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Change in Individual Chronotype Over a Lifetime: A Retrospective Study

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Background and Objective Sleep disturbances resulting from a mismatch between the sleep-wake schedule and an individual's chronotype can influence work or school performance and numerous health outcomes. Individual chronotype can be determined by genetic factors, and is influenced by environmental factors which could change throughout life. We aimed to examine self-reported changes in chronotype during three different periods of life (childhood, teenage years, and adulthood).

Methods Three hundred forty-three (age: 37.8 ± 11.6 years, range: 18-82; F : M = 214 : 129) adult visitors to a National Museum in Korea were recruited for this study. The Korean version of the Horne-Östberg Morningness-Eveningness Questionnaire (MEQ-K) was administered and standard MEQ-K scores were used to categorize subjects as morning type (MT), evening type (ET), or neither type (NT). Binary logistic regression analyses were applied to examine the relationships of gender, current age, and childhood/teenager ME type with change in chronotype between childhood, teenage years, and adulthood.

Results The ages, gender distribution, and years of education were different between the chronotype groups ($p < 0.01$). Individuals who reported childhood MT or ET had a lower probability of changing their chronotype between childhood and their teenage years compared with individuals reporting childhood NT ($p < 0.0001$), whereas individuals reporting teenage MT or ET had a higher probability ($p < 0.0001$). Furthermore, older individuals had a lower probability of reporting a chronotype change between childhood or teenage years and adulthood ($p < 0.01$).

Conclusions Most individuals reported the same chronotype from childhood to their teenage years but a different chronotype between the teenage years and adulthood. Older age was associated with a lower probability of reporting a different chronotype during childhood or teenage years.

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Key Words Chronotype, Morningness-Eveningness, Diurnal type, Aging.

INTRODUCTION

Circadian rhythms of physiology and behavior are universal phenomena in most living organisms. The central circadian clock, located in the suprachiasmatic nuclei in mammals, is synchronized by external Zeitgeber (time cues), typically exposure to light and darkness. Chronotype refers to an individual's preference for scheduling their sleep and wake with respect to the 24 h day.[1] Although chronotype is a continuum from the extreme morning type (MT) ('larks') to the extreme evening type (ET) ('owls') with the majority of individuals falling in the middle as 'neither' type, prior research studies of chronotype have typically compared morning and ETs.[2] Individuals with MT have been shown to not only have earlier sleep and wake times than those with ET, they have been shown to have earlier timing of their circadian rhythms of melatonin, core body temperature, and cortisol when compared to individuals with ET.[3,4] Furthermore, MTs have also been shown to have a difference in the relative timing of their circadian rhythms to their sleep timing than ETs, such that while they go to bed and wake at an earlier clock time, the biological timing of sleep is later in MTs than in ETs.[3,5]

The Morningness-Eveningness Questionnaire (MEQ)[6] of Horne and Östberg has been

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widely used for assessing individual chronotype. After the 19 items of the MEQ are scored, chronotype can be classified into five types [moderate and definite MT, moderate and definite ET, and Neither Type (NT)] or more simply into three types (MT, ET, and NT). The reliability and validity of the MEQ have been verified in many previous studies.[7,8] The Munich Chronotype Questionnaire (MCTQ)[9] is different from the MEQ in that it classifies chronotype by calculating the midpoint between bedtime and waketime on free (non-work or school) days (mid-sleep on free days, MSF), and asks individuals to classify themselves into one of seven different chronotypes (extreme, moderate, or slight early type, normal type, or extreme, moderate, or slight late type). MSF from the MCTQ was reported to be highly correlated with MEQ score.[10]

There have been reports that an individual's chronotype changes throughout development, although most studies of chronotype have been cross-sectional rather than longitudinal. In childhood, MT is predominant; however, during adolescence this changes with many more ETs being reported.[11,12] With middle and older age, MTs again become predominant.[1,13] Despite these findings, the underlying factors contributing to these age-related changes have not been revealed in previous studies. In genetic studies on morningness-eveningness, there have been reports that about 50% of chronotype differences can be explained by genetic factors, with no difference in this genetic contribution between different age groups.[17,18] However, one study that reported on the contribution of the PER3[15] gene to chronotype suggested that the genetic influence of that polymorphism to chronotype gradually decreased with age.[16]

In previous studies on adolescents, individuals reporting ET increased with grade level,[19] and the bedtime discipline at home attenuated the extent of the shift to eveningness.[20] Further support that environmental factors play a contributory role to chronotype has been that cultural patterns such as siesta, occupation (outdoor vs. indoor work),[21,22] the timing of work,[23,24] and even the time of local sunrise[25] appear to be associated with chronotype, likely through their influence on the timing and amount of light exposure.

Most previous studies evaluating the relationship of chronotype to demographic and/or clinical parameters were cross-sectional studies, as noted above. Whether chronotype changes in an individual across their lifetime is not known, although one prior study used retrospective questions about chronotype and found it supported cross-sectional data.[1] If there are changes in chronotype within individuals over their lifetime, understanding typical changes may help in managing sleep complaints and health problems resulting from mismatches between chronotype and sleep-wake schedule timing. Furthermore, understanding the relationship of chronotype change during specific developmental periods could aid in understanding the causal factors associated with changing chronotype. Thus, in the present study we aimed to examine the pattern of chronotype change in individuals retrospectively using the MEQ and the MCTQ, and to explore the factors associated with such chronotype changes.

METHODS

Subjects

The Korean Sleep-Wake Questionnaire (SWQ-K) was administered to 416 adults (aged 18 years or older) who visited the Chuncheon National Museum in Korea between September 2009 and May 2010. A study staff member from Kangwon National University Hospital was present at the museum to solicit participants and administer the questionnaire.

Korean Version of Sleep-Wake Questionnaire (SWQ-K)

The SWQ-K consists of Korean versions of the MEQ, the Pittsburg Sleep Quality Index[26] (PSQI-K), the Epworth Sleepiness Scale[27] (ESS-K), and four questions from the MCTQ. The four questions from the MCTQ were the ones in which the individual is asked to classifying themself into one of seven chronotype categories [extreme early type (0), moderate early type (1), slight early type (2), normal type (3), slight late type (4), moderate late type (5), and extreme late type (6)] at present, as a child, as a teenager, and as a younger adult (this latter question was answered only by those individuals older than age 65). The chronotypes in childhood and teenage years were defined as MT if the rating was 0-2, NT if 3, and ET if 4-6. Because all the participants were adults, chronotype in adulthood was also classified according to MEQ score[6]: MT if the score was above 59, ET if below 41, and NT if between 41 and 59.

A reliability study on the SWQ-K resulted in Cronbach's alphas for the MEQ-K, ESS-K, and PSQI-K of 0.77, 0.60 and 0.74 (component)/0.84(individual items), respectively. A test-retest reliability study in 21 subjects on the MEQ-K, ESS-K, and PSQI-K found all three to be significant ($r = 0.914, 0.515, 0.740$; $p < 0.05$). Our preliminary data from a validity study using the MEQ-K showed that the acrophases of sleep-wake rhythms of the MT, NT, and ET were significantly different ($p < 0.0001$), and that the MT had earlier acrophases than those of ET and NT ($p < 0.05$; data to be reported elsewhere).

Statistical Analysis

Age, gender, and education level were compared among MT, ET, and NT groups by χ^2 test or one-way analysis of variance. The changes in chronotype across the three age categories (childhood, teenager and adulthood) were first coded for each participant: for example, an individual who rated himself as MT in childhood, ET in teenage years, and ET in adulthood was coded as MEE. For all existing combinations of chronotype change, frequencies were calculated. Kappa statistics were applied to examine the agreement of chronotype between childhood, teenage years and adulthood. We created a binary variable to code the chronotype change between childhood, teenage years, and adulthood chronotypes. If the chronotype of the previous age period was the same as the next age period, it was coded zero (0), an absence of change; if not, it was coded as one (1), the presence of change. Binary logistic regression analyses were used to examine the prediction of chronotype change by age, gender, childhood chronotype, and teenage chronotype. The NT served as the reference group to the MT and ET. A linear regression model was applied to examine the effect of age on the MEQ score. SPSS for Windows (version 18.0, SPSS Inc., Chicago, IL, USA) was used for all analyses except the linear regression analysis (SAS, version 9.1). The level of statistical significance was set to 0.05.

RESULTS

Among 416 subjects who took the SWQ-K, 52 subjects doing shift work (night work between 11:00 PM and 6:00 AM), 6 subjects receiving treatment for sleep disorders, and 15 subjects with incomplete SWQ-K were excluded from analysis. Three hundred forty-three subjects (age: 37.8 ± 11.6, range: 18-82, F : M = 214 : 129) were included. There was a significant difference in the gender ratio between MT, NT and ET groups (Table 1).

In the linear regression analysis, age had a significant main effect on MEQ score ($F_{1,341} = 81.70$, $p < 0.001$), such that older ages were associated with higher (more morning-like) scores on the MEQ. There were 67 subjects who were current MT, 229 NT, and 47 ET according to their MEQ scores. The ages, gender distribution, and years of education were significantly different between the MT, NT, and ET groups, with the MT being older and less educated than the NT and ET groups, and the proportion of men being higher in the MT group compared to the NT and ET groups (Table 1).

When we examined the self-reported change in chronotype between childhood, teenage years, and adulthood, we found that among the 27 possible patterns, MT-MT-NT was the most frequent (23.9%), with ET-ET-NT second (16.6%) and MT-MT-MT third (13.7%). In examining this further, we first looked at the agreement between the childhood and teenage chronotype, finding a weighted kappa of 0.61.The reported change in chronotype between childhood and teenage years did not differ by gender, but was significantly related to childhood chronotype and current age. Individuals who reported childhood MT and ET had a significantly lower probability to change chronotype as a teenager compared to individuals who reported their childhood chronotype as NT (Table 2). Individuals who were older also had a significantly lower probability of reporting that their chronotype changed from childhood to teenage years (Table 2).

We next examined the agreement between self-reported teenage and adult chronotype and found a weighted kappa of 0.13. When we examined the self-reported change in chronotype between teenager and adulthood, again this did not differ by gender but was significantly related to the teenage chronotype and current age. Individuals who reported teenage MT or ET had a higher probability to report a change in their chronotype between teenage years and adulthood compared to individuals who reported that their teenage chronotype was NT (Table 2), and individuals who were older had a lower probability of reporting

Table 1. Demographic characteristics of the 343 study participants by chronotype

	MT (n = 67, 19.5%)	NT (n = 229, 66.8%)	ET (n = 47, 13.7%)	χ^2 or F value	p	Post-hoc result (on percentage or mean)
Gender (n, %)						
Female	30 (44.8%)	149 (65.1%)	35 (74.5%)	$\chi^2 = 12.479$	0.002	MT < NT = ET
Male	37 (55.2%)	80 (34.9%)	12 (25.5%)			
Age (yr) Mean (± SD)	46.04 (11.79)	36.52 (10.95)	32.32 (8.75)	F = 26.94	< 0.001	MT > NT > ET
Education (yr) Mean (± SD)	12.99 (4.15)	14.87 (2.53)	14.93 (2.12)	F = 11.66	< 0.001	MT < NT = ET

Kruskal-Wallis test or ANOVA.
MT: morning type, NT: neither type, ET: evening type.

Table 2. Association of chronotype changes in childhood, teenager and adulthood with age, gender and morningness-eveningness type. Note that Neither Type is used as the reference value

	Childhood → Teenager			Teenager → Adult	
	OR (95% CI)	p		OR (95% CI)	p
Age (every year increase)	0.941 (0.915-0.967)**	< 0.0001	Age	0.972 (0.951-0.993)*	0.008
Gender (female vs. male)	1.049 (0.585-1.882)	0.873	Gender	1.063 (0.644-1.754)	0.811
Childhood morning type	0.269 (0.145-0.501)**	< 0.0001	Teenager morning type	6.906 (3.468-13.752)**	< 0.0001
Childhood evening type	0.105 (0.045-0.243)**	< 0.0001	Teenager evening type	8.319 (4.023-17.202)**	< 0.0001

*p < 0.01, **p < 0.0001 (Binary logistic regression analysis).

that their chronotype changed from teenage years to adulthood (Table 2).

DISCUSSION

In our study sample, we found that the demographic features were different among MT, NT, and ET groups. The proportion of men in the MT group was higher than those of the NT and ET groups, while the average age of the ET group was younger compared to the MT group. In addition, the MT group was less educated than the NT and ET groups. The higher mean age in the MT group could explain their lower education level, as older Koreans tend to be less educated than younger Koreans.[30] While our finding that the MT group was older than the ET group was consistent with previous studies,[10,13,24] prior studies have either reported no association of gender with chronotype[19,32] or have found that females were more likely to report being MT.[8,10,28] This difference from prior reports may be due to the fact that among our sample, the men tended to be older than their MT and ET female counterparts.

Prior studies have established that in general, there is a strong morning preference in childhood, and that this phase preference starts to be delayed during adolescence,[11,12,19] with a tendency towards an evening preference peaking around age 20.[1] With advancing age, phase preference moves earlier.[13,24] In addition to the studies described above, there have been numerous cross-sectional studies comparing the association of chronotype with age in the population;[3,13,24,31] however, few studies have attempted to examine how chronotype changes across developmental periods (childhood, teenage years, and adulthood) within an individual. In our study, about 70% of all subjects reported a change in their chronotype at least once across the three time periods. Between childhood and teenage years, about twice as many subjects reported that their chronotype became later than those who reported it becoming earlier (15.45% vs. 7.29%), while between the teenage years and adulthood nearly equal numbers of subjects reported their chronotype becoming later as those who reported it becoming earlier (31.2% vs. 29.45%). The higher proportion of individuals reporting a delay in chronotype between childhood and teenage years was consistent with results from previous studies.[11,19,31]

In our study, the probability of reporting that chronotype changed between childhood and teenage years, or between teenage years and adulthood, decreased with age (Table 2). One possibility for this finding is that older individuals were less likely to remember what their chronotype was earlier in life than younger adults. However, a previous study on the relationship of chronotype with the PER3 genotype suggested that the genetic influence of the PER3 polymorphism and chronotype was predominant in young adults (18-29 years old), had the least influence in the 40's (40-49 years old), and had an influence again in individuals older than 50.[16] If true, such a finding might help explain our results. If environmental/social influences on sleep timing are reduced with older age as individuals retire from work and have reduced responsibilities in their family and/or their society, then genetic influences could play a more predominant role in sleep timing, and have the chronotype return to their original one, resulting in a lower probability of chronotype change. This could explain why the probability of chronotype change between teenage years and adulthood decreased with age in our study.

Age had a significant effect on the MEQ score in our subjects, consistent with many previous studies.[11,12,18] Our study did not find a significant relationship between gender and chronotype change. While many prior studies have reported a greater morning preference among women than men,[8,28,29] not all studies have found a difference in chronotype according to gender.[19,32] In our study, there was a difference in age between men and women (Male: 40.78 $\pm$ 13.52; Female: 36.42 $\pm$ 9.96, $p < 0.01$) and therefore, we cannot conclude that gender difference did not affect the chronotype change.

There was a high probability that the reported childhood chronotype was unchanged during the teenage years, but that the reported teenage chronotype changed in adulthood. In particular, individuals who reported that their teenage chronotype was MT or ET had a higher probability of changing chronotype in adulthood than those who reported that they were NT as a teenager. Environmental factors influencing sleep timing would be strong in childhood and teenage years, when parents presumably play a dominant role in determining the timing of sleep. Several studies on adolescents have reported that delayed sleep timing is correlated with pubertal development.[11] This delay of sleep timing and circadian phase with pubertal development was also observed when assessed under controlled laboratory conditions,[33-35] suggesting that the immediate environmental factors present during assessment of circadian phase were not contributing directly to the association, although the environmental factors (self-selected delayed bed time and associated evening light exposure, together with delayed wake time and lack of morning light exposure) in the days or weeks prior to the assessment may likely have played a role. In typical Korean teenagers, their bedtime is delayed and their waketime moves earlier due to their study burden and school schedule.[19,36] The reduction in sleep due to externally-imposed environmental factors constraining sleep and sleep timing results in lower academic achievement and a vulnerability to depression in adolescents,[37,38] and would be expected to impact ET adolescents to an even greater degree.

Our findings did not support prior findings of greater eveningness in teenage years than in childhood or adulthood. There are several possible explanations for this. First, as noted above it may be that adults asked for retrospective recall of their chronotype in their teenage years and childhood may not remember accurately. It is also possible that the adults in our study, whose average age was 37 but who ranged in age up to 82 years, were adolescents at a time when there were fewer evening distractions such as television, internet, mobile phones, etc., that have been reported to keep today's adolescents up late. Our study used a retrospective design to try to determine whether chronotype changes in an individual, whereas prior studies have not attempted to follow individuals across time, but rather compared individuals in separate age groups.

The higher probability of chronotype change between teenage years and adulthood in our study might be explained by environmental influences on self-reported chronotype becoming greater in adulthood. Both occupational requirements and family demands play a large role in sleep-wake timing in adulthood,[24] and could lead individuals who report being ET or MT as children or teenagers to adjust to their sleep timing as adults. Recent studies in adults have found that sleep-wake homeostatic factors also play an important role in chronotype[39,40] and sleep homeostasis changes profoundly with age. Thus, some of the reported changes in chronotype in adulthood may also be due to changes in sleep homeostatic factors.

While the population of our study may not be a representative sample of Korean adults, prior studies have indicated that socioeconomic factors do not affect chronotype.[24] Another limitation of our study (as in most studies of chronotype) is that we did not attempt to determine the environmental factors (work schedule, child care, home responsibilities, sleeping environment) that might influence the sleep timing (and thus chronotype) of our study participants. In addition to the above limitations, our study had a retrospective design depending on the study subjects' own memories of chronotype in childhood and teenage years, and if those memories were faulty then they may have been more inaccurate among the older participants. Ideally, studies which follow individuals prospectively to determine if their chronotype changes and if so, what environmental/social factors influence those changes could be conducted, although such long-duration studies were not within the scope of our study design.

In conclusion, the present results suggest that individual chronotype may change with age, and that this change, which is greater between the teenage years and adulthood than between childhood and teenage years, might result from changes in the relative influence of genetic and environmental factors on chronotype at these different ages.

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Conflicts of Interest

The authors have no financial conflicts of interest.

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