Development of Late Circadian Preference: Sleep Timing From Childhood to Late Adolescence

Liisa Kuula, MA[1], Anu-Katriina Pesonen, PhD[1], Ilona Merikanto, PhD[1], Michael Gradisar, PhD[2], Jari Lahti, PhD[1,3], Kati Heinonen, PhD[1], Eero Kajantie, MD, PhD[4,5,6], and Katri Räikkönen, PhD[1]

Objectives To assess differences relating to circadian preference in objectively measured sleep patterns from childhood to adolescence over a 9-year period. We hypothesized there is developmental continuity in sleep timing and duration according to circadian preference.

Study design Young participants (N = 111, 65% girls) from a community-based birth cohort underwent sleep actigraphy at mean ages 8.1 (SD = 0.3), 12.3 (SD = 0.5), and 16.9 (SD = 0.1) years. A short version of Morningness-Eveningness Questionnaire was administered in late adolescence. At each follow-up, sleep midpoint, duration, wake after sleep onset, sleep efficiency, and weekend catch-up sleep were compared between those reporting morning, intermediate, and evening preferences in late adolescence.

Results Mixed model analyses indicated that sleep timing was significantly earlier among morning types compared with evening types at all ages (*P* values < .04). The mean differences in sleep midpoint between morning and evening types increased from a mean of 19 minutes (age 8), 36 minutes (age 12), to 89 minutes (age 17). The largest change occurred from age 12 to 17 years. Sleep duration, wake after sleep onset, sleep efficiency, and catch-up sleep did not differ according to circadian preference.

Conclusions This study found significant continuity in sleep timing from childhood to adolescence over 9 years, indicating that late circadian preference reported in late adolescence begins to manifest in middle childhood. Further studies are needed to establish whether sleep timing has its origins at an even earlier age. *(J Pediatr 2017;■■:■■-■■).*

Circadian preference varies between individuals and is influenced by genetic factors[1-3] and external cues.[4] This results in differences in activities such as sleep timing. Later circadian preference is associated with several adverse outcomes.[5-8]

During childhood, sleep timing is highly dependent on parental guidance. This typically changes during adolescence, when more autonomy is gained over schedules.[9] Together with emerging biological pressure toward a later-timed circadian rhythm, adolescence is a particularly vulnerable period for problems in circadian regulation[10,11]: several reports emphasize that adolescents have a high risk for developing delayed sleep phase disorder,[12] as they tend to have the most irregular sleep behavior and a large amount of weekend catch-up sleep compared with other age groups.[13]

Previous cross-sectional studies have reported shorter sleep duration and later sleep midpoint among those who report a preference for eveningness.[14-16] In this longitudinal study, we investigated how self-reported circadian preference reflects in the developmental trajectories of objectively measured sleep patterns from middle childhood to late adolescence and hypothesized there is significant variation in the trajectories specifically related to sleep duration and its timing. We expected that compared with adolescents with a morning preference, adolescents with a circadian preference toward eveningness would have a later sleep midpoint from middle childhood onwards, resulting in shorter sleep duration over time.

Methods

Participants were recruited from an urban community-based cohort composed of 1049 healthy singletons born in 1998 in Helsinki, Finland. Details are

BMI	Body mass index
MD	Mean difference
MEQ	Morningness-Eveningness Questionnaire
T1	Time point 1
T2	Time point 2
T3	Time point 3
WASO	Wake after sleep onset

From the [1]Department of Psychology and Logopedics, University of Helsinki, Helsinki, Finland; [2]School of Psychology, Flinders University, Adelaide, Australia; [3]Helsinki Collegium for Advanced Studies, University of Helsinki, Helsinki, Finland; [4]Chronic Disease Prevention Unit, National Institute for Health and Welfare, Helsinki; [5]Children's Hospital, Helsinki University Hospital and University of Helsinki, Helsinki, Finland; and [6]PEDEGO Research Unit, MRC Oulu, Oulu University Hospital and University of Oulu, Oulu

Supported by The Academy of Finland (1287174), the Juho Vainio Foundation, the Signe and Ane Gyllenberg Foundation, the PsyCo Doctoral Programme of Psychology, the Sigrid Jusélius Foundation, the Foundation for Pediatric Research, the Novo Nordisk Foundation, the Emil Aaltonen Foundation, and the Australian Research Council. M.G. received funding from Re-Timer Pty Ltd, is a paid consultant for the Australian Psychological Society and Little Brown Book Company, and owns stock in ResMed. The other authors declare no conflicts of interest.

https://doi.org10.1016/j.jpeds.2017.10.068

described in previous reports.[17,18] The current study builds on objective sleep measurements from 3 time points across 9 years, from age 8 and 12 to age 17 years. **Figure 1** (available at www.jpeds.com) illustrates the participation in the follow-ups.

In 2006 (time 1 [T1], at 8 years of age), we invited a subsample of the initial cohort members who had given permission to be included in a follow-up and who were traceable. Because of the original research interests, this subsample was weighted on mothers who consumed more glycyrrhizin (which inhibits placental 11β-HSD2 function) in the form of licorice during pregnancy.[17] In 2009-2011 (time 2 [T2], at 12 years of age), all the initial cohort members (n = 1049) who had given permission to be contacted and whose addresses were traceable were invited to a follow-up, of whom 692 (75.2%) could be contacted by phone (mothers of the adolescents).

In 2014-2015 (time 3 [T3], at 17 years of age), we invited all cohort members who participated at T2 and lived within a 30-km radius from Helsinki to participate in a follow-up. At T3, the Morningness-Eveningness Questionnaire (MEQ)[19] was administered, resulting in data from 189 adolescents. As the result of missing responses to some of the questions in the full MEQ, we used a previously validated short form of MEQ (rMEQ)[20] comprising 6 of the 19 items in full MEQ.

Complete sleep actigraphy data from all the 3 measurement points and rMEQ data from T3 were available for 112 adolescents. One participant was excluded from analysis due to sleep midpoint differing over 4 SDs from the mean at T3. Thus, our analytical sample consisted of 111 (64% females) adolescents who had complete sleep data and information on circadian preference.

The ethics committees of the City of Helsinki Health Department and Children's Hospital in Helsinki University Central Hospital approved the study protocols (HUS 400/E7/05 for T1 and T2; 177/13/03/03/2014 for T3). Informed written child and parent consent were obtained at T1 and T2 and only adolescent consent at T3.

The representativeness of the samples at each time point T1,[21] T2,[22] and T3[16] in relation to the original cohort has been reported previously. The sample in this study (n = 111) did not differ from the rest of the participants at T3 (n = 86) regarding any of the sleep variables, body mass index (BMI), sex, age, mother's BMI, mother's age at birth, gestational age, maternal alcohol consumption, length at birth, birth weight, pubertal development, or highest education level of the parents. Those in the sample had mothers reporting lower maternal licorice consumption compared with other T3 participants ($P = .03$). With regard to the initial cohort, there were no differences between the current sample (n = 111) and the rest of the initial cohort (n = 938) in mother's BMI, maternal licorice consumption, maternal alcohol consumption, gestational age, length at birth, and birth weight ($P > .07$), but current participants were more likely to be girls ($P = .002$) and had older mothers ($P = .003$).

Sleep

Actigraphs are watch-like, wrist-worn devices containing motion accelerometers to measure limb movements. Actigraphy is a widely used objective method used to study sleep–wake patterns in pediatric populations.[23] We measured sleep duration, quality, and timing using actigraphs (Actiwatch AW4 at T1 and AW7 at T2 and T3; CamNtech Ltd, Cambridge, United Kingdom). All measurements were completed with medium sensitivity and 1-minute epochs. We used the validated Actiwatch algorithm[23] to detect sleep onset and offset.

Participants were instructed to wear actigraphs for 10 days at T1, T2, and T3 on their nondominant wrists and completed sleep diaries during the measurement period. Actigraphy data were handled as described previously.[18] Participants were instructed to document all temporary pauses into the sleep log and to report other significant occurrences, such as travel or illness. Nights were excluded from further sleep analyses if (1) the actigraph was not in use; (2) information on bedtimes was missing; (3) the data on reported bedtime indicated that the person was already asleep (suggesting that the bedtime was incorrectly reported); (4) information on waking time was missing and the activity pattern was unclear; or (5) a change in normal life was reported, such as sleepovers, daytime napping, illness, or travel.

Sleep duration, onset, offset, and wake after sleep onset (WASO) were extracted from the data by the software (Actiwatch Activity & Sleep Analysis versions 5.42 and 7.0; CamNtech Ltd). Sleep efficiency was calculated as the time spent asleep divided by the amount of time in bed, multiplied by 100 (reported as a percentage). Sleep midpoint was defined as the time point when one half of assumed sleep (time in bed) had passed since sleep onset. Sleep onset, offset, and midpoints were calculated for both weekdays and weekends separately. Irregular sleep patterns were operationalized as the amount of catch-up sleep during the weekend (calculated as the subtraction of weekday nights' sleep duration from weekend nights' sleep duration), assumed to be an indicator of cumulative sleep debt.[12] In addition, we calculated differences in mean sleep midpoint, sleep onset, sleep offset, weekend catch-up sleep, sleep duration, WASO, and, sleep efficiency from T1 to T2, from T1 to T3, and from T2 to T3 to study the amount of change in these variables over development.

Circadian preference was assessed at T3 using the 6-item short version of the MEQ.[19,20] MEQ is a questionnaire that evaluates an individual's preference to perform their daily tasks at a certain time. Questions include both direct questions about a person's circadian preference and descriptions of hypothetical situations in which an individual has to select which time frame would result in optimal performance. As described previously,[16] we used a rating yielding in a 3-class circadian preference: morning, intermediate, and evening. We used the following cut-off points for the classification of rMEQ types: 5-12 for eveningness, 13-18 for intermediate, and 19-27 for morningness.[20]

Information on age and sex were derived from initial cohort records, and these were controlled for in all analyses. Pubertal development was self-reported with the Pubertal Development Scale[24] at T2 and T3, as described previously.[22] The Pubertal Development Scale is a validated, 5-item self-report scale for body hair, growth spurts, skin changes, and men-

FLA 5.5.0 DTD ■ YMPD9571_proof ■ December 6, 2017