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Zhiwei Liu  
*Cambridge-Suda (CAM-SU) Genomic Resource Center, Jiangsu Key Laboratory of Neuropsychiatric Diseases Research, Medical College of Soochow University, Suzhou 215123, Jiangsu, China*

Yingying Dong  
*Cambridge-Suda (CAM-SU) Genomic Resource Center, Jiangsu Key Laboratory of Neuropsychiatric Diseases Research, Medical College of Soochow University, Suzhou 215123, Jiangsu, China*

Ying Xu  
*Cambridge-Suda (CAM-SU) Genomic Resource Center, Jiangsu Key Laboratory of Neuropsychiatric Diseases Research, Medical College of Soochow University, Suzhou 215123, Jiangsu, China*

Fei Zhou  
*Cambridge-Suda (CAM-SU) Genomic Resource Center, Jiangsu Key Laboratory of Neuropsychiatric Diseases Research, Medical College of Soochow University, Suzhou 215123, Jiangsu, China*

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Chronotype distribution in the Chinese population

Zhiwei Liu§, Yingying Dong§, Ying Xu, Fei Zhou (✉)

Cambridge-Suda (CAM-SU) Genomic Resource Center, Jiangsu Key Laboratory of Neuropsychiatric Diseases Research, Medical College of Soochow University, Suzhou 215123, Jiangsu, China

§These authors contributed equally to this work.

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KEYWORDS
circadian rhythm, chronotype, Morningness–Eveningness Questionnaire (MEQ), distribution

ABSTRACT

Purpose: Individual chronotypes are reported to be closely associated with mood, health status, and even disease progression. However, no reports of chronotype distribution in the Chinese population have been made available to date.

Methods: We performed a chronotype survey using the classic Morningness–Eveningness Questionnaire both online and offline. The webpage-based online survey was distributed via a social network application on mobile phones. The offline survey was distributed to local primary and middle schools. A total of 9476 questionnaires were collected, of which 8395 were valid. The mean age of the participants was 30.38 ± 11.47 years, and 37.38% were male.

Results: Overall, the Chinese chronotypes showed a near-normal distribution with a slight shift toward eveningness. When analyzed in different age groups, the overall Chinese population was shown to be “latest” in their early twenties. In the young population, two significant points of change in chronotype were identified at the ages of 10 and 16 years. The chronotype composition remained relatively stable during early adulthood (from 17 to 28 years of age).

Conclusion: This study generated the first overview of chronotype distribution in the Chinese population and will serve as essential background data for future studies.

1 Introduction

The circadian clock helps organisms to adapt to the changing environment by scheduling the metabolic cycle and maintaining energy homeostasis [1]. The physiology of living organisms oscillates on a near-24-h cycle, as a result of circadian regulation [2]. Although the activities and sleep schedules of humans are controlled by the circadian clock with a period about 24 h, the timings (or phases) of individuals are different. These different rhythms are known as chronotypes.

A variety of factors impact an individual’s chronotype, including environment, age, gender, and genetic mutations [3–9]. Chronotype is also reported to be closely associated with physiology, behavior, and psychiatry [10–12]. Therefore, the assessment of individual chronotypes is valuable.

Address correspondence to Fei Zhou, fzhou@suda.edu.cn
in predicting disease risk, diagnostic assays, and improving treatments. The gold standard for assessing personal chronotype is the measurement of dim-light melatonin onset (DLMO) [13, 14], which is believed to be an accurate index of the central clock phase. Other tools for measuring an individual’s circadian status have been developed using samples of tissues such as blood and skin [15–22]. Although these methods generate objective results, they require human samples, which limits their use in larger populations. Therefore, chronotype questionnaires, such as the Morningness–Eveningness Questionnaire (MEQ) [23] and Munich ChronoType Questionnaire (MCTQ) [6, 24], have been developed and utilized to investigate personal chronotypes by enquiring about preferred times for sleep and engagement in activities. Comparisons between questionnaire results and DLMO measurements have been carried out to validate the accuracy of the questionnaires [25]. The MEQ, MCTQ, and their derivatives have been used and validated in a variety of nationwide chronotype investigations [6, 25–32], but there are no reports of their use in the Chinese population. In this study, we used the classic MEQ to conduct a wide-ranging survey and generate the first overview of chronotype distribution in the Chinese population.

2 Materials and methods

2.1 Survey participants

We built a webpage containing the MEQ (Chinese translated) and delivered it via a social network to invite participation from people all over China. Offline MEQs were distributed to local primary and middle schools. By the end of 2018, 8008 and 1468 MEQ results were collected online and offline, respectively. Offline questionnaires contained a significant portion of invalid results, which contained no age or gender information or were incomplete. After excluding these invalid results, only 939 of these surveys were included in the final statistics. Age and gender were mandatory for the submission of online questionnaires. Therefore, online questionnaire results were only screened to exclude those with abnormal age values and 7996 results were qualified for further evaluation. In summary, 8935 valid questionnaires were collected, and subjected to further analyses.

2.2 Determination of chronotype

A Chinese translated version of the MEQ (Supplementary S1) was used. For each valid completed questionnaire, an MEQ score was calculated according to a previously defined scoring standard [23]. The MEQ scores were either used directly in statistical analyses or used to generate corresponding chronotypes according to established standards: 16–30, Extreme Evening; 31–41, Evening; 42–58, Normal; 59–69, Morning; or 70–86, Extreme Morning.

2.3 Ethical considerations

We followed the principles of the Declaration of Helsinki as well as the guidelines of the Ethics Committee of Soochow University to conduct the study. The chronotype survey was based on a well-established questionnaire, which does not collect identity-sensitive information and, hence, does not bring any ethical concern. For the online survey, a clear notice was provided on the webpage to inform participants that the questionnaire results would be used in a scientific publication. The survey results were stored in a local database at the CAM-SU (Cambridge-Suda) Genomic Resource Center without identity-sensitive information. All staff involved in the data collection and processing were trained in information security and signed information confidentiality agreements.
2.4 Statistics

Both the MEQ scores and chronotype percentages were used in the statistical evaluations. In brief, the frequency distribution of the MEQ scores was analyzed to investigate the overall distribution of chronotypes, and then the percentages of each were evaluated. To further investigate the dynamic changes in chronotype with age, the survey results were analyzed in different age groups. The mean MEQ scores and the chronotype percentages were plotted separately to visualize the age-dependent changes. The data summary was primarily conducted with Microsoft Excel, and statistical analyses, such as frequency distribution, were performed using GraphPad Prism 8 (GraphPad Software, Inc).

3 Results

3.1 Age and gender

Among the final 8935 valid questionnaires, female participants were dominant (5595/8935, 62.62%), and this gender bias was observed mainly in the online survey [Fig. 1(A) and Table 1]. Survey participants were aged between 8 and 82 years, and the mean age (mean ± SD) was 30.38 ± 11.47 years. The major portion (25th–75th percentile) was 23–37 years of age for both genders (Table 1).

As shown in the age distribution [Fig. 1(B)], the number of participants older than 55-years was low, and no significant difference in age distribution was noted between males and females.

3.2 The Chinese population exhibits near-normal chronotype distribution

The overall frequency of MEQ scores showed a near-normal distribution with a slight shift toward eveningness [smaller scores, Fig. 2(A)]. When the percentages of chronotypes were quantified, the dominant chronotype in the whole population was Normal [70.60%, Fig. 2(B)]. The percentage of people with the Evening chronotype was greater than that of people with the Morning chronotype (17.10% and 10.78%, respectively; Table 2), which contributed to a skewed overall distribution. The percentages of Extreme Morning or Extreme Evening chronotypes in both genders were small but, relatively, more individuals tended to have the Extreme Evening chronotype (0.55% and 0.97%, respectively). When different gender groups were analyzed separately, the percentage of females with the Normal chronotype was slightly greater than that of males (72.05% and 68.17%, respectively), while the male population exhibited greater percentages of Morning.
and Evening chronotypes. The dominance of the Evening chronotype over the Morning chronotype was seen in both genders [Fig. 2(B) and Table 2].

3.3 Chinese people are “latest” in their early twenties

To further analyze the chronotypes at different ages, participants were grouped into 5-year intervals: 10-years (including participants at 8–10 years old), 15-years (including participants at 11–15 years old), 20 years (including participants at 16–20 years old), and so on. Participants over 55 years of age were binned into a single 55+ years group due to a limited sample number. The numbers of participants in each age group are listed in Table 3. When the MEQ scores were

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**Table 1** Demographic statistics of survey participants.

|        | All          | Male          | Female         |
|--------|--------------|---------------|----------------|
| N (%)  | Total        | 3340          | 5595           |
|        | Online       | 2858          | 5138           |
|        | Offline      | 482           | 457            |

| Age     | Min | Max | Average | SD | 25th–75th Percentile |
|---------|-----|-----|---------|----|----------------------|
| Min     | 8   | 8   | 30.38   | 11.47 | 23–37                |
| Max     | 82  | 82  | 30.26   | 12.05 | 22–37                |
| Average | 30.46| 30.46| 30.46   | 11.10 | 23–37                |

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**Table 2** Percentages of different chronotypes in Chinese population.

| MEQ Score | Chronotype       | All (N (%) | Male (N (%)) | Female (N (%)) |
|-----------|------------------|------------|--------------|----------------|
| 70–86     | Extreme Morning  | 49 (0.55)  | 18 (0.54)    | 31 (0.55)      |
| 59–69     | Morning          | 963 (10.78)| 399 (11.95)  | 564 (10.08)    |
| 42–58     | Normal           | 6308 (70.60)| 2277 (68.17)| 4031 (72.05)   |
| 31–41     | Evening          | 1528 (17.10)| 611 (18.29)  | 917 (16.39)    |
| 16–30     | Extreme Evening  | 87 (0.97)  | 35 (1.05)    | 52 (0.93)      |

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**Fig. 2** Normal distribution of chronotypes in Chinese population. (A) Frequency distribution of MEQ scores is near-normal with a slight skew toward eveningness. The distribution patterns for different genders are similar. (B) Percentage of different chronotypes in total (green), male (red), and female (blue) participants. The percentage numbers are indicated above each column.
evaluated, they showed a consistently changing pattern with age in both genders [Fig. 3(A)]. Primary school children under 10 years of age exhibited a relatively high mean MEQ score (Morning-type on average), but the score decreased sharply (> 5 MEQ score per interval) toward...
eveningness on entering puberty. The mean MEQ score reached its lowest value in the 25-years group and then gradually increased (~1 MEQ score per interval), indicating an increasing ratio of Morning chronotypes in the older population. Furthermore, the dynamics of chronotype ratios in each age group were plotted to investigate their age-dependent dynamics [Fig. 3(B)]. The Extreme Morning chronotype was absent in 16–30-year-olds, whereas the Extreme Evening chronotype was absent in participants older than 55 years. In other age groups, the percentages of extreme chronotypes were small, except for a relatively high ratio of Extreme Morning (9.13%) chronotypes in the 10-years group. The curves of the Morning and Evening chronotypes showed opposite trends. The proportion of people of Evening-type peaked in the 25-years group, at which point that of the Morning-type reached its lowest point. The percentage of people of Normal chronotype was generally stable (> 60%), except for people under 10 or over 55 years of age, in which the Morning-type prevailed (> 40%).

3.4 Chronotype composition of Chinese dramatically changes at the ages of 10 and 16 years

As indicated in the analytical results of the age groups, the chronotype composition of the young population changed dramatically between the 10- and 30-years groups. Therefore, we conducted an in-depth investigation by dividing the survey participants into their years of age (Table 4). To better visualize the dynamics of the chronotype ratios, the percentages of chronotypes were plotted, and two points of change were identified at the ages of 10 and 16 years (Fig 4). The Morning chronotype prevailed in children under 10 years, and its percentage peaked at the age of 9 years (65.08%). The first significant change in chronotype composition occurred at the age of 10 years when the percentages of Extreme Morning and Morning chronotypes dropped dramatically, and the Normal chronotype began to dominate (44.19% Morning vs. 48.84% Normal). The Morning-type ratio continued to drop until the age of 17 years and was maintained at a low level (~ 5%) in early adulthood. However, the percentage of people with the Evening chronotype began to increase at the age of 13 years and rose sharply at the age of 17 years (> 10% increment), before peaking at about 22 years. The chronotype composition changed for a second time at the age of 16 years, when the Evening-type ratio surpassed the Morning-type ratio (11.9% Evening vs. 8.33% Morning). In people between the ages of 17 and 28 years, the Evening-type ratio remained at a significant level (> 20%) but began to decrease.

Fig. 3 Chronotype distribution changes with increasing age. (A) The changing pattern of mean MEQ scores with age. The patterns for different genders are similar. Data are shown as mean ± SD. (B) The dynamics of chronotypes with increasing age. The changing patterns of Morning and Evening chronotypes show opposite trends.
Fig. 4 Dramatic changes to chronotype composition occur at the ages of 10 and 16 years. The chronotype composition was analyzed at 1-year intervals. The percentage of Morning chronotype peaks at the age of 9 years and starts to decline at 10 years, when the Normal chronotype begins to dominate. The percentage of Evening chronotype starts to rise sharply at the age of 16 years and surpasses that of the Morning chronotype.

Table 4 Chronotype percentage in young population (8–30 years).

| Age | N   | Extreme Morning | N (%) | Morning | N (%) | Normal | N (%) | Evening | N (%) | Extreme Evening | N (%) |
|-----|-----|----------------|-------|---------|-------|--------|-------|---------|-------|----------------|-------|
| 8   | 59  | 8              | (13.56)| 30      | (50.85)| 21     | (35.59)| 0       | (0.00)| 0              | (0.00) |
| 9   | 63  | 8              | (12.70)| 41      | (65.08)| 12     | (19.05)| 2       | (3.17)| 2              | (3.17) |
| 10  | 86  | 3              | (3.49) | 38      | (44.19)| 42     | (48.84)| 2       | (2.33)| 1              | (1.16) |
| 11  | 88  | 5              | (5.68) | 33      | (37.50)| 45     | (51.14)| 5       | (5.68)| 0              | (0.00) |
| 12  | 49  | 0              | (0.00) | 16      | (32.65)| 32     | (65.31)| 1       | (2.04)| 0              | (0.00) |
| 13  | 76  | 0              | (0.00) | 20      | (26.32)| 49     | (64.47)| 7       | (9.21)| 0              | (0.00) |
| 14  | 88  | 1              | (1.14) | 15      | (17.05)| 67     | (76.14)| 5       | (5.68)| 0              | (0.00) |
| 15  | 68  | 0              | (0.00) | 7       | (10.29)| 55     | (80.88)| 4       | (5.88)| 2              | (2.94) |
| 16  | 168 | 0              | (0.00)| 14      | (8.33) | 133    | (79.17)| 20      | (11.90)| 1              | (0.60) |
| 17  | 125 | 0              | (0.00)| 4       | (3.20) | 89     | (71.20)| 32      | (25.60)| 0              | (0.00) |
| 18  | 268 | 0              | (0.00)| 18      | (6.72) | 183    | (68.28)| 61      | (22.76)| 6              | (2.24) |
| 19  | 206 | 0              | (0.00)| 10      | (4.85) | 152    | (73.79)| 43      | (20.87)| 1              | (0.49) |
| 20  | 233 | 0              | (0.00)| 8       | (3.43) | 170    | (72.96)| 54      | (23.18)| 1              | (0.43) |
| 21  | 222 | 0              | (0.00)| 10      | (4.50) | 153    | (68.92)| 59      | (26.58)| 0              | (0.00) |
| 22  | 302 | 0              | (0.00)| 5       | (1.66) | 204    | (67.55)| 92      | (30.46)| 1              | (0.33) |
| 23  | 314 | 0              | (0.00)| 9       | (2.87) | 208    | (66.24)| 88      | (28.03)| 9              | (2.87) |
| 24  | 489 | 0              | (0.00)| 16      | (3.27) | 338    | (69.12)| 128     | (26.18)| 7              | (1.43) |
| 25  | 436 | 0              | (0.00)| 14      | (3.21) | 306    | (70.18)| 112     | (25.69)| 4              | (0.92) |
| 26  | 384 | 0              | (0.00)| 12      | (3.13) | 261    | (67.97)| 101     | (26.30)| 10             | (2.60) |
| 27  | 426 | 0              | (0.00)| 17      | (3.99) | 290    | (68.08)| 117     | (27.46)| 2              | (0.47) |
| 28  | 425 | 0              | (0.00)| 24      | (5.65) | 297    | (69.88)| 93      | (21.88)| 11             | (2.59) |
| 29  | 315 | 0              | (0.00)| 16      | (5.08) | 237    | (75.24)| 57      | (18.10)| 5              | (1.59) |
| 30  | 331 | 0              | (0.00)| 18      | (5.44) | 246    | (74.32)| 64      | (19.34)| 3              | (0.91) |

Thereafter. In the same age range, the chronotype composition of the Chinese population was relatively stable, which was consistent with the stable chronotype plateau in early adulthood reported previously [26, 33].

4 Discussion

This MEQ survey was conducted online and offline by a relatively wide range of participants and enabled us to form the first overview of chronotypes in the Chinese population. Since chronotype is closely associated with personal health status, population-based results are valuable
references for the evaluation of personal circadian status and to guide personalized chronotherapy. Chronotype displays a near-normal distribution in the Chinese population with a slightly positive skew (toward eveningness), which is similar to previous reports of MCTQ and DLMO results from other countries [24, 25, 28]. Some studies have reported that chronotypes have shifted toward morningness over the past decade [34, 35], while another study reported stable morningness–eveningness scores over a long sampling period (10 years) [36]. Since our survey was completed in less than one year, and no historical data were available for the Chinese population, we were unable to investigate the shift in overall chronotype distribution. However, this is an interesting topic, which would help investigate the influence of lifestyle changes in recent years on individual chronotypes.

The changing patterns in chronotypes with increasing age were also investigated in this study. These are similar to those previously reported, but the exact chronotype changing points we observed are different. A study using the Composite Scale of Morningness questionnaire, covering 0–30-year-old participants, demonstrated that the morningness score decreases right from the beginning and reaches its lowest value at the ages of 18 and 15 for boys and girls, respectively [36]. In other studies, it is generally reported that the maximum lateness in chronotype occurs during late adolescence or early adulthood at around the age of 20 years, and adult chronotypes begin to move toward morningness thereafter [7, 26, 37, 38]. This significant alteration in chronotype may be due to the dramatic change in hormone secretion during puberty and is proposed as a marker for the end of adolescence [38]. However, in our study, we noted two dramatic points of change in chronotype composition, one at the age of 10 years and the other at 16 years. At 10 years, the Morning chronotype ratio drops from its peak and is overtaken by the Normal chronotype. The percentage of people with the Morning chronotype continues to drop thereafter and is surpassed by the Evening chronotype at the age of 16 years. The participants in this age range were generally primary and middle school students, and there was no significant difference in the school time schedule. Therefore, these two dramatic points of change in chronotype composition may be closely related to the development and maturation of an individual’s circadian clock. The percentage of people with the Evening chronotype is persistently high in participants between 17 and 28 years of age with a “lateness” peak at the age of 22 years. The distinct time point of the “lateness” peak may be due to progressive delays in the sleep schedule of adults due to lifestyle changes, e.g., late-night internet surfing, the use of mobile devices, and corresponding nighttime light exposure. It has also been reported that there is another turning point in chronotype distribution at around the age of 50 years [37, 38]. However, we were not able to investigate this time point further, due to our limited sample number at this age and older. Gender differences in chronotype have previously been suggested [28, 37]. When we analyzed groups at 5-year intervals, however, we generally observed paralleled changes in MEQ scores in both genders.

Although a large number of survey results were collected, our study still has certain limitations. The online survey required the use of smartphones, and corresponding social network applications excluded the participation of juveniles and the poorly educated elderly. As shown in the results, our participants were relatively young, and the number of aged participants was quite small. There is also a possibility that the online distribution of the questionnaire through social networks
has some directional preference, which may lead to biased interpretations. Education level, employment status, and other demographic information were not included in the online survey, so we were not able to dissect the data further. We distributed the questionnaires to surrounding primary and middle schools to recruit juvenile participants, but the samples were only from local schools, which may not have been fully representative. Additionally, China spans multiple time zones geographically but uses unified Beijing Time, which may have influenced our survey results. However, it is complicated to calibrate the MEQ results derived from multiple questions that are both time-dependent and independent, and no geological location information was recorded. Therefore, we are developing other objective measurements to investigate personal chronotypes more precisely. Considering all these limitations, our results may be biased but are still of great significance in understanding the chronotype distribution of the Chinese population.

5 Conclusions

Our survey provides an overview of Chinese chronotype distribution for the first time. The chronotypes in the Chinese population show a near-normal distribution. When analyzed in 5-year intervals, Chinese people are “latest” in their early twenties. The percentage of the population with the Evening chronotype peaks at 25-years group. Two obvious turning points in chronotype occur at the ages of 10 and 16 years, but the chronotype composition of the Chinese population maintains a relatively stable pattern in early adulthood. The dynamic pattern of chronotype summarized in this study may be used as a reference to guide further investigations into social jetlag and other aspects of this field of study.

Competing interests

The authors declare no competing financial or nonfinancial interests.

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References

[1] Sharma VK. Adaptive significance of circadian clocks. Chronobiol Int. 2003, 20(6): 901–919.
[2] Lowrey PL, Takahashi JS. Mammalian circadian biology: elucidating genome-wide levels of temporal organization. Annu Rev Genomics Hum Genet. 2004, 5: 407–441.
[3] Park YM, Matsumoto K, Seo YJ, et al. Changes of sleep or waking habits by age and sex in Japanese. Percept Mot Skills. 2002, 94(3 Pt 2): 1199–1213.
[4] Adan, Natale V. Gender differences in morningness-eveningness preference. Chronobiol Int. 2002, 19(4): 709–720.
[5] Duffy JF, Czeisler CA. Age-related change in the relationship between circadian period, circadian phase, and diurnal preference in humans. Neurosci Lett. 2002, 318(3): 117–120.
[6] Roenneberg T, Wirz-Justice A, Merrow M. Life between clocks: daily temporal patterns of human chronotypes. J Biol Rhythms. 2003, 18(1): 80–90.
[7] Randler C. Age and gender differences in morningness-eveningness during adolescence. J Genet Psychol.
[8] Collado Mateo MJ, Diaz-Morales JF, Escribano Barreno C, et al. Morningness-eveningness and sleep habits among adolescents: age and gender differences. *Psicothema*. 2012, **24**(3): 410–415.

[9] Randel C, Engelke J. Gender differences in chronotype diminish with age: a meta-analysis based on morningness/chronotype questionnaires. *Chronobiol Int*. 2019, **36**(7): 888–905.

[10] Levandovski R, Dantas G, Fernandes LC, et al. Depression scores associate with chronotype and social jetlag in a rural population. *Chronobiol Int*. 2011, **28**(9): 771–778.

[11] Chelminski I, Ferraro FR, Petros TV, et al. An analysis of the “eveningness-morningness” dimension in “depressive” college students. *J Affect Disord*. 1999, **52**(1–3): 19–29.

[12] Gao Q, Sheng J, Qin S, et al. Chronotypes and affective disorders: A clock for mood? *Brain Sci Adv*. 2019, **5**(3): 145–160.

[13] Lewy AJ, Cutler NL, Sack RL. The endogenous melatonin profile as a marker for circadian phase position. *J Biol Rhythms*. 1999, **14**(3): 227–236.

[14] Klerman EB, Gershengorn HB, Duffy JF, et al. Comparisons of the variability of three markers of the human circadian pacemaker. *J Biol Rhythms*. 2002, **17**(2): 181–193.

[15] Wu G, Ruben MD, Schmidt RE, et al. Population-level rhythms in human skin with implications for circadian medicine. *Proc Natl Acad Sci USA*. 2018, **115**(48): 12313–12318.

[16] Laing EE, Möller-Levet CS, Poh N, et al. Blood transcriptome based biomarkers for human circadian phase. *Elife*. 2017, **6**: e20214.

[17] Hughey JJ. Machine learning identifies a compact gene set for monitoring the circadian clock in human blood. *Genome Med*. 2017, **9**(1): 19.

[18] Hughey JJ, Hastie T, Butte AJ. ZeitZeiger: supervised learning for high-dimensional data from an oscillatory system. *Nucleic Acids Res*. 2016, **44**(8): e80.

[19] Ueda HR, Chen WB, Minami Y, et al. Molecular-timetabled methods for detection of body time and rhythm disorders from single-time-point genome-wide expression profiles. *Proc Natl Acad Sci USA*. 2004, **101**(31): 11227–11232.

[20] Wittenbrink N, Ananthasubramaniam B, Münch M, et al. High-accuracy determination of internal circadian time from a single blood sample. *J Clin Invest*. 2018, **128**(9): 3826–3839.

[21] Ruben MD, Wu G, Smith DF, et al. A database of tissue-specific rhythmically expressed human genes has potential applications in circadian medicine. *Sci Transl Med*. 2018, **10**(458): eaat8806.

[22] Braun R, Kath WL, Iwanaszko M, et al. Universal method for robust detection of circadian state from gene expression. *Proc Natl Acad Sci USA*. 2018, **115**(39): E9247–E9256.

[23] Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol*. 1976, **4**(2): 97–110.

[24] Roenneberg T, Kuehnle T, Juda M, et al. Epidemiology of the human circadian clock. *Sleep Med Rev*. 2007, **11**(6): 429–438.

[25] Kantermann T, Sung H, Burgess HJ. Comparing the morningness-eveningness questionnaire and Munich ChronoType questionnaire to the dim light melatonin onset. *J Biol Rhythms*. 2015, **30**(5): 449–453.

[26] Randel C, Freyth-Weber K, Rahafar A, et al. Morningness-eveningness in a large sample of German adolescents and adults. *Heliyon*. 2016, **2**(11): e00200.

[27] Burgess HJ, Kikyo F, Valdespino-Hayden Z, et al. Do the Morningness-Eveningness questionnaire and Munich ChronoType questionnaire change after morning light treatment? *Sleep Science Practice*. 2018, **2**: 12.

[28] Fischer D, Lombardi DA, Marucci-Wellman H, et al. Chronotypes in the US - Influence of age and sex. *PLoS One*. 2017, **12**(6): e0178782.

[29] Roveda E, Vitale J, Montaruli A, et al. Predicting the actigraphy-based acrophase using the Morningness-Eveningness Questionnaire (MEQ) in college students of North Italy. *Chronobiol Int*. 2017, **34**(5): 551–562.

[30] Ryu H, Joo EY, Choi SJ, et al. Validation of the Munich ChronoType questionnaire in Korean older adults. *Psychiatry Investig*. 2018, **15**(8): 775–782.

[31] Komada Y, Okajima I, Kitamura S, et al. A survey on the variability of three markers of the human circadian clock. *Sleep Biol Rhythms*. 2019, **17**(4): 417–422.

[32] Inomata Y, Echizenya M, Takeshima M, et al. Validity and reliability of the Japanese version of the Morningness-Eveningness Questionnaire evaluated from actigraphy. *Sleep Biol Rhythm*. 2014, **12**(4): 289–296.
[33] Di Milia L, Adan, Natale V, et al. Reviewing the psychometric properties of contemporary circadian typology measures. *Chronobiol Int*. 2013, 30(10): 1261–1271.

[34] Broms U, Pitkäniemi J, Bäckman H, et al. Long-term consistency of diurnal-type preferences among men. *Chronobiol Int*. 2014, 31(2): 182–188.

[35] Roenneberg T, Allebrandt KV, Merrow M, et al. Social jetlag and obesity. *Curr Biol*. 2012, 22(10): 939–943.

[36] Randler C, Faßl C, Kalb N. From Lark to Owl: developmental changes in morningness-eveningness from new-borns to early adulthood. *Sci Rep*. 2017, 7: 45874.

[37] Tonetti L, Fabbri M, Natale V. Sex difference in sleep-time preference and sleep need: a cross-sectional survey among Italian pre-adolescents, adolescents, and adults. *Chronobiol Int*. 2008, 25(5): 745–759.

[38] Roenneberg T, Kuehnle T, Pramstaller PP, et al. A marker for the end of adolescence. *Curr Biol*. 2004, 14(24): R1038–R1039.

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**Zhiwei Liu** received his Ph.D. degree from Model Animal Research Center of Nanjing University, China (2014). Then he has been working as a lecturer at Cambridge-Suda Genomic Resource Center, Soochow University. His research interests focus on the cross-talk between circadian clock and other physiological systems. E-mail: zwliu@suda.edu.cn

**Yingying Dong** received her Ph.D. degree from Model Animal Research Center of Nanjing University, China (2011) and then received her postdoctoral training in Nankai University. She is now an associate professor of Cambridge-Suda Genomic Resource Center, Soochow University. Her current research interests focus on the regulatory mechanisms of circadian rhythms and reproductive development. E-mail: yydong@suda.edu.cn

**Ying Xu** received her M.D. degree in pathology from Saitama Medical School in Japan (1996), and Ph.D. degree in cell biology from the University of Tokyo in Japan (2001). She then conducted postdoctoral research in the University of California, San Francisco (2003–2006). She was a professor in Nanjing University (2006–2014) and is currently the director of Cambridge-Suda Genomic Resource Center, Soochow University. Her research interests focus on the regulatory mechanism of circadian rhythms and the relationship between circadian clock and homeostasis. E-mail: yingxu@suda.edu.cn

**Fei Zhou** received his Ph.D. degree in biology from Model Animal Research Center of Nanjing University, China (2011). He then worked as a senior scientist in WuXi AppTec (2011–2014) and is now an associate professor of Cambridge-Suda Genomic Resource Center, Soochow University. His research interests focus on the regulatory roles of circadian rhythm in cardiovascular system. E-mail: fzhou@suda.edu.cn