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ORIGINAL RESEARCH

Actigraphy-Based Characteristics of Sleep in Paediatric Cancer Patients in Remission and a Comparison with Their Healthy Peers in the Recovery Stay

Tomáš Vyhlídal, Jan Dygrýn, František Chmelík

Faculty of Physical Culture, Palacký University Olomouc, Olomouc, Czech Republic

Correspondence: Tomáš Vyhlídal, Email tomas.vyhlidal@upol.cz

Background: Previous research has demonstrated that paediatric cancer survivors (PCS) have lower sleep quality than their healthy peers. However, the research to date has focused mainly on self-reported data. Therefore, the aim of this cross-sectional study was to characterise selected sleep parameters in PCS using objective monitoring techniques and to compare them with a control group (CG) of their healthy peers during a structured recovery stay. A specific objective was to characterise sleep with respect to gender, age, and cancer type.

Methods: 26 PCS and 38 CG aged 7–15 years participated in the study. Selected sleep indicators (time in bed, total sleep time, sleep efficiency) were objectively assessed with an Actigraph wGT3X-BT accelerometer for 12 days during the recovery stay.

Results: No significant differences were found between the PCS and CG groups in terms of the selected sleep parameters. The total time in bed was 543.1 min/day in the PCS and 537.2 min/day in the CG (p=0.91). The total sleep time was 455.3 min/day in the PCS and 457.5 min/day in the CG (p=0.57). Sleep efficiency was 85.3% in the PCS and 86.3% in the CG (p=0.36). Sleep efficiency >85% was achieved by 62% of the PCS (n=16) and 68% of the CG (n=26). There were no significant differences in sleep parameters in terms of variables such as gender, age, or cancer type.

Conclusion: The results of our study suggest that – under the same conditions – the PCS did not differ from their healthy peers in terms of the indicators of time in bed, total sleep time, and sleep efficiency. No significant differences according to age, gender, or cancer type were found.

Keywords: sleep, accelerometry, cancer survivors, children

Introduction

Sleep plays an essential role in the healthy development of children.[1–3] The benefits of healthy sleep include, for instance, lower risk of cardiovascular disease, type 2 diabetes, and higher quality of life or enhanced cognitive functioning.[2,4–7]

Childhood cancer is associated with a wide range of potential adverse treatment consequences.[8–10] The disease has a negative impact on the sleep patterns and sleep quality of the children who are treated.[11–13] Reduced sleep quality is a significant negative factor affecting the quality of life in this target group even many years after diagnosis and treatment.[14–18] Reduced sleep time, increased wakefulness during the night, and reduced sleep efficiency have been demonstrated for almost all types of cancer in childhood.[11]

Currently, we continue to encounter studies that focus on the subjective assessment of sleep, either by study participants themselves or their parents.[18–24] This is despite it being known that objective assessment using an accelerometer provides more consistent and detailed information compared to self-reporting.[25]

Furthermore, the subjective sleep data provided by respondents and objective instrumental measurements show significant differences.[26–28] In addition, published studies often analyse sleep data during the period of patient hospitalisation[29–31] and we lack information on patient sleep in the post-treatment periods.

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Thus, further studies using objective sleep monitoring are needed in order to understand sleep better in paediatric cancer survivors[32,33] and focus on understanding risk factors, which may include gender, age, or cancer type.[34]

On the basis of these findings, the main aim of this study is to objectively characterise selected sleep parameters in children with cancer in remission and compare them with those of their healthy peers during an organised recovery stay. This stay is unique in terms of providing an environment and duration that are identical for both groups. A specific objective is to characterise sleep parameters in terms of gender, age, and cancer type.

Methods

Design and Participants

Paediatric cancer survivors PCS in remission and their healthy peers – control group (CG) participated in the study. Both groups were in the age range of 7–15 years.

For the PCS, the inclusion criterion of the study was completion of active oncological treatment at the Department of Paediatric Oncology at the University Hospital Brno; all participants had to be in remission < five years after the end of the maintenance phase of treatment and had to have permanent residence in the Czech Republic. The exclusion criterion was a disability or health disadvantage unrelated to the treatment. Because of the large number of cancer types, we decided to divide the diseases into a) haematological malignancy and b) solid tumours. This division is in line with a number of other studies.[35,36] We further split the participants by gender and by age. Age categories were divided into primary school age (7–11 years) and secondary school age age (12–15 years).

For the CG, the research inclusion criterion was defined as age 7–15 years and permanent residence in the Czech Republic. The exclusion criterion was having undergone active cancer treatment and another type of disability or health disadvantage.

Recruitment of Participants

The total numbers of participants approached to join the research study who met the criteria for PCS and CG were 32 and 44, respectively. For the PCS group, four participants were not interested in participating in the research survey. The data of two participants could not be evaluated because they did not wear the device for the minimum period. For the CG, six participants were not interested in participating in the research. Thus, in total, data was evaluated for 26 PCS and 38 CG. On the basis of the inclusion and exclusion criteria of the research study, the legal guardians of potential participants were approached by the main organiser of the recovery stay, the KRTEK Children's Oncology Foundation. The legal guardians of the participants were addressed two weeks prior to the implementation of the research investigation.

Data Collection

The data collection took place between 19 and 30 August 2018 and lasted 12 days. The data was collected during a recovery stay organised by the KRTEK Children's Oncology Foundation for PCS treated at the Department of Paediatric Oncology of the University Hospital Brno in the period from 18 August to 31 August 2018. These recovery stays are of an integrative nature and are attended by both PCS and their healthy peers (CG). The uniqueness of the data collection in the PCS and CG is mainly seen in the fact that the data collection took place during the recovery stay. As a result, both groups were able to follow the same daily routine (same wake-up time, same daily activities, same bedtime, same diet). Consent of the legal guardians was required for participation in the study. The study was approved by the Ethics Committee of the Faculty of Physical Culture of Palacký University in Olomouc under the reference number 48/2018.

Sleep Monitoring

An ActiGraph wGT3X-BT (ActiGraph, Pensacola, FL, USA) accelerometer was attached to the non-dominant wrist of the participants on the first day of the recovery stay. The participants were instructed to wear the device on their non-dominant wrist for 12 consecutive days, except for when swimming and bathing. The device was initialised to collect accelerations at 100 Hz using the Actilife software (ActiGraph, Pensacola, FL, USA). Next, the raw accelerometer data

was processed using the R package GGIR (v2.1–0, https://cran.r-project.org/web/packages/GGIR/).[34] We consider this length of monitoring to be unique, as objectively assessed sleep parameters often range from three to five days.[29,30] The measuring device was distributed to the participants on the first day of the recovery stay. The Body Mass Index (BMI) was calculated by dividing the child's weight (kg) by height (m) squared. The participants' body weight and height were measured on the first day of the recovery stay using a TanitaTM calibrated digital scale (UM-075 type; Tanita Corporation, Tokyo, Japan) and the Leicester height measure.

Sleep Assessment

Indicators for assessing sleep duration and quality were determined as "Time in bed" (Difference between onset and waking time), "Total sleep time" (actual sleep time of the participant), and "Sleep efficiency" (calculated as: [Total sleep time/Time in bed]*100).[37,38] The National Sleep Foundation's sleep duration recommendation for healthy populations is set for the School-age group: 6–13 years 9 to 11 hours of sleep and for the Teenagers group: 14–17 years 8 to 10 hours.[39] The "Sleep efficiency" indicator shows the ratio between the time spent in bed and the time for which a given participant actually sleeps. This indicator is the most commonly used measure to objectively assess sleep quality[40] and can provide essential information about the health status of an individual.[41] Sleep efficiency ≥ 85% is an indicator of good sleep quality.[42]

Statistical Analysis

The characteristics of the study sample are presented using descriptive statistics (median and interquartile range). To compare the study groups (age, gender, type of oncologic disease), the Mann–Whitney *U*-test was used. The level of statistical significance was set at α=0.05. The effect size coefficients were interpreted as follows: $0.2 \leq d < 0.5$ – small effect size, $0.5 \leq d < 0.8$ – medium effect size, and $d \geq 0.8$ – large effect size.

Results

In Table 1 we present the basic descriptive characteristics of the PCS and CG research population. We found no significant differences between the study groups (PCS and CG) in either boys (age: p = 0.91, body height: p = 0.56, body weight: p = 0.31, BMI: p = 0.45) or girls (age: p = 0.74, body height: p = 0.91, body weight: p = 0.85, BMI: p = 0.87).

The overview of selected actigraphy-based sleep characteristics of the PCS and CG are presented in Table 2. No significant differences were found between the groups (PCS, CG). The total time in bed was 543.1 min/day in the PCS (CG 537.2 min/day). The total sleep time in the PCS was 455.3 min/day (CG 457.5 min/day). Sleep efficiency in the PCS was 85.3% (CG 86.3%). Sleep efficiency >85% was achieved by 62% of the PCS and 68% of the CG.

An overview of selected sleep parameters of the target and control groups according to age, sex, and type of cancer is presented in Table 3. There were no significant differences between the PCS and CG in terms of the individual parameters.

Discussion

The main finding of this study was that the PCS and CG did not differ significantly in terms of the selected sleep parameters.

For comparison, we were unable to identify a study that objectively characterised selected sleep parameters in PCS and their healthy peers in a recovery stay setting that was the same for all participants. Objectively measured sleep indicators are most commonly found in the hospital setting during hospitalisation.[29–31] Here, the measurements are often between two and five days. The study by Nunes et al[31] for example, points out that the hospital environment and the period of hospitalisation are very specific and these sleep indicators cannot be generalised to other settings. The aforementioned study also supports other research investigations and points to the need to focus on other types of environments for this target group.

Similarly to our research, no significant differences in terms of gender, age, or cancer type were found in other studies either.[31,43] Comparable objectively measured results were obtained in the study by Russell et al[43] in survivors of acute lymphoblastic leukaemia and their healthy peers/siblings. Here again, no significant differences in selected sleep

Table 1 Descriptive Characteristics of the Paediatric Cancer Survivors and Control Group

		Age (Years)		Body Height (cm)		Body Weight (kg)		BMI (kg/m^2)	
	N	Mdn	IQR	Mdn	IQR	Mdn	IQR	Mdn	IQR
Paediatric cancer survivors (n=26)									
Gender									
Boys	12	12.4	3.6	156.4	30.1	39.6	16.5	17.4	3.4
Girls	14	12.1	3.7	150.2	14.7	47.7	21.3	20.3	6.6
Age									
7–11 years	12	10.1	2.1	140.6	12.1	35.3	10.3	18.1	3.7
12–15 years	14	13.2	2.3	160.7	13.1	53.0	19.7	20.0	5.7
Type of disease									
Haematological malignancy	14	12.0	3.5	154.1	19.9	49.2	23.9	20.3	5.0
Solid tumours	12	12.5	4.2	146.0	26.0	35.5	16.4	17.2	4.0
TOTAL	26	12.1	3.5	151.9	20.5	40.3	18.9	18.8	4.7
Control group (n=38)									
Gender									
Boys	12	12.4	1.9	153.8	13.2	44.1	10.2	17.4	3.1
Girls	26	12.1	4.3	149.5	26.9	47.9	24.6	20.3	4.5
Age									
7–11 years	16	9.4	2.8	139.4	21.4	35.2	12.4	17.3	4.5
12–15 years	22	13.2	1.7	162.6	16.6	53.6	15.0	20.7	4.8
TOTAL	38	12.2	3.6	153.6	24.5	45.0	18.9	18.9	4.0

Abbreviations: N, number of participants; Mdn, median; IQR, interquartile range.

Table 2 Overview of Selected Sleep Parameters

	Paediatric Cancer Survivors (n=26)		Control Group (n=38)		Difference	
	Mdn	IQR	Mdn	IQR	p-value	d
Time in bed (min/day)	543.1	32.5	537.2	32.2	0.91	0.03
Total sleep time (min/day)	455.3	30.4	457.5	30.9	0.57	0.14
Sleep efficiency (%)	85.3	4.3	86.3	5.3	0.36	0.23
Sleep efficiency >85% (n, %)	16	62	26	68		

Abbreviations: Mdn, median; IQR, interquartile range; d, effect size coefficient.

parameters between PCS and CG were confirmed. These results are also consistent with the previously published study by Greenfeld et al.[44]

The factor of age did not prove to be significant in our results, which is in line with the study by Kocevska et al[28] who reported that gender differences in sleep parameters are only observable from adulthood onwards. Adult females spend a longer time in bed compared to males, but have lower sleep efficiency.

Compared to recommendations for a healthy paediatric population,[39] we must mention that neither PCS nor CG achieve the established sleep recommendation for optimal support of their health.

Although a number of studies have pointed to impaired sleep quality in PCS, objective measurements of sleep parameters suggest that even after the completion of paediatric cancer treatment, these patients are able to match their

Table 3 Overview of Selected Sleep Parameters by Gender, Age, and Type of Cancer

	Paediatric Cancer Survivors		Control Group		Difference	
	Mdn	IQR	Mdn	IQR	p-value	d
Gender						
Boys	(n=12)		(n=12)			
Time in bed (min/day)	544	44.1	531	36.5	0.51	0.28
Total sleep time (min/day)	457	40.1	451	32.3	1.00	0.0
Sleep efficiency (%)	85.1	5.0	87.4	6.1	0.27	0.45
Sleep efficiency >85% (n, %)	7	58	8	67		
Girls	(n=14)		(n=26)			
Time in bed (min/day)	539	18.7	537	37.2	0.83	0.07
Total sleep time (min/day)	454	29.3	459	33.0	0.50	0.22
Sleep efficiency (%)	85.6	3.9	86.2	4.7	0.78	0.09
Sleep efficiency >85% (n, %)	9	64	18	69		
Age						
Age 7–11	(n=12)		(n=16)			
Time in bed (min/day)	544	24.5	540	32.9	0.95	0.35
Total sleep time (min/day)	460	26.8	465	26.2	0.73	0.14
Sleep efficiency (n, %)	85.5	3.4	86.6	5.4	0.40	0.03
Sleep efficiency >85% (%)	8	67	11	69		
Age 12–15	(n=14)		(n=22)			
Time in bed (min/day)	532	39.8	530	31.0	0.99	0.11
Total sleep time (min/day)	451	38.6	455	32.9	0.55	0.21
Sleep efficiency (%)	85.3	5.4	86.1	5.4	0.60	0.17
Sleep efficiency >85% (n, %)	8	57	15	68		
Cancer type						
Haematological malignancy	(n=14)					
Time in bed (min/day)	539	29.6				
Total sleep time (min/day)	454	37.0				
Sleep efficiency (%)	85.5	3.5				
Sleep efficiency >85% (n, %)	9	64				
Solid tumours	(n=12)					
Time in bed (min/day)	544	34.2				
Total sleep time (min/day)	457	27.7				
Sleep efficiency (%)	85.3	5.1				
Sleep efficiency >85% (n, %)	7	58				

Abbreviations: Mdn, median; IQR, interquartile range; d, effect size coefficient.

healthy peers in remission. However, this finding needs to be confirmed by further studies and should be a standard part of treatment (not just an adjunct), as also pointed out by Merz and Tomfohr-Madsen.[45]

The main strength of this study is the objectively measured selected sleep parameters in a recovery stay setting in which the same conditions (daily routine, diet, accommodation) were set for both groups. Also, the length of the research investigation is unique compared to other available studies.

The smaller sample size of the PCS may be a limitation of the study. Another limitation was the use of the objective method of actigraphy, which, compared to polysomnography, does not allow the analysis of other sleep disorders (such as sleep breathing disorders, parasomnia or sleep movement disorders) that may affect sleep quality. It is also important to mention that actigraphy provides information about the presumed sleep based on the analysis of the patient's movements, whereas only polysomnography indicates as objectively as possible that the patient is asleep and what the structure of his sleep is. Not using supplementary tools such as self-reported sleep diary or missing data on anxiety-depressive symptoms may also have posed a limitation to our findings.

Conclusions

The results of our study suggest that under the same conditions the PCS do not differ from their healthy peers in terms of time in bed, total sleep time, and sleep efficiency. No significant differences were found in terms of age, gender, or cancer type.

As sleep is one of the important pillars of a healthy lifestyle, by examining it, we can draw conclusions and recommendations that may lead to systematic support for the target group and to the mitigation or prevention of late effects of treatment.

Data Sharing Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Palacký University Olomouc (No. 48/2018).

Consent to Participate

Informed consent was obtained from legal guardians.

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Disclosure

The authors declare no competing interests.

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