Physical and psychosocial effects related to sleep in children with neurodevelopmental disorders

A study of the relationship between motor proficiency, sleep efficiency and possible influencing factors
Abstract

The purpose of the study was to examine the relationship between sleep patterns, motor proficiency and commonly co-occurring neurodevelopmental disorders in children, attitude to physical activity, mental health, and age. The study also looked at differences in sleep efficiency, as well as, perceived adequacy in physical activity between typically developing children and children with low motor proficiency. The sample consisted of 127 participants, 6-12 years old living in Perth, Western Australia. 51% participants were considered typically developing and 49% to have low motor proficiency. Motor proficiency, indications of Attention-Deficit/Hyperactivity Disorder, Autism Spectrum Disorder and anxiety/depression, adequacy in, or predilection for physical activity did not show a relationship to sleep efficiency. Significant differences between groups in sleep efficiency or adequacy in physical activity were not found. No interaction effect of neurodevelopmental disorders were identified. Sleep in children with movement impairments caused by neurodevelopmental disorders is an area where continued studies are of great importance. Although no relationship was identified in the current study, previous research has suggested sleep may play an important role for development and optimal everyday functioning. A better understanding of physical and psychological consequences and possible contributing factors, of low motor proficiency in childhood is important as the risk of long-term dysfunction in emotional, cognitive and physical areas may be reduced in an optimal environment.

Nyckelord
Low motor proficiency, Sleep disturbances, Neurodevelopmental disorders, Developmental Coordination Disorder, Autism Spectrum Disorder, Attention-Deficit/Hyperactivity Disorder, Self-efficacy, Physical activity, Mental health
Introduction

Low motor proficiency is the main characteristic of Developmental Coordination Disorder, hereafter abbreviated DCD, one of the most common neurodevelopmental disorders, hereafter abbreviated NDD, in childhood. DCD results in motor impairments that consistently interfere with daily living. Low motor proficiency is also frequently found in association with NDD, for instance Attention-Deficit/Hyperactivity Disorder, hereafter abbreviated ADHD, and Autism Spectrum Disorder, hereafter abbreviated ASD. Both disorders commonly co-occur with DCD (American Psychiatric Association, APA, 2013).

A common view is that avoidance of physical activity and poor fitness is a result of impaired motor functioning. However, a reversed causality have been proposed, suggesting lack of physical activity and poor fitness being a cause of movement deficits, as the acquisition of motor skills requires participation in motor activities (Cairney & Veldhuizen 2013). The level of participation in physical activity seems to be influenced by both physical and psychological barriers, such as self-efficacy beliefs (Schoemaker & Smits-Engelsman, 2015). Less successful performances, due to reduced ability in execution of motor skills, tends to result in reduced enjoyment, low self-esteem and low self-efficacy towards physical activity (Skinner & Piek, 2001). Low levels of physical activity have been linked to reduced physical (Hay, 1992; Cermak et al., 2015; Cairney, Hay, Faught, Léger & Mathers, 2008) and mental well-being (Hay, 1992). Mental illnesses are a globally increasing problem (World Health Organisation, 2011) with depression, estimated to affect 350 million people, being one of the most common mental illnesses worldwide. The comorbidity of depression and anxiety is high (World Health Organisation, 2016). Children with NDD have been found to have an increased risk of developing mental illnesses, such as depression and anxiety disorders (Rigoli & Piek, 2016; Missiuna et al., 2014), which might be explained by social isolation as a result of experiencing little social support and reduced athletic competence (Skinner & Piek, 2001). Depression and anxiety are associated with more sleep disturbances (APA, 2013) and the prevalence of sleep disturbances have been found to be higher in children with ADHD (Dillon & Chervin, 2012) as well as ASD (Liu, Hubbard, Fabes & Adam, 2006) when compared to typically developing peers. A similar relationship has been suggested for DCD (Barnett & Wiggs, 2012).

Looking at previous research, sleep, NDD, physical activity and mental illnesses, might also share a common denominator, namely the neurotransmitter dopamine, as studies have found associations between abnormalities and alterations in the dopaminergic system (Dichter, Damiano & Allen, 2012; knab & Lightfoot, 2010). This neurobiological link further
motivates studies of a possible relationship. Few studies have looked at sleep in children with DCD and the specific impact of low motor proficiency. There also seems to be a gap in existing research regarding the impact of co-occurring ADHD and ASD on sleep-related variables. Most importantly; no previous study have, to the authors knowledge, looked at sleep patterns, motor proficiency, co-occurrence of NDD, attitudes toward physical activity, age, and psychological aspects in the same study, making this study unique. Previous findings of associations indicate they could all influence each other.

Since both sleep and physical activity have been suggested to play an important role for everyday functioning, optimal development and health (Gruber, 2013), the purpose of the study was to look at different psychological and physical aspects, seemingly related to sleep, in order to get a better understanding of their relationship and possible effects on children with NDD. The study aimed to: 1) examine the relationship between sleep patterns, motor proficiency, symptoms of commonly co-occurring NDD, mental health, and age in 6-12 year old children, and 2) look at differences in sleep efficiency and perceived adequacy in physical activity between typically developing children and children with low motor proficiency. As low motor proficiency has been previously associated with sleep disturbances (Barnett & Wiggs, 2012) as well as less perceived adequacy in physical activity (Hay, 1992).

The hypothesis was that sleep-related variables and self-efficacy variables, would be positively related to motor proficiency. A negative relationship was expected to emerge between motor proficiency and indications of ADHD, ASD and anxiety/depression, based on previous findings of comorbidity (APA, 2013) and reduced mental well-being in children with low motor proficiency (Missiuna et al., 2015). It was also hypothesized that children with co-occurring NDD would experience more sleep disturbances, as comorbidity have been suggested to increase functional disturbances (Canchild, 2016; Rigoli & Piek, 2016; Missiuna et al., 2014). The hypothesized relationship between variables is presented in Figure 1.
Figure 1. The hypothesized relationship between neurodevelopmental disorders, sleep disturbances, mental well-being and physical activity based on findings in previous studies. 

Note. DCD = Developmental coordination disorder, ASD = Autism Spectrum Disorder, ADHD = Attention-Deficit/Hyperactivity Disorder. Predilection and adequacy is in relation to physical activity.

Neurodevelopmental disorders

NDD are a group of conditions characterized by developmental deficits that results in impairments of social, academic, occupational and personal functioning. NDD include specific learning disorders, intellectual disability, communication disorders, ASD and ADHD, as well as the NDD motor disorders, developmental coordination disorder, stereotypic movement disorder and tic disorders. The onset is in the developmental period, often before the child enters grade school and the developmental deficits are ranging from very specific to global impairments in areas such as learning, movement control, communication, intelligence and social skills. Different NDD often co-occur (APA, 2013).
Developmental Coordination Disorder

DCD is one of the most common NDD in childhood and in many cases affecting fundamental movement skill acquisition and performance (Chia et al., 2012). Impairments in the speed and accuracy of movements, resulting in difficulties performing a broad spectrum of activities, such as getting dressed, eating with utensils, using a scissor and participation in physical activity along with others. The motor deficits persistently interfere with activities of the child’s daily life, as well as academic performance, leisure and play (APA, 2013). A diagnostic criteria for DCD is that acquisition and execution of coordinated motor skills have to be considerably below what is expected for his or her age and opportunity for skill learning and use. The motor skill deficits are not consequences explained by intellectual disability, visual impairment, or another neurological condition affecting movements.

The prevalence of DCD in children, aged 5-11, is 5% - 6% and the condition is more common in males, with a ratio between 2:1 to 7:1. Consequences of DCD include poor self-esteem and sense of self-worth, emotional and behavioural problems, impaired academic achievements, reduced participation in team play and sports, poor physical fitness, reduced physical activity and obesity DCD also commonly co-occur with other NDD, for example ADHD and ASD (APA, 2013). Low scores on different tests of motor proficiency, such as MABC-2, can be an indication of DCD.

Autism Spectrum Disorder

ASD is characterized by persistent impairments in reciprocal social communication and social interaction, as well as restricted repetitive patterns of behaviour, interests or activities (APA, 2013). The symptoms impair everyday functioning as individuals with ASD have a reduced ability to develop, maintain and understand relationships, causing difficulties engaging with others. Excessive adherence to routines are common resulting in distress at even small changes from the usual and motor impairments, along with intellectual and/or language-, and motor impairments are common. The prevalence of ASD is around 1%, with four times as many males as females being diagnosed (APA, 2013). The incidence of co-occurrence between ADHD symptoms and ASD have been found to range between 30% - 50% (Leitner, 2014) and motor impairments have been found in 79% of children with ASD (McPhillips, Bejerot & Hanley, 2014). The condition is also associated with specific learning difficulties and an increased risk of developing depression and anxiety in adolescence and adulthood (APA, 2013).
Attention-Deficit/Hyperactivity Disorder

ADHD is a persistent pattern of inattention and/or hyperactivity-impulsivity that is interfering the individuals functioning or development. To be diagnosed with ADHD, symptoms have to be inconsistent with what is expected for the child’s chronological age and negatively impact social and academic/occupational activities for a period of six months or more (APA, 2013). Inattention can present as being disorganized, lacking persistence or having difficulties sustaining focus. Hyperactivity is referring to excessive motor activity, such as fidgeting, tapping, talkativeness, restlessness and running around when not appropriate. Impulsivity includes hasty actions, social intrusiveness and/or decision making without thoughts of long term consequences. The prevalence of ADHD in children is around 5% and the condition is more frequent in males than females, with a ratio of 2:1. Functional consequences of ADHD are social rejection and reduced school performance with low academic attainment. Comorbid disorders, such as, obsessive-compulsive disorder, tic disorder and ASD are common. 50% of children diagnosed with ADHD are also diagnosed with DCD (Canchild, 2016) As for other NDD, anxiety and depression disorder are presenting more frequently than in the general population and an increased risk of developing obesity have been suggested (APA, 2013).

Because of the wide variety of symptoms and characteristic features (see Figure 2) it is unlikely that NDD can be explained by one single factor. However, a possible explanation might be found in the dopaminergic system (Graybiel, 2000) as dopamine seems to play an important role in control of motor movements, motivation, reward and learning (Knab & lightfoot, 2010). Alterations to the dopamine system is suggested as a primary mechanisms of ADHD (Knab & lightfoot, 2010) and might also play a role in ASD as dopamine are affecting the areas of the brain associated with the symptoms characteristic for the disorder (Kriete & Noelle, 2015). Since dopamine have been found essential for locomotor movements (Knab & Lightfoot, 2010; Kerby & Drew, 2013), it is also likely that the neurotransmitter is involved in DCD (Kerby & Drew, 2013) Additionally, variations in dopaminergic genes have been suggested to be a contributing factor to the severity of co-occurring symptoms of ADHD, ASD and emotional dysregulation (e.g. depression, anxiety, anger and irritability [Gadow, Pinsonneault, Perlman & Sadee, 2014]).
Neurodevelopmental disorders and their main characteristics.

**Figure 2.** Neurodevelopmental disorders and their main characteristics.

*Note. ASD = Autism Spectrum Disorder, ADHD = Attention-Deficit/Hyperactivity Disorder, Tic = Tic Disorders, ID = Intellectual Disability, CD = Communication Disorder, SLD = Specific Learning Disorder, SMD = Stereotypic Movement Disorder.*

**Physical activity**

Children with NDD are commonly thought to spend less time on physical activity due to experienced motor difficulties, with poor fitness as a consequence (Rivilis, Hay, Cairney, Klentrou, Liu, & Faught, 2011). However, Cairney and Veldhuizen (2013) question this view, suggesting that lack of exposure to physical activities is causing motor impairments as children do not get enough practice in performing motor skills. Motor learning requires participation in motor activities and for children with DCD and other NDDs associated with low motor proficiency, interventions are important for improving movement proficiency (Schoemaker & Smits-Engelsman, 2015). Participation in physical activity have been found to
improve both motor-, and social skills in both children and adults with ASD (Sowa & Meulenbroek, 2012) and physical activity have also been associated with less difficulties falling asleep and less disrupted sleep, sleep disturbances that are commonly found in children with ASD (Wachob & Lorenzi, 2015). Physical activity have also been found beneficial for both children and adolescents with ADHD. Smith et al. (2013) found moderate-to-vigorous physical activity daily over a period of eight school weeks to be beneficial for motor, cognitive, social, and behavioral functioning, albeit to varying degree, in children with the disorder and Gawrilow, Stadler, Langguth, Naumann, and Boeck (2016) found that physical activity was associated with better response inhibition, improved executive functioning and affect in children and adolescents with ADHD. Participation in physical activity is suggested to be influenced by several different factors, one being poor motor learning, but also by contextual and psychological barriers, such as attitudes and social support, as well as perceived self-efficacy (Schoemaker & Smits-Engelsman, 2015). The environmental impact is supported by Farah, Hackman & Meaney (2010) who suggest a link between environmental factors, such as a stimulating environment and social interactions, and neural development, indicating that movement impairments can be prevented or reduced, by providing the child with beneficial conditions.

The delays in motor development that are characteristic for DCD (APA, 2013) negatively impact the development of fundamental movement skills important for successful performance and participation in sporting activities (Wrotniak Epstein, Dorn, Jones & Kondili, 2006), which may have both psychological and physical consequences. A review by Rivilis et al. (2011) found children with DCD to have a more sedentary behaviour than typically developing peers. They also found poor motor proficiency to predict less participation in physical activities as well as less successful performances on measures of physical fitness. Wrotniak et al. (2006) had similar findings. They found that motor proficiency explained 8,7% of the variance in physical activity and that children in the greatest quartile of motor proficiency were more physically active than children in the lower quartiles.

Since a sedentary lifestyle is a globally growing issue, an increase in research focusing on the role of self-efficacy, as a mean to increase participation in physical activity, can be seen (Voskuil & Robbins 2015). Generalised self-efficacy towards physical activity in children can be measured through questionnaires like the Children’s Self-perception of Adequacy in, and Predilection for Physical Activity (CSAPPA), where adequacy refers to the child’s confidence in his or her ability to successfully perform a particular activity or skill,
and predilection refers to how much the child likes, also described as his or her preference for, physical activity (Cairney, Hay, Faught, Léger & Mathers, 2008). Bandura (1997) states that high levels of self-efficacy, a form of self-confidence for a specific skill or situation, predicts higher goals, a stronger commitment and a tendency to expect favourable outcomes. Self-efficacy beliefs also determine how obstacles and barriers are perceived, where a person with high levels of self-efficacy are more likely to see them as challenges instead of a hindrance (Bandura, 2004). The most important source influencing self-efficacy is enactive mastery experiences, referring to previous successful outcomes in a particular task or situation (Bandura, 1997). The belief a particular action will produce a desired outcome is important for the individuals motivation and persistence. Behaviour is also governed by personal feelings and social responses, with social approval as an important outcome factor (Bandura, 2004).

As children who perceive themselves to be less adequate in their physical abilities have been found more likely to engage in more sedentary activities, psychological factors might play an important role in influencing the level of participation in activities requiring motor activities (Cairney et al., 2008). The beneficial effects of exercise can be seen through the self-efficacy theory, which argues that mental health improves when perceived ability improves (Kiluk Weden & Culotta, 2009). Self-efficacy towards physical activity is the individual’s personal evaluation of his or her capability related to the particular situation as well as the perceived power to choose to participate in physical activity despite existing barriers (Voskuil & Robbins, 2015). Support for the role of self-efficacy was found in a study by Cairney et al. (2008) who found low levels of self-efficacy towards physical activity in a sample of 2245 typically developing children, to negatively impact performance. They also found development of motor skills (such as object control proficiency, e.g. throwing, kicking and catching) important for a positive perception of sports competence, which increased physical activity and fitness level in adolescence. According to Knab and Lightfoot (2010) voluntary physical activity has two main components: motor movement and motivation/reward. The motivational/rewarding component is what differs voluntary physical activity from general locomotion. Because of the suggested influence dopamine have on both motor movements and motivation, the dopaminergic could have a regulatory role in physical activity.

Wrotniak (2006) identified that children who scored low on the predilection factor of CSAPPA had significantly lower motor proficiency, suggesting that motor proficiency is influenced by the attitude towards physical activity. Less feelings of enjoyment for physical
activity in children with low motor proficiency indicates a neurologic component could be involved as less efficient movements are thought to cause a higher energy expenditure. Being more easily fatigued may impact the attitude and feelings towards physical activity as successful performances requires more effort. A higher energy expenditure in children with DCD as a result of impairments in activating and sequencing movement patterns have also been suggested by Chia et al (2013). The higher energy expenditure and the difficulties experienced may result in less possibilities, and will to, participate in physical activities. Besides associations between motor proficiency and psychological aspects of participation in physical activity, a relationship between physical activity and sleep patterns is proposed. Studies of typically developing children have shown that more physical activity tend to result in healthier and more consistent sleep patterns. Physical activity levels have also been significantly associated with sleep quality in a population with ASD, where more physically active children experienced less difficulties falling asleep and had less disrupted sleep patterns (Wachob & Lorenzi, 2015). Linking it back to the dopaminergic system, dopaminergic activity have been found to increase with more motor activity and decrease with rest. Reduced dopaminergic signaling have been associated with enhanced memory retention (Berry, Cervantes-Sandoval, Chakraborty & Davis, 2015), once again highlighting the importance of sleep, as memory plays an important role in learning (Gruber, 2013).

Sleep disturbances

Most people would likely agree that sufficient sleep is important for every day functioning and it is supported by research finding insufficient sleep to have several harmful effects, such as learning and behavioural problems (Angriman Caravale, Novelli, Ferri, & Bruni, 2015). Gruber (2013) suggested sleep plays an important role in the way people think, feel and behave and highlights the substantial body of evidence showing that appropriate levels of sleep are necessary for optimal physical, cognitive and emotional health. Sleep is thought to have a restorative effect on brain functioning (Gruber et al., 2011) and sleep deprivation and fatigue will negatively impact a child’s development as it impairs the learning process and memory consolidation. During sleep, neural networks associated with new learning processes are reactivated. Inadequate sleep results in less reactivation and may therefore cause reduced function of hippocampus, which is the centre of memory-encoding. According to Diagnostic and statistical manual of mental disorders: DSM-5 (APA, 2013) sleep-wake disorders causes dissatisfying quality, timing or, amount of sleep, resulting in daytime distress and impairment and persistent sleep disorders have several negative
consequences, for instance an increased risk of developing mental illnesses (APA, 2013). Sleep disorders are often co-occurring with depression, anxiety and cognitive changes (APA, 2013) and have been found to compromise quality of life for both children and their families. Sleep deprivation might also have negative effects on academic achievements, cognition and neurobehavioral functioning, affecting attention/response, inhibition and problem solving. Additionally, sleep deprivation is associated with behavioural disturbances (Angriman et al., 2015) and impaired emotion regulation, resulting in more emotional problems (Gruber, 2013).

The prevalence of sleep disorders and sleep disturbances have been found higher in children with NDD compared to the general population and they tend to be chronic, lasting into adolescence or adulthood (Angriman et al., 2015). Children with DCD have shown a higher incidence of sleep disturbances, particularly problems with bedtime resistance, parasomnias and daytime sleepiness, than typically developing children (Barnett & Wiggs, 2012) and sleep disturbances are also common in ADHD, with restless legs, elevated periodic limb movements and circadian rhythm disorders in addition (Dillon & Chervin, 2012). Evidence of excessive daytime sleepiness was found in children with ADHD (van der Heijden, Smits & Gunning, 2005) which might be a further indication of possible insufficient sleep at night. For individuals with ASD, the prevalence of sleep disturbances have been found to exceed 80% (Robinson-Shelton & Malow, 2016; Angriman et al., 2015; Liu, Hubbard, Fabes & Adam, 2006) with insomnia being most common (Robinson-Shelton & Malow, 2016; Liu et al., 2006). Liu et al. (2006) found a positive relationship between the severity of ASD and sleep problems. However, sleep disturbances does not have to be chronic or even long-term to affect the child. Fluctuations in sleep quality, time in bed and daytime tiredness were found by Könen, Dirk, & Schmiedek (2015) to predict fluctuations in cognitive performance the following day in elementary school children, further illustrating the need for healthy sleep habits. Children with lower average performance in general showed stronger relationships between sleep and cognitive fluctuations, indicating that children with low average performance might experience greater benefits from high quality sleep. Interestingly, poor performance was linked to both too little and too much time in bed, suggesting that there could be ideal sleep patterns for optimal social and emotional functioning (Könen et al. 2015).

Based on previous studies linking impaired sleep with reduction in daytime functioning in individuals with DCD, Barnett and Wiggs (2012) propose that sleep disturbances might impact the development or maintenance of the socio-emotional problems characteristic for the disorder. A reduction in daytime functioning was also identified by Gruber et al. (2011) in a study examining the impact of sleep on neurobehavioral functioning in children with ADHD.
A cumulative reduction in sleep duration of 40.7 minutes showed a deterioration in vigilance and sustained attention, which are thought to be essential for optimal cognitive and academic success. Both typically developing children and children with ADHD were negatively affected, and for children with ADHD the decreased sleep duration could cause a diagnostic change, with children going from a subclinical to a clinical range. The relationship between attentional deterioration and shorter sleep duration might be explained by previous findings of attentional networks requiring more sleep for recovery. Chorney, Detweiler, Morris & Kuhn (2008) argue that there is a big overlap between anxiety, depression and sleep disturbances where anxiety and stress appear to cause sleep disturbances which are resulting in intensified emotional problems, creating a negative cycle. Similar relationships have been suggested by Åkerstedt et al. (2012) who found poor sleep quality to correlate with higher levels of anxiety and worries about possible events the following day, as well as by Könen et al. (2015) who found that the fluctuations in performance, predicted by sleep quality, only affected the children’s performance on school days, which they argue are naturally more demanding and stressful.

Mental disorders

Depression and anxiety are categorised as mental disorders (APA, 2013) and are often co-occurring (World health organisation, 2016). Both conditions commonly start in childhood or adolescence and can become chronic and last into adulthood if not treated. Depressive disorders are characterized by negative emotions, loss of interest or pleasure, poor concentration decreased energy, feelings of guilt, low self-worth, disturbed sleep as well as appetite and poor concentration. The problems can result in reduced functioning and decreased ability to take care of everyday responsibilities (APA, 2013; World Health Organisation, 2016). Anxiety is defined as persistent and exaggerated feelings of fear and worries, in particular to future events. Anxiety disorder often presents as excessive caution and avoidant behaviour but can manifest in various different ways resulting in various behavioural disturbances (APA, 2013). Mental disorders are highly preventable and can be treated with sufficient knowledge and adequate resources (World Health Organisation, 2016).

Children with low motor proficiency have been found to have an increased risk for mental health difficulties, such as anxiety and depression (Rigoli och Piek, 2016; Missiuna et al., 2015) and the motor dysfunctions seems to have a negative effect on the childs perceived self-worth and athletic competency, among other variables (Skinner & Piek, 2001). Missiuna et al. (2014) found a significant correlation between DCD and symptoms associated with
anxiety and depression as well as a heightened risk of developing mental disorders when DCD and ADHD were co-occurring, which indicates a possibility that comorbidity also will negatively affect the child in other areas associated with the disorders. Their results are supported by the outcomes of a twin-study by Pearsall-Jones, Piek, Rigoli, Martin and Levy (2011) who identified higher levels of anxiety and depression in twins with movement dysfunction when looking at twin pairs. Besides supporting the increased incidence of anxiety and depression in NDD, their finding also indicates that depression and anxiety is influenced by environmental factors and not a result of a genetic component.

A relationship between anxiety, depression and physical activity in NDD has also been suggested. For instance Kiluk et al. (2009) saw that children with ADHD who played 3 or more sports displayed less symptoms of anxiety and depression, compared to children playing less than 3 sports. Exercise have been found to alleviate symptoms of depression and is therefore commonly used as a treatment (Knab & Lightfoot). Physical activities are thought to increase production and metabolism of neurotransmitters, such as dopamine, resulting in improved mood, learning capacity, neuronal plasticity, cognitive functioning, learning and mood (Knab & Lightfoot, 2010). Dopamine have also been suggested to be involved in anxiety disorders as dopamine availability was found lower in individuals with general anxiety disorder as well as social anxiety disorder (Lee et al., 2015).

In conclusion, low motor proficiency and the NDDs associated with movement deficits, have physical and psychological consequences for the child. The reduced ability to perform motor skills and participate in social physical activity, affects the child’s physical fitness and motor proficiency as well as mental health and self-efficacy. Self-efficacy seems to have an important role for participation in physical activity as participation is influenced by the child’s perception of their ability (Hay, 1992; Cairney et al., 2008). NDD have been associated with a heightened risk of developing mental disorders (Missiuna et al., 2014; Skinner & Piek, 2001; Rigoli & Piek, 2016; APA, 2013) and the incidence of sleeping disturbances are higher than in the general population (Angriman et al., 2015; Robinson-Shelton & Malow, 2016). Sleep is important for adequate development and health in childhood (Gruber et al., 2011) as it plays a key role in physical, cognitive and emotional functioning (Gruber 2013). A high rate of co-occurrence have been found between DCD and other NDD, in particular ADHD (Canchild, 2016; APA, 2013), but also with ASD (APA, 2013). Comorbidity causes impairments in several domains, increasing functional disturbances (Canchild, 2016, Rigoli & Piek, 2016, Missiuna et al., 2014) which indicates a possibility of increased sleep disturbances with co-occurrence. As NDD, such as DCD,
ADHD and ASD, physical activity and mental health have been associated with sleep disturbances and since previous studies have found sleep to be of importance for optimal development and functioning it is interesting to look at their relationship. The suggested connection to the dopaminergic system strengthens the notion of interplay.

The purpose of the study was: 1) examine the relationship between sleep patterns, motor proficiency, commonly co-occurring NDD, mental health, and age in 6-12 year old children and 2) look at differences in sleep efficiency and perceived adequacy in physical activity between typically developing children and children with low motor proficiency. A greater understanding of how sleep patterns and motor proficiency are related, as well as an understanding of possible influencing factors and their effects on physical and psychological well-being, is important in understanding how to prevent and minimize the negative consequences of NDD. If there is a connection between sleep efficiency and NDD, finding ways to improve sleep for this population, might reduce the risk of long-term dysfunction in emotional, cognitive and physical areas, resulting in more physical activity and improved motor proficiency which could positively impact self-efficacy and mental well-being. It was hypothesized that sleep-related variables, as well as variables involved in self-efficacy, would be positively related to motor proficiency, while a negative relationship would emerge between motor proficiency, sleep latency and indications of ADHD, ASD and anxiety/depression. It was also hypothesized that children with co-occurring neurodevelopmental conditions would experience more sleep disturbances since comorbidity between different disorders have been suggested to increase the impairments resulting in more functional disturbances (Canchi, 2016, Rigoli & Piek, 2016, Missiuna et al., 2014).

Method

Participants

127 age matched children, 45 females (35,4%) and 82 males (64,6%), aged 6-12 years old (m = 8,94, SD = 1,9) living in Perth, Western Australia were recruited through the University of Western Australia (UWA) Paediatric Exercise Programs and the wider community. 65 (51,2%) participants fell under the category “Typically developing” and 62 participants (48,8%) fell under the category “Low motor proficiency” with a possible occurrence of DCD based on test scores from Movement Assessment Battery for Children-2 (MABC-2). Children categorised as having low motor proficiency had scores falling at or
below the 16th percentile. 126 participants completed the Children’s Self perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA), a response rate of 97.7% (missing values = 1). 95 participants (74.8%) completed measures of sleep (missing values = 32), 77 participants (60.6%) answered the Autism Spectrum Quotient (AQ-10), screening for ASD (missing values = 50), and 75 participants (59.1%) responded to Vanderbilt ADHD Parent Rating Scale (VADPRS), screening for ADHD and anxiety/depression (missing values = 52). To be eligible to participate in the study the child could not present with any disorder or medical condition that prevents physical activity. 14 participants (11%) showed signs of ASD based on the AQ-10 and 63 participants (49.6%) had no indications of the disorder. 57 participants (44.9%) showed no signs of ADHD, 13 participants (10.2%) indicated having one subtype and 5 participants (3.9%) indicated having both the attention-deficit-, and the hyperactive subtype.

**Instruments**

Motor proficiency was assessed using the MABC-2, a revision of the Movement Assessment Battery for Children, and is one of the most widely used tools to identify motor dysfunctions in children (Schults, Henderson, Sugden & Barnett, 2010; Brown & Lalor, 2009). The MABC-2 assesses motor proficiency through eight different motor tasks on three main components; manual dexterity, aiming and catching, and balance (static and dynamic). The MABC-2 has two parts: 1) The performance test, where children are scored and rated according to their performance in gross and fine motor skills and 2) The checklist, consisting of 30-items that provides information about the child’s performance of everyday movements at home or in school (Schoemaker, Niemeijer, Flapper, & Smits-Engelsman, 2012). Age adjusted standard scores and percentiles are calculated for each component. MABC-2 is designed for assessing motor proficiency in children aged 3-16 years, in one of three age bands (AB1: 3-6 years, AB2: 7-10, AB3: 11-16 years). Both the checklist (Schoemaker et al., 2012) and the performance test are useful instruments for assessing suspected motor dysfunctions in children and adolescents (Brown & Lalor, 2009). Verbal instructions and demonstrations were given to the child before each skill performance. Children with an overall percentile falling on or below the 16th percentile were considered to have low motor proficiency. Children with scores above the 16th percentile were classified as typically developing (Henderson et al., 2007). According to Wuang, Su & Su (2012) the MABC-2 test has excellent internal consistency (Cronbach’s α = 0.90) and excellent test-retest reliability for the total score (Intraclass correlation coefficient (ICC) = 0.97). The MABC-2 checklist has an
excellent internal consistency (Cronbach’s $\alpha = 0.94$) for all 30 items together, indicating high reliability and have been found to be able to discriminate between typically developing children and children with low motor proficiency (Schoemaker et al., 2012). Concurrent validity, measured by calculating correlations between the checklist, test, and the DCDQ’07, showed agreement between the test and the checklist to be 80%. Sensitivity was 41% and specificity was 88% when using the MABC-2 test as reference standard with cut-off at 15th percentile (Schoemaker et al., 2012).

Indications of ADHD was assessed with VADPRS, a 45-item symptom scale including all 18 symptoms that are characteristics of ADHD as described in Diagnostic and Statistical manual of Mental Disorders – 4th edition (DSM-4) where parents rate their child on a 4-point scale ranging from never (0) to very often (3) (Wolraich, Lambert, Doffing, Bickman, Simmons, & Worley, 2003). Fundamental diagnostic criteria have not changed between DSM-4th edition and DSM-5th edition (ADHD institute, 2017). VADPRS also includes an 8-item oppositional defiant scale, a 12-item conduct disorder scale and a 7-item screen for anxiety and depression. Additionally, an 10-item performance section is available which assesses functioning in general school settings, reading, mathematics, written expression, parent relations, sibling relations, peer relations, and games and team activities. The performance scale has ratings ranging from “Problematic” to “Above Average” (Wolraich et al, 2003). When compared with Vanderbilt ADHD Diagnostic Teacher Rating Scale (VADTRS) and Computerized Diagnostic Interview Schedule for Children (C-DISC-IV) ratings of children in clinical and nonclinical samples, factor structure, as well as internal consistency (0.93) were acceptable and consistent with DSM-IV and other established measures of ADHD. VADPRS have a high concurrent validity ($r = .79$) and Cronbach’s alpha for the anxiety/depression scale was acceptable (Cronbach’s $\alpha = 0.79$) when comparing with C-DISC-IV (Wolraich et al., 2003). The results are supported by Bard, Wolraich, Neas, Doffing and Beck (2013) who found estimates of coefficient alpha ranging from .91 to .94 and test-retest reliability to exceeded .80. The same study identified a sensitivity of .80, specificity of .75, a positive predictive value of .19, and negative predictive value of .98, supporting the utilisation of VADPRS as a diagnostic rating scale for ADHD. For the current study question number 40 (He/she has forced someone into sexual activity) was excluded in the study since the question were not found to be appropriate for the age group. The oppositional defiant scale and the conduct disorder scale where not included in the analysis as measures were not relevant for the purpose of the study.
Indications of ASD was measured using the child version of AQ-10, a tool designed to evaluate whether a full diagnostic assessment of ASD should be considered. AQ-10 is based on AQ-50 (child), a parent-report questionnaire, consisting of 50 items, developed to detect autistic traits in children 4–11 years old. AQ-10 (child) consists of statements referring to areas associated with ASD; social skills, attention switching, attention to detail, communication and imagination. The statements were rated on a 4-point scale ranging between “Definitely agree” and “Definitely disagree” with reversed scoring on 4 of the 10 statements. Only 1 point could be scored for each question, with a total score ranging between 0-10. Higher scores relates to autistic traits/symptoms (Auyeung, Baron-Cohen, Wheelwright & Allison, 2008). Individual scores above 6 of 10 indicates that further assessment should be considered. AQ-10 (child) have shown high internal consistency (Cronbach’s α > 0.85) sensitivity (.95) specificity (.97) and Positive Predictive Value (.94) (with a cut-point above 6). AQ-10 have been shown to significantly correlate with the AQ-50 (Child) (r = 0.94) (Allison, Auyeung, & Baron-Cohen, 2012). The child version of AQ-50 (child) have high internal consistency (Cronbach’s α = 0.97) and test-retest reliability (r = 0.85) (Auyeung et al. 2008).

CSAPPA was used to establish levels of generalized self-efficacy towards physical activity. CSAPPA is a 20-item questionnaire, developed for children aged 9-16 years old (Cairney et al., 2008). The scale have three imbedded factors; perceived adequacy in, predilection for physical activity and enjoyment of physical education class. The scale, designed to assess children’s perceptions of their adequacy to perform, and desire to participate, in physical activity, have been found to be a useful tool in identifying children with low perceived adequacy in, and predilection for, physical activity and therefore have an increased risk of hypoactivity (Hay, 1992). The children are presented to pairs of statements and are asked to choose the alternative, they think describes them best. A higher score indicates greater self-efficacy (Cairney et al., 1997). In the current study scores for each factor was used separately. The scale have shown high test-retest reliability (r = 0.84 - 0.90) as well as high predictive and construct validity (Hay, 1992; Cairney et al., 2007). The internal consistency for each subscale have been found to be good (adequacy, Cronbach’s α = 0.83; predilection, Cronbach’s α = 0.83; and enjoyment, Cronbach’s α = 0.86). CSAPPA have also been found appropriate as a screening instrument for motor difficulties, such as DCD (Cairney et al., 2007). For the current study the subscale enjoyment of physical education class were excluded as the variable physical activity was not limited to an educational context.
Sleep were assessed via Actigraph monitors, wGT3X-BT, worn on the wrist during bed time in their home environment. The Actigraph device monitor movements and the recorded activity scores are translated to sleep-wake scores based on computerized scoring algorithms (Sadeh, 2011). The Actigraph monitors used in the study measured total sleep time, sleep latency and sleep efficiency. The algorithm used to perform sleep scoring on actigraphy data was the Sadeh2 algorithm, as this algorithm is considered appropriate for younger populations (Actigraph, 2015). In addition to Actigraph measures, children’s parents/caregivers reported bed time, lights out time and wake up time through sleep diaries. The information provided by the parents/caregivers where then used as help when scoring sleep data from actigraph measures. Data consisted of a mean value based on 4 nights, where at least one night was a night of the weekend (night of Friday, Saturday or Sunday). Actigraphy have been found sensitive in detecting sleep patterns unique for a specific sleep disorder, as well as in detecting characteristics of other medical or neurobehavioral conditions (Sadeh, 2011). Actigraphs can be used for sleep assessment in clinical research or as a diagnostic tool in sleep medicine. Reasonable test-retest reliability have been demonstrated with good stability over time. A reasonable validity between actigraph measures and subjective reports of sleep schedule and sleep period have also been suggested (Sadeh, 2011). Comparisons between wrist actigraphy and polysomnography (PSG) measures in children aged 1-12 showed that agreement rates (85,1 - 88,6) predictive value for sleep (91,6 - 94,9) and sensitivity (90.1 - 97,7) when relating actigraphy to PSG were high. Actigraphy was found reliable for determining total sleep time and sleep efficiency (Hyde et al., 2007).

Procedure

Data of sleep patterns (latency, efficiency and total sleep time), generalised self-efficacy towards physical activity (adequacy, predilection), motor proficiency and demographics (age, gender) were collected as part of an ongoing study. Comprehensive information about instruments and procedures used for data collection were given at the start of the current study and continued contact with responsible personnel were held. For the current study existing raw material were complemented with data collection of symptoms indicating ADHD, through VADPRS and ASD, through AQ-10, from the same sample. The VADPRS and AQ-10 were sent to the families as an online form via e-mail. The questionnaires were also sent as a hard copies to the families who had not responded within the set time frame. Absent responses and imprecise answers were treated as missing values.
Raw data for all variables for each participant were converted and scored according to established guidelines for each individual measure. The scores of MABC-2, measuring motor proficiency was used as both a continuous and a categorical variable. For the categorical testing of motor proficiency the children with raw scores on or below the 16th percentile were categorised as having low motor proficiency, as suggested in the examiners manual by Henderson, Sugden and Barnett (2007). The VADPRS was scored according to the VADPRS scoring instructions and participants were thereafter categorised into one of the three groups; no indications of ADHD, indications of one subtype or indications of both subtypes, for a Pearson’s test of correlation, and the two groups; no indications of ADHD or indications of ADHD, for the purpose of a multiple regression. VADPRS anxiety depression scale and AQ-10, screening for ASD, both had two categories: no indications of the disorder and indications of disorder. Data of sleep efficiency was measured in percentage and total sleep time as well as sleep latency was measured in minutes. For the variable co-occurring NDD, the participants were categorised into one of four groups with indications of: no NDD, ADHD, ASD or Co-occurring NDD.

Data were analysed using IBM SPSS statistics 23. As proposed by Pallant (2010) and Brace, Kemp & Snelgar (2013), data were screened for errors and outliers. No data were excluded as no extreme values were identified (Wilson & MacLean, 2011) and trimmed mean values did not differ greatly from mean value (Pallant, 2010). A preliminary analysis were done to obtain descriptive statistics about the characteristics of the sample, as well as checking for normality, including skewedness, kurtosis and missing values. Homoscedasticity were assessed through scatterplots. A Kolmogorov – Smirnov test displayed normal distribution of sleep efficiency ($p = .20$) total sleep time ($p = .057$) and age ($p = .067$). As common in the social sciences (Pallant, 2010), all variables did not have a normal distribution. However, most parametric techniques are tolerant of violations to the assumption of normality (Pallant, 2010) hence, parametric techniques were used for analysing the data where no non-parametric techniques fitted the purpose of the study.
**Ethics**

The study was part of a larger study which was approved by the UWA Human Research Ethics Committee. According to Codex (2016) research ethics, the participants were informed about the purpose of the study. They were also informed that participation was voluntary, that they had the right to withdraw from the study and/or choose not to answer at any time without consequences. Ethical guidelines regarding confidentiality were followed as data were stored in such way only people working with the study had access. The participants were deidentified to secure participants anonymity (Codex, 2016).

**Results**

To examine the degree of relationship between sleep efficiency, motor proficiency, sleep latency, total sleep time, indications of ADHD and ASD, adequacy in, and predilection for physical activity (hereafter referred to as adequacy and predilection), anxiety/depression and age, a two-tailed Pearson’s test of correlation was conducted. The significant correlations revealed in the analysis were a positive relationship between motor proficiency and adequacy, motor proficiency and predilection and a negative relationship between motor proficiency and the variables indications of ASD, indications of ADHD, and anxiety/depression. A positive correlation was found between adequacy and predilection. Adequacy was negatively correlated with indications of ASD, indications of anxiety/depression, sleep efficiency, and age. A positive relationship was found between indications of ADHD and anxiety/depression as well as between indications of ADHD and indications of ASD. Indications of ASD was negatively correlated with predilection towards physical activity and predilection towards physical activity was negatively correlated to indications of anxiety/depression. Indications of ASD was negatively correlated with total sleep time. Total sleep time and sleep efficiency showed a positive relationship, while a negative relationship was found between sleep latency and sleep efficiency. Relationships, ranging between 0-.2 are considered weak, ranging between .3-.6 considered are moderate and ranging between .7–1 are considered strong (Brace et al., 2013). A relatively equal distribution between weak and moderate relationships emerged. The correlation between adequacy and predilection towards physical activity were the only relationship considered strong. The result of Pearson’s test of correlation is presented in Table 1.
The relatively high amount of significant correlations emerging in a Pearson’s test of correlation, led to further analysis with the purpose of examining the strength of associations and estimate to which degree the predicting variables (motor proficiency, sleep efficiency, sleep latency, total sleep time, indications of ADHD and ASD, adequacy, predilection, anxiety/depression, and age) could explain the variance in observed sleep efficiency (Brace et al., 2013). Variables that were significantly correlated, or previously had been found related to the criterion variable, were entered as predictors of sleep efficiency, using a standard method multiple regression. The analysis showed a significant model: F(9,54) = 6.677, p < .001. The model explains 44.8% of the variance in sleep efficiency (Adjusted R² = .448). Sleep latency, total sleep time, and age were significant predictors. Age and total sleep time had a positive relationship to sleep efficiency and sleep latency had a negative relationship to the predictor variable. Motor proficiency, adequacy, predilection, anxiety/depression, and indications of ASD, ADHD were not significant predictors. The result of the multiple regression is presented in Table 2.

Table 2. The unstandardised and standardised regression coefficients for the variables entered into the multiple regression.

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Proficiency</td>
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<td>.038</td>
<td>.078</td>
<td>.515</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>-.131</td>
<td>.052</td>
<td>-.247</td>
<td>.016</td>
</tr>
<tr>
<td>Total sleep time</td>
<td>.091</td>
<td>.015</td>
<td>.200</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Adequacy</td>
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<td>.172</td>
<td>-.606</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Predilection</td>
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<td>.129</td>
<td>.025</td>
<td>.855</td>
</tr>
<tr>
<td>ASD</td>
<td>.207</td>
<td>1.921</td>
<td>.013</td>
<td>.914</td>
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<tr>
<td>ADHD</td>
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<td>1.690</td>
<td>-.065</td>
<td>.577</td>
</tr>
<tr>
<td>Anxiety/depression</td>
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<td>2.019</td>
<td>-.014</td>
<td>.896</td>
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<tr>
<td>Age</td>
<td>.975</td>
<td>.326</td>
<td>.296</td>
<td>.004</td>
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</table>

*Note. ASD = Autism Spectrum Disorder, ADHD = Attention-Deficit/Hyperactivity Disorder.*

In order to look at differences between typically developing children and children with low motor proficiency, and the effect of co-occurring developmental disorders on sleep efficiency and adequacy in physical activity, two two-way between subjects ANOVAs was conducted. The two-way ANOVA examining the effect of low motor proficiency and co-occurring NDD on sleep efficiency showed that co-occurring NDD did not significantly affect sleep efficiency (F(3,57) = .433, p = .730, η² = .022, power = .131). Neither did low motor proficiency (F(1,57) = .077, p = .782, η² = .001, power = .059). No interaction between co-
occurring NDD and motor proficiency on sleep efficiency was found (\(F(2,57) = .025, p = .976, \eta^2 = .001, power = .054\)). The two-way between subjects ANOVA conducted on adequacy in physical activity showed that low motor proficiency did not have a significant effect on adequacy (\(F(1,67) = .264, p = .609, \eta^2 = .004, power = .08\)) and neither did co-occurring NDD (\(F(3,67) = 1.478, p = .228, \eta^2 = .062, power = .374\)). There were no significant interaction effect between co-occurring NDD and motor proficiency on adequacy in physical activity (\(F(2,57) = .326, p = .723, \eta^2 = .010, power = .100\)). No typically developing children showed signs of co-occurring developmental disorders when the cut off score for LMP was at the 16th percentile or below. A 95% confidence interval were used for all statistical analysis.
Table 1. Illustration of sample size, correlation coefficients (r) of a Pearson’s test of correlations and explained variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
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<td>1. Motor proficiency</td>
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<td>2. Sleep efficiency</td>
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<td>3. Sleep latency</td>
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<td>-.203*</td>
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<td>4. Total sleep time</td>
<td>-.007</td>
<td>.588**</td>
<td>.022</td>
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<td>5. Adequacy</td>
<td>.369**</td>
<td>-.229*</td>
<td>.073</td>
<td>-.077</td>
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<td>6. Predilection</td>
<td>.422**</td>
<td>-.126</td>
<td>-.018</td>
<td>-.080</td>
<td>.702**</td>
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<tr>
<td>7. ASD</td>
<td>-.441**</td>
<td>-.049</td>
<td>-.189</td>
<td>-.277*</td>
<td>-.324**</td>
<td>-.299**</td>
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<tr>
<td>8. ADHD</td>
<td>-.438**</td>
<td>-.137</td>
<td>.017</td>
<td>-.094</td>
<td>-.163</td>
<td>-.224</td>
<td>.329**</td>
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<tr>
<td>9. Anxiety/depression</td>
<td>-.278*</td>
<td>.085</td>
<td>-.111</td>
<td>.058</td>
<td>-.319**</td>
<td>-.315**</td>
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<tr>
<td>10. Age</td>
<td>-.129</td>
<td>.235*</td>
<td>.068</td>
<td>-.110</td>
<td>-.203*</td>
<td>-.047</td>
<td>.208</td>
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<td>75</td>
<td>75</td>
<td>127</td>
</tr>
</tbody>
</table>

Note. ASD = Autism Spectrum Disorder, ADHD = Attention-Deficit/Hyperactivity Disorder.
For interpretation from $r^2$ to explained variance in %; $r^2 = 0.136$ explains 13.6% of variance.
** p < 0.01 level
* p < 0.05 level
Discussion

NDD such as DCD, ADHD and ASD are all associated with low motor proficiency and other neurological impairments affecting everyday life (APA, 2013). Several studies have also found sleep to play a major role in optimal physical and psychological functioning and health (Gruber, 2013). Therefore, the purpose of the study was to look at different psychological and physical aspects, seemingly related to sleep patterns, in order to get a better understanding of their relationship and possible effects on children with NDD. The study also aimed to look at differences in sleep efficiency and adequacy in physical activity between typically developing children and children with low motor proficiency. Based on previous findings, the hypothesis was that sleep efficiency, motor proficiency, sleep latency, total sleep time, symptoms of ADHD and ASD, adequacy in, and predilection for, physical activity, anxiety/depression, and age would correlate. It was also hypothesized that children with co-occurring NDD would experience more sleep disturbances as comorbidity is suggested to increase the impairments resulting in more functional disturbances (Canchild, 2016, Rigoli & Piek, 2016, Missiuna et al., 2014).

In line with the hypothesis and previous studies, adequacy in, and predilection for physical activity was positively correlated with motor proficiency (Cairney et al., 2008). The positive correlation indicates that self-efficacy is associated with motor proficiency and that children with motor impairments are more likely to experience it. A positive relationship also emerged between adequacy and predilection, which could mean two things: children with low motor proficiency experience less enjoyment in physical activity because of their motor impairment, or the reduced feelings of enjoyment contributes to reduced participation, resulting in low motor proficiency. The positive relationship that emerged between indications of ADHD and indications of ASD supports the view of frequent comorbidity (APA, 2013). Indications of ADHD and indications of ASD also negatively correlated with movement proficiency. The negative correlation further strengthens previous findings of comorbidity, as low motor proficiency is one of the main characteristics for DCD. It also shows that the children who displayed indications of ADHD and ASD had lower motor proficiency, which is in line with common features of the disorders as described in Diagnostic and statistical manual of mental disorders: DSM-5 (APA, 2013).

As several NDD have been associated with higher levels of anxiety and depression (APA, 2013), the significant positive correlation between indications of ADHD and
anxiety/depression was expected. However, no correlation was found between anxiety/depression and indications of ASD, which can be an indication of several things, such as limitations of the instrument and insufficient statistical power. It could also mean that ADHD have a stronger association to anxiety and depression than ASD. Dopamine have been suggested to play a role in both anxiety/depression (Lee et al, 2015; Knab & Lightfoot, 2010) and ADHD (Knab & lightfoot, 2010; Gadow et al, 2014). Although, dopamine has also been suggested to be involved in ASD (Kriete & Noelle, 2015), the relationship between ASD and the dopaminergic system does not appear to be as clear. If dopamine plays a major role in both anxiety/depression disorders and ADHD, but not in ASD the differences in indications of anxiety/depression found in the current study, might be explained by ADHD and ASD’s different relationships to dopamine.

Motor proficiency was negatively correlated with anxiety/depression, which supports findings by Rigoli and Piek (2016) and Pearsall-Jones et al. (2011). This could either mean that anxiety/depression is a consequence of low motor proficiency, or that higher levels of anxiety/depression contributes to motor impairments (APA, 2013). Many social consequences associated with DCD, such as withdrawal from participation in physical activities and other social contexts are known risk factors for depression (Missiuna et al., 2014) but the symptoms of anxiety (e.g. exaggerated worries or fears, excessive caution and avoidant behaviour) as well as of depression (e.g. negative emotions and low self-worth) are likely to also cause further withdrawal and isolation. Insufficient physical activity, suggested by (Cairney & Veldhuizen, 2013) could possibly cause further impairments, due to lack of experience and training. Children with indications of anxiety/depression and ASD showed less adequacy in, and predilection for, physical activity. Kiluk et al. (2009) suggest that perceived ability will influence mental health, which the current finding supports. Characteristic of ASD is impairments in social communication and social interaction, restricted repetitive patterns of behaviour, interests or activities and motor proficiency (APA, 2013). Low perceived adequacy might be a result of the child’s perception of being different as well as actual motor problems. Children with ASD was in the current study also found to have lower scores on the predilection factor of CSAPPA which might reflect their impairments in social interaction as physical activity often involves a social component. Wrotniak (2006) suggested that the relationship between low motor proficiency and predilection could be a result of children being more easily fatigued, resulting in reduced feelings of enjoyment. Children with ASD, who often have a wide spectrum of deficits involving both motor, cognitive and social components (APA, 2013), are then likely to
experience excessive fatigue both physically and psychologically, which could explain why this population stands out in the context of predilection for physical activity. Predilection was also lower in children with indications of anxiety/depression, which was expected, due to the characteristics of the conditions.

As previously mentioned, the purpose of the study was to examine the relationship between low motor proficiency, co-occurring NDD and sleep with a main focus on sleep efficiency. The first hypothesis included that sleep-efficiency and total sleep time would be positively related to motor proficiency but negatively correlated with indications of NDD. A negative relationship between indications of ASD and total sleep time emerged in Pearson’s test of correlations, which could indicate that children with ASD have either more interrupted sleep or a longer sleep latency (the time between going to bed and falling asleep). Insomnia (problems with falling asleep) has been found to be the most common sleep disturbance in children with ASD (Robinson-Shelton & Malow, 2016; Liu et al., 2006). However, neither motor proficiency or indications of ADHD or ASD was significantly related to sleep efficiency which was an unexpected finding based on results of previous studies (Angriman et al, 2015; Dillon & Chervin, 2012, Liu et al., 2006). A high sleep efficiency was associated with a longer duration in total sleep time and shorter sleep latency which makes sleep latency an interesting variable to study further. If sleep efficiency is an outcome of the time it takes to fall asleep, the reason for differences in latency could be a key in improving sleep efficiency. Sleep disturbances are associated with a multifactorial etiology, where disturbances are caused by neurological, medical, and psychiatric factors (Angriman et al, 2015). A proposed neurobiological cause is changes in dopamine signaling, caused by arousal and physical activity. Dopaminergic activity is suggested to increase with locomotor activity (Berry et al., 2015) and an increase in locomotor activity has been associated with increased dopamine signaling contributing to alertness and wakefulness (Volkow et al., 2012).

The negative relationship, suggesting that high sleep efficiency is related to low perceived adequacy, is somewhat surprising, as high sleep efficiency were thought to be both physically and psychologically beneficial (Gruber, 2013). As low adequacy was identified in children with low motor proficiency, as well as associated with indications of ADHD and ASD, the negative relationship between adequacy and sleep efficiency might be explained by these children being more fatigued due to the impairments. The absence of correlations between sleep-related variables and low motor proficiency as well as NDD, indicates a need for alternative explanations to previous suggestions of sleep patterns and
their possible effect on the population of interest. Wrotniak (2006) and Chia et al. (2013) suggested that children with motor impairments had a higher energy expenditure due to impairments in activating and sequencing movement patterns (Chia et al., 2013). The higher energy expenditure are suggested to result in children being more easily fatigued, which would increase the need for sleep and therefore not cause any significant alterations in sleep compared to typically developing children.

The reason for the absence of correlations between sleep measures and motor proficiency as well as NDD might be a result of errors or insufficient specificity of the measure, since the validity of actigraph measures in special populations have been questioned, mainly due to low specificity found in previous studies. Significant discrepancies have been reported between measures derived from PSG and actigraphy measures in studies of children with intellectual deficits and motor handicaps (Sadeh, 2011). The expected outcome in terms of correlations and predicatability of age was unclear as few studies seem to have payed special attention to the age factor within their sample. A negative relationship between age and motor proficiency as well as adequacy in physical activity was identified. A possible explanation to older children diplaying lower motor proficiency, even if the test have shown to be a useful instrument for assessing suspected motor dysfunctions in children (Brown & Lalor, 2009), might be an effect of the MABC-2 test itself and its ability to correctly reflect age-related differences. Older children with low motor proficiency could also possibly have an increased awareness of their impairments whereby a possible explanation may be found in the self-efficacy theory. Cairney et al. (2008) found an association between less perceived adequacy (a component of self-efficacy) and sedentary time. As previously discussed, practice in performing motor skills are required to develop motor proficiency and as participation in physical activity, in the current and previous studies, have been found related to self-efficacy beliefs (Schoemaker & Smits-Engelsman, 2015), improved self-efficacy might be a key to increase participation and reduce physical and mental health problems common in children with low motor proficiency. Sleep efficiency was in the study found to improve with age. Skinner & Piek (2001) suggested children with DCD to experience more anxiety, have lower self-worth, less perceived social support and less perceived competency in several domains, including athletic competency. A comparison between children and adolescents showed that the negative feelings were significantly higher in adolescents, hypothesized being a consequence of the cumulative effect of failed mastery attempts (mastery being an important component for developing self-efficacy) and increased accuracy in terms of self-judgments. If movement impairments result
in more fatigue due to a higher energy expenditure, as were reflected on previously, it is also possible that increased emotional problems will have a similar effect, resulting in higher sleep efficiency.

The multiple regression conducted to examine the predictability of sleep efficiency, through the variables of interest, revealed a significant model explaining 44.8% of the variance in sleep efficiency. Sleep latency, total sleep time and age were significant predictors. Age and total sleep time were positively correlated with sleep efficiency but sleep latency had a negative relationship to the predictor variable. Motor proficiency, adequacy in and predilection for physical activity, indications of ASD, ADHD and anxiety/depression were not significant predictors whereby the result indicates that low motor proficiency, co-occurring NDD, adequacy in, and predilection for physical activity and anxiety/depression does not have a significant impact on sleep efficiency. However, further studies are important as the result could be attributable to limitations in the design of the study. Total sleep time and sleep latency, were the only variables, except age, to predict sleep efficiency. The intercorrelation between the sleep-related variables is important to acknowledge as it can cause problems when trying to draw inferences about the relative contribution of sleep latency and total sleep time on sleep efficiency (Brace et al., 2013). It is possible that the explained variance could be attributed to one single sleep variable, whereof continued studies, examining the contribution of each variable is recommended.

The second hypothesis suggested a difference between typically developing children and children with low motor proficiency, and that children with co-occurring NDD would experience more sleep disturbances as comorbidity have been suggested to increase functional disturbances (Rigoli & Piek, 2016). The absence of differences between groups as well as the absence of interaction effect between low motor proficiency and co-occurring NDD supports results of the multiple regression where neither motor proficiency or co-occurring NDD were found to be predictors of sleep efficiency. As adequacy was significantly related to variables in all measured categories, examining the difference between the groups; low motor proficiency and typically developing children on adequacy in physical activity was motivated. However, there were no significant differences in terms of adequacy between the groups and no interaction effect was identified.

The absence of relationships between sleep efficiency and other sleep-related variables, as well as the finding that there were no differences between groups or interaction effect of comorbidity means the null hypothesis can not be rejected.
Sleep was recorded for 4 nights, which might not be enough to get an accurate measure as recordings of 5 nights have been found appropriate for achieving reliable measures in children and adolescents (≥ .70) according to Acebo et al. (1999) and Sadeh (2011). Actigraph recordings have also been found to have limitations in terms of specificity detecting wakefulness within sleep periods, which is affecting the validity and needs to be taken into account when reading the result. The validity of the instrument have been questioned in special populations, and in individuals with sleep disturbances, as factors such as motor handicaps showed discrepancies between polysomnography (the gold standard measure) and actigraph measures in a study comparing the two instruments (Sadeh, 2011).

Measures of self-efficacy towards physical activity, indications of ADHD and ASD as well as measures of possible anxiety/depression was measured through questionnaires, which are subjective measures and therefore means their comparability can be questioned. The subjectivity is an issue both in the use of parent-rating scales (AQ-10 and VADPRS) and self-ratings scales (Wilson & MacLean, 2011).

The cut off between typically developing children and children considered to have low motor proficiency were at the 16th percentile. According to the MABC-2 examiners manual, scores at or below the 16th percentile indicates that the child have is at risk of having a movement difficulty. Scores at or below the 5th percentile suggest a significant movement difficulty (Henderson et al., 2007). Using the 5th percentile as the cut off level between typically developing and low motor proficiency children might have showed a different result.

**Limitations**

The unequal group sizes were a limitation with the study. The distribution of participants based on motor proficiency was relatively equal (low motor proficiency = 48.8%, typically developing = 51.2%), but with other variables, such as indications of ADHD, ASD and anxiety depression, the group sizes were unequal, compromising the power of the study. As power is based on the smallest sample equal-sized groups have more power than unequal-sized groups when N is the same (Karen, 2017). Unequal sizes were expected, as deviations from the normal are less common also in a greater population.

Because of their nature, normality could not be assumed for the majority of the variables. Normality is said to be a requirement for parametric statistical testing (Wilson & MacLean, 2011). Parametrical tests have been found to be robust even when parametrical requirements are not met. For instance, when comparing t-test to its non-parametrical equivalent, Fagerland (2012) found that the use of non-parametric tests are sometimes used
unnecessarily, and it is suggested that non-parametric tests are best for small sample sizes and might give in misleading answers when sample size is large. Fagerland’s (2012) findings are supported by Lumley, Diehr, Emerson & Chen (2002) who found that both t-test and linear regression are valid for any distribution if the sample size is sufficient. It can be argued that the study did not use a large enough sample for this to be applicable. However, Lumley et al. (2002) suggest the number of participants large enough for t-tests and linear regression is less than 100, which supports the use of parametrical statistical tests in the current study. Pallant (2011) additionally argues that violations of the assumption of normality will not cause major problems with a large enough sample size (e.g. 30+). Since parametrical tests have been found to be robust even with some deviations from parametrical assumptions (Lumley et al., 2002) parametric tests were utilized, since no non-parametrical equivalents to the statistical analysis used in this study was appropriate for the purpose.

A benefit with the use of parametric tests are the higher statistical power (Brace et al., 2013; Wilson & MacLean, 2011). As the response rate of AQ-10 and VADPRS were relatively low, the sample size was effected. A small sample have less statistical power and therefore less chance of detecting an existing effect. It is suggested that the power should be at least 0.8 as that means the chance of obtaining a significant result is more than 80%. The recommended power was not achieved in the two-way ANOVA on either sleep efficiency or adequacy in physical activity, which possibly could explain why no significant effects were found.

A convenience sample was used for the study whereby it is possible that the participants are not representative for the population (Wilson & MacLean, 2011). Moreover, the sample only consisted of children from Perth, Western Australia, which might have implications for the generalizability of the result. It is also worth mentioning that the sample consisted of more males (64.6%) than females (35.4%). As DCD, ADHD and ASD are more prevalent in males (APA, 2013) the overrepresentation of males should not compromise the samples representativeness greatly. The AQ-10 and VADPRS were coded 1 for no indications and 2 for indications of ASD respectively anxiety/depression. For the current study theses variables were considered to be categorical but not dichotomous, since both conditions are more or less prevalent with varying degrees of impact on the child. There were no randomisation of participants as distribution to groups were dependent on naturally existing conditions, such as low motor proficiency or existing symptoms of NDD. The quasi experimental design also means there were limitations in terms of control of confounding variables. It is therefore possible that there are other variables involved contributing to the result (Wilson & MacLean,
The lack of control is particularly evident with sleep measures as they were recorded in the children’s homes. However, the ecological validity of the study should be relatively high due to the natural setting (Wilson & MacLean, 2011).

The relatively large amount of non-response on sleep measures, and the questionnaires, AQ-10 and VADPRS in particular, should be considered as it may have further implications than just result in a smaller sample. For instance, the respondents might differ from the non-respondents, which could have had a significant impact on the result. As both AQ-10 and VADPRS are filled out by the child’s parent/caregiver it could possibly indicate differences in home environment.

As the study was part of an ongoing study the instruments were not selected specifically for the current study, whereof other measures may have been more suitable. However, being part of another study was beneficial in terms of sample size and the amount of variables that could be examined. The possible disadvantages of existing measures are not considered an issue as the instruments used are well established (Allison, et al., 2012; Wolraich et al., 2003; Sadeh, 2011; Hyde et al., 2007; Schoemaker et al., 2012; Brown & Lalor, 2009; Cairney et al., 2007).

**Further implications**

The lack of correlations is interesting as it shows that sleep itself might not be a primary cause or even a significant effect of NDD or the physical and psychological consequences associated. However, the correlational analysis did find adequacy in physical activity to be significantly related to motor proficiency, indications of ASD, anxiety/depression, sleep efficiency, age and predilection towards physical activity. The relationship between both sleep, physical and psychological variables indicates that perceived adequacy might be an important factor in terms of finding ways to improve physical and mental well-being. Adequacy in, and predilection for, physical activity had the strongest relationship, likely showing that feeling capable are increasing positive emotions towards physical activity. Adequacy and predilection for physical activity have been suggested important for participation in physical activity (Hay, 1992; Cairney et al, 2008) which is important for physical and mental well-being (Hay, 1992; Cermak et al., 2015). Physical and mental well-being have been associated with more sleep disturbances (APA, 2013; Chorney et al., 2008) and sleep seems to be an important factor for optimal development and everyday functioning (Gruber, 2013). Instead of sleep being the factor to focus on in terms of improving quality of life for children with low motor proficiency and co-occurring ADHD and ASD, some
attention on the role of self-efficacy is suggested. Providing the right conditions for physical activities, where the children can improve and feel adequate, will likely increase feelings of enjoyment, boost participation and result in more experience. More experience are then likely to result in improved proficiency which could positively affect self-efficacy. Physical activity have been found to reduce symptoms of anxiety and depression and if depression and anxiety are mainly the cause of environmental factors, as suggested by Pearsall-Jones et al. (2011), there might be a chance to increase mental well being in this population by providing children with the support they need.

**Conclusion**

The current study does not provide information about causality but is still valuable as the findings can serve as a basis for further research. As previously mentioned, a greater understanding of how sleep patterns and motor proficiency are related, as well as possible influencing factors and their effects on physical and psychological well-being, is important in terms of how to approach the issues to prevent and minimize the negative consequences of low motor proficiency and NDD in children. The current study did not find sleep latency, sleep efficiency or total sleep time to be significantly correlated with motor proficiency, ADHD or ASD, except for ASD that seemed to be associated with a shorter total sleep time.

**Future research**

The development of movement skills and perceived sports competence in childhood have been associated with higher levels of fitness and more participation in physical activity in adolescent by Cairney et al. (2008). Their suggestion, together with the result of the current study, motivates future longitudinal studies where changes in motor proficiency, self-efficacy and participation in physical activity can be monitored over a period of time. For future studies it would be relevant to further examine both possible neurobiological and environmental correlations and also look for causal relations. As the current study, contrary to previous studies, did not find a relationship between sleep efficiency and low motor proficiency or ADHD and ASD, it would be of particular interest to look at how low motor proficiency, and emotional disturbances affect the child both physically and psychologically possibly increasing fatigue and sleepiness as a result of higher energy expenditure.
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