Effect of a sleep intervention on mental health indicators of adolescents at risk for type 2 diabetes: Preliminary findings from the Sleep Manipulation in Adolescents at Risk of Type 2 Diabetes (SMART2D) Study

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ABSTRACT

Background: Many adolescents are not meeting the recommended sleep guidelines. Lack of sleep in adolescents is a major public health concern, since short sleep duration has been associated with an increased risk of chronic diseases such as obesity, type 2 diabetes, cardiovascular disease, and mental health problems. Canadian youth also show a high prevalence of mental health disorders. One segment of the population particularly at risk is those who are at risk for type 2 diabetes. There is currently a lack of experimental sleep studies in this population and knowing how sleep manipulations can impact mental health outcomes is important to inform future intervention strategies.

Purpose: To examine how experimental changes in time in bed (decrease and increase by 1.5-hour per night for one week) affect mental health indicators (depression symptoms, mood, and behavioural problems) in adolescents at risk for type 2 diabetes.

Methods: A sample of 10 adolescents who were considered to be at risk for type 2 diabetes was recruited. A randomized, counterbalanced, crossover study (within-subjects experimental design) was used. Participants wore an Actiwatch 2 for a total of four weeks, which included a baseline sleep week, an increased sleep week, a decreased sleep week, and a washout period of one week in between. Validated self-report questionnaires were used to measure depression symptoms, mood, and behavioural problems.

Results: Preliminary findings showed improvements in depression symptoms, mood, and impact score after increasing time in bed by 1.5-hour per night for one week compared to decreasing time in bed by 1.5-hour.

Conclusion: Compared with decreased sleep, adolescents at risk of type 2 diabetes may obtain mental health benefits with sleep extension, even over a short period of time.

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LIST OF ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
B	Boy
BDI	Beck Depression Inventory
BMI	Body Mass Index
BRUMS	Brunel Mood Scale
CDI	Children's Depression Inventory
CES-D	Center for Epidemiological Studies Depression Scale
CHAL	Centre for Healthy Active Living
CVD	Cardiovascular disease
DISC-IV	Diagnostic Interview Schedule for Children Version IV
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders 4th edition
DSM-V	Diagnostic and Statistical Manual of Mental Disorders 5th edition
F	Female
G	Girl
GD	Gestational diabetes
GHQ	General Health Questionnaire
HADS	Hospital Anxiety and Depression Scale
HChol	Hypercholesterolemia
HDL	High Density Lipoproteins
HT	Hypertension
KADS	Kutcher Adolescent Depression Scale
M	Male

NCA-S	National Comorbidity Survey Adolescent Supplement
PANAS	Positive and Negative Affective Schedule
PEDS-QL	Pediatric Quality of Life Inventory
PHQ-A	Patient Health Questionnaire for Adolescents
POMS	Profile of Mood States
SDQ	Strengths and Difficulties Questionnaire
SES	Socioeconomic status
SMART2D	Sleep Manipulation in Adolescents at Risk of Type 2 Diabetes
T2D	Type 2 diabetes
TAG	Triacylglycerides
TST	Total sleep time
WHO	World Health Organization
YSR	Youth Self Report

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MY ROLE

In addition to writing this thesis, I play an instrumental role in the Sleep Manipulation in Adolescents at Risk of Type 2 Diabetes (SMART2D) study. I am responsible for the mental health investigation of the SMART2D study; however, I work on other themes of the project as well. Before we started data collection, there were many months of pilot testing and learning new techniques such as electroencephalography capping. Each testing day is around eight hours long and I am responsible for tasks such as capping and spinning blood. I have gained knowledge about insulin sensitivity, brain functions, and mental health throughout this project. At this point, I am still involved in data collection and processing. An article will be published once the whole participant sample is obtained.

CHAPTER 1: INTRODUCTION

While many people focus on physical activity to prevent various health problems, another behaviour should be added to this equation, namely sleep. Sleep is a vital part our daily lives and it represents more than a third of daily behaviours of adolescents (Tremblay et al., 2016). It seems very foreign that until recently sleep has not been part of the behaviours list when it comes to healthy lifestyle. Adolescents are a subgroup of the population that consistently does not meet the recommended sleep guidelines (Boak, Hamilton, Adlaf, Henderson, & Mann, 2015; Chaput & Janssen, 2016; Gariépy, Janssen, Sentenac, & Elgar, 2017). According to the Canadian 24-Hour Movement Guidelines for Children and Youth, teens who are 13-years-old should sleep between 9 and 11 hours per night and those who are 14 to 17-years-old should sleep between 8 and 10 hours per night (Tremblay et al., 2016). Additionally, sleep duration of adolescents in Canada has been declining in recent years, especially on weekdays (Matricciani, Olds, & Petkov, 2012; Patte, Qian, & Leatherdale, 2017). This sleep deficit is due to several factors including, but not limited to, increased tobacco use, increased caffeine consumption, exposure to artificial light in the evening, and social media use in the hours preceding bedtime (Bartel, Gradisar, & Williamson, 2015; Sampasa-Kanyinga, Hamilton, & Chaput, 2018). Furthermore, adolescent social and biological clocks become misaligned; adolescents want to stay up later but are forced to wake up early, usually for school, resulting in a shorter sleep duration. This has been referred to "social jetlag" in the literature, where adolescents shift their weekend sleep schedule to be more reflective of their biological needs while also engaging in catch-up sleep (Wittmann et al., 2006). Sleep curtailment in adolescents is a major public health concern, since short sleep duration has been associated with increased risk of chronic diseases such as obesity, type 2 diabetes, cardiovascular disease, and mental health problems (Chaput et al., 2016; Owens, 2014).

Mental health problems (e.g., depression and mood) are becoming a predominant problem in Canadian youth (Boak et al., 2015). In Ontario, 34% of high school students meet the benchmark for moderate-to-serious psychological distress and 14% for severe distress (Boak et al., 2015). As stated above, Chaput and colleagues (2016) have recently reported on the associations between lack of sleep and adverse mental health outcomes in children and youth (Chaput et al., 2016). Adolescents at risk of type 2 diabetes are a subgroup of the youth population who are particularly vulnerable to mental health problems. Obesity, low physical activity levels, and dyslipidemia together represent important factors that put adolescents at risk for type 2 diabetes (Panagiotopoulos, Hadjiyannakis, & Henderson, 2018). Furthermore, youth with obesity are more likely to experience depression, anxiety, and emotional problems (Quek, Tam, Zhang, & Ho, 2017; Russell-Mayhew, Mcvey, Bardick, & Ireland, 2012). This was further supported in a recent study by Buchholz and colleagues (2019), which showed 58% of youth attending a weight management clinic in Ottawa, Canada, had one or more mental health comorbidity. This value is higher than the 34% reported by Boak and colleagues (2015).

While most current studies on the association between sleep and mental health indicators are cross-sectional in nature, the literature provides some basic knowledge and outlines the need for more experimental research in this field. The bulk of experimental studies on sleep and most outcomes have been focused on decreasing and depriving sleep; it is time to move on from sleep restriction interventions and examine whether extending sleep duration can improve mental health indicators in adolescents at risk for type 2 diabetes. Therefore, the purpose of this study was to measure mental health indicators (depression symptoms, mood, and behavioural problems) before and after both increasing and decreasing time in bed in adolescents who are at risk for type 2 diabetes, as part of the Sleep Manipulation in Adolescents at Risk of Type 2 Diabetes (SMART2D)

study. This study aims to provide the most robust evidence to date on whether extending time in bed for one week, compared to decreasing time in bed for one week, can result in improvements in mental health indicators in adolescents at risk for type 2 diabetes. If improvements are found once the full sample is obtained, translating these findings for healthcare providers may provide a more comprehensive toolkit to help these professionals enforce the positive effects of sleep on mental health indicators in this population.

CHAPTER 2: REVIEW OF THE LITERATURE

The thought that sleep affects mental health indicators has been around for many years; it has been shown that adults with sleep problems are more likely to have mental health problems (Ford & Kamerow, 1989) including depressive symptoms, mood problems, and behaviours such as drug and alcohol abuse. Ford and Kamerow's work provided important insights on the association between sleep duration and mental health indicators in adults. However, for the present thesis, it is important to understand the role of sleep and its impact on depression symptoms, mood, and behavioural problems in adolescents. This literature review focuses on the association between sleep duration and these three mental health indicators in adolescents. The literature review begins with studies pertaining to sleep duration and mental health indicators (depression symptoms, mood, and behavioural problems), diving into the experimental and observational evidence, then ties in the population of interest and puberty. Depression symptoms and depressive symptoms are used interchangeably. Sleep durations are defined by time in bed.

2.1 Sleep duration and mental health indicators

Many people, especially adolescents, sacrifice sleep for reasons such as homework, sports, and screen time (National Adolescent and Young Adult Health Information Center, 2014). Establishing the directionality of these association is important as this relationship may not only be bidirectional but it is plausible that they are mutually reinforcing; as lack of sleep may cause mental health problems, and mental health problems may cause inadequate sleep (Alvaro, Roberts, & Harris, 2013).

2.2 Depression

According to the Diagnostic and Statistical Manual of Mental Disorders Version V (DSM-V, 5th ed.; *DSM–V*; American Psychiatric Association, 2013), "Major Depressive Disorder" is defined as a "depressed mood or a loss of interest or pleasure in daily activities for more than two weeks", which leads to impaired social, occupational, and educational capacity. Depressive symptoms include: depressed mood or irritability, decreased interest or pleasure, significant weight change (generally defined as a 5% change in weight in a period of a month) or change in appetite, change in sleep, change in activity, fatigue or loss of energy, guilt/worthlessness, diminished concentration, and suicidality (DSM-V, 5th ed.; *DSM–V*; American Psychiatric Association, 2013). Major Depressive Disorder is diagnosed when at least five of these symptoms occur almost every day in a period of two weeks, and either depressed mood or loss of interest or pleasure are present (DSM-V, 5th ed.; *DSM–V*; American Psychiatric Association, 2013). Depression is a problem for obvious reasons, including that it interferes with every day activities and can potentially lead to suicide. A recent meta-analysis showed that both short and long sleep durations are associated with an increased risk of depression in adults (Zhai, Zhang, & Zhang, 2015), but this relationship is not as well documented in adolescents.

Experimental Evidence

Few experimental studies have been conducted to investigate the effect of sleep duration on depression symptoms in adolescents. Three randomized cross-over trials have explored this relationship and as a result mixed findings have been reported (Baum et al., 2014; Van Dyk et al., 2017; Vriend, Davidson, Shaffner, Corkum, & Rusak, 2011). The first cross-over trial was conducted in Canada (Vriend et al., 2011) and examined the effect of increasing and decreasing

sleep by one hour over the course of one week on emotional regulation in apparently healthy children aged 8-12 years. Sleep was measured using actigraphy as participants slept at home and emotional regulation was proxy- (by one parent) and self-reported using the Emotion Questionnaire (Rydell, Berlin, & Bohlin, 2003; Vriend et al., 2011), which has proven to be valid in 8- and 9-years-old children (Rydell, Thorell, & Bohlin, 2007). After a baseline week, a two-hour difference in total sleep time (TST) was sought by altering time spent in bed by increasing and decreasing sleep by one hour from Tuesday through Friday of the two experimental weeks (Vriend et al., 2011). An average difference of 73 minutes was found (485 minutes in the decreased sleep condition, 558 minutes in the increased sleep condition) (Vriend et al., 2011). Findings revealed poorer parent-reported emotional regulation in the decreased sleep condition compared to the increased sleep condition; however, there were no such differences reported by the children (Vriend et al., 2011). There were important limitations in this study; first, there was an interaction effect between the condition and the order indicating that the order of the intervention condition may have had an impact on emotional regulation score (Vriend et al., 2011). Second, the self-reported questionnaire used in this study was only validated for children between 8 and 9 years of age, while the age range of the study was 8 to 12 years. Important factors that may have affected sleep and emotional regulation were also not considered in the present study (e.g., diet, physical activity, and pubertal status). Also, the intervention was only four days which may be too short to see differences. Finally, the emotion questionnaire measures sadness and positive emotions, but also measures anger and fear which may have mitigated these results (Vriend et al., 2011). Therefore, considering the methodological issues in this study, e.g., the length of the washout period between conditions being too short (3 nights), the use of a questionnaire with lack of documented validity in the study population, and the use of apparently healthy children, it is

impossible to draw a definitive conclusion on the effect of sleep on depressive symptoms in this population.

The second cross-over trial attempted to compare 10 hours to 6.5 hours of sleep over the course of five days each in 50 adolescents aged 14-17 years (Baum et al., 2014). The increased sleep group averaged 8.9 hours of sleep per night while the restricted sleep group averaged 6.3 hours (Baum et al., 2014). Sleep duration was measured by actigraphy and the Profile of Mood States (POMS) (Mcnair, Lorr, & Droplleman, 1971) proxy- and self-reported questionnaires were used to measure depression, which has been validated in adolescents (Baum et al., 2014; Terry, Lane, Lane, & Keohane, 1999). The POMS looks at seven depression index: unhappy, sad, hopeless, discouraged, miserable, helpless, and worthless (Terry et al., 1999). An additional purpose of the study was to validate the subscale of the Vanderbilt Assessment Scales (Wolraich et al., 2003) that was also used to measure depression (Baum et al., 2014). There were no significant differences found in either depression index measure between the increased and decreased sleep conditions (Baum et al., 2014). This crossover had a washout period of two days in between the experimental conditions and they tested for period and carryover effects, but it is unclear if they found any significant differences (Baum et al., 2014). Similarly to Vriend and colleagues (2011), it is possible that five intervention days was not enough to elicit changes in depression scores and two days of washout may not have been enough to return to baseline. Furthermore, a questionnaire designed specifically to measure depression symptoms more thoroughly may be more appropriate and sensitive to changes over a short period of time than the POMS, which mostly measures mood with a single subscale pertaining to depression. Finally, we may not see differences in apparently healthy adolescents.

The third cross-over trial is a recent study by Van Dyk and colleagues, who also used the POMS in a similar population (14- to 18-years-old) and included adolescents who reported sleeping between five and seven hours per night (Van Dyk et al., 2017). The adolescents participated in one baseline week of sleep. Afterwards, they either continued as the baseline sleep measurements for two weeks or increased their sleep by 1.5 hours on weeknights by manipulating bed and wake times, and then crossed over (Van Dyk et al., 2017). In the end, a 73-minute increase in TST was obtained on average, as measured by actigraphy (6.2 hours in the habitual sleep condition, 7.4 hours in the increased sleep condition) (Van Dyk et al., 2017). There were no significant differences found in depression levels throughout the study (Van Dyk et al., 2017). In addition to the possible lack of sensitivity of the POMS to measure depression symptoms, this methodology introduces another important limitation. Since they used apparently healthy participants who averaged as little as five hours of sleep per night (Van Dyk et al., 2017), adding on at most 1.5 hours of sleep still falls short of the recommended sleep duration of 8 to 10 hours per night contained in the 24-hour movement guidelines for children and youth (Tremblay et al., 2016). Therefore, these null results may not indicate a lack of effect of increasing sleep on depressive symptoms as the increase in sleep duration may have been insufficient. This study was nevertheless instrumental in showing that sleep extension of 1.5 hours for two weeks is feasible in adolescents, with a high level of adherence (93% adhered to the sleep intervention prescribed) (Van Dyk et al., 2017). However, another important criticism of this study is that in the absence of adding some stress (i.e., a sleep restriction condition), it is impossible to understand the possible dose-response effect of sleep on depression symptoms.

Observational Evidence

While there is a lack of experimental studies investigating the effect of sleep duration on depression symptoms, many observational studies (longitudinal and cross-sectional) have examined this association. Sleep is typically assessed subjectively in observational studies, which may not reflect actual time spent asleep (Girschik, Fristchi, Heyworth, & Waters, 2012). While many sleep questionnaires have been validated, many studies have used questionnaires with unknown psychometric properties.

A few longitudinal studies have been conducted to investigate the association between sleep duration and depression symptoms over time (Asarnow, McGlinchey, & Harvey, 2014; Fredriksen, Rhodes, Reddy, & Way, 2004; Lovato, Short, Micic, Hiller, & Gradisar, 2017; Meijer, Reitz, Deković, van den Wittenboer, & Stoel, 2010; Roberts & Duong, 2014). These longitudinal studies used various self-reported sleep measurements, none of which were psychometrically validated for adolescents, except for Lovato and colleagues (2017) who used the Center for Epidemiological Studies Depression Scale (CES-D, Radloff, 1977; Vilagut, Forero, Barbaglia, & Alonso, 2016). Depression was measured by interviews or questionnaires, including the Youth Self Report (YSR, Achenbach, 1991), a shortened version of the Children's Depression Inventory (CDI) (Kovacs, 1980), the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, 4th ed., text rev.; *DSM–IV–TR*; American Psychiatric Association, 2000), and the Diagnostic Interview Schedule for Children Version IV (DISC-IV) (Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). The YSR, DSM-IV, and DISC-IV are validated depression symptoms questionnaires (Lacalle Sisteré, Domènech Massons, Granero Pérez, & Ezpeleta Ascaso, 2014; Shaffer et al., 2000) while the CDI has only been validated among children aged 8-12 years (Ahlen

& Ghaderi, 2017), and Asarnow and colleagues (2014) created their own questionnaire that has not been validated.

Asarnow and colleagues (2014) found that short sleep duration (< 9 hours per night) did not predict emotional distress one, six, or seven years later in grades 7 to 12 children. Limitations include that TST was only self-reported at the first two-time points and emotional distress was only measured at the last time point; the conclusions made were based on measurements that did not occur at the same time (Asarnow et al., 2014). Furthermore, the adolescent population should sleep between 8-10 hours a night according to public health guidelines (Tremblay et al., 2016); sleeping less than nine hours is still within the recommended range, making it unsurprising that no differences in emotional distress were found. Meijer and colleagues (2010) used the YSR to show that sleep duration was negatively associated with feelings of depression in children aged 12-17 years; however, depression and anxiety were combined into one construct and the authors acknowledged this may be a mistake because sleep may act on depression and anxiety differentially (Meijer et al., 2010). Fredriksen and colleagues (2004) found a significant correlation ($r = -0.34$) between depression symptoms measured by the CDI and mean sleep times of grade 6-8 children who did not meet the recommended sleep duration of 8-10 hours (Tremblay et al., 2016). Roberts and colleagues (2014) showed that both weeknight and weekend sleep durations of less than six hours were associated with depression and its symptoms in 4175 youth aged 11-17 years using the DSM-IV and the DISC-IV. When 3134 of the original participants were re-evaluated a year later, short sleep at time one increased the risk for depression at time two (Roberts & Duong, 2014). Lovato and colleagues (2017) studied 138 Australian adolescents at two time points over a year. This study showed CES-D scores did not predict TST at time one, but did predict TST at time two, suggesting that depressed mood may act as a precursor to shorter sleep durations (Lovato

et al., 2017). The pubertal status was controlled for only in the Asarnow and colleagues' (2014) study and none of the studies controlled for important covariates such as weight status, physical activity levels or food intake; this along with previously mentioned flaws in the methodology limit the applicability of the results of these studies.

Many cross-sectional studies have examined the relationship between sleep duration and depression symptoms (Barnes & Meldrum, 2014; De Souza & Hidalgo, 2014; Dewald-Kaufmann, Bogels, Oort, & Meijer, 2013; Gangwisch et al., 2010; Kang et al., 2014; Lee, Cho, Cho, & Kim, 2012; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2014; McHale, Kim, Kan, & Updegraff, 2011; Paciência, Barros, Araújo, & Ramos, 2013; Pallesen et al., 2011; Short, Gradisar, Lack, & Wright, 2013; Sivertsen, Harvey, Lundervold, & Hysing, 2014; Suzuki et al., 2011; Wolfson & Carskadon, 1998; Yen, King, & Tang, 2010). The CES-D is a commonly used instrument to measure depression. The CES-D has been systematically reviewed and is considered an acceptable measure to screen for depression among adolescents and adults; however, it is not a comprehensive diagnostic tool for clinical depression (Vilagut, Forero, Barbaglia, & Alonso, 2016). Several studies have used the CES-D to observe the association between sleep duration and depression symptoms in adolescents (12-18 years); in these studies, sleep was measured via sleep diary reports, interviews, or self-reported questionnaires (Barnes & Meldrum, 2014; De Souza & Hidalgo, 2014; Dewald-Kaufmann et al., 2013; Gangwisch et al., 2010; Kang et al., 2014; Lee et al., 2012; Lemola et al., 2014; McHale et al., 2011; Paciência et al., 2013; Pallesen et al., 2011; Short et al., 2013; Sivertsen et al., 2014; Suzuki et al., 2011; Wolfson & Carskadon, 1998; Yen et al., 2010). Overall, most cross-sectional studies reported a negative association between sleep duration and depression symptoms (Barnes & Meldrum, 2014; Dewald-Kaufmann et al., 2013; Gangwisch et al., 2010; Lemola et al., 2014; Lovato et al., 2017; Short et al., 2013; Yen et al.,

2010). Gangwisch and colleagues (2010) showed that sleep duration of less than five hours per night, measured in a large sample (n= 15,659) of adolescents in grades 7 to 12, was associated with significantly more depression symptoms. Only one study reported no association between sleep duration and depressive symptoms (McHale et al., 2011).

Another commonly used depression scale is the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). The BDI has been validated in adolescent populations (Kauth & Zettle, 1990). Several cross-sectional studies have used the BDI to associate depression with sleep (De Souza & Hidalgo, 2014; Kang et al., 2014; Paciência et al., 2013). Looking at a cut-off of seven hours of sleep, it was found that adolescents in grades 7-10 who slept at least seven hours had less depressive symptoms than those who slept less than seven hours (Kang et al., 2014). In contrast, when comparing 12- to 21-years-old students with less than mild depression symptoms and those with at least mild depression symptoms, there was no differences in sleep durations between groups (De Souza & Hidalgo, 2014). De Souza and Hidalgo (2014) did not control for pubertal status or age in this comparison.

Other studies have used different tools to measure depression signs and symptoms when examining the association between sleep duration and depression in adolescents (Dewald-Kaufmann et al., 2013; Ogawa, Kitagawa, Fukushima, Yonehara & Nishida, 2018, Owens, Belon, & Moss, 2010; Pallesen et al., 2011; Sivertsen et al., 2014; Suzuki et al., 2011; Wolfson & Carskadon, 1998; Yeo et al., 2019). All eight cross-sectional studies found negative associations between sleep duration and depression scores. Depression measures used included the Dutch version of the Child Depression Inventory (CDI) (Kovacs, 2002), the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983), the Short Mood and Feelings Questionnaire (Angold, Costello, & Messer, 1995), the General Health Questionnaire (Goldberg, Rickels,

Downing, & Hesbacher, 1976), the Japanese version of the General Health Questionnaire (GHQ) (Doi & Minowa, 2003), the Depressive Mood Scale (Kandel & Davies, 1982) and the Kutcher Adolescent Depression Scale (KADS) (Leblanc, Almudevar, Brooks, & Kutcher, 2002). Only the Short Mood and Feelings Questionnaire, the Depressive Mood Scale, the General Health Questionnaire, the KADS, and the HADS have been validated in adolescents (Baksheev, Robinson, Cosgrave, Baker, & Yung, 2011; Kandel & Davies, 1982; Leblanc et al., 2002; Tait, French, & Hulse, 2003; Turner, Joinson, Peters, Wiles, & Lewis, 2014).

Based on the available experimental studies investigating the effect of sleep duration on depressive symptoms in youth, there is no effect of sleep on depressive symptoms according to self-report. However, there is a clear need for more experimental studies with rigorous designs that account for possible biases (e.g., carry-over effect) and important confounding factors to better understand the impact of sleep manipulation on depression symptoms in "high-risk" adolescents. Additionally, observational studies suggest that short sleep durations, mostly measured subjectively, are unfavourably associated with depression symptoms in the pediatric population. However, it is important to consider that changes in sleep is one of the symptoms of clinical depression. More experimental studies are needed that use objective measures of sleep and control for confounding factors in order to make stronger conclusions and causal inferences.

2.3 Mood

While mood can encompass a variety of mood disorders such as major depressive disorders, bipolar disorder, and mania. For the purpose of this study, mood is defined as a set of subscale items which include: anger, confusion, depression, fatigue, tension, and vigour. A recent systematic review across all ages demonstrated a reciprocal relationship between sleep and mood,

where both objective and subjective measures of sleep were bidirectionally associated with mood outcomes (Konjarski, Murray, Lee, & Jackson, 2018). It is important to look at the studies in adolescents in order to further investigate this relationship.

Experimental Evidence

Three cross-over trials have looked at the effect of sleep duration on mood (Baum et al., 2014; Van Dyk et al., 2017; Vriend et al., 2011). Vriend and colleagues (2011) used the Emotion Questionnaire which measures sadness, anger, fear, and positive emotions, and an affective response task which was validated in an unpublished doctoral thesis (Leotta, 1999). Only the parent-report version emotion questionnaire yielded differences after a 73 minutes difference in TST, showing emotional regulation improved with increased sleep according to the parents (Vriend et al., 2011). The affective response task showed a difference in positive affective response, but no difference in negative affective response (Vriend et al., 2011). Both Baum (2014) and Van Dyk (2017) used the POMS to assess mood. Baum and colleagues (2011) found that adolescents were significantly less angry, confused, fatigued, tense, and more vigorous in the healthy sleep condition (average: 8.9 hours/night) compared to the sleep restriction condition (average: 6.3 hours/night). Similarly, Van Dyk and colleagues (2017) found that short-sleeping adolescents were significantly less angry, confused, fatigued, and more vigorous after extending their sleep duration (average: 7.4 hours/night) compared to their habitual sleep duration (average: 6.2 hours/night) by an average of 73 minutes. While these discoveries are important, these studies suffer from multiple methodological flaws as mentioned previously, emphasizing the need for more experimental research.

Observational Evidence

A commonly used mood measure is the Positive and Negative Affective Schedule (PANAS, Watson & Clark, 1988) which measures positive affect (enthusiastic, active, and alert) and negative affect (subjective distress and unpleasurable engagement). Multiple studies have used the PANAS in combination with sleep duration (Cousins et al., 2011; Garcia, Zhang, Holt, Hardeman, & Peterson, 2014; Shen, van Schie, Ditchburn, Brook, & Bei, 2018). A recent study with a large sample size (n=4582) of adolescents found self-reported shorter sleep durations were associated with lower positive affect and self-reported poor sleep quality was associated with more negative affect (Shen et al., 2018), supporting the results from Vriend and colleagues (2011). Another study that used the PANAS in children and adolescents found no association in healthy controls between sleep and affect, but did find associations in youth with anxiety and depression (Cousins et al., 2011). More TST was associated with better mood the next day; however, differences arose between the two groups of children regarding time in bed, wake after sleep onset and sleep onset latency (Cousins et al., 2011). Similarly, a study in Latina adolescents living in a Midwestern State in the USA found that negative mood predicted poorer sleep quality but found no associations with sleep quantity (Garcia et al., 2014). The conflicting evidence supports the need for more experimental evidence.

Other mood measures have been used to study the relationship between mood and sleep. Using the POMS, shorter sleep durations were associated with lower mood scores in apparently healthy adolescents (Fuligni & Hardway, 2006). A US national cross-sectional study that used the National Comorbidity Survey Adolescent Supplement (NCA-S), which included in-depth interviews with over 10 000 adolescents, found that shorter sleep durations were associated with increased odds of mood disorders (Zhang et al., 2017). Finally, using subjective measures of sleep

duration, fatigue, mood, and stress, positive associations were found between sleep duration and the three other variables in female youth athletes (Watson & Brickson, 2018). A rigorous study design is needed in order to determine if these associations exist between sleep duration and mood, as well as to determine the directionality of these associations.

2.4 Behavioural Problems

This section of the literature review focuses on five main behavioural problems: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behaviour. All five indicators have been associated with sleep difficulties in 8- to 11-years-old children (Hoedlmoser, Kloesch, Wiater, & Schabus, 2010). Furthermore, it has been shown that a child who sleeps one hour less per night than the average sleep duration is at increased risk of conduct problems, but not emotional symptoms or hyperactivity (Holley, Hill, & Stevenson, 2011). Some evidence has been discovered elucidating this relationship in adolescents.

Experimental Evidence

All three cross-over trials mentioned previously measured inattention or hyperactivity (Baum et al., 2014; Van Dyk et al., 2017; Vriend et al., 2011). Vriend and colleagues (2011) found that parent-reported inattention was greater in the short sleep duration group compared to the long sleep duration group using the revised Conners' Parent Rating Scale, which is validated for their population (Conners, Sitarenios, Parker, & Epstein, 1998). In contrast, Baum and colleagues (2014) found no cross-condition differences in hyperactivity when comparing the increased sleep condition (average: 8.9 hours/night) with the sleep restriction condition (average: 6.3 hours/night). Hyperactivity was measured using a shortened version of the Hyperactivity/Impulsivity subscale

of the Vanderbilt Assessment Scales which was validated by one of the authors (Beebe et al., 2008). Van Dyk's group (2017) also found no differences in self-report of inattention between the habitual sleep condition and the extended sleep condition; however, there was a difference in parent-reported inattention between the habitual sleep weeks and the baseline sleep weeks, which was a much smaller difference in sleep duration. This indicates that there may be a confounding variable that affected the results. Inattention was measured by a sub-scale of the Vanderbilt Assessment Scales which has been previously validated in children (Beebe et al., 2008; Van Dyk et al., 2017; Wolraich et al., 2003).

Observational Evidence

Shorter time spent asleep has also been associated with behaviour problems in some cross-sectional studies (Dewald-Kaufmann et al., 2013; Lam & Yang, 2008; Lin & Yi, 2014; Liu & Zhou, 2002; Meijer et al., 2010; Sarchiapone et al., 2014; Simon et al., 2019; Zhang et al., 2017). Simon and colleagues (2019) used objectively measured sleep duration while sleep durations were self-reported through various questions or questionnaires in the other studies. Behaviour outcomes were measured via a variety of techniques. The YSR was used to measure social problems, attention problems, and aggressive behaviour (Dewald-Kaufmann et al., 2013; Liu & Zhou, 2002; Meijer et al., 2010). Attention deficit hyperactivity disorder (ADHD) tendency was measured via a subscale of the Conners' Adolescent Self-Report Scale (Conners, 2000, Simon et al., 2019). The Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997) was used to measure multiple behaviour components including emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behaviour (Sarchiapone et al., 2014; Simon et al., 2019). Conduct problems were also measured by participants indicating if they

participated in each of the following behaviours in the last year: skipping class, fighting, and substance abuse (Lin & Yi, 2014). The NCA-S was used to address behavioural disorders (conduct disorders and oppositional defiant disorder) (Zhang et al., 2017). Finally, Medical doctors were also used to diagnose ADHD in the Lam and Yang (2008) study. Only the SDQ and the Conners' Adolescent Self-Report Scale have been validated (Conners et al., 1998; Goodman, 1997).

In a population of adolescents with overweight/obesity, total SDQ scores were negatively associated with sleep duration, indicating more behavioural problems among the shorter sleepers (Simon et al., 2019). Overall, in apparently healthy populations ages 11- to 19-years-old, these studies show that shorter sleep durations are associated with greater attention problems, social problems, aggressive behaviour, conduct problems, higher ADHD scores and more behavioural disorders (Dewald-Kaufmann et al., 2013; Lam & Yang, 2008; Lin & Yi, 2014; Liu & Zhou, 2002; Meijer et al., 2010; Zhang et al., 2017). Total SDQ scores, as well as subscale scores regarding emotional problems, peer relationship problems, and conduct problems were also found to be higher among the shorter sleepers (Sarchiapone et al., 2014). Shorter sleep durations were also associated with increased odds of behavioural disorders (Zhang et al., 2017).

While some evidence exists regarding the relationship between sleep quantity and behavioural problems, it is almost all cross-sectional besides inattention and hyperactivity. An experimental design is needed to address these and other behavioural problems such as emotional problems, conduct problems, and peer relationships.

2.5 Risk of type 2 diabetes

Family history of type 2 diabetes, physical inactivity, high body weight, dyslipidemia, and the transition into puberty are all factors to put one at risk for type 2 diabetes (Fletcher,

Gulanick, & Lamendola, 2002). Many people fall into this category and are at risk for other complications such as sleep problems and mental health problems. Most of the previously mentioned studies were conducted in apparently healthy populations. In a recent review, Dutil and Chaput (2017) showed that lack of sleep is associated with type 2 diabetes in children and adolescents. Furthermore, a new publication has shown that 58% of youth attending a weight management clinic had one or more mental health comorbidity (Buchholz et al., 2019). Notably, 8% of the population was diagnosed with depression and 14% was diagnosed with ADHD (Buchholz et al., 2019). One commonality among this population is the presence of risk factors for type 2 diabetes.

A bidirectional relationship between depressive symptoms and type 2 diabetes has been shown in other studies as well (Golden et al., 2008; Mezuk, Eaton, Albrecht, & Golden, 2008). A recent study showed that 37.5% of participants with type 2 diabetes in a 200 person sample had depression symptoms using the BDI (Kav, Yilmaz, Bulut, & Dogan, 2017). Furthermore, type 2 diabetes has been linked to diabetes distress, which consists of feeling overwhelmed by their condition, the future of their condition, and what they need to do to manage it (Snoek, Pouwer, Welch, & Polonsky, 2000). Further research is needed to address the psychological comorbidities that accompany type 2 diabetes (Perrin, Davies, Robertson, Snoek, & Khunti, 2017). In another study, the CES-D flagged 35% of adolescent participants with type 2 diabetes to be further evaluated, which is double what is expected from the general population (Cullum, Howland, & Instone, 2016). Other studies have replicated similar findings in youth (Hannon, Rofey, Lee, & Arslanian, 2013; Silverstein et al., 2015; Walders-Abramson, 2014). Additionally, adolescents with type 2 diabetes have shown worse internalizing, externalizing, and total problem behaviours compared to apparently healthy controls using the Child Behavior Checklist

(Brady et al., 2017). Further research is necessary to look beyond depression to investigate other components of mental well-being in adolescents with type 2 diabetes, controlling for other factors such as puberty. Since most of these studies did not control for sleep in the association between type 2 diabetes and various mental health indicators, it is impossible to determine its role in these associations.

2.6 Puberty

There are several reasons to explain why adolescents have a negative shift in sleep duration relative to younger children; some of these are biological, while others are psychosocial. Recent literature has begun to focus a lot on the associations between sleep and different lifestyle habits, such as caffeine use, tobacco use, and screen time (Bartel et al., 2015; Sampasa-Kanyinga et al., 2018). Even though these lifestyle factors may be of more importance than the biological factors (Maume, 2013), it is still important to consider the biological changes that result from puberty.

It has been suggested that on top of the behavioural changes, there may be changes in the circadian timing system physiologically that impacts the later bedtimes seen in adolescents (Darchia & Cervena, 2014). Furthermore, the timing of brain maturation has been linked to the timing of puberty as well and these changes are most apparent between the ages of 11 and 17 (Darchia & Cervena, 2014). It was proposed that these changes, seen by a decrease in delta and theta waves, are due to synaptic pruning (Campbell et al., 2011). Another factor is the delayed secretion of melatonin that comes with pubertal development (Carskadon, Acebo, Richardson, Tate, & Seifer, 1997). Finally, Carskadon developed a theory which says that adolescents develop a resistance to sleep pressure which allows them to stay up later (Marcus, Caroll, Donnelly, & Loughlin, 2008), and in turn their circadian cycle is shifted. Hagenauer and colleagues (2009)

summarized similar findings and found more mature adolescents were better at tolerating staying awake for longer periods of time than pre-pubertal adolescents.

One important biological difference between sexes to note is the menstrual cycle. Most women experience at least one symptom of premenstrual syndrome leading up to their menses, and about 20% of cases may be clinically relevant (Yonkers, O'Brien, & Eriksson, 2008). These symptoms include: irritability, mood swings, depression, fatigue, headaches, bloating, and cramping (Mehta, Shafi, & Bhat, 2015). These symptoms include mental health indicators and sleep problems, making the timing of the menstrual cycle a crucial element to consider.

The effects of puberty are not only biological as it occurs during a time of crucial life transitions. The social changes that coincide with puberty such as going to high school result in changes in sleep duration. Adolescents tend to stay up later, which may be biological, but also may be due to social factors, such as social media popularity. For example, adolescents may stay up later in order to keep up with their social media by posting pictures or speaking to a significant other, which becomes more likely during adolescence. The timing of puberty is a key determinant to consider when looking at sleep and its effects on health outcomes.

2.7 Summary and gap

Collectively, this literature review demonstrated a need for randomized trials in order to assess the effect of sleep duration on mental health indicators (i.e., depression symptoms, mood, and behaviour problems). Most of the literature on this topic consists of cross-sectional studies using self-reported sleep. The main limitation with the cross-sectional study design is that it precludes inferences about causality. While sleep may affect mental health, mental health status is also likely to affect sleep, as shown in adult populations (Ji et al., 2017). Since sleep is an important

health indicator for both physical and mental well-being, more experimental studies are needed to better understand the role of sleep manipulations on mental health indicators. No study exists that increases and decreases sleep duration in a population of adolescents who are at risk for type 2 diabetes, a vulnerable part of the population, while looking at symptoms of depression and mood and behaviour problems. This study will be the first of its kind to measure these mental health outcomes in this population after sleep manipulations and will be using psychometrically valid instruments. This information is of high clinical and public health relevance and may help to provide additional tools to health care providers on the potential benefits of a good night's sleep for the prevention of adverse mental health outcomes in a "high risk" group of adolescents for type 2 diabetes.

2.8 Research question

Main objective

The purpose of this study was to examine how experimental changes in time in bed (decreased and increased by 1.5-hour per night for one week) affect mental health outcomes in adolescents at risk for type 2 diabetes.

Specific objective

Document the effects of sleep manipulation (decrease and increase in time in bed by 1.5 hours per night for one week) on depressive symptoms, mood (anger, depression, tension, fatigue, vigour, and confusion), and behavioural problems (emotional problems, conduct problems, hyperactivity, peer relationship problems, and impact on daily life [difficulties in home life, leisure activities, friendship, and classroom learning]) in adolescents at risk for type 2 diabetes.

2.9 Research hypothesis

It was hypothesized that participants' scores would decrease (improve) on the Patient Health Questionnaire for Adolescents (PHQ-A), indicating less symptoms of depression, after the increased sleep duration week compared to the decreased and habitual sleep weeks. It was also hypothesized that participants would have a lower total score on the Brunel Mood Scale (BRUMS), indicating better mood, after the lengthened sleep week compared to the shortened sleep and habitual sleep weeks. Furthermore, it was hypothesized that for the mood subscales participants would fall into lower percentiles for anger, depression, tension, fatigue, and confusion, but a higher percentile for vigour, after the increased sleep week compared to the decreased and habitual sleep weeks. Finally, it was hypothesized that participants' behavioural problems scores according to the SDQ would fall into lower percentiles for total SDQ score, impact score, emotional problems, conduct problems, hyperactivity, and peer relationship problems, after the increased sleep week compared to the increased and habitual sleep weeks, indicating less behaviour problems.

CHAPTER 3: METHODOLOGY

3.1 PICOS

Population: Adolescents (13 to 18 years of age) at risk of type 2 diabetes.

Intervention: Increasing time in bed by 1.5-hour per night for a week.

Comparator: Decreasing time in bed by 1.5-hour per night for a week and habitual time in bed for a week.

Outcomes: Depressive symptoms (measured by the PHQ-A), mood (measured by the Brunel Mood Scale [BRUMS]), and behavioural problems (measured by SDQ + impact supplement).

Study design: Randomized crossover study (within-subjects experimental design).

3.2 METHODS

Brief overview of the larger study

This master's thesis is part of a larger project that aims to investigate the effect of sleep manipulation on insulin sensitivity and brain functions in adolescents at risk of type 2 diabetes. More precisely, the objective of the larger project is to determine if extending time in bed (by 1.5-hour/night) for a week compared with decreasing time in bed (by 1.5-hour/night) for a week, and baseline habitual sleep, improves systemic as well as cognitive and motor functions in adolescents presenting with risk factors for type 2 diabetes. A randomized, counterbalanced, crossover study (within-subjects experimental design) is used (see **Figure 1**). A block randomization was created by a third-party using IBM SPSS statistical software (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). From the block randomization envelopes for boys (B) and girls (G) were created for the purpose of allocation concealment. Funding for this project was received through the CHEO Research Institute, awarded to Dr. Jean-Philippe Chaput. Data collection began in April 2019 and is still underway, with an expected

completion date in the summer of 2020. Until now, all measurements and protocols have been performed by both me and a Ph.D. candidate from the Healthy Active Living and Obesity Research Group (Caroline Dutil) since the present study is part of a larger research program under the supervision of Dr. Chaput.

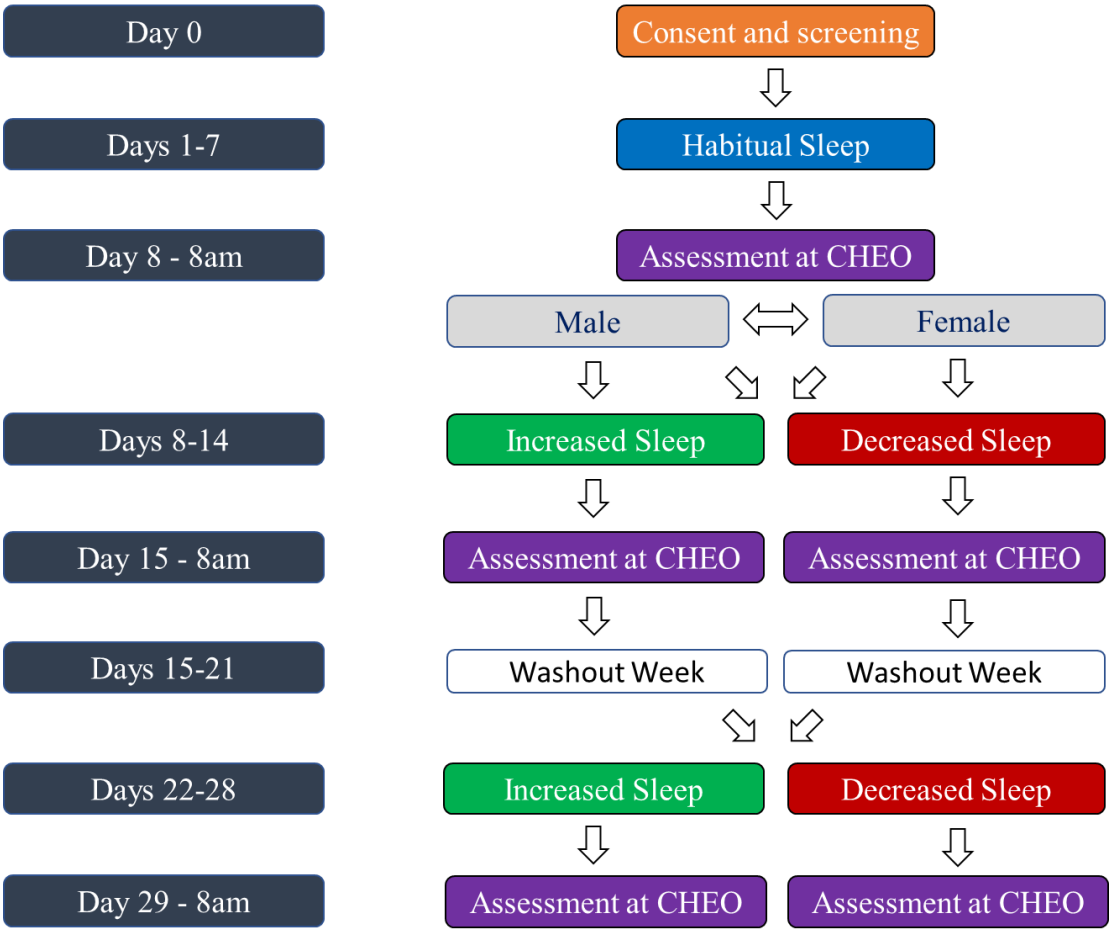

Figure 1. Outline of the study protocol

3.3 Participants

Our study recruits adolescents between the ages of 13 and 18 years who are considered at high risk for type 2 diabetes. The primary inclusion criteria for adolescents at high risk of type 2 diabetes are as follows: a body mass index (BMI) $\geq 95^{th}$ percentile and dyslipidemia (defined as having one or more of the following values: HDL < 1.00 mmol/L, TAG > 1.45 mmol/L, Non-HDL > 3.4 mmol/L). A low amount of physical activity (i.e., participate in less than 30 minutes of self-reported moderate-to-vigorous physical activity per day) is also necessary. The secondary inclusion criteria include: diagnosed with polycystic ovarian syndrome or non-alcoholic fatty liver disease (NAFLD) or a BMI in the $\geq 99^{th}$ percentile with no other known comorbidity. The recruitment goal for the larger project based on power calculations (insulin sensitivity as the primary outcome) is n=50 adolescents meeting the above-mentioned criteria. For the mental health outcomes, it was determined that the recruitment goal of the larger project was adequate as similar study designs on mental health outcomes had sample sizes ranging between 32 and 54 participants (Baum et al., 2014; Van Dyk et al., 2017; Vriend et al., 2011). The primary recruitment strategy was to target adolescents who have been referred to the Centre for Healthy Active Living (CHAL) by their primary physician. We targeted CHAL's waiting and discharge lists allowing us to seek out a population who had already been diagnosed with dyslipidemia while ensuring that they were not involved in any behavioural intervention, treatment, or other studies, thus avoiding undesired contamination.

Another important inclusion criterion pertained to sleep duration; adolescents who reported sleeping between 6.5 and 8 hours of sleep per night were eligible for this study. This criterion was critical for the interventions to be successful and to observe both the positive effect of increasing sleep (without reaching a ceiling effect) and the negative effect of decreasing sleep (without

causing excessive sleep deprivation). Participants were excluded if they had a history of chronic disease (including type 2 diabetes mellitus) and/or diagnosed psychiatric conditions, were using medications that could affect sleep (e.g., methylphenidate [stimulant medication]) or glucose homeostasis (e.g., metformin) or had a history of sleep problems (e.g., sleep apnea). A Consolidated Standards of Reporting Trials-style diagram of participant flow through the study is shown in **Figure 2**.

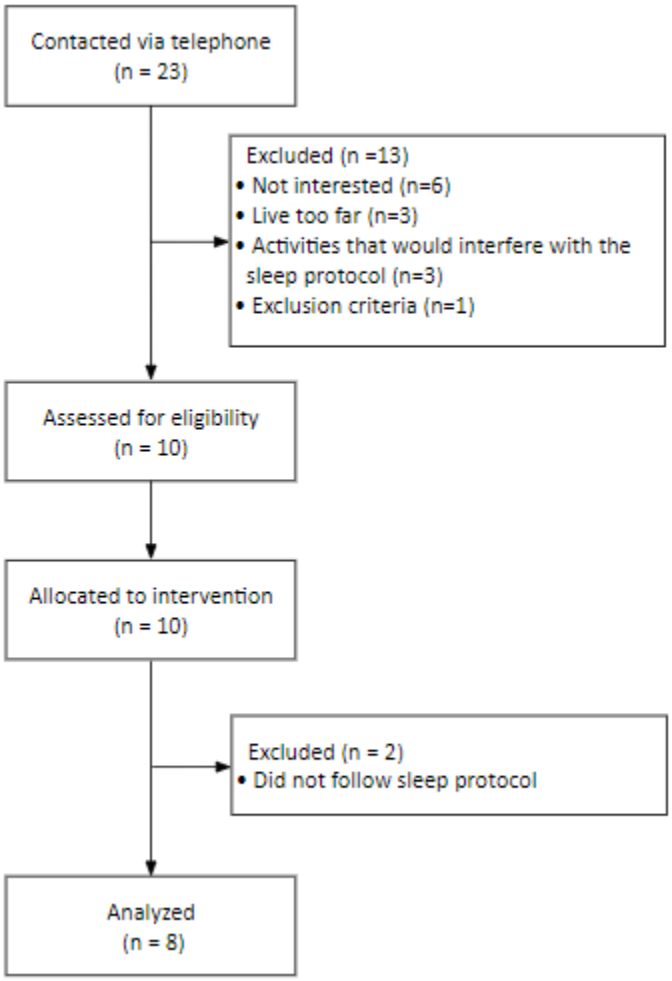

Figure 2. Flowchart of participants during the SMART2D study.

3.4 Ethical Considerations

Ethics approval was granted through the Research Ethics Board at the Children's Hospital of Eastern Ontario and the University of Ottawa (see **Appendices A** and **B** for the REBs approval letters).

3.5 Protocol

Recruitment

As mentioned above, our initial recruitment strategy was to target the CHAL waitlist and discharged list. Furthermore, we conducted chart reviews of patients from the following physicians at CHEO to see if any patients met our criteria: Dr. Caroline Zuijdwijk, Dr. Scott Somerville, Dr. Karine Khatchadourian, Dr. Sarah Lawrence, and Dr. Ellen Goldbloom (all endocrinologists and colleagues of Dr. Stasia Hadjiyannakis who have agreed to help with recruitment for the SMART2D study). When potential participants were identified, the treating physicians were contacted to obtain permission to contact. Once completed, the adolescents and their parents/guardians were contacted and given information regarding the study. Based on the phone conversation with one of our study coordinators, the participant was either deemed potentially eligible, or ineligible. For eligible adolescents, a meeting for consent/intake was arranged in order to obtain consent and confirm eligibility. Participants of age of consent and/or their parents/guardians were required to read the consent form (**Appendix C**) and sign before any further measurements were taken.

Planned Interventions

The two conditions were increasing and decreasing time in bed by 1.5 hours per night for seven days (based on averaged baseline measurement of sleep duration) and these two conditions were separated by a washout period of seven days (see **Figure 1**). This sleep intervention was based on similar studies in children and adolescents (Hart et al., 2013; Van Dyk et al., 2017). This sleep schedule protocol has been shown to be feasible in children with a 95% retention rate and led to a 2 hours and 21 minutes sleep duration difference between conditions in a recent study (Hart et al., 2013). Whereas Baum and colleagues (2014) used a washout period of two nights, we used a week-long washout to eliminate the effect of the first condition and to provide enough time for the participants to return to their normal sleeping schedule. Including the baseline assessment, each participant took four weeks to complete the study. Baseline measurement of sleep was obtained using an actigraph watch (Actiwatch 2; Phillips Respironics, Bend, OR, USA) worn 24-hours per day for seven days, in order to confirm time spent sleeping and to determine the length of time they spent in bed during the experimental phases. Then, participants were assigned to go to bed either 1.5 hours earlier or 1.5 hours later for seven days (as per the randomization). Bedtimes were chosen on an individual basis based on each day's wake up time throughout the study. After the first condition, participants had a break between conditions of seven days (washout period; week three of the study) (see **Appendix D** for a sample of a testing month schedule). In week four, they participated in the second condition that differed from the one they were assigned in the first period. A difference of at least one-hour of time in bed between conditions was needed in order to deem the sleep intervention successful.

The Actiwatch 2 was used to objectively measure sleep. Specifically, the Actiwatch was used to measure time in bed, sleep time, sleep efficiency, and wake after sleep onset. Actigraphs

have shown high sensitivity for evaluating sleep compared to the gold standard measure, polysomnography (Meltzer, Walsh, Traylor, & Westin, 2012). One-minute epochs were used based on a previous study (Hart et al., 2013). Participants were required to wear the actigraph watch on their non-dominant wrist throughout the entire four weeks of the experiment. They were instructed to only remove the watch if they went swimming or when they showered/bathed. The participants were instructed not to nap throughout the duration of the study. The Actiwatch 2 protocol can be found in **Appendix E**. Participants were also required to fill out a sleep log recording what time they went to bed and woke up at, as well as when they removed the watch, which was later confirmed through analyzing the Actiwatch 2 data. Sleep satisfaction was assessed using a single question in the sleep log, which asked "How did you feel when you woke up this morning" on a 5-point scale (0=exhausted, 1=fatigued, 2=somewhat refreshed, 3=refreshed, and 4=fully rested) after each night of sleep. In order to increase participants' compliance with the sleep schedule, participants were contacted via text messages daily for the entire length of the study. The second strategy to increase participant adherence to the sleep schedule included offering our participants monetary compensation in the form of $5 for each night they complied with the sleep protocol.

Primary Outcomes

For the present thesis, the outcome measurements were obtained in the laboratory at the end of weeks one (baseline), two (first sleep condition), and four (second sleep condition). The three primary outcomes for this thesis were depression symptoms, mood, and behaviour problems as these mental health indicators have been shown to fluctuate with changes in sleep duration, have a significant impact on daily living, and can be measured through the use of validated

questionnaires (Chaput et al., 2016). The participants were asked to complete three questionnaires that assessed these mental health indicators of interest. This occurred after the second blood draw (see **Appendix F** for the full assessment schedule). Each adolescent was given verbal and written instructions on how to complete the questionnaires. They were instructed to ask us questions if the questions felt unclear to them. The three mental health questionnaires that were used are the PHQ-A (Johnson, Harris, Spitzer, & Williams, 2002), the BRUMS (Birmaher et al., 1997), and the SDQ (Goodman, 1997) and were administered in that order. In most instances it took participants less than 20 minutes to complete. In order to reduce attrition, $30 and parking fees were provided to participants at each lab visit.

Depression

Patient Health Questionnaire for Adolescents (PHQ-A). This questionnaire assesses the severity of depressive disorders and episodes, and has been validated in this population (Cronbach's $\alpha = 0.84$) (Johnson et al., 2002; Kroenke, Spitzer, & Williams, 2001). The PHQ-A asked nine questions based upon the lead question "How often have you been bothered by each of the following symptoms during the past 7 days?" measured on a 4-point scale (0=Not at all; 1=Several days; 2=More than half the days; and 3=Nearly every day). This questionnaire was always administered first. The raw scores were summed, and the total was interpreted as a category of depression severity (0-4=None-minimal; 5-9=Mild; 10-14=Moderate; 15-19=Moderately severe; and 20-27=Severe). The questionnaire can be found in **Appendix G.**

Mood

Brunel Mood Scale (BRUMS). The BRUMS is based on the Profile of Mood States (Mcnair et al., 1971) and contains six subscales: anger, confusion, depression, fatigue, tension and vigour (Terry et al., 1999). This questionnaire has been validated in this population (Cronbach's $\alpha = 0.79 - 0.85$) (Terry et al., 1999). Participants were provided with a list of words and were instructed to cross the box that best describes how they felt over the last week. It is composed of 4 items (words) for each subscale rated on a 5-point scale (0=Not at all; 1=A little; and 2=Moderately; 3=Quite a bit; and 4=Extremely). Raw BRUMS subscale scores were transformed into T-scores for 12- to 17-year-old children based on the User Guide for the Brunel Mood Scale, which was acquired from Professor Peter Terry from the University of Queensland (e.g., a 7 on the vigour subscale was translated to the 50^{th} percentile) (Terry & Lane, n.d.). The raw total mood score and raw total mood score without the fatigue subscale were also used for analyses, the latter because the sleep intervention directly influences the fatigue subscale. This questionnaire can be found in **Appendix H**.

Behaviour Problems

Strengths and Difficulties Questionnaire (SDQ). The SDQ is a widely-used behavioural screening method that looks at five different subscales: emotional problems, conduct problems, hyperactivity/inattention, peer problems, and prosocial behaviour. This questionnaire has been validated in this population (Cronbach's $\alpha = 0.75$) (Goodman, 1997; Theunissen, Wolff, & Reijneveld, 2019). Participants were provided with 25 statements (five statements per subscale) on a 3-point scale (0=Not true; 1=Somewhat true; and 2=Certainly true) and were instructed to base their answers on how things have been for them in the past week. Furthermore, this

questionnaire contained the impact supplement which asked follow-up questions about how the intervention has impacted their lives (e.g., "In the past week, have you had difficulties in one or more of the following areas: emotions, concentration, behaviour or being able to get on with other people?"). Raw SDQ scores were converted into percentiles based on USA normative data (including age and sex) from the 2001 National Health Interview Survey Supplement (e.g., for a 14-year-old male a total SDQ score of 10 translates to the 73rd percentile for total difficulties). The USA normative data can be found in **Appendix I**. Raw scores were also categorized into the following categories: close to average; slightly raised/lowered; high/low; very high/low. These categories are different for each subscale; for example, a score of 6 on emotional problems is considered high, while a score of 6 on conduct problems is considered very high. Categorization can be found in **Appendix J** along with the questionnaire. Externalizing and internalizing scores were kept as raw scores since no normative data exist.

Descriptive measurements at baseline

Intake Questionnaire. Age was measured through date of birth and dates of testing. Gender was self-reported using the question, "How do you describe yourself?" with the following responses: Male; Female; Trans Male/Trans Man; Trans Female/Trans Woman; Genderqueer/Gender Non-Conforming; and Different Identity. Sex was self-reported using the question, "What sex were you assigned at birth, such as on an original birth certificate?" with the following responses: Male; Female. Ethnicity was self-reported using the question, 'What is your race or ethnicity (select all that apply)?" with the following responses: White or Caucasian; Hispanic, Latino, or Spanish; Black, African descent, or Caribbean descent; Asian or Asian Indian; Middle Eastern or North African; Aboriginal (First Nations, Inuit, and Métis); Pacific Islander;

and Other (with a space provided to self-identify). A proxy measure of socioeconomic status was obtained based on the highest level of education attained by at least one parent in their household and these were coded into three categories as follows: very low to low was assigned to those with parents that did not complete high school; low to medium was assigned to those with at least one parent who completed high school and some college; and medium to medium-high was assigned to those with at least one parent that graduated from a bachelor's or a postgraduate degree (Chaput et al., 2018). Family history of type 2 diabetes and type 2 diabetes risk was self-reported using the following open-ended questions about their mother, father, and siblings: "Is anybody in your family being treated for type 2 diabetes?" and "Does anybody in your family have a history of heart disease, type 2 diabetes, or high cholesterol?".

Anthropometric Measurements. Weight was measured using a digital scale (A&D Medical, Milpitas, California, USA) and height was measured with a portable stadiometer (SECA, Hamburg, Germany) in the Frankfurt plane. Both height and weight were measured twice, and a third measurement was taken if the difference between the two first measurements exceeded 0.5 cm and 0.1 kg, respectively. The World Health Organization (WHO) BMI z-scores for age and sex were then used to calculate BMI percentiles (de Onis et al., 2007) (see **Appendix K** for WHO growth charts for age and sex).

Pubertal Status. A self-assessment questionnaire was used with images to assess pubertal status from stages 1-5 for descriptive purposes (Rasmussen, Wohlfahrt-veje, Renzy-martin, & Hagen, 2015). Questions regarding facial hair and deepening of the voice were also provided for males; whereas questions regarding the menstrual cycle were provided for females. The lowest

stage identified by participants on the graphics was considered their current stage of development. Information regarding the menstrual cycle was used to see if this may have an effect on sleep and mental health outcomes. The complete measure can be found in **Appendix L**.

Pediatric Quality of Life Inventory (PEDS-QL). Participants filled out a questionnaire assessing their quality of life for descriptive purposes (Varni, Seid, & Rode, 1999). It assesses four factors: physical, emotional, social, and school functioning. This questionnaire has been validated (Baloun & Velemínský, 2018). It is composed of 23 questions on a 5-point scale (0=Never; 1=Almost never; 2=Sometimes; 3=Often; and 4=Almost always). Scores are converted as follows: 0=100, 1=75, 2=50, 3=25, and 4=0. A total score was obtained by averaging all 23 questions. A score below 70 indicates the possible presence of a major chronic condition (Huang et al., 2009). This questionnaire can be found in **Appendix M**.

Potential Risks

While the risk to participants was assessed to be minimal for the present thesis study, we took necessary precautions regarding participants' mental health. Although adolescents with known psychiatric disorders were excluded from the study, if we found any concerning answers on the PHQ-A, we consulted with Dr. Gary Goldfield who is a clinical psychologist in our research group. His opinion on the matter informed our course of action. Specifically, consultation occurred if the total score of the PHQ-A ≥15 and/or any response besides 0 (none of the days in the past week) on the Question 9, "Thoughts that you would be better off dead, or of hurting yourself in some way?". Also, the 1.5-hour reduction in sleep was of minimal risk compared to other studies that have restricted sleep duration to four hours in adolescents (Klingenberg et al., 2013).

3.6 Statistical Analysis

Sleep data were downloaded, verified, and cleaned by both me and Caroline Dutil. In order to be included in analyses, participants required to not deviate from their bedtime or wake up times by more than 30 minutes for five or more nights. Questionnaire data were entered by either me, Caroline Dutil, or a support volunteer from CHEO, and then verified by a second person. If questionnaire data were incomplete, scores were recalculated, and a new mean was generated based on the remaining data. Descriptive characteristics of our sample are provided (as means and standard deviations, when relevant). For the purpose of this thesis, participants were excluded if they neglected to follow the sleep protocol as previously defined in the sleep methods section. Intention to treat analysis will be used once the full sample is obtained.

Time in bed data were tested for assumptions of normality including the following tests: the Shapiro-Wilk test, the Kolmogorov Smirnov test, the Mauchly test for sphericity, and skewness and kurtosis were assessed. Time in bed was deemed to not violate any assumptions of normality. Repeated-measures ANOVA was used to see if time in bed was affected by the three sleep conditions (habitual, increased, and decreased sleep). Alpha values of < 0.05 were considered significant. Upon finding significant differences, a Bonferroni post-hoc test was used to identify the loci of the individual differences between each condition. We were unable to conduct tests for carry-over effects or period effects of the sleep intervention due to small sample size. However, once the full sample is obtained these tests will be performed. A paired t-test was also used to identify differences between the increased and decreased sleep conditions.

Sleep efficiency, wake after sleep onset, and wake after sleep onset adjusted for time in bed data were also tested for assumptions of normality, as described above. These sleep measurements also did not violate any assumptions of normality. Paired t-tests on these sleep

measures were used to identify significant differences between increased and decreased sleep conditions. Additionally, a Wilcoxon signed-rank test was used to test for a difference between conditions for sleep satisfaction based on question 6 in the sleep log.

Mental health outcomes (PHQ-A scores, total mood score, total mood score without fatigue, anger, tension, confusion, depression, fatigue, vigour, total SDQ score, impact score, emotional problems, conduct problems, hyperactivity, peer relationship problems, prosocial behaviour, externalizing problems, and internalizing problems) data were tested for assumptions of normality including the following tests: the Shapiro-Wilk test, the Kolmogorov Smirnov test, and tests for skewness and kurtosis. If any outliers were found (i.e., less than Q1-[3*IQR] or more than Q3+[3*IQR] was identified as an extreme outlier and less than Q1-[1.5*IQR] or more than Q3+[1.5*IQR] was identified as an outlier), the participant was removed, and assumptions of normality were retested. After removing the outliers, normality tests were reconducted. If the data were normally distributed, parametric analyses were conducted (paired t-tests). Meanwhile, if the data still failed assumptions of normality despite the removal of the outliers, non-parametric tests (Wilcoxon signed-rank test) were conducted with the outliers in the sample, since the removal of outliers are not required to satisfy assumptions of non-parametric tests.

For clinical relevance, effect sizes based on parametric testing were reported using the Cohen's *d* method where values of 0.2, 0.5, 0.8, and 1.3 represent small, medium, large, and very large effect sizes, respectively (Cohen, 1988; Rosenthal, 1996). Whereas, effect sizes based on non-parametric testing were determined using *r* where values of 0.1, 0.3, 0.5, and 0.7 represent small, medium, large, and very large effect sizes (Rosenthal, 1996; Rosenthal, 1994).

CHAPTER 4: RESULTS

Complete results from the data analyses can be found in **Tables 1-6** and **Figures 3-10**. The written results are a summary of the important findings. These results are preliminary in nature as data collection for the SMART2D study is still ongoing.

4.1 Sample's Descriptive Statistics at Baseline

A total of 10 participants (4 male, 6 female) with a mean age of 14.7 ± 1.4 years and a BMI percentile > 99.8 were screened and accepted into the study. Of these 10 participants, two were dropouts due to a total lack of adherence to the sleep protocol. Out of our sample, all 10 participants identified with their sex at birth. Five participants self-identified as White/Caucasian, two as Middle Eastern/North African, one as Asian/Asian Indian, one as Hispanic/Latino/Spanish, and one as Black/African Descent/Caribbean. Our participants reported an average pubertal stage of 3.4 (1 = pre-adolescence and 5 = attained physiological/physical maturity). Quality of life scores ranged from 48 and 88, with an average of 69. The average quality of life falls below 70, indicating a possible presence of a major chronic condition. Eight of the ten participants reported immediate family members with risk factors of type 2 diabetes. The average time in bed was 7 hours and 55 minutes at baseline. Socioeconomic status ranged from very low to medium-high. Descriptive statistics for individual participants can be found in **Table 1**.

During the habitual sleep week, participants averaged 41 minutes/night of catch-up sleep during weekends and holidays. Three out of ten participants met the cut-off for sleep disturbances (sleep efficiency < 85%) determined by Lacks and Morin (1992). During the habitual sleep week, participants spent an average of 48 minutes awake throughout the night. For more details on baseline sleep, see **Table 2**.

4.2 Intervention and Comparator Sleep Duration

The increased sleep week resulted in an average increase of 38 minutes ± 24 minutes of time in bed from habitual sleep. The decreased sleep week resulted in an average decrease of 87 minutes ± 35 minutes of time in bed from habitual sleep. There was an average difference of 125 minutes ± 29 minutes of time in bed between the increased and decreased sleep conditions. The increased sleep week resulted in an average increase of 29 minutes ± 26 minutes of sleep time from habitual sleep. The decreased sleep week resulted in an average decrease of 65 minutes ± 37 minutes of sleep time from habitual sleep. There was an average difference of 93 minutes ± 31 minutes of sleep time between the increased and decreased sleep conditions. Repeated-measures ANOVA revealed a significant effect of the sleep condition on time in bed, $F(2, 14) = 75.131$, $p = < 0.001$). Post-hoc tests using Bonferroni corrected t-tests indicated significant differences between habitual and increased sleep ($p = 0.01$), habitual and decreased sleep ($p = 0.001$), and increased and decreased sleep ($p < 0.001$). Cohen's *d* was 2.96 between the increased and decreased sleep conditions, indicating a very large effect size. While these differences are significant, the difference between habitual and increased time in bed of 38 minutes does not meet our cut-off of 60 minutes and therefore is not considered to be meaningful; thus, the outcome comparisons were based on the increased and decreased sleep weeks. There was no significant difference between time in bed during the washout week ($M = 468.7$ minutes, $SD = 59.3$) and the habitual sleep week ($M = 481.3$ minutes, $SD = 39.4$); $t(6) = 0.8652$, $p = 0.42$. Visual representations of the time in bed for each condition can be found in **Figures 3 and 4**.

Table 1. Descriptive characteristics for the SMART2D participants (n=10).

	Age	Gender	Sex	Ethnicity	BMI z-score (percentile)	Puberty Stage	SES	PEDS-QL Score	Family history
Participant 1					3.31 (> 99.9)	3	Medium to medium-high	62	One parent: HChol
Participant 2					4.78 (> 99.9)	3	Low to medium	48	One parent: HChol and HT
Participant 3					4.46 (> 99.9)	4	Medium to medium-high	88	One parent: HT
Participant 4					4.42 (> 99.9)	4	Low to medium	66	None
Participant 5		Individual values not reported in order to maintain anonymity			2.93 (> 99.8)	3	Low to medium	63	None
Participant 6					3.27 (> 99.9)	3	Medium to medium-high	73	One parent: GD
Participant 7					3.49 (> 99.9)	4	Very low to low	77	One parent: GD
Participant 8					3.15 (> 99.9)	3	Low to medium	84	One parent: HT, CVD, HChol
Participant 9					4.64 (> 99.9)	4	Medium to medium-high	62	Both parents: T2D One parent: HChol
Participant 10					3.98 (> 99.9)	3	Medium to medium-high	67	One parent: HT
Mean (SD) or percentages	14.7 (1.4)	60% G	60% F	50% White/Caucasian	3.8 (0.7)	3.4 (0.5)	50% medium to medium-high	69 (12)	80% at least one parent

Note. These were participants collected from April 2019 to August 2019.
Abbreviations: B, boy; BMI, body mass index; CVD, cardiovascular disease; G, girl; GD, gestational diabetes; HChol, hypercholesterolemia; HT, hypertension; PEDS-QL, pediatric quality of life inventory; SES, socioeconomic status; SMART2D, A Sleep Manipulation in Adolescents at Risk of Type 2 Diabetes; T2D, type 2 diabetes.

Table 2. Habitual sleep parameters (minutes per night) objectively measured over a period of 7 days (n=10).

		Time in Bed (min)			**Sleep Time (min)**			**Sleep Efficiency (%)**			**Wake After Sleep Onset (min)**		
		Total	Weekday	Weekend/ Holiday	Total	Weekday	Weekend/ Holiday	Total	Weekday	Weekend/ Holiday	Total	Weekday	Weekend/ Holiday
Participant 1	Mean	503.0	468.0	529.3	459.7	433.0	480.0	89.1	88.0	89.8	43.3	35.0	49.3
	SD	90.2	108.9	78,98	79.7	93.8	74.6	2.2	1.0	2.8	14.4	15.1	12.4
Participant 2	Mean	498.4	505.0	482.0	463.6	471.0	446.0	90.6	90.0	90.8	34.9	34.0	36.0
	SD	68.2	45.6	137.2	56.6	42.9	104.7	3.8	2.5	7.9	14.2	6.0	32.5
Participant 3	Mean	458.1	431.0	494.3	399.9	376.0	432.0	85.3	86.0	84.6	58.3	55.0	62.3
	SD	80.4	48.0	111.8	62.8	36.9	84.2	2.0	1.4	2.8	20.5	12.3	31.4
Participant 4	Mean	495.0	473.3	444.0	446.0	424.8	407.0	81.6	81.7	81.0	43.7	48.5	37.0
	SD	134.2	174.3	88.1	138.7	176.0	104.7	12.4	15.4	10.0	22.9	27.8	17.6
Participant 5	Mean	435.2	393.0	519.0	379.2	343.0	452.0	83.3	82.0	85.7	56.0	51.0	67.0
	SD	81.6	60.9	32.5	70.7	52.0	31.1	3.1	3.0	1.8	13.6	13.7	1.4
Participant 6	Mean	440.3	426.8	474.0	392.1	381.6	419.0	88.1	89.0	86.0	48.1	45.2	56.0
	SD	77.7	68.1	120.2	72.5	63.2	116.7	3.9	3.8	4.5	15.2	17.5	3.5
Participant 7	Mean	401.7	336.3	532.5	373.0	317.0	485.0	89.6	90.0	88.7	28.7	19.3	47.5
	SD	130.0	29.7	174.7	114.7	26.6	161.2	3.4	3.9	3.5	16.4	5.6	13.4
Participant 8	Mean	464.4	454.6	489.0	390.3	385.0	403.5	76.7	75.4	80.0	74.1	69.6	85.5
	SD	41.0	41.6	38.2	39.9	46.8	17.7	5.3	5.9	0.5	14.3	10.6	20.5
Participant 9	Mean	497.9	503.0	485.0	443.1	444.6	439.5	88.1	87.5	89.4	54.7	58.4	45.5
	SD	58.3	69.5	24.0	44.3	52.6	26.2	2.9	3.4	0.3	17.9	20.5	2.1
Participant 10	Mean	553.3	542.0	581.5	512.7	505.2	531.5	86.2	86.4	85.6	40.6	36.8	50.0
	SD	61.7	70.0	31.8	55.8	65.0	27.6	3.2	3.5	3.8	9.7	8.7	4.2
Total	Mean	474.7	453.3	503.1	426.0	408.1	449.6	85.9	85.6	86.2	48.2	45.3	53.6
	SD	43.4	59.8	38.5	45.8	58.1	39.7	4.3	4.6	3.7	13.1	14.5	14.9

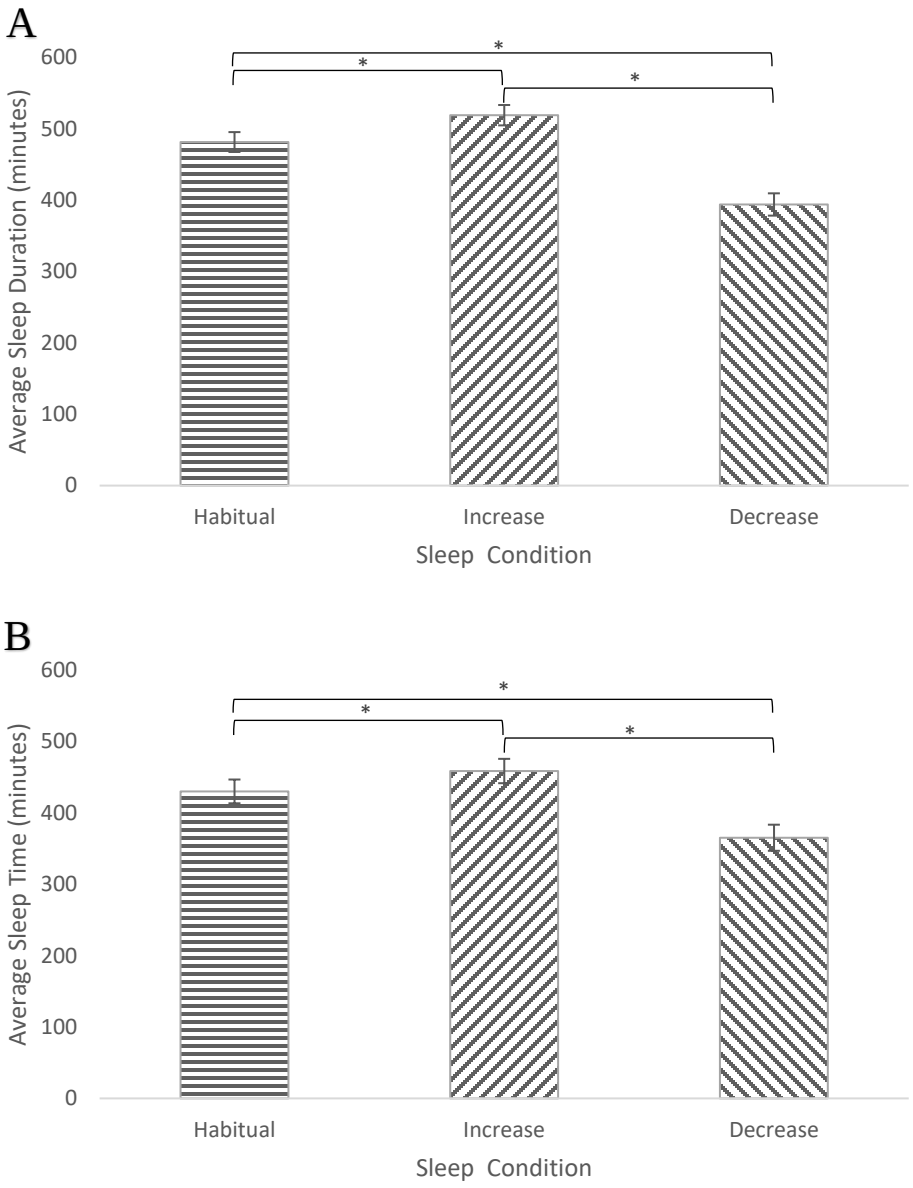

Figure 3. Results of repeated-measures ANOVA for (A) average sleep duration and (B) average sleep time between habitual, increased, and decreased sleep conditions (n=8).

Note: Means and standard errors are reported. *Indicates a significant difference at $p < 0.05$.

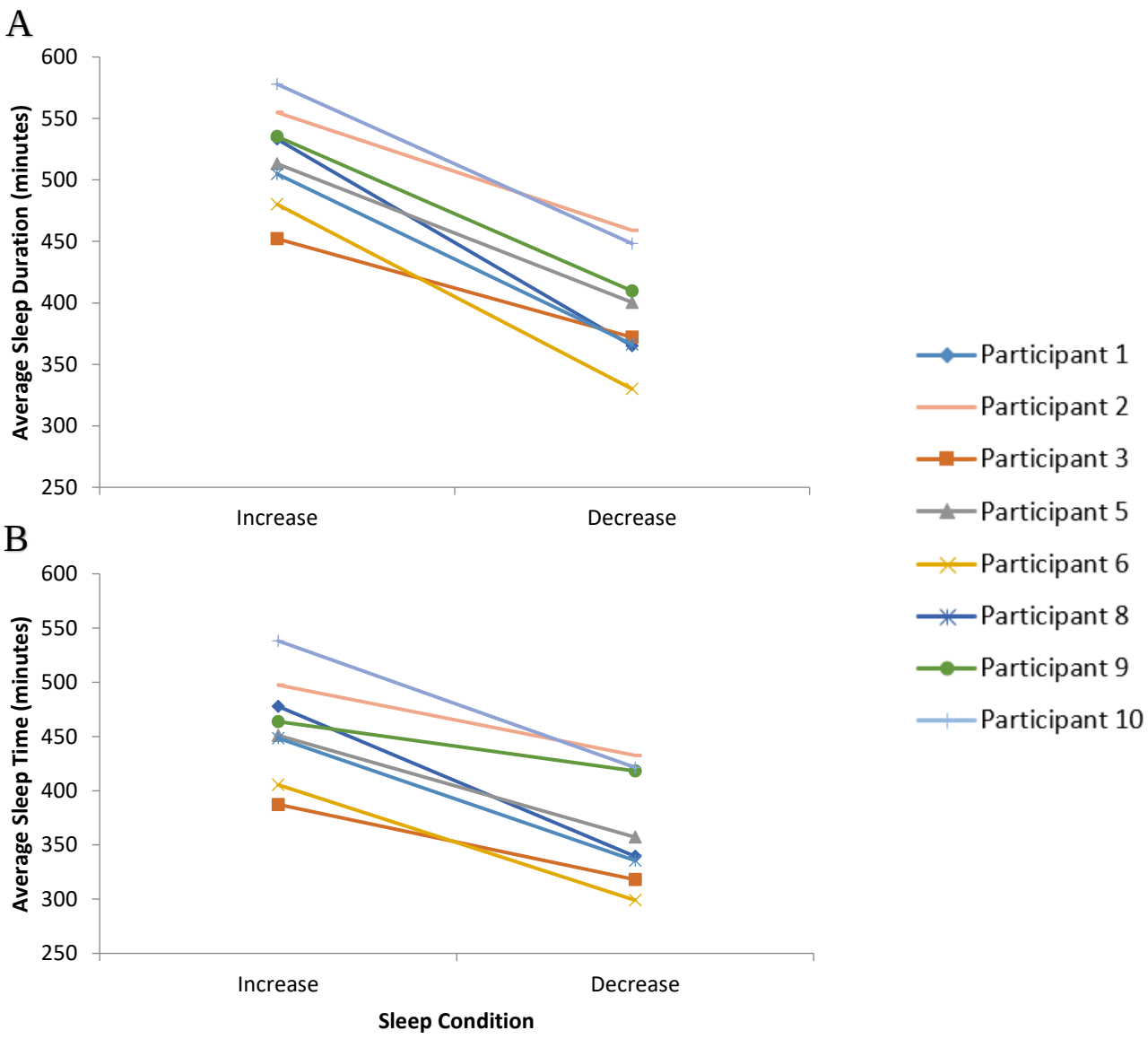

Figure 4. Results of paired t-test for (A) average sleep time and (B) average sleep duration between increased and decreased sleep conditions (n=8).

Additionally, for complete results on increased and decreased sleep see **Table 3** and **Table 4**, respectively.

4.3 Outcomes

Based on normality assessment described in the statistical analysis section, multiple outcomes violated assumptions of normality (PHQ-A, total mood score, anger, tension, fatigue, confusion, conduct problems, peer problems, prosocial behaviour, and total SDQ score), while the outcomes total mood scores without fatigue and the mood subscale for vigor were deemed normally distributed. Further investigations revealed that Participant 2's PHQ-A score and total mood score were identified as an extreme outlier and outlier, respectively. After excluding Participant 2, the data for PHQ-A and total mood scores became normally distributed. For all other outcomes where the removal of outliers did not improve normality, non-parametric Wilcoxon signed-rank tests were performed with the entire sample.

Depressive symptoms as measured by PHQ-A Scores

Participants reported fewer depressive symptoms in the increased sleep condition compared to the decreased sleep condition as measured by the PHQ-A, as shown in **Table 5**, **Figure 5**, and **Figure 6**. This significant finding represents a large effect size according to a Cohen's d of 0.94. The average score during the decreased sleep conditions was indicative of mild depressive symptoms but during the increased sleep condition the average score improved to none to minimal depressive symptoms.

Table 3. Increased sleep parameters (minutes per night) objectively measured over a period of 7 days (n=8).

		Time in Bed (min)			**Sleep Time (min)**			**Sleep Efficiency (%)**			**Wake After Sleep Onset (min)**		
		Total	Weekday	Weekend/ Holiday	Total	Weekday)	Weekend	Total	Weekday	Weekend/ Holiday	Total	Weekday	Weekend/ Holiday
Participant 1	Mean	533.1	525.0	554.0	477.7	471.0	494.0	86.1	86.0	85.5	55.4	54.0	60.0
	SD	23.3	17.1	29.7	21.7	21.2	17.0	2.5	2.3	4.0	7.8	5.9	12.7
Participant 2	Mean	554.9	556.0	554.0	497.4	495.0	501.0	86.5	88.0	85.0	57.4	61.0	53.0
	SD	16.6	23.0	5.6	20.3	24.1	18.1	5.2	6.0	4.5	25.6	31.3	21.2
Participant 3	Mean	452.1	455.0	444.0	387.3	391.0	377.0	82.2	84.0	76.5	64.9	64.0	67.0
	SD	71.2	75.1	87.7	55.5	58.2	67.9	6.0	3.6	8.8	17.5	18.9	19.8
Participant 5	Mean	513.1	501.4	542.5	451.0	440.6	477.0	85.7	85.2	86.7	62.1	60.8	65.5
	SD	59.0	67.8	6.4	53.3	61.3	10.0	2.6	3.0	0.7	9.6	11.3	3.5
Participant 6	Mean	480.1	464.5	501.0	405.4	394.3	420.3	83.0	83.1	82.9	74.7	70.3	80.7
	SD	42.0	49.6	21.1	45.1	59.9	12.0	4.0	4.8	3.8	14.6	11.3	18.7
Participant 8	Mean	504.9	498.4	521.0	448.4	439.2	471.5	85.1	84.4	86.9	56.4	59.2	49.5
	SD	26.8	27.7	22.6	26.0	28.8	9.2	4.8	86.9	0.5	17.6	19.6	13.4
Participant 9	Mean	535.3	552.4	492.5	463.7	473.8	438.5	86.0	85.0	88.6	71.6	78.6	54.0
	SD	34.6	19.5	23.3	42.0	45.4	23.3	6.7	7.9	0.9	39.1	45.5	0.0
Participant 10	Mean	577.9	591.2	544.5	538.1	548.0	513.5	84.3	84.9	82.8	39.7	43.2	31.0
	SD	46.4	48.6	19.1	43.3	48.4	13.4	3.9	4.5	1.7	10.5	10.2	5.7
Total	Mean	524.3	517.0	529.8	468.0	461.6	473.2	84.6	84.8	83.7	60.3	61.4	57.6
	SD	45.4	46.4	41.5	55.9	55.8	51.1	1.5	1.7	3.3	10.9	10.5	14.6

Table 4. Decreased sleep parameters (minutes per night) objectively measured over a period of 7 days (n=8).

		Time in Bed (min)			**Sleep Time (min)**			**Sleep Efficiency (%)**			**Wake After Sleep Onset (min)**		
		Total	Weekday	Weekend/ Holiday	Total	Weekday	Weekend	Total	Weekday	Weekend/ Holiday	Total	Weekday	Weekend/ Holiday
Participant 1	Mean	365.0	363.0	371.0	339.4	334.0	352.0	88.3	88.0	90.2	25.6	28.0	19.0
	SD	8.4	5.5	14.1	12.7	5.6	19.8	3.3	3.3	3.1	5.7	3.1	5.7
Participant 2	Mean	459.0	443.0	523.0	432.6	412.0	459.0	84.7	83.0	85.3	42.3	32.0	64.0
	SD	58.2	53.0	N/A	42.6	42.7	N/A	3.8	4.2	N/A	18.7	13.6	N/A
Participant 3	Mean	372.0	387.0	334.5	318.0	330.0	287.5	81.2	81.0	82.9	54.0	57.0	47.0
	SD	112.6	120.3	119.5	82.9	83.0	105.4	3.3	3.8	0.5	32.6	38.9	14.1
Participant 5	Mean	400.4	398.5	403.0	357.1	343.8	390.5	84.0	87.1	79.7	43.3	41.0	46.3
	SD	68.8	94.2	29.6	57.7	21.9	122.3	6.8	2.2	9.2	15.2	15.1	17.9
Participant 6	Mean	330.0	300.0	405.0	299.0	271.0	369.0	88.6	88.3	89.3	31.0	29.0	36.0
	SD	72.2	36.9	100.4	63.4	30.3	82.0	2.9	3.5	0.3	10.2	7.4	18.4
Participant 8	Mean	366.3	374.8	345.0	335.6	343.2	316.5	80.0	83.4	71.7	30.7	31.6	28.5
	SD	32.9	36.1	24.8	34.3	38.8	28.3	8.7	5.7	12.3	7.1	8.4	3.5
Participant 9	Mean	409.7	426.2	368.5	372.6	392.2	323.5	89.3	90.6	86.1	37.1	34.0	45.0
	SD	69.7	78.0	6.4	67.7	69.5	37.5	5.5	3.1	10.6	16.3	10.7	31.1
Participant 10	Mean	448.3	444.0	459.0	421.4	419.4	426.5	91.6	91.3	92.2	26.9	24.6	32.5
	SD	14.9	13.0	18.4	18.0	19.7	17.7	2.4	2.9	0.9	6.9	7.0	0.7
Total	Mean	393.8	392.1	401.1	359.5	355.7	365.6	86.0	86.6	84.7	36.4	34.7	39.8
	SD	44.2	48.0	63.0	47.4	49.5	58.0	4.1	3.7	6.6	9.7	10.2	13.8

Table 5. Effect of sleep manipulation, increased and decreased sleep for a week, on mental health outcomes.

	n	Mean (SD) or Median		t/z	p-value	Cohen's *d*/*r*
		Increase	Decrease			
Depression symptoms (PHQ-A)						
Total PHQ-A score	7[a]	2.1 (1.2)	5.3 (3.9)	2.455	**.049**	1.09
Mood (BRUMS)						
Total mood score	7[b]	12.3 (6.0)	30.1 (11.0)	3.069	**.023**	1.98
Total mood score without fatigue	8	13.5 (8.4)	20.9 (7.2)	1.900	.099	0.94
Vigour	8	49.6 (11.8)	41.3 (4.9)	-1.809	.113	-0.93
Anger	8	44	54	1.378	.168	0.49
Depression	8	44	47.5	1.483	.138	0.52
Tension	8	43.5	47.5	1.069	.285	0.38
Fatigue	8	42	66	2.201	**.028**	0.78
Confusion	8	44.5	46	1.095	.273	0.39
Behavioural problems (SDQ)						
Total SDQ	8	76.2	78.95	0.314	.753	0.11
Impact score	8	87.5 (3.5)	93.7 (4.2)	3.421	**.011**	1.62
Emotional problems	8	67.7 (20.8)	67.6 (21.4)	0.027	.979	-0.003
Hyperactivity	8	75.3 (13.2)	79.6 (11.1)	0.827	.435	0.35
Conduct problems	8	58.55	58.55	0.447	.655	0.16
Peer problems	8	85.7	84.55	0	1.000	0
Prosocial behaviour	8	56.5	77.95	0.730	.465	0.26
Externalizing problems	8	4.5 (2.1)	5.0 (1.9)	0.707	.502	0.25
Internalizing problems	8	4.0 (2.0)	4.1 (2.6)	0.215	.836	0.05

Note. Means, standard deviations, t-scores, and Cohen's *d* are reported when paired t-tests were performed on parametric data. Medians, z-scores, and *r* are reported when Wilcoxon signed-rank tests were performed on non-parametric data. Significant differences are bolded when $p < 0.05$. Cohen's *d* of 0.2, 0.5, 0.8, and 1.3 represent small, medium, large, and very large effect sizes, respectively. *R* of 0.1, 0.3, 0.5, and 0.7 represent small, medium, large, and very large effect sizes, respectively.

Abbreviations: BRUMS, Brunel Mood Scale; PHQ-A, Patient Health Questionnaire for Adolescents; SDQ, Strengths and Difficulties Questionnaire.

[a]Participant 2 excluded from analysis due to being an extreme outlier.

[b]Participant 2 excluded from analysis due to being an outlier.

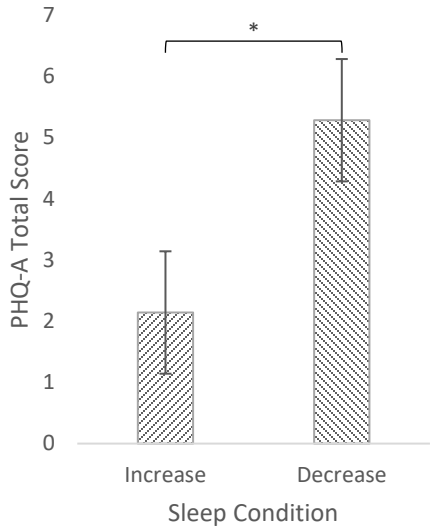

Figure 5. Effect of sleep manipulation, increased and decreased sleep for a week, on average PHQ-A total score (n=7).
Note. Means and standard errors are reported. *Indicates a significant difference between conditions at $p < 0.05$.
Abbreviations: PHQ-A, Patient Health Questionnaire for Adolescents.

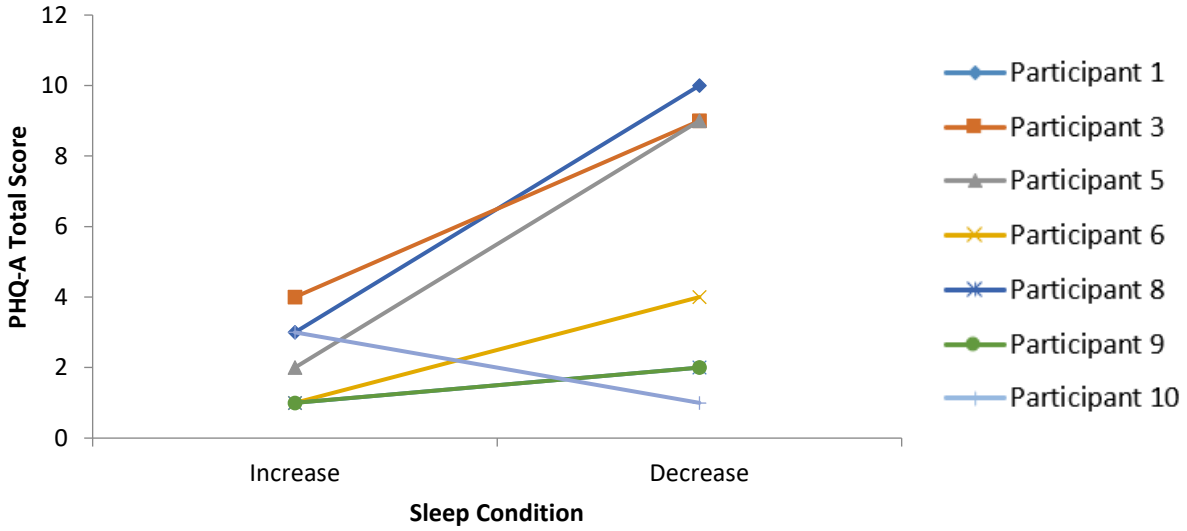

Figure 6. Effect of sleep manipulation, increased and decreased sleep for a week, on individual PHQ-A scores (n=7).

Abbreviations: PHQ-A, Patient Health Questionnaire for Adolescents.

Mood as measured by BRUMS Scores

Paired t-test revealed a significant difference between total mood scores after the increased and decreased sleep duration week, where decreased duration sleep worsened mood as observed by an increase in the mood score that more than doubled the average total mood score compared to the increased sleep condition (M = 30.1, SD = 11.0 and M = 12.3, SD = 6.0 for decreased and increased sleep, respectively). This significant finding represents a large effect size (Cohen's *d* =1.16). After removing the fatigue subscale from the total mood score, the differences between conditions became statistically non-significant but with a large effect size (t (6) = 2.213, p = 0.069, Cohen's *d* = 0.83). Individual subscale analyses of mood showed an effect of the sleep intervention on fatigue with a very large effect size (Cohen's *d* = 0.78). The other subscales (vigour, depression, anger, tension, and confusion) were not significantly different based on p-value; however, they showed very large, large, medium, medium, and medium effect sizes, respectively. Results of the paired t-tests and results of the Wilcoxon signed-rank tests can be found in **Table 5**. Visual representations of scores can be found in **Figures 7, 8, and 9.**

Behavioural Problems assessed by the SDQ questionnaire

No significant differences were found in the total SDQ scores after the increased and decreased duration sleep week (small effect size, no participants deviated from close to average); however, there was an effect on the impact score. Participants impact scores decreased from the decreased duration sleep week (M = 93.7, SD = 4.2) to the increased duration week (M = 87.5, SD = 3.5), showing that the increased sleep intervention positively affected their difficulties involving their home life, friendships, classroom learning, and leisure activities. This significant finding

represents a very large effect size (Cohen's *d* =1.62). Seven out of eight participants showed improvements in their categorization.

Individual subscale analyses of behaviour showed no significant differences. A medium effect size was found in the hyperactivity subscale; whereas, low effect sizes were found in the conduct problems, prosocial behaviour, and externalizing problems subscales. Most participants did not change categories for any of the subscales. Results of the paired t-tests and results of the Wilcoxon signed-rank tests can be found in **Table 5**. Visual representations of scores can be found in **Figures 9 and 10**.

4.4 Sleep Quality

Average changes in objective sleep quality can be found in **Table 6**. Paired t-test revealed no significant difference between sleep efficiency in the increased duration sleep week (M = 84.9%, SD = 1.6) and in the decreased duration sleep week (M = 86.0%, SD = 4.1) conditions; t (7) = 0.762, p = 0.47. The effect size was found to be small (Cohen's *d* = 0.36). During the increased sleep condition, three different participants than habitual sleep met the cut off for sleep disturbances (sleep efficiency < 85%) (Lacks and Morin, 1992) and participants spent an average total of 59 minutes/night of wakefulness throughout the night. As for the decreased sleep condition four out of eight participants met the cut off for sleep disturbances (sleep efficiency < 85%) (Lacks and Morin, 1992) and participants spent an average total of 35 minutes/night of wakefulness throughout the night. Two of these participants met the cut off in one of the other conditions (one in increased and one in habitual) and two only met the cut off in decreased sleep. Paired t-test did indicate a significant difference between wake after sleep onset in the increased sleep (M = 60.3 minutes, SD = 10.9) and in the decreased sleep (M = 36.9 minutes, SD = 9.9) conditions; t (7) =

5.964, p = 0.001. Cohen's *d* was 2.24 indicating a very large effect size. After adjusting for time in bed, paired t-test continued to indicate a significant difference between wake after sleep onset in the increased sleep (M = 0.118, SD = 0.027) and in the decreased sleep (M = 0.094, SD = 0.026) conditions; t (7) = 3.324, p = 0.013. While the effect size became smaller, Cohen's *d* was 0.88 representing a large effect size. Wilcoxon signed-rank test revealed no significant difference between conditions for the subjective satisfaction (Question 6 of the sleep log) regarding subjective sleep quality, z = -1.730, *p* = 0.084, r = .612 (representing a large effect size).

Table 6. Differences between increased and decreased sleep conditions for each sleep parameter (n=8).

Sleep parameter	**Mean (SD)**		***t***	**p-value**	**Cohen's *d***
	Increase	Decrease			
Time in bed (min)	518.9 (40.4)	393.8 (44.2)	12.387	< **0.001**	2.96
Sleep time (min)	458.6 (48.3)	365.2 (51.7)	8.490	< **0.001**	1.87
Sleep efficiency (%)	84.9 (1.6)	86.0 (4.1)	0.762	.471	0.36
Wake after sleep onset (min)	60.3 (10.9)	36.9 (9.9)	5.964	**.001**	2.24
Wake after sleep onset adjusted for time in bed	0.118 (0.027)	0.094 (0.026)	3.325	**.013**	0.88

Note. Means, standard deviations, t-scores, p-values, and Cohen's *d* are reported. Significant differences are bolded when p < 0.05

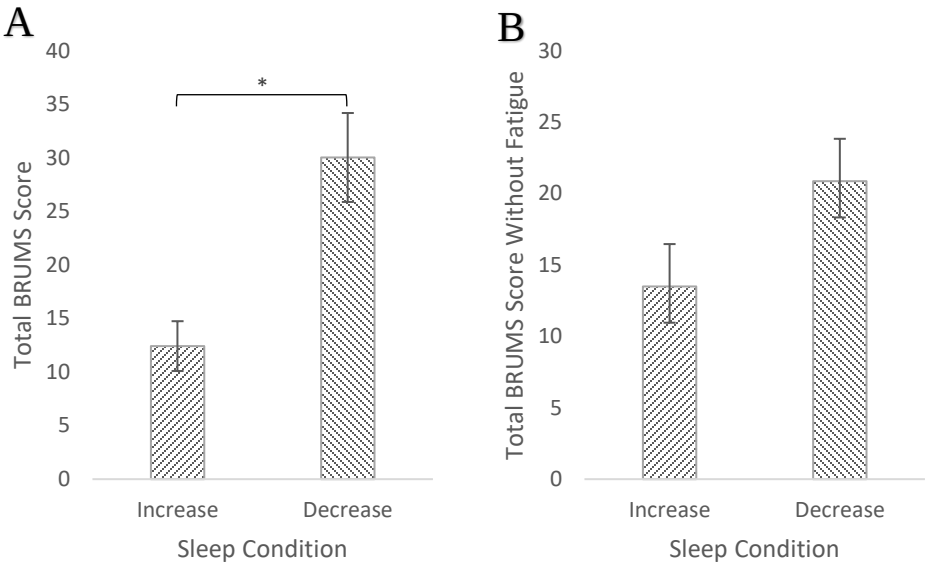

Figure 7. Effect of sleep manipulation, increased and decreased sleep for a week, on (A) average BRUMS scores (n=7) and (B) average BRUMS score without the fatigue subscale (n=8).

Note. Means and standard errors are reported. *Indicates a significant difference between conditions at $p < 0.05$.
Abbreviations: BRUMS, Brunel Mood Scale.

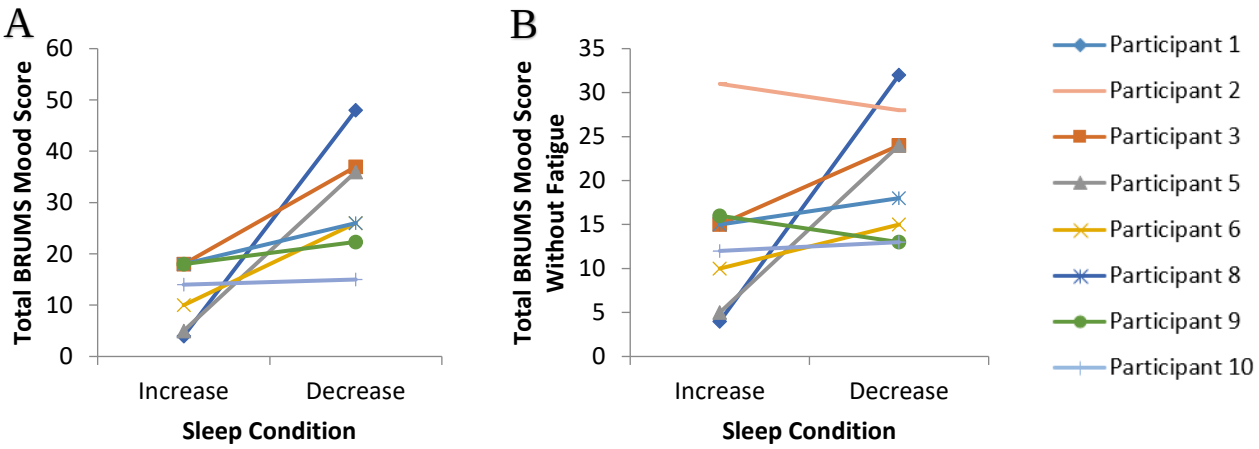

Figure 8. Effect of sleep manipulation, increased and decreased sleep for a week, on (A) total BRUMS mood scores (n=7) and (B) total BRUMS mood scores without the fatigue subscale (n=8).

Abbreviations: BRUMS, Brunel Mood Scale.

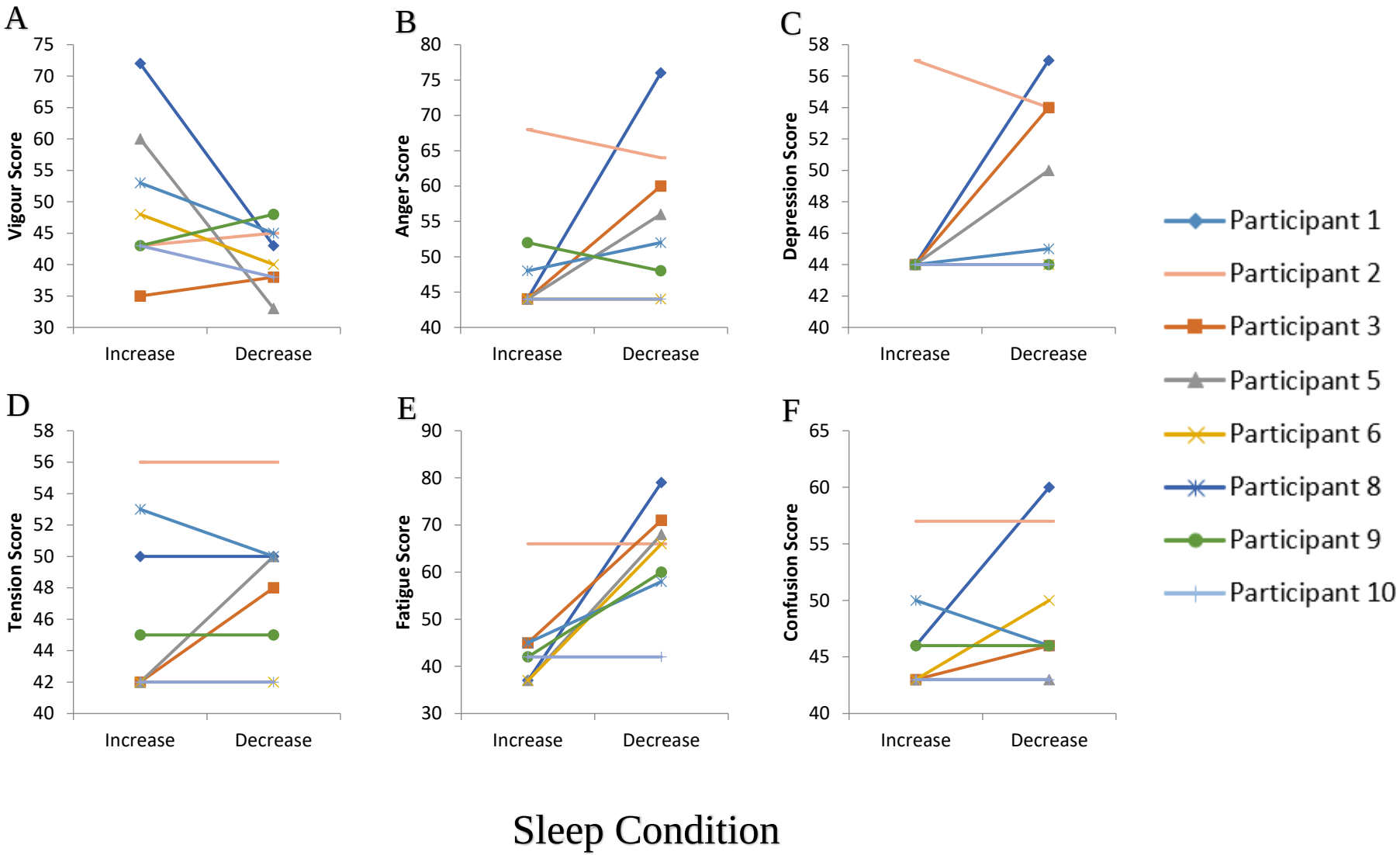

Figure 9. Effect of sleep manipulation, increased and decreased sleep for a week, on (A) vigour, (B) anger, (C) depression, (D) tension, (E) fatigue, and (F) confusion (n=8).

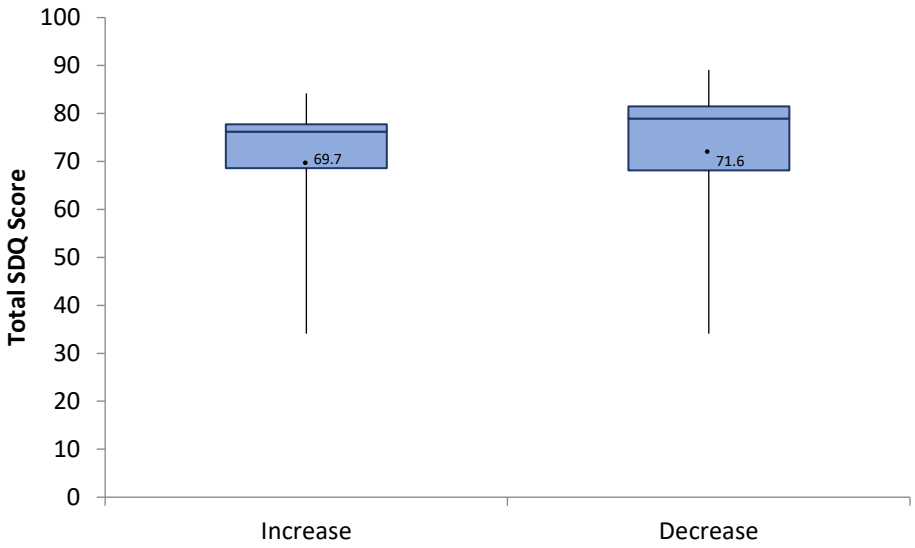

Figure 10. Effect of sleep manipulation, increased and decreased sleep for a week, on average SDQ scores (n=8).

Note. Box plot with the mean, median and quartiles is provided.
Abbreviations: Strength and Difficulties Questionnaire (SDQ).

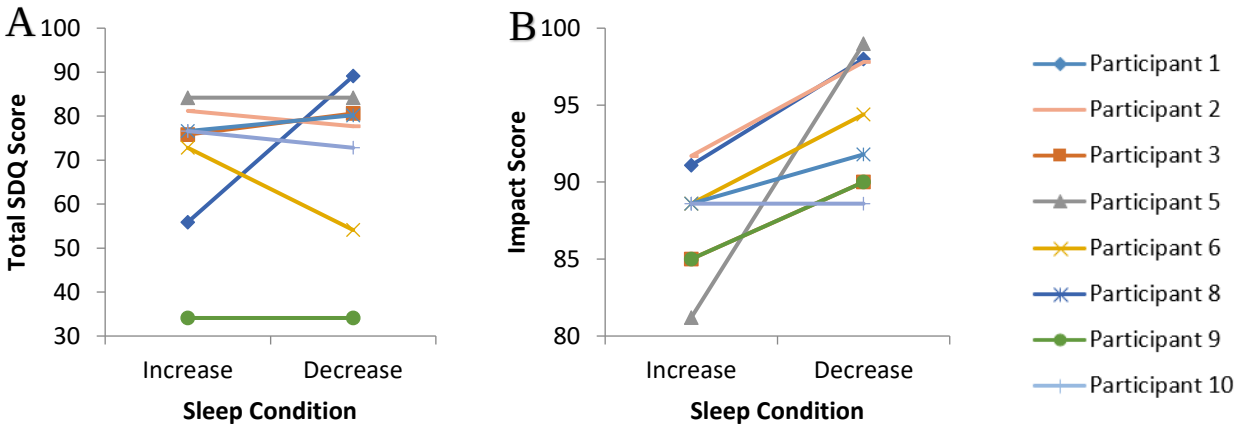

Figure 11. Effect of sleep manipulation, increased and decreased sleep for a week, on (A) total SDQ scores and (B) impact scores (n=8).

Abbreviations: SDQ, Strengths and Difficulties Questionnaire.

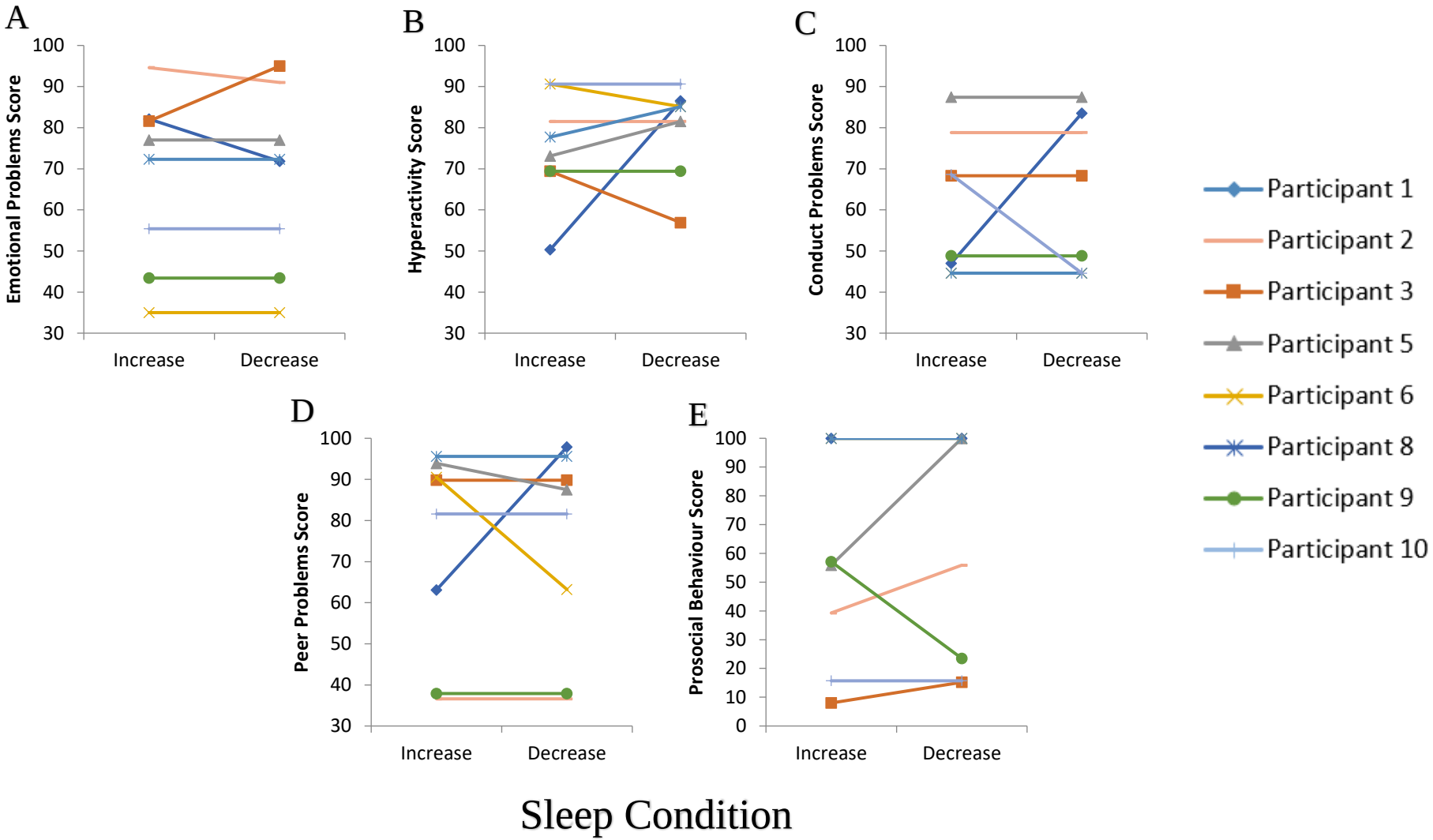

Figure 12. Effect of sleep manipulation, increased and decreased sleep for a week, on (A) emotional problems, (B) hyperactivity, (C) conduct problems, (D) peer relationship problems, and (E) prosocial behaviour (n=8).

Abbreviations: F, female; M, male.

CHAPTER 5: DISCUSSION

This thesis was part of the SMART2D study and it aimed to measure the effects of a sleep intervention on mental health indicators in adolescents (ages 13 to 18 years) at risk of type 2 diabetes. A crossover design was implemented to increase and decrease time in bed by 1.5-hour per night over the course of one week, based on a week of habitual sleep. Sleep was objectively measured at home, via the Actiwatch 2. The effect of sleep manipulation on mental health indicators was determined by measuring depressive symptoms, mood, and behavioural problems using the PHQ-A, BRUMS, and SDQ questionnaires, respectively. The preliminary findings suggest that one week of increased time in bed by 1.5-hour resulted in significant improvement for depressive symptoms, total mood scores, and behavioural problems impact scores compared to a week of decreased time in bed by 1.5-hour. These significant findings were also accompanied by large effect sizes, indicating the clinical relevance of increasing time in bed over a period of a week on these mental health outcomes. However, the long-term effect of increasing time in bed on mental health indicators remains unknown but should be investigated. The following discussion will address the findings as they relate with the literature starting with the descriptive characteristics of our study population, followed by the sleep intervention and comparator, sleep characteristics, and mental health outcomes. Additionally, a section on the proposed mechanisms for the effect of sleep on mental health indicators is provided. Finally, the thesis ends with limitations and strengths of the study section, study significance, and a short conclusion.

5.1 Adolescents at risk for type 2 diabetes

All our participants presented with risk factors for type 2 diabetes and were above the 99th percentile for BMI. We had an ethnically diverse sample with similar teenagers in the midst of puberty and coming from a variety of socioeconomic statuses. Our sample came from CHAL's wait and discharge lists, which treats a subsample of the pediatric population with extreme levels

of obesity. Recently, Buchholz and colleagues (2019) published descriptive statistics about their pediatric patients in which they reported that 58% have one or more mental health comorbidity and 89% have one or more medical comorbidity. The mental health comorbidities that were the most prevalent were learning disorders at 31%, generalized anxiety disorder at 16%, ADHD at 14%, global developmental delay at 11%, depression at 8%, and autism spectrum disorders at 5% (Buchholz et al., 2019). The medical comorbidities included hyperlipidemia (60%), NAFLD (42%), asthma (28%), sleep apnea (20%), hypertension (2.4%), and type 2 diabetes (1.4%) (Buchholz et al., 2019). Notably, we did exclude participants with psychiatric disorders, ADHD (if medicated), diabetes, and sleep disorders. However, Buchholz and colleagues (2019) work provides important insights on the population used and the difficulty in recruiting adolescents without psychiatric disorders.

In term of quality of life, the average score of our sample was 69, which meets the cut off for a possible major chronic condition; thus, suggesting this population has a lower quality of life than average (Huang et al., 2009). This is not surprising considering our sample is a sub-sample of Buchholz and colleagues (2019) who reported that their average score was 68. One of the phenotypes and risk factors of adolescent-onset type 2 diabetes is a family history of systemic dysfunctions. In this vein, the majority of our sample has immediate family members with diabetes and/or other systemic dysfunctions (Meigs, Cupples, & Wilson, 2000).

We had two dropouts within our study. First, one participant was unable to follow the sleep protocol due to severe depression and difficulties at home. Our second dropout was due to the fact that the participant did not want to participate in the study and was forced to participate by family members; this resulted in a complete lack of adherence to the sleep protocol in the first intervention

week. Upon that realization, the participant was thanked for her efforts, compensated, and dismissed from the study.

5.2 The sleep intervention

Our sleep intervention resulted in an average difference of 125 minutes in time in bed between the two sleep conditions. This compares closely to the Hart and colleagues (2014) study who used the same sleep intervention and had a similar result of 141 minutes in a younger sample of 8-11-year-old children. Our weekly average difference in sleep time was 93 minutes, which again is similar to Hart and colleagues (2014) who obtained an average difference in sleep time of 106 minutes. Our findings suggest that this type of sleep intervention is feasible in this population, thus implying the SMART2D study should continue to use this sleep intervention. We were unable to establish the 73 minutes increase per night in time in bed that Van Dyk and colleagues (2017) obtained in their sleep extension study; we obtained an average difference of 38 minutes per night. One explanation could be that since they did not include a decreased sleep condition their participant burden might have been lower since they only had one intervention (Van Dyk et al., 2017). They also had more involvement from parents and gave more money to participants than us (Van Dyk et al., 2017). Furthermore, while we did not expect a full 3-hour difference between conditions, there are several reasons that may explain the 125 minutes we obtained between the two sleep conditions. Altering bed and wake times is not a perfect science in adolescents but the alternative of having adolescents sleep in a sleep laboratory for three weeks in a month is not feasible and realistic. But manipulating sleep duration in this population became especially problematic during the summer; this affected seven out of ten participants who currently completed the study. Overall, the proportion of the full sample that participates during the summer will be

much smaller as we expect data collection to be completed by summer 2020. However, two major sleep duration problems arose during the summer, the first being related to luminosity. Six of the ten participants were required to go to bed before the sun descended at some point during the study. Without having proper blinds in the bedroom, this could have hindered their ability to fall asleep. Wake times were also later during the summer since they did not have to wake up for school, so the sunrise occurred a few hours before their wake times which could have had an impact as well. The second problem about summer was related to participant's daily routines. During the school year, on weekdays, we only had to manipulate bedtimes since they had a set wake up time established for school. In the summer, we had to manipulate both bed and wake times, adding another dimension to the sleep protocol, making it more difficult to facilitate participant adherence. Relative to the school year, wake up times were much later during the summer due to lack of engagement in summer camps and only one participant worked part-time. Therefore, waking up early to be at CHEO at 8:00am was a complete deviation from their sleep patterns. We consistently saw our participants sleeping a shorter duration on the seventh night (night before testing) during the increased sleep week since they were unable to fall asleep at an earlier time than they were used to. We attempted to attenuate this problem by enforcing a two-hour limit for wake-up times from the time they needed to wake up the morning of testing days. For example, if they had to wake up at 7:00am in order to get to testing by 8:00am, we would limit sleep in times to 9:00am during the rest of the week. However, the schedule discrepancy remained a problem and is one of the reasons we did not obtain a larger difference between the habitual and increased sleep conditions. Another solution would have been to change the testing starting time on an individual basis so that participants could wake up at their normal time on testing days; however, this was

not possible because the SMART2D study includes an oral glucose tolerance test which requires an overnight fast.

There are other factors that were out of our control that could have affected the participants' sleep. Although we asked participants if they were ill during each testing day, they could have been sick during the week leading up to the testing day which could have affected their sleep and more. One participant revealed to us afterwards that they had been sick for part of the intervention, which could have affected all outcomes. A solution could be to ask participants daily how they are feeling via text messages through the week. We also provided participants with sleep hygiene tips but cannot ensure they followed them. For example, one participant tends to fall asleep on the couch with the television on which would affect their ability to sleep efficiently. In addition, we realized when participants were not actively engaged in text messaging, they were less likely to follow the sleep protocol. Participants were not fully engaged for several reasons including: did not own a cell phone, cell phone was getting fixed, no phone plan while travelling in the USA, and lack of responses. Further emphasizing the importance of responding daily to text messages directly with the participants is one way to try avoiding this problem. Finally, although we asked about prior commitments and ensured they would not affect the sleep protocol, it is possible unexpected events occurred throughout the study and affected the sleep protocol.

While we did establish significant differences in time in bed between the three sleep conditions, we could not deem our sleep intervention completely successful since it did not meet the one-hour difference between the habitual and increased sleep duration conditions that we aimed for. However, this may not be all that uncommon as Hart and colleagues (2013) also only reported the effect of increased and decreased sleep duration on their outcomes, they also did not use habitual sleep as an additional comparator. For those reasons, we decided that it was appropriate

to only use the decreased sleep intervention as the comparator to the increased sleep intervention in our analyses.

5.3 Sleep quality

We expected to see an increase in wake after sleep onset and a decrease in sleep efficiency when increasing sleep. We found an increase in bouts of wake time in the night in the increased sleep condition compared to the decreased sleep condition with a very large effect size, which is similar to what was found in 8- to 11-year-old children (Hart et al., 2013). Though there was a small effect size, no differences were found regarding sleep efficiency. This finding contrasts with Hart and colleagues (2014) and Van Dyk and colleagues (2017) who did find a significant difference. Also, average sleep efficiencies were higher in their study (Van Dyk et al., 2017), perhaps indicating adolescents at risk of type 2 diabetes experience worse sleep efficiency than their healthy peers. Participants were not consistently above or below the cut-offs established by Lacks and Morin (1992) for sleep disturbances. It is possible our sample has a low sleep average efficiency due to their risk of developing sleep apnea, as seen in 20% of CHAL patients (Buchholz et al., 2019). We found no differences in sleep satisfaction between conditions, but we did find a large effect size. None of the other sleep intervention studies in youth measured sleep satisfaction. The full sample of the SMART2D study will provide more power, which is needed to see if there are significant differences in objective sleep quality. However, it is important to note that sleep quality is not a main outcome as the sleep intervention has a direct impact on these values; but with the full sample it may be possible to investigate its potential as a moderator in the relationship between our interventions and outcomes.

5.4 Depression

As hypothesized, a significant difference was found between the PHQ-A scores in the two conditions where increasing sleep improved depressive symptoms compared to decreasing sleep. This result is contrary to the findings of Baum and colleagues (2014) and Vriend and colleagues (2017), which found no differences in the depression subscale measured by the POMS. The robustness of our study and including a decreased sleep week could explain this difference. Our results indicate that extending time in bed by 1.5-hour improved depression symptoms compared to decreasing time in bed by 1.5-hour. On top of being significant, the results were also meaningful as the average score in the increased sleep week normative interpretation was the None-Minimal Depressive Symptoms category, while the normative interpretation for the average score after the decreased sleep week was to Moderate Depressive Symptoms category, one category worse. Only one participant reported suicidal ideation which was dealt appropriately in accordance with the safety protocol. The PHQ-A used in the present study is a validated questionnaire for this population (Johnson et al., 2002); however, it is important to note that one of the questions asks about fatigue, so the intervention has a direct influence on part of the total score. Additionally, it should be noted that while the PHQ-A assesses depressive symptoms, it should not be used as a clinical diagnostic tool for depression. Therefore, these results should be interpreted as changes in depressive symptoms in non-clinical populations only; the effect of sleep manipulation on clinical depressions remains unknown.

5.5 Mood

The only significant differences found were in the total mood score and the fatigue subscale. It is important to note there is no normative data for total mood score, and raw scores

were used for this comparison. The decrease in the fatigue score after increasing sleep compared to decreasing sleep is in line with both Baum et al. (2014) and Van Dyk et al.(2017), indicating participants felt less fatigued. However, these studies also showed differences in anger, fatigue, confusion, and vigour, as well as tension in the former study (Baum et al., 2014; Van Dyk et al., 2017), which we did not find. This discrepancy could be due to our current lack of power; but all the other subscales showed at least medium effect sizes. As the study goes on and the sample size increases, these differences may become statistically significant. Total mood score without the fatigue subscale was also analyzed to see if this subscale was responsible for the improved mood after the increased sleep week compared to the decrease sleep week. Removing the fatigue subscale did change our results, making the result not statistically significant; however, a large effect size remained in the same direction.

The BRUMS is validated for adolescents (Terry et al., 1999); however, our participants had some difficulties filling it out. Some of the items in this questionnaire were not completely understood by participants, most notably “muddled” and “downhearted” which fall in the confusion and depression subscales, respectively. This problem was worsened in our younger participants (13 and 14 years old) and our French participants. The lack of a French version of the questionnaire is a limitation, especially because it is difficult to describe a word without using another item in the questionnaire since there are synonyms within the subscales. This may have resulted in underreporting of their mood changes.

5.6 Behavioural Problems

A difference was observed in the impact score where participants reported fewer difficulties after increasing time in bed by 1.5-hour compared to decreasing time in bed by 1.5-

hour. We observed that 87.5% of our sample's interpreted normative scores improved by at least one category after increasing sleep compared to decreasing sleep. Specifically, differences were seen in "difficulties upset or distress child", "interference with home life", "interference with classroom learning", and "interference with leisure activities". Interestingly, no interference with friendships were reported with lack of sleep compared to more sleep. This suggests that peer relationships may not be affected by the sleep manipulation, but other areas of their lives are. Summer may have played a role here as well since they may not have been with their friends as much as they would if they were in school and some questions were related to the classroom.

There were no differences found in the total score or any of the subscales between the increased and decreased sleep conditions. The existing experimental evidence exclusively looked at hyperactivity and did not find any differences either (Baum et al., 2014; Van Dyk et al., 2017). Compared to the observational evidence, we did not find the improvements in emotional problems, conduct problems, and peer relationship problems that we had expected to find (Dewald-Kaufmann et al., 2013; Lam & Yang, 2008; Lin & Yi, 2014; Liu & Zhou, 2002; Meijer et al., 2010; Zhang et al., 2017). This was demonstrated as we did not find any medium effect sizes or higher and most participants were close to average for each subscale, which did not change between conditions. Notably, peer relationship problems had a p-value of 1.0, suggesting there is no relationship whatsoever between sleep duration and peer relationship problems; this will have to be confirmed when the full sample is obtained.

A limitation to this measure is that it may not be sensitive enough to highlight changes over a week due to the fact it only uses a 3-point scale. While the questionnaire is able to look at difficulties over different periods of time, it was originally created for use over the last month

(Goodman, 1997). As discussed, there are also questions that may not be applicable during the summer which could mask the effects of sleep. These results should be interpreted cautiously.

While none of our participants reported being sick the day of the study, a participant had to postpone their third testing date because they were sick. An illness could have a large impact on both sleep and the mental health indicators. This participant was deemed an outlier in the mental health indicators data and was excluded from some analyses for this reason. It is not unconceivable that this participant might have been sick during their second testing day, which could have also affected their responses on the day of assessments.

5.7 Possible Mechanisms

The biological mechanism explaining the link between sleep and mental health indicators is not well understood. Harvey and colleagues (2011) speculated about the connections between circadian systems, serotonin and dopamine systems, and psychiatric disorders. There seems to be a mutually reinforcing relationship between the circadian systems and serotonin and dopamine levels. Our circadian clock regulates our sleep-wake cycles over 24-hour periods and affects multiple systems from metabolism to sleep (Farhud & Aryan, 2018). Two important neurotransmitters in the body are serotonin and dopamine. Studying the effects of sleep on serotonin and dopamine is important because they both have recognized roles in a variety of psychiatric disorders including mood disorders (Berk et al., 2007; Sivertsen et al., 2014). Serotonin is commonly known for treating depression through inhibiting serotonin reuptake and is also involved in other physiological functions (Young, 2007). Dopamine has many functions as well, playing a key role in motor control and also in reward behaviour (Mishra, Singh, & Shukla, 2018). Serotonin and dopamine both play a role in sleep (Hannibal & Fahrenkrug, 2006; Ongini,

Bonizzoni, Ferri, Milani, & Trampus, 1993; Wisor et al., 2001). A study in cats showed that blocking serotonin synthesis resulted in a disruption of the sleep-wake cycle, and the cats became insomniacs (Denoyer, Kitahama, Sallanon, Touret, & Jouvet, 1989). Denoyer and colleagues (1989) were able to reverse the effect by injecting serotonin into the ventrolateral preoptic area of the hypothalamus which is responsible for inducing slow-wave sleep. The mechanism is not fully understood (Rancillac, 2016). Dopamine receptors are involved in controlling wakefulness and physiological arousal in the lateral hypothalamus and the midbrain (Li, Luo, Wang, Qu, & Huang, 2017). On the other hand, sleep can also impact serotonin and dopamine. Interestingly, sleep deprivation has shown to acutely increase serotonin levels in the suprachiasmic nucleus (Grossman, Mistlberger, Antle, Ehlen, & Ca, 2000). Another study showed that sleep deprivation reduces the sensitivity of serotonin receptors, which is similar to what is seen in depression (Novati et al., 2008). Perhaps the increase in serotonin levels is because the receptors lose sensitivity and the body tries to compensate. Sleep deprivation has shown to decrease levels of dopamine receptors in the ventral striatum (Volkow et al., 2012). It seems that sleep deprivation leads to an attenuated effect of both serotonin and dopamine. The circadian system has also been shown to be a moderator of both positive mood and reward activation (Murray et al., 2009), which supports this notion. Serotonin and dopamine transport and availability have also been investigated comparing adults with and without obesity. Serotonin binding ratios were negatively correlated with BMI in the midbrain in the sample with obesity (Nam et al., 2018). This finding could help to explain why our sample is more at risk for mental health problems. No differences were found with dopamine (Nam et al., 2018). Wong and colleagues (1984) have shown that the number of serotonin and dopamine receptors varies with age. It is important to note adolescent brains are at a different point of development so this may not be reflective of our population (Dutil et al., 2018).

Based on these findings, it is possible that extending sleep can facilitate serotonin and dopamine functions in the body. Perhaps extending sleep results in higher levels of serotonin and dopamine, more transporters, more receptors, and a beneficial effect overall. These findings were based on longer periods of sleep deprivation than the present thesis; however, they are still a good beginning of where to look for a potential mechanism to explain the beneficial effects of increasing sleep duration after a one-week sleep intervention.

Coping abilities could help to explain the relationship between sleep and mental health indicators as well. Two main coping strategies include engagement coping and disengagement coping (Dijkstra & Homan, 2016). Engagement coping occurs when people actively address the stressor; while disengagement coping is when people avoid the stressor (Dijkstra & Homan, 2016). Engagement coping is generally more effective than disengagement coping (Dijkstra & Homan, 2016). A recent study in adolescents showed a negative relationship between sleep duration and disengagement coping, implying those who sleep longer are less likely to use disengagement coping (Matthews, Hall, Cousins, & Lee, 2017). Having better coping abilities may supplement the biological mechanisms behind the beneficial effects of increasing sleep duration on the mental health indicators.

5.8 Limitations

In addition to the limitations previously mentioned in each section, there are more factors to consider. First, we were limited to the questionnaires we could use since most mental health questionnaires are based upon the past month. We needed to use questionnaires that could be based upon a one-week interval; it is possible there are better alternatives for a different period of time. Second, we have no way to guarantee our participants cared enough to answer the questionnaires

honestly. One of our less mature participant's responses on their questionnaires were not in line with what they were expressing verbally. One solution to this problem could be to adjust our target age group to 15- to 18-years-old to include only adolescents who can understand the importance of research, but this would limit the external validity and recruitment in this population is already very difficult. Controlling for age in analyses of the full sample may help elucidate this issue. Other factors that we could not control that could have influenced our results include outside stressors that may vary week to week (two participants had exams during the intervention) and their interest in the study (some participants were more actively engaged than others). Finally, we altered more than just sleep duration, by introducing the sleep intervention we made sleep schedules more consistent. Sleep timing and sleep consistency have beneficial effects on mental health indicators as shown by Biggs et al. (2011) where high sleep variability increased the risk of scoring in the 95^{th} percentile or higher for behavioural difficulties in children. In future analyses, day-to-day sleep consistency should be considered to see if there was an effect on the mental health indicators.

5.9 Strengths

The SMART2D study is ongoing and shows many strengths, including its methodology. This is the first study to look at the effects of a sleep intervention on the mental health indicators of adolescents at risk for type 2 diabetes. The within-subjects crossover design used is crucial in determining causality by investigating the effect of sleep duration on mental health indicators. An increase and decrease of 1.5-hour of sleep between conditions provides a realistic goal; the findings can be incorporated into a useful intervention while minimizing participant burden. The washout period between experimental conditions helps to ensure participants return to their baseline sleep between conditions in order to eliminate possible carryover effects. We use a comprehensive

screening strategy and intake questionnaire in order to be able to describe our participants thoroughly. We measure sleep at home using an objective measure allowing participants to sleep in a more realistic environment compared to in a laboratory setting, while collecting reliable data. We use validated questionnaires to assess mental health indicators as accurately as possible. Finally, our strategies to encourage participant compliance and adherence to the protocol have proven to be effective.

The larger study also measures more variables including: screen time, sedentary behaviour, physical activity, food intake, and caffeine intake. Once the sample size increases, it will be important to see if these variables change between sleep conditions. It is possible participants learned to cope to their sleep schedule throughout the week by altering other daily behaviours. For instance, adolescents may drink more caffeine, eat more calorie dense food, and spend more time on their screens during the decreased sleep weeks. Studying these coping mechanisms will be important to further understand the effects of sleep on mental health indicators.

5.10 Significance

This study has shown preliminary evidence that extending time in bed may result in improvements in mental health indicators (depression, mood, and behavioural problems impact) in adolescents at risk for type 2 diabetes mellitus. If increasing sleep duration results in improved mental health indicators, then there is very little downside in adding sleep to the intervention toolkit used by health care providers. Furthermore, early school start times have negative consequences on adolescents' sleep duration, and this study, if found successful, could encourage policymakers to consider delaying school start times so that our youth sleep more at night. Another way to increase adolescent sleep is to discourage late-night extracurricular activities (e.g., sports) that

impede adolescents from going to bed at a reasonable time. Additionally, sleep hygiene should be added to school curricula so that all children understand that good sleep is just as important as other lifestyle factors such as physical activity and nutrition (e.g., no screens before bed, no pets in the bedroom, reduced quantity of blue light during the day, etc.). Translating the SMART2D findings to the scientific community, health professionals and the general population is going to be important to help change the perspective and social norm on sleep. Canadians need to stop sacrificing their sleep, and hopefully this study can encourage people to do so and potentially help to improve these mental health indicators among youth.

5.11 Conclusion

This was the first study of its kind to investigate the effects of a 1.5-hour increase and decrease in time in bed on mental health outcomes in adolescents at risk for type 2 diabetes. A crossover study design was used to determine causality in the relationship between sleep duration and depression symptoms, mood, and behavioural problems. Preliminary findings show promising effects of sleep duration on improving depressive symptoms, overall mood, and the impact of the intervention on daily life. The SMART2D study should continue to operate in order to elucidate the effects of sleep on mental health indicators. These findings could encourage health care providers to incorporate sleep into their existing toolkit when assessing mental health indicators.

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APPENDICES

Appendix A. CHEO REB Approval Letter

Expéditeur: <nanderson@cheo.on.ca>
Date: 18 mars 2019 à 13:22:18 UTC−4
Destinataire: "Chaput Jean-Philippe(Principal Investigator)" <jpchaput@cheo.on.ca>
Cc: <nanderson@cheo.on.ca>
Objet: REB Protocol No: 17/63X - Annual Renewal Certificate

CHEO

Research Ethics Board
Annual Renewal Approval Letter

Principal Investigator: Dr. Jean-Philippe Chaput

REB Protocol No: 17/63X
Romeo File No: 20170184
Project Title: CHEOREB# 17/63X - Effect of Increasing Sleep Duration on Insulin Sensitivity in Adolescents having Risk Factors for Type 2 Diabetes
Primary Affiliation: HALO\HALO
Protocol Status: Active
Approval Date: March 18, 2019
Approval Expiry Date: April 15, 2020

This is to notify you that the CHEO REB has granted approval to the renewal for the above named research study for a period of one year. The renewal was reviewed in the delegated stream and approved by the Chair or a delegate of the Chair. Decisions made by the Chair under delegated review are ratified by the full Board at its subsequent meeting.

Approval is granted with the understanding that the investigator agrees to comply with the following requirements:

1. The investigator must conduct the study in compliance with the protocol and any additional conditions set out by the Board.
2. The investigator is responsible for complying with all applicable guidelines and regulations regarding the ethical conduct of research with humans, as applicable to the research project.
3. Investigators must obtain annual renewal approval prior to the expiry date stated above.
4. The investigator must not implement any deviation from, or changes to, the protocol without the approval of the REB except where necessary to eliminate an immediate hazard to the research subject, or when the change involves only logistical or

administrative aspects of the study (e.g., change of telephone number or research staff). As soon as possible, however, the implemented deviation or change, the reasons for it and, if appropriate, the proposed protocol amendment(s) should be submitted to the Board for review and approval.

5. The investigator must, prior to use, obtain approval from the Board for changes to the study documentation, e.g., changes to the informed consent letters, recruitment materials.
6. Investigators must obtain approval from the Board of French version(s) of the consent/assent form(s), unless a waiver has been granted. An interpreter should be offered to participants as required or at the request of the participant throughout the course of research.
7. For clinical drug or device trials, investigators must promptly report to the REB all adverse events that are both serious and unexpected (SAEs) or unexpected and untoward occurrences (including the loss or theft of study data and other such privacy breaches.
8. For SAE reports on clinical drug trials, the investigator must also comply with the hospital-wide Policy regarding, Procedures for Considering Medical Error in the Differential Diagnosis of Severe Adverse Events (SAE) Associated with the Drugs Administered in a Clinical Trial.
9. Investigators must promptly report to the REB any new information regarding the safety of research subjects (e.g., changes to the product monograph or investigator's brochure of drug trials). Where available, any reports produced by the Data Safety Monitoring Board should also be promptly submitted to the REB for acknowledgement.
10. Investigators must notify the REB of any study closures (closed to accrual, temporary, premature or permanent).
11. Investigators must submit a study closure event form at the conclusion of the study.

If you have any questions, pertaining to this letter, please contact the Research Ethics Board Office at (613) 737-7600, ext. 3350 or 2128.

Regards,

Richard Carpentier, PhD
Chair, Research Ethics Board
Président, Comité d'éthique de la recherche

Appendix B. uOttawa REB Approval Letter

26/08/2019

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

Lettre d'approbation administrative | Letter of administrative approval

Numéro de dossier / Ethics File Number	H-08-19-4893
Titre du projet / Project Title	Effect of increasing sleep duration on insulin sensitivity in adolescents having risk factors for type 2 diabetes
Type de projet / Project Type	Thèse de doctorat / Doctoral thesis
CÉR primaire / Primary REB	CHEO / CHEO
Statut du projet / Project Status	Approuvé / Approved
Date d'approbation (jj/mm/aaaa) / Approval Date (dd/mm/yyyy)	26/08/2019
Date d'expiration (jj/mm/aaaa) / Expiry Date (dd/mm/yyyy)	15/04/2020

Équipe de recherche / Research Team

Chercheur / Researcher	Affiliation	Role
Caroline DUTIL	École des sciences de l'activité physique / School of Human Kinetics	Chercheur Principal / Principal Investigator
Jean-Philippe CHAPUT	Département de pédiatrie / Department of Paediatrics	Superviseur / Supervisor
Denis PRUD'HOMME		Co-superviseur / Co-supervisor
Anastasia HADJIYANNAKIS		Co-chercheur / Co-investigator
Mark TREMBLAY	CHEO Research Institute	Co-chercheur / Co-investigator
Anthony CARLSEN	École des sciences de l'activité physique / School of Human Kinetics	Co-superviseur / Co-supervisor

Conditions spéciales ou commentaires / Special conditions or comments:

CHEO REB # 17/63X

26/08/2019

Université d'Ottawa

Bureau d'éthique et d'intégrité de la recherche

University of Ottawa

Office of Research Ethics and Integrity

L'Université d'Ottawa a signé une Entente, conforme aux exigences de la plus récente version de l'EPTC et tout autre règlement ou législation applicable, permettant au CÉR ci-haut nommé d'être désigné comme CÉR primaire pour les projets de recherche où

1) les activités principales de recherche sont menées sous l'autorité ou sous les auspices de l'établissement lié au CÉR primaire et

2) Une partie du projet est également réalisé sous l'autorité ou sous les auspices de l'Université d'Ottawa.

Cette lettre confirme que l'Université d'Ottawa a autorisé que le CÉR primaire soit le CÉR officiel pour l'évaluation et la supervision de ce projet de recherche. Ceci n'est pas une approbation éthique.

Afin de nous aider à garder votre dossier à jour, veuillez soumettre une copie de toutes demandes de modification, renouvellement d'approbation éthique etc. soumis à et approuvé par le CÉR primaire dès qu'elles sont disponibles.

Cette approbation administrative est valide pour la durée indiquée ci-haut et est sujette aux conditions énumérées dans la section intitulée « Conditions spéciales ou commentaires ».

The University of Ottawa has signed an Agreement, compliant with current TCPS guidelines and any other applicable guidelines or legislation regarding multisite review, allowing the REB named above to serve as Board of Record (BoR) for research projects where

1) the main research activities are conducted within the auspices or jurisdiction of the BoR's institution and

2) parts of the project are also conducted under the jurisdiction or auspices of the University of Ottawa.

This letter confirms that the University of Ottawa has authorized the REB named above to serve as Board of Record for the review and oversight of this research project. This is not an REB approval.

In order to help us keep your file up to date, please submit a copy of all amendment requests, project renewals or any other changes submitted to and approved by the BoR, as they become available.

Administrative approval is valid for the period indicated above and is subject to the conditions listed in the section entitled «Special conditions or comments».

Catherine PAQUET
Directeur / Director
Pour/For **Daniel LAGAREC** Président(e) du/ Chair of the **Comité d'éthique de la recherche en sciences sociales et humanités / Social Sciences and Humanities Research Ethics Board**

Appendix C: Consent Form

Information and Consent Form

Protocol Title: Sleep Manipulation in Adolescents at Risk of Type 2 Diabetes (SMART2D) Study

Investigator: Dr. Jean-Philippe Chaput

Address: Healthy Active Living and Obesity Research Group, CHEO, 401 Smyth Road, Ottawa, ON K1H 8L1

Telephone Number: (613) 737-7600 Ext. 3683 **Fax:** (613) 738-4800

For more simplicity, the word "you", when used in this form, means "yourself" or "your child".

You are being invited to join in a research study about the possible benefit of increasing sleep duration on systemic functions (insulin levels), brain functions (executive functions, working memory, and attention), and mental health outcomes (mood, depression symptoms, and behavioural problems) in adolescents at risk for type 2 diabetes. You are being invited to join this study because it will greatly help scientists working in health research with paediatric populations. Before agreeing to take part in this study, it is important that you read and understand this document.

Taking part in this study is voluntary. You are free to withdraw from the study at any time and there will be no penalty to you.

Why is this study being done?

This study is being done because healthy sleep is gaining recognition worldwide as an important lifestyle habit associated with the prevention of chronic diseases including type 2 diabetes. However, it is currently unknown whether extending sleep duration can improve systemic functions (insulin levels), brain functions (executive functions, working memory, and attention), and mental health outcomes (mood, depression symptoms, and behavioural problems) in a population at risk of type 2 diabetes. This issue is of high clinical and public health relevance and may help to provide additional tools to health care providers on the benefits of a good night's sleep for the prevention of type 2 diabetes in teenagers.

How many people will participate?

We are recruiting 50 adolescents between the ages of 13 and 18 for this study. We preferably want to recruit adolescents with excess weight, who are physically inactive (<30 minutes of exercise per day) and who may have dyslipidemia. If you consent to participate, you will be asked to come to CHEO on 3 separate occasions (between 8:00 AM and 2:00 PM), on dates which will be arranged between you and the research coordinator, at your convenience.

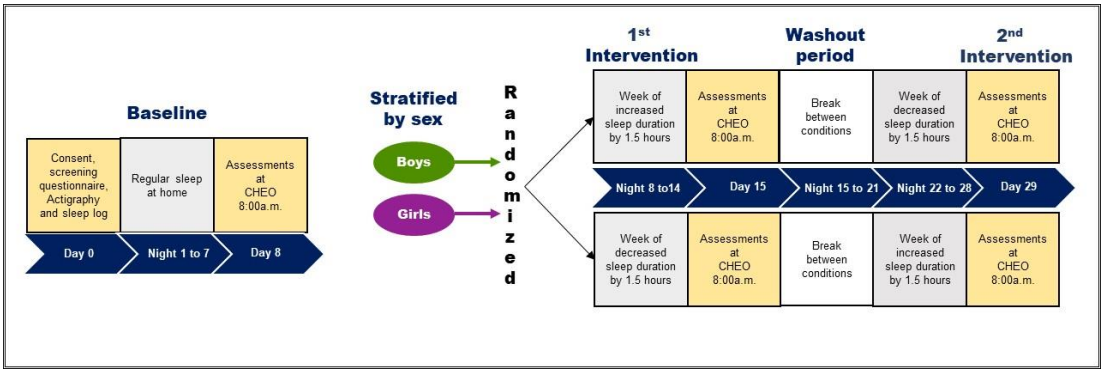
What will I have to do?

Before your 3 visits at CHEO, you will be asked to respect the following 3 sleep conditions at home:

- Normal sleep schedule for 1 week

- Decreased time in bed by 1.5 hours per night for 1 week
- Increased time in bed by 1.5 hours per night for 1 week

You will be randomized to either the decreased or increased sleep condition first (you have 1 in 2 chance of starting with the decreased sleep condition first). You will be involved in both sleep interventions for this study. Sleep duration will be recorded using a small device (Actiwatch 2, Philips Respironics) worn on your wrist (like a watch) and there will be a 1-week break between the “decreased” and “increased” time in bed conditions. Modifications of your time in bed will be made by asking you to change your bedtimes while your wake times will remain constant. On day 8 of each three sleep conditions mentioned above, you will be asked to come to CHEO at 8:00 AM after an overnight fast for the measurement of your insulin levels and other parameters listed below. We will also serve you a breakfast and lunch.
A schematic overview of the study protocol is presented below.



On day 8 of each sleep condition, you will come to CHEO for the assessment of your insulin levels. To do so, you will be asked to drink a juice high in sugar and a research nurse will collect a small amount of your blood (~12 mL) right before ingestion and at 30, 60, 90, and 120 minutes after drinking the juice. In addition to the collection of blood samples, we will measure your height and weight, body composition (fat and lean mass) and blood pressure at every visit. You will also complete short questionnaires on food consumption and appetite, mental wellbeing, quality of life (first visit only), sleepiness, sedentary behaviour, and a questionnaire to determine your pubertal status (first visit

only). Additionally, we will conduct an experiment to test your brain function. You will be standing, arms at your side facing a screen or you will be positioned in a chair. You will be asked to make wrist extension movements between a 'home' position and a target (approximately 25°) in a single continuous motion. You will respond by extending your wrist after an auditory or visual stimulus. Some of the experiment while standing will be conducted with your eyes open and some will be conducted with your eyes closed. Your physical activity level will be assessed using the same watch that you will wear for determining your sleep duration. Finally, you will be asked to fill out a 3-day food diary during each of the 3 sleep conditions (2 weekdays and 1 weekend day). This will help us to assess your eating patterns.

Are there any risks to participating?

The procedures of the proposed study have been chosen to minimize the burden and risk posed to the personal safety of study participants. A small amount of blood will be collected (~100 mL), and you may experience discomfort during this assessment. Based on our experience, this is not considered a problem by most participants and our research nurses are very experienced with this technique. Any abnormalities in blood work will be assessed by our physician, Dr. Stasia Hadjiyannakis, and appropriate feedback and referrals for follow-up testing with family physicians will be provided. Additionally, the 1.5-hour reduction in sleep duration per night for a week may make you tired during the day. You need to be careful if you are driving or if you engage in activities that require attention to avoid accidents.

During the experiment to test your brain function, you will be making repeated movements while standing and sitting and your muscles may become slightly tired. This risk will be decreased by providing rest periods every 10 minutes. During the eyes closed portion of the testing you may feel a little less stable as our vision contributes to our standing balance, but nothing will be done to destabilize you, and experienced personnel will be there to ensure your safety. Muscle and brain activity will be recorded using plastic sensors attached to the surface of your skin and scalp. The skin beneath each sensor will be lightly scrubbed, which may cause brief minor irritation. As the electrode is sticky, you may experience some very minor discomfort when the electrode is removed (it is similar to removing a Band-Aid). Be assured that every effort will be made to minimize these risks.

When filling out questionnaires (pubertal stage, mood, depression symptoms, and behavioral difficulties questionnaires) you may feel uncomfortable answering some of the questions. You do not have to answer any questions that you do not feel comfortable answering, and you do not have to give the reason why you chose to not answer a particular question.

Are there any benefits to participating?

If you decide to participate, you may not benefit from participating in this study; however, you will receive feedback related to your health. Additionally, the knowledge gained from this study may significantly benefit other adolescents with insulin resistance. At the conclusion of the study, you will be given a summary of the results if you so wish.

Will I be paid to participate?

Yes. You will receive $30 for each laboratory visit after each sleep condition (total of $90), and we will provide you with free parking or transit passes depending on your mode of transportation. In addition, we will compensate you if you are able to respect the “decreased” and “increased” sleep schedules ($5 per day, so the possibility of an extra $105 if you are adherent to the sleep protocol). You will still receive the $30 compensation if you choose to withdraw from the study and we will still give you the $5 per day for days you are compliant with the sleep schedule. If you come to all assessments and complete the sleep interventions, we will also give you a letter attesting that you have completed 40 volunteering hours by participating in our study, which is the number of hours required to graduate high school by the province of Ontario. You will not be held accountable for the loss or damage to the sleep watch used in the study if it happens.

What if I get injured?

In the event that you or your child suffer injury as a direct result of participating in this study, normal legal rules on compensation will apply. Medical care will be provided to you or your child. 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.

What about confidentiality and privacy?

For this study we will be collecting date of birth and gender for the research purposes described in this consent form. Representatives from the CHEO Research Ethics Board may look at your records at the site where these records are held, to check that the study is following the proper laws and guidelines. Your personal information will be kept strictly confidential except as required or permitted by law. The data produced from this study will be stored in a locked filing cabinet. Only members of the research team will have access to the data. Following completion of the research study the data will be kept for 7 years after the last publication of this study. They will then be destroyed. You will not be identified in any publication or presentation of this study. A copy of the signed consent form will be provided to you.

Is the research team benefiting from the study?

The research team members are not benefiting personally, financially or in some other way from this study.

What if I have questions?

If you have any questions concerning participation in this study, you can contact the principal investigator, Dr. Jean-Philippe Chaput, jpchaput@cheo.on.ca, at 613-737-7600 Ext. 3683.

This study has been reviewed and approved by the CHEO Research Ethics Board. The CHEO Research Ethics Board is a committee of the hospital that includes individuals from different professional backgrounds. The Board reviews all human research that takes place at the hospital. Its 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 or child's judgment about what decisions and choices are best for them. You may contact the Chair of the Research Ethics Board, for information regarding patient's rights in research studies at 613-737-7600 Ext. 3272, although this person cannot provide any health-related information about the study. You may also contact the Protocol Officer for Ethics in Research at the University of Ottawa. They are located at 550 Cumberland Street, Room 154, Ottawa, ON, K1N 6N5, and can also be reached by phone (613-562-5387) or email (ethics@uottawa.ca).

Consent form Signatures

By signing this consent form I agree that:

- I am voluntarily agreeing to participate in this research study;
- I understand the information within this consent form;
- All of the risks and benefits of participation have been explained to me;
- All of my questions have been answered;
- I do not give up my legal rights by signing this form.

Signature of Parent or Legal Guardian	Name of Parent or Legal Guardian	Date

Signature of Participant	Name of Participant	Date
Signature of Person Obtaining Informed Consent	Name of Person Obtaining Informed Consent	Date

Appendix D. Sample testing month schedule

EXAMPLE: February 2019

☐ First visit at ☐ Assessments at CHEO starts at ☐ No food after 9pm

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 **Visit at CHEO for intake questionnaires** **1st night of habitual sleep**	2 2nd night of habitual sleep
3 3rd night of habitual sleep	4 4th night of habitual sleep	5 5th night of habitual sleep	6 6th night of habitual sleep	7 **Do not eat food after 9pm.** 7th night of habitual sleep	8 **1st assessment at CHEO 8:00am to 2pm. 1st night of decreased sleep**	9 2nd night of decreased sleep
10 3rd night of decreased sleep	11 4th night of decreased sleep	12 5th night of decreased sleep	13 6th night of decreased sleep	14 **Do not eat food after 9pm.** 7th night of decreased sleep	15 **2nd assessment at CHEO 8:00 to 2pm.** **1st night of returning sleep to normal**	16 2nd night of normal sleep
17 3rd night of normal sleep	18 4th night of normal sleep	19 5th night of normal sleep	20 6th night of normal sleep	21 7th night of normal sleep	22 **No assessment at CHEO but begin increased sleep.** **1st night of increased sleep**	23 2nd night of increased sleep
24 3rd night of increased sleep	25 4th night of increased sleep	26 5th night of increased sleep	27 6th night of increased sleep	28 **Do not eat food after 9pm.** 7th night of increased sleep	1 **Last assessment at CHEO 8:00am to 2pm.** **THANK YOU!**	2

Appendix E. Actiwatch Protocol

Actiwatch Protocol

Initial Assessment

1. **File**. **New subject…** Fill in Identity (see **Save as** below), DOB and Gender, press **OK**.
2. **Show Actiwatch console.** Select Actiwatch 2. **Configure…** Select appropriate subject. **Next.** Epoch Length: 1 minute. Logging Mode: Activity and Photopic Light. **Next.** Start time: 2:30 PM today. Data Collection Duration: 14 days for baseline. Time zone = Eastern Time (Us & Canada). **Configure. Continue.**

Lab Assessment 1

3. **Show Actiwatch console.** Select Actiwatch 2. **Retrieve…** Make sure Launch Actogram is checked and press **Save Data.** Select **Put Actiwatch to sleep for later use.**
4. FOR HABITUAL SLEEP: Click on **Statistics Table.** Inspect the values in the Sleep tab, look at Sleep Time column. If any sleep duration > 600 minutes or < 270 minutes, copy paste the Sleep -> Sleep Time column into the New Sleep Duration Average excel sheet in the Actiwatch Data folder. Remove these values, and recalculate average.
5. Copy and paste Sleep tab into V:\HALO\SMART2D\Actiwatch Data\Sleep Data.
6. **File. Export. No.** Save in V:\HALO\SMART2D\Raw Sleep Data according to **Save As** (see below).
7. **New Subject…** Fill in Identity (see **Save as** below), DOB and Gender, press **OK. Next.** Epoch Length: 1 minute. Logging Mode: Activity and Photopic Light. **Next.**

Start time: 2:30 PM today. Data Collection Duration: 14 days for first condition. Time zone = Eastern Time (Us & Canada).

Lab Assessment 2

8. **Show Actiwatch console.** Select Actiwatch 2. **Retrieve…** Make sure Launch Actogram is checked and press **Save Data.** Select **Put Actiwatch to sleep for later use.**
9. Copy and paste Sleep tab into V:\HALO\SMART2D\Actiwatch Data\Sleep Data.
10. **File. Export. No.** Save in V:\HALO\SMART2D\Raw Sleep Data according to **Save As** (see below).
11. **New Subject…** Fill in Identity (see **Save as** below), DOB and Gender, press **OK. Next.** Epoch Length: 1 minute. Logging Mode: Activity and Photopic Light. **Next.** Start time: 2:30 PM today. Data Collection Duration: 21 days for second condition + washout. Time zone = Eastern Time (Us & Canada).

Lab Assessment 3

12. **Show Actiwatch console.** Select Actiwatch 2. **Retrieve…** Make sure Launch Actogram is checked and press **Save Data.** Select Put logger to sleep for later use and press **Next.**
13. Copy and paste Sleep tab into V:\HALO\SMART2D\Actiwatch Data\Sleep Data.
14. **File. Export. No.** Save in V:\HALO\SMART2D\Raw Sleep Data according to **Save As** (see below).

Save as: the participant ID followed by the condition

- **Participant ID** is **S** followed by the number i.e., **S01**

- **Conditions:** Habitual sleep condition- **HB**; Increased sleep condition- **IN**; Decreased sleep condition-**DE**
- **Example: S01_HB**

Appendix F. Assessment Schedule

SMART2D Study: Lab Assessments Schedule

Time	Sequence of events during the laboratory sessions
8:00	Participant arrives at the laboratory
8:05	Measurement of weight, BIA, BP, HR, and S_aO_2
8:25	Begin oral glucose tolerance test (OGTT) Insert catheter and take fasting blood sample (minute 0)
8:35	Participant drinks glucose drink and water
8:45	Screen time and sedentary behaviour questionnaire
	Epworth Sleepiness Scale
9:10	First blood sample (30 minutes after)
9:15	Patient Health Questionnaire - Adolescents
	Brunel Mood Scale
	Strengths and Difficulties Questionnaire
9:40	Second blood sample (60 minutes after)
9:45	Commence EEG Capping
10:10	Third blood sample (90 minutes after)
10:15	EMG and Goniometer
10:40	Fourth blood sample (120 minutes after)
10:45	VAS Pre-Breakfast, Breakfast, and VAS Post-Breakfast
11:10	Dual-task paradigm (STST)
12:45	Affective shifting task (FFOO)+PANAS
13:40	VAS pre-lunch, *Ad libitum* lunch, and VAS post-lunch
14:00	End of laboratory testing

Appendix G – PHQ-A

G3: PHQ-A Severity Measure for Depression

Severity Measure for Depression—Child Age 11–17*

*PHQ-9 modified for Adolescents (PHQ-A)—Adapted

Name:_____ **Age:** _____ **Sex: Male** ❑ **Female** ❑ **Date:**_____

Instructions: How often have you been bothered by each of the following symptoms during the past **7 days**? For each symptom put an "**X**" in the box beneath the answer that best describes how you have been feeling.

						Clinician Use
						Item score
		(0) Not at all	(1) Several days	(2) More than half the days	(3) Nearly every day	
1.	Feeling down, depressed, irritable, or hopeless?					
2.	Little interest or pleasure in doing things?					
3.	Trouble falling asleep, staying asleep, or sleeping too much?					
4.	Poor appetite, weight loss, or overeating?					
5.	Feeling tired, or having little energy?					
6.	Feeling bad about yourself—or feeling that you are a failure, or that you have let yourself or your family down?					
7.	Trouble concentrating on things like school work, reading, or watching TV?					
8.	Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you were moving around a lot more than usual?					
9.	Thoughts that you would be better off dead, or of hurting yourself in some way?					
					Total/Partial Raw Score:	
					Prorated Total Raw Score: (if 1-2 items left unanswered)	

Modified from the PHQ-A (J. Johnson, 2002) for research and evaluation purposes

Appendix H – BRUMS

The Brunel Mood Scale

Below is a list of words that describe feelings. Please read each one carefully. Then cross the box that best describes **HOW YOU HAVE FELT OVER THE LAST WEEK**. Make sure you answer every question.

		Not at all	A little	Moderately	Quite a bit	Extremely
1.	Panicky	❑	❑	❑	❑	❑
2.	Lively	❑	❑	❑	❑	❑
3.	Confused	❑	❑	❑	❑	❑
4.	Worn out	❑	❑	❑	❑	❑
5.	Depressed	❑	❑	❑	❑	❑
6.	Downhearted	❑	❑	❑	❑	❑
7.	Annoyed	❑	❑	❑	❑	❑
8.	Exhausted	❑	❑	❑	❑	❑
9.	Mixed-up	❑	❑	❑	❑	❑
10.	Sleepy	❑	❑	❑	❑	❑
11.	Bitter	❑	❑	❑	❑	❑
12.	Unhappy	❑	❑	❑	❑	❑
13.	Anxious	❑	❑	❑	❑	❑
14.	Worried	❑	❑	❑	❑	❑
15.	Energetic	❑	❑	❑	❑	❑
16.	Miserable	❑	❑	❑	❑	❑
17.	Muddled	❑	❑	❑	❑	❑
18.	Nervous	❑	❑	❑	❑	❑
19	Angry	❑	❑	❑	❑	❑
20.	Active	❑	❑	❑	❑	❑
21.	Tired	❑	❑	❑	❑	❑
22.	Bad tempered	❑	❑	❑	❑	❑
23.	Alert	❑	❑	❑	❑	❑
24.	Uncertain	❑	❑	❑	❑	❑

Appendix I – SDQ normative data

SDQ frequency distribution for American 11-14 year olds

1) SDQ total difficulties score, American 11-14 year olds

Total difficulties score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	5.8	5.8	6.2	6.2	5.4	5.4
1	7.6	13.4	9.3	15.5	6.1	11.4
2	9.8	23.2	8.8	24.3	10.8	22.3
3	9.5	32.7	11.6	35.9	7.4	29.6
4	9.8	42.5	8.7	44.5	10.9	40.5
5	8.9	51.4	9.6	54.1	8.3	48.8
6	7.0	58.4	8.2	62.3	5.9	54.7
7	5.7	64.2	6.1	68.4	5.4	60.1
8	4.7	68.9	4.4	72.8	5.0	65.1
9	4.2	73.1	3.8	76.6	4.6	69.7
10	3.4	76.5	3.5	80.2	3.3	73.0
11	3.6	80.1	2.4	82.6	4.7	77.7
12	2.9	83.0	2.3	84.8	3.5	81.2
13	2.7	85.7	2.4	87.3	2.9	84.2
14	1.9	87.5	2.6	89.9	1.1	85.3
15	1.6	89.1	1.1	90.9	2.0	87.3
16	1.7	90.8	1.8	92.8	1.6	88.9
17	1.7	92.5	0.8	93.5	2.7	91.6
18	1.5	94.0	1.8	95.3	1.2	92.8
19	1.0	95.1	0.8	96.2	1.2	94.0
20	0.9	95.9	0.9	97.1	0.8	94.8
21	0.6	96.5	0.6	97.7	0.5	95.4
22	0.5	97.0	0.3	98.0	0.8	96.2
23	0.5	97.6	0.3	98.3	0.7	96.9
24	0.6	98.1	0.5	98.7	0.7	97.6
25	0.3	98.5	0.2	99.0	0.4	98.0
26	0.3	98.8	0.1	99.0	0.5	98.5
27	0.2	98.9	0.2	99.2	0.1	98.7
28	0.3	99.2	0.3	99.5	0.2	98.9
29	0.4	99.6	0.4	99.9	0.4	99.3
30	0.0	99.6	0.0	99.9	0.1	99.4
31	0.1	99.7	0.1	100.0	0.1	99.5
32-40	0.3	100.0	0.0	100.0	0.5	100.0

2) SDQ emotional symptoms score, American 11-14 year olds

Emotional symptoms score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	37.7	37.7	35.0	35.0	40.4	40.4
1	21.1	58.8	20.4	55.4	21.7	62.1
2	15.9	74.7	16.9	72.3	15.0	77.0
3	9.2	83.9	9.9	82.2	8.5	85.5
4	6.2	90.1	6.9	89.2	5.5	91.0
5	3.5	93.6	3.3	92.5	3.6	94.6
6	2.8	96.4	3.0	95.5	2.7	97.3
7	1.5	97.9	1.9	97.4	1.1	98.5
8	1.1	99.0	1.1	98.5	1.0	99.5
9	0.6	99.6	1.0	99.5	0.2	99.7
10	0.4	100.0	0.5	100.0	0.3	100.0

3) SDQ conduct problems score, American 11-14 year olds

Conduct problems score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	43.0	43.0	44.6	44.6	41.6	41.6
1	23.2	66.2	24.0	68.6	22.3	63.9
2	14.8	81.0	14.5	83.2	15.0	78.8
3	7.8	88.7	7.0	90.1	8.5	87.4
4	4.6	93.3	4.3	94.5	4.8	92.2
5	2.7	96.0	2.8	97.2	2.6	94.8
6	2.0	98.0	1.5	98.8	2.5	97.3
7	0.8	98.8	0.6	99.4	1.0	98.3
8	0.7	99.5	0.5	99.9	0.8	99.1
9	0.3	99.8	0.1	100.0	0.5	99.7
10	0.2	100.0	0.0	100.0	0.3	100.0

4) SDQ hyperactivity-inattention score, American 11-14 year olds

Hyperact. inattention score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	22.3	22.3	25.9	25.9	18.7	18.7
1	18.1	40.4	21.0	46.9	15.3	34.0
2	16.1	56.5	16.9	63.8	15.4	49.4
3	13.9	70.4	13.9	77.7	14.0	63.4
4	8.6	79.0	7.4	85.1	9.7	73.1
5	6.9	86.0	5.5	90.6	8.4	81.5
6	4.4	90.3	4.0	94.5	4.7	86.2
7	3.1	93.5	1.9	96.4	4.3	90.6
8	2.6	96.0	1.6	98.1	3.5	94.1
9	1.6	97.6	1.0	99.1	2.2	96.3
10	2.4	100.0	0.9	100.0	3.7	100.0

5) SDQ peer problems score, American 11-14 year olds

Peer problems score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	38.9	38.9	41.2	41.2	36.6	36.6
1	22.4	61.3	21.9	63.2	23.0	59.5
2	18.2	79.5	18.4	81.6	18.0	77.5
3	9.5	89.0	8.9	90.5	10.0	87.5
4	5.8	94.8	5.1	95.6	6.4	93.9
5	2.7	97.4	2.1	97.7	3.2	97.1
6	1.5	98.9	1.4	99.2	1.5	98.7
7	0.5	99.5	0.5	99.7	0.6	99.3
8	0.4	99.8	0.2	99.9	0.5	99.8
9	0.1	100.0	0.1	100.0	0.2	100.0
10	0.0	100.0	0.0	100.0	0.0	100.0

6) SDQ prosocial behavior score, American 11-14 year olds

Prosocial behavior score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	0.2	0.2	0.0	0.0	0.3	0.3
1	0.3	0.5	0.3	0.3	0.3	0.6
2	0.7	1.1	0.4	0.7	1.0	1.5
3	0.9	2.1	0.2	1.0	1.6	3.2
4	1.6	3.6	1.6	2.5	1.6	4.7
5	4.1	7.7	2.4	5.0	5.7	10.4
6	4.9	12.6	3.2	8.2	6.5	16.9
7	7.9	20.5	7.5	15.7	8.3	25.1
8	13.9	34.4	13.6	29.3	14.2	39.3
9	17.6	51.9	18.6	47.9	16.5	55.9
10	48.1	100.0	52.1	100.0	44.1	100.0

7) SDQ impact score, American 11-14 year olds

Impact score	All (N=2770)		Female (N=1344)		Male (N=1426)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	84.9	84.9	88.6	88.6	81.2	81.2
1	4.4	89.2	3.2	91.8	5.5	86.7
2	2.8	92.0	2.6	94.4	2.9	89.6
3	1.6	93.6	1.2	95.6	2.1	91.7
4	1.9	95.5	1.3	96.9	2.5	94.2
5	1.7	97.2	1.3	98.2	2.1	96.3
6	1.1	98.4	0.8	99.0	1.5	97.8
7	0.3	98.7	0.4	99.4	0.2	98.0
8	0.7	99.3	0.3	99.7	1.0	99.0
9	0.3	99.6	0.1	99.8	0.4	99.4
10	0.4	100.0	0.2	100.0	0.6	100.0

SDQ frequency distribution for American 15-17 year olds

1) SDQ total difficulties score, American 15-17 year olds

Total difficulties score	**All** (N=2265)		**Female** (N=1095)		**Male** (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	6.3	6.3	6.7	6.7	5.9	5.9
1	8.6	14.9	8.5	15.2	8.7	14.6
2	10.9	25.9	11.5	26.8	10.4	25.0
3	9.2	35.1	9.3	36.1	9.1	34.1
4	10.1	45.1	10.7	46.7	9.6	43.6
5	9.3	54.4	9.1	55.9	9.4	53.1
6	6.2	60.6	5.6	61.5	6.8	59.9
7	6.2	66.8	5.1	66.6	7.1	67.0
8	5.5	72.3	6.2	72.8	4.9	71.9
9	4.0	76.3	4.1	76.9	3.9	75.8
10	5.2	81.5	5.7	82.6	4.8	80.6
11	2.5	84.0	2.3	84.9	2.6	83.2
12	1.9	85.9	1.4	86.3	2.4	85.6
13	3.2	89.1	2.8	89.1	3.5	89.1
14	2.1	91.2	1.6	90.7	2.6	91.8
15	1.7	93.0	2.1	92.8	1.4	93.2
16	1.8	94.8	2.1	94.9	1.5	94.7
17	0.7	95.4	0.6	95.5	0.7	95.4
18	1.0	96.4	0.7	96.2	1.2	96.6
19	0.5	96.9	0.6	96.8	0.5	97.0
20	0.6	97.5	0.9	97.6	0.3	97.3
21	0.5	98.0	0.8	98.5	0.3	97.6
22	0.5	98.5	0.3	98.8	0.7	98.3
23	0.1	98.6	0.0	98.8	0.2	98.5
24	0.4	99.0	0.4	99.2	0.5	98.9
25	0.2	99.2	0.1	99.2	0.3	99.2
26	0.1	99.4	0.0	99.2	0.2	99.5
27	0.3	99.7	0.3	99.5	0.4	99.8
28	0.1	99.7	0.1	99.6	0.0	99.8
29	0.1	99.8	0.1	99.7	0.1	99.9
30	0.1	99.9	0.2	99.9	0.1	100.0
31	0.1	100.0	0.1	100.0	0.0	100.0
32-40	0.0	100.0	0.0	100.0	0.0	100.0

2) SDQ emotional symptoms score, American 15-17 year olds

Emotional symptoms score	All (N=2265)		Female (N=1095)		Male (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	38.3	38.3	32.9	32.9	43.4	43.4
1	22.9	61.2	21.4	54.3	24.4	67.7
2	15.7	76.9	17.5	71.8	13.9	81.6
3	8.9	85.8	10.3	82.1	7.6	89.2
4	6.5	92.3	7.3	89.4	5.8	95.0
5	3.2	95.5	4.4	93.8	2.1	97.1
6	2.1	97.6	3.2	97.0	1.0	98.1
7	1.2	98.8	1.4	98.4	1.0	99.2
8	0.7	99.5	0.9	99.3	0.5	99.7
9	0.3	99.8	0.4	99.8	0.1	99.8
10	0.2	100.0	0.2	100.0	0.2	100.0

3) SDQ conduct problems score, American 15-17 year olds

Conduct problems score	All (N=2265)		Female (N=1095)		Male (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	47.9	47.9	47.0	47.0	48.8	48.8
1	20.3	68.3	21.2	68.2	19.5	68.3
2	15.0	83.2	15.3	83.5	14.7	83.0
3	7.9	91.2	8.0	91.4	7.9	90.9
4	4.1	95.3	3.5	95.0	4.6	95.6
5	2.5	97.7	3.2	98.2	1.8	97.3
6	1.0	98.8	0.6	98.7	1.5	98.8
7	0.7	99.4	0.6	99.3	0.7	99.5
8	0.3	99.7	0.3	99.6	0.3	99.9
9	0.2	100.0	0.3	100.0	0.1	100.0
10	0.0	100.0	0.0	100.0	0.0	100.0

Hyperact. inattention score	All (N=2265)		Female (N=1095)		Male (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	26.9	26.9	30.9	30.9	23.0	23.0
1	18.4	45.3	19.4	50.3	17.5	40.5
2	16.5	61.8	16.7	66.9	16.4	56.9
3	13.1	74.9	13.8	80.7	12.5	69.4
4	8.0	82.9	5.7	86.5	10.1	79.5
5	5.3	88.2	4.8	91.3	5.8	85.3
6	5.1	93.3	5.0	96.3	5.1	90.4
7	2.5	95.7	1.3	97.6	3.6	94.0
8	2.3	98.0	0.9	98.5	3.6	97.6
9	1.0	99.0	0.9	99.4	1.1	98.7
10	1.0	100.0	0.6	100.0	1.3	100.0

5) SDQ peer problems score, American 15-17 year olds

Peer problems score	All (N=2265)		Female (N=1095)		Male (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	38.5	38.5	39.2	39.2	37.9	37.9
1	22.6	61.2	23.9	63.1	21.4	59.3
2	19.1	80.2	18.6	81.7	19.6	78.9
3	9.6	89.8	8.1	89.8	10.9	89.8
4	5.8	95.6	5.7	95.5	5.8	95.6
5	2.4	98.0	2.3	97.9	2.6	98.1
6	1.2	99.3	1.3	99.2	1.2	99.3
7	0.6	99.9	0.7	99.9	0.5	99.9
8	0.1	100.0	0.1	100.0	0.1	100.0
9	0.0	100.0	0.0	100.0	0.0	100.0
10	0.0	100.0	0.0	100.0	0.0	100.0

6) SDQ prosocial behavior score, American 15-17 year olds

Prosocial behavior score	All (N=2265)		Female (N=1095)		Male (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	0.2	0.2	0.2	0.2	0.1	0.1
1	0.2	0.4	0.0	0.3	0.3	0.4
2	0.4	0.8	0.3	0.6	0.5	1.0
3	0.4	1.2	0.1	0.7	0.7	1.7
4	1.4	2.6	1.3	2.0	1.5	3.1
5	3.5	6.1	2.1	4.1	4.8	8.0
6	6.5	12.6	5.8	9.9	7.2	15.2
7	7.3	19.9	6.2	16.1	8.3	23.5
8	14.4	34.3	13.7	29.8	15.2	38.6
9	18.5	52.8	18.5	48.3	18.5	57.1
10	47.2	100.0	51.7	100.0	42.9	100.0

7) SDQ impact score, American 15-17 year olds

Impact score	All (N=2265)		Female (N=1095)		Male (N=1170)	
	%	Cumul. %	%	Cumul. %	%	Cumul. %
0	86.3	86.3	87.8	87.8	85.0	85.0
1	4.2	90.5	3.3	91.1	5.0	90.0
2	3.5	94.0	3.3	94.4	3.7	93.6
3	1.5	95.5	1.3	95.7	1.7	95.4
4	1.5	97.1	1.0	96.7	2.0	97.4
5	1.0	98.1	1.2	97.9	0.8	98.2
6	0.4	98.5	0.1	98.0	0.7	98.9
7	0.4	98.9	0.6	98.6	0.2	99.1
8	0.6	99.5	0.8	99.4	0.4	99.6
9	0.2	99.7	0.2	99.7	0.2	99.7
10	0.3	100.0	0.3	100.0	0.3	100.0

Appendix J – SDQ

Strengths and Difficulties Questionnaire

S 11-17
FOLLOW-UP

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain . Please give your answers on the basis of how things have been for you **over the last month**.

Your name..... Male/Female

Date of birth.....

	Not True	Somewhat True	Certainly True
I try to be nice to other people. I care about their feelings	☐	☐	☐
I am restless, I cannot stay still for long	☐	☐	☐
I get a lot of headaches, stomach-aches or sickness	☐	☐	☐
I usually share with others, for example CD's, games, food	☐	☐	☐
I get very angry and often lose my temper	☐	☐	☐
I would rather be alone than with people of my age	☐	☐	☐
I usually do as I am told	☐	☐	☐
I worry a lot	☐	☐	☐
I am helpful if someone is hurt, upset or feeling ill	☐	☐	☐
I am constantly fidgeting or squirming	☐	☐	☐
I have one good friend or more	☐	☐	☐
I fight a lot. I can make other people do what I want	☐	☐	☐
I am often unhappy, depressed or tearful	☐	☐	☐
Other people my age generally like me	☐	☐	☐
I am easily distracted, I find it difficult to concentrate	☐	☐	☐
I am nervous in new situations. I easily lose confidence	☐	☐	☐
I am kind to younger children	☐	☐	☐
I am often accused of lying or cheating	☐	☐	☐
Other children or young people pick on me or bully me	☐	☐	☐
I often offer to help others (parents, teachers, children)	☐	☐	☐
I think before I do things	☐	☐	☐
I take things that are not mine from home, school or elsewhere	☐	☐	☐
I get along better with adults than with people my own age	☐	☐	☐
I have many fears, I am easily scared	☐	☐	☐
I finish the work I'm doing. My attention is good	☐	☐	☐

Do you have any other comments or concerns?

Since increasing/decreasing your sleep in the past week, are your problems:

Much worse	A bit worse	About the same	A bit better	Much better
☐	☐	☐	☐	☐

Has changing your sleep been helpful in other ways, e.g. providing inform00ation or making the problems more bearable?

Not at all	Only a little	A medium amount	A great deal
☐	☐	☐	☐

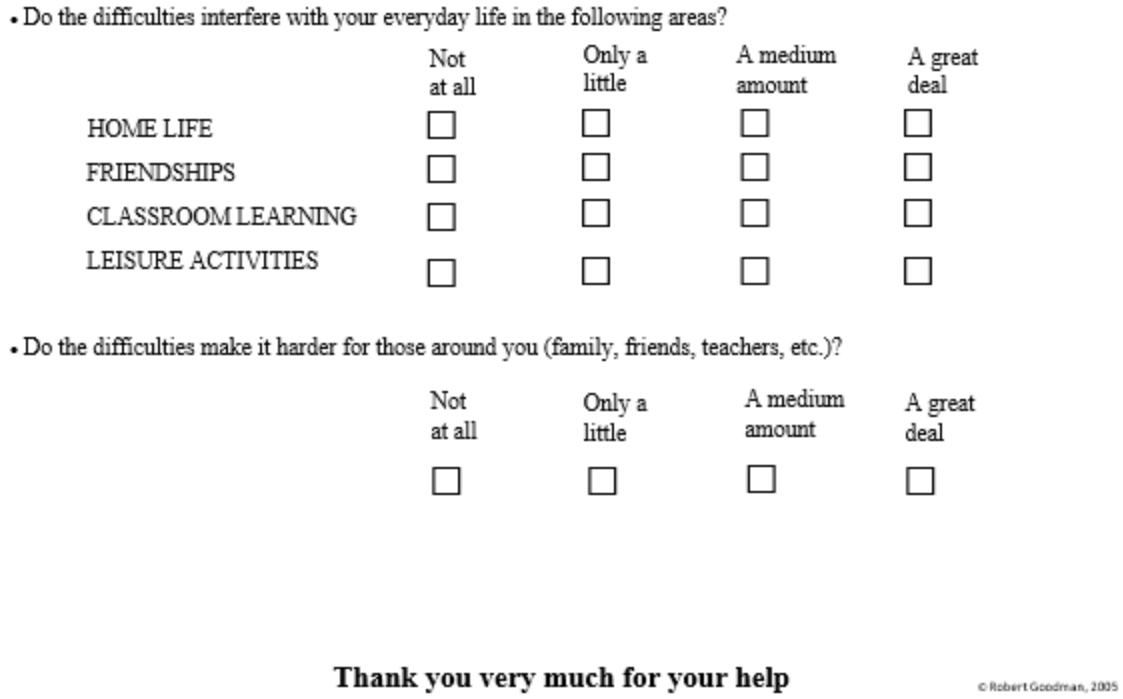
In the past week, have you had difficulties in one or more of the following areas: emotions, concentration, behaviour or being able to get on with other people?

No	Yes-minor difficulties	Yes-definite difficulties	Yes-severe difficulties
☐	☐	☐	☐

If you have answered "Yes", please answer the following questions about these difficulties:

- Do the difficulties upset or distress you?

Not at all	Only a little	A medium amount	A great deal
☐	☐	☐	☐



• Do the difficulties interfere with your everyday life in the following areas?

	Not at all	Only a little	A medium amount	A great deal
HOME LIFE	☐	☐	☐	☐
FRIENDSHIPS	☐	☐	☐	☐
CLASSROOM LEARNING	☐	☐	☐	☐
LEISURE ACTIVITIES	☐	☐	☐	☐

• Do the difficulties make it harder for those around you (family, friends, teachers, etc.)?

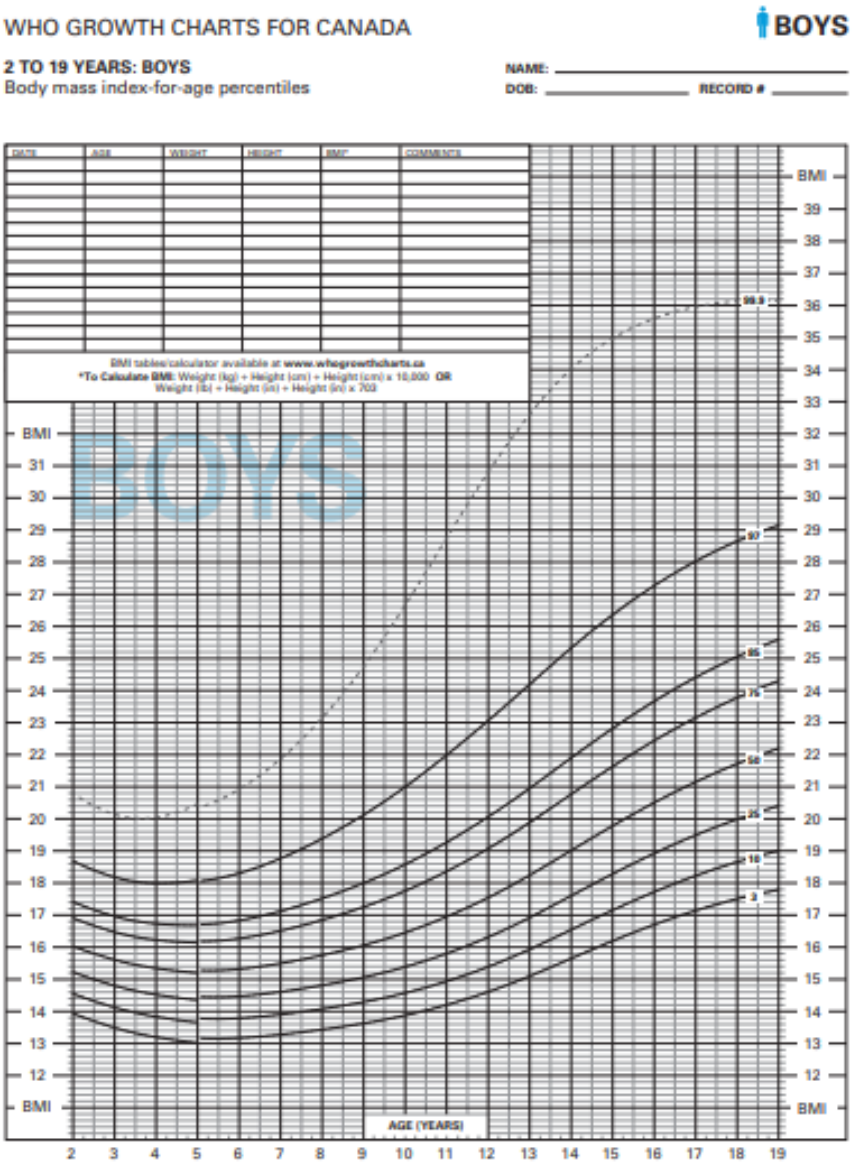
Not at all	Only a little	A medium amount	A great deal
☐	☐	☐	☐

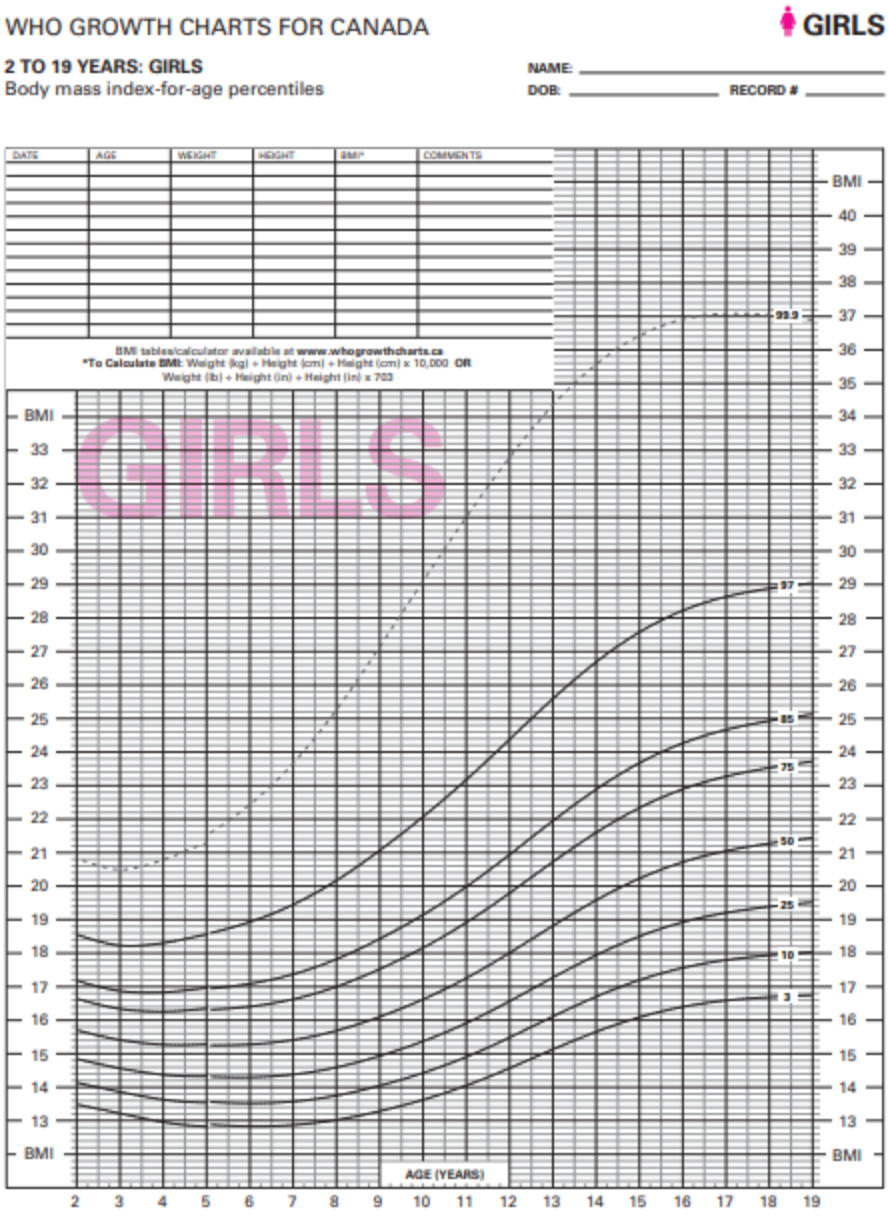
Thank you very much for your help

Table 7**.** Categorization of SDQ Scores.

	Close to average	**Slightly raised/ (slightly lowered)**	**High/ (low)**	**Very high/ (very low)**
Total difficulties	0-14	15-17	18-19	20-40
Emotional problems	0-4	5	6	7-10
Conduct problems	0-3	4	5	6-10
Hyperactivity/Inattention	0-5	6	7	8-10
Peer problems	0-3	3	4	5-10
Prosocial behaviour	7-10	6	5	0-4
Impact	0	1	2	3-10

Appendix K – WHO growth charts




WHO GROWTH CHARTS FOR CANADA
GIRLS
2 TO 19 YEARS: GIRLS
Body mass index-for-age percentiles
NAME:
DOB:
RECORD #
DATE
AGE
WEIGHT
HEIGHT
BMI*
COMMENTS
BMI tables/calculator available at www.whogrowthcharts.ca
*To Calculate BMI: Weight (kg) ÷ Height (cm) ÷ Height (cm) x 10,000 OR
Weight (lb) ÷ Height (in) ÷ Height (in) x 703
GIRLS
BMI
AGE (YEARS)
99.9
97
85
75
50
25
10
3

Appendix L - A Self-Administered Rating Scale for Pubertal Development

2. Have you begun to menstruate (started to have your period)?

a) Yes

b) No

If yes, how old were you when you started to menstruate?_____

If yes, when did your last cycle begin and end?

Begin: dd/mm_____

End: dd/mm_____

2. Have you noticed a deepening of your voice?

a) Yes

b) No

c) My voice cracks sometimes

3. Have you begun to grow enough hair on your face to necessitate to shave?

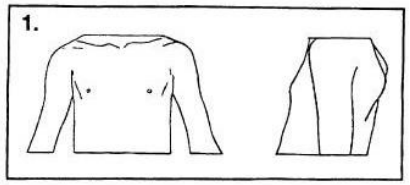
a) Yes

b) No

Study Subject No:

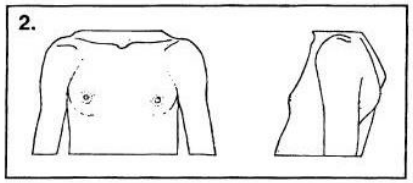
- Please put a tick in the box that looks most like you now....

1.



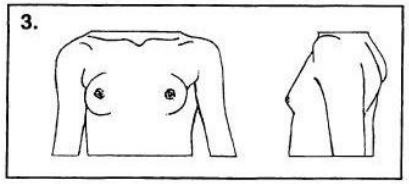
The breasts are flat.

2.



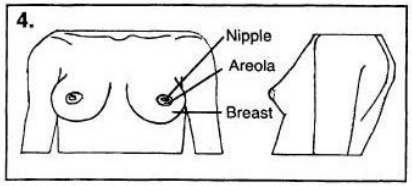
The breasts form small mounds.

3.



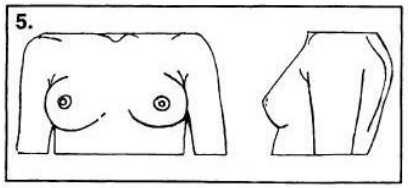
The breasts form larger mounds than in 2.

4.



The nipple and the surrounding part *(the Areola)* make up a mound that sticks up above the breast.

5.

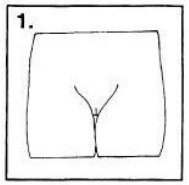


Only the nipple sticks out beyond the breast.

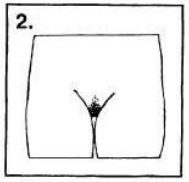
- Please put a tick in the box that looks most like you now....

1.

No hairs

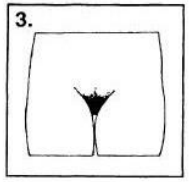


2.



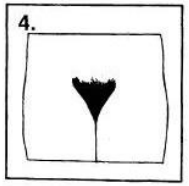
Very little hair

3.



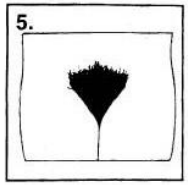
Quite a lot of hair

4.



The hair has not spread over the thighs

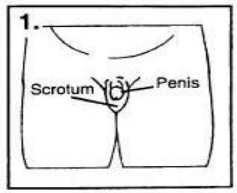
5.

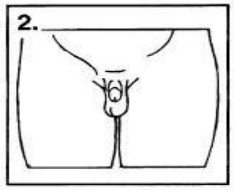


The hair has spread over the thighs

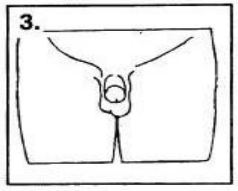
- Please look at the **Penis** and **Scrotum** only in these pictures.
- Please put a tick in the box that looks most like you now.

1. Scrotum and Penis same size as when you were younger.

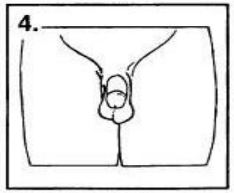




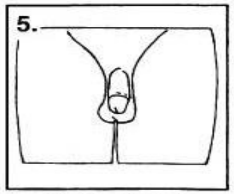
2. The Scrotum has lowered a bit and the Penis is a little larger.



3. The Penis is longer the Scrotum is larger.



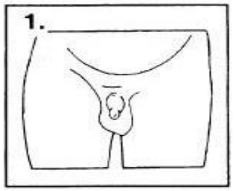
4. The Penis is longer and wider the Scrotum is darker and bigger than before

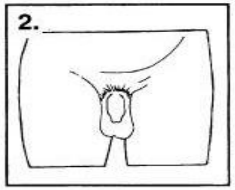


5. The Penis and Scrotum are the size and shape of an adult.

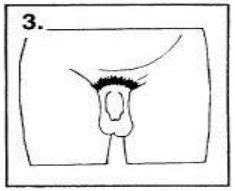
- Please look at the **Pubic Hair** only in these pictures.
- Please put a tick in the box that looks most like you now.

1. No hairs

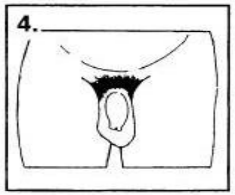




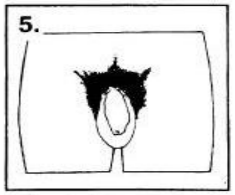
2. Very little hair



3. Quite a lot of hair



4. The hair has not spread over the thighs



5. The hair has spread over the thighs

Appendix M. PedsQL

PedsQL ™

Paediatric Quality of Life Inventory

Version 4.0 – English (Canada)

TEEN REPORT (ages **13-18**)

Directions

On the following page is a list of things that might be a problem for you. Please tell us **how much of a problem** each one has been for you during the **PAST MONTH** by circling:

0 if it is **never** a problem
1 if it is **almost never** a problem
2 if it is **sometimes** a problem
3 if it is **often** a problem
4 if it is **almost always** a problem

There are not right or wrong answers.
If you do not understand a question, please ask for help.

In the **PAST MONTH**, how much of a **problem** has this been for you ...

About My Health and Activities (problems with...)	Never	Almost never	Some-times	Often	Almost Always
1. It is hard for me to walk more than one block	0	1	2	3	4
2. It is hard for me to run	0	1	2	3	4
3. It is hard for me to do sports activity or exercise	0	1	2	3	4
4. It is hard for me to lift something heavy	0	1	2	3	4
5. It is hard for me to take a bath or shower by myself	0	1	2	3	4
6. It is hard for me to do chores around the house	0	1	2	3	4
7. I hurt or ache	0	1	2	3	4
8. I have low energy	0	1	2	3	4
About My Feelings (problems with...)	**Never**	**Almost never**	**Some-times**	**Often**	**Almost Always**
1. I feel afraid or scared	0	1	2	3	4
2. I feel sad or blue	0	1	2	3	4
3. I feel angry	0	1	2	3	4
4. I have trouble sleeping	0	1	2	3	4
5. I worry about what will happen to me	0	1	2	3	4
How I Get Along with Others (problems with...)	**Never**	**Almost never**	**Some-times**	**Often**	**Almost Always**
1. I have trouble getting along with other teens	0	1	2	3	4
2. Other teens do not want to be my friend	0	1	2	3	4
3. Other teens tease me	0	1	2	3	4
4. I cannot do things that other teens my age can do	0	1	2	3	4
5. It is hard to keep up with other teens my age	0	1	2	3	4
About School (problems with...)	**Never**	**Almost never**	**Some-times**	**Often**	**Almost Always**
1. It is hard to pay attention in class	0	1	2	3	4
2. I forget things	0	1	2	3	4
3. I have trouble keeping up with my schoolwork	0	1	2	3	4
4. I miss school because of not feeling well	0	1	2	3	4
5. I miss school to go to the doctor or hospital	0	1	2	3	4