Chapter 4

Sleep in Down Syndrome

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Abstract

Sleep disorders are common, often overlooked problem in Down syndrome, particularly during childhood. Comorbidities such as congenital heart disease often present early and management of these needs to take priority. However, this can result in the lack of early development of good sleep habits and may also lead to the perception that sleep issues are an expected problem in children with Down syndrome, which do not require intervention. Studies have shown that sleep problems continue to be under-reported by parents of children with Down syndrome, even though conditions such as obstructive sleep apnoea are up to six times more common in this population. Therefore an understanding of the nature of sleep problems in Down syndrome is important for anyone working with this group. In this chapter we provide an overview of this topic, highlighting the key sleep issues encountered by children with Down syndrome, as well as providing a general approach to evaluation and management.

Keywords: Down syndrome, child, sleep, paediatrics

1. Introduction

Down syndrome (DS) or Trisomy 21 has an estimated prevalence ranging from 1/650 to 1/1000 live births [1–3], with over 270 affected babies born in Australia per year since 2007 [4]. It is the most common genetic cause of significant intellectual disability [5]. The condition is characterised by decline of IQ during infant and toddler years, well-documented impairments in the assimilation and expressive use of language, as well as in cognitive flexibility and memory [6]. Large inter-individual differences are seen within the DS population and numerous factors including genetics, epigenetics, early neural development and the environment are thought to have a role in how the DS phenotype expresses itself in each individual [7]. Variation in sleep patterns and sleep disruption, has been highlighted as another potential factor that could contribute to the wide phenotypic differences in DS; individuals with DS often have sleep fragmentation

due to common co-existing sleep disorders [8–15]. The degree of sleep difficulties in an individual with DS may be important in determining their predisposition to cognitive decline, by contributing to pathological ageing [16].

2. Prevalence of sleep disorders in children with Down syndrome

Several clinical features of DS potentially lead to disturbed sleep and/or increased risk for sleep disordered breathing (SDB). However, not all of these characteristics are present in every child, and when present, vary in intensity [5]. Obstructive sleep apnoea (OSA) results from hypotonia, macroglossia and midface hypoplasia. Progressive obesity is an additional risk factor. Children with DS are also at increased risk for congenital heart disease, pulmonary hypertension, leukaemia, ear infections and scoliosis, [17] all comorbidities potentially associated with disrupted sleep [5].

Polysomnography (PSG) sleep studies undertaken in children with DS all suggest a much higher prevalence of OSA in children with DS compared to the 1–5% prevalence in the general paediatric population [18]. Studies estimate prevalence of OSA in children with DS ranging between 31 and 79% [8–10, 19, 20]. This wide range may be due to differences in study design; mean age of the children varied, with some groups using non-referred community-based samples [8, 9, 19, 20] and others including mixed groups with some participants who had been specifically referred with sleep concerns [10]. Individual groups also defined OSA differently, with some using higher cut-offs for apnoea-hypopnea (AHI) index than others. More accurate prevalence data comes from studies where the population has been better defined. Shott et al. [21] looked only at pre-school children with DS aged 2–4 years and found up to 80% had abnormal PSG results with 57% having evidence of OSA (defined as AHI >1/h). Others have shown that the prevalence of OSA remains high up to early school years [22]. Fitzgerald et al. [12] studied a referred sample of DS children who snored, reporting a mean AHI of 12.9/h, in 32/33 (97%) children. In the largest PSG study to date, Maris et al. [23] found a prevalence of OSA of 66.4% (AHI > 2.0/h) in 122 children with DS, with and without positive history for OSA, who underwent full overnight PSG. Importantly, even in those with a negative history for OSA, the prevalence was 53.8%. Regardless of the differences in study design, it is clear that the prevalence of OSA in children with DS is much higher than that in otherwise healthy children, being at least six times more common in DS.

Information regarding the prevalence of non-respiratory sleep difficulties in children with DS is obtained largely from questionnaire-based studies of parental report and is therefore subjective. Bedtime resistance, sleep anxiety, night waking, parasomnias and daytime sleepiness have all been reported commonly in children with DS [11, 13–15, 24]. Carter et al. [11] used the Child Sleep Habits Questionnaire (CSHQ) and found that parents universally reported sleep problems in school-aged children with DS that persisted into teenage years. Maris et al. [25] reported an overall prevalence of sleep problems of 74.1% in children with DS using the same questionnaire, with no correlation between sleep problems and underlying OSA. In a large email study of parents of children with DS, Rosen et al. [14] reported difficulties initiating sleep in 138/253 (51.8%) and difficulties maintaining sleep in 175/252 (69.4%) of children,

with over half of the children (51.4%) described as having some degree of excessive daytime sleepiness. The response rate for this survey was only 46.5% from those contacted and therefore these results may not be truly representative of the entire population. However, similar findings have been shown by other groups [13].

3. Individual sleep disorders in children with Down syndrome

3.1. Obstructive sleep apnoea

Obstructive sleep apnoea (OSA) (**Figure 1**) refers to the presence of prolonged episodes of increased respiratory effort, associated with partial or complete upper airway obstruction and various combinations of snoring, intermittent hypoxia, hypercarbia, restless sleep, and increased number of awakenings [26]. Children with DS are anatomically at risk due to midfacial and mandibular hypoplasia, relative macroglossia with a posterior tongue position, a shortened palate and narrowed nasopharynx. Hypotonia may also contribute to airway

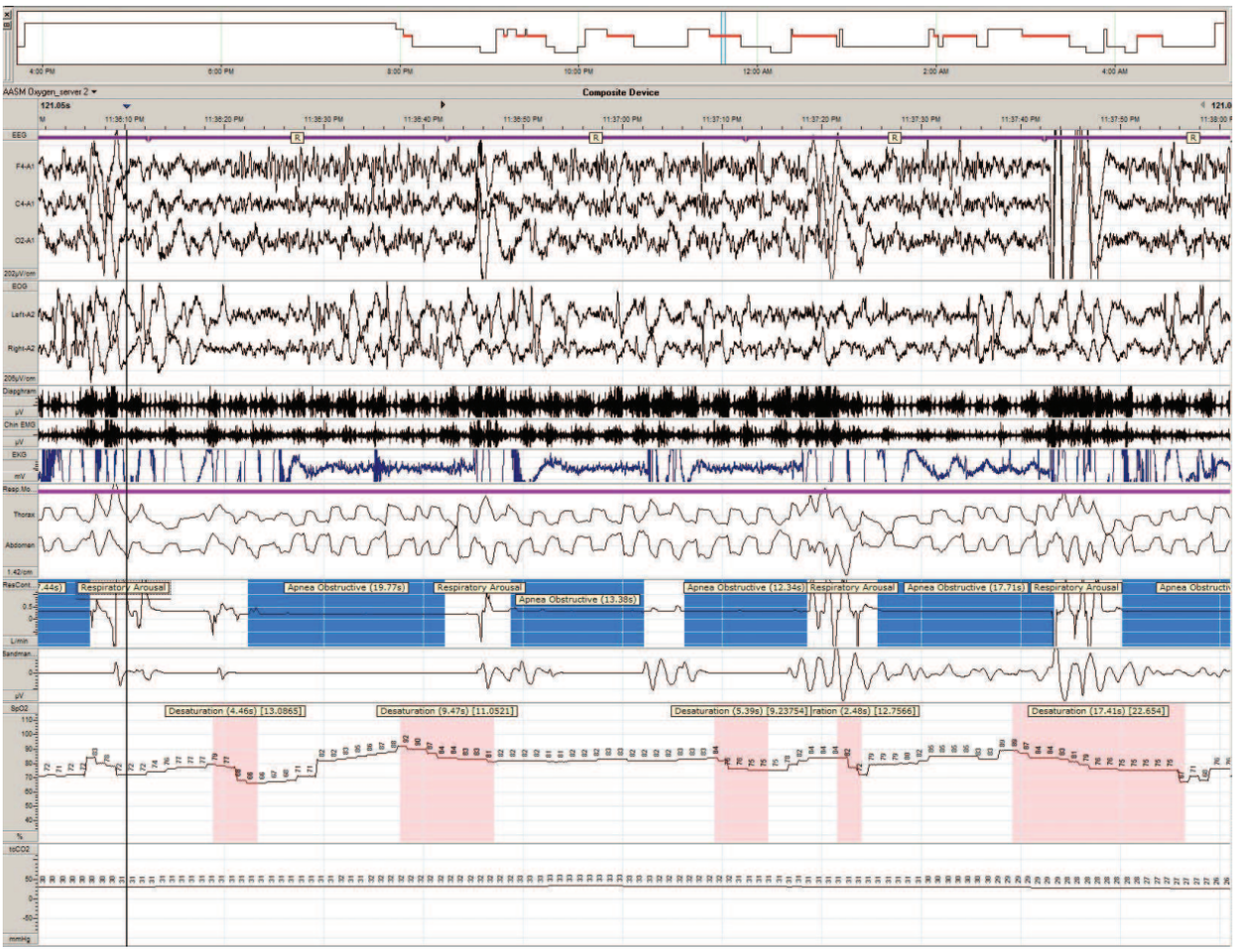

Figure 1. Diagnostic polysomnography (sleep study) recording demonstrating severe OSA-obstructive sleep apnoea in a 3 year old child with Down syndrome. Repetitive obstructive apnoeas are seen with absence of airflow but persisting and paradoxical respiratory effort. Associated respiratory arousals and oxygen desaturations (SpO2) are seen >3%.

collapse during sleep [27]. Lingual tonsil hypertrophy is also more common in DS with an 11-fold increase in incidence relative to typical controls [28]. Progressive obesity is an additional contributing risk factor and co-existing conditions such as gastro-oesophageal reflux disease, hypothyroidism and airway abnormalities such as laryngomalacia, subglottic and tracheal stenosis, which are more common in DS, may further exacerbate OSA [29]. Severity of OSA in DS often waxes and wanes, subsiding transiently through school age, due to growth and improved tone, but then reoccurring with onset of obesity in adolescent years.

International guidelines therefore recommend screening for OSA in children with DS [30, 31] but methods for screening are variable, largely due to available resources. The simplest method for screening is through clinical history from parental report. However, this often does not correlate with PSG findings; In their study of 65 children with DS, Shott et al. found that 69% of parents reported no sleep problems, yet 54% of these children had abnormal PSG [21]. Marcus et al. had similar results with only 32% of parents reporting clinical suspicion of OSA, despite a 100% incidence of abnormal study results [10].

Oximetry as a screening tool for OSA specifically in children with DS has had limited evaluation with conflicting results from available studies [32–34], which may be explained by differences in sample size. Increased sensitivity of oximetry to detect OSA may be possible through use of the McGill oximetry score [35] but further evaluation of this method is required before it can be recommended for clinical practice. Central events are recognised to occur with increased frequency in children with DS and may lead to difficulty with interpreting oximetry data [34] with respect to OSA. Similarly there may be more night-to-night variation of oximetry results in children with DS due to difficulties in achieving technically adequate monitoring [36]. Combined data from oximetry, parental report, actigraphy and audio-visual recording of sleep at home may overcome these difficulties, and provide a feasible method of screening for sleep disorders in children with DS [37].

At present, PSG (in-lab sleep study) remains the key investigation for diagnosis and quantification of OSA in DS. Sleep fragmentation, frequent awakenings and arousals and periodic leg movements are characteristic features described from early PSG studies in children with DS. These appear to occur with and without features of OSA [27]. Compared to controls, children with DS have been shown to have lower sleep efficiency and higher percentages of slow wave sleep (SWS) as well as reduced rapid eye movement (REM) sleep [38]. Mean oxygen saturation was also lower in children of all ages with DS and, in children aged 2–6.9 years the oxygen saturation nadir was lower in the DS subjects compared to controls. Another group have also demonstrated that children with OSA and DS had a similar symptom profile but slightly worse gas exchange than closely matched controls with OSA of similar severity [33]. This increased vulnerability to OSA may be partly due to the relative hypotonia and blunted cardiovascular responses seen in children with DS [39]. Congenital abnormalities in the pulmonary vasculature also increase the risk of pulmonary hypertension in DS [40].

Treatment of OSA in DS is not dissimilar to that in the TD population. Conservative measures such as weight loss and pharmacological treatments, including intranasal steroids or oral cysteinyl-leukotriene receptor antagonists (e.g. montelukast), can be tried in the first instance. Adenotonsillectomy (AT) remains the mainstay of treatment but has been shown to be associated

with a higher respiratory complication rate [41] and appears to be less successful at treating the OSA in the DS population; Subjectively from parental report, Rosen et al. [14] found that out of 83 children with DS who had undergone AT, 38 (47.5%) continued to have witnessed apnoea and 22 (28.9%) continued to gasp and choke during sleep more than once a month. Objectively, three groups have shown that post AT, OAHI is reduced but does not fully normalise in this population, with approximately half of all children consistently shown to have a degree of residual OSA in all three studies [42–44]. All studies were however retrospective and included small numbers of patients. Two recent systematic reviews assessing outcomes post AT in DS children with OSA highlight the limited objective data available and also discuss some of the additional difficulties with drawing conclusions from existing evidence [45, 46]. The OAHI cut-offs taken to indicate benefit of surgery varies between studies and follow up times at which repeat PSG was performed also varied. It is also not clear from all studies whether repeat evaluation with PSG was performed in all patients post surgery or only those with residual symptoms which may introduce bias, with a paucity of data from those who may have improved. Nevertheless, despite these issues, the estimates of residual OSA have been reassuringly consistent and therefore cannot be entirely disregarded. In addition to the propensity for upper airway collapse and hypotonia, children with DS have multiple other comorbidities such as obesity and hypothyroidism, which likely contribute to the reasons why OSA persists in this group.

A variety of other surgical procedures including uvulopalatopharyngoplasty, lingual tonsillectomy, supraglottoplasty, partial midline glossectomy and tongue suspension with or without lingual tonsillectomy can be considered in children with persisting OSA post adenotonsillectomy. However, currently there is limited evidence to support the routine use of these procedures [47]. The benefit of these more aggressive surgical options for OSA specifically in the DS group is also unclear; Merrell and Shott [43] evaluated the use of lateral pharyngoplasty with adenotonsillectomy in the initial treatment of OSA in children with DS and found no additional benefit when compared to adenotonsillectomy alone. Wootten et al. [48] published their experience using combined genioglossus advancement and radiofrequency ablation of the tongue base in children with OSA refractory to AT. Successful treatment using this method (defined as a decrease in apnoea-hypopnea index, AHI, to <5/h on polysomnography, PSG) occurred in 12/19 patients with DS included in this study, suggesting this may be a promising option for future use but larger studies are required. The role of pre-evaluation of the airway with drug-induced sleep endoscopy (DISE) and cine magnetic resonance imaging (Cine-MRI) to direct surgical options for persistent OSA continues to undergo evaluation. However, these techniques have not yet been clearly linked to outcomes [47].Therefore, at present conservative treatment with continuous positive airway pressure (CPAP) or less commonly, bi-level (BPAP) therapy, is often preferred for management of residual OSA, preventing the need for further invasive surgical procedures including tracheostomy. Such therapy is however challenging in paediatrics and even more so in patients with DS, where behavioural and intellectual impairment may hinder the establishment and adherence to therapy. This may in particular apply to those children with comorbidity such as autism. Trois et al. [49] showed that in nine adults with DS who were prescribed CPAP, five had excellent compliance and experienced improvements in daytime functioning and excessive daytime sleepiness. Rosen [50] reported use of CPAP in three infants with DS and demonstrated spontaneous

resolution of OSA after several months of use. Aside from this and early case reports, little has been published relating to CPAP use in the DS paediatric population.

3.2. Central sleep apnoea

Ferri et al. [51] 1st recognised the increased preponderance of central apnoeas (cessation of airflow and respiratory effort) in DS, which occurred in 89.4% of their patients (n = 10) irrespective of the presence of OSA (**Figure 2**). Coverstone et al. [34] reported that 32/119 (26.9%) children with DS had central apnoea indices ≥2.5/h on PSG, with 13 subjects (10%) having more central events than obstructive events. Another group found a prevalence of CSA (defined as central apnoea index CAI ≥1/h) of 41.6% in their study of 36 children with DS who underwent PSG evaluation [52]. In this study, AT for treatment of OSA resulted in resolution of CSA in 10 of these patients (66.7%). The mechanism behind this reduction was unclear and only a small number of children were included. Exactly what defines an abnormal CAI level in children, and particularly those with neurodevelopmental conditions, is unclear. Although a CAI > 1/h is by convention diagnostic of CSA, a CAI up to 5/h has been reported in healthy children up to the age of 13 years [53, 54]. Dysfunction of central respiratory control at a brainstem level

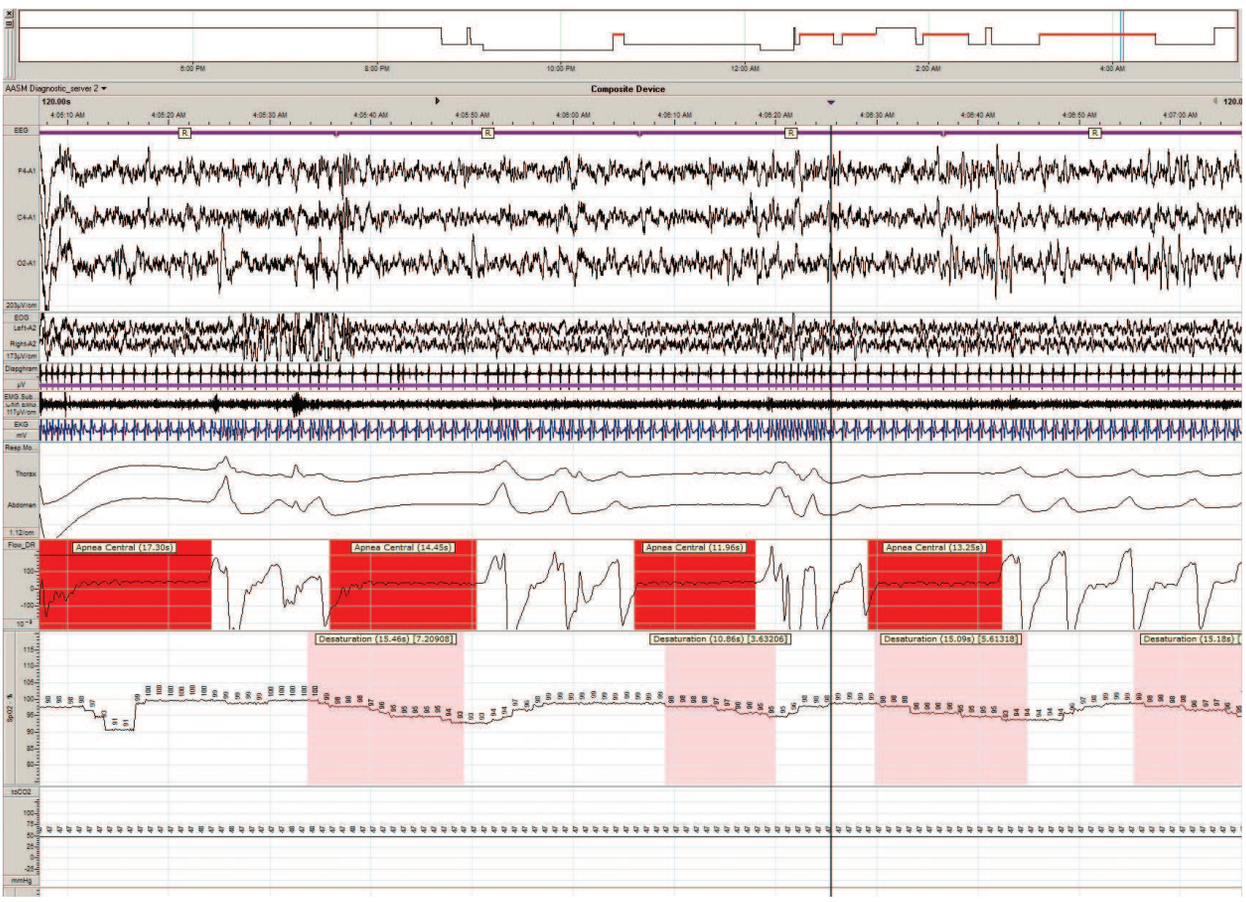

Figure 2. Diagnostic polysomnography (sleep study) recording demonstrating CSA-central sleep apnoea in a 6 year old child with Down syndrome. Repetitive central apnoeas are seen in a periodic breathing pattern, with absence of airflow and respiratory effort. Associated oxygen desaturations (SpO2) are seen >3%.

has been proposed as a potential aetiology for CSA in DS [51]. This could help to explain why there is an increased propensity for CSA in the very young DS group, who have immature respiratory control combined with hypotonia, which lessens over time [55]. Specific management and outcomes of CSA in DS have not been well described. A general approach would be to provide supplemental oxygen, with careful monitoring of carbon dioxide levels to ensure no increase occurs. Alternatively, if CSA is severe, non-invasvive ventilatory (NIV) support may be required to correct associated hypoxemia and hypoventilation with regular re-evaluation to monitor for spontaneous resolution of symptoms with age.

3.3. Non respiratory sleep disorders & circadian rhythm disorders

Studies have shown that bedtime resistance, sleep anxiety, night waking, parasomnias and daytime sleepiness are reported commonly in children with DS [11, 13–15]. These problems appear to begin at an early age and may continue to persist with increasing age. They also appear to persist despite treatment of OSA; Bassell et al. found that among 108 children with DS who had undergone AT for OSA, 55 (51%) continued to have sleep problems specifically in night awakenings, restless sleep, snoring and daytime sleepiness [56]. This would suggest that the sleep disruption seen in children with DS is not solely related to SDB, but is rather a feature of the condition itself. As seen with other disabilities, the child's intellectual limitation or communication problems may interfere with the acquisition of good sleep habits. Similarly the pressures associated with raising a child with developmental delay may impact parenting abilities, including the ability to cope with their child's sleep problems [57]. Comorbidities are also frequently described in children with DS and management of these can often take priority over the need to attend to sleep difficulties. Many of these can further exacerbate sleep problems either by increasing the risk for sleep disturbance in their own right, or by requiring the administration of medication that disrupts sleep continuity. The best example of this would be the use of stimulant drugs for attention-deficit-hyperactivity disorder (ADHD), a condition which has a high prevalence in children with DS [58].

Assessment of non-respiratory sleep disorders generally begins by obtaining a thorough sleep history from the child's main carer, gathering information on usual sleep habits and main areas of difficulty (e.g. difficulties with sleep onset through bedtime resistance or frequent night wakenings). Asking the parent/carer to keep a written sleep diary at home over a 1–2 week period, documenting the child's sleep over this time can be a useful way of gaining further details regarding usual routines.

Actigraphs, which are small movement detectors (accelerometers) placed on the child's wrist, can distinguish sleep from wake using algorithms to quantify the reduced movement associated with sleep. They have been shown to be a reliable method for determining sleep in children when compared against polysomnography (PSG) [59]. For clinical use the American Academy of Sleep Medicine recommends use of actigraphy for delineating sleep patterns and to document treatment responses in normal infants and children, and in special paediatric populations [60]. Objective data using actigraphy to assess sleep patterns in children with DS is limited. Chen et al. [61] found that children with disabilities in general experience difficulty with initiating sleep and maintaining sleep. However, the exact number of children with DS

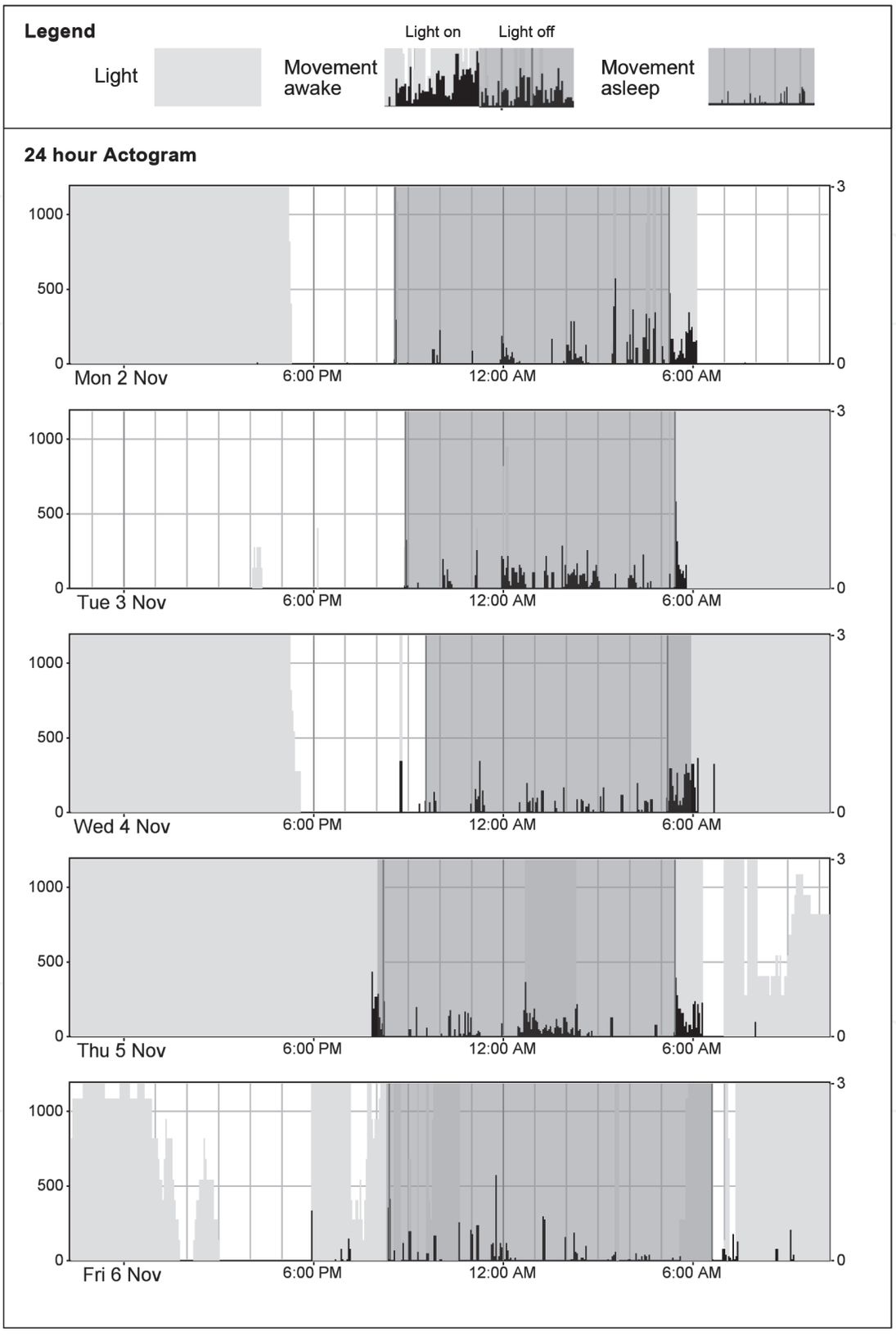

Figure 3. Example of how actigraphy demonstrates sleep-wake patterns recording shows variable sleep time, intermittent difficulty with sleep onset, restlessness and some overnight wakening.

in this study is not clearly specified. Ashworth et al. [62] undertook a cross comparison of sleep problems in children with DS and Williams syndrome (WS) using actigraphy. Children with DS were found to have disrupted sleep, with considerably more night wakings, wake after sleep onset (WASO) and lower sleep efficiency than children with WS and TD controls. These studies suggest that actigraphy is feasible to undertake in children with DS and may be a useful tool to provide more objective data regarding sleep problems in this group in the future (**Figure 3**).

Several of the issues that lead to sleep difficulties in children with DS also present challenges in evaluation and management. Poor parental perception of sleep problems leads to under-reporting of these symptoms and therefore a lack of recognition and subsequent treatment by physicians. Due to the brain abnormalities present, sleep physiology and sleep-wake patterns may differ in this population resulting in children struggling to learn aspects of how and when to fall asleep. Studies investigating sleep and rhythm-related disturbances using mouse models of Down syndrome have consistently shown abnormal parameters but further study in human subjects is still required [63]. Psychological parental factors in this group likely impact on the ability to achieve a consistent, disciplined approach to their child's sleep pattern and to instil independent sleep habits [64]. Measures that are utilised in the TD such as parental education to encourage healthy sleep habits, behavioural interventions and selective use of pharmacological treatments such as melatonin can be used in children with DS. However, efficacy studies assessing response are limited in this group and success is likely to be dependent on parental capabilities and commitment, as well as the child's willingness and ability to comply [57].

Therefore currently, treatment options for non-respiratory sleep disorders in children with DS are not dissimilar to those for the TD. Good sleep hygiene as defined by routine, clear expectations and limit setting, self-calming strategies and management of light/dark are key to successful implementation of sleep initiation and scheduling challenges.

4. Potential impact of sleep disorders in children with Down syndrome

The adverse effects of poor sleep are increasingly recognised with studies in TD children describing substantial morbidities affecting the central nervous system (CNS), cardiovascular, metabolic systems and somatic growth, ultimately leading to reduced quality of life [65]. Children with DS are more vulnerable to these complications as they are already at high risk for some of these conditions. For example, infants with DS have been shown to have a higher prevalence of pulmonary hypertension [40], which is also associated with OSA in patients with DS [66] and therefore cardiovascular complications of OSA are likely to be even more dangerous in patients with DS as compared with patients without DS [29].

Of particular relevance to the DS population is the mounting evidence in TD children regarding the negative impact of sleep deprivation [67] and SDB [68–73] on cognition, behaviour and academic performance. Sleep disruption in children with neurodevelopmental disorders

may exacerbate learning difficulties and disturbed behaviour that are part of the developmental disorder itself [38]. The high prevalence of sleep disorders during childhood may make children with DS particularly susceptible to ill effects during critical periods of cognitive development. Small cross sectional studies have found deficits in IQ [6], cognitive and behavioural function [74–77] and accomplishment of daily activities [78] in children with DS and co-existing sleep problems, suggesting an association between poor sleep and these deficits in this group. The age range evaluated in these studies has varied with some groups concentrating on pre-school children with DS [75–77] and others examining older children [6, 74, 78]. All the studies evaluating cognition and behaviour include very small numbers of children with the largest being an un-referred community sample of 38 individuals. The differences in study design used by each group makes it difficult to combine findings from these small reports for meta-analysis, with the major difficulty being the different measures used by each group. Some have used formal assessment with PSG or cardiorespiratory polygraphy to identify sleep problems, focusing primarily on the presence of SDB, whereas others have relied on questionnaire-based parental reports of broad sleep problems, primarily using the Child Sleep Habits Questionnaire (CSHQ). The cognitive and behavioural outcomes evaluated have also differed greatly with some groups undertaking batteries of tests examining various different aspects of cognitive and behaviour performance and others concentrating on a specific area, such as executive function or language. Three groups clearly stated that the participants were from community samples whereas in other studies this was not clearly defined. Control groups of TD children for comparison were included in some designs but not others. Despite this heterogeneity in study methodology, results do consistently suggest an association between sleep and cognitive and behavioural outcomes. Two studies have examined inter-group differences; comparing DS children with sleep and without sleep problems. Breslin et al. [6] compared 19 children with DS and comorbid OSA on PSG (AHI > 1.5/h) with 12 children with DS and no OSA. This study convincingly demonstrated worse outcomes in the OSA group with a 9-point difference in Verbal IQ and impairments in cognitive flexibility in children with DS and comorbid OSA, compared to those without OSA. Edgin et al. [75] divided their group of pre-school children with DS into poor sleepers (DS PS) and good sleepers (DS GS) using actigraphy data and compared them to each other, as well as to TD controls, assessing language skills and behaviour. Strikingly they found that only 31.6% of children with DS in the PS group were combining words, as compared to 80% of good sleepers. Additionally poorer language was shown to relate to the level of sleep disruption.

Only one group has assessed the association between sleep and functional ability in children with DS. Churchill et al. [78] conducted a large internet based cross sectional survey study which included 110 parents of children with DS and 29 parents of children with TD aged 5–18 years. They found that sleep disturbances, assessed with the CSHQ, were negatively related to accomplishment of daily life functions described using the Life Habit questionnaire (Life-H). This finding is an important one as it suggests that sleep disorders in this population have significant impact of daily life and this has wider implications on how these children may function later in life. As the authors point out, the unanswered question is whether treating sleep problems in children with DS leads to improved accomplishment of daily life habits and other important life outcomes. Further work in this area is necessary as improved understanding of the interaction between sleep and functional outcomes in this group may lead to

significant long-term benefits for these children. It may also help to inform researchers who are currently working to understand the role of poor sleep and increased risk of development of Alzheimer's disease seen in adult patients with DS.

5. Summary

Understanding that children with DS are high risk for a variety of common sleep problems and the potential impact of this on both the child and their family is essential for health professionals working with this population. Existing international guidelines recommend regular screening for sleep problems as part of routine clinical care for children with DS [30, 31]. However resources for sleep evaluation are limited and an awareness of the potential negative impact of untreated sleep problems in this population is lacking among both clinicians and parents. Currently there is wide variation in practice relating to this area, with often the perception that these problems can be ignored and left untreated in children with DS as these children already have established intellectual disability. The fact that treatment is often more challenging in DS compared to TD children can also contribute to the lack of attempt to treat sleep disorders in this group. Treatment options are similar to those in TD children but have less successful outcomes. In particular many children are left with residual OSA, highlighting the need for further evaluation of strategies that may improve toleration of conservative measures such as CPAP therapy, as well as exploring newer surgical options to determine specific benefit in this population. Other areas of future research include improving the understanding of the link between poor sleep and long-term outcomes in children with DS, which may assist in improving quality of life and independence for this population, through earlier treatment of sleep difficulties using specifically tailored sleep programmes.

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