Sleep Science

ORIGINAL ARTICLE

Work start time and chronotype of indoor and outdoor daytime workers

Horários de início de trabalho e cronotipo de trabalhadores diurnos de ambientes internos e externos

Flávio Back[1], Claudia Roberta de Castro Moreno[2], Fernando Mazzilli Louzada[3], Luis Menna-Barreto[4]

ABSTRACT

Background and objective: Natural light exposure has important effects on the biological timing systems. One could suppose that this exposure might promote a better adjustment between biological rhythms and early working times among outdoor diurnal workers. The aim of this study was to compare the morningness/eveningness preferences and the relationship between actual and ideal timing to work on diurnal workers exposed to different light conditions. **Methods:** The study was conducted with two groups of workers (n=49) living in a rural area and exposed to similar social conditions. One group worked indoor (n=20, mean age 30.8 years (21-50); standard deviation=9.8), and the other group worked outdoor (n=29, mean age 30.8 years (17-50); standard deviation=10.0). The workers filled out a morningness-eveningness questionnaire (MEQ). A one-way ANOVA was carried out in order to compare MEQ scores between the two groups of workers. **Results:** As expected, Outdoor Environment Group (OEG) showed a higher average when compared to Indoor Environment Group (IEG), which means a trend to a morning preference (OEG: 58.4±7.9; IEG: 47.4±6.4), with a significant difference (F=26.22; p<0.001). According to the reported data related to working times, the OEG would like to postpone the working time by 31 minutes, while the IEG would postpone by 96 minutes their actual working time (F=7.71; p<0.01). **Conclusions:** The results of this study suggested that natural light exposure may promote better adjustment to early working hours.

Keywords: Chronobiology phenomena; Work hours; Night work; Sleep deprivation; Rural workers

RESUMO

Introdução e objetivo: A exposição à luz natural tem efeitos relevantes no sistema de temporização biológica. Pode-se supor que essa exposição poderia promover um ajuste melhor entre os ritmos biológicos e os horários de início de trabalho entre trabalhadores diurnos de ambientes externos. O objetivo deste estudo foi comparar a matutinidade/vespertinidade e a relação entre o horário de trabalho real e o ideal em trabalhadores diurnos expostos a condições de iluminação distintas. **Métodos:** O estudo foi conduzido com dois grupos de trabalhadores (n=49) que residiam em uma área rural e tinham condições sociais similares. Um grupo trabalhava em ambiente interno (n=20, idade média 30,8 anos (21-50); desvio padrão=9,8) e o outro grupo trabalhava em ambiente externo (n=29, idade média 30,8 anos (17-50); desvio padrão=10,0). Os trabalhadores preencheram um questionário de matutinidade/vespertinidade (MEQ). Foi realizada uma ANOVA de um fator com o intuito de comparar os escores do MEQ entre os dois grupos de trabalhadores. **Resultados:** Como esperado, o Grupo do Ambiente Externo (GAE) apresentou média de escores mais elevada que o Grupo do Ambiente Interno (GAI), o que significa uma tendência à matutinidade (GAE: 58,4±7,9; GAI; 47,4±6,4), com significância estatística (F=26,22; p<0,001). De acordo com os dados relatados em relação aos horários de trabalho, o GAE gostaria de atrasar seu horário de trabalho em 31 minutos, em média, enquanto que o GAI gostaria de atrasar em 96 minutos seu horário de trabalho (F=7,71; p<0,01). **Conclusões:** Os resultados desse estudo sugerem que a exposição à luz natural pode promover um ajuste melhor aos horários de início de trabalho matutinos.

Descritores: Fenômenos cronobiológicos; Jornada de trabalho; Trabalho noturno; Privação do sono; Trabalhadores rurais

INTRODUCTION

The solar clock, that is, the alternation between day and night has been considered as the main environmental event which is able to synchronize the organism oscillators [1-3]. Synchronization starts with the action of light on the ganglion cells of the retina. The processing of such information by the central nervous system allows entrainment, triggering internal syn-

Study carried out at Instituto de Ciências Biomédicas, Universidade de São Paulo – USP, São Paulo (SP), Brazil.
[1]Instituto de Ciências Biomédicas, Universidade de São Paulo – USP, São Paulo (SP), Brazil.
[2]Faculdade de Saúde Pública, Universidade de São Paulo – USP, São Paulo (SP), Brazil.
[3]Setor de Ciências Biológicas, Universidade Federal do Paraná – UFPR, Curitiba (PR), Brazil.
[4]Instituto de Ciências Biomédicas, Universidade de São Paulo – USP, São Paulo (SP), Brazil; Escola de Artes, Ciências e Humanidades, Universidade de São Paulo – USP, São Paulo (SP), Brazil.
Corresponding author: Fernando Mazzilli Louzada – Department of Physiology, Universidade Federal do Paraná – Caixa Postal 19031 – CEP 81531-990 – Curitiba (PR), Brazil – Tel.: (41) 3361-1552 – E-mail: flouzada@ufpr.br
Received: February 20, 2009; Accepted: March 31, 2010

chronization processes. In order to trigger such processes, the central nervous system uses different output signals to spread the circadian message throughout the brain and the body [4]. This process involves direct and indirect neuronal projections and secretion of polypeptides [5,6]. The internal synchronization process is based on multiple feedback mechanisms, resulting in a coordinated rhythmicity of the organism's physiology and behavior. Detailing the mechanisms that involve the synchronizing processes allows for the understanding of their plasticity, as well as their limits.

Human species is diurnal. However, there are marked individual differences concerning preferences for sleep and wakefulness as well as other activities, which is a characteristic called "chronotype" originally described by Horne and Östberg [7] in 1976. In the last decade, diurnal preferences have been associated to clock-genes polymorphisms [8-10] and to the endogenous circadian period. Morning-type individuals show a shorter intrinsic period when compared to evening-type individuals [11]. Differences between the phase angles of entrainment have been reported, with the shorter phase angles being related to evening-types [12,13]. Wright et al. [14] showed that the phase angle of entrainment may be affected by the intrinsic period and by the duration and intensity of light exposure.

There is room for the supposition that the reduction of time exposure to natural light in contemporary society may modify the phase angle of entrainment and affect morningness/eveningness preferences. Roenneberg et al. [15] evaluated the chronotype distribution of 500 individuals and found a positive correlation between time exposure to natural light and advanced sleep phase. Goulet et al. [16] described patterns of light exposure along 24 consecutive hours in individuals with different diurnal preferences in a situation with minimal external constraints on their sleep schedules and found that morning-type individuals are exposed to higher light intensities in the morning when compared to evening-type individuals. Recently, Roenneberg et al. [17] showed an association of longitude to sleep phase preferences. People living in cities with early sunrise times showed a tendency for more pronounced morningness. The authors suggest that the human circadian-timing system is predominantly entrained by sun time rather than social time. Although the availability of food can be stronger than light among most of animals, with a genetic regulation as well, there is a need for further studies to discuss it in the case of human beings [18].

Exposure to light has been used as a means to promote adjustment of the worker's biological rhythms [19,20]. It has also been demonstrated that short periods of exposure to light may produce the same effects as long periods of exposure to light. For instance, there is a study that demonstrates that exposure to intermittent light (six 40-minute light pulses) produces an adjustment of the circadian rhythmicity [21].

On an extended review article about the subject, Burgess et al. [22] recommend exposure to medium intensity light and/or to intermittent light during night work as a strategy to promote adaptation to the work schedule. On the other hand, exposure to solar light on the way back home after night work may prevent adaptation. Wearing sunglasses on the way back home has also been recommended by many researchers [22,23].

Based on these findings, one could suppose that the natural light exposure is capable of promoting a better adjustment between biological rhythms and early working times among outdoor diurnal workers, when compared to indoor workers.

The aim of this study was to compare the morningness/eveningness preferences and the relationship between actual and ideal timing to work on diurnal workers exposed to different light conditions.

METHODS

Subjects

The study was conducted with two groups of workers (n=49) in a rural area in Paraná, Brazil, between June and October 2007 (average of annual temperature=22.1ºC; average of relative humidity=69.3%). One group worked indoor (n=20, mean age 30.8 years (21-50); standard deviation (SD)=9.8) and the other group worked outdoor (n=29, mean age 30.8 years (17-50); SD=10.0).

The Indoor Environment Group (IEG) was comprised by bench lathe workers, electrical machine operators and one desk-bound office worker. The working time of this group was from 8 to 18h, from Monday to Friday, and Saturday from 8 to 16h. Their commuting time ranged from 5 to 20 minutes walking or riding a motorcycle. The Outdoor Environment Group (OEG) was comprised by agricultural workers. This group worked from Monday to Friday (7 to 17h); their commuting time ranged from 30 to 60 minutes. They used to walk for around 15 minutes to get a ride in an opened truck body. These workers had been submitted to natural bright light during working time for 11.7±10.6 years, while IEG had been exposed to artificial light during working time for 1.8±1.2 (four months to five years).

Both groups lived at the same city (latitude: S 23º 5'; longitude: W 52º 36'), with 2,000 inhabitants, and they had similar sociocultural background. Workers taking drugs that interfered in the sleep-wake cycle and those who reported sleep disturbances were excluded from the sample.

Light intensity measures

The light intensity in both workplaces was measured in the morning (8h) and in the afternoon (15h) using a light meter with a maximum of sensitivity of at 20,000 lux (THDL-

400®). A photodiode sensor was held at the researcher's eyes level to measure the light intensity at the workplace.

One subject of each group wore a wrist actigraph with light sensor (Ambulatory Monitoring®) during 24 hours of a workday in order to measure duration and intensity of light exposure. The device had a light sensitivity ranging from 0 to 3,995 lx. These results were used to illustrate the light exposure pattern of the groups. Workers did not wear goggles during the study period.

There was a gradual increase of the light intensity during sunrise, which used to take around 70 minutes to reach the limit of sensivity at 20,000 lux. During data collection, the photoperiod varied: sunrise ocurred between 5h58 and 7h06 and sunset between 17h52 and 18h35.

Morningness-eveningness identification and questions about working times

The workers filled out a Portuguese version of the Morningness-Eveningness Questionnaire (MEQ) [7] and questionnaires about their working times. A one-way ANOVA was carried out in order to compare MEQ scores between the two groups of workers.

A questionnaire on working times was answered by the workers as well as questions about work span, commuting time, time of starting and ending work. A question related to workers' preference for the ideal time to start working taking into account their sleep quality was also included. Difference between the ideal working time (according to their preferences) and the actual working time was calculated.

Differences between the actual and ideal work time were calculated and the averages were compared through ANOVA.

For each group, linear regression analysis between age and MEQ scores was carried out and a correlation coefficient was obtained.

The study was approved by the ethical committee of Universidade de São Paulo (USP).

RESULTS

The IEG was exposed to a range of 50 to 500 lx during most part of the day and the OEG was exposed up to at least 20,000 lx, measured by a portable light sensor, although the detection limit of the wrist light sensor was 3,995 lx.

Examples of light exposure intensities of every hour on two workers from each group have been plotted on Figure 1.

As expected, OEG showed a higher average of MEQ than the IEG (OEG: 58.4±7.9; IEG: 47.4±6.4). A significant difference between groups was detected ($F=26.22$; $p<0.001$). It was also observed that the chronotype distribution was quite wide, with the extremes being far apart. The distribution of MEQ scores for each group is shown in Figure 2.

According to the data obtained, the OEG would like to postpone their working time by 31 minutes, while the IEG would like to have it postponed by 96 minutes. In other words, the OEG seems to be more satisfied with their working hours. Figure 3 shows the differences between actual and ideal work time. A significant difference was detected between groups ($F=7.71$; $p<0.01$).

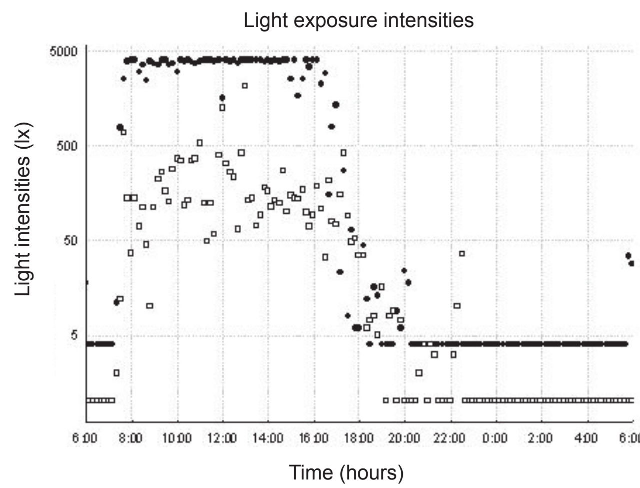

Figure 1: Light exposure pattern of one subject per group within 24h (measured each 4 min). Black circles represent an Outdoor Envirnoment Group individual and open squares represent an Indoor Environment Group individual. On the Y axis are shown the light intensity level, in lux, logaritimic scale. Axis X represents time in hours.

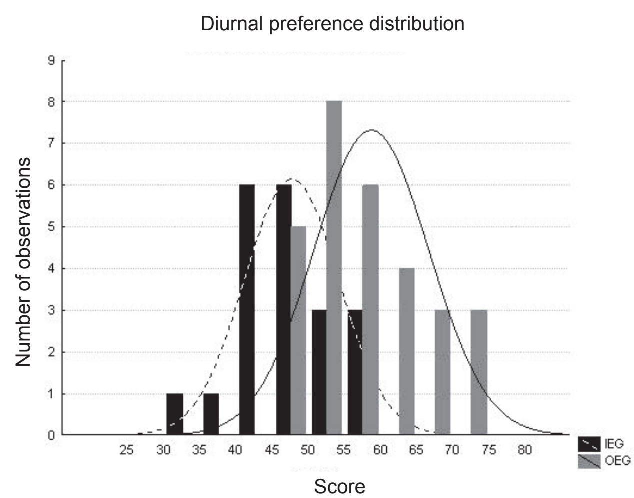

Figure 2: Distribution of morningness-eveningness questionnaire (MEQ) scores for the two groups overlapped. Gray columns represent the Outdoor Environment Group (OEG), while black columns represent the Indoor Environment Group (IEG). On the axis Y are shown the number of subjects. On the axis X are shown the MEQ scores. Higher morningness-eveningness scores are associated with morning-like preferences, whereas lower scores are associated with evening-like preferences.

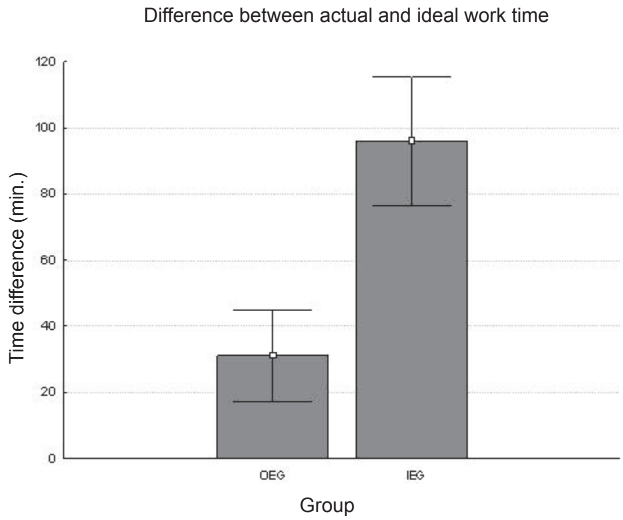

Figure 3: Columns represent Outdoor Environment Group (OEG) and Indoor Environment Group (IEG). On the Y axis are displayed time difference between actual and ideal working times. Open squares represent means and bar error refers to the standard error of the mean.

Differences according to age were detected as well. Figure 4 shows the correlations between age and MEQ score for both groups. Older workers showed higher MEQ score. A positive significant correlation was found only on the OEG (r=0.61; p=0.0004), IEG (r=0.28; p=0.21).

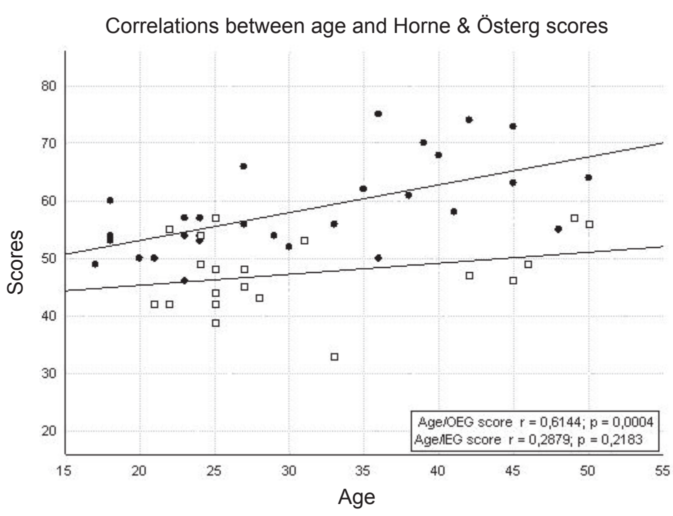

Figure 4: Correlation between age and morningness-eveningness questionnaire (MEQ) scores. Black circles represent Outdoor Environment Group (OEG); open squares represent the Indoor Environment Group (IEG). On the Y axis are shown the morningness-evemimgmess questionnaire scores. On the X axis are plotted the age of the subjects.

DISCUSSION

The discussion about the deleterious effects upon alertness due to early working times is not new in the literature. According to Tucker et al. [24], an early work starting time, around 6h, for instance, might lead to reduced alertness and is also associated with poor psychological and physical health. The results of this study indicate that natural light exposure may promote better adjustment to early working hours. The workers exposed to natural light during working time (OEG) were earlier types when compared to workers from the indoor group. This fact could explain why the differences between ideal and actual working times are smaller in this group, even taking into account that they started work one hour earlier than those working indoor (IEG).

Several factors are related to the expression of morningness-eveningness preference. According to some studies, morning type individuals are exposed to natural light earlier when compared to evening types [15,16]. Diurnal preference changes with development. Adolescents tend to delay and older adults advance their circadian rhythms [25-27]. Genetic influences on these tendencies have been proposed [8-10]. Studies in rodents and humans suggest that differences in duration and intensity of light exposure since birth also play a significant role [28-32]. In addition, recent studies show that recent photic history modifies the responses of the circadian system; melatonin secretion depends on previous exposure to light [33-35]. OEG subjects were submitted to natural light during the day with levels up to 20,000 lx. It is reasonable to suppose that their circadian system response to artificial light at home is quite different when compared to the responses of IEG subjects.

The significant correlation between age and chronotype in the OEG suggests that environmental factors may have a role of increasing or modifying ontogenetic trends.

Morning tendencies in OEG subjects might be explained exclusively by the fact that they were exposed to natural bright light predominantly during advanced portions of the phase response curve. However, recently, Scheer et al. [36] compared the intrinsic period of subjects submitted to different light/dark regimens. The results represent the first demonstration of the plasticity of the human intrinsic period, which had already been described in rodents by Pittendrigh and Daan [37]. In the interpretation of our data, effects of chronic exposure to bright light on the intrinsic period plasticity should not be ruled out.

The effects of artificial light exposure in worksites have been documented as a means of promoting alertness during night work or for promoting adjustment of workers' biological rhythms [22,38]. However, few studies have aimed to investigate the effect of natural light exposure on workers. Kaida et al. [39] showed, in a lab study, the positive effects of natural light exposure at lunchtime on workers' performance and alertness levels. Our results reinforce the idea of natural light exposure as a means of promoting alertness and facilitating early awakening among day workers with an early start to the day shift.

Limitations and future studies

The present study was conducted under limitations. The limited number of workers who have used the actigraphs with light sensor and the limitations of the light meter sensitivities are some examples. Another limitation is the fact that the two groups studied had different work starting times. Also, data regarding sleep habits and diurnal sleepiness were not gathered. Thus, further investigation involving larger numbers of subjects is necessary to provide better insight into the discussion of the effects of natural light exposure on morningness/eveningness characteristics as well as on sleepiness and sleep, safety, health and working time satisfaction.

ACKNOWLEDGMENTS

We acknowledge the support of Fundação de Amparo à Pesquisa do Estado de São Paulo (Fapesp), grant number 05/57597-2.

REFERENCES

1. Duffy JF, Wright KP Jr. Entrainment of the human circadian system by light. J Biol Rhythms 2005;20(4):326-338. Review.
2. Khalsa SB, Jewett ME, Cajochen C, Czeisler CA. A phase response curve to single bright light pulses in human subjects. J Physiol. 2003;549(Pt 3):945-52.
3. Klerman EF, Duffy JF, Dijk DJ, Czeisler CA. Circadian phase resetting in older people by ocular bright light exposure. J Investig Med. 2001;49(1):30-40.
4. Brandstaetter R. Circadian lessons from peripheral clocks: is the time of the mammalian pacemaker up? Proc Natl Acad Sci. 2004;101(16):5699-700.
5. Albrecht U. The mammalian circadian clock: a network of gene expression. Front Biosci. 2004;9:48-55.
6. Saper CB, Scammel TE, Lu J. Hypothalamic regulation of sleep and circadian rhythms. Nature. 2005;437(7063):1257-63.
7. Horne J, Östberg O. A self-assessment questionnaire to determine morningess-eveningness in human circadian rhythms. Int J Chronobiol. 1976;4(2):97-110.
8. Katzenberg D, Young T, Finn L, Lin L, King DP, Takahashi JS, et al. A CLOCK Polymorphism associated with human Diurnal preference. Sleep. 1998;21(6):569-76.
9. Archer SN, Robilliard DL, Skene DJ, Smits M, Williams A, Arendt J, et al. A length Polymorphism in the circadian clock gene Per3 is linked to delayed sleep phase syndrome and extreme diurnal preference. Sleep. 2003;26(4):413-5.
10. Pereira DS, Tufik S, Louzada FM, Benedito-Silva AA, Lopez AR, Lemos NA, et al. Association of the length polymorphism in the human Per3 gene with the delayed sleep-phase syndrome: does latitude have an influence upon it? Sleep. 2005;28(1):29-32.
11. Duffy JF, Rimmer DW, Czeisler CA. Association of intrinsic circadian period with morningness-eveningness, usual wake time, and circadian phase. Behav Neurosci. 2001;115(4):895- 9.
12. Duffy JF, Dijk DJ, Hall EF, Czeisler CA. Relationship of endogenous circadian melatonin and temperature rhythms to self-reported preference for morning or evening activity in young and older people. J Investig Med. 1999;47(3):141-50.
13. Liu X, Uchiyama M, Shibui K, Kim K, Kudo Y, Tagaya H, et al. Diurnal preference, sleep habits, circadian sleep propensity and melatonin rhythm in healthy human subjects. Neurosci Lett. 2000;280(3):199-202.
14. Wright KPJr, Gronfier C, Duffy JF, Czeisler CA. Intrinsic period and light intensity determine the phase relationship between melatonin and sleep in humans. J Biol Rhythms. 2005;20(2):168-77.
15. Roenneberg T, Wirz-Justice A, Merrow M. Life between clocks – daily temporal patterns of human chronotypes. J Biol Rhythms. 2003;18(1):80-90.
16. Goulet G, Mongrain V, Desrosiers C, Paquet J, Dumont M. Daily light exposure in morning-type and evening-type individuals. J Biol Rhythms. 2007;22(2):151-8.
17. Roenneberg T, Kumar CJ, Merrow M. The human circadian clock entrains to sun time. Curr Biol. 2007;17(2):44-5.
18. Fuller PM, Lu J, Saper CB. Differential rescue of light- and food-entrainable circadian rhythms. Science. 2008;320(5879):1074-7.
19. Czeisler CA, Dijk DJ. Use of bright light to treat maladaptation to night shift work and circadian rhythm sleep disorders. J Sleep Res. 1995;4(S2):70-3.
20. Crowley SJ, Lee C, Tseng CY, Fogg LF, Eastman CI. Combinations of bright light, scheduled dark, sunglasses, and melatonin to facilitate circadian entrainment to night shift work. J Biol Rhythms. 2003;18(6):513-23.
21. Baehr EK, Fogg LF, Eastman CI. Intermittent bright light and exercise to entrain human circadian as rhythms to night work. Am J Physiol. 1999;277(6 Pt2):R1598-604.
22. Burgess HJ, Sharkey KM, Eastman CI. Bright light, dark and melatonin can promote circadian adaptation in night shift workers. Sleep Med Rev. 2002;6(5):407-20.
23. Eastman CI, Stewart KT, Maboney MP, Liu L, Fogg LF. Dark goggles and bright light improve circadian rhythm adaptation to night-shift work. Sleep. 1994;17(6):535-43.
24. Tucker P, Smith L, Macdonald I, Folkard S. Shift length as a determinant of retrospective on-shift alertness. Scand J Work Environ Health 1998;24 Suppl. 3:49-54.
25. Carskadon MA, Vieira C, Acebo C. Association between puberty and delayed phase preference. Sleep. 1993;16(3):258-62.
26. Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, et al. A marker of the end of adolescence. Curr Biol. 2004;14(24):1038-9.
27. Monk TH, Kupfer DJ. Which aspects of morningness-eveningness change with age? J Biol Rhythms 2007;22(3):278-80.
28. Cambras T, Díez-Noguera A. Evolution of rat motor activity circadian rhythm under three different light patterns. Physiol Behav. 1991;49(1):63-8.
29. Natale V, Adan A. Season of birth modulates morningness-eveningness preference in humans. Neurosci Lett. 1999;274(2):139-41.
30. Canal-Corretger MM, Vilaplana J, Cambras T, Díez-Noguera A. Effect of light on the development of the circadian rhythm of motor activity in the mouse. Chronobiol Int. 2001;18(4):683-96.
31. Canal-Corretger MM, Cambras T, Díez-Noguera A. Effect of light during lactation on the phasic and tonic responses of the rat pacemaker. Chronobiol Int. 2003;20(1):21-35.

32. Natale V, Adan A, Scapellato P. Are seasonality of mood and eveningness closely associated? Psychiatry Res. 2005;136(1):51-60.
33. Hébert M, Martin SK, Lee C, Eastman CI. The effects of prior light history on the suppression of melatonin by light in humans. J Pineal Res. 2002;33(4):198-203.
34. Smith KA, Schoen MW, Czeisler CA. Adaptation of human pineal melatonin suppression by recent photic history. J Clin Endocrinol Metab. 2004;89(7):3610-4.
35. Jasser SA, Hanifin JP, Rollag MD, Brainard GC. Dim light adaptation attenuates acute melatonin suppression in humans. J Biol Rhythms. 2006;21(5):394-404.
36. Scheer FA, Wright KP Jr, Kronauer RE, Czeisler CA. Plasticity of the intrinsic period of the human circadian timing system. PloS ONE. 2007;2(1):e721.
37. Pittendrigh CS, Daan S. A functional analysis of circadian pacemakers in nocturnal rodents. 1. the stability and lability of spontaneous frequency. J Comp Physiol. 1976;106:223-52.
38. Boivin DB, James FO. Light treatment and circadian adaptation to shift work. Ind Health. 2005;43(1):34-48.
39. Kaida K, Takahashi M, Haratani T, Otsuka Y, Fukasawa K, Nakata A. Indoor exposure to natural bright light prevents afternoon sleepiness. Sleep. 2006;29(4):462-9.