

ORIGINAL ARTICLE

Sleep quantity and its relation with physical activity in children with cerebral palsy; insights using actigraphy

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Aim: To objectively assess the sleep quantity, and explore the relationships between sleep quantity and quality, and physical activity and sedentary behaviour in children and adolescents with cerebral palsy (CP).

Methods: An observational cross-sectional study was conducted. In total, 36 children with spastic CP (mean age 15y 4mo, SD 2y 6mo; classified as Gross Motor Function Classification System levels I (25), II (9), III (1) and IV (1)) were included. Active time, sedentary time and sleep quantity were measured using an activity monitor for 7 consecutive days.

Results: Total sleep duration of children with CP ranged between 7.2 and 11.2 h. No significant correlations were found between active time and sleep quantity for total week, weekdays, and weekend days. Moderate negative correlations were found between sedentary time and sleep quantity during total week ($r = -0.456$, $P = 0.005$), weekdays ($r = -0.453$, $P = 0.006$) and weekend days ($r = -0.48$, $P = 0.003$).

Conclusions: Our findings suggest that children with CP are getting the recommended sleep duration, and that sedentary behaviour is correlated with sleep quantity in children with CP and may be more applicable to children with better motor functions. Future studies using more elaborate, objective sleep quantity and quality measures are recommended.

Key words: cerebral palsy; children; physical activity; sedentary behaviour; sleep.

What is already known on this topic

- 1 Sleep deficiency has a negative impact on growth and development.
- 2 Interventions based on changes in physical activity and sedentary behaviour can influence sleep quantity and quality.

What this paper adds

- 1 Sedentary behaviour is strongly correlated with sleep time in children with cerebral palsy.
- 2 No correlations were found between active time and sleep time.
- 3 Two-third of the children and 20% of the adolescents with cerebral palsy sleep more than current sleep duration recommendations during the weekend.

Cerebral palsy (CP) is caused by an insult to or malformation of the developing brain that affects motor control centres and leads to alterations in growth and development. CP is the most common paediatric-onset physical disability, with a prevalence of 1.7–3.1 per 1000 live births in high-income countries, and higher prevalence in low-income countries.^{1,2} Although the brain lesion that causes CP is non-progressive, it affects overall health throughout the life-span.¹ To improve overall health, and decrease disease risk factors in general, there is a need to

encourage higher levels of physical activity (PA) and reduce sedentary behaviour (SB), consistent with CP-specific movement guidelines.³ More recently, for typically developing children, there has been a move to develop guidelines that take the entire day into account. Referred to as 24-h integrated movement guidelines, they acknowledge that the ‘whole day matters’ and a balanced interplay of movement behaviours such as PA, SB and sleep throughout the day are important.⁴

Children with CP usually have low levels of light, moderate and vigorous physical activities, and high levels of sedentary lifestyles.³ It is therefore no surprise that research and guidelines in children with CP have focused on the health implications of PA and SB.³ However, the prevalence of sleep disorders in children with CP is reported to range from 20 to 46% according to different studies of literature that used care giver-reported sleep measures.^{5,6} This makes sleep disorders in children with CP a topic that, following the whole day matters philosophy, needs

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attention and more objective measures. Various co-morbidities related to CP, such as spasticity, dystonia, pain, epilepsy, behavioural issues and visual impairments, may be negatively associated with sleep disorders.⁷ These factors are, however, difficult to influence. Sleep medication is often used as first-line treatment to improve sleep quantity and quality. However, since most medications might cause side effects, like constipation, diarrhoea, headache, as well as drug tolerance and drug dependency, it is important to look at non-pharmacological alternatives to improve sleep.

The impact of sleep disorders in children with CP on well-being and physical health, both for the individual and their family, is significant.⁷ Sleep deficiency has a negative impact on growth and development,⁷ and is, in the general population, associated with several adverse health-related outcomes like adiposity, emotional regulation and lower quality of life and well-being.⁸ In typically developing children, sleep deficiency also has a negative impact on attention, executive functions, learning and flexible thinking, which are important factors in daily living.⁸

Non-pharmacological interventions that have proven to influence sleep quantity and quality are interventions based on changes in PA and SB.⁹ Small, positive associations between PA and sleep have been reported.¹⁰ Therefore, exercise-based interventions are regularly recommended in order to improve sleep.^{11,12} Furthermore, negative associations between SB and sleep have been found.^{12,13} Although it has been shown that children with CP often have sleep problems, low levels of light, moderate and vigorous PA and high levels of sedentary time, no associations between these variables have been described before.^{6,7}

Therefore, the aim of this study is to: (i) objectively assess the sleep quantity; and (ii) explore the relationships between sleep quantity and quality, and PA and SB in children and adolescents with CP.

Methods

Study design

This study is an observational cross-sectional study. Baseline data from children and adolescents with CP who participated in the Health in Adapted Youth Sports (HAYS) study and the Sport-2-Stay-Fit (S2SF) study was used.^{14,15} Both studies were designed to investigate the associations of sports participation with physical fitness, PA, cardiovascular health, attention and psychosocial health in children and adolescents with chronic diseases and physical disabilities. The protocol and administrative site of both studies were approved by the Medical Ethical Committee of University Medical Centre Utrecht, the Netherlands (NTR4698). Participants for the S2SF study were recruited during the school year, among four schools for special education in the Netherlands. Participants for the HAYS study were recruited in the same period in the Netherlands from different patients associations, paediatric physical therapy practices, Wilhelmina Children's Hospital in Utrecht, De Hoogstraat Rehabilitation in Utrecht, Fitkids, schools for special education and sport clubs.

Participants

Inclusion and exclusion criteria

For the current study, a subgroup of children from the S2SF and HAYS studies was used.^{14,15} Children and adolescents were eligible for inclusion in the current study if they were aged between 6 and 18 years, were able to walk with or without walking aids, and were diagnosed with spastic CP. After reviewing the dataset for these criteria, a total of 36 children were included in the present study. Participant characteristics are displayed in Table 1.

Data collection

General information

Possible factors that could influence outcomes, such as age and gender were identified by a general questionnaire. Height was measured in a standing position using a stadiometer. In participants who were not able to stand up, arm span width was measured. A weighing scale was used to measure body weight. Body mass index was calculated as weight (kg)/height (m)².

Motor function

Motor function was classified using the Gross Motor Function Classification System (GMFCS).¹⁶ The GMFCS is a five-level qualification system to assess the severity of CP, based on the gross motor function. Children with a higher GMFCS level have more severe disabilities than children with a low GMFCS level. The functional mobility scale is used as a tool to measure walking ability.

PA and sleep quantity

In order to measure PA, SB and sleep quantity, the Activ8 activity monitor (2 M engineering, Valkenswaard, the Netherlands) was used. This device is an accelerometer that measures acceleration in three planes (3D), and is valid to detect body postures and movement.¹⁷ Participants were instructed to wear the Activ8 for 7 consecutive days. At least 2 school days with a minimum of 600 min wear time was needed for a representative weekday. For weekend days, at least 1 day of 600 min wear time was required.¹⁸ Participants wore the Activ8 on the ventral side of the upper leg on the dominant side. The device was fixed with

Table 1 Participant characteristics

	Participants (n = 36)
Gender (boys/girls)	22/14
Age, years, months, mean (SD)	15, 4 (2, 6)
Weight, kg, mean (SD)	63.2 (20.6)
Height, cm, mean (SD)	164.5 (11.6)
BMI, mean (SD)	22.9 (5.7)
GMFCS-level, n (%)	
GMFCS I	25 (69)
GMFCS II	9 (25)
GMFCS III	1 (3)
GMFCS IV	1 (3)

BMI, body mass index; GMFCS, Gross Motor Function Classification System; SD, standard deviation.

Tegaderm (3M, Delft, the Netherlands) waterproof tape allowing participants to take a shower or swim. Parents were instructed to fill out a PA diary that included bed times on a daily basis. This allowed us to distinguish lying from sleeping. Sedentary time (time spent lying and sitting), active time (time spent standing, walking, cycling and running) and sleep (time spent lying in bed based on sleep-wake diary) were calculated in minutes and hours.

Sleep quality

In addition, sleep quality was assessed using a single item sleep quality scale. This item could be answered by grading the quality of sleep within a range of 1 (worst possible sleep) to 10 (best possible sleep).¹⁹ Participants were asked to answer this item, with the help of their parent/care giver, at the end of the week and their scores represent the average sleep quality experienced during that past week. Participants were instructed to fill out the sleep question and were allowed help from a parent.

Statistical analysis

Raw data collected with the Activ8 was processed using Matlab (version 2016a, MathWorks Inc., Natick, MA, USA) and SPSS (version 21.0, SPSS Inc. Chicago, IL, USA). All participants met the minimum wear time of the activity monitor and were included in the analyses. Absolute time was calculated for PA, SB and sleep for each day. A mean was calculated for the absolute time of active, sedentary and sleep time over the whole week, and for weekdays and weekends separately. To identify the participants who did not meet the sleep duration recommended by the Canadian 24-Hour Movement Guidelines for Children and Youth, participants were divided into two age groups.⁴ The first group contained the participants aged 6–13 (recommended sleep 9–11 h), the second group consisted of participants aged 14–17 (recommended sleep 8–10 h). The Pearson's correlation coefficient was used to determine the correlation between outcome variables. The correlation coefficients were interpreted according to three scales: >0.5 = strong, 0.3 – 0.5 = moderate, 0.1 – 0.3 = small.²⁰ Beforehand, the variables age, gender, GMFCS-level, weight and body mass index were explored as potential confounders. However, none of these variables showed an association with both sleep variables and PA or SB variables. Therefore, they were not taken into account during the analysis.

Results

Descriptive statistics for sleep quantity as well as active time and sedentary time per age group are shown in Table 2. The wide range of participants' characteristics (age and GMFCS level) shows the variation in active time and sedentary time and sleep of children and adolescents with CP.

In the youngest age group (6–13 years of age), all children met the number of recommended hours of sleep during week and weekend days. Four children (67%) slept more than the recommended hours in the weekend. In the older age group (14–17 years of age), only two children did not meet the number of recommended hours during the week, and one child did not meet the number of recommended hours during the weekend.

Table 2 Means of sleep quantity and physical activity measures

	Mean (SD)	Range
Ages 6–13 ($n = 6$)†		
Total week		
Sleep duration, h/day ($n = 6$)	10.3 (0.7)	9.3–11.2
Sedentary time, min/day	523.4(61.5)	426.1–590.3
Active time, min/day	161.5(63.1)	75.6–248.9
Weekdays		
Sleep duration, h/day ($n = 6$)	9.51 (0.4)	9.23–10.19
Sedentary time, min/day	542.3 (54.8)	461.9–620.7
Active time, min/day	155.4(58.9)	83.9–235
Weekend days		
Sleep duration, h/day ($n = 6$)	11.05 (1.2)	9.35–12.52
Sedentary time, min/day	480.7 (85.9)	345.5–580.7
Active time, min/day	170.1(82.1)	59.1–283.4
Ages 14–17 ($n = 30$)‡		
Total week		
Sleep duration, h/day ($n = 30$)	9.1 (0.9)	7.2–10.6
Sedentary time, min/day	579.6 (87.8)	278.4–692.2
Active time, min/day	156.9 (43.0)	79.42–245.6
Weekdays		
Sleep duration, h/day ($n = 30$)	8.9 (0.91)	6.55–11.06
Sedentary time, min/day	574.5 (95.1)	204.5–690.2
Active time, min/day	196.7 (45.1)	89.9–259.3
Weekend days		
Sleep duration, h/day ($n = 30$)	9.64 (1.36)	7.22–12.55
Sedentary time, min/day	596.7 (110.8)	400.7–782.3
Active time, min/day	124.2 (56.1)	23.1–243.4

†Recommended sleep duration for this age group = 9–11 h.

‡Recommended sleep duration for this age group = 8–10 h.

Six children (20%) slept more than the recommended number of hours.

PA: Sleep quantity

No significant correlations were found between active time and sleep quantity for total week, weekdays and weekend days. Moderate negative correlations were found between sedentary time and sleep quantity during the total week ($r = -0.456$, $P = 0.005$), weekdays ($r = -0.453$, $P = 0.006$) and weekend days ($r = -0.48$, $P = 0.003$).

PA: Self-rated sleep quality

Sleep quality scored a mean (SD) of 8.2 (1.4) with a range of 6–10. No significant correlation was found between active time and sleep quality, and a moderate negative correlation was found between sedentary time and self-rated sleep quality ($r = -0.367$, $P = 0.028$).

Discussion

The aims of this study were to assess the sleep quantity and to explore the relation between PA, SB and sleep quantity and quality in children and adolescents with CP. In accordance with the current sleep duration recommendations, the daily sleep durations of the children in our study population also varied from 8 to 11 h. Recently, Atmawidjaja *et al.*²¹ found, using a

questionnaire completed by the main care giver, that a large proportion (~40%) of children with CP were not even getting 8 h of sleep per day. This finding is in contrast with our, more objective findings, which suggests that children with CP are getting the recommended sleep duration. However, it should be noted that Atmawidjaja *et al.*²¹ included children with more severe gross motor impairments and are likely to have more severe comorbidities, like pain, epilepsy and respiratory issues, which might have a profound impact on their sleep quantity, sleep quality and PA. The present study also shows that two-third of children and one-fifth of the adolescents sleep more than current sleep duration recommendations during the weekend. This proportion may be an indication that the sleep quantity during the week is not sufficient for this population. However, the fact that children and adolescents sleep less than 1 h longer in weekends compared to weekdays, is consistent with recommendations that suggest that having consistent bedtimes and wake-up times are preferable for overall health.²²

The relations that were found between sedentary time and sleep are somewhat comparable to results found in other populations. Since PA and SB are only few of the various factors that influences sleep in children with CP, no high correlations could be expected. However, other studies found lower, sometimes even negligible, correlations.^{12,13,23} For example, Stone *et al.*¹² and Ortega *et al.*¹³ found a negative correlation of -0.086 and -0.358 between sleep quantity and SB in children who are typically developing, respectively. Johnson *et al.*²³ found that adolescents who are typically developing, and who were more physically inactive, were at higher risk for developing sleep problems. The correlation found in the current study might be higher due to the fact that children with CP often have a more sedentary life-style and a higher prevalence of sleep problems when compared to typically developing peers.³

No correlations were found between PA and sleep quantity, which is in contrast to results found in other studies among children who are typically developing.^{12,13} Stone *et al.*¹² and Ortega *et al.*¹³ found a small but significant correlation of 0.087 and 0.208 between active time and sleep quantity in children who are typically developing, respectively. Ortega *et al.*¹³ stated that children who slept >10 h were more active and spent less time sedentary compared to children who slept <10 h. This confirms the probable positive relation between sleep and PA in children who are typically developing. There are several explanations for the fact that no correlation was found in the current study. First of all, our study has a small sample size compared to the studies by Stone *et al.*¹² and Ortega *et al.*¹³ who had sample sizes of 856 and 2241 children, respectively. Second, the group of children in this study had sufficient sleep quantity. Third, children with CP are known to spend most of their time sedentary. It might therefore be possible that participants did not spend enough time being active to influence sleep. However, this is not the case in all children with CP, as is shown in the large variation in active time and sedentary time among our participants. In our study, standing was regarded as PA (active time) as well. Other studies often did not consider standing as PA, since only light and moderate to vigorous activity were measured.^{12,13} This makes comparing these results with other studies more difficult. Fourth, other studies showed that participants who engaged in high-intensity activities had a

significant better sleep quality.²⁴ In the current study, no distinction was made between different intensities of PA.

Translating these results into clinical practice is difficult, since only cross-sectional associations were defined. Moreover, the group of children that have more severe motor impairments classified as GMFCS levels III (3%) and IV (3%) was very small in this study population. It is therefore not possible to generalise these results to the whole CP population and these results should be considered as exploratory findings that are likely to be more relevant for children who are classified as GMFCS levels I and II. These groups are often able to walk independently and have the opportunity and ability to interrupt their SB more frequently. Even though no causal relation can be defined due to the cross-sectional study design, these results do provide us with some insight. The correlation between SB and sleep might indicate that there is a vicious circle at play in this population that should be interrupted. This could be achieved by actively trying to decrease time spent sedentary and by encouraging active time. Furthermore, activities performed outdoors might be beneficial. Daylight suppresses melatonin production, and as a result, children may be less tired,²⁵ which in turn could lead to a more active life-style. Therapists could actively promote these simple advices to parents whose children experience sleeping issues. Additionally, new interventions could be developed that focus on both sleep and PA and SB together as a whole (i.e. considering a 24-h vision), instead of considering the three variables in isolation.

Given the limitations of this current exploratory study, caution should be taken when interpreting the results of this study. In future studies, different intensities of active time should be analysed, to give more accurate information about the association between the intensity of activity and sleep. Unfortunately, we did not collect data to characterise the included children in terms of cognitive function, behaviour, presence of epilepsy, blindness, chronic pain, wearing night splints; all of these potentially influencing the sleep. Finally, we have used subjective and objective measures to assess sleep quality and quantity in this study. Participants were asked what their mean sleep quality was over the whole week. It would have been more reliable if both sleep duration and quality were assessed for each day of the week separately, and with more than one question alone, for example, by using a complete sleep diary throughout the week. Also, the activity monitor that we have used in this study, was not able to distinguish between sleep and lying down accurately. This could have resulted in an overestimation of the actual sleep duration in this study. A more objective sleep quantity and quality measure that is able to provide information about the time it takes to fall asleep, the number of times waking up during nights, and percentages spent in the different sleep stages (rapid eye movement sleep, light sleep, deep sleep) would provide valuable information needed to characterise the sleep architecture of children with CP.

Conclusions

This study assessed the sleep quantity and explored the relationship between PA, SB and sleep quality and quantity in children and adolescents with CP. Our findings suggest that children with

CP are getting the recommended sleep duration, and that SB is correlated with sleep quantity in children with CP.

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