LBP-099 Sleep spirals: novel visualization of childhood circadian rhythms and physical activity

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OBJECTIVES

Circadian rhythms are patterns in behaviour and physiology that recur on a 24 hour time period, such as the sleep-wake cycle and daily changes in body temperature. These rhythms are not simply a response to environmental changes, but are driven by endogenous timing mechanisms present in every mammalian cell [1]. Circadian clocks are disrupted when time cues such as light exposure and food intake are not synchronised with innate 24h rhythms. Studies in adults have associated circadian disruption with insulin insensitivity, weight gain and obesity [2], and there is some evidence for similar relations in children [3-5]. In addition, childhood obesity is widely associated with disrupted sleep [6], and increased evening time activity [4]. Disrupted sleep in children with obesity appears to be independent of sleep duration [7,8], which is a strong indicator of underlying circadian mechanisms. Studies of circadian rhythms in children with obesity are limited by the difficulties of applying longitudinal 24h sampling protocols, as well as uncertainly about how interventions might be implemented.

Advances in wrist-worn sensor technology and data analytics allow physical activity, sleep and circadian rhythms to be monitored unobtrusively over long time periods. This technology has multiple potential applications in the treatment of obesity, since reduced physical activity, sleep disruption and disrupted circadian rhythms are all components of both the pathogenesis and morbidity of this condition. Visualization of the patterns and levels of daily physical activity over long time periods can be used to inform children with obesity about circadian rhythms and to provide them with tangible evidence of the effect of interventions. We describe a novel data visualization for communicating longitudinal rhythms in physical activity to children and their parents.

CASE

Children with obesity presenting at W82GO Child and Adolescent Weight Management service in CHI at Temple Street, Dublin

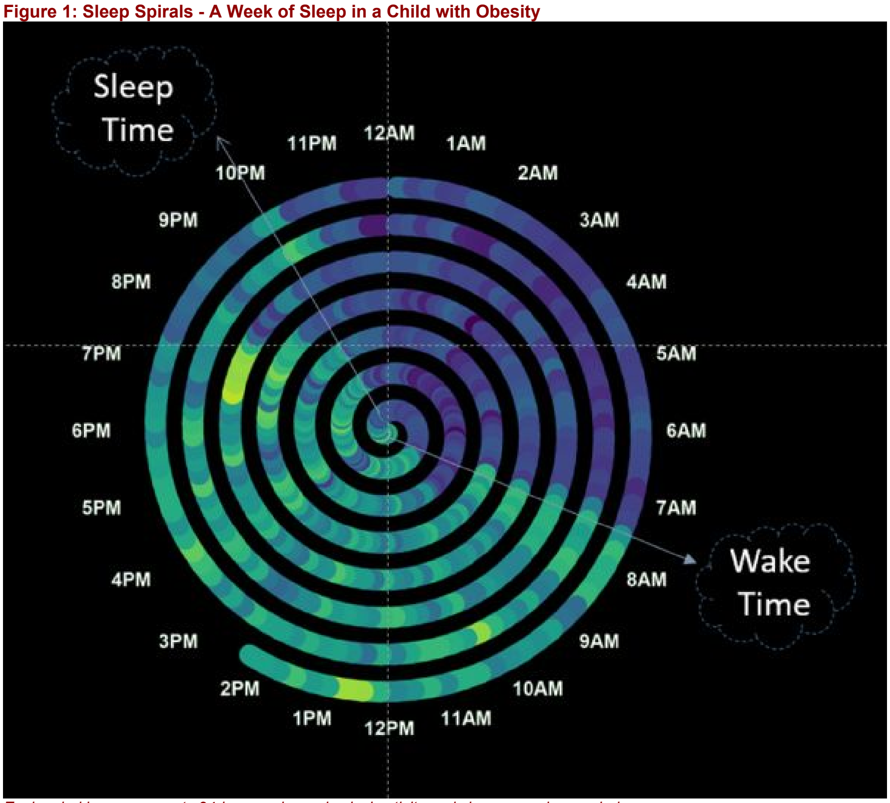
MATERIALS-METHODS

Following ethical approval daily physical activity was monitored in 29 children presenting for treatment of obesity at a tertiary clinic (Table 1). Data were acquired using a triaxial accelerometer (Geneactiv, UK) that the children wore on the wrist for 7 days. Daily locomotor activity was visualized by plotting a spiral polar bar chart, with the magnitude of acceleration indicated by a colour heatmap (Figure 1). For comparison, each dataset was also plotted using conventional methods for visualizing daily locomotor activity data, actigrams and line plots. Actigrams show activity levels on the y-axis and time of day on the x-axis, with each day represented by a single line of data. Line plots show absolute activity levels (x-axis) against days (y-axis) over one week. The data from each individual were plotted using all three methods for visual comparison of variations in circadian rhythms over the 7 days of recording. The open access software, R was used for all analysis.

Table 1: Demography of Participants

Age (mean ± sd)	14 ± 1
Gender Male (n,%) Female (n,%)	 6, 21% 23, 79%
Physical Activity Subjective report (min/week)	68.4 ± 21.7

Figure 1: Sleep Spirals - A Week of Sleep in a Child with Obesity



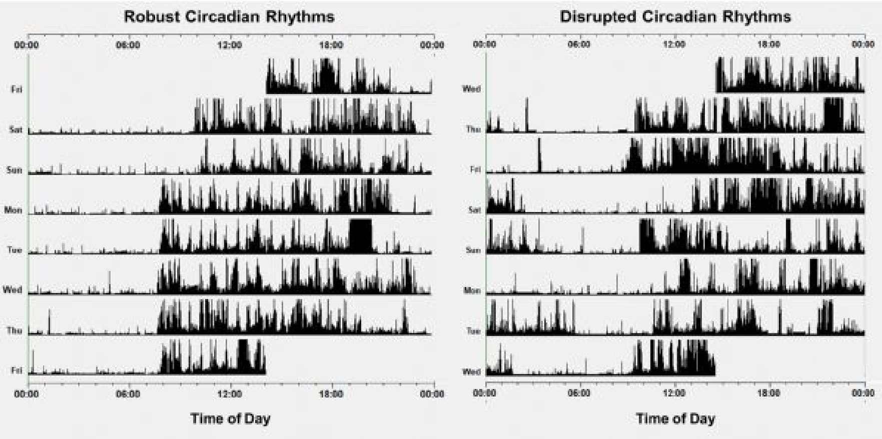
Each spiral loop represents 24-hours, where physical activity and sleep are colour-coded.

RESULTS

There was considerable variation in the circadian patterns of activity in the participants of this study. Some children had erratic sleep and wake times, increased night time activity, and irregular patterns of daily activity (disrupted rhythms), while others showed regular sleep wake times, and consolidated sleep duration (robust rhythms). Most children showed a phase delay of wake time at weekends.

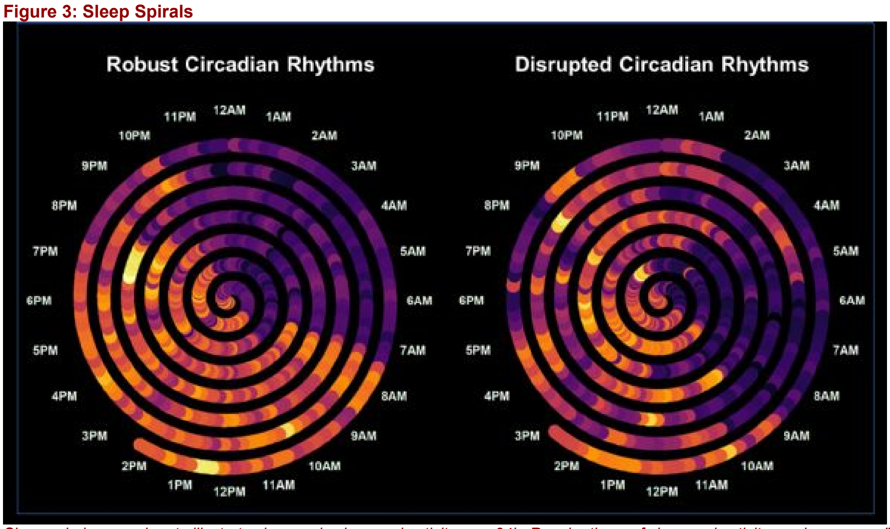
The plots below compare circadian rhythms in a child with regular rhythms to a child with evidence of disrupted rhythms, against a child with robust rhythms. Data from the same two participants were used in each type of plot shown side by side.

Figure 2: Actigrams



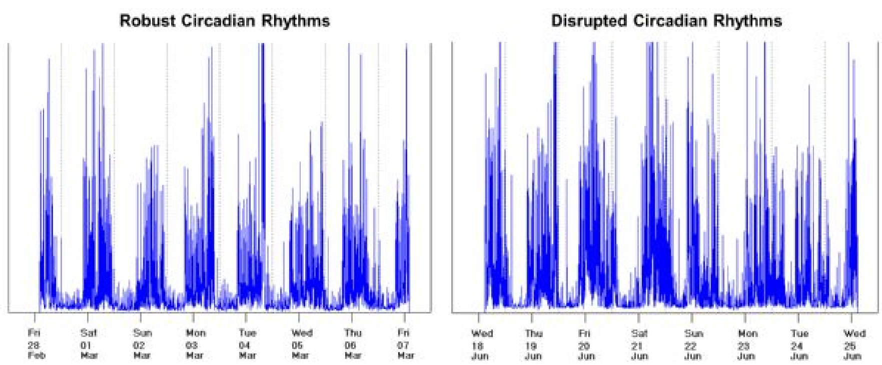
Actigrams show activity levels on the y-axis and time of day on the x-axis. Days are represented by a series of stacked vertical line plots. The plot on the right shows variable sleep and wake times and irregular patterns of daytime activity. Note the phase delay in wake times at weekends.

Figure 3: Sleep Spirals



Sleep spirals use colour to illustrate changes in sleep and activity over 24h. Regular times of sleep and activity can be seen as "pie-slice" sections of uniform colour, as in the figure on the left, compared with more disrupted patterns of plot on the right.

Figure 4: Line Plots



Line plots show absolute activity levels (x-axis) against days (y-axis) over one week. These are good plots for illustrating total physical activity but convey little information about circadian rhythms.

DISCUSSION

There is increasing evidence that disrupted circadian rhythmicity has a role in the pathophysiology of childhood obesity [3-5], possibly though primary disruption of innate circadian timing mechanisms. Circadian rhythms can be manipulated through entrainment by external timing cues such as light and food intake, raising the possibility of clinical interventions in children with obesity based on these mechanisms. Simple and effective methods for measuring circadian rhythms in children are required to facilitate investigation of the potential importance of timing cues in the treatment of children with obesity.

Qualitative analysis of the circadian rhythms of the children in this study showed variable disruption between individual that was evident from all of the data plots. Many of the children showed a phase delay in activity at weekends (Figure 2), a pattern that is typical of adult rhythms, and indicative of disrupted circadian rhythms [2].

Actigrams are a useful method for illustrating circadian rhythms, but they have two dimensions to the y-axis (day and activity level) and are further complicated by representation of time of day on a linear scale. In contrast, sleep spirals present weekly data as a continuum, showing how disruption accumulates across days, and allowing simultaneous interpretations of physical activity levels through colour change (Figure 3). Line plots are widely used in research applying accelerometer data, but these plots are poor illustrations of circadian rhythms (Figure 4).

Sleep spirals are a novel way of educating children about their activity levels and circadian rhythms. They have potential application for engaging children in their treatment, and for conveying the impact of interventions to modify the rhythmicity and level of physical activity. Sleep spirals convey information on 3 parameters that are important in obesity (i) circadian rhythms, (ii) sleep timing and (iii) physical activity. These are simultaneously displayed using colour gradients, and visual patterns. Sleep spirals capture trends in physical activity and circadian rhythms in a single colourful data plot, that can increase children's engagement and understanding of interventions to modify circadian rhythms, activity and sleep.

CONCLUSIONS

Novel methods for monitoring circadian rhythms could be useful clinical tools in the management of childhood obesity. Capturing clinical information through data visualisations such as sleep spirals is an innovative way of engaging patients in treatment and of incentivising lifestyle change.

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