The Association of Sleep Quality and Loneliness with Perceived Physical and Mental Health Status in Autistic Adults

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The Association of Sleep Quality and Loneliness with Perceived Physical and Mental Health Status in Autistic Adults

Nicholas Charles Clark Russell

A dissertation submitted to the faculty of Brigham Young University in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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Abstract

The Association of Sleep Quality and Loneliness with Perceived Physical and Mental Health Status in Autistic Adults

Nicholas Charles Clark Russell
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Doctor of Philosophy

Autistic individuals report a greater prevalence of physical and mental health difficulties, compared to the general population. This study examines factors which impact physical and mental health in the general population to evaluate whether they potentially underlie this increased prevalence in autistic individuals. We compared twenty-two autistic adults, twenty-three adults reporting symptoms of insomnia, and twenty-one neurotypical adults. The primary factors were sleep quality and insomnia; secondary factors were level of autistic traits, alexithymia, and prosocial behavior. Participants completed self-report measures looking at each of these factors as well as their perceived physical and mental health. Participants also wore an actigraphy watch for up to fourteen days to characterize their sleep behavior. This actigraphy data suggested that autistic adults slept longer than those with symptoms of insomnia and the neurotypical group. Multiple regressions identified which primary or secondary factors were associated with change in perceived physical and mental health. Transdiagnostic dimensional analyses suggested that both lower sleep quality and higher levels of loneliness predicted lower perceived physical and mental health, with the effect being greater for perceived mental health. The addition of secondary factors identified higher levels of alexithymia as a significant predictor of lower levels of perceived mental health but did not improve the model. For the autistic group, no factors were predictive of change in perceived physical health; however, follow-up analyses identified more insomnia symptoms as predicting reduced perceived physical
health. Both reduced sleep quality and greater loneliness predicted lower perceived mental health in the autistic adults. More sleep impairment and more symptoms of insomnia also predicted lower perceived mental health but did not better explain this change when included together over when included separately. These study findings suggest that sleep quality and loneliness are salient factors in the mental health of autistic adults and that understanding these, and sleep factors in general, may help to explain mental health challenges in these individuals.

Keywords: autism, sleep quality, loneliness, physical health, mental health, actigraphy
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The Association of Sleep Quality and Loneliness with Perceived Physical and Mental Health Status in Autistic Adults

Autism spectrum disorder, hereafter autism, refers to a broad range of differences in social communication and a preference for sameness, which can interfere with back-and-forth interactions with neurotypical peers. (American Psychological Association [APA], 2013; Fountain et al., 2011; Rutter, 2006). Autistic individuals often experience secondary physical and mental health challenges, many of which are associated with substantial and lasting disruption of everyday function.

Estimates of mortality rate – the number of deaths within a specific population, over a certain period of time, relative to the size of the population – are commonly used comparatively to estimate the impact of certain factors in life expectancy. Few studies of mortality rate in an autism population are available. However, those that have supplied estimates suggest that the mortality rate in autism is between two and ten times the rate of the general population, suggesting that a greater proportion of autistic individuals die in a particular time period than in the general population (Bilder et al., 2013; Chesney et al., 2014; Gillberg et al., 2010; Hirvikoski et al., 2016; Mouridsen et al., 2008). Indeed, Guan and Li (2017) suggested that those diagnosed with autism live half as long as those without autism – about 36 years vs. 72 years. A recent report commissioned by autism charity Autism Speaks highlights the notion that “Autism itself is not a cause of premature mortality” but health conditions associated with autism are instead responsible for premature mortality. Furthermore, they note that many of these conditions are “treatable and/or preventable” (Autism Speaks, 2017). For example, Guan and Li (2017) found that children with autism are 160 times more likely to drown than children in the general population. Identifying and elucidating which conditions, situations, and factors influence this
increased mortality rate is key to ensuring that individuals with autism receive appropriate treatment, care, and resources to not only alleviate symptoms and functional difficulties they sometimes face but also these health challenges associated with autism.

**Physical and Mental Health in Autism**

In light of these great health difficulties, many researchers have sought to identify the specific aspects of health that may be at risk. Two recent studies have looked at the health status of adults with autism (Croen et al., 2015; Fortuna et al., 2016). Croen et al. (2015) found a greater prevalence in autism of a number of disorders, including: autoimmune disease, allergy, asthma, cardiovascular diseases, diabetes, obesity, pituitary gland and hypothalamic control, thyroid disease, neurologic diseases, gastrointestinal (GI) disorders, sleep disorders, nutrition conditions, and genitourinary disorders. Of particular note is the rate of epilepsy (11.94% in autism vs. 0.73% in the control sample) which has been highlighted in a number of other studies (Spence & Schneider, 2009; Sundelin et al., 2016; Tuchman & Rapin, 2002) and of nutrition conditions and deficiencies (37.23% vs. 18.72%) that have also been highlighted elsewhere (Barnhill et al., 2015; Liu et al., 2016; Mari-Bauset et al., 2015). In addition, Croen et al. (2015) also found higher rates of hearing impairment, low vision, and blindness. Among young adults with autism (age 18-29), Fortuna et al. (2016) found higher rates of seizure disorder, depression, hypertension, and allergies. Seizure disorders, depression, and allergies were also higher across older age groups. By contrast, all age groups with autism demonstrated lower rates of tobacco use, alcohol misuse, and sexually transmitted illness. Furthermore, more adults with autism also utilize more primary care and laboratory services, have more hospitalizations for ambulatory care sensitive diagnoses, and have a higher mean annual health cost than the general population (Zerbo et al., 2019). While these rates of physical health challenges reflect the health status of
adults with autism, (Gurney et al., 2006) found that children with autism had increased prevalence of respiratory, skin, and food allergies as well as asthma, diabetes, ear infections, and bone, joint, and muscle problems. In addition, they were more likely to be using prescribed medication (54.7% vs 21.1%) with many of them (51.4% vs. 14.5%) expecting to take this medication for twelve months or longer. These physical health conditions have the potential to influence those with autism in multiple areas of daily life. Indeed, Fortuna et al. (2016) found that only 50% of the sample aged 18-29 years were independent with all activities of daily living.

Psychiatric conditions in the general population are relatively common (approximately 20%; MentalHealth.gov, 2017) and have been identified as a priority target by many health organizations (Department of Health, 2014). In autism, however, the prevalence is even greater. For example, a recent review by Hossain et al. (2020) suggested that over 90% of individuals with autism have a diagnosable associated psychiatric disorder. These include anxiety, attention deficit disorders, bipolar disorder, dementia, depression, obsessive-compulsive disorder, and schizophrenia (Buck et al., 2014; Croen et al., 2015; Levy et al., 2010; Schendel et al., 2016). Furthermore, adults with autism are suggested to be up to nine times more likely to attempt suicide than the general population (Cassidy et al., 2014; Croen et al., 2015) and 8 times more likely to die from suicide (Hirvikoski et al., 2016). This outcome might be expected given the high rate of depression in autism. However, Croen et al. (2015) found that half of these individuals attempting suicide did not have a diagnosis of depression. Of all emergency department visits for suicide analyzed in one study, 7.3% were made by individuals with autism (Kato et al., 2013).

In order to alleviate some of the functional impairment of these mental health challenges, antipsychotics are often prescribed (Buck et al., 2014; Langworthy-Lam et al., 2002), even in
children (Mandell et al., 2008; Spencer et al., 2013). In part, this is due to the scant evidence for the effectiveness of psychological interventions in individuals with autism (Foley & Trollor, 2015). Unfortunately, these medications also bring with them numerous potential side-effects which further elevate the chances of acquiring other physical health challenges (e.g., obesity, diabetes, cardiovascular disease; Croen et al., 2015). While there is a clear physical and mental health challenge faced by individuals with autism and their families, little is known about the mechanisms by which this occurs. Research in the general population has pointed towards a number of factors that influence physical and mental health. This study will address the potential impact on individuals with autism for several of these factors.

**Potential Primary Factors**

*The Influence of Sleep*

In its constitution, the World Health Organization (WHO) states that “Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.” (WHO, 2018). There are many significant challenges that may contribute to this lack of health, both in autism and in the general population. One such factor is sleep. Over a third of adults in the US get fewer than the recommended seven hours of sleep per night, making them more vulnerable to numerous risk factors for health as well as certain chronic health conditions (Centers for Disease Control and Prevention, 2017). This figure doubles when we consider the sleep duration of adolescents (Wheaton et al., 2016). Of notable concern is the worrying trend of continued reduction in sleep duration and an increase in health challenges (Matricciani et al., 2017). A reduction in sleep duration alone has been associated with increased mortality (Cai et al., 2015; Hall et al., 2015), hypertension (Bathgate et al., 2016; Lu et al., 2015), cardiovascular disease (Aziz et al., 2017; Bertisch et al., 2018), diabetes (Leng et al., 2016), and metabolic
syndrome (Fernandez-Mendoza et al., 2017; Mesas et al., 2014). As well as sleep duration, important aspects of sleep to consider are an individual’s sleep efficiency (how easily they get to sleep), their sleep timing (when they go to sleep), their alertness/sleepiness (how well they maintain attentive wakefulness), and their sleep satisfaction/quality (subjective assessment of how well they sleep; Buysse, 2014). Many of these are also associated with increased risk for major physical and mental health challenges (see Buysse, 2014 for a review). In addition, sleep duration (Van Dongen et al., 2003) and alertness/sleepiness (Dinges et al., 1997) have been associated with impaired cognitive performance and sleep timing has been associated with increased adverse events (Barger et al., 2006). Indeed, the US Navy, after linking the collisions of two destroyers to sleep deprivation, has recently increased its research in this area (Osborn, 2018). There have been calls for increased public health programs (St-Onge et al., 2016) and recommendations for a minimum of seven hours for an adult to promote good health (Watson, 2015). However, reduced sleep duration and quality remain significant health risk factors in the general population.

Insomnia refers to chronic dissatisfaction with sleep quality or quantity associated with difficulty either initiating sleep, maintaining sleep, or with early morning awakening (APA, 2013). Rates of insomnia in the general population range from 10% to about 40% depending on how it is defined (Bos & Macedo, 2019; Fernandez-Mendoza & Vgontzas, 2013; Mai & Buysse, 2008; Williams et al., 2020). As well as the immense direct effect on individuals and families, insomnia costs the US economy around $100 billion per year due to factors like lost workplace productivity and increased accidents (Wickwire et al., 2016). Individuals with insomnia also demonstrate increased healthcare utilization, whether at inpatient, outpatient, or emergency department, levels of care and in prescription use (Wickwire et al., 2019).
Like those in the general population with sleep disturbances, individuals with insomnia suffer from elevated rates of physical and mental health challenges but to a greater extent (Williams et al., 2020). For example, individuals with insomnia are at greater risk for psychiatric dysfunction, with anxiety and depression being frequently reported as elevated compared to controls and those with lack of sleep (Freeman et al., 2017; Neckelmann et al., 2007; D. J. Taylor et al., 2005; Tutek et al., 2019). In the Tutek et al. (2019) study, the presence of psychological dysfunction (e.g., anxiety and depression) was a better discriminator of poor sleep than daytime dysfunction (e.g., fatigue, sleepiness, occupational challenges). Insomnia has been linked with increased risk for paranoia, hallucinations, and mania (Freeman et al., 2017), with alcohol use disorder (Miller et al., 2017), and with substance abuse (Roane & Taylor, 2008). Furthermore, individuals with insomnia report increased suicidality (Chu et al., 2017) with a more than threefold increase in suicide risk compared to individuals without insomnia (Lin et al., 2018). This increased risk is present in a number of populations, including the elderly (Nadorff et al., 2013), military service members, and college athletes (Khader et al., 2020), with women, those aged 25-44, and people with other psychiatric disorders being at increased risk (Lin et al., 2018).

As with mental health challenges, those with insomnia are at increased risk for physical health challenges. These challenges include hypertension and mortality (Khan & Aouad, 2017), cardiovascular disease (Hsieh & Martin, 2019), inflammatory disease (Irwin & Opp, 2017), chronic pain conditions (Sivertsen et al., 2009), and type 2 diabetes mellitus (LeBlanc et al., 2018). Not only can insomnia increase the risk for physical conditions, these conditions can carry their own risk for other health concerns. For example, in the case of inflammatory disease, (Irwin and Opp (2017) found that while insomnia increased the risk for inflammatory diseases, both
insomnia and the presence of inflammatory disease independently contributed to an increased risk for depression; this double impact compounds the effects that insomnia can have.

For individuals with autism, sleep difficulties appear to be pervasive and disruptive. Indeed, the proportion of children with autism suffering from reduced sleep duration and poor sleep hygiene is more than twice the level found in the general population (64.7% vs. 25.1%; Van der Heijden et al., 2018). This number has been suggested to be as high as 80% for young children (Reynolds et al., 2019) and for adolescents and young adults with autism (Øyane & Bjorvatn, 2005). In the Øyane and Bjorvatn (2005) study, sleep questionnaires did not capture as much sleep disruption as was measured using actigraphy. Therefore, sleep challenges may be underestimated by parents/individuals affected by autism, or they may just adapt their expectations to this disrupted level of sleep routine. These problems have the potential to affect whole families. For example, Mazurek & Sohl (2016) found that, in children with autism, sleep disturbances (especially night-time awakening) were associated with increased levels of dysregulation and behavioral problems (see also Malow & McGrew, 2008). For children with autism who have sleep disorders, about 46% (aged 4-10 years) take medication for it (Malow et al., 2016); in this study, those children taking medication to aid sleep also demonstrated worse daytime behavior and reduced quality of life. Sleep has also been associated with reduced quality of life in autistic adolescents and adults (Lawson et al., 2020). Furthermore, in a study by Mazurek and Petroski (2015) individuals with autism who suffered from anxiety or sensory over-responsivity also experienced greater problems with their sleep. These problems included bedtime resistance, delay of sleep onset, reduced sleep duration, night awakening, and worries about sleep. It has also been suggested that infants aged 6-12 months who go on to receive an
autism diagnosis are more likely to experience sleep onset problems at this age (MacDuffie et al., 2020b).

Adults with autism are more likely to suffer from a circadian rhythm sleep-wake disorder and this association increases with level of unemployment (Baker & Richdale, 2017). They also have less efficient sleep, longer sleep onset, and report feeling less refreshed upon waking, compared to controls (Baker & Richdale, 2015). In addition, autistic individuals appear to be at greater risk for sleep difficulties in early adulthood and middle age, particularly in the form of reduced sleep quality and longer sleep onset latency (Jovevska et al., 2020). Goldman et al. (2017) also found that adults with autism have a reduced sleep latency. However, they found no significant difference in the time that individuals with autism went to bed, compared to controls.

Sleep quality is generally seen as representing an amalgamation of a number of factors relevant to sleep (e.g., sleep onset latency, number of awakenings, wake after sleep onset; Ohayon et al., 2017) and it is seen as an important factor for helping the public understand the impact their sleep has on physical and mental health. In autistic children and adolescents, sleep quality has been associated with mental health and behavioral difficulties (Cohen et al., 2018; Richdale & Schreck, 2009), poor daytime functioning (Lambert et al., 2016), reduced physical activity (Wachob & Lorenzi, 2015), and discordant peer relationships (Phung & Goldberg, 2017). In adults with high functioning autism, sleep quality had been associated with a diagnosis of anxiety and depression (Baker & Richdale, 2015) and unemployment (Baker et al., 2019a).

Further understanding of sleep quality in autistic adults is lacking, along with our understanding of its influence on their perception of their physical and mental health. Autistic individuals and those with insomnia face challenges with sleep quality and with physical and mental health. Understanding the pattern of impairment between those with autism and those with insomnia
could be key to understanding the role of sleep quality, and the contribution of other factors, to the reduced health status of these individuals.

The Influence of Social Support

A growing body of research has suggested links between social relationships and physical and mental health outcomes, like cardiovascular disease and mortality (see Holt-Lunstad et al., 2010; Ross et al., 2019; Uchino, 2009). These links can have similar effects to other factors that influence health and mortality (e.g., smoking) and even exceed others (e.g., physical inactivity or obesity). Furthermore, it has been suggested that health behaviors and outcomes can spread through social networks for up to “three degrees of influence” (Christakis & Fowler, 2013). The notion that one believes they have access to social support if they need it – known as perceived support – can yield positive effects on health as well as actually having been given support – known as received support (Uchino, 2009). Research suggests that a lack of social support can exacerbate symptoms or reduce the benefits of other treatment. For example, reduced social support has been linked with poor dietary adherence in diabetes (Weaver et al., 2014), reduced cognitive flexibility and therapy outcomes in those with psychosis (Jolley et al., 2014), as well as poorer outcomes in depression (Cruwys et al., 2014; Schwarzbach et al., 2014) and anxiety (Stanton & Campbell, 2014). Other factors relevant to the influence of these social relationships include the number of social ties, the presence of conflict (Brissette et al., 2000), and whether support is given before or after it is requested (Uchino, 2009).

Social isolation (lack of actual social contact) and loneliness (subjective experience of social isolation) have themselves been associated with significantly increased risk for mortality in the general population (29% increase for isolation; 26% increase for loneliness; Holt-Lunstad et al., 2015). It has been suggested that these factors influence mortality via behavioral processes
(e.g., health behaviors or treatment adherence) and psychological appraisals (e.g., low mood or lack of control; Reblin & Uchino, 2008; Uchino, 2006). Specific mechanisms which have been implicated include increased inflammatory response (Steptoe et al., 2004), increased cardiovascular disease and stroke (Valtorta et al., 2016), smoking (Shankar et al., 2011), less exercise (Hawkley et al., 2009; Theeke, 2010), and poorer sleep (Schalkwijk et al., 2015; Stafford et al., 2017).

Social support also has profound impacts on individuals with insomnia. For example, Troxel et al. (2010) found that when older adults with insomnia had more social support, they had reduced sleep onset latency; higher social support was also associated with both controls and those with insomnia waking for less time during the night. Reduced social support has been shown to increase the risk for insomnia in various populations, including Japanese daytime workers (Nakata et al., 2004), nurses (Portela et al., 2015), and victims of sexual abuse (Steine et al., 2012). Notably, the relationship between social support and insomnia may be bi-directional; for example, while reduced social support may increase the risk for insomnia, insomnia has been associated with reduced interpersonal and psychological functioning in adolescents (Roberts et al., 2002).

**Loneliness and Insomnia.** It has been suggested that sleep may be one of the mechanisms by which loneliness impacts mental and physical health. For example, a meta-analysis by Griffin et al. (2020) found that loneliness correlates with self-reported sleep disturbance; similarly, another meta-analysis, by (Hom et al., 2017b) found an association between severe insomnia symptoms and greater feelings of loneliness, part of which was accounted for by depression symptoms. However, the causal direction of these influences, and the potential role of depression, are not well defined. It has also been suggested that loneliness in
insomnia – arising from being awake when most people are not – gives rise to the increased suicidal ideation, via the concept of thwarted belongingness, often seen in individuals with insomnia (Chu et al., 2016, 2017; Hom et al., 2017a). For some individuals with insomnia, it has been shown that they report being awake at times when they were, in fact, asleep, referred to as paradoxical insomnia (see Rezaie et al., 2018 for a review). It is not yet known whether these individuals with paradoxical insomnia report loneliness to the extent that individuals with more accurate self-reports.

**Loneliness and Autism.** While social support can help and loneliness can harm mental and physical health, both in the general population and in those with insomnia, this relationship may be less straightforward in autism. For example, autistic individuals have reported experiencing “intense loneliness” (Hickey et al., 2018); however, this loneliness has been referred to as “paradoxical” as autistic individuals often desire social connection but it does not come easily, causing them to sometimes seek isolation (Haertl et al., 2013). This social isolation has been reported to increase with age (Müller et al., 2008). Furthermore, individuals with autism who reported elevated anxiety also reported increased social loneliness (White & Roberson-Nay, 2009), which has been associated with an increased risk of suicide in individuals with autism (Jackson et al., 2018). Those with autism have been shown to report higher frequencies of bullying and lower levels of social support (Symes & Humphrey, 2010); their opportunity for social interaction is also reduced due to quick “thin slice” judgements that neurotypical peers make about them (Sasson et al., 2017). While autistic individuals often experience a reduced ability and opportunity for social connection, as well as challenging loneliness, it is unclear whether social support can confer a protective health effect for them and whether increased loneliness will have a negative effect on health.
Potential Secondary Factors

While sleep and social support have a large impact on physical and mental health, particularly affecting sleep quality and loneliness, there are other factors which have either been shown to influence health or influence sleep and social support themselves, or which may help to better characterize what may contribute towards physical and mental health challenges or improvements. These factors may be useful in helping further out understanding of sleep and loneliness and how physical and mental health may be influenced. Four such factors will be discussed here: daytime activity, helping behavior, alexithymia, and degree of autism traits.

Daytime Activity

Adequate daytime activity has a major protective benefit against numerous diseases and is the subject of a global action plan by the WHO (WHO, 2018). It has been associated with reduced mortality (Loprinzi, 2017), especially in older adults (Taylor, 2014). There is also an association between reduced physical activity and sleep loss (Schmid et al., 2009) and inactivity and lack of social satisfaction have been seen to predict insomnia (Morgan, 2003; Ohayon et al., 2001). However, both extremes of activity and inactivity have been associated with increased insomnia symptoms (Hartescu & Morgan, 2019), suggesting a delicate balance in the processes that influence these sleep-related factors. However, increased activity may also be a protective factor against insomnia in later life (Morgan, 2003), suggesting that there may be multiple factors at play. In addition, there is believed to be an association between physical activity and social support but the research is inconsistent as to which direction this relationship is in (Scarapicchia et al., 2017).

While there is an association between activity levels and mortality, which is as strong as the association between cardiovascular disease and mortality, this association is even stronger for
those with severe diseases (Liu et al., 2018). Individuals with autism have been seen to be at greater risk for inactivity (Taylor & Hodapp, 2012; Wagner et al., 2005) and have more sedentary behaviors (Jones et al., 2017). This is partly due to the frequently low rates of employment, and lower community involvement (Gray et al., 2014). In addition, children with autism may experience an increase in sleep quality (Wachob & Lorenzi, 2015) and sleep duration (Tatsumi et al., 2015) when they have had more daytime activity. Therefore, while daily activity may be associated with reduced physical and mental health, it appears that some of this association may act via sleep and social factors. However, this remains to be explored in adults with autism.

Helping Behavior

While a lack of social support and caring for others has been associated with increased risk for negative impact on health, offering other types of support – like volunteering, random acts of kindness, or donating to those in need – have been associated with protective benefits. These benefits of these prosocial behaviors extend to reduced mortality rate and increased longevity (see Wilson et al., 2016 for a review). For example, productive behaviors aimed at helping others have been shown to offer protective effects against depressive symptoms (Choi et al., 2013), even when those symptoms represent a natural increase due to advancing age (Poulin & Holman, 2013). Helping others also offered protection against depressive symptoms for individuals who had recently lost a spouse (S. L. Brown et al., 2008; Li, 2007). These protective effects, reported here as life satisfaction and mood, can be seen from as little as a single hour and a half session of “paying it forward” and can be present days afterwards (Pressman et al., 2015). Children aged 9 to 11 years also benefited from increased psychological well-being, in a study by Layous et al. (2012), after performing three acts of kindness. In addition, Martela & Ryan
(2016) reported that psychological benefits were seen when individuals donated rice that they won via computer-based tasks, even when the recipients of their actions were not present and were anonymous.

Acts performed for the benefit of others are also associated with physical health benefits. For example, volunteering has been seen to reduce hypertension (Burr et al., 2011; Piferi & Lawler, 2006) and reduce risk of cardiovascular disease (Heisler et al., 2013). It has also been shown to increase prospective health (consisting of functional health, cognitive functioning, depression, and level of comorbidity) and longevity (Hilbrand et al., 2017). In a sample of neurotypical individuals over 45 years of age, social activity was associated with a reduced length of hospital stays (Newall et al., 2015). Finally, spending money/earned income on others has been shown to increase the happiness of the individual over time (Dunn et al., 2011). With the potential of helping behavior to influence health for the better, it is possible that it may offset some of the impact of sleep or loneliness. Research has suggested that higher prosocial behavior in five-year-olds predicts lower sleep disturbance at the age of fourteen (Sadeghi Bahmani et al., 2016). Helping behaviors generally increase across the lifespan (Hammond & Brownell, 2015). However, research into helping behaviors in autism focus almost exclusively on early childhood and have yielded largely mixed results (Dunfield, 2014). Helping behaviors in adults are relatively unexplored as is the potential association with perceived physical and mental health. Given the desires of some individuals with autism to seek out social connection as adults as they increase in their awareness of themselves and others (Haertl et al., 2013) it is important to understand whether this also extends to helping others. In addition, understanding whether these behaviors have a protective effect similar to the general population would provide a valuable area of focus to further understand the experience of individuals with autism.
Alexithymia

Individuals with alexithymia have a difficulty understanding and describing the internal emotional states of themselves and others (Sifneos, 1973; Watters et al., 2016). In the general population, this has been associated with drug use, alcohol use, angry/aggressive behavior, and risk-taking behavior (Kealy et al., 2018). Having alexithymia is also believed to influence perceived stress, general mental health, and social functioning (Beshlideh et al., 2015). Furthermore, alexithymia often causes increased stress which leads to worse sleep experiences (Alfasi & Soffer-Dudek, 2018). Alexithymia also mediates the relationship between sleep quality and paranoia (Rehman et al., 2018) and produces poor sleep quality outside of depression and anxiety (Murphy et al., 2018). Individuals with insomnia tend to score higher on the Toronto Alexithymia Scale—20, primarily due to comorbid anxiety; however, they also show elevations on the Externally Oriented Thinking subscale which does not correlate with anxiety (Lundh & Broman, 2006). This suggests that those with insomnia may have a tendency to ignore or miss sleep cues within themselves; although, it is unclear what the causal direction of such a link may be. This thinking style had also been suggested to deploy attention away from negative information – possibly conferring some protection in terms of mood but potentially being harmful for social relationships and coping (Wiebe et al., 2017).

Alexithymia is believed to alter physiological arousal both in the general population and in individuals with autism (Gaigg et al., 2018). It is also associated with reduced enjoyment of social interactions in individuals with autism, as well as an increase in negative social potency (e.g. being cruel, callous, or using others for personal gain) and passivity (Foulkes et al., 2015). Alexithymia also increases anxiety, sensory processing difficulties, and poor emotion regulation in individuals with autism (Milosavljevic et al., 2016). While alexithymia appears to influence
mental and physical health, it, too, impacts social perceptions and sleep. Therefore, understanding the contribution towards sleep and loneliness could help characterize its influence on health.

**Degree of Autism Traits**

By definition, autism is a spectrum condition (APA, 2013). As such, autism traits are detectable in the general population but are usually present to a greater degree in those with autism (Ruzich et al., 2015). While research is divided as to whether autism traits represent a single factor or multiple factors (Ronald & Hoekstra, 2011) an increase in autism traits has been linked with difficulties with things like attachments style, emotional acceptance, alexithymia, and intolerance of uncertainty (Gallitto & Leth-Steensen, 2015; Maisel et al., 2016). While individuals with autism have a greater proportion of physical and mental health difficulties, compared to the general population, it is unknown what is responsible for this disparity. By understanding factors like sleep, and loneliness and their influence on perceived mental and physical health, and how the degree of autism traits influences this association, it may be possible to gain insight into not only how these factors may impact those with autism but how autism traits may influence those without autism.

**Present Study**

The purpose of this study is to examine several of the factors discussed above, that may be associated with reported physical and mental health of adults with autism. While much research has indicated that these individuals do indeed suffer from reduced physical and mental health, little research has sought to identify specific factors or mechanisms by which this association may occur. A component of social support of particular relevance in autism is loneliness. Sleep difficulties and loneliness have both been seen to be substantially associated
with physical and mental health in clinical and non-clinical samples in the general population. They have also both been seen to be relatively deficient in individuals with autism but few attempts have been made to identify their relationship to physical and mental health in autism. Specifically, it is unclear whether sleep quality affects autistic adults’ perception of physical and mental health and how this compares to that of neurotypical adults or those with insomnia. In addition, while autistic adults do experience loneliness, it is unclear whether this loneliness impacts their perception of their physical and mental health. This is particularly of interest with autistic individuals given the difficulty they sometimes have understanding and engaging in social situations, despite often wanting to do so. It is also not known how these factors relate to each other and whether that differs between autistic and non-autistic individuals. In light of this, and given the lack of understanding regarding insomnia in autistic adults and how it differs from insomnia in non-autistic individuals, we included a non-autistic insomnia comparison group, as well as non-autistic control group. This was to enable us to look at a range of sleep difficulty and its association with a number of factors and characterize any difference in their impact on physical and mental health. Furthermore, it is not known whether the factors associated with differences in health act similarly for both physical and mental health or whether separate mechanisms operate individually. In addition to the primary factors of sleep and loneliness, this study explored the association of certain secondary factors: daily activity, helping behavior, alexithymia, and degree of autism traits (see Figure 1). This model proposes the mechanism of influence for the discussed factors of perceived physical and mental health. While this model cannot explicitly be tested in the present study, because of its cross-sectional design, this study seeks to establish potential associations between these factors which may allow further future
investigation of the model. The basic relationships to be tested in this study can be seen in Figure 2.

Many autistic individuals seek out social connection; however, as they often find social connection to be challenging, and they are sometimes subject to biased judgements by others, they often either self-isolate or have fewer opportunities for social connection. This unmet desire would suggest that loneliness could be an issue for autistic individuals and, consequently, it may still influence their perceived physical and mental health. Therefore, this study sought to further support the presence of this unmet need seen in previous studies and understand the relationship this has with the perceived physical and mental health of individuals with autism. We set out to determine whether self-reported health (both physical and mental health) are associated with self-reported sleep quality and loneliness and the similarity of these effects in individuals reporting impairment in sleep. These factors are pertinent to autistic adults and need to be better elucidated given their potential impact on mortality; these factors also potentially impact salient factors for this population, including healthcare cost and utilization, employment, clinical treatment and assessment, and quality of life.

There are real advantages to analyzing mental health data in dimensional terms (Brown & Barlow, 2005) and the distribution of autism traits across the spectrum lends itself well to this approach. In order to take advantage of the dimensional nature of autism traits
Figure 1 Conceptual representation of the relationship between factors
(Kamp-Becker et al., 2010; Ruzich et al., 2015) the data from all groups will be combined for the primary analyses. This will enable a broader understanding of the association of sleep quality and loneliness.

**Figure 2** Illustration of the associations to be investigated in this study using multiple regressions for Primary Factors (left) and Primary Plus Secondary Factors (right)

**Aims & Hypotheses**

**Aim 1**

Characterize the sleep profile of those with autism (AUT group), those complaining of insomnia symptoms (INS group) and neurotypical controls (NT group).

- **Hypothesis 1a.** Using the self-report measures, the profile of the TD group and the INS group will differ significantly with respect to each measure. The sleep profile of the AUT group will also differ significantly from the TD group and will pattern more closely with the INS group.

- **Hypothesis 1b.** Using the actigraphy data, the sleep profile of the AUT group will pattern more closely to the INS group and differ significantly from the TD group.
Aim 2

Quantify the association of sleep disturbance and loneliness on perceived physical health status and separately with perceived mental health status. Characterize this association for both dimensional and categorical versions of the data and in a combined perceived physical and mental health dimensional model.

- **Hypothesis 2a.** Higher sleep disturbance and higher levels of loneliness will both be associated with lower perceived physical health status in the combined dimensional sample, as they are in the general population (significant coefficients will be identified by p-value of t-tests and model fit indicated by significant F-ratio). That is, poor sleep and reports of loneliness will be associated with worse perceived physical health status.

- **Hypothesis 2b.** Similar to Hypothesis 2a, higher sleep disturbance and higher levels of loneliness will both be associated with lower perceived mental health status in the combined dimensional sample, as they are in the general population (significant coefficients will be identified by p-value of t-tests and model fit indicated by significant F-ratio). That is, poor sleep and feelings of loneliness will be associated with worse perceived mental health status.

- **Hypothesis 2c.** In the categorical sample (i.e. individuals with autism and those without analyzed on their own) the previous relationships of sleep disturbance and loneliness will hold both for the model predicting perceived physical health status and the model predicting perceived mental health status (significant coefficients will be identified by p-value of t-tests and model fit indicated by significant F-ratio). However, the proportion of variance in perceived physical or mental health
explained will be greater for the AUT group and the INS group (indicated by a greater adjusted $R^2$).

**Aim 3**

Ascertain how the secondary factors (daily activity, helping behavior, alexithymia, and degree of autism traits) contribute towards the total variance explained in perceived physical health status and perceived mental health status. A transdiagnostic dimensional sample will be utilized.

- **Hypothesis 3a.** For perceived physical health status, lower daily activity and a higher level autism traits will both be associated with lower perceived physical health (significant coefficients will be identified by $p$-value of $t$-tests and model fit indicated by significant $F$-ratio). That is, those with more autism traits and those who are active less will have poorer perceived physical health. This will reduce the size of the sleep disturbance coefficients.

- **Hypothesis 3b.** For perceived mental health status, higher alexithymia and lower helping behavior will both be associated with lower perceived mental health (significant coefficients will be identified by $p$-value of $t$-tests and model fit indicated by significant $F$-ratio). That is, those who struggle to interpret their emotions and those who help others less will have poorer perceived mental health. This will be associated with a higher loneliness coefficient.

- **Hypothesis 3c.** For both perceived mental health and perceived physical health, the addition of alexithymia, autism traits, and helping behavior will not improve the prediction of perceived mental and physical health (identified by non-
significant change in adjusted $R^2$; this is due to the impact of these factors being applied via the primary factors (see Figure 1).

**Aim 4**

Further investigate the secondary factors on the autism group along with the impact of sleep impairment and insomnia severity when included individually with loneliness and together with sleep quality.

- **Hypothesis 4.** Higher sleep impairment and insomnia severity will also predict lower perceived physical and mental health when included separately with insomnia and when included together with loneliness and sleep quality (significant coefficients will be identified by $p$-value of $t$-tests and model fit indicated by significant $F$-ratio).

**Methods**

**Participants**

Three groups of participants took part in the study: a group of adults diagnosed with an autism spectrum disorder (AUT), a group of typically developing individuals (NT), and a group of adults with at least subthreshold insomnia symptoms (INS). The AUT group ($n = 22$) had a diagnosis of autism which was confirmed by the administration of the Autism Diagnostic Observation Schedule—2nd Edition (Lord et al., 2012), given by a licensed psychologist trained to research reliability or graduate student with previous ADOS-2 experience under the supervision of the research reliable psychologist. The INS group ($n = 23$) comprised adults reporting a pattern of dysfunctional sleep and who scored ten and above (the optimal threshold for identifying insomnia in community samples; Morin et al., 2011) on the Insomnia Severity Index (ISI; Bastien et al., 2001). The NT group ($n = 21$) consisted of typically developing adults
with no history of severe head trauma or neurological condition. They also scored seven or below (indicating no clinically significant insomnia symptoms) on the ISI.

The AUT group was primarily recruited via community adverts and through a local private practice offering psychological services with a particular emphasis on autism. The NT and INS groups were recruited through a research participation program run by Brigham Young University and were primarily university students. They were previously recruited as part of a study looking at insomnia in adults and were sent an e-mail invitation to take part in the current study. Please see Table 1 for descriptive data relating to each of the groups.

Table 1

*Characteristics of Study Participants*

<table>
<thead>
<tr>
<th></th>
<th>AUT (n = 22)</th>
<th>INS (n = 23)</th>
<th>NT (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.26 (3.97)</td>
<td>24.95 (4.64)</td>
<td>23.55 (4.88)</td>
</tr>
<tr>
<td>Gender</td>
<td>6 Female (27.3%)</td>
<td>11 Female (47.8%)</td>
<td>13 Female (61.9%)</td>
</tr>
<tr>
<td>ISI Score</td>
<td>7.42 (5.69)</td>
<td>14.41 (3.69)</td>
<td>2.85 (2.48)</td>
</tr>
</tbody>
</table>

Measures

*Diagnostic Confirmation Measure.*

*Autism Diagnostic Observation Schedule–Second Edition (ADOS-2; Lord et al., 2012):* The ADOS-2 is a semi-structured, standardized measure assessing various aspects of autism. Used in both clinical and research settings, it is part of the "gold standard" of assessment for autism (Kanne et al., 2008). It consists of five modules for individuals of differing ages and expressive language ability. For this study, Module 4 (suitable for verbally fluent older
adolescents and adults) was used with all participants. Administration is involved and dynamic and it is recommended that assessors have extensive experience with autism.

In terms of internal consistency (Cronbach's α) for Module 4, the social communication domain exceeded 0.75, the social interaction domain was 0.85, and the restricted and repetitive behaviors was 0.47 (values for this domain are lower for all modules; McCrimmon & Rostad, 2014). Correlations between items and domains ranged from 0.50 and 0.88. In one study, ADOS Module 4 was able to classify 74.2% of the cases correctly as having autism or not (Bastiaanssen et al., 2011).

**Primary Measures**

**Perceived Physical Health and Mental Health Status Measures.**

**Thirty-Six-Item Short Form Health Survey (SF-36; Ware et al., 1993):** The SF-36 is a thirty-six-item questionnaire looking at various aspects of an individual’s health. Each question varies in its number of responses, with some responses being “Yes/No” and other being answered on a number of different Likert scales.

The SF-36 has an internal consistency (Cronbach’s α) reported as ranging from 0.68 to 0.94 (Gandek et al., 1998; McHorney et al., 1994; Ware et al., 1993). It also has demonstrated construct validity (Ware & Gandek, 1998) and test-retest reliability (Ware et al., 1993).

As well as yielding eight factors (physical functioning, role limitation due to physical health, role limitation due to emotional problems, energy/fatigue, emotional well-being, social functioning, pain, and general health), the SF-36 can be used to calculate a physical component summary (PCS) and a mental component summary (MCS; Ware et al., 1994). There are a number of ways, however, that these scores can be calculated. Each method involves creating a z-score dependent upon a combination of the eight factors and then applying weighted
coefficients, normed for specific populations, and then applying them to the z-scores. The two components can be calculated by not allowing them to be correlated (orthogonal) or by allowing them to do so (oblique). It has been suggested that the oblique method is more relevant to populations who likely have physical or mental health challenges (Hann & Reeves, 2008).

**World Health Organization Quality of Life Abbreviated Questionnaire (WHOQOL-BREF; The WHOQOL Group, 1998):** The WHOQOL-BREF is a 26-item self-report measure designed to assess aspects of quality of life relevant to the WHO’s own definition of quality of life; these domains are physical health, psychological health, social relationships, and environment (The WHOQOL Group, 1998). It is based upon the larger, 100-question version – the WHOQOL-100 – with each domain score correlating highly (≥ 0.89) between versions.

The internal consistency (Cronbach’s α) of each domain of the WHOQOL-BREF was reported by (Skevington et al., 2004) as 0.82 (physical health), 0.81 (psychological health), 0.68 (social relationships), and 0.80 (environment). It also has demonstrated discriminant validity, construct validity, and test-retest reliability (Skevington et al., 2004; The WHOQOL Group, 1998).

**Depression, Anxiety, and Stress Scale–Twenty-One Item Version (DASS-21; Lovibond & Lovibond, 1995):** The DASS-21 is a short, self-report measure of distress. An individual is asked to respond to the questions in relation to the previous week. Answers are given using a 4-point likert scale, ranging from "0 – Did not apply to me at all" to "3 – Applied to me very much, or most of the time". Separate scores are obtained for each axis (Depression, Anxiety, and Stress) and cut-off scores indicate level of severity along a continuum (scores on the DASS-21 are multiplied by two in order to use the same cut-off scores as the forty-two-item version). Research also supports the use of a DASS-21 total score, akin to general distress.
To give a broad understanding of psychological distress, this total score will be utilized in the present study.

Each axis of the DASS-21 has its own internal consistency. For the anxiety axis, Cronbach’s $\alpha$ has been suggested to be 0.81 (McDonald’s coefficient-w was 0.82) with an average inter-item correlation of 0.40 (Osman et al., 2012). In addition, it has a convergent validity of 0.69 with the Beck Anxiety Inventory. The DASS-21 total score also has high internal consistency ($\alpha > .90$; Osman et al., 2012).

**Sleep Measures.**

**Insomnia Severity Index (ISI; Bastien et al., 2001):** The ISI is a seven-item self-report measure which looks at the nature of sleep-related problems, including severity, impairment in functioning, and resulting distress. Participants are asked to rate each question on a five-point Likert scale. An example of the scales used includes responses from “0 – Not at all noticeable” to “4 – Very much noticeable.”

The ISI has an internal consistency in both community (Cronbach’s $\alpha = 0.90$) and clinical (Cronbach’s $\alpha = 0.91$) samples. The ISI also displays convergent validity with subjective sleep reports (from sleep diaries), sleep efficiency (measured by polysomnography), and the Pittsburgh Sleep Quality Index ($r = 0.80$; Morin et al., 2011).

**Patient Reported Outcomes Measurement Information System—Sleep Disturbance, Short Form 8a (PROMIS-SD-8a; Yu et al., 2012):** The PROMIS Sleep Disturbance Short Form is an eight-item self-report measure that assesses perceptions of sleep quality, sleep depth, and level of sleep restoration. Participants are asked to provide responses relative to the previous seven days and assign their responses on a five-point Likert scale ranging from “very poor” or “not at all” to “very good” or “very much”
The PROMIS-SD-8a was constructed using item response theory (IRT) and, as such, has varying reliability. However, it has been shown to have high reliability, generally functioning with a reliability above .90. It has convergent validity ($r = 0.83$) with the Pittsburgh Sleep Quality Index and discriminant validity ($r = 0.30$) with the Epworth Sleepiness Scale (Yu et al., 2012). In this study, this measure will be referred to as “sleep quality.”

**Patient Reported Outcomes Measurement Information System—Sleep-Related Impairment, Short Form 8a (PROMIS-SRI-8a; Yu et al., 2012):** The PROMIS Sleep-Related Impairment Short Form is an eight-item self-report measure that assesses perceptions of alertness, sharpness, and tiredness (during waking hours) as well as perceived functional impairment. Participants are asked to provide responses relative to the previous seven days and assign their responses on a five-point Likert scale ranging from “not at all” to “very much”.

The PROMIS-SRI-8a was also constructed using IRT. It has been shown to have high reliability, generally functioning with a reliability above .90. It has convergent validity ($r = 0.68$) with the Pittsburgh Sleep Quality Index and discriminant validity ($r = 0.46$) with the Epworth Sleepiness Scale (Yu et al., 2012). In this study, this measure will be referred to as “sleep impairment.”

**Night-time Actigraphy:** Behavioral measures of sleep were obtained using a Philips Actiwatch Spectrum Plus (Philips, 2020b) worn on the participant’s non-dominant wrist. Placement on the non-dominant wrist has been shown to provide more accurate results than hip placement (Ancoli-Israel et al., 2003; Slater et al., 2015; Zinkhan et al., 2014). Movements were recorded for up to fourteen days to ensure seven days of complete data. For sleep data, seven days provides an optimal compromise between length and accuracy (Acebo et al., 1999; Rowe et al., 2008).
Actigraphs recorded movements both day and night. For night-time, sleep onset latency (SOL; time taken to get to sleep from when they first go to bed), total sleep time (TST; time from first falling asleep to the time the arise for the following day), wake after sleep onset (WASO; the length of time they were awake during the night, after falling asleep), and sleep efficiency (SE; the percentage of time asleep related to time spent in bed) were be calculated, (see Kay et al., 2015).

**Sleep Diary.** A modified version of the Pittsburgh Sleep Diary (Monk et al., 1994) was completed electronically by each participant at night before going to bed and when they arose each morning. The diary was modified to include questions regarding actigraphy (e.g., whether they went to bed right after turning out their lights.) The evening measure also included the question “How lonely did you feel today?” with a Likert scale from “1 – Not at all lonely” to “5 – Extremely lonely.” Each participant was sent a link, via an automated e-mail, to the relevant section of the sleep diary prior to their estimated bedtime and awakening time. The sleep diaries were also used to confirm the measurement of SOL, TST, WASO, and SE. Participants were instructed to complete the sleep diaries (sleep time and wake time) as soon as they woke each morning. As an extra verification procedure, participants were asked to press a button on the actiwatch to indicate their intent to go to sleep. This left a marker on the actigraphy data that was used in conjunction with the sleep diary and the actigraphy data to confirm the SOL. To calculate TST, the SOL was subtracted from the time between first attempting to go to sleep and arising in the morning. SE was calculated by dividing TST by the time spent in bed and multiplying it by one hundred.
Loneliness Measure.

UCLA Loneliness Scale—Version 3 (Russell et al., 1980; Russell, 1996): The UCLA Loneliness Scale is a brief, 20-item, self-report measure of loneliness. The third version has slightly revised questions to increase the ease of responding. Each question begins with “How often do you feel…” and is answered using a 4-point Likert scale, ranging from “1 – Never” to “4 – Always.” Nine of the items are reverse scored.

The scale has been shown to have an internal consistency ranging from 0.89 to 0.94 (Cronbach’s α) and a 1-year test-retest reliability (r = 0.73; Russell, 1996). It also has support for convergent validity with the NYU Loneliness Scale (r = 0.65) and the Differential Loneliness Scale (r = 0.72).

Secondary Measures

Alexithymia Measure.

Toronto Alexithymia Scale—20 (TAS-20; Bagby et al., 1994a). The TAS-20 is a twenty-item self-report questionnaire looking at areas of alexithymia-related difficulty across three domains (difficulty identifying feelings, difficulty describing feelings, externally-oriented thinking). It uses a five-point Likert scale ranging from “strongly disagree” to “strongly agree.”

The total score of the TAS-20 has a reported internal consistency (Cronbach’s α) of .81 with the domains ranging from .66 to .78. It also has a three-week test-retest reliability of .77 (p < .01). Using the NEO Personality Inventory (NEO-PI; Costa & McCrae, 1985), (Bagby, Taylor, et al., 1994b) showed correlations with dimensions and facets helped to support convergent validity—for example, a strong negative correlation (r = -0.55, p < .01) with “openness to feelings”—and discriminant validity—non-significant correlation with “agreeableness” (r = -.09, p > .05) and “conscientiousness” (r = -.21, p > .05).
Autism Trait Measure.

Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). The AQ is a 50-item self-report questionnaire which measures the extent of an individual’s autism-like traits across five domains (social skills, attention switching, attention to detail, communication, and imagination). It uses a four-point Likert scale ranging from “definitely agree” to “definitely disagree.” It is designed to give a dimensional and not diagnostic impression.

Internal consistency (Cronbach’s α) for each domain has been reported as moderate-to-high (social skills = .77, attention switching = .67, attention to detail = .63, communication = .65, and imagination = .65). It also has two-week test-retest reliability of .70 (p = .002). Convergent validity (r = .64, p < .01) with the Social Responsiveness Scale (Constantino et al., 2000) has been supported (Armstrong & Iarocci, 2013).

Helping Behavior Measure.

Prosocial Tendencies Measure (PTM; Carlo & Randall, 2002): The PTM is a 23-item self-report measure that assesses six types of prosocial behaviors (public, anonymous, dire, emotional, compliant, and altruistic). An individual is asked to respond how much each statement describes them on a Likert scale from “1 – does not describe me at all” to “5 – describes me greatly.”

The PTM scales have internal consistencies (Cronbach’s α) ranging from 0.54 to 0.88 and two-week test-retest reliability ranging from 0.60 to 0.80. The measure also has adequate convergent and discriminant validity with relevant measures (Carlo & Randall, 2002).

Procedure

All of the procedures were approved by the Brigham Young University Institutional Review Board (IRB). Each questionnaire was completed by the individual using an online
service once they had completed and returned their signed consent form. Participant in the INS and NT groups were given a $10 voucher for completing the measures. Individuals in the AUT group received remuneration as part of a larger study. After completing the online measures, each participant was then seen in person and briefed on the use of the actigraph and the sleep diary. Before leaving the training session, participants and carers/companions were questioned on the wearing of the actigraph and completion of the sleep diary to ensure compliance with the standards set out and given a sheet containing a recap of these standards and contact details to use in case the actigraph malfunctioned. Participants were offered $2 per day that they wore the actigraph – for a maximum of ten days – with a $10 bonus for promptly completing all of the evening and morning sleep diaries. They were given the actigraph device and training on the same day and were instructed to use it (and complete the e-mailed sleep diary each morning and night) for up to fourteen consecutive days, beginning with the day they received the actigraph. Participants were instructed to wear the actigraph at all times, day and night, except for activities which might damage it (i.e., lifting weights, high-contact sports). The participants returned the actigraph after fourteen days.

**Coronavirus Alterations**

Given the emergence of the COVID-19 pandemic and resulting restrictions, it was necessary to make certain modifications to the study protocol. These alterations were approved by the IRB that originally approved the study. Firstly, for those participants recruited during this time, verbal consent was sufficient to indicate their participation in the study. Secondly, it became necessary to conduct six of the ADOS-2 assessments using video-conferencing to the best extent possible. Finally, collection of actigraphy data had to cease due to in-person contact not being allowed and to avoid potential risk to the participants. This occurred during the
collection of actigraphy data for the AUT group. Consequently, this group size is reduced compared to the other groups.

**Data Preparation and Analyses**

**Actigraphy Data**

Data was compiled using the Actiware 6 software (Philips, 2020a), using 30 second epochs. Given the age of the sample, the actigraph model to be used, and that there are no algorithms specifically validated for use with autistic samples, the Cole-Kripke algorithm was used to calculate rest periods (when the participant is attempting to sleep; Cole et al., 1992). This has been validated for use with wrist-mounted sleep actigraphy and has been shown to be the most accurate algorithm in adults (Quante et al., 2018). Rest periods were input manually using a hierarchy of information. Firstly, the participants pressed a button on the actigraph to indicate that they were attempting to sleep; these button presses appeared in the data. If the participant indicated in their sleep diary that they pressed the button before they went to sleep, the marks were used as the primary source for initiating a rest period. If there was no button press, or the participant indicated in the diary that they did not press the button, light was used as a secondary indicator. If participant reported that they did not push the button, they were asked if they attempted to sleep right after they turned out their lights. If they responded affirmatively to this question, the rest period was initiated at the point the yellow light dropped to zero. If they did not indicate this, the bedtime indicated in their sleep diary was utilized instead. If none of these parameters were available, a rest period was deemed ambiguous and that night was not included in any further analyses. Priority was always given to the self-reported button press, even if the light and movement data did not completely match the self-reported time. This is because it would not be unexpected that individuals would move after attempting to initiate sleep (e.g.,
using the bathroom, trying to distract themselves) and that light may continue to be detected (e.g., roommate returning). For times where a participant had the actigraph but no data was recorded (e.g., if the actigraph had been removed), and it was not possible to accurately identify the beginning or end of a rest period, no data for this night was included in the analyses.

Participants typically wore the watch for ten to fourteen days; however, only seven days of data were used for the analysis (Acebo et al., 1999; Rowe et al., 2008). For each participant, the first seven days of complete and reliable data were used; it was also ensured that these seven days included two weekend days to account for variation in weekday and weekend habits.

Given the difference on the sample sizes for the AUT group compared to the INS and NT groups for the actigraphy data, potential analyses were limited. Therefore, mean TST was chosen as a single priority variable to analyze using a one-way ANOVA – with TST as the dependent variable and group (i.e., AUT, INS, or NT) as the independent variable. TST was chosen as this information often focused on from a public health perspective (e.g., by the American Academy of Sleep Medicine and the Sleep Research Society; Watson et al., 2015) as being an important indicator of sleep-related habits. Data were analyzed for and satisfied ANOVA assumptions. No outliers were detected. The mean and standard deviation of each of the other actigraphy variables was calculated.

**Multiple Regression Analyses**

For the comparison of group means, assumptions were checked and verified. No univariate or bivariate outliers were identified (Doornik & Hansen, 2008; Henze & Zirkler, 1990; Mardia, 1970; Shapiro & Wilk, 1965). For regression analyses, those data points that may have been potential outliers were scrutinized to ensure that they were not due to measurement or data entry error; all potential outliers were deemed to be acceptably part of the data. Given the nature
of the data, it was decided to retain those potential outliers to retain the richness of the data. Following each regression analysis, assumptions were checked to confirm that the analysis was valid. Normality of residuals was investigated with a combination of factors, including P-P/Q-Q plots, and the Shapiro-Wilk test. Studentized residuals were calculated to ascertain extreme residuals (greater than ±3) and Cook’s d was used to identify influential cases. Heterogeneity was considered using a scatterplot of the studentized residuals and the Breusch-Pagan test. Transformation of the data occurred with the perceived physical health and perceived mental health dependent variables to assist with homogeneity of variance (Tukey, 1977). For all analyses, except where highlighted, data from individuals in each of the three groups was combined to create a dimensional sample.

For Hypotheses 2a-2b, separate multiple regressions were conducted for perceived physical and perceived mental health. These were both the dependent variables in their respective multiple regression and loneliness (UCLA Loneliness Scale) and sleep quality (PROMIS-SD-8a) were the predictors. For Hypothesis 2c, multiple regressions were utilized to follow-up the results obtained with the previous dimensional models. Here, each sample (AUT, INS, and NT) was analyzed separately using individual regressions with perceived physical health status and perceived mental health status. The same dependent variables and predictor variables as were used in the dimensional models were again used. In order to look at the relationship between the main factors between the main groups, Fisher’s Z-test will be utilized to compare correlations between the main variables, across groups.

For Hypothesis 3a, the three secondary factors (alexithymia, degree of AUT traits, and helping behaviors – without daily activity) were added to the previous dimensional multiple regression with perceived physical health status as the dependent variable. All previous
predictors were included in the regression with the secondary factors. For Hypothesis 3b, the methods described for Hypothesis 3a were followed with the exception of the dependent variable which was now perceived mental health status. For Hypothesis 3c, hierarchical linear regression was employed with the initial regression model with the primary factors (loneliness and sleep quality) being compared to the model with significant secondary predictors included. The significance value of the positive change in adjusted $R^2$ was used as a measure of model improvement.

For Hypothesis 4, a series of multiple regressions were conducted with just the AUT group. For each regression, the dependent variable was either perceived physical or perceived mental health. Firstly, the secondary factors were included as the only predictors; secondly, sleep impairment (PROMIS-SRI-8a) and insomnia severity (ISI) were included separately; finally, sleep impairment, sleep quality, and insomnia severity were included together with loneliness.

The SF-36 is was designed to capture health-related quality of life; in this study, we are using the physical component score and mental component score to represent perceived physical and mental health. In order to confirm that using these component scores is a sufficient proxy for perceived physical and mental health, we ran correlational analyses for the physical component score and the physical health domain of the WHOQOL-BREF. Similarly, we ran correlational analyses for the mental component score and the DASS-21 as well as the psychological domain of the WHOQOL-BREF. These analyses revealed strong correlations between the physical component score and the physical health domain of the WHOQOL-BREF ($r = .78$), for the mental component score and the DASS-21 ($r = -.77$), and for the mental component score and the psychological domain of the WHOQOL-BREF ($r = .80$). This suggests that the physical
component and mental component scores are sufficient approximations for perceived physical and mental health.

**Results**

**Aim 1: Characterize Groups**

*Hypothesis 1a – Group Profile of Self-Report Measures*

The means for each measure, by group, can be seen in Table 2. Compared to the NT group, the AUT sample was characterized by worse perceived physical health, worse perceived mental health, lower sleep quality, higher levels of loneliness, more autism traits, and similar levels of prosocial behavior. Of note, the AUT group had reduced perceived mental health compared to the insomnia group but similar levels of sleep quality.

*Hypothesis 1b – Actigraphy Variables*

A one-way ANOVA was conducted to determine whether total sleep time was different between the three groups. There was a significant difference between the three groups ($F(2, 51) = 5.48, p = .007$). A Tukey post-hoc test revealed that the AUT group slept for longer than the INS group (77.66 minutes more, $p = .007$) and the NT group (66.33 minutes more, $p = .011$). The patterns for the rest of the actigraphy variables can be seen in Table 3.
Table 2

*Relationship of Self-Report Measures Between Groups*

<table>
<thead>
<tr>
<th>Measure</th>
<th>AUT (n = 22)</th>
<th>INS (n = 23)</th>
<th>NT (n = 21)</th>
<th>Direction of Relationship†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Physical Health (SF-36 PCS)</td>
<td>47.33 (10.85)</td>
<td>51.93 (7.39)</td>
<td>55.45 (4.05)</td>
<td>(NT&gt;AUT)≈INS</td>
</tr>
<tr>
<td>Perceived Mental Health (SF-36 MCS)</td>
<td>43.96 (8.90)</td>
<td>49.01 (8.77)</td>
<td>52.94 (7.58)</td>
<td>(NT≈INS)&gt;AUT</td>
</tr>
<tr>
<td>Sleep Quality (PROMIS-SD-8a)</td>
<td>50.61 (10.89)</td>
<td>52.59 (6.45)</td>
<td>42.45 (5.62)</td>
<td>(AUT≈INS)&gt;NT</td>
</tr>
<tr>
<td>Loneliness (UCLA-LS)</td>
<td>45.67 (9.43)</td>
<td>41.91 (10.23)</td>
<td>34.84 (9.58)</td>
<td>(AUT&gt;NT)≈INS</td>
</tr>
<tr>
<td>Autism Traits (AQ)</td>
<td>25.52 (9.83)</td>
<td>18.82 (7.27)</td>
<td>13.72 (6.26)</td>
<td>AUT&gt;(INS≈NT)</td>
</tr>
<tr>
<td>Alexithymia (TAS-20)</td>
<td>50.71 (11.75)</td>
<td>43.73 (11.27)</td>
<td>40.21 (9.54)</td>
<td>AUT&gt;(INS≈NT)</td>
</tr>
<tr>
<td>Prosocial Tendencies (PTM)</td>
<td>2.79 (0.44)</td>
<td>2.77 (0.28)</td>
<td>2.95 (0.31)</td>
<td>AUT≈NT≈INS</td>
</tr>
</tbody>
</table>

† Groups inside parentheses are applied to operator and group outside parentheses.
Table 3

*Characteristics of Actigraphy Data*

<table>
<thead>
<tr>
<th></th>
<th>AUT (n = 7)</th>
<th>INS (n = 23)</th>
<th>NT (n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Bedtime (minutes*)</td>
<td>1371.77 (99.58)</td>
<td>1439.93 (81.27)</td>
<td>1445.05 (71.68)</td>
</tr>
<tr>
<td>Equivalent Time (24h clock)</td>
<td>22:52</td>
<td>00:00 (midnight)</td>
<td>00:05</td>
</tr>
<tr>
<td>Waketime (minutes*)</td>
<td>506.04 (37.49)</td>
<td>462.04 (114.79)</td>
<td>505.39 (313.27)</td>
</tr>
<tr>
<td>Equivalent Time (24h clock)</td>
<td>08:26</td>
<td>07:42</td>
<td>08:25</td>
</tr>
<tr>
<td>Sleep Onset Latency (minutes)</td>
<td>24.40 (19.77)</td>
<td>16.48 (13.50)</td>
<td>11.03 (7.86)</td>
</tr>
<tr>
<td>Wake After Sleep Onset (minutes)</td>
<td>53.65 (23.83)</td>
<td>39.57 (14.17)</td>
<td>32.57 (13.37)</td>
</tr>
<tr>
<td>Sleep Efficiency (%)</td>
<td>83.62 (6.30)</td>
<td>85.19 (4.53)</td>
<td>84.42 (17.72)</td>
</tr>
<tr>
<td>Activity (counts per min.)</td>
<td>223.02 (68.11)</td>
<td>274.38 (85.13)</td>
<td>270.91 (61.72)</td>
</tr>
<tr>
<td>Total Sleep Time (minutes)</td>
<td>485.21 (80.44)</td>
<td>414.56 (51.59)</td>
<td>418.89 (39.81)</td>
</tr>
</tbody>
</table>

* Minutes after midnight the previous night (e.g., 60 minutes represents 01:00 am)

Aim 2: Association of Sleep Quality and Loneliness with Perceived Mental and Physical Health—Dimensional Sample

Hypothesis 2a – Perceived Physical Health

A multiple linear regression was conducted to predict perceived physical health from loneliness and sleep quality (Table 4). A significant regression equation was found, indicating that the predictors accounted for 29.4% of the variance in perceived physical health. Both loneliness and sleep quality were significant predictors of perceived physical health.
Table 4

*Multiple Regression Analysis for the Association of Sleep Quality and Loneliness with Perceived Physical Health in the Dimensional Sample*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Model</td>
<td>13.88</td>
<td>2, 60</td>
<td>.294 &lt; .001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2790.82</td>
<td>671.03</td>
<td>[-4133.08, -1448.56]</td>
<td>.001</td>
<td></td>
<td>&lt; .001</td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-1173.83</td>
<td>583.40</td>
<td>[-2340.81, -6.86]</td>
<td>.049</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>332492.7</td>
<td>35581.19</td>
<td>[261319.7, 403665.7]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hypothesis 2b – Perceived Mental Health**

A multiple linear regression was conducted to predict perceived mental health from loneliness and sleep quality (Table 5). A significant regression equation was found such that the predictors accounted for 45.7% of the variance in perceived mental health. Both loneliness and sleep quality were significant predictors of perceived mental health.

Table 5

*Multiple Regression Analysis for the Association of Sleep Quality and Loneliness with Perceived Mental Health in the Dimensional Sample*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Model</td>
<td>27.12</td>
<td>2, 60</td>
<td>.457 &lt; .001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2267.67</td>
<td>618.89</td>
<td>[-3505.62, -1029.73]</td>
<td>.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-2788.82</td>
<td>538.06</td>
<td>[-3865.10, -1712.54]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>352947.9</td>
<td>32815.94</td>
<td>[287306.3, 418589.6]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hypothesis 2c – Categorical Sample

For each group (i.e., AUT, INS, and NT) a multiple regression was conducted for separately with perceived physical health (Table 6) and perceived mental health (Table 7) as the dependent variable. In each case, loneliness and sleep quality were the predictors.

**Perceived Physical Health.** For the AUT group, the regression equation was not significant. Neither sleep quality nor loneliness were significant predictors of perceived physical health. For perceived physical health in the INS group, a significant regression equation was found indicating that the predictors accounted for 38.4% of the variance in perceived physical health. Sleep quality was a significant predictor of perceived physical health but loneliness was not. For the NT group, a significant regression equation was found, suggesting that the predictors explained 31.8% of the variance in perceived physical health. Loneliness was a significant predictor of perceived physical health but sleep quality was not.

**Perceived Mental Health.** For the AUT group, a significant regression equation was found such that the predictors accounted for 40.7% of the variance in perceived mental health. Both loneliness and sleep quality were significant predictors of perceived mental health. For the INS group, the regression equation was significant with the predictors accounting for 19.7% of the variance in perceived mental health. Sleep quality was not a significant predictor but loneliness was. For the NT group, a significant regression equation was found, which suggested that the predictors accounted for 43.3% of the variance in perceived mental health. Loneliness was a significant predictor of perceived mental health but sleep quality was not.
Table 6

*Multiple Regression Analysis for the Association of Sleep Quality and Loneliness with Perceived Physical Health Within Each Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUT Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>2.03</td>
<td>2, 18</td>
<td>.093</td>
<td>.161</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2525.24</td>
<td>1257.18</td>
<td>[-5166.47, 116.00]</td>
<td>.060</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-16.62</td>
<td>1473.78</td>
<td>[-3112.91, 3079.67]</td>
<td>.991</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>254394.9</td>
<td>90693.38</td>
<td>[63855.16, 444934.6]</td>
<td>.012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INS Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>7.87</td>
<td>2, 20</td>
<td>.384</td>
<td>.003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-4930.30</td>
<td>1358.72</td>
<td>[-7764.54, -2096.06]</td>
<td>.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-1701.32</td>
<td>856.93</td>
<td>[-3488.84, 86.21]</td>
<td>.061</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>478332</td>
<td>83788.44</td>
<td>[303552.7, 653111.9]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NT Group</strong></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>5.19</td>
<td>2, 16</td>
<td>.318</td>
<td>.018</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sleep Quality</td>
<td>-1256.35</td>
<td>1471.61</td>
<td>[-4376.03, 1863.33]</td>
<td>.406</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-1911.63</td>
<td>896.68</td>
<td>[-3812.51, -10.76]</td>
<td>.049</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>292899.6</td>
<td>52444.81</td>
<td>[181721.6, 404077.7]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7

Multiple Regression Analysis for the Association of Sleep Quality and Loneliness with Perceived Mental Health Within Each Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUT Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>7.85</td>
<td>2, 18</td>
<td>.407</td>
<td>.004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2440.35</td>
<td>809.63</td>
<td>[-4141.31, -739.39]</td>
<td>.007</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Loneliness</td>
<td>-2241.44</td>
<td>949.11</td>
<td>[-4235.45, -247.42]</td>
<td>.030</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>324275.1</td>
<td>58406.75</td>
<td>[201567.1, 446983.1]</td>
<td>&lt; .001</td>
<td></td>
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<td></td>
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<tr>
<td><strong>INS Group</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>3.69</td>
<td>2, 20</td>
<td>.197</td>
<td>.043</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2422.74</td>
<td>1661.04</td>
<td>[-5887.60, 1042.12]</td>
<td>.160</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-2551.54</td>
<td>1047.60</td>
<td>[-4736.78, -366.29]</td>
<td>.024</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>362317.1</td>
<td>102431.2</td>
<td>[148649.3, 575984.9]</td>
<td>.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NT Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>7.86</td>
<td>2, 16</td>
<td>.433</td>
<td>.004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-1543.09</td>
<td>1942.72</td>
<td>[-5661.46, 2575.29]</td>
<td>.439</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-3332.86</td>
<td>1183.73</td>
<td>[-5842.26, -823.46]</td>
<td>.012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>341628.4</td>
<td>69233.8</td>
<td>[194869.3, 488407.5]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In order to compare the relationship between the factors across each group, Fisher’s Z-test was employed to compare Pearson correlations between the AUT group and a combined NT and INS group (to better contrast with the AUT group). Given the low sample size and the greater
power needed to include interactions in multiple regressions, it was not possible to look at group relationships using interactions. Therefore, Fisher’s Z-test of correlations was utilized instead. All tests (See Table 8) did not reach the critical value. That is, there was no difference in the correlation between these variables across groups, for either comparison.

Table 8

*Fisher’s Z-Test Comparing the Correlation of Pairs of Variables Between the AUT Group and the Combined NT/INS Group*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Correlations (AUT/NT+INS)</th>
<th>z-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep Quality &amp; Loneliness</td>
<td>.068 / .337</td>
<td>.990</td>
</tr>
<tr>
<td>Sleep Quality &amp; Perceived Physical Health</td>
<td>-.370 / -.567</td>
<td>.913</td>
</tr>
<tr>
<td>Sleep Quality &amp; Perceived Mental Health</td>
<td>-.491 / -.426</td>
<td>.298</td>
</tr>
<tr>
<td>Loneliness &amp; Perceived Physical Health</td>
<td>-.0316 / -.440</td>
<td>1.545</td>
</tr>
<tr>
<td>Loneliness &amp; Perceived Mental Health</td>
<td>-.443 / -.589</td>
<td>.700</td>
</tr>
</tbody>
</table>

**Aim 3: Association of Secondary Factors**

**Hypothesis 3a – Perceived Physical Health**

A multiple linear regression was conducted to predict perceived physical health as in Hypothesis 2a (Table 9) with the addition of the secondary factors (i.e., autism traits, alexithymia, and prosocial tendency). A significant regression equation was found, with the predictors accounting for 27.7% of the variance in perceived physical health. Sleep quality was the only significant predictor of perceived physical health; loneliness, autism traits, prosocial tendency, and alexithymia were not.
Table 9

Multiple Regression Analysis for the Association of Primary and Secondary Factors with Perceived Physical Health in the Dimensional Sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Model</td>
<td></td>
<td></td>
<td></td>
<td>58.53</td>
<td>5.54</td>
<td>.277</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2706.48</td>
<td>714.89</td>
<td>[-4139.74, -1273.21]</td>
<td></td>
<td></td>
<td></td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Loneliness</td>
<td>-1252.44</td>
<td>820.51</td>
<td>[-2897.46, -392.57]</td>
<td></td>
<td></td>
<td></td>
<td>.133</td>
</tr>
<tr>
<td>Prosocial</td>
<td>2449.07</td>
<td>19044.51</td>
<td>[-35732.88, 40631.01]</td>
<td></td>
<td></td>
<td></td>
<td>.898</td>
</tr>
<tr>
<td>Autism Traits</td>
<td>1384.53</td>
<td>833.46</td>
<td>[-286.47, 3055.52]</td>
<td></td>
<td></td>
<td></td>
<td>.293</td>
</tr>
<tr>
<td>Alexithymia</td>
<td>-813.89</td>
<td>766.82</td>
<td>[-2351.27, 723.49]</td>
<td></td>
<td></td>
<td></td>
<td>.293</td>
</tr>
<tr>
<td>Intercept</td>
<td>333392.7</td>
<td>78630.0</td>
<td>[175749, 491036.4]</td>
<td></td>
<td></td>
<td></td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Hypothesis 3b – Perceived Mental Health

A multiple linear regression was conducted to predict perceived mental health as in Hypothesis 2b (Table 10) with the addition of the secondary factors (i.e., autism traits, alexithymia, and prosocial tendency). A significant regression equation was found which indicated that the predictors accounted for 51.8% of the variance in perceived mental health. Loneliness, sleep quality, and alexithymia were significant predictors of perceived mental health. Prosocial tendency and autism traits were not significant predictors of perceived mental health.
Table 10

*Multiple Regression Analysis for the Association of Primary and Secondary Factors with Perceived Mental Health in the Dimensional Sample*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Model</td>
<td></td>
<td></td>
<td></td>
<td>13.69</td>
<td>5,54</td>
<td>.518</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>-2122.52</td>
<td>611.82</td>
<td>[-3349.16, -895.89]</td>
<td></td>
<td></td>
<td></td>
<td>.001</td>
</tr>
<tr>
<td>Loneliness</td>
<td>-2164.69</td>
<td>702.21</td>
<td>[-3572.54, -756.84]</td>
<td></td>
<td></td>
<td></td>
<td>.003</td>
</tr>
<tr>
<td>Prosocial</td>
<td>-628.37</td>
<td>16298.87</td>
<td>[-33305.63, 32048.89]</td>
<td></td>
<td></td>
<td></td>
<td>.969</td>
</tr>
<tr>
<td>Autism Traits</td>
<td>1152.38</td>
<td>713.30</td>
<td>[-277.70, 2582.47]</td>
<td></td>
<td></td>
<td></td>
<td>.112</td>
</tr>
<tr>
<td>Alexithymia</td>
<td>-1815.48</td>
<td>656.27</td>
<td>[-3131.22, -499.74]</td>
<td></td>
<td></td>
<td></td>
<td>.008</td>
</tr>
<tr>
<td>Intercept</td>
<td>381052</td>
<td>67293.93</td>
<td>[246135.8, 515968.2]</td>
<td></td>
<td></td>
<td></td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

**Hypothesis 3c – Comparing Regression With and Without Secondary Factors**

A hierarchical regression was conducted for perceived physical health comparing the model with primary factors (i.e., loneliness and sleep quality) with the model including the secondary factors (e.g., autism traits, alexithymia, and prosocial tendency). The analysis yielded an $R^2$ difference value of .022 with a non-significant regression equation ($F(3, 54) = .287, p = .834$). This suggests that adding the secondary factors to the primary factors did not improve the prediction of perceived physical health. For perceived mental health, the analysis yielded an $R^2$ difference between value of .084 with a non-significant regression equation ($F(3, 54) = 2.585, p = .061$). This suggests that adding the secondary factors to the model with the primary factors also does not improve the prediction of perceived mental health.
Aim 4: The Association of Secondary Factors and Other Sleep Factors with the AUT Group

Hypothesis 4 – Characterizing the AUT Group

In order to investigate the contribution of the secondary factors (i.e., autism traits, alexithymia, and prosocial behavior), they were included separately in separate multiple regressions for perceived physical health and perceived mental health (Table 11). Non-significant regression equations were obtained from the analyses for both perceived physical health and perceived mental health with none of the secondary factors being significant predictors.

Next, sleep impairment was included with loneliness as a predictor in separate regression for both perceived physical health and perceived mental health (Table 12). For perceived physical health, the regression yielded a non-significant regression equation with no significant predictors. For perceived mental health, the regression yielded a significant regression equation such that the predictors accounted for 43.4% of the variance. Both sleep impairment and loneliness were significant predictors of perceived mental health.

Insomnia severity was next included in two separate multiple regressions for perceived physical health and perceived mental health (Table 13). Loneliness was included as a second predictor. For perceived physical health, the analysis yielded a non-significant regression equation. For perceived mental health, the analysis yielded a significant regression equation such that insomnia severity and loneliness accounted for 52.7% of the variance in perceived mental health. Both loneliness and insomnia severity were significant predictors.
Table 11

Multiple Regression Analysis for the Association of Autism Traits, Alexithymia, and Prosocial Behavior with Perceived Physical Health and Perceived Mental Health for the AUT Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perceived Physical Health</strong></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>2.22</td>
<td>3, 17</td>
<td>.155 .123</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prosocial</td>
<td>1017.22</td>
<td>1870.73</td>
<td>[-2929.68, 4964.12]</td>
<td>1.22</td>
<td>3</td>
<td>.594</td>
<td>.123</td>
</tr>
<tr>
<td>Autism Traits</td>
<td>3823.73</td>
<td>2085.77</td>
<td>[-576.87, 8224.33]</td>
<td>3.73</td>
<td>3</td>
<td>.084</td>
<td></td>
</tr>
<tr>
<td>Alexithymia</td>
<td>-2731.33</td>
<td>1966.63</td>
<td>[6880.56, 1417.89]</td>
<td>1.80</td>
<td>3</td>
<td>.183</td>
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</tr>
<tr>
<td>Intercept</td>
<td>142330</td>
<td>100016.6</td>
<td>[-68686.56, 353346.5]</td>
<td>2.88</td>
<td>3</td>
<td>.173</td>
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<tr>
<td><strong>Perceived Mental Health</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>2.88</td>
<td>3, 17</td>
<td>.218 .067</td>
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</tr>
<tr>
<td>Prosocial</td>
<td>1406.76</td>
<td>1430.83</td>
<td>[-1612.03, 4425.56]</td>
<td>1.22</td>
<td>3</td>
<td>.339</td>
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</tr>
<tr>
<td>Autism Traits</td>
<td>1042.82</td>
<td>1595.31</td>
<td>[-2322.99, 4408.63]</td>
<td>3.73</td>
<td>3</td>
<td>.522</td>
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</tr>
<tr>
<td>Alexithymia</td>
<td>-2219.47</td>
<td>1504.18</td>
<td>[-5393.02, 954.08]</td>
<td>1.80</td>
<td>3</td>
<td>.158</td>
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</tr>
<tr>
<td>Intercept</td>
<td>150913.1</td>
<td>76497.94</td>
<td>[-10483.39, 312309.7]</td>
<td>2.88</td>
<td>3</td>
<td>.002</td>
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Table 12

*Multiple Regression Analysis for the Association of Sleep Impairment and Loneliness with Perceived Physical Health and Perceived Mental Health for the AUT Group*

<table>
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<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
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<tbody>
<tr>
<td><strong>Perceived Physical Health</strong></td>
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<tr>
<td>Overall Model</td>
<td>0.99</td>
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<td>&lt; -.001</td>
<td>.390</td>
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<tr>
<td>Sleep Impairment</td>
<td>-1663.43</td>
<td>1186.05</td>
<td>[-4155.22, 828.37]</td>
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<td>.178</td>
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</tr>
<tr>
<td>Loneliness</td>
<td>-12.50</td>
<td>1551.56</td>
<td>[-3272.22, 3247.22]</td>
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<td>.994</td>
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</tr>
<tr>
<td>Intercept</td>
<td>206874.3</td>
<td>88342.75</td>
<td>[21273.05, 392475.5]</td>
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<td></td>
<td>.031</td>
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<tr>
<td><strong>Perceived Mental Health</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
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<td>2, 18</td>
<td>.434</td>
<td>.002</td>
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<tr>
<td>Sleep Impairment</td>
<td>-2288.35</td>
<td>710.35</td>
<td>[-3780.73, -795.96]</td>
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<td></td>
<td>.005</td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-2153.20</td>
<td>929.26</td>
<td>[-4105.51, -200.90]</td>
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<td>.032</td>
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<tr>
<td>Intercept</td>
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<td>52910.12</td>
<td>[196614.3, 418934.4]</td>
<td></td>
<td></td>
<td>&lt; .001</td>
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</table>
Table 13

*Multiple Regression Analysis for the Association of Insomnia Severity and Loneliness with Perceived Physical Health and Perceived Mental Health for the AUT Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
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<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td><strong>Perceived Physical Health</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>2.60</td>
<td>2, 15</td>
<td>.159 .107</td>
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<td></td>
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<td></td>
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<tr>
<td>Insomnia Severity</td>
<td>-6074.33</td>
<td>2665.05</td>
<td>[-11754.75, -393.90]</td>
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<td>.038</td>
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<tr>
<td>Loneliness</td>
<td>510.12</td>
<td>1595.21</td>
<td>[-2889.99, 3910.24]</td>
<td></td>
<td></td>
<td>.754</td>
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</tr>
<tr>
<td>Intercept</td>
<td>149061.8</td>
<td>74515.68</td>
<td>[-9764.56, 307888.3]</td>
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<td></td>
<td>.064</td>
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<tr>
<td><strong>Perceived Mental Health</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>10.46</td>
<td>2, 15</td>
<td>.527 .001</td>
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<td></td>
</tr>
<tr>
<td>Insomnia Severity</td>
<td>-5258.07</td>
<td>1601.40</td>
<td>[-8671.37, -1844.77]</td>
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<td>.005</td>
<td></td>
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<tr>
<td>Loneliness</td>
<td>-2389.11</td>
<td>958.54</td>
<td>[-4432.20, -346.02]</td>
<td></td>
<td></td>
<td>.025</td>
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</tr>
<tr>
<td>Intercept</td>
<td>251707.8</td>
<td>44775.56</td>
<td>[156271, 347144.6]</td>
<td></td>
<td></td>
<td>&lt; .001</td>
<td></td>
</tr>
</tbody>
</table>

Given the large association of insomnia severity with both perceived physical and mental health in the AUT group, the same analyses were also conducted with the combined NT and INS group (Table 14). For perceived physical health, the analysis yielded a significant regression equation. However, loneliness only approached significance as a predictor. For perceived mental health, the analysis yielded a significant regression equation. Loneliness was a significant predictor and accounted for 31.1% of the variance in perceived mental health.
Table 14

Multiple Regression Analysis for the Association of Sleep Impairment and Loneliness with
Perceived Physical Health and Perceived Mental Health for the Combined NT and INS Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Physical Health</td>
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<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>5.83</td>
<td>2, 37</td>
<td>.199</td>
<td>.006</td>
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</tr>
<tr>
<td>Insomnia Severity</td>
<td>-1979.54</td>
<td>1096.02</td>
<td>[-4200.29, 241.21]</td>
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<td>.079</td>
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<tr>
<td>Loneliness</td>
<td>-1436.87</td>
<td>708.61</td>
<td>[-2872.66, -1.08]</td>
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<td></td>
<td>.050</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>232120.4</td>
<td>26751</td>
<td>[177917.7, 286323.1]</td>
<td>&lt; .001</td>
<td></td>
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</tr>
<tr>
<td>Perceived Mental Health</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Model</td>
<td>9.79</td>
<td>2, 37</td>
<td>.311</td>
<td>&lt; .001</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Insomnia Severity</td>
<td>-1338.64</td>
<td>1212.69</td>
<td>[-3795.78, 1118.50]</td>
<td></td>
<td></td>
<td>.277</td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-2803.43</td>
<td>784.04</td>
<td>[-4392.05, -1214.80]</td>
<td></td>
<td></td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>262773</td>
<td>29598.58</td>
<td>[202800.6, 322745.4]</td>
<td>&lt; .001</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Finally, sleep impairment and insomnia severity were included with sleep quality and loneliness in separate regressions for perceived physical health and perceived mental health (Table 15). For perceived physical health, the analysis revealed a non-significant regression equation. For perceived mental health, the analysis revealed a significant regression equation such that the predictors accounted for 46.5% of the variation in perceived mental health. Only loneliness was a significant predictor.
Table 15

*Multiple Regression Analysis for the Association of sleep Quality, Sleep Impairment, Insomnia Severity, and Loneliness with Perceived Physical Health and Perceived Mental Health for the AUT Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>F</th>
<th>df</th>
<th>Adj. R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perceived Physical Health</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Overall Model</td>
<td>1.42</td>
<td>4, 13</td>
<td>.091</td>
<td>.281</td>
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<tr>
<td>Sleep Quality</td>
<td>-981.72</td>
<td>2975.12</td>
<td>[-7409.08, 5445.65]</td>
<td>.747</td>
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</tr>
<tr>
<td>Sleep Impairment</td>
<td>2789.91</td>
<td>2993.63</td>
<td>[-3677.44, 9257.25]</td>
<td>.368</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insomnia Severity</td>
<td>-9975.90</td>
<td>6824.99</td>
<td>[-24720.38, 4768.59]</td>
<td>.168</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>446.79</td>
<td>1692.57</td>
<td>[-3209.78, 4103.35]</td>
<td>.796</td>
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<tr>
<td>Intercept</td>
<td>94581.86</td>
<td>148217.9</td>
<td>[-225623.5, 414787.2]</td>
<td>.534</td>
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<tr>
<td><strong>Perceived Mental Health</strong></td>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Overall Model</td>
<td>4.69</td>
<td>4, 13</td>
<td>.465</td>
<td>.015</td>
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<tr>
<td>Sleep Quality</td>
<td>-516.23</td>
<td>1827.96</td>
<td>[-4465.30, 3432.85]</td>
<td>.782</td>
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<tr>
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<td>-505.82</td>
<td>1839.34</td>
<td>[-4479.46, 3467.82]</td>
<td>.788</td>
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<tr>
<td>Insomnia Severity</td>
<td>-3278.75</td>
<td>4193.38</td>
<td>[-12338, 5780.50]</td>
<td>.448</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loneliness</td>
<td>-2461.03</td>
<td>1039.94</td>
<td>[-4707.68, -214.38]</td>
<td>.034</td>
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<tr>
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<td>291517.2</td>
<td>91067.45</td>
<td>[94777.89, 488256.4]</td>
<td>.007</td>
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</tbody>
</table>

A Pearson’s correlation was calculated for each of the sleep-related variables – sleep quality, sleep impairment, insomnia severity – with one another. Each variable combination,
sleep quality and sleep impairment \( (r = .832) \), sleep quality and insomnia severity \( (r = .829) \), and sleep impairment and insomnia severity \( (r = .896) \), was strongly correlated.

**Discussion**

This study sought to explore whether certain factors which impact mental and physical health in the general population are associated with higher or lower perceived mental and physical health of autistic individuals, individuals with insomnia, and neurotypical individuals. Autistic individuals experience a disproportionate level of physical and mental health challenges (Croen et al., 2015; Fortuna et al., 2016). They also experience a greater mortality rate – up to ten times – compared to the general population, with accident and injury among the leading causes of death (Guan & Li, 2017). While low physical and mental health has obvious implications for mortality, little is known about which particular factors are important in influencing this reduction in physical and mental health status for autistic individuals. Working towards understanding this is key to beginning to consider ways to ease the challenges such health status confers.

Our first hypothesis related to the profile of each group with respect to the actigraphy data and our self-report measures. In terms of the actigraphy data, we hypothesized that the AUT group would pattern alongside the INS group more than the NT group. Our results differed with respect to physical and mental health. For physical health, the AUT group was indeed more similar to the INS group, with both reporting lower physical health than the NT group. For mental health, the AUT group reported worse mental health than both the INS and NT group. For the primary self-report measures of sleep quality and loneliness, the AUT group reported no difference with respect to the INS group but lower sleep quality and higher levels of loneliness compared to the NT group, in line with our hypothesis. Autism traits and alexithymia were both
reported as higher in the AUT group, as expected, while prosocial tendencies were similar across all three groups. These self-report measures largely supported our hypothesis. It is not surprising that the AUT group reported greater autism traits and alexithymia than the INS and NT groups. The lower perceived mental health supports other research which points to a substantially elevated rate of psychiatric conditions in autistic individuals (Vohra et al., 2016). Of note, both the INS group and NT group reported levels of mental health close to the population mean, whereas the AUT individuals were over half a standard deviation below. Over time, and combined with lower physical health, this has the potential to substantially impact the lives of autistic individuals. Finding lower levels of sleep quality and loneliness for both the AUT and INS group supports other research suggesting loneliness as a major factor in insomnia (Hom et al., 2017b) and points to the potentially impairing level of sleep challenges in individuals with autism (Jovevska et al., 2020). Additionally, while sleep quality was similar and lower in both the AUT and INS groups, their scores on the ISI were vastly different. This suggests that, while it is clear that autistic individuals have sleep-related challenges, assessing for insomnia symptoms may not fully capture the level of impairment. This points to the need for multiple approaches when evaluating the sleep challenges of autistic individuals to ensure that these challenges are accurately captured.

While the sample size for the actigraphy data was smaller than anticipated, what the results indicate is notable. The actigraphy data for the AUT group suggests that they slept significantly longer (over eight hours) than both the INS and the NT group (under seven hours each). While this, in itself, may not be concerning, the pattern of the other actigraphy measures suggests that the AUT group also took longer to get to sleep, and were awake for longer during the night; this would support other research with autistic adults in this area (Baker & Richdale,
This pattern of sleep behavior, combined with their lower sleep quality, has the potential to give rise to further difficulty. In addition, given the participants were all adults, it is possible that their longer total sleep time – and earlier bedtime – comes as a result of many years of taking a long time to sleep, waking for a long time at night, or having a lower sleep quality. That is, this could be a positive behavior to counteract their difficulties with sleep. This concept is similar to the findings of Øyane & Bjorvatn (2005); they found that families under-estimated sleep disturbance in their autistic children and suggested that these families had learnt to adapt their expectations to the disrupted sleep routine.

Loneliness and Sleep Quality in the Combined Sample

Our second hypothesis related to the association of loneliness and sleep quality with the combined sample. Our results showed that both loneliness and sleep quality were associated with differences in physical and mental health; specifically, higher loneliness and lower sleep quality predicted lower perceived physical health. This is in line with previous research in the general population (Hinz et al., 2017; Holt-Lunstad et al., 2015). Furthermore, these two factors accounted for almost a third of the variation in perceived physical health. The results were similar for Hypothesis 2b and perceived mental health; while higher levels of loneliness and lower sleep quality predicted lower perceived mental health, they accounted for almost half of the variation in perceived mental health. The finding that loneliness and sleep quality both predicted perceived physical health and perceived mental health is an important one. It highlights the potential influence of these two factors in health outcomes but also points to them as potential prime candidates for treatment. Not only may treating loneliness help lower mental health challenges and treating sleep quality help lower physical health challenges, as may reasonably be expected, treating either of them has the potential to provide a double compliment
of remediation. That is, treating either loneliness or sleep quality has the potential to improve both physical and mental health. Furthermore, only a single factor representing sleep (i.e., sleep quality) and a single factor related to social support (i.e., loneliness) were used, yet their impact on physical and mental health was substantial. It may be possible to account for more of the variation in perceived mental and physical health using these other facets of social support and sleep.

**Loneliness and Sleep Quality in Each Individual Group**

While the transdiagnostic dimensional analyses help us to understand the general impact of loneliness and sleep quality, understanding their impact within each group can help to elucidate where emphasis should be placed for these individuals. Therefore, we explored the effect of loneliness and sleep quality in each group. We predicted that the AUT and INS groups would demonstrate a similar pattern to each other and that this would differ from the NT group. However, we found almost opposite results. For example, the AUT group did not yield any significant predictors for physical health from loneliness and sleep quality; whereas, in the INS group, sleep quality predicted physical health. Only loneliness predicted physical health in the NT group. Conversely, for perceived mental health in the AUT group, loneliness and sleep quality were both significant predictors, in that higher levels of loneliness and lower sleep quality predicted lower perceived mental health. Here, only loneliness was predictive of mental health in the INS group. Again, only loneliness was predictive in the NT group. These results suggest that mental health may be more greatly impacted by these factors in autistic individuals, while those with insomnia may experience greater difficulty with their physical health. One theory why mental health is so impacted by sleep in autistic individuals is the hyperarousal hypothesis (Baker et al., 2019b). This theory suggests that dysregulation of the hypothalamic-
pituitary-adrenal axis – indicated by lower evening cortisol levels – and pre-sleep arousal. Research also suggests that traumatic experiences in early life can lead to reduced cortisol levels in individuals which can exacerbate psychological vulnerability (Yehuda & Seckl, 2011). Furthermore, as noted with the combined sample, loneliness and sleep quality are only single facets of social support and sleep and the absence of an effect with these factors does not preclude social support and sleep in general from impacting perceived mental and physical health. It is also notable that both factors were predictive of mental health difficulties in the AUT group and to such a great extent. While mental health challenges in autistic individuals are highly prevalent, loneliness and sleep quality are scarcely entertained as being involved in this. Clinically, this has relevance to treatment approaches and suggests that attention should be paid to at least screening for difficulty with sleep quality and loneliness. This also has particular relevance to suicide in autistic individuals. Research has shown a higher rate of suicide in autistic individuals (Cassidy et al., 2014; Croen et al., 2015); however, Croen et al. (2015) also reported that half of those that attempted suicide did not have a diagnosis of depression, typically associated with suicide attempts in the general population. While these individuals may present to mental health professionals without depression, we suggest that suicide should always be considered. For loneliness and sleep, the important question is whether their association with perceived mental health acts via a similar mechanism (i.e., presenting with depression) or some other mechanism (i.e., not explicitly related to lower mood or loss of interest in activities). Furthermore, as autistic individuals generally have lower perceived mental health than the general population, an important question is whether they are typically even presenting for treatment. If this is not the case, this leads to a need for a broader understanding of these challenges in autism.
Secondary Factors in the Combined Sample

For our third hypothesis, we aimed to explore the impacts of secondary factors (i.e., autism traits, alexithymia, and prosocial behavior) on perceived physical and mental health. Instead of investigating them alone and negating the impact of the primary factors, we combined the with the primary factors to look at their combined association. With regard to perceived physical health, only lower sleep quality was predictive. Adding the secondary factors to the model, however, did not improve the amount of variation in perceived physical health that was explained by the model.

For perceived mental health, loneliness, sleep quality, and alexithymia we all predictive, When this model was compared with the model for perceived mental health, loneliness, and sleep quality, the predictors did not explain more of the variance in perceived mental health. Alexithymia has been linked with lower levels of mental health (Beshlideh et al., 2015). However, it has also been linked with sleep and social functioning (Rehman et al., 2018; Wiebe et al., 2017). Having loneliness and sleep quality already in the model might explain the modest difference in explained variance that alexithymia yields but also why it did not add to the model.

Further Characterization of Difficulties in the AUT Group

As the secondary factors did not add to the contribution of the primary factors in the prediction of physical or mental health in the combined sample, we looked at whether the secondary factors were predicting any of the variance when they were on their own (i.e., without sleep quality or loneliness). We were particularly interested in the AUT group, given the dearth or research into these factors and health. Autism traits, alexithymia, and prosocial behaviors were not significant predictors of both perceived physical health and perceived mental health in the AUT group. As mentioned, these factors are related to social support and sleep on their own in
the general population and it is possible that their association with health in the literature is due to such. It also further emphasizes the size of the effect seen with loneliness and sleep quality. 

In order to better understand the association of sleep with the AUT group, two other sleep-related measures, sleep impairment (PROMIS-SRI-8a) and the insomnia severity index (ISI) were used, individually, in conjunction with loneliness to see their association in the model. For physical health, both sleep impairment and insomnia severity were not significant predictors. For perceived mental health, both sleep impairment and insomnia severity revealed a significant regression equation such that they accounted for 43.4% and 52.7% respectively, of the variation in perceived mental health. All three sleep-related measures – sleep quality, sleep impairment, and insomnia severity – displayed the same pattern with respect to predicting perceived physical or mental health, namely no effect on perceived physical health but a significant predictor of perceived mental health. Each of these measures was then combined with loneliness in a multiple regression. Again, a significant predictor was only identified for perceived mental health; this time, only loneliness significantly predicted perceived mental health, accounting for almost half of the variance. While each sleep-related measure was significant on its own, combining them resulted in them, effectively, canceling each other out. In addition, each measure was found to be highly correlated with each other. It is likely that, being so correlated, they each competed for the same variance and diluted their effect on the model, leaving only loneliness with its own variance. This is important for two reasons. Firstly, it suggests that sleep quality, sleep impairment, and insomnia severity each help capture a similar concept of sleep difficulty in autistic individuals. While their score on the ISI does not appear to capture the level of sleep challenges faced by an autistic individual, it does help to predict their perceived mental health. In addition, using only one of these measures appears necessary to adequately capture the impact on
perceived mental health. Secondly, this result suggests that loneliness captures a separate aspect of variance to the sleep measures and highlights the importance of including both factors when seeking to understand an autistic individual’s perceived mental health.

**Future Directions**

As well as understanding whether loneliness and sleep quality impact perceived physical or mental health, it is also important to investigate whether treating these factors can improve physical and mental health. This would help support a causal link and be invaluable in aiding health professionals to provide suitable treatments. Linked to this is the question of whether and how loneliness and sleep quality might be protective for mental health as well as predictive. That is, can maintaining a state of low loneliness and of good sleep quality prevent against mental health challenges in individuals with autism? Another area of future research is to understand how influential each of these factors is. For example, loneliness and sleep quality are individual aspects of the much larger constructs of social support and sleep. While it is important to show the impact of these individual factors, it is also important to appreciate which other aspects of sleep and social support might be influential in terms of perceived physical and mental health. Similarly, understanding which components of physical and mental health these factors impact (i.e., disorder specific, or state vs. trait) will allow more targeted interventions to be provided. As this study was cross sectional, further research should look at these effects longitudinally. There are two main reasons why this would be helpful. Firstly, it would allow greater precision with regards to changes in loneliness and sleep quality impacting physical and mental health. Secondly, it would enable the testing of our suggestion that the greater total sleep time in the AUT group is a type of behavioral modification to account for other challenges related to their
sleep. Perhaps the most important question for future research is why the AUT and INS groups have different predictors and by what mechanism.

Given the prevalence and intensity of sleep challenges in autistic individuals, it may be helpful to consider whether sleep is an integral part of autism traits, rather than a separate, associated condition. For example, researchers have pointed towards animal models of autism, some of which display similar sleep challenges to autistic individuals (Wintler et al., 2020), and that sleep onset difficulties in infants aged six to twelve months are associated with a later autism diagnosis (MacDuffie et al., 2020a). Additionally, it has been suggested that sleep problems at age four predict “higher-order” restricted and repetitive behaviors (e.g., insistence on sameness, compulsive behaviors; MacDuffie et al., 2020b) and that shorter sleep duration is predictive of autistic severity (Veatch et al., 2017). If sleep difficulties are part of autism itself, it could help to explain not only their prevalence in autism but the higher rates of physical and mental health challenges. However, our understanding of sleep in autism mouse models is in its early days, as is research attempting to tap causal mechanisms across time. The issue of whether sleep or autism comes first, or whether they come together is one that warrants further research. Whether or not poor sleep is a precursor to autism, we would suggest that, for adults, sleep difficulties, autism symptoms, and physical and mental health challenges exacerbate one another.

Limitations

The most immediate limitation of this study is the low sample size for the actigraphy data in the AUT group. While this was unavoidable in this case because of pandemic-related restrictions, any indications from the data should be understood as such. Data collection will continue for the larger study and firmer conclusions will be able to be drawn once it is completed. The make-up of the sample could also be considered a limitation. For example, much
of the AUT group reside at a school for young adults with autism. This facility provides classes and employment opportunities that other autistic individuals in the community may not receive. This imposed routine may help provide structure for their sleeping patterns and may provide more socialization than living elsewhere. Despite this, however, the AUT sample still demonstrated lower sleep quality and higher levels of loneliness. Similarly, the NT and INS groups were largely taken from a university student population. These factors may limit the generalizability of the study results to other populations.

While the SF-36 has been widely used in looking at health-related quality of life, there are other measures designed to capture similar constructs that have been seen to differ from one another in the data that they capture from certain populations. For example, Huang et al. (2006) suggest that the SF-36 and WHOQOL-BREF measure different constructs – health-related quality of life and global quality of life respectively. Furthermore, the SF-36 is designed as a health-related quality of life measure which can be separated into a physical component and a mental component – rather than being designed specifically to capture physical and mental health. While we feel that the SF-36 was sufficient to capture the data that this study required, we utilized two other measures – namely the DASS-21 and the WHOQOL-BREF – to help capture the representativeness of the SF-36 with regard to perceived mental health and the utility of other health-related quality of life measures, respectively. These correlational analyses revealed a strong correlation between the mental component score of the SF-36 and the DASS-21; they also revealed strong correlations between the physical component and mental component scores of the SF-36 and the physical health and psychological domains of the WHOQOL-BREF, respectively. Therefore, it appears that using the SF-36 physical and mental health component scores provides a satisfactory approximation for perceived physical and
mental health. In addition, the SF-36 allows for the physical component score and the mental component score to be calculated in different ways (the orthogonal method – where subscales are not allowed to correlate – and the oblique method – where subscales are allowed to correlate). The oblique method has been suggested to be more clinically relevant for populations with physical and mental health challenges and was chosen for this study. Correlational analyses revealed strong correlation between each method.

It is also important to note that sleep quality and loneliness are subjective concepts and their interpretation may vary from individual to individual. By extension, it is also possible that their interpretation may vary from population to population (i.e., between autistic and neurotypical individuals). In addition, sleep quality and loneliness are typically considered part of the construct of mental health in particular. Thus, it could be expected that a change in these factors would yield a change in perceive mental health. As such, measure often contain questions about such factors when establishing aspects of mental health. However, the SF-36, the mental component score of which was used here to represent perceived mental health, does not contain any questions that explicitly relate to the sub-constructs of sleep quality or loneliness. This reduces the likelihood that what this study measured as being sleep quality and loneliness was also being measured as perceived physical and mental health.

The findings of this study suggest that sleep quality and loneliness are important factors in understanding perceived physical and mental health; however, their association likely differs depending upon the population. For individuals with insomnia sleep quality is important for perceived physical health and loneliness for perceive mental health. For autistic individuals, however, the greatest value of sleep quality and loneliness appears to be in predicting perceived mental health. While these factors have been identified in the general population as being
associated with a multitude of physical and mental health impacts, this study is the first to specifically highlight the association that sleep quality and loneliness have with perceived mental health in autistic individuals and offers an important starting point for future clinical assessment and intervention aimed and perceived mental health.
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