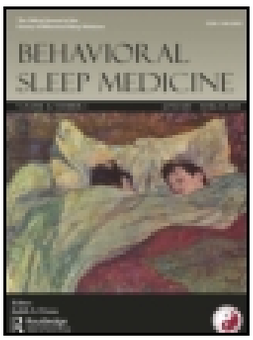

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Chronotype Differences in Health Behaviors and Health-Related Quality of Life: A Population-Based Study Among Aged and Older Adults

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This study investigates health behaviors, health-related quality of life (HRQOL) and sleep among chronotypes in a community-based sample (n = 2,976). Analysis of covariance indicated evening

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types (E-types) had a significantly higher percentage of current smokers and more sleep-interfering behaviors compared to intermediate and morning types (M-type), and also lower physical activity and more sleep disturbance compared to M-types. E-types also had worse mental HRQOL compared to both chronotypes, and worse physical HRQOL compared to M-types. Exploratory analyses indicated E-types consumed more caffeinated beverages at night, smoked or ate heavy meals before bedtime, kept irregular sleep-wake schedules, and took more naps. Mediational analyses indicated that sleep-interfering behavior partially mediated the relationship between chronotype and sleep disturbance, and physical activity partially mediated the relationship between chronotype and mental HRQOL. E-types had more unhealthy behaviors, which may subsequently place them at higher risk for health problems.

Chronotype is a characteristic that constitutes interindividual differences in the circadian phase and requires a specific preference for sleep and activity timing. Chronotypes are divided into the terms "morningness" and "eveningness" to distinguish people who endorse extreme diurnal preferences. Individuals with morning preference (M-type) show extreme preferences for daytime activity, while those with eveningness (E-type) have an endogenous predisposition to initiate their activities later in the day; in these individuals, heightened alertness and peak performance are linked to the evening hours (Adan et al., 2012; Baehr, Revelle, & Eastman, 2000; Bailey & Heitkemper, 2001; Duffy, Dijk, Hall, & Czeisler, 1999; Horne & Ostberg, 1976). A majority of individuals can be categorized as Intermediate type (I-type), and fall in between M-types and E-types.

Research suggests that circadian preferences, particularly those with strong eveningness tendencies, may have more health problems and poorer mental health compared to M-types (Paine, Gander, & Travier, 2006; Taillard et al., 2011). Previous studies have indicated that E-types are more likely to have higher odds for type 2 diabetes, arterial hypertension, faster resting heart rate, lower systolic blood pressure, lower levels of serum total alcohol, more low-density lipoprotein cholesterol, bronchial asthma, and nocturnal asthma compared to M-types in a population-based study (Merikanto, 2013; Merikanto, Englund, et al., 2014). In another study, E-types were associated with cancer progression in breast cancer patients, especially for those who had later misaligned bedtimes (Hahm et al., 2013). A recent study also found that misalignment with sleep timing was associated with metabolic risk factors associated with diabetes and atherosclerotic cardiovascular disease (Wong, Hasler, Kamarck, Muldoon, & Manuck, 2015). E-types have also been associated with poorer mental health, with higher likelihood of mood disorders such as depression compared to M-types (Merikanto, 2013; Taillard, Philip, Chastang, Diefenbach, & Bioulac, 2001).

Additionally, E-types are more vulnerable to insufficient sleep and sleep disturbance, because E-types tend to shift their sleep schedules between weekdays and weekends in an attempt to compensate for sleep debt that accumulates throughout their work or school week (Wittmann, Dinich, Merrow, & Roenneberg, 2006). Irregularity in sleep schedules for E-types also influences their sleep beliefs, and can lead to higher frequency of poor sleep hygiene (Adan, Fabbri, Natale, & Prat, 2006). In a study by Taillard and colleagues (Taillard, Philip, & Bioulac, 1999), morningness and eveningness preferences were examined in a sample of adults using a French cohort. Out of 617 men and women, eveningness was related to difficulty initiating sleep and morning sleepiness. An epidemiology study by Merikanto and colleagues (Merikanto et al., 2012) utilized a population-based sample from the Finnish population, and found evening types

were more prone to report insomnia symptoms, use sleep medication, and experience nightmares than morning types.

Having higher likelihood of health problems and poorer mental health in E-types may affect health-related quality of life (HRQOL) of E-types. Few previous studies have investigated HRQOL in different chronotypes, most of which have been conducted with adolescents. Two studies (Roeser, Bruckner, Schwerdtle, Schlarb, & Kubler, 2012) found that evening types had lower health-related QOL in adolescents, with lower scores on HRQOL indicators such as vitality, physical and psychological well-being, body image, relations with parents and teachers, schoolwork, and global health scale. There has been one study where burnout in 177 teachers has been related to eveningness (Randler, 2015). As of yet, there have been few comparing health-related quality of life in chronotypes among adults.

One important factor linking chronotype and physical health is health behaviors, such as smoking, alcohol consumption, physical activity, and practice of good sleep hygiene. It has been documented that E-types lead a less regulated lifestyle compared to M-types (Wittmann et al., 2006). E-types have greater alcohol consumption (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002), exercise less (Digdon & Howell, 2008; Monk, Buysse, Potts, DeGrazia, & Kupfer, 2004), smoke more (Broms et al., 2011; Schneider et al., 2011), and have poorer regulation of meal timings and unhealthy dietary habits (Fleig, 2009; Kanerva et al., 2012). Additionally, E-types tend to be more obese than M-types, which is a significant risk factor for many diseases (Randler, 2011). However, a majority of these studies have been studied in adolescents or college freshman, and little is known about differences in health behaviors among chronotypes in middle-aged and older adults.

The present study is a step toward comparing differences in health behaviors and HRQOL based on chronotype in a population-based study comprised of an adult sample. Specifically, the objectives of the current study are to investigate the following hypotheses: (a) E-types will have worse health behaviors, such as more smoking, more alcohol consumption, less physical activity, more sleep-interfering behaviors and worse sleep quality compared to M-types or intermediate type (I-types), (b) E-types will be more likely to have reduced HRQOL compared to other chronotypes, and (c) health behaviors will mediate the relationship between chronotype and health or HRQOL.

MATERIALS AND METHODS

Study Design and Sample

Participants of the present study were part of a larger study, namely the Korean Genome and Epidemiology Study (KoGES), which is an ongoing, population-based cohort study that started in 2001 under the original title, Korean Health and Genome Study. Detailed information on the study design and aims of the KoGES has been previously reported (Baik & Shin, 2008). The current study used a subset of individuals from the original cohort members recruited from Ansan, South Korea, because the measures used that were pertinent to the current study were introduced in 2011–2012.

The current study focuses on a large sample of 2,976 participants, selected from the original 3,026 who completed the Morningness-Eveningness Questionnaire. From the original sample, 1 participant with traumatic brain injury, 1 participant with dementia, and 48 participants with cerebrovascular disease were excluded due to limited ability to complete the questionnaire of interest in this study. An informed consent form was signed by each participant, and the study procedure was approved by the institutional review board of the Korea University Ansan Hospital.

Measures

Demographic variables

All participants provided complete information about age, gender, education, marital status, and general physical health. Body mass index (BMI) information was also collected using height and weight measurements.

Chronotype

The Morningness-Eveningness Questionnaire (MEQ) consists of 19 self-reported items associated with habitual rising and bedtimes, preferred behavioral sleep schedules, and alertness in the morning (Horne & Ostberg, 1976). Scores on the MEQ range from 16 to 86, with higher scores reflecting stronger preference for morningness, and lower scores reflecting stronger preference for eveningness. MEQ classifies participants into M-types (scores 59–86), I-types (scores 42–58), and E-types (scores 16–41). All subjects relevant to this study completed MEQ questionnaires.

Health-Related Quality of Life (HRQOL)

The Medical Outcomes Study–Short-Form (SF-12) was used to assess physical and psychological dimensions of HRQOL. The SF-12 yields eight primary subscales (Physical Functioning, Role Physical, Bodily Pain, General Health, Vitality, Social Functioning, Role Emotional, Mental Health) and two component scores: the Physical Component Summary (PCS) and Mental Component Summary (MCS). Both component scores and all subscales are standardized with a mean of 50 and a standard deviation of 10. The SF-12 has reported excellent reliability and validity, especially in chronically ill populations (Ware, Kosinski, & Keller, 1996).

Physical activity

Seven-Day Physical Activity Recall (PAR) provides a retrospective account of moderate and vigorous physical activity during the prior week (Blair et al., 1985). Metabolic equivalent task (MET) value was adopted to calculate a summary index of energy expenditure for the prior week at each assessment (Ainsworth et al., 2011). One MET is equivalent to the energy required for sitting quietly, approximately 1 kcal/kg/h.

Smoking

Smoking status was obtained by self-report and measured as a categorical variable (current smoker, past smoker, never smoker). Additionally, pack-years (number of packs smoked per day X multiplication sign years as a smoker) were calculated.

Drinking

Total alcohol consumption was obtained as grams/day by calculating total beverage-specific amount of alcohol and total amount of liquor consumed. Moderate to heavy drinking was defined by alcohol consumption of 15 g/day or more (Baik & Shin, 2008).

Sleep-interfering behavior

The Sleep Behavior Scale (SBS) is a 12-item self-report questionnaire that assesses how often the participant practices behaviors that have been shown to interfere with sleep (Suh et al., 2014). Participants were asked to indicate the frequency of sleep-interfering behaviors, including consuming alcohol before bed, consuming caffeinated beverages after dinner, smoking before bedtime, heavy meals before bedtime, vigorous activity prior to bedtime, taking naps longer than 30 min, irregular sleep and wake times, sleep medication use, engaging in activities in bed that are not related to sleep (i.e., talking on the phone, eating), going to bed when not sleepy, staying in bed when unable to stay asleep, and worrying about not getting enough sleep. Participants were asked to rate the frequency of these behaviors based on the past month using a 5-point Likert scale (1 =Never, 2 = 1–2 times per week, 3 = 3–4 times per week, 4 = more than 5 times per week, and 5 = every day). Scores on the SBS scale range from 12 to 60.

Sleep quality

Participants completed the Pittsburgh Sleep Quality Index (PSQI), a self-report questionnaire assessing sleep quality and disturbances over a one-month interval (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The scale yields a total score that ranges from 0 to 21, with higher scores reflecting more difficulties with sleep. The questionnaire also has 7 subscales including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Sleep duration was also calculated for both weekdays and weekends, which were derived from the sleep duration subscale of the PSQI. Additionally, a variable for difference in sleep duration between weekdays and weekends was also calculated.

Statistical Analysis

Three chronotype groups were compared in demographic using analysis of variance (ANOVA) or chi-square test, as appropriate. Analysis of covariance (ANCOVA) was conducted to compare the differences in health behaviors and HRQOL among different chronotypes controlling for age, sex, education, and marital status. Additionally, exploratory analyses were conducted to investigate differences in sleep-interfering behavior between

chronotypes. Post-hoc analyses using the Bonferroni method were used to investigate differences between the three chronotypes.

To test the hypothesis that health behaviors mediated the relationship between chronotype and health outcomes, a series of multiple regression analyses was conducted. The bootstrap technique recommended by Shrout and Bolger (2002) was used to directly test the mediating effects of health behaviors between chronotype and health (HRQOL, sleep). Mediation analyses were conducted using the PROCESS macro for SPSS Statistics 23, following procedures recommended by Hayes (2013). Indirect effects were evaluated using a bootstrapping resampling procedure: 5,000 bootstrapped samples were drawn from the data, and bias-corrected 95% confidence intervals (CI) were used to estimate the indirect effects of each of the resampled data sets. If the 95% CI for the estimates of indirect effect does not include zero, it suggests the significant mediation at the 0.05 level (Hayes, 2013; Shrout & Bolger, 2002).

RESULTS

Characteristics of Participants

Among the 2,976 participants included in the study, 146 (4.9%) were E-types, 1,692 (56.9%) were I-types, and 1,138 (38.2%) were M-types. Mean age of participants was 58.02 years (±7.05 years), with ages ranging from 49 to 79 years. There was a significant difference in age, marital status, and education ($p < 0.0001$), with E-types being significantly younger and less likely to be married, and having higher levels of education. Demographic information on the sample can be found in Table 1.

Chronotype and Health Behaviors

There were significant differences between chronotypes based on health behavior for physical activity, smoking status, and sleep-interfering behavior ($p < 0.001$), but not for alcohol consumption after controlling for age, sex, education, and marital status. Post-hoc analyses revealed that M-types had significantly higher levels of physical activity compared to E-types and I-types, although there was no difference between E-types and I-types. Additionally, E-types had a higher percentage of current smokers compared to I-types and M-types. Finally, E-types also displayed worse sleep-interfering behaviors compared to the other two

TABLE 1
Demographic Information

	E-type	*I-type*	*M-Type*	*p value*
N	146 (4.9%)	1692 (56.9%)	1138 (38.2%)	
Age	54.63 (*SD* 5.01)	56.54 (*SD* 6.14)	60.65 (*SD* 7.68)	< 0.0001
Sex (% male)	83 (56.8%)	828 (49.0%)	535 (47.0%)	0.07
Married	122 (84.7%)	1521 (93.0%)	958 (88.3%)	< 0.0001
Education (12+)	44 (30.1%)	282 (16.7%)	186 (16.4%)	< 0.0001

Note. Abbreviations: E-type = Evening type; I-type = Intermediate type; M-type = Morning type.

chronotypes. There was also a significant difference in PSQI scores, with E-types reporting significantly more sleep disturbance than M-types, and I-types reporting more sleep disturbance than M-types, although there was no difference between E-types and I-types. For overall total sleep time, there were no differences between E-types compared to other chronotypes. There were no significant differences for sleep duration for weekdays and weekends among chronotypes. There was also no significant difference for weekday–weekend sleep duration differences among chronotypes.

There were no differences in pack year, alcohol consumption and heavy drinking, or BMI, between chronotypes. Results can be found in Table 2.

Chronotype and Specific Sleep-Interfering Behaviors

An exploratory analysis was conducted to investigate differences in specific sleep-interfering behaviors among chronotypes on individual items of the SBS. Results indicated that E-types endorsed significantly higher on 3 out of 12 items on the SBS compared to both chronotypes: Item 2 ("Drinking caffeinated beverages after dinner"; $p < .0.0001$), Item 3 ("Smoking cigarettes before bedtime"; $p < 0.0001$), and Item 4 ("Eating a heavy meal before bedtime"; $p < 0.0001$). E-types also scored significantly higher on 4 items on the SBS compared to M-types, but did not show a significant difference with I-types: Item 6 ("Taking naps more than 30 minutes"; $p = 0.01$), Item 7 ("Irregular sleep and wake times"; $p < 0.0001$), Item 11

TABLE 2
Differences Between Health Behaviors Based on Chronotype

	E-type	*I-Type*	*M-type*	*F or chi-square*	*p value*	*Post-hoc comparisons*
N	146 (4.9%)	1692 (56.9%)	1138 (38.2%)			
7-day physical activity (MET value)	14.54 (23.33)	19.69 (25.85)	24.70 (30.41)	10.12	< 0.0001	E = I, I < M, E < M
Smoking				53.10	< 0.0001	E > I > M
Never smoker	81 (60.8%)	939 (59.8%)	660 (62.4%)			
Past smoker	21 (15.7%)	393 (25%)	316 (29.9%)			
Current smoker	32 (23.9%)	237 (15.1%)	82 (7.8%)			
Smoking (pack year)	28.98 (17.20)	25.63 (26.92)	24.38 (20.42)	2.53	0.08	
Drinking (g/day)	5.90 (12.09)	6.22 (12.89)	5.73 (13.72)	0.07	0.92	
% Heavy drinking	18 (13.5%)	190 (12.3%)	107 (10.2%)	3.25	0.19	
BMI	24.86 (3.47)	24.85 (5.27)	25.04 (6.88)	0.43	0.64	
Sleep Behavior Scale	17.07 (4.29)	15.71 (3.94)	14.70 (3.28)	31.07	< 0.0001	E > I > M
PSQI	4.77 (2.99)	4.54 (3.03)	4.14 (2.80)	11.65	0.001	E = I, I > M, E > M
Total Sleep Time	6.10 (1.21)	6.23 (2.20)	6.15 (1.226)			
Weekdays	5.79 (1.22)	5.98 (1.24)	6.06 (1.29)	2.18	0.11	
Weekends	6.40 (1.42)	6.48 (3.87)	6.23 (1.46)	0.60	0.54	
Weekday–Weekend Difference (hours)	0.71 (1.04)	0.58 (3.68)	0.28 (1.10)	2.16	0.11	

Note. Continuous variables controlled for age, sex, education, marital status. Abbreviations: E-type = Evening type; I-type = Intermediate type; M-type = Morning type; BMI = Body Mass Index; PSQI = Pittsburgh Sleep Quality Index.

TABLE 3
Differences in Sleep-Interfering Behaviors Based on Chronotype

SBS Item	*E-Type M (SD)*	*I-Type M (SD)*	*M-Type M (SD)*	*p-value*	*Post-hoc comparisons*
1. Drinking alcohol at bedtime	1.57 (0.99)	1.55 (0.94)	1.50 (0.94)	0.62	
2. Drinking caffeinated beverages after dinner	1.93 (1.44)	1.53 (1.11)	1.36 (0.97)	< 0.0001	E > I > M
3. Smoking cigarettes before bedtime	1.65 (1.43)	1.37 (1.12)	1.17 (0.76)	< 0.0001	E > I > M
4. Eating a heavy meal before bedtime	1.55 (0.98)	1.25 (0.61)	1.14 (0.48)	< 0.0001	E > I > M
5. Vigorous exercise before bedtime	1.04 (0.22)	1.04 (0.30)	1.02 (0.19)	0.32	
6. Taking naps more than 30 min	1.72 (1.24)	1.58 (1.07)	1.56 (1.08)	0.01	E = I, I = M, E > M
7. Irregular sleep and wake times	1.29 (0.74)	1.17 (0.83)	1.21 (0.81)	< 0.0001	E = I, I > M, E > M
8. Regularly taking sleep medication	1.06 (0.48)	1.06 (0.45)	1.06 (0.45)	0.49	
9. Engaging in sleep-unrelated behaviors in bed, such as eating, talking on the phone, or work	1.28 (0.77)	1.22 (0.76)	1.17 (0.70)	0.16	
10. Trying to sleep even though not feeling sleepy	1.34 (0.85)	1.30 (0.80)	1.21 (0.67)	0.002	E = I, I > M, E = M
11. Staying in bed even though you can't fall asleep	1.40 (0.91)	1.38 (0.86)	1.25 (0.70)	< 0.0001	E = I, I > M, E > M
12. Worrying about not getting enough sleep	1.36 (0.88)	1.28 (0.79)	1.18 (0.61)	< 0.0001	E = I, I > M, E > M

Note. Continuous variables controlled for age, sex, education, marital status. Abbreviations: SBS = Sleep Behavior Scale.

("Staying in bed even though you can't fall asleep"; $p < 0.0001$), and Item 12 ("Worrying about not getting enough sleep"; $p < 0.0001$). There was also one item where I-types had significantly higher scores compared to M-types, but not E-types: Item 10 ("Trying to stay asleep even though not feeling sleepy"; $p = 0.002$). Results can be found in Table 3.

Chronotype and HRQOL

E-types had significantly lower physical HRQOL ($p = 0.001$) and also lower mental HRQOL compared to M-types, but not I-types after controlling for age, sex education, and marital status ($p < .0001$). E-types reported having lower levels of physical functioning, general health, vitality, and mental health compared to both I-types and M-types ($p \leq 0.0001$). Additionally, E-types had lower physical role functioning and emotional role functioning compared to M-types, but no significant differences compared to I-types ($p \leq 0.002$). Results can be found in Table 4.

Health Behaviors as a Mediator Between Chronotype and HRQOL

Based on analyses above, five mediation analyses were conducted investigating the following: (a) sleep-interfering behavior as a mediator between chronotype and sleep quality; (b) physical activity as a mediator between chronotype and physical QOL; (c) physical activity as a mediator between chronotype and mental QOL; (d) smoking status as a mediator between chronotype and physical QOL; and (e) smoking status as a mediator between chronotype and mental QOL. Among the five mediation analyses above, Model 1 and 3 met the requirements to establish a mediation suggested by Baron & Kenny (1986). Therefore, significance of indirect effects was

TABLE 4
Health-Related Quality of Life Indicators and Chronotype

	E-type	*I-type*	*M-type*	*F*	*p-value*	*Post-hoc comparisons*
N	146 (4.9%)	1692 (56.9%)	1138 (38.2%)			
SF-12 PCS	48.84 (*SD* 7.94)	49.78 (*SD* 7.05)	49.76 (*SD* 6.90)	6.77	0.001	E = I, I < M, E < M
SF-12 MCS	52.64 (*SD* 8.05)	53.81 (*SD* 7.17)	55.61 (*SD* 6.62)	25.11	< 0.0001	E = I, I < M, E < M
Physical Functioning	83.14 (24.42)	86.66 (23.94)	86.22 (24.52)	7.65	< 0.0001	E < I < M
Role Physical	91.19 (19.52)	93.38 (16.73)	94.17 (15.18)	5.85	0.003	E = I, I = M, E < M
Body Pain	90.15 (18.47)	90.73 (18.47)	92.01 (17.30)	5.96	0.003	E = I, I < M, E = M
General Health	45.27 (23.51)	49.64 (20.62)	52.76 (20.29)	19.84	< 0.0001	E < I < M
Vitality	55.30 (28.31)	60.15 (26.08)	64.24 (27.75)	19.75	< 0.0001	E < I < M
Social Functioning	95.80 (12.84)	96.76 (12.11)	97.83 (9.97)	5.69	0.003	E = I, I < M, E = M
Role Emotional	94.89 (11.95)	96.23 (11.36)	97.60 (9.46)	9.09	< 0.0001	E = I, I < M, E < M
Mental Health	72.25 (20.09)	75.54 (18.95)	80.22 (18.25)	28.85	< 0.0001	E < I < M

Note. Continuous variables controlled for age, sex, education, marital status. Abbreviations: SF-12 PCS = Short-Form-12, Physical Component Summary; SF-12 MCS = Short-Form 12, Mental Component Summary.

tested only for these hypotheses. Table 5 presents the results from the mediation analyses and the test of indirect effects using bootstrapping.

For analyses examining the relationship of sleep-interfering behaviors (SBS) between chronotype and sleep disturbance (PSQI), the overall regression model explained a significant portion of variance in sleep disturbance (R^2 = .02, F[2, 2753] = 33.75, p < .001). Chronotype significantly predicted sleep-interfering behaviors (β = –0.09, p < .0001), and sleep-interfering behaviors significantly predicted sleep disturbance (β = 0.09, p < .0001). The direct effects of chronotype on sleep disturbance remained significant after accounting for the effects of sleep-interfering behavior (β = –0.02, p = .001). In the test of mediation, the indirect effect from chronotype to sleep disturbance through sleep-interfering behaviors was significant (bias-corrected 95% CI: –0.03, –0.01, p < .0001).

For analyses examining the mediating relationship of physical activity between chronotype and Mental QOL (SF-MCS), the overall regression model explained a significant portion of variance in Mental QOL (R^2 = .03, F[2, 2740] = 46.05, p < .001). Chronotype significantly predicted physical activity (β = 0.48, p < .0001), and physical activity significantly predicted Mental QOL (β = 0.02, p < .0001). The direct effects of chronotype on Mental QOL remained significant after accounting for the effects of Physical Activity (β = 0.13, p < .0001). In the mediation test, the indirect effect from chronotype to Mental QOL through physical activity was significant (bias-corrected 95% CI: 0.006, 0.02, p = .0004).

DISCUSSION

The current study investigated chronotype, health behaviors, and HRQOL in a population-based study in Korea. The purpose of the study was to investigate whether E-types had worse health behaviors (smoking, alcohol consumption, physical activity, and sleep-interfering behaviors) and reduced HRQOL compared to other chronotypes (I-types or M-types). We also conducted mediational analyses to examine whether health behaviors mediated the relationship between

TABLE 5
Health Behaviors as a Mediator Between Chronotype

				Path a	*Path b*	*Path c*	*Path c'*	*Indirect effect*
Predictor	*Mediator*	*Outcome*		*β (SE)*	*β (SE)*	*β (SE)*	*β (SE)*	*β (SE) [Bias-corrected 95% CI]*
(1)	MEQ	SBS	PSQI	–0.09 (0.01)***	0.09 (0.01)***	–0.03 (0.006)***	–0.02 (0.006)**	–0.02 (0.005) [–0.03 ~ –0.01]
(2)	MEQ	PA	PCS	0.48 (0.06)***	0.03 (0.004)***	0.01 (0.02)	–0.004 (0.02)	
(3)	MEQ	PA	MCS	0.48 (0.06)***	0.02 (0.004)***	0.14 (0.01)***	0.13 (0.02)***	0.01 (0.003) [0.006 ~ 0.02]
(4)	MEQ	Smoking Status	PCS	–0.007 (0.001)***	1.37 (0.19)***	0.009 (0.02)	0.02 (0.02)	
(5)	MEQ	Smoking Status	MCS	–0.007 (0.001)***	–0.23 (0.01)***	0.14 (0.01)***	0.14 (0.01)***	

Note. Abbreviations: MEQ = Morningness-Eveningness Questionnaire; SBS = Sleep Behavior scale; PA = Physical Activity (METs); PSQI = Pittsburgh Sleep Quality Index; PCS = SF-36 Physical Component Summary; MCS = SF-36 Mental Composite Summary. 5000 Bootstrap samples: Path a = Predictor → Mediator, Path b = Mediator → Outcome, Path c = Predictor → Outcome, Path c' = Predictor → Outcome (controlling for mediator).
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

chronotype and HRQOL and sleep. To the best of our knowledge, this is the first population-based study using a large sample that explored the association of chronotype and various health behaviors and HRQOL, especially in a middle-aged to older population in South Korea.

Results from our study suggested that E-types had a significantly higher proportion of smokers and worse sleep-interfering behaviors compared to both I-types and M-types.

Most of these findings are consistent with previous research for various health behaviors. For smoking, there was a higher proportion of current smokers (23.9% in E-types vs. 15.1% in I-types vs. 7.8% in M-types) among E-types, although the amount of smoking did not differ by chronotype. This is consistent with past research that show smokers tend to be later chronotypes (Wittmann, Paulus, & Roenneberg, 2010). In a study by Schneider and colleagues (Schneider et al., 2011) with 372 college students, E-types had a 3.65 odds ratio of smoking compared to other chronotypes. Another study by Wittmann et al. (2010) showed that use of stimulants such as cigarettes and caffeinated beverages mediated the relationship between chronotype and psychological well-being, such as depression and sleep quality. In this study, only E-types who smoked and consumed alcohol showed lower scores in psychological well-being and sleep disturbance. One explanation is that E-types, who are more prone to "social jet lag," which is defined by the discrepancy between work and free days or between social and biological time, may use stimulants such as cigarettes as a way to cope with sleep debt that occurs when sleep hours during work days are curtailed due to social responsibilities (Wittmann et al., 2006). However, our data did not support this, as there was no difference between total sleep time on weekdays or weekends, or weekday–weekend sleep duration difference.

Another interesting finding in our study was the difference in frequency of sleep-interfering behaviors among chronotypes. In an exploratory analysis, E-types were found to be much more likely to engage in certain sleep-interfering behaviors, such as drinking caffeinated beverages during the evening, smoking or eating heavy meals before bedtime, or taking naps for more than 30 min. There were also sleep-interfering behaviors that both E-types and I-types were more likely to engage in compared to M-types, such as keeping irregular sleep and wake schedules, staying in bed despite being unable to fall asleep, and worrying about getting enough sleep. Many of these particular items in the Sleep Behavior Scale are conducive to guidelines for practicing sleep hygiene, which are ultimately helpful in preventing sleep disturbance and insomnia. High frequency of sleep-interfering behaviors was also reflected in poor sleep quality (on the PSQI) in E-types, with E-types reporting higher levels of sleep disturbance compared to M-types. Our results also indicated that more sleep-interfering behaviors mediated the relationship between chronotype and sleep quality. There is ample evidence that E-types carry negative consequences for sleep, such as worse sleep quality, shorter sleep duration, higher levels of daytime sleepiness, more variability in their sleep schedules, and waking distress greater than expected in association with levels of insomnia severity (Giannotti et al., 2002; Merikanto et al., 2012; Ong, Huang, Kuo, & Manber, 2007; Taillard et al., 1999). This is the first study to show that E-types have a higher frequency of specific sleep-interfering behaviors, which may be associated with E-types being more vulnerable to sleep disturbance. The finding that E-types were found to be much more likely to engage in certain sleep-interfering behaviors may be helpful for clinicians to focus on these specific behaviors in insomnia patients with eveningness tendencies, which has been suggested in the literature (Richardson, Gradisar, & Barbero, 2015). Specifically, nonpharmacological interventions such as cognitive-behavioral therapy for

insomnia target sleep-interfering behaviors to alleviate sleep disturbance, and knowing sleep-interfering behaviors that E-types are more prone to engage in (e.g., worrying about not getting enough sleep) may be helpful in tailoring treatments for this population.

In our study, E-types were found to have significantly lower levels of physical activity compared to M-types. In addition, physical activity also mediated the relationship between chronotype and mental HRQOL. One area of research that has received wide attention for health problems in chronotypes is obesity. Past studies have shown that E-types are more likely to be obese, which can be a risk factor for a variety of illnesses (Schubert, 2008). In our study, there was an average of approximately 10 MET differences per week between E-types and M-types. In our study, there was no difference in BMI between chronotypes (Table 2). One reason that we may not have found a difference in BMI among chronotypes is that our study did not account for circadian misalignment. Circadian misalignment, and not chronotype per se, may contribute to being overweight and obese, through constantly shifting circadian rhythms during weekday and weekends. This type of chronodisruption may cause the metabolic pathways and hormones to misalign, which eventually leads to weight gain and high BMIs (Garaulet & Madrid, 2009).

In regard to HRQOL, our results indicate that E-types also had significantly worse physical HRQOL compared to both chronotypes, and also had lower scores for mental HRQOL compared to M-types. More specifically, E-types reported having lower levels of physical functioning, general health, vitality, and mental health compared to both I-types and M-types. Additionally, E-types also had lower physical role functioning and emotional role functioning compared to M-types. This is the first study showing reduced HRQOL in E-types among middle- and older-aged adults. The results are generally consistent with the adolescent literature, which shows that E-types have overall poorer mental and HRQOL (Prieto, Diaz-Morales, Barreno, Mateo, & Randler, 2012), For mental HRQOL, there is evidence that E-types are more prone to psychiatric illnesses such as depression, with evening types reporting more severe depressive symptoms and more likelihood of attempting violent suicides than other chronotypes (Adan et al., 2012; Gaspar-Barba et al., 2009; Selvi et al., 2011). One population-based study by Merikanto and colleagues (Merikanto et al., 2013) found that the odds ratio for a range of indicators of depression (core depressive symptoms, diagnosis or treatment of depression, and use of antidepressant medication) were 2.7- to 4.1-fold higher for E-types compared to M-types. However, based on past research, it is possible that the observed chronotype findings reflect greater health problems and morbidity (Merikanto, Lahti, et al., 2014). It may be possible that a bidirectional relationship between eveningness and disease is present, and future studies are needed to clarify this relationship.

In our study, we originally hypothesized that E-types would be demarcated from both I- and M-types for health and health behavior. However, while this was the case for certain health behaviors and HRQOL domains, there was also evidence suggesting a protective effect of morningness beyond the most common intermediate chronotype. This was true for physical activity, sleep quality (measured by PSQI), and physical and mental HRQOL. Morningness being a protective factor for negative mood has been suggested in previous studies. One study by Biss and Hasher (2012) found younger and older adults who scored high on morningness reported higher levels of positive affect and subjective health compared to their lower-scoring counterparts (Hasher, 2012). Another study by Nielsen (2010) suggested that morningness may be a protective factor in delaying onset of negative

affective systems such as neuroticism and depression (Nielsen, 2010). Additionally, it has also been shown that earlier set parental bedtimes in adolescents, mirroring morningness lifestyles, could be protective against depression and suicidal ideation by lengthening sleep duration (Gangwisch et al., 2010). It should also be noted that there was a smaller proportion of E-types (4.9%) and a higher proportion of M-types (38.2%) in our sample. Although this is consistent with the overall data that suggest approximately 40% of the adult population is classified as an E-type or M-type, there was an unbalanced distribution of the M-types and E-types. One alternative explanation for the data is that chronotypes differ according to age, with morningness scores tending to increase after the end of adolescence (Kim et al., 2010; Merikanto et al., 2012). Additionally, the main sample was representative of the population of Ansan city, which is primarily industrial, and it is possible that cultural factors, such as strict work ethic, may have played a part in the higher proportion of M-types.

Limitations

This study has limitations, which should be taken into account when interpreting the results. First, the cross-sectional design of this study makes it difficult to make causal inferences about the relationship between chronotype, health behaviors, and HRQOL. Second, all measurements used in the study were based on self-reports, and additional objective indicators of health behaviors would have made the study findings more accurate, as it is possible that some health behaviors such as alcohol consumption may have caused underreporting from certain individuals. Third, it should be noted that while differences in health domains such as HRQOL, especially subscales such as pain or social functioning, were statistically significant, the magnitude of their differences may not be clinically significant, and thus should be interpreted with caution and examined further in future studies. Finally, in regard to the mediational analyses, sleep-interfering behaviors and physical activity were statistically significant mediators but should be interpreted with caution due to small effect sizes, and other mediators should be further explored in future studies.

CONCLUSIONS

Our study found that eveningness was associated with unhealthy behaviors that may eventually place E-types at higher risks for a variety of health hazards. The finding that E-types were much more likely to engage in certain sleep-interfering behaviors, such as drinking caffeinated beverages during the evening, smoking or eating heavy meals before bedtime, or taking naps for more than 30 min may be helpful for clinicians to tailor treatment for insomnia patients with eveningness tendencies.

E-types also had reduced physical HRQOL, and especially worse general health and physical functioning compared to the other two chronotypes. Additionally, E-types also had reduced mental HRQOL compared to M-types, which may imply that circadian preference may underlie a higher risk for mental health problems. Future studies should focus on behavioral interventions that target unhealthy behaviors in E-types, which may be able to elucidate some of the underlying mechanisms between health behaviors and chronic illness and mental health in chronotypes. Additionally, sleep education programs made available to the public that include elements of evidence-based treatment

such as cognitive-behavioral therapy for insomnia may be helpful in preventing health risks for physical and sleep disorders and should be developed in the future.

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