas after the exercise intervention. However, this was not the case for the control group who showed a decrease in problem behaviour score and minimal changes with their sleep which indicates sleep and behaviour did not improve simultaneously. Conversely, it is possible that exercise affected other aspects related to the etiology of problematic sleep as previously discussed and that behaviour was independently affected by exercise. Future research should continue to explore the relationship between behaviour, sleep, and exercise in children with ASD.

The Physical Activity Questionnaire for Older Children was used to rate the children's participation in PA before the start of the study to gauge their general activity levels. The experimental group had an average rating between moderate to high levels of

PA at baseline (Figure 11). Despite the fact that the PA data was self-reported, previous research has used this tool for children with ASD (Kamal Nor et al., 2019). Kamal Nor et al. (2019) incorporated this questionnaire into their methods and documented similar scores when comparing characteristics in overweight/obese and healthy weight/underweight children with ASD. Furthermore, a study that involved children with TD, found that a value equal to, or more than 2.9 for males and 2.7 for females was considered to be "sufficiently active" (Voss, Ogunleye, & Sandercock, 2013). In this study, four out of five participants were above this cut-off value at baseline. That being said, it is possible that the families were attracted to this type of program because of their previous involvement and interest in PA leading to a bias in the sample; future research needs to engage with a representative sample of children with ASD. Wachob and Lorenzi (2015) found that the more active children with ASD presented higher sleep quality, however, the baseline scores from the current study appear to contradict these findings. For example, the participant (P2) with the lowest PA score has less sleep challenges and the participant (P5) with the highest PA score presents some of the worst sleep scores. The conflicting pattern may be related to the characteristics of the participants, such as the complex diagnostic profile of P5 and/or the high activity level reported by P5 which is uncommon in children with ASD (Case et al., 2020). Overall, our results are not consistent with the literature in this relatively new area of research; however, subjective estimates of participation in PA may not be an effective method to evaluate a relationship between exercise and sleep.

Unexpectedly, there was a significant difference between the groups from pre- to post-assessment on the Physical Activity Questionnaire for Older Children in which the experimental group demonstrated a lower PA score at the post-test while the control group

stayed at the same score (Figure 11). By offering a program two times per week it was anticipated that the additional amount of exercise would be reflected on the final score of the participants in the experimental group but instead, the experimental group was no longer considered to be "sufficiently active" (Voss et al., 2013). There are a few possibilities that may be linked to this unique finding; first, the tool requires children to recall their participation in PA throughout an entire week which is inclusive of their time at school (recess, lunch, and/or physical education classes). During the final week of the intervention period when the post-test data was collected, the participants missed up to three days of school on account of a programmed day off (professional activity day) for public school children in addition to two days' home due to a provincial wide strike. Therefore, it is possible their responses on the questionnaire were not a clear indication of their usual activity levels due to the disruption in their weekly schedules. Another possibility is that this questionnaire is recommended for children between the ages of 8-14 years which suggests that the questions are tailored for children of older ages, however, the 6-year-old participant also completed this form. Originally, the age range of the study was 8-10, but it was lowered to six after experiencing difficulty with recruitment so, the younger age of the participant may have affected their responses. Finally, it is possible that the pre-test scores could have been overestimated by the participants which is often (72%) the case with indirect measures of PA (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009). For instance, a study by Corder et al. (2010) found that 40% of inactive children overestimated their activity level, therefore, compensatory behaviour may have contributed to the unexpected decrease in PA score from pre-test to post-test. Overall, the results of the Physical Activity Questionnaire for Older Children for the experimental group may have

been lower at the post-assessment due to inconsistent school attendance, age restrictions of the tool, and heightened scores on the pre-assessment.

The final aim of this study was to determine whether the use of a rating of perceived exertion scale was feasible for children with ASD by measuring the participants' effort from the perspective of the child, parent, and instructor. The interventions were designed to be a specific range of intensity; the exercise intervention targeted moderate to vigorous intensity while the arts and crafts program was intended to be a very light to light intensity. The researcher has an undergraduate degree in Kinesiology and experience in similar programs for children of all abilities which contributed to the appropriate design of the interventions. According to the effort demonstrated by the children and the ratings of perceived exertion, the targeted intensities were met. Specifically, the average rating of the experimental group was within the moderate to vigorous range whereas the control group rated their efforts within the light range (Table 6). Ideal measures of PA and exercise include heart rate monitors, accelerometers, or pedometers, as they provide more accurate and objective indications of exertion or level of participation in PA (Gammon et al., 2016; Pescatello, 2014). The use of an objective tool was not deemed to be feasible for the present study as children with ASD as they often experience more sensitivities than other children, especially with touch (Srinivasan et al., 2014). Moreover, rating of perceived exertion has rarely been used for children with ASD. The instructor focused on participation and physical responses of exercise, such as breathing rate or talking capability, to contribute to the ratings of exertion (Bozinovski et al., 2009). We can infer that the design of the two programs was relatively accurate since all participants rated their exertion close to what was expected in addition to the similarity in the ratings between each child and instructor.

Therefore, the results of the current study suggest that children with ASD may be able to accurately rate their exertion. Incorporating rating of perceived exertion was a form of acknowledging fidelity of the sessions in addition to evaluating the utility of the pictorial scale for children with ASD; ultimately, the findings of the current study indicate that an exercise intervention of moderate to vigorous intensity can lead to positive changes in sleep.

Strengths and Limitations

As with all studies, there are strengths and limitations of this research that need to be addressed. Generally, the implementation of exercise interventions to improve sleep behaviour in children with ASD is not well researched, but this is one of the first studies to compare two groups of children with ASD. Therefore, this study provides a foundation for future research to compare sleep behaviour in children with ASD under different movement conditions. Additionally, the mode of exercise (obstacle courses, circuits, and fun and active games) used for experimental group is unique to this study and proved to be effective for the participants as measured by the rating of perceived exertion scores. In particular, the exercise intervention consisted of a number of safe, age-appropriate, and enjoyable activities which may have helped to maintain the interest of the participants and adherence to the program (Lang et al., 2010). Approximately one third of the sessions was devoted to active games which were similar to traditional childhood games (e.g. variations of tag), therefore, they could be easily transferred outside of the instructional environment. Another strength of this study was the opportunity for the participants to self-report, which is not common amongst research involving children, specifically, children with developmental disabilities (Foley et al., 2012). This is important since the children were personally

experiencing challenges with sleep and it is possible they could provide more insight to the problem than their parents.

The small sample size was one of the limitations of this study and therefore results should be interpreted cautiously as this study was underpowered to detect differences. The researchers only intended to recruit 10-12 participants with ASD, however, only five children enrolled in the study. Recruitment for this study was slow which prompted the research team to re-evaluate the parameters of the study design and led to the expansion of the age range. The delayed response could have been related to the timing of the recruitment process and/or the commitment required to participate fully in the study. It has also been recognized that recruitment for experimental studies can be challenging (Page & Persch, 2013). The initial advertisements for the study were posted in early fall which is a busy time for most families and the period when most of the fall after-school programs begin. Registration for these programs typically opens in the summer, therefore, it is possible that the children and families had obligations prior to their knowledge of this opportunity. Additionally, two nights a week could be too much of a commitment for some families; this was the case for the participants in the control group. Once the age range was adjusted, a few interested families contacted the research team, but eventually the researchers made the decision to begin the study with five participants. Another limitation of the study was the lack of random assignment which was dictated by the availability of the families. The sleep tools could be considered a strength of the study since they are well validated for children with TD and in some cases, children with ASD, however, the Sleep Disturbance questionnaires have not been previously used, to our knowledge, for children with ASD. Furthermore, a modified version of the Children's Sleep Habits Questionnaire

for children with ASD was only validated in one study, therefore, the subjective measures were considered a limitation. Moreover, the high activity levels of the participants could have attracted the children and their families to this type of study which could be considered a bias of the study. In addition, the researcher had previously worked with two of the participants which could have contributed to the success of the program due to participant compliance and familiar activity modification strategies for these individuals. Despite these limitations, this study was the first to use an exercise intervention consisting of obstacle courses, circuits, and active games to improve sleep behaviour.

Future Research

Understanding the relationship between sleep and exercise in children with ASD is a generally new subject of research and the results from the current study highlights areas that should be expanded upon in future research. Further exploration of exercise to improve sleep behaviour in children with ASD should be pursued. Specifically, researchers should consider a larger sample size, longer exercise interventions, and objective measures of sleep and exercise in addition to girls and attention deficit hyperactivity disorder as variables in future studies. First, one of the limitations of the current study was the small number of participants, therefore, the sample is not entirely representative of children with ASD. Researchers should aim to include more participants and a diverse sample of children with ASD of varying levels of functioning. Furthermore, the current study used obstacles courses, small circuits, as well as fun and active games of a moderate to vigorous intensity as the main exercise activities; future studies should consider alternative modes of exercise. More importantly, researchers should prioritize exploring the most effective quantity of exercise to improve sleep behaviour in children with ASD. Finally, the current study

employed subjective tools to assess exercise and sleep, however, objective measures should be considered for more conclusive results.

Conclusion

In summary, the current study aimed to improve problematic sleep behaviour in children with ASD through an exercise intervention as an initial step to better understanding the effects between these variables in children with ASD. Following the intervention, a significant improvement was demonstrated in the participants from the experimental group in comparison to the control participants on the Sleep Disturbance Parent Proxy short form. This finding in addition to the improvements on the other sleep measures are a promising indication that exercise could lead to positive change in sleep behaviour, but more research is warranted to fill in the gaps from the current study. As a secondary objective, problem behaviour was assessed prior to and following the intervention where both groups showed improvements, but the experimental group displayed a larger change. Additionally, the children in the experimental group reported a decrease in PA summary score after the exercise intervention whereas the control group reported the same score at the post-test. Lastly, a rating of perceived exertion scale was incorporated into the study procedures to explore the feasibility in children with ASD and as a result, the participants showed effective utilization with the tool.

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CHAPTER 4: CONCLUSION

Summary

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder described by challenges with social and behavioural skills that affects 1 in every 66 children in Canada (American Psychiatric Association, 2013; Public Health Agency of Canada, 2018). In addition to the diagnostic criteria, children with ASD often experience problematic sleep behaviour, such as bedtime resistance, delayed sleep onset, waking after sleep onset (WASO), and/or early waking (Hodge, Carollo, Lewin, Hoffman, & Sweeney, 2014; Richdale & Prior, 1995; Wiggs & Stores, 2004). Sleep difficulties are reported in approximately 44-83% of children with ASD and often persist into adolescence and adulthood (Hodge et al., 2014; Richdale & Prior, 1995). Poor sleep can have a negative effect on multiple developmental domains in children with ASD, therefore, it is important to intervene to minimize those effects, not only for the child's well-being and quality of life, but the whole family as well (Veatch, Maxwell-Horn, & Malow, 2015). That being said, non-pharmacological approaches to manage sleep such as exercise, could also be beneficial to other challenging areas of development in children with ASD.

It is also common for children with ASD to demonstrate low levels of participation in physical activity (PA) and exercise in comparison to children with typical development (TD) and some other developmental disorders (Case, Ross, & Yun, 2020; MacDonald, Esposito, & Ulrich, 2011; Tyler, MacDonald, & Menear, 2014). Furthermore, it has been shown that as individuals with ASD get older, their participation in PA and exercise continuously decreases (Pan & Frey, 2006). However, exercise has been shown to be beneficial for children with ASD by improving social and behavioural skills as well as physical fitness, psychological health, and quality of life (Lang et al., 2010; Sowa &

Meulenbroek, 2012; Toscano, Carvalho, & Ferreira, 2018). Further exploration was needed to better understand whether exercise can also have a positive effect on sleep behaviour in children with ASD.

Children with TD demonstrate a bidirectional relationship between sleep and exercise (Baldursdottir, Taehtinen, Sigfusdottir, Krettek, & Valdimarsdottir, 2017; Lang et al., 2013; Lin et al., 2018; Nixon et al., 2009; Stone, Stevens, & Faulkner, 2013) although this relationship is not well understood in children with ASD. As previously mentioned, sufficient sleep and participation in exercise share similar health and behavioural outcomes, in addition, exercise can positively affect many of the potential aetiologies of sleep challenges in children with ASD, therefore, it is possible that exercise indirectly affects sleep behaviour by improving the symptoms associated with poor sleep. Of the few studies that have investigated the bidirectional association between sleep and exercise in recent years, significant correlations have been reported, suggesting that individuals with ASD who participate in less PA and exercise, also experience more sleep difficulties (Benson et al., 2018; Wachob & Lorenzi, 2015). Other researchers have intervened in a unidirectional manner to analyze the effects of increased participation in exercise on sleep in children with ASD which also produced positive findings (Brand, Jossen, Holsboer-Trachsler, Puhse, & Gerber, 2015; Oriel, Kanupka, DeLong, & Noel, 2016). More specifically, aquatic, aerobic and motor skill interventions were effective at improving sleep duration, sleep latency, and WASO, although other modes of exercise need to be studied. The current study aimed to improve sleep behaviour through the implementation of an exercise intervention for children with ASD between the ages of 6-10 years while

comparing the results to a control group. In addition, behavioural outcomes and the feasibility of a rating of perceived exertion scale were assessed.

Our findings were consistent with previous research given that majority of the participants had problematic sleep based on the parent-reported Children's Sleep Habits Questionnaire and Sleep Disturbance Parent Proxy short form. Additionally, all children in the current study recognized their own sleep challenges using the self-report Sleep Disturbance questionnaire; four out five parents and participants were in agreement that the participants had sleep disturbances that were considered to be worse than average. It is important to consider the perspective of the children in addition to parent report when assessing sleep behaviour, since it could provide insight that their parent(s) cannot capture. Following the exercise intervention, all participants demonstrated improvements in sleep behaviour which was consistent on all sleep measures, with a statistically significant difference between the experimental and control group from pre- to post-test on the Sleep Disturbance Parent Proxy short form. Sleep behaviour improved significantly after implementing only 20% of the national moderate to vigorous PA recommendations into their weekly routines.

Moreover, our secondary findings suggest that all participants demonstrated problem behaviour that was considered to be within the clinical range at the pre-test. Both groups showed improvements in problem behaviour at the post-assessment although the experimental group experienced greater improvements. The results from the Physical Activity Questionnaire for Older Children demonstrated a decrease in PA summary score within the experimental group from pre-test to post-test, but the score of the control group did not change. Furthermore, the rating of perceived exertion scale was shown to be

effective for children with ASD in that the groups rated their exertion within the targeted ranges. The current study also highlighted unique findings in terms of sex, and comorbid conditions, that warrant further investigation in future studies. The results on the sleep measures indicate that the female participants experienced more problematic sleep than the male participants. In addition, more sleep challenges were present in the participants with ADHD than the participants who did not have any comorbid conditions.

Sleep Problems, Exercise & WHO-ICF

The World Health Organization International Classification of Functioning, Disability and Health (WHO-ICF) is a framework used to describe health and health-related conditions and functioning (World Health Organization, 2001). It contains multiple components that must be considered for the methods and results of the current study in which the activity and participation factors were the most relevant components of the model. The 'activity' refers to the participants' sleep behaviour which, based on the literature, is often limited in children with ASD (Richdale & Prior, 1995); in other words, sleep is applicable to the 'activity' section. The baseline results indicated that four out of five parents reported problematic sleep in their children and all participants reported disturbances with their own sleep suggesting that there was a limitation in the 'activity'. Conversely, the 'participation' section describes an individual's involvement in an activity with the consideration of any restrictions they may experience; for the current study, 'participation' is referring to exercise participation. Children with ASD demonstrate low levels of participation in PA and exercise (Case et al., 2020), therefore, this area was manipulated through the interventions with the intention of improving the 'activity' (sleep) in the experimental group. Following the exercise intervention, sleep improved on all

measures, one of which produced a significant improvement with the experimental group improving their sleep behaviour more than the control group. In other words, the 'activity' (sleep) improved by adjusting 'participation' (exercise) suggesting this study found a positive unidirectional interaction between exercise and sleep. The participants in the control group also experienced problematic sleep, but they did not increase their participation in moderate to vigorous exercise and as a result, demonstrated little change in sleep.

The other factors of the WHO-ICF framework that are important for understanding the health and functioning in children with ASD includes body structure and functions as well as personal and environmental factors. The presence of comorbid conditions, functional properties of sleep, and the possible aetiologies of sleep difficulties in children with ASD are incorporated into the body structures and functions component. More specifically, the participants that had a dual diagnosis of ASD and attention deficit hyperactivity disorder reported greater sleep difficulties compared to the participants with only ASD which could have an impact on the effects of exercise on sleep. The personal factors are related to age, sex, and the behavioural profile of the participants whereas the environmental factors include the intervention setting and structure as well as the environment within the home and bedroom of the participants. The results of the current study demonstrated that the female participants had more sleep challenges than the male participants. Having said that, there is a lower prevalence of ASD in girls, but the ASD phenotype can be different in females (Kreiser & White, 2014); therefore, future research should focus on sex differences in sleep. Moreover, a positive change in problem behaviour occurred in both groups of participants, but a greater improvement was reported in the

experimental group; it is possible that problem behaviour influences the relationship between sleep and exercise in children with ASD. The WHO-ICF framework provides a foundation to understand the effects of exercise on sleep behaviour in children with ASD in which the activity and participation components of the WHO-ICF framework were most applicable. Furthermore, the findings support a potential interaction between all components as demonstrated in the model, however, more research is needed to better understand the relationship between all factors highlighted in this study.

Recommendations

The research in the area of sleep behaviour and exercise in children with ASD is emerging and requires further investigation to better understand the complex relationship between sleep and exercise in children with ASD. The present study demonstrated promising results, but as with all research, this study had limitations that should be addressed in future research. Foremost, larger sample sizes that are inclusive of children with ASD of varying levels of functioning would provide a better understanding of exercise and sleep across the autism spectrum. Intervention duration and dosage (amount per session, and week) should also be a focal point of future research to observe the effects of consistent participation in exercise on sleep. Furthermore, alternative modes of exercise at a moderate to vigorous intensity should be studied in respect to sleep. Additionally, it is recommended that objective measures such as, actigraphy, accelerometers or heart rate monitors, be used in future research to gain a quantitative understanding of exercise and sleep as well as to explore the various sleep parameters such as sleep onset latency, WASO, and/or sleep efficiency in children with ASD. The current study also highlighted other areas that require further investigation such as the differences in sleep between males and

females in addition to sleep problems in children with multiple conditions (e.g. attention deficit hyperactivity disorder). The results provided insight into the potential for children with ASD to report their own sleep challenges which should be included in future studies. Moreover, children with TD demonstrate a reciprocal relationship between sleep and exercise which means there is potential for improved sleep to lead to increased participation in exercise in children with ASD. However, the current evidence is preliminary and researchers have yet to investigate the inverse side of the relationship in children with ASD; it is also suggested that researchers assess whether sleep leads to increased exercise participation in children with ASD. Overall, more research is needed to understand the relationship and effects between exercise and sleep in both directions as well as the variables identified in this study.

Practical Recommendations

The findings of the current study suggest that just 45 minutes of moderate to vigorous exercise, two times per week, had a positive effect on sleep behaviour even though children should be participating in at least 60 minutes of moderate to vigorous PA every day according to the Canadian guidelines (Tremblay et al., 2016). It is possible that meeting the minimum national recommendations could lead to even greater improvements in sleep in children with ASD which should be addressed in future research. Furthermore, the national guidelines emphasize an accumulation of activity, meaning the PA does not have to be the same uninterrupted activity; it is possible that constant moderate to vigorous activity is also not sustainable on a daily basis for children with ASD. Therefore, future studies should consider implementing short bouts of exercise throughout the day to analyze whether it is as effective at improving sleep and/or maintainable for children with ASD.

Furthermore, future studies should consider whether it is participation in an exercise program or meeting the daily PA guidelines that has the most beneficial outcome on sleep.

In terms of the mode of exercise, the exercise intervention combined a number of activities into each session including, a short period of running, obstacle courses, small circuits, as well as multiple fun and active games. Although the session was 45 minutes long, the activities were continuously changing allowing for momentary breaks during the transitions. This was effective and enjoyable for the participants in the experimental group, possibly due to the shorter bouts and the variety of the activities. In addition, the curriculum consisted of traditional childhood games (e.g. tag) with some modification to limit the competitive aspect (peer-to-peer) which may have allowed for the participants to adhere to the program and maintain motivation throughout the entirety of each session. In summary, interventions and programs should consider implementing similar types of activities and program structure, as it can be easily implemented in multiple environments for children of all abilities.

Conclusion

In conclusion, the purpose of the current study was to better understand the effects of exercise on sleep behaviour in children with ASD by providing an opportunity to participate in an exercise program which resulted in improved sleep following the intervention and was deemed feasible. The exercise intervention incorporated fun and active games that were adapted from traditional childhood games, that could be easily implemented into physical education classes, community programs, and/or at home. Furthermore, health care workers, education staff, and family members must work in partnership and make a conscious effort to encourage healthy behaviour in children with

ASD and implement regular exercise into their routines. This preliminary research is important for children with ASD and their families because of the numerous benefits associated with sufficient sleep and exercise.

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CHAPTER 5: APPENDICES

Appendix 1: Certificate of Approval & Amendment Approval from OntarioTech Research Ethics Board

Date:	*September 05, 2019*
To:	*Meghann Lloyd*
From:	*Paul Yielder, REB Vice-Chair*
File # & Title:	*15482 - The effects of an exercise intervention on sleep behaviour in children with Autism Spectrum Disorder*
Status:	***APPROVED***
Current Expiry:	***September 01, 2020***

Notwithstanding this approval, you are required to obtain/submit, to UOIT's Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The University of Ontario, Institute of Technology (UOIT) Research Ethics Board (REB) has reviewed and approved the research study named above to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 2014), the UOIT Research Ethics Policy and Procedures and associated regulations. As the Principal Investigator (PI), you are required to adhere to the research protocol described in the REB application as last reviewed and approved by the REB. In addition, you are responsible for obtaining any further approvals that might be required to complete your project.

Under the Tri-Council Policy Statement 2, the PI is responsible for complying with the continuing research ethics reviews requirements listed below:

Renewal Request Form: All approved projects are subject to an annual renewal process. Projects must be renewed or closed by the expiry date indicated above ("Current Expiry"). Projects not renewed 30 days post expiry date will be automatically suspended by the REB; projects not renewed 60 days post expiry date will be automatically closed by the REB. Once your file has been formally closed, a new submission will be required to open a new file.

Change Request Form: If the research plan, methods, and/or recruitment methods should change, please submit a change request application to the REB for review and approval prior to implementing the changes.

Adverse or Unexpected Events Form: Events must be reported to the REB within 72 hours after the event occurred with an indication of how these events affect (in the view of the Principal Investigator) the safety of the participants and the continuation of the protocol (i.e. un-anticipated or un-mitigated physical, social or psychological harm to a participant).

Research Project Completion Form: This form must be completed when the research study is concluded.

Always quote your REB file number (**15482**) on future correspondence. We wish you success with your study.

Sincerely,

Dr. Paul Yielder	Emma Markoff
REB Vice-Chair	Research Ethics Assistant
paul.yielder@uoit.ca	researchethics@uoit.ca

NOTE: If you are a student researcher, your supervisor has been copied on this message.

Date:	*December 12, 2019*
To:	*Meghann Lloyd*
From:	*Ruth Milman, REB Chair*
File # & Title:	*15482 - The effects of an exercise intervention on sleep behaviour in children with Autism Spectrum Disorder*
Status:	***CHANGE REQUEST APPROVED***
Current Expiry:	***September 01, 2020***

Notwithstanding this approval, you are required to obtain/submit, to Ontario Tech's Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The Ontario Tech Research Ethics Board (REB) has reviewed and approved the change request related to the research study named above. This request has been reviewed to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 2014), the Ontario Tech Research Ethics Policy and Procedures, and associated regulations. As the Principal Investigator (PI), you are required to adhere to the research protocol described in the REB application as last reviewed and approved by the REB.

Under the Tri-Council Policy Statement 2, the PI is responsible for complying with the continuing research ethics reviews requirements listed below.

Renewal Request Form: All approved projects are subject to an annual renewal process. Projects must be renewed or closed by the expiry date indicated above ("Current Expiry"). Projects not renewed 30 days post expiry date will be automatically suspended by the REB; projects not renewed 60 days post expiry date will be automatically closed by the REB. Once your file has been formally closed, a new submission will be required to open a new file.

Change Request Form: If the research plan, methods, and/or recruitment methods should change, please submit a change request application to the REB for review and approval prior to implementing the changes.

Adverse or Unexpected Events Form: Events must be reported to the REB within 72 hours after the event occurred with an indication of how these events affect (in the view of the Principal Investigator) the safety of the participants and the continuation of the protocol (i.e. un-anticipated or un-mitigated physical, social or psychological harm to a participant).

Research Project Completion Form: This form must be completed when the research study is concluded.

Always quote your REB file number (**15482**) on future correspondence. We wish you success with your study.

Sincerely,

Dr. Ruth Milman	Emma Markoff
REB Chair	Research Ethics Assistant
ruth.milman@uoit.ca	researchethics@uoit.ca

NOTE: If you are a student researcher, your supervisor has been copied on this message.

Appendix 2: Recruitment Approval from Grandview Children's Centre

OntarioTech UNIVERSITY

Tayler Runge <tayler.runge@ontariotechu.net>

FW: Grandview ethics Application

Angela Kielbowski <Angela.Kielbowski@grandviewkids.ca> Tue, Sep 24, 2019 at 5:00 PM
To: Meghann Lloyd <Meghann.Lloyd@uoit.ca>, "Dr. Carolyn Hunt" <Dr.Carolyn.Hunt@grandviewkids.ca>
Cc: Tayler Runge <tayler.runge@uoit.net>

Hi Meghann and Tayler,

I'm happy to inform you that after receiving your clarification about your study we have approved our participation in the recruitment portion. I have requested our Communications team to post this ASAP on the following platforms:

✓ Grandview's Facebook/Twitter https://www.facebook.com/GrandviewKids / @GrandviewKids

✓ Family Advisory Committee (closed Facebook page)

Should you have any questions, please contact me.

All the best and good luck with recruitment!

Angela

Angela Kielbowski

Research Assistant

Grandview Children's Centre

600 Townline Road South, Oshawa, ON L1H 0C8

(905) 728-1673 x 2547

angela.kielbowski@grandviewkids.ca

Stay connected to Grandview Kids

GrandviewKids.ca | Facebook | Twitter | Instagram | e-Newsletter |

GrandviewKids

Appendix 3: Informed Consent Form

Informed Consent: Exploring the Impact of Exercise on Sleep Behaviour in Children with Autism Spectrum Disorder

Investigators:

Tayler Runge	Faculty of Health Sciences University of Ontario Institute of Technology 905-721-8668, ext. 5988 tayler.runge@uoit.net
Dr. Meghann Lloyd	Faculty of Health Sciences University of Ontario Institute of Technology 905-721-8668, ext. 5308 (office) ext. 5988 (lab) meghann.lloyd@uoit.ca

Introduction

You are invited to participate in a research study entitled *Exploring the Impact of Exercise on Sleep Behaviour in Children with Autism Spectrum Disorder*. You are being asked to take part in a research study. Please read the information about the study presented in this form. The form includes details on study's procedures, risks and benefits that you should know before you decide if you would like to take part. You should take as much time as you need to make your decision. You should ask the Principal Investigator (PI) or study team to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish including your family and friends. Participation in this study is voluntary.

This study has been reviewed and received by the University of Ontario Institute of Technology (Ontario Tech University) Research Ethics Board [REB #15482] on September 5th, 2019.

Background and Rationale:

The purpose of this project is to investigate if an exercise intervention is effective at improving sleep behaviour in 6-10 year-old children with Autism Spectrum Disorder (ASD). We will measure sleep behaviour, physical activity levels and behavioural

characteristics and explore the feasibility of a perceived exertion scale in children with ASD.

Why is this work important?

Children with ASD often experience poor sleep, most commonly related to difficulty initiating and/or maintaining sleep. Additionally, children with ASD demonstrate low levels of participation in physical activity and exercise. Both, physical activity and sleep, are important for physical and mental health in children and achieving the Canadian recommendations (9-11 hours of sleep, less than 2 hours of sedentary activity, several hours of light physical activity, and 1 hour of moderate to vigorous physical activity) can provide greater health benefits. In children with typical development, sleep and physical activity positively influence one another however, it is not well understood in the ASD population. Promising results have been demonstrated from studies in recent years suggesting physical activity and exercise could be a feasible and non-pharmacological method to improving sleep behaviour in children with ASD; although, a better understanding is needed.

Study Procedures:

Children who participate in this study will be randomly assigned to an intervention or control group. One group will participate in an exercise intervention while the other group participates in a fine motor and social skills (arts and crafts) intervention. The participants in the arts and crafts program will have an opportunity to participate in the exercise intervention after the interventions and assessments.

We will ask you and your child to visit the UOIT (Ontario Tech University) Motor Behavior and Physical Activity Lab for 2 separate 1-hour assessment sessions (before and after the interventions), in addition to, the 4-week intervention programs which will occur 2 times per week for 45-minutes per session (6 hours total). Each child will be assessed individually with his/her parent/guardian present. You and your child will also be asked to provide a rating of perceived exertion of the child efforts during the program after each session.

Study Plan:

Group A	Group B

Pre-test (1 hour)
- Demographic Information Form (pre-test only)
- Anthropometric measurements
  - Height
  - Weight
- Sleep (questionnaires)
  - Children's Sleep Habits Questionnaire
  - PROMIS Sleep Disturbance Questionnaire
- Physical Activity (questionnaire)
  - Physical Activity Questionnaire for Older Children
- Behavioural Skills (questionnaire)
  - Child Behaviour Checklist
	Pre-test (1 hour)
	- Demographic Information Form (pre-test only)
	- Anthropometric measurements
	  - Height
	  - Weight
	- Sleep (questionnaires)
	  - Children's Sleep Habits Questionnaire
	  - PROMIS Sleep Disturbance Questionnaire
	- Physical Activity (questionnaire)
	  - Physical Activity Questionnaire for Older Children
	- Behavioural Skills (questionnaire)
	  - Child Behaviour Checklist

Exercise Intervention (6 hours total) 45 minutes, 2 times per week for 4 weeks	**Control Intervention (6 hours total)** 45 minutes, 2 times per week for 4 weeks
Post-test (1 hour) - Post-Intervention Parent Questionnaire (post-test only) - Repeat all measures	**Post-test (1 hour)** - Post-Intervention Parent Questionnaire (post-test only) - Repeat all measures
	Exercise Intervention (6 hours total) 45 minutes, 2 times per week for 4 weeks

More details about each part of the study are included below:

- A demographic information form will be completed at the initial assessment to provide more details about the demographic and diagnostic information about the child and identify the differences between the participants.

- Anthropometric measurements (height and weight) will be collected at both assessments.

- Sleep behaviour will be measured using the Children's Sleep Habits Questionnaire (CSHQ) and the PROMIS Sleep Disturbance Questionnaire. The CSHQ is one of the most common assessment of sleep habits for children. The PROMIS Sleep Disturbance Questionnaire is used to assess sleep characteristics in children. These tools will provide us with a better understanding of your child's sleep problems. The sleep evaluation tools will be measured at both assessment points.

- Physical activity levels will be assessed using the "Physical Activity Questionnaire for Older Children (PAQ-C)". The PAQ-C is a standardized questionnaire that parents will complete with their children to evaluate their child's participation in physical activity. This questionnaire will be completed at both assessments.

- Behaviour will be assessed with a standardized questionnaire called the "Child Behaviour Checklist-6-18 (school-age). This questionnaire will ask you to rate your child's behavioural skills and any challenges they experience. This questionnaire will be completed at both assessments.

- The exercise intervention will focus on achieving moderate to vigorous intensity of physical activity. It will take place at the Motor Behaviour and Physical Activity Lab at UOIT (Ontario Tech University) and will be run by highly trained students. Each intervention session will consist of a warm-up, fun run, obstacle course, circuit, active group games and a cool-down. The sessions will run for 45-minutes per session, 2 times per week for 4 weeks – 6 hours of exercise total.

- The arts and crafts intervention will target fine motor and social skills. It will take place at the Motor Behaviour and Physical Activity Lab at UOIT (Ontario Tech University) and will be run by highly trained students. Each intervention session will consist of instruction and demonstration of the crafts/activities, individual material preparation, the completion of 2 crafts/activities that follow a different theme at each session and a debrief. The sessions will run

immediately after the exercise group for 45-minutes per session, 2 times per week for 4 weeks – 6 hours of exercise total.

- A 3-5 item parent questionnaire will be completed at the post-assessment about your perceptions of any changes post-intervention and the effectiveness of the program

Risks and Benefits:

Your child's participation in this study does not pose any risk that differs from what they would normally encounter in daily life. All physical activities are similar to standard physical education and sport/recreation activities. As with any physical activity, there is a risk of falling, however, all the equipment is standard physical education equipment and safety is our first priority. All arts and crafts activities are similar to standard arts classes in school or in the community. In the event of an injury, the facility's standard emergency procedures will be followed. In the event that your child suffers injury as a direct result of participating in this study, normal legal rules for compensation will apply. By signing this consent form you are in no way waiving your legal rights or releasing the investigator and the sponsor from their legal and professional responsibilities.

Your child will potentially benefit from this study by receiving valuable physical activity and fine motor training which may help to improve their sleep, motor skills, social interactions and behavioural skills. The research findings will also help to shape future exercise interventions that will potentially help other children to become healthier.

Use and Storage of Data:

All participant data will be kept secure in the Motor Behaviour and Physical Activity Lab. The building has controlled access where a key-code is necessary to enter the building, the lab is locked and all files are kept in locked filing cabinets. Participant names will only be found on the consent forms signed by the parents, from that point on, all participants will be given a unique identifier for paper protocols. Publication of research findings will only contain de-identified data.

Electronic data will be encrypted and stored on the secure UOIT (Ontario Tech University) Google drive where only select members of the research team have access. Additionally, all data files will be password-protected. No electronic data will be housed on a USB key or external drive. All data will be stored on the secure UOIT (Ontario Tech University) google drive.

Confidentiality:

The data collected in this study is used for current research and will be secured safely. With the exception of the consent form, all information that you and your child provide will be numbered and will not contain names. All information collected during this study, including you or your child's personal information, will be kept confidential and will not be shared with anyone outside the study unless required by law. You and your child will not be named in any reports, publications, or presentations that may come from this study. Overall results may be published for scientific purposes, but the participant's identity will remain confidential. Limits of this confidentiality include situations of suspected child abuse, concerns of harm to self or others, or any request for information by court order.

Right to Withdraw:

You are free to withdraw your child at any time without penalty. If you choose to withdraw, any data that has been collected from your child will be destroyed and will not be used in any analyses, publications or further research. If you wish to withdraw your child from the study you can do so by contacting one of the investigators by telephone or email (see contact information above).

Debriefing and Dissemination of Results:

Upon completion of the study, you will be provided with a summary of your child's results. This will be provided approximately 2 months after the study is completed in the form of document sent to you via email. The results will demonstrate the assessments at the two time points (before and after the intervention).

Questions about the study:

If you have any questions about this study, please contact Tayler Runge at 905-721-8668, ext. 5988 or Dr. Meghann Lloyd at 905-721-8668, ext. 5308 (office) or ext 5988 (lab). This study has been approved on September 5th, 2019 by the University of Ontario Institute of Technology (Ontario Tech University) Research Ethics Board (REB #15482), which is a committee of the university whose goal is to ensure the protection of the rights and welfare of people participating in research. The Board's work is not intended to replace a parent/guardian or child's judgment about what decisions and choices are best for you. By signing this form, you do not give up any of your legal rights against the investigators, sponsor or involved institutions for compensation, nor does this form

relieve the investigators, sponsor or involved institutions of their legal and professional responsibilities. If you have any questions about your child's rights as a research participant you may contact the University of Ontario Institute of Technology (Ontario Tech University) Research Ethics Board at 2000 Simcoe St. N., Oshawa, On, L1H 7K4, 905-721-8668, ext. 3693 or researchethics@uoit.ca

Informed Consent to Participate: Exploring the Impact of Exercise on Sleep Behaviour in Children with Autism Spectrum Disorder

I, _____,
(Your Name)

the parent/guardian of _____ :
(Your Child's Name)

☐ **Give consent** to my child's participation in the above study.

OR

☐ **Do not** give consent for my child to participate in this study.

I have read and understood the attached information sheet or had the attached information sheet verbally explained to me, and have received a copy of this consent form. I have been fully informed of the details of the study and have had the opportunity to discuss my concerns. I understand that I am free to withdraw my child at any time or not answer questions. I understand that by consenting, I do not waive any legal rights or recourse.

☐ I am willing to receive further information regarding future research studies that my child may be eligible for.

Email: _____

Name of Child

Name of Parent/Guardian

Contact Phone Number

Signature of Parent/Guardian

Date

Appendix 4: Child Assent Form

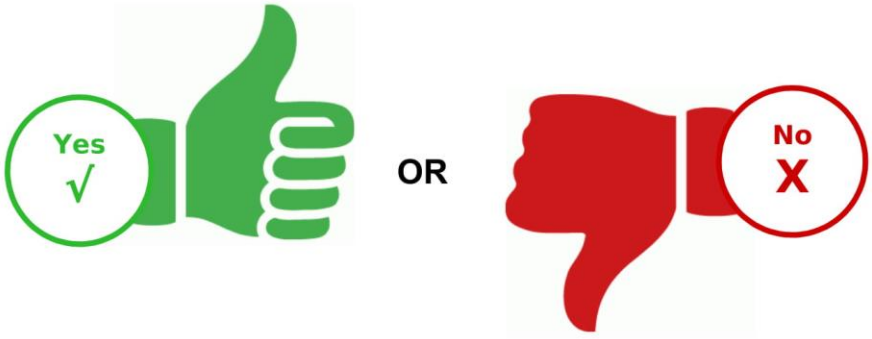
Child Assent Form

Hi _____, your mom/dad/guardian has said it is okay for you to be part of my research project and an exercise or an arts and crafts program; but first I want to ask you it is okay with you. The reason we are doing this project is to help us understand more about your sleep and whether being active helps you sleep.

We will ask you a few questions about different activities you are involved in. You will also get to play in a program with other kids your age. You will get to practice your skills through different games and activities in the program.

You don't have to participate if you don't want to, and the information you tell us won't be shared with anyone except you and your parents. You can decide to stop the study at any time.

Do you want to participate in this project?



The researcher will record the answer indicated by the participant. If the child says or points to "yes", the researcher will circle "yes"/thumbs up. If the child says or points to "no", the researcher will circle "no"/thumbs down.

Ontario Tech University | 2000 Simcoe Street North, Oshawa, Ontario L1G 0C5 Canada | ontariotechu.ca

Appendix 5: Recruitment Flyer

OntarioTech UNIVERSITY

Do you or someone you know, have a child
6-10 years of age with Autism Spectrum Disorder that experiences difficulty with sleep?

We are looking for 8-10-year-old children with ASD to participate in an exercise program conducted by UOIT researchers. This study is examining the impact of exercise on sleep behaviour.

For more information, CONTACT TAYLER RUNGE OR MEGHANN LLOYD:

905-721-8668 EXT. 5988

tayler.runge@uoit.net

meghann.lloyd@uoit.ca

REB#15482

905-721-8668, EXT. 3693

compliance@uoit.ca

Ontario Tech University | 2000 Simcoe Street North, Oshawa, Ontario L1G 0C5 Canada | ontariotechu.ca

Appendix 6: Demographic Information Form

Demographic Information Form

This form includes questions about your child that will help to describe the information we learn through this study and identify factors that may relate to children's rate of progress and development. Please feel free to ask questions if you would like further clarification. All questionnaires are optional.

1. Participant ID #: _____
2. Birth Date: _____ (day, month, and year)
3. What is your child's diagnosis? (i.e. ASD, Asperger's syndrome, PDD, PDD-NOS)?

   _____
4. At what age did your child receive their diagnosis? _____
5. Has your child also been diagnosed with any of the following?

☐ Anxiety	☐ Learning Disability
☐ Attention Deficit Disorder	☐ Operational Defiant Disorder
☐ Attention Deficit Hyperactivity Disorder	☐ Seizures
☐ Developmental Delay	☐ Sensory Integration Disorder
☐ Epilepsy	☐ Visual Problems
☐ Intellectual Disability	☐ Other: _____

6. Please list any medications your child is currently taking:

_____

_____

_____

7. Please briefly describe any issues that your child experiences with their sleep.

_____

_____

_____

_____

Page **1** of **2**

8. Has your child ever received any motor interventions (i.e. physical therapy, occupational therapy)? If yes, please specify from what age and the duration.

_____

_____

_____

9. Is your child currently receiving any other form of therapy (i.e. speech-language, ABA-based services, etc.)? If yes, please specify type and duration.

_____

_____

_____

10. Please self-declare your child's ethnicity using the options below:
(consistent with Statistics Canada, 2011)

- ☐ Aboriginal
- ☐ Chinese
- ☐ Korean
- ☐ Southeast Asia
- ☐ Arab/West Asian
- ☐ Filipino
- ☐ Latin American
- ☐ White
- ☐ Black
- ☐ Japanese
- ☐ South Asian
- ☐ Undeclared
- ☐ Bi-racial
- ☐ Other:_____

11. Please indicate the highest level of education completed by each parent:

Mother:_____ Father: _____

12. Please estimate the annual household income (optional):

- ☐ Under $20,000
- ☐ $20,000 – $39,000
- ☐ $40,000 – $59,000
- ☐ $60,000 – 79,000
- ☐ $80,000 – $99,000
- ☐ Over $100,000

Appendix 7: Modified Children's Sleep Habits Questionnaire

Child's Sleep Habits
(Preschool and School-Aged)
(Modified Version)

_____
Coding

The following statements are about your child's sleep habits and possible difficulties with sleep. Think about the past week in your child's life when answering the questions. If last week was unusual for a specific reason (such as your child had an ear infection and did not sleep well or the TV set was broken), choose the most recent typical week. Answer USUALLY if something occurs **5 or more times** in a week; answer SOMETIMES if it occurs **2-4 times** in a week; answer RARELY if something occurs **never or 1 time** during a week. Also, please indicate whether or not the sleep habit is a problem by circling "Yes," "No," or "Not applicable (N/A)".

Sleep Initiation and Duration

Write in child's bedtime: _____

Child's usual amount of sleep each day: _____ hours and _____ minutes
(combining nighttime sleep and naps)

	3 Usually (5-7)	2 Sometimes (2-4)	1 Rarely (0-1)	Problem?		
Child sleeps the right amount	☐	☐	☐	Yes	No	N/A
Child sleeps the same amount each day	☐	☐	☐	Yes	No	N/A
Child sleeps too little	☐	☐	☐	Yes	No	N/A
Child falls asleep within 20 minutes after going to bed	☐	☐	☐	Yes	No	N/A
Child struggles at bedtime (cries, refuses to stay in bed, etc.)	☐	☐	☐	Yes	No	N/A
Child goes to bed at the same time at night (R)	☐	☐	☐	Yes	No	N/A

Sleep Anxiety and Co-sleeping

	3 Usually (5-7)	2 Sometimes (2-4)	1 Rarely (0-1)	Problem?		
Child needs parent in the room to fall asleep	☐	☐	☐	Yes	No	N/A
Child is afraid of sleeping alone	☐	☐	☐	Yes	No	N/A
Child falls asleep alone in own bed (R)	☐	☐	☐	Yes	No	N/A
Child falls asleep in parent's or sibling's bed	☐	☐	☐	Yes	No	N/A
Child moves to someone else's bed during the night (parent, brother, sister, etc.)	☐	☐	☐	Yes	No	N/A

Coding

Night Waking and Parasomnias

Write the number of minutes a night waking usually lasts: _____

	3 Usually (5-7)	2 Sometimes (2-4)	1 Rarely (0-1)	Problem?		
Child awakens alarmed by a frightening dream	☐	☐	☐	Yes	No	N/A
Child awakes more than once during the night	☐	☐	☐	Yes	No	N/A
Child talks during sleep	☐	☐	☐	Yes	No	N/A
Child is restless and moves a lot during sleep	☐	☐	☐	Yes	No	N/A
Child awakes once during the night (cries, refuses to stay in bed, etc.)	☐	☐	☐	Yes	No	N/A
Child is afraid of sleeping in the dark	☐	☐	☐	Yes	No	N/A

Daytime Alertness

Write in the time of day the child usually wakes in the morning: _____

	3 Usually (5-7)	2 Sometimes (2-4)	1 Rarely (0-1)	Problem?		
Child takes a long time to become alert in the morning	☐	☐	☐	Yes	No	N/A
Child has difficulty getting out of bed in the morning	☐	☐	☐	Yes	No	N/A
Child wakes up in a negative mood	☐	☐	☐	Yes	No	N/A
Child seems tired	☐	☐	☐	Yes	No	N/A
Adult or siblings wake up child	☐	☐	☐	Yes	No	N/A
Child wakes up by him/herself	☐	☐	☐	Yes	No	N/A

Appendix 8: Sleep Disturbance Parent Proxy and Pediatric short forms

PROMIS® Parent Proxy Item Bank v1.0 – Sleep Disturbance – Short Form 8a

Parent Proxy Sleep Disturbance – Short Form 8a

Please respond to each question or statement by marking one box per row.

	In the past 7 days…	Never	Almost never	Sometimes	Almost always	Always
sq005p	My child had difficulty falling asleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq020p_r	My child slept through the night	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
sq041p_r	My child had a problem with his/her sleep.....	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq042p	My child had trouble sleeping.....	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq017p	It took my child a long time to fall asleep..	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq010p	My child worried about not being able to fall asleep.....	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq022p	My child woke up at night and had trouble falling back to sleep.....	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq036p	My child tossed and turned at night	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

05 September 2018

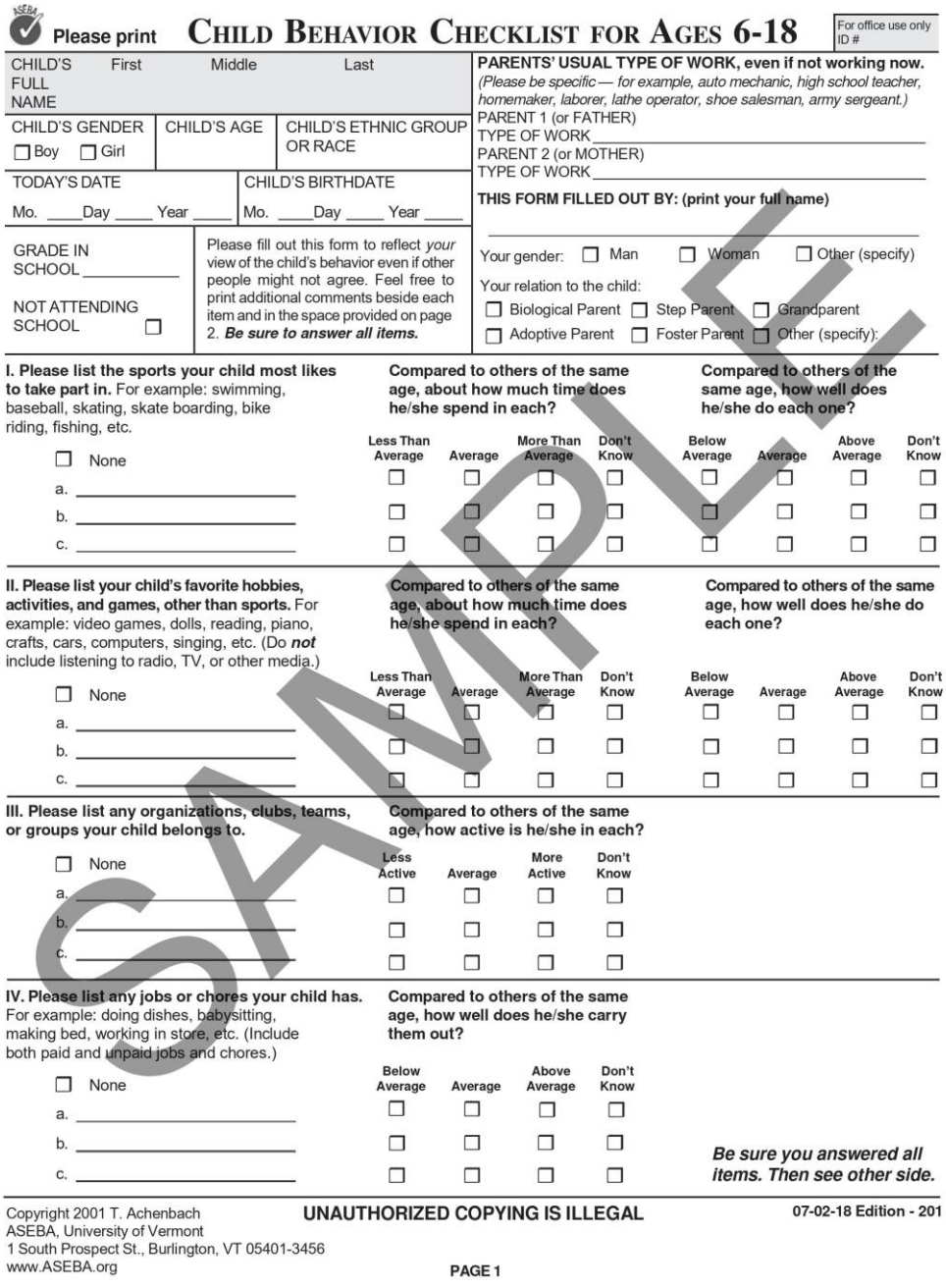
Pediatric Sleep Disturbance – Short Form 8a

Please respond to each question or statement by marking one box per row.

	In the past 7 days…	Never	Almost never	Sometimes	Almost always	Always
sq005c	I had difficulty falling asleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq020c_r	I slept through the night	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1
sq041c_r	I had a problem with my sleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq042c	I had trouble sleeping	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq017c	It took me a long time to fall asleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq010c	I worried about not being able to fall asleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq022c	I woke up at night and had trouble falling back to sleep	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
sq036c	I tossed and turned at night	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

05 September 2018

Appendix 9: Child Behaviour Checklist 6-18



Please print **CHILD BEHAVIOR CHECKLIST FOR AGES 6-18** For office use only ID #

CHILD'S FULL NAME First Middle Last

CHILD'S GENDER ☐ Boy ☐ Girl | CHILD'S AGE | CHILD'S ETHNIC GROUP OR RACE

TODAY'S DATE Mo. ____ Day ____ Year ____ | CHILD'S BIRTHDATE Mo. ____ Day ____ Year ____

GRADE IN SCHOOL _____

NOT ATTENDING SCHOOL ☐

Please fill out this form to reflect *your* view of the child's behavior even if other people might not agree. Feel free to print additional comments beside each item and in the space provided on page 2. ***Be sure to answer all items.***

PARENTS' USUAL TYPE OF WORK, even if not working now.
(Please be specific — for example, auto mechanic, high school teacher, homemaker, laborer, lathe operator, shoe salesman, army sergeant.)
PARENT 1 (or FATHER)
TYPE OF WORK _____
PARENT 2 (or MOTHER)
TYPE OF WORK _____

THIS FORM FILLED OUT BY: (print your full name)

_____

Your gender: ☐ Man ☐ Woman ☐ Other (specify)

Your relation to the child:
☐ Biological Parent ☐ Step Parent ☐ Grandparent
☐ Adoptive Parent ☐ Foster Parent ☐ Other (specify):

I. Please list the sports your child most likes to take part in. For example: swimming, baseball, skating, skate boarding, bike riding, fishing, etc.

☐ None
a. _____
b. _____
c. _____

Compared to others of the same age, about how much time does he/she spend in each?

	Less Than Average	Average	More Than Average	Don't Know
a.	☐	☐	☐	☐
b.	☐	☐	☐	☐
c.	☐	☐	☐	☐

Compared to others of the same age, how well does he/she do each one?

	Below Average	Average	Above Average	Don't Know
a.	☐	☐	☐	☐
b.	☐	☐	☐	☐
c.	☐	☐	☐	☐

II. Please list your child's favorite hobbies, activities, and games, other than sports. For example: video games, dolls, reading, piano, crafts, cars, computers, singing, etc. (Do ***not*** include listening to radio, TV, or other media.)

☐ None
a. _____
b. _____
c. _____

Compared to others of the same age, about how much time does he/she spend in each?

	Less Than Average	Average	More Than Average	Don't Know
a.	☐	☐	☐	☐
b.	☐	☐	☐	☐
c.	☐	☐	☐	☐

Compared to others of the same age, how well does he/she do each one?

	Below Average	Average	Above Average	Don't Know
a.	☐	☐	☐	☐
b.	☐	☐	☐	☐
c.	☐	☐	☐	☐

III. Please list any organizations, clubs, teams, or groups your child belongs to.

☐ None
a. _____
b. _____
c. _____

Compared to others of the same age, how active is he/she in each?

	Less Active	Average	More Active	Don't Know
a.	☐	☐	☐	☐
b.	☐	☐	☐	☐
c.	☐	☐	☐	☐

IV. Please list any jobs or chores your child has. For example: doing dishes, babysitting, making bed, working in store, etc. (Include both paid and unpaid jobs and chores.)

☐ None
a. _____
b. _____
c. _____

Compared to others of the same age, how well does he/she carry them out?

	Below Average	Average	Above Average	Don't Know
a.	☐	☐	☐	☐
b.	☐	☐	☐	☐
c.	☐	☐	☐	☐

Be sure you answered all items. Then see other side.

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Please print. Be sure to answer all items.

V. 1. About how many close friends does your child have? (Do *not* include brothers & sisters)
☐ None ☐ 1 ☐ 2 or 3 ☐ 4 or more

2. About how many times a week does your child do things with any friends outside of regular school hours? (Do *not* include brothers & sisters) ☐ Less than 1 ☐ 1 or 2 ☐ 3 or more

VI. Compared to others of his/her age, how well does your child:

	Worse	Average	Better	
a. Get along with his/her brothers & sisters?	☐	☐	☐	☐ Has no brothers or sisters
b. Get along with other kids?	☐	☐	☐	
c. Behave with his/her parents?	☐	☐	☐	
d. Play and work alone?	☐	☐	☐	

VII. 1. Performance in academic subjects. ☐ **Does not attend school because** _____

Check a box for each subject that child takes	Failing	Below Average	Average	Above Average
a. Reading, English, or Language Arts	☐	☐	☐	☐
b. History or Social Studies	☐	☐	☐	☐
c. Arithmetic or Math	☐	☐	☐	☐
d. Science	☐	☐	☐	☐
e. _____	☐	☐	☐	☐
f. _____	☐	☐	☐	☐
g. _____	☐	☐	☐	☐

Other academic subjects–for example: computer courses, foreign language, business. Do ***not*** include gym, shop, driver's ed., or other nonacademic subjects.

2. Does your child receive special education or remedial services or attend a special class or special school?
☐ No ☐ Yes—kind of services, class, or school:

3. Has your child repeated any grades? ☐ No ☐ Yes—grades and reasons:

4. Has your child had any academic or other problems in school? ☐ No ☐ Yes—please describe:

When did these problems start?

Have these problems ended? ☐ No ☐ Yes–when?

Does your child have any illness or disability (either physical or mental)? ☐ No ☐ Yes—please describe:

What concerns you most about your child?

Please describe the best things about your child.

Be sure you answered all items.

Please print. Be sure to answer all items.

Below is a list of items that describe children and youths. For each item that describes your child ***now or within the past 6 months***, please circle the ***2*** if the item is ***very true or often true*** of your child. Circle the ***1*** if the item is ***somewhat or sometimes true*** of your child. If the item is ***not true*** of your child, circle the ***0***. Please answer all items as well as you can, even if some do not seem to apply to your child.

0 = Not True (as far as you know) **1 = Somewhat or Sometimes True** **2 = Very True or Often True**

0 1 2 1. Acts too young for his/her age
0 1 2 2. Drinks alcohol without parents' approval (describe):
0 1 2 3. Argues a lot
0 1 2 4. Fails to finish things he/she starts
0 1 2 5. There is very little he/she enjoys
0 1 2 6. Bowel movements outside toilet
0 1 2 7. Bragging, boasting
0 1 2 8. Can't concentrate, can't pay attention for long
0 1 2 9. Can't get his/her mind off certain thoughts; obsessions (describe):
0 1 2 10. Can't sit still, restless, or hyperactive
0 1 2 11. Clings to adults or too dependent
0 1 2 12. Complains of loneliness
0 1 2 13. Confused or seems to be in a fog
0 1 2 14. Cries a lot
0 1 2 15. Cruel to animals
0 1 2 16. Cruelty, bullying, or meanness to others
0 1 2 17. Daydreams or gets lost in his/her thoughts
0 1 2 18. Deliberately harms self or attempts suicide
0 1 2 19. Demands a lot of attention
0 1 2 20. Destroys his/her own things
0 1 2 21. Destroys things belonging to his/her family or others
0 1 2 22. Disobedient at home
0 1 2 23. Disobedient at school
0 1 2 24. Doesn't eat well
0 1 2 25. Doesn't get along with other kids
0 1 2 26. Doesn't seem to feel guilty after misbehaving
0 1 2 27. Easily jealous
0 1 2 28. Breaks rules at home, school, or elsewhere
0 1 2 29. Fears certain animals, situations, or places, other than school (describe):
0 1 2 30. Fears going to school
0 1 2 31. Fears he/she might think or do something bad
0 1 2 32. Feels he/she has to be perfect
0 1 2 33. Feels or complains that no one loves him/her
0 1 2 34. Feels others are out to get him/her
0 1 2 35. Feels worthless or inferior
0 1 2 36. Gets hurt a lot, accident-prone
0 1 2 37. Gets in many fights
0 1 2 38. Gets teased a lot
0 1 2 39. Hangs around with others who get in trouble
0 1 2 40. Hears sound or voices that aren't there (describe):
0 1 2 41. Impulsive or acts without thinking
0 1 2 42. Would rather be alone than with others
0 1 2 43. Lying or cheating
0 1 2 44. Bites fingernails
0 1 2 45. Nervous, highstrung, or tense
0 1 2 46. Nervous movements or twitching (describe):
0 1 2 47. Nightmares
0 1 2 48. Not liked by other kids
0 1 2 49. Constipated, doesn't move bowels
0 1 2 50. Too fearful or anxious
0 1 2 51. Feels dizzy or lightheaded
0 1 2 52. Feels too guilty
0 1 2 53. Overeating
0 1 2 54. Overtired without good reason
0 1 2 55. Overweight
56. Physical problems ***without know medical cause:***
0 1 2 a. Aches or pains (***not*** stomach or headaches)
0 1 2 b. Headaches
0 1 2 c. Nausea, feels sick
0 1 2 d. Problems with eyes (***not*** if corrected by glasses) (describe):
0 1 2 e. Rashes or other skin problems
0 1 2 f. Stomachaches
0 1 2 g. Vomiting, throwing up
0 1 2 h. Other (describe):

Please print. Be sure to answer all items.

0 = Not True (as far as you know) **1 = Somewhat or Sometimes True** **2 = Very True or Often True**

0 1 2 57. Physically attacks people
0 1 2 58. Picks nose, skin, or other parts of body (describe):
0 1 2 59. Plays with own sex parts in public
0 1 2 60. Plays with own sex parts too much
0 1 2 61. Poor school work
0 1 2 62. Poorly coordinated or clumsy
0 1 2 63. Prefers being with older kids
0 1 2 64. Prefers being with younger kids
0 1 2 65. Refuses to talk
0 1 2 66. Repeats certain acts over and over; compulsions (describe):
0 1 2 67. Runs away from home
0 1 2 68. Screams a lot
0 1 2 69. Secretive, keeps things to self
0 1 2 70. Sees things that aren't there (describe):
0 1 2 71. Self-conscious or easily embarrassed
0 1 2 72. Sets fires
0 1 2 73. Sexual problems (describe):
0 1 2 74. Showing off or clowning
0 1 2 75. Too shy or timid
0 1 2 76. Sleeps less than most kids
0 1 2 77. Sleeps more than most kids during day and/or night (describe):):
0 1 2 78. Inattentive or easily distracted
0 1 2 79. Speech problem (describe):
0 1 2 80. Stares blankly
0 1 2 81. Steals at home
0 1 2 82. Steals outside the home
0 1 2 83. Stores up too many things he/she doesn't need (describe):
0 1 2 84. Strange behavior (describe):
0 1 2 85. Strange ideas (describe):
0 1 2 86. Stubborn, sullen, or irritable
0 1 2 87. Sudden changes in mood or feelings
0 1 2 88. Sulks a lot
0 1 2 89. Suspicious
0 1 2 90. Swearing or obscene language
0 1 2 91. Talks about killing self
0 1 2 92. Talks or walks in sleep (describe):
0 1 2 93. Talks too much
0 1 2 94. Teases a lot
0 1 2 95. Temper tantrums or hot temper
0 1 2 96. Thinks about sex too much
0 1 2 97. Threatens people
0 1 2 98. Thumb-sucking
0 1 2 99. Smokes, chews, or sniffs tobacco
0 1 2 100. Trouble sleeping (describe):
0 1 2 101. Truancy, skips school
0 1 2 102. Underactive, slow moving, or lacks energy
0 1 2 103. Unhappy, sad, or depressed
0 1 2 104. Unusually loud
0 1 2 105. Uses drugs for nonmedical purposes (***don't*** include alcohol or tobacco) (describe):
0 1 2 106. Vandalism
0 1 2 107. Wets self during the day
0 1 2 108. Wets the bed
0 1 2 109. Whining
0 1 2 110. Wishes to be of opposite sex
0 1 2 111. Withdrawn, doesn't get involved with others
0 1 2 112. Worries
113. Please write in any problems your child has that were not listed above:
0 1 2
0 1 2
0 1 2

Please be sure you answered all items.

Appendix 10: Physical Activity Questionnaire for Older Children

Physical Activity Questionnaire (Elementary School)

Name:_____ Age:_____

Sex: M_____ F_____ Grade:_____

Teacher:_____

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:
1. There are no right and wrong answers — this is not a test.
2. Please answer all the questions as honestly and accurately as you can — this is very important.

---

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping	❍	❍	❍	❍	❍
Rowing/canoeing	❍	❍	❍	❍	❍
In-line skating	❍	❍	❍	❍	❍
Tag	❍	❍	❍	❍	❍
Walking for exercise	❍	❍	❍	❍	❍
Bicycling	❍	❍	❍	❍	❍
Jogging or running	❍	❍	❍	❍	❍
Aerobics	❍	❍	❍	❍	❍
Swimming	❍	❍	❍	❍	❍
Baseball, softball	❍	❍	❍	❍	❍
Dance	❍	❍	❍	❍	❍
Football	❍	❍	❍	❍	❍
Badminton	❍	❍	❍	❍	❍
Skateboarding	❍	❍	❍	❍	❍
Soccer	❍	❍	❍	❍	❍
Street hockey	❍	❍	❍	❍	❍
Volleyball	❍	❍	❍	❍	❍
Floor hockey	❍	❍	❍	❍	❍
Basketball	❍	❍	❍	❍	❍
Ice skating	❍	❍	❍	❍	❍
Cross-country skiing	❍	❍	❍	❍	❍
Ice hockey/ringette	❍	❍	❍	❍	❍
Other:					
_____	❍	❍	❍	❍	❍
_____	❍	❍	❍	❍	❍

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE ❍
Hardly ever ❍
Sometimes ❍
Quite often ❍
Always ❍

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

Sat down (talking, reading, doing schoolwork) ❍
Stood around or walked around ❍
Ran or played a little bit ❍
Ran around and played quite a bit ❍
Ran and played hard most of the time ❍

4. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork) ❍
Stood around or walked around ❍
Ran or played a little bit ❍
Ran around and played quite a bit ❍
Ran and played hard most of the time ❍

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None ❍
1 time last week ❍
2 or 3 times last week ❍
4 times last week ❍
5 times last week ❍

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None ❍
1 time last week ❍
2 or 3 times last week ❍
4 or 5 last week ❍
6 or 7 times last week ❍

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... ❍
1 time ..... ❍
2 — 3 times ..... ❍
4 — 5 times ..... ❍
6 or more times ..... ❍

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort ..... ❍

B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ..... ❍

C. I often (3 — 4 times last week) did physical things in my free time ..... ❍

D. I quite often (5 — 6 times last week) did physical things in my free time ..... ❍

E. I very often (7 or more times last week) did physical things in my free time ..... ❍

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday	❍	❍	❍	❍	❍
Tuesday	❍	❍	❍	❍	❍
Wednesday	❍	❍	❍	❍	❍
Thursday	❍	❍	❍	❍	❍
Friday	❍	❍	❍	❍	❍
Saturday	❍	❍	❍	❍	❍
Sunday	❍	❍	❍	❍	❍

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ..... ❍
No ..... ❍

If Yes, what prevented you? _____

Appendix 11: Sample of exercise session and arts and crafts session

OntarioTech UNIVERSITY

Exercise Intervention

Session # 1

Time	Activity
5 minutes	Warm-up - Running on the spot, high knees, rear kicks, crossover star toe touches, ski jumps, jumping on the spot, hopping on the spot, arm circles, air punches, and slow burpees
5 minutes	Fun Run - Run around room in a large circle
10 minutes	Obstacle Course - Agility ladder - Jumping over hurdles - Zig zag cone run - Side shuffle
10 minutes	Circuits - Crab toe taps/crab walk - Step ups - Inch worm - Skaters
10 minutes	Group Game - Lizard Tag - Noodle Soup
5 minutes	Cool-down - Quadricep stretch, calf stretch, knee lunge, seated hamstring stretch, butterfly stretch, overhead arm stretch, shoulder stretch, bicep stretch, and triceps stretch

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Arts and Crafts Intervention

Session # 1

Theme: Flight

Time	Activity
5 minutes	Introduction & Demonstration - All activities will be demonstrated by an instructor
5 minutes	Individual material preparation - A list of materials will be displayed with pictures - All materials will be placed on a table - The participants must go to the table and grab all of the materials they need/want to complete the activity
15 minutes	Craft 1 - Airplanes
15 minutes	Craft 2: - Miniature Catapults
5 minutes	De-brief (show and tell) - Participants will be given 5 minutes to play with their crafts and share what they did - Example: try their new catapults and each take a turn to see how far a cotton ball with travel

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Appendix 12: Participant Case Descriptions

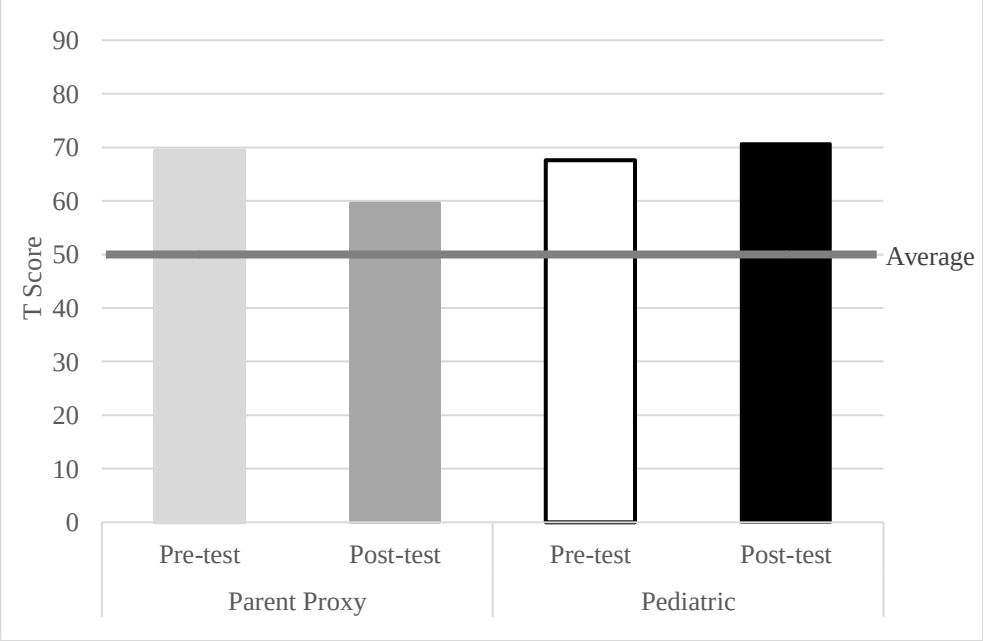
Experimental (Exercise) – Participant 1

Participant 1 (P1) was a 10-year-old male who was diagnosed with ASD at the age of nine; he had also been diagnosed with ADHD two years' prior. The parents did not report P1 taking any medications. It was reported that P1 participates in one additional recreational program, once per week. P1's height was measured at 137.9 cm and he weighed 34.6 kg at the start of the intervention and he remained the same height and weighed 34.4 kg at the post-test. P1 was assigned to the experimental group based on the family's availability.

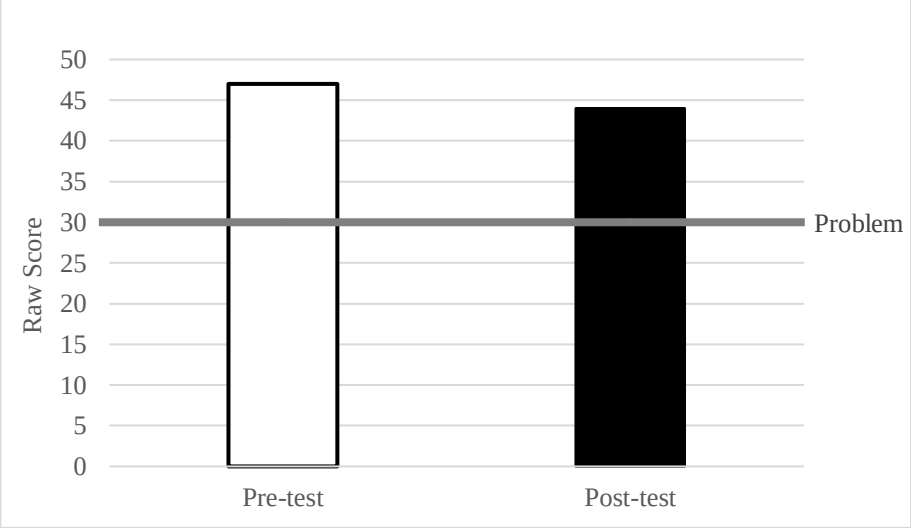
Raw scores from the Sleep Disturbance Parent Proxy (SDPP) and Pediatric (SDP) Forms for P1 from pre-test to post-test.

	Parent Proxy		Pediatric	
	Raw Score	Interpretation	Raw Score	Interpretation
Pre-test	27	Worse than average	29	Worse than average
Post-test	18	Worse than average	32	Worse than average

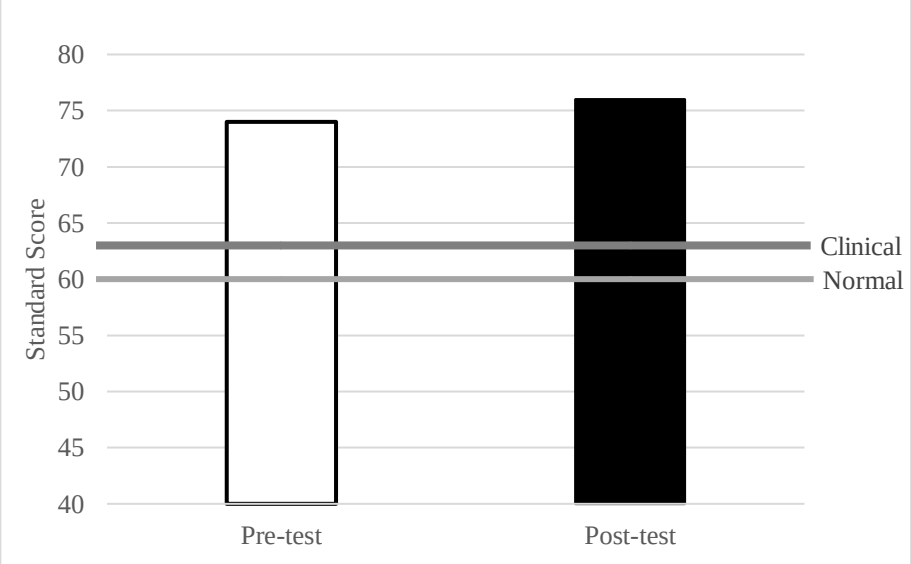
T scores of P1 from the SDPP in comparison to the SDP at the pre-test and post-test.



Raw scores from the CSHQ for P1 from pre-test to post-test.



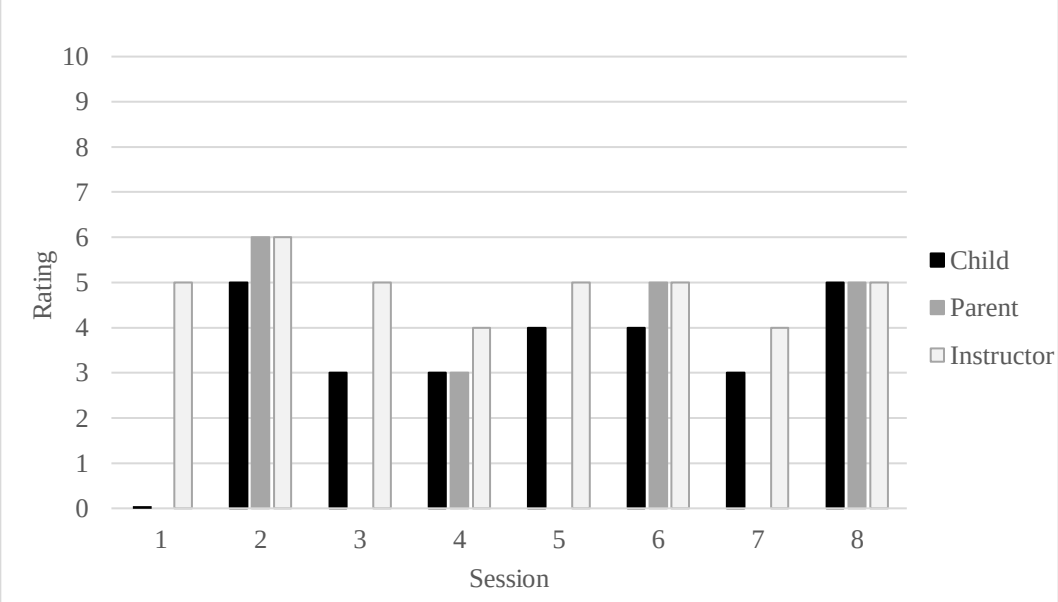
Total Problems T Scores on the CBCL at pre- and post-test for P1.



Raw score from the PAQ-C for P1 from pre-test to post-test.

	Raw Score	Rating
Pre-test	2.98	Moderate
Post-test	2.05	Moderately Low
Pre to Post Change	(-) 0.93	

Ratings of perceived exertion over the 8 exercise sessions for P1.



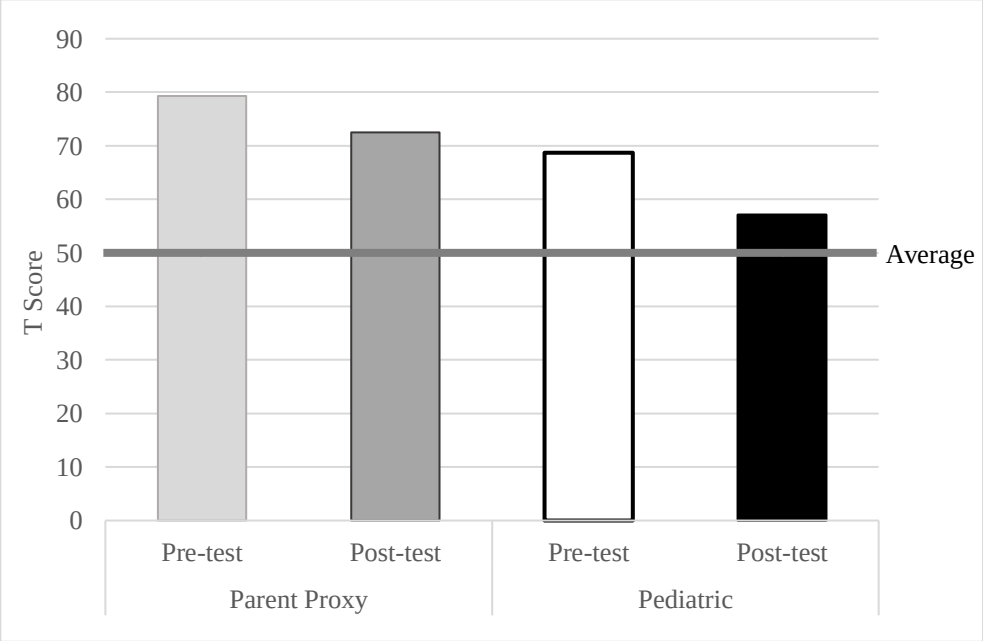
Experimental (Exercise) – Participant 3

Participant 3 (P3) was diagnosed with an ASD phenotype just before the start of the study at eight years of age. P3 was an 8-year-old female who also has a diagnosis of attention deficit disorder, attention deficit hyperactivity disorder, sensory integration disorder and Ehlers-Danlos syndrome and it was reported that she was taking an antihistamine medication (Rupall). At the pre-test, P3 was 122.2 cm tall and weighed 30.8 kg and following the intervention, she was 124.8 cm in height and weighed 31.2 kg. P3 was assigned to the experimental group with her sibling, P4, based on the remaining spaces available in the two groups and convenience for the family.

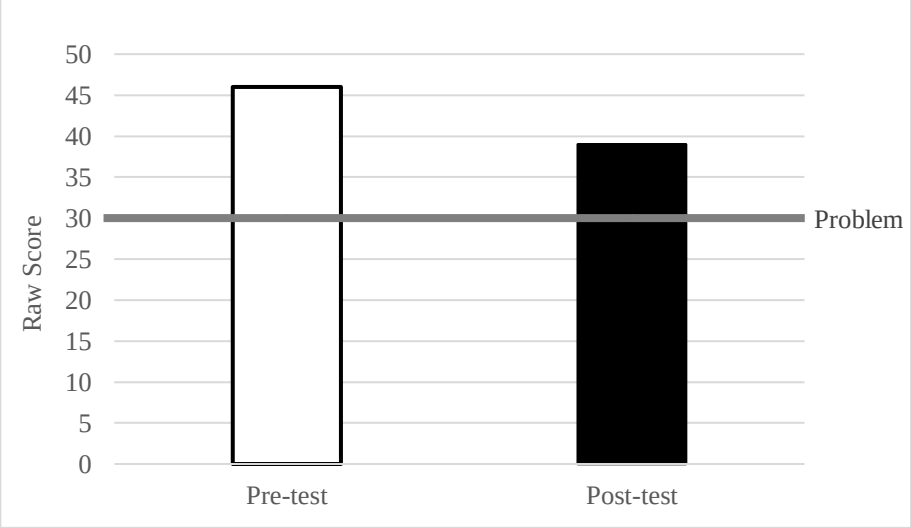
Raw scores from the SDPP and SDP Forms for P3 from pre-test to post-test.

	Parent Proxy		Pediatric	
	Raw Score	Interpretation	Raw Score	Interpretation
Pre-test	36	Worse than average	30	Worse than average
Post-test	30	Worse than average	19	Worse than average

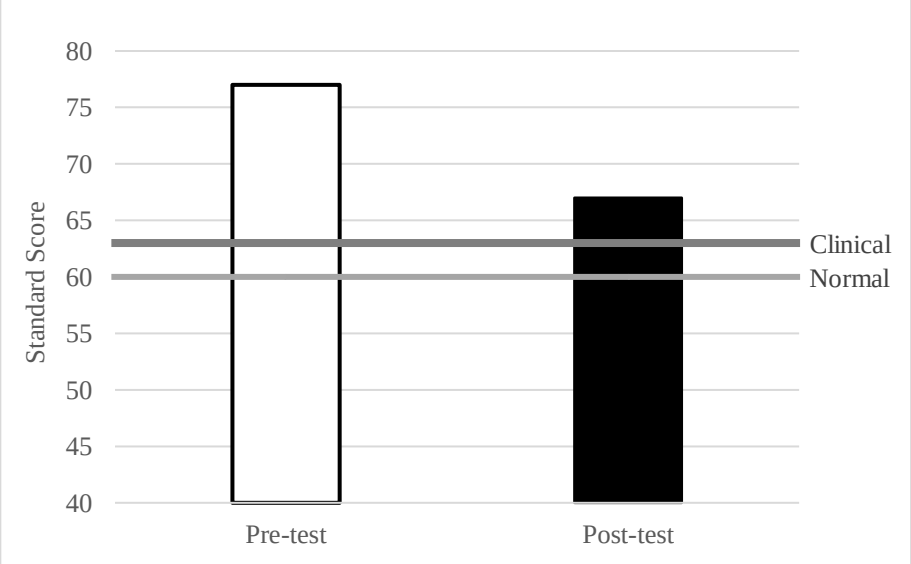
T scores of P3 from the SDPP in comparison to the SDP at the pre-test and post-test.



Raw scores from the CSHQ for P3 from pre-test to post-test.



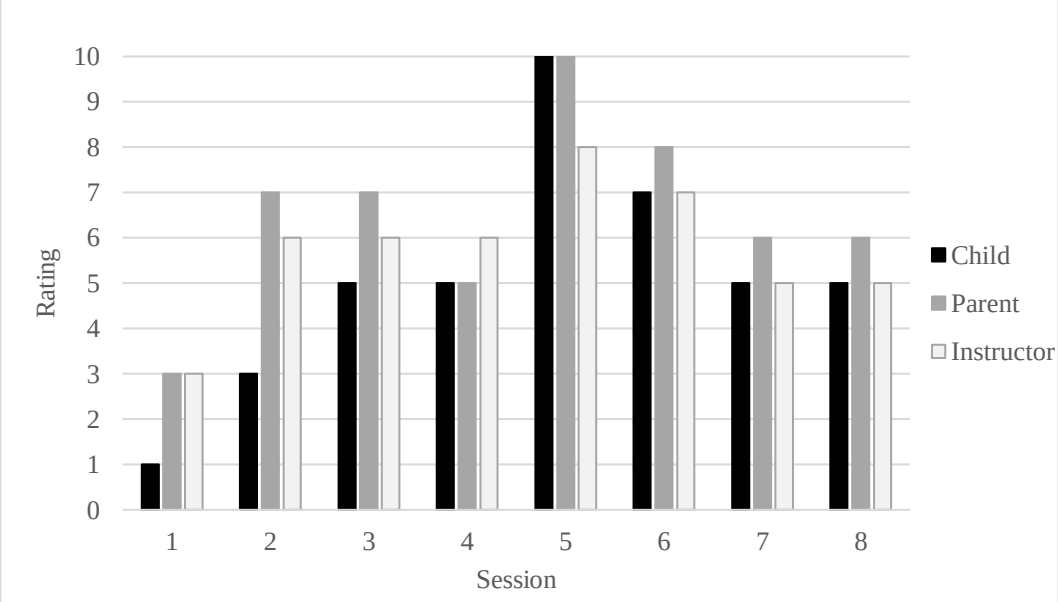
Total Problems T Scores on the CBCL at pre- and post-test for P3.



Raw score from the PAQ-C for P3 from pre-test to post-test.

	Raw Score	Rating
Pre-test	2.81	Moderate
Post-test	2.27	Moderately Low
Pre to Post Change	(-) 0.54	

Ratings of perceived exertion over the 8 exercise sessions for P3.



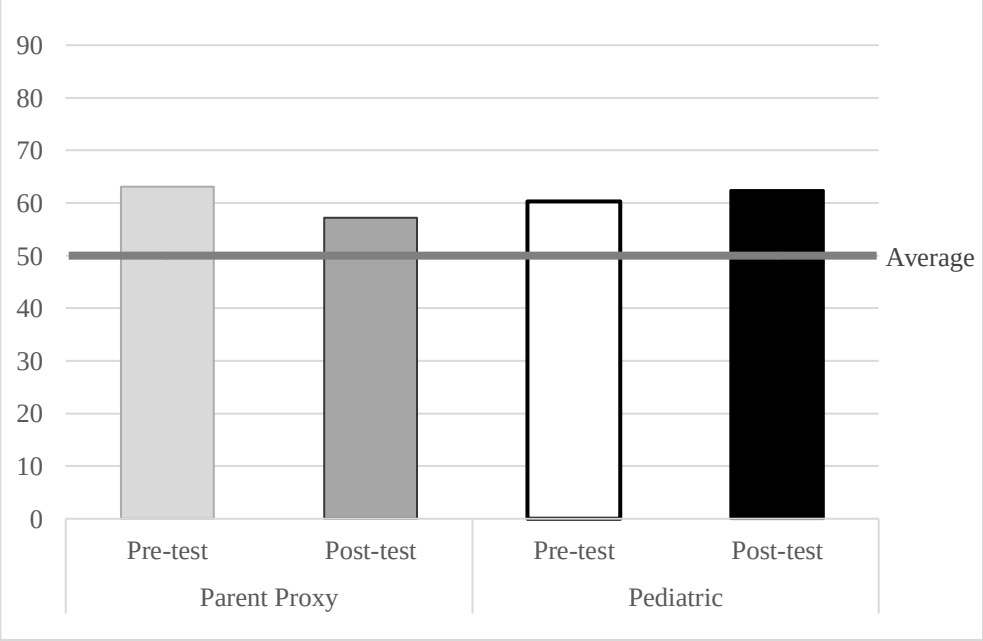
Experimental (Exercise) – Participant 4

Participant 4 (P4) was a 6-year-old male who was diagnosed with ASD at the age of four and also has a diagnosis of Ehlers-Danlos syndrome. The parents reported that P4 was not taking any medication. He had previously participated in motor interventions and continues to participate in occupational therapy sessions. P4 was also attending sessions with a speech and language pathologist. Prior to the intervention, P4's height was 111 cm and he weighed 21 kg, and at the post-test, he was measured at 112.5 cm in height and weighed 21.4 kg. P4 was assigned to the experimental group with his sibling, P3, based on the remaining spaces available in the two groups and convenience for the family.

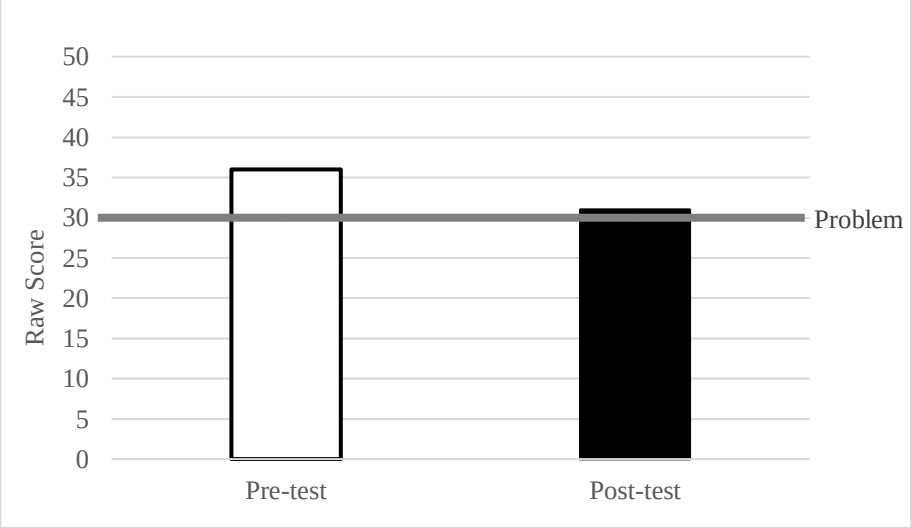
Raw scores from the SDPP and SDP Forms for P4 from pre-test to post-test.

	Parent Proxy		Pediatric	
	Raw Score	Interpretation	Raw Score	Interpretation
Pre-test	21	Worse than average	22	Worse than average
Post-test	16	Worse than average	24	Worse than average

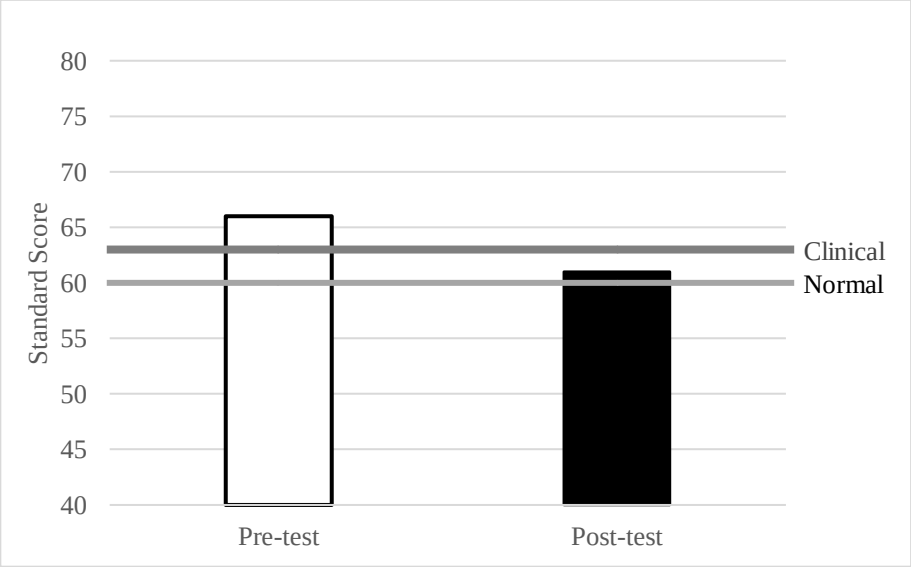
T scores of P4 from the SDPP in comparison to the SDP at the pre-test and post-test.



Raw scores from the CSHQ for P4 from pre-test to post-test.



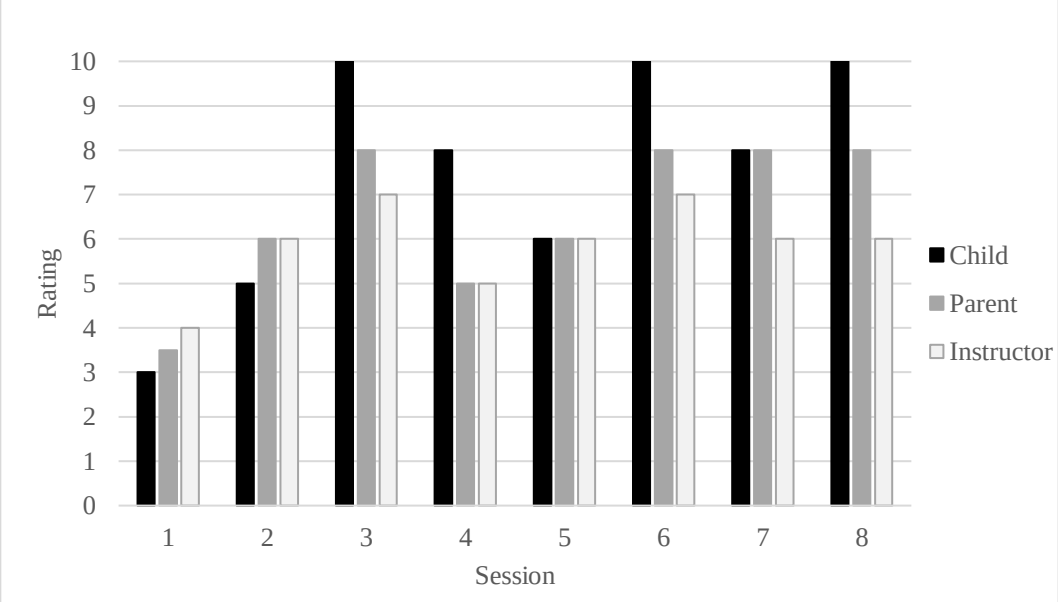
Total Problems T Scores on the CBCL at pre- and post-test for P4.



Raw score from the PAQ-C for P4 from pre-test to post-test.

	Raw Score	Rating
Pre-test	3.21	Moderate
Post-test	1.91	Moderately Low
Pre to Post Change	(-) 1.30	

Ratings of perceived exertion over the 8 exercise sessions for P4.



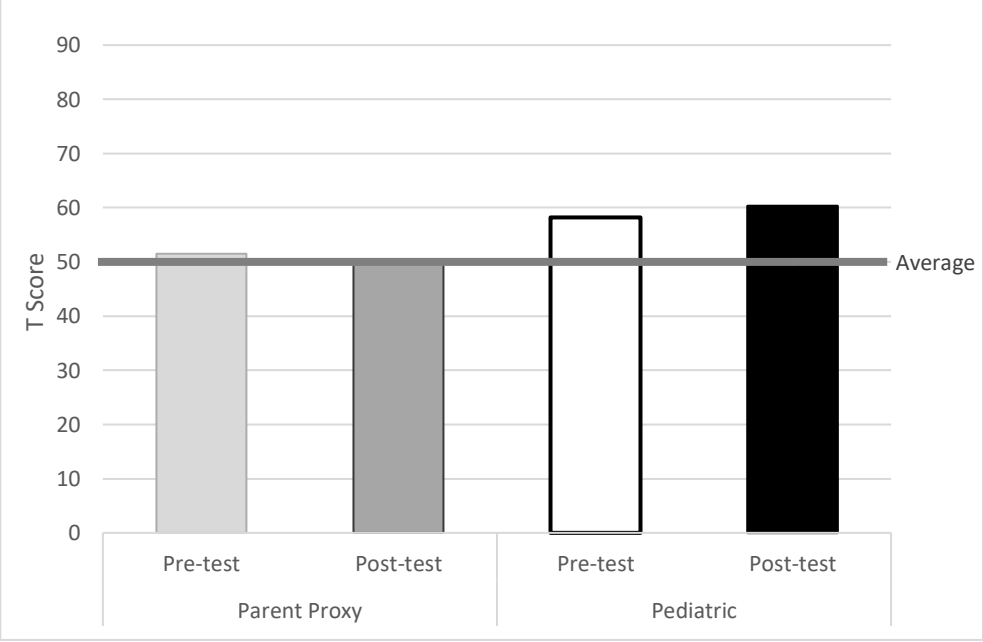
Control (Arts & Crafts) – Participant 2

Participant 2 (P2) was diagnosed with ASD (Level 1) at the age of seven and was ten years old at the time of the study. This male participant had no additional diagnoses. At the pre-test, P2 weighed 56.6 kg and 55.7 kg at the post-test. The initial height measurement (131.4 cm) was deemed to be an incorrect record based on the height of P2 at the post-test (138.7 cm). This participant was assigned to the control group based on his availability to participate in the sessions.

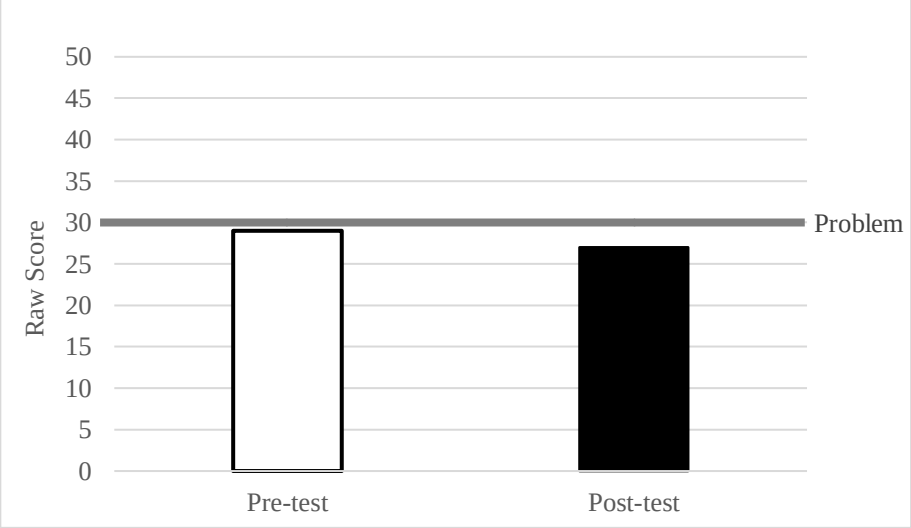
Raw scores from the SDPP and SDP Forms for P2 from pre-test to post-test.

	Parent Proxy		Pediatric	
	Raw Score	Interpretation	Raw Score	Interpretation
Pre-test	12	Average	20	Worse than average
Post-test	11	Average	22	Worse than average

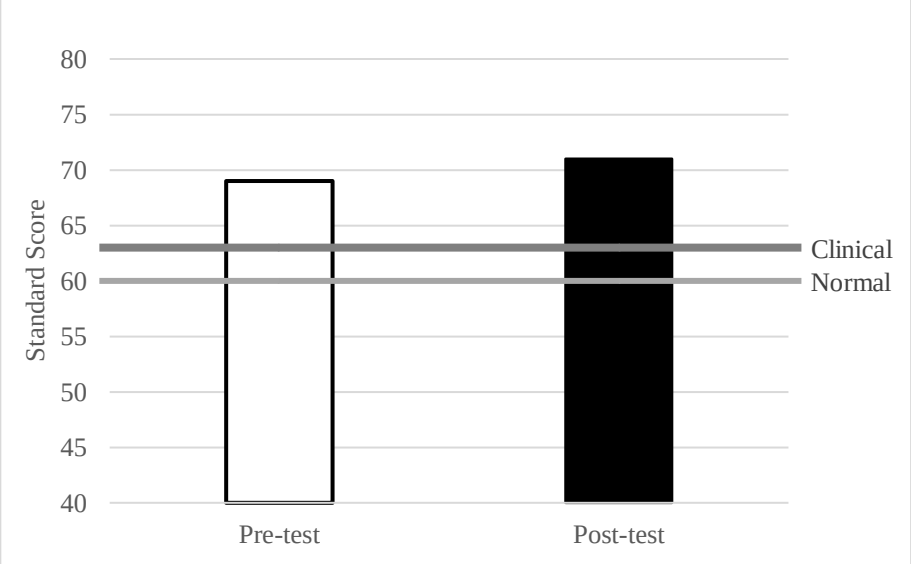
T scores of P2 from the SDPP in comparison to the SDP at the pre-test and post-test.



Raw scores from the CSHQ for P2 from pre-test to post-test.



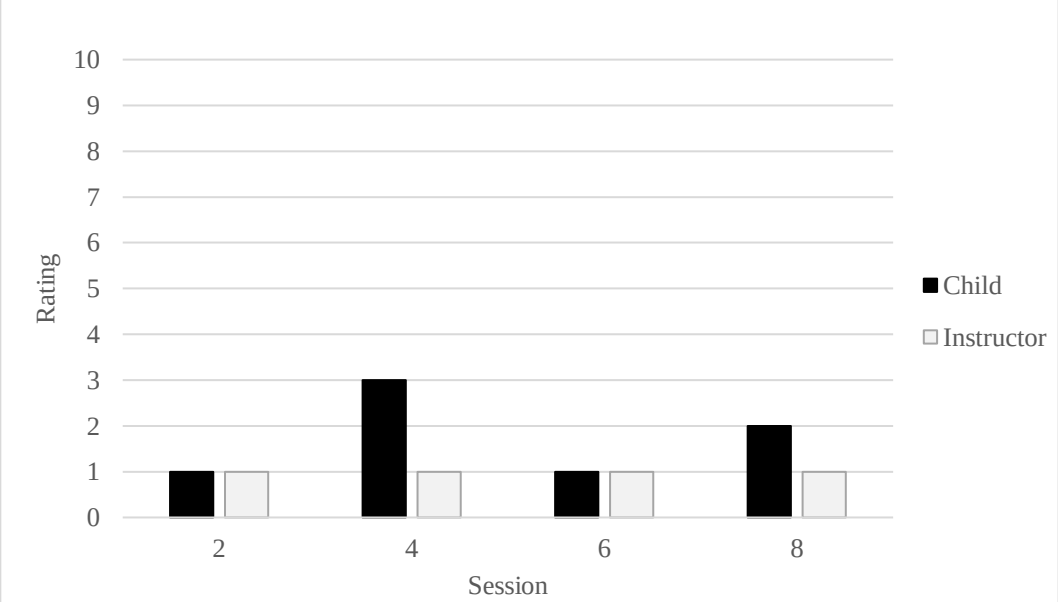
Total Problems T Scores on the CBCL at pre- and post-test for P2.



Raw score from the PAQ-C for P2 from pre-test to post-test.

	Raw Score	Rating
Pre-test	2.43	Moderately Low
Post-test	2.41	Moderately Low
Pre to Post Change	(-) 0.02	

Ratings of perceived exertion over the 4 arts and crafts sessions for P2.



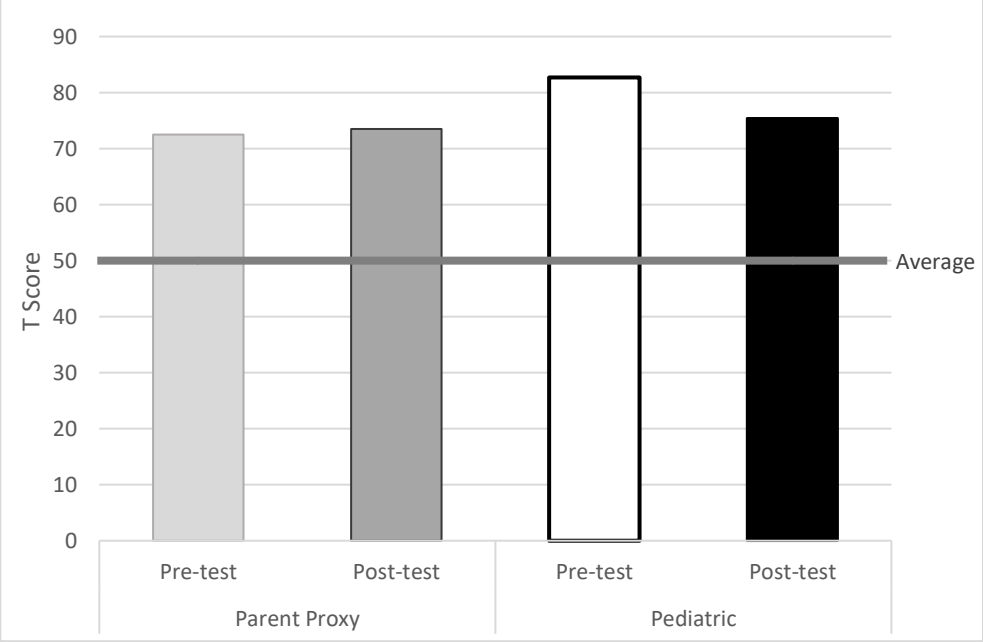
Control (Arts & Crafts) – Participant 5

Participant 5 (P5) was a 9-year-old female who was diagnosed with ASD at two and a half years of age. She has also been diagnosed with Anxiety, ADHD, Intellectual Disability, and Learning Disability. P5 was taking three medications (Zoloft, Vyvanse, and Clonidine), one of which was prescribed specifically to improve her sleep. She had previously attended motor interventions and continues to do so in addition to taking swimming lessons once per week and dance on multiple occasions throughout the week. Applied Behaviour Analysis therapy was another therapy that P5 had previously attended. At the beginning of the study, P5 was 129 cm in height and weighed 30.4 kg and at the post-test, she was 129.8 cm in height and weighed 31.3 kg. She was assigned to the control group based on her availability to participate in the sessions.

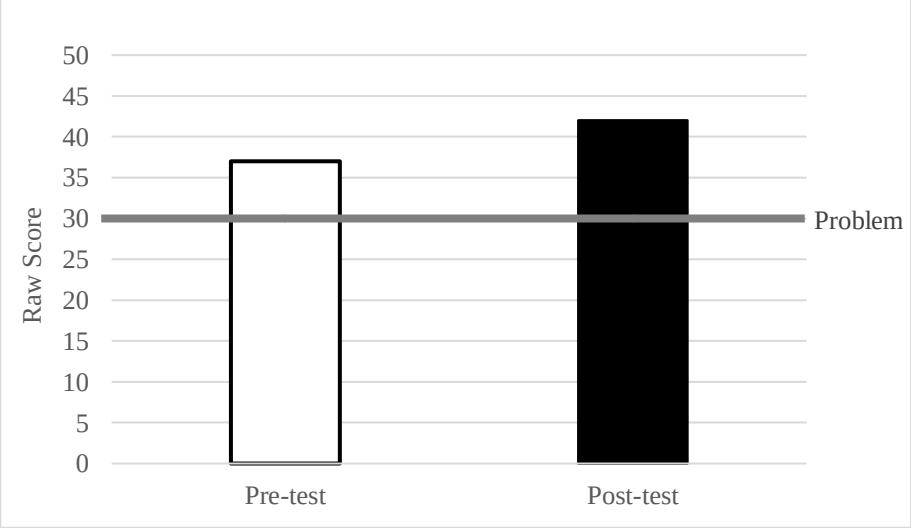
Raw scores from the SDPP and SDP forms for P5 from pre-test to post-test.

	Parent Proxy		Pediatric	
	Raw Score	Interpretation	Raw Score	Interpretation
Pre-test	30	Worse than average	40	Worse than average
Post-test	31	Worse than average	35	Worse than average

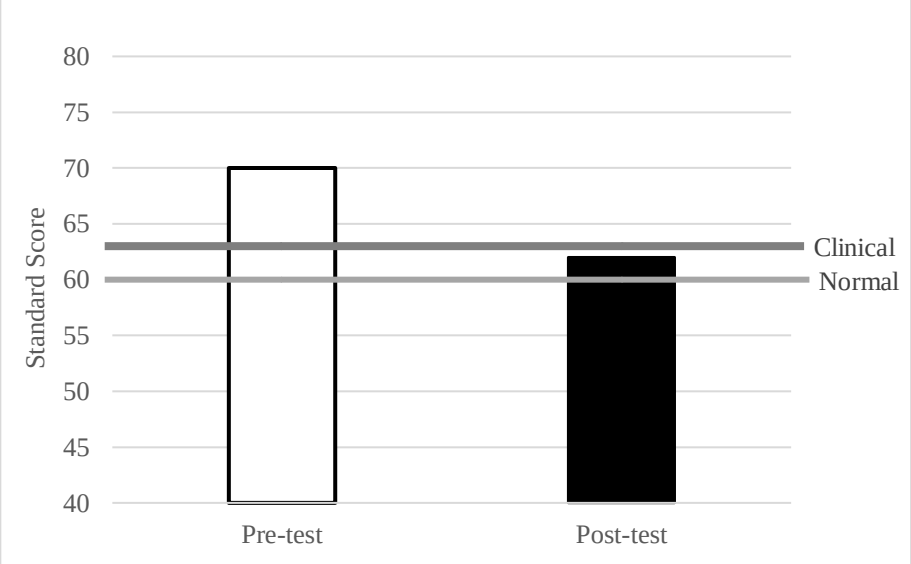
T scores of P5 from the SDPP in comparison to the SDP at the pre-test and post-test.



Raw scores from the CSHQ for P5 from pre-test to post-test.



Total Problems T Scores on the CBCL at pre- and post-test for P5.



Raw score from the PAQ-C for P5 from pre-test to post-test.

	Raw Score	Rating
Pre-test	4.53	High
Post-test	4.40	High
Pre to Post Change	(-) 0.13	

Ratings of perceived exertion over the four arts and crafts sessions for P5.