Chronotype and trait self-control distinctively predicted subjective sleep quality via sleep hygiene behaviors and bedtime media use

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Abstract

This study examined the distinctive roles of chronotype and trait self-control in predicting sleep quality and the mediation of sleep hygiene components and bedtime media use of the relations between chronotype, trait self-control and sleep quality. Self-report questionnaires measuring chronotype, trait self-control, sleep hygiene behaviors, bedtime media use and sleep quality was administered in 224 Chinese adults (83.5% female). A multiple mediation model was examined with sleep hygiene components and bedtime media use as parallel mediators of the relations between chronotype, trait self-control and sleep quality. Chronotype and trait self-control positively predicted sleep quality. Mediation analyses indicated that trait self-control predicted sleep quality directly and indirectly through pre-sleep stress management and comfortable sleeping environment, whereas chronotype predicted sleep quality indirectly through pre-sleep stress management and bedtime media use. The present study highlights the protective effect of sleep hygiene that enables people to be less susceptible to poor sleep quality, and supports the proposition that self-regulatory abilities lie in the difficulties in adhering to sleep hygiene and refraining from media use at bedtime. The findings provide further knowledge on mechanisms through which late chronotype and low trait self-control undermine sleep quality.

Introduction

Poor or insufficient sleep can lead to serious consequences for physical and mental health [1]. Although much attention has been on health consequences of sleep loss, a line of sleep research has shifted the focus to a behavioral component of sleep, i.e., sleep hygiene. Sleep

hygiene, for instance, having regular bedtimes or avoiding sleep-disrupting activities, has been shown to have a protective effect on sleep problems in adolescents [2]. Drawn on the self-control strength model and propositions that self-regulatory abilities contribute to difficulties in adhering to sleep hygiene [3, 4], the present study focused on two individual differences that determine self-regulation abilities—i.e., chronotype and trait self-control. The primary objective was to examine the distinctive roles of chronotype and trait self-control in predicting sleep hygiene behaviors and sleep quality. The second objective was to examine sleep hygiene behaviors and bedtime media use as potential mediators of the relationships between chronotype, self-control and sleep quality. As most research on this topic tested only the mediating effect of a single pre-sleep habit (e.g., electronic media use) or a general sleep hygiene index, this study sought to provide evidence regarding whether multiple aspects of sleep hygiene behaviors, along with bedtime media use, would explain the effect(s) of chronotype and/or self-control on sleep quality.

Self-control, sleep hygiene and sleep quality

Self-control entails the ability to alter, maintain or terminate one's current activity or behavior in order to meet long-term personal goals or social demands [5]. The self-control strength model states that exertion of self-control enables individuals to execute necessary actions and resist impulses that may jeopardize their long-term goal achievements. However, because self-control resources are limited in nature, its depletion causes failures in self-regulation, resulting in decisions that prioritize instant gratification over long-term goals [3, 6].

Self-control has been considered as a stable individual difference across situations and times (i.e., trait self-control) [7]. Research showed that trait self-control predicted a

myriad of health-related behaviors (such as following a healthy diet), whereas low trait self-control predicted behaviors indicative of self-regulatory problems, such as procrastination [5, 8]. Moreover, it has been suggested that trait self-control promotes sleep quality in two ways [4]. First, self-control capacities enable individuals to better resist temptations that disrupt sleep (e.g., the lure of social media and TV watching) [9]. Second, trait self-control underlines adaptive responses to stress and effective strategies to deal with anxiety-provoking thoughts [10].

Accumulating evidence suggests that trait self-control is associated with more adaptive habits, which enable people high in trait self-control to effortlessly engage in health-promoting behaviors or refrain from unhealthy behaviors [11, 12]. In sleep contexts, sleep hygiene serves as a set of adaptive behaviors that individuals can purposefully employ in order to promote positive sleep outcomes. Empirical evidence supported that higher self-control capacities (either assessed with a hand-grip task or a self-report measure) predicted better sleep hygiene [13]. Sleep hygiene comprises a wide range of behaviors that ensure sufficient and good quality of sleep, including but not limited to, maintaining regular bedtimes and rise times, reducing worry or arousing emotion before bedtime, making sleep environment comfortable, avoiding excessive exercise, and limiting caffeine, alcohol or nicotine consumption [14]. In general, sleep hygiene accounted for 23% of the variance in subjective sleep quality in college students [15]. Pre-sleep stress management, among other sleep hygiene components, is particularly crucial for sleep quality, given the well-documented association between stress and disturbed sleep [16]. Findings from a diary study indicated that people high in trait self-control were less reactive and had more adaptive responses to stress [10]. Thus, we expected that sleep hygiene

components, in particular pre-sleep stress management, would mediate between trait self-control and sleep quality.

Bedtime media use has been widely studied for its negative impacts on sleep quality [17]. A growing body of research has linked low trait self-control to procrastinatory media use at bedtime [18]. For example, studies conducted among Belgian or Dutch adults found that low trait self-control predicted greater bedtime procrastination (i.e., voluntary sleep delays without obvious reasons [19]), directly and indirectly through increased deficient self-regulation via TV watching [9]. Moreover, procrastinatory TV watching was found to predict poor sleep quality via increased stress and pre-sleep cognitive arousals [20]. Given these findings, we proposed that people low in self-control (vs. those high in self-control) would be more likely to turn to media for instant gratification and pleasurable experience, which further undermine sleep quality [18]. We expected that bedtime media use would mediate the effect of self-control on sleep quality.

Chronotype, sleep hygiene, and sleep quality

Apart from trait self-control, another characteristic that determines self-regulation abilities and contributes to sleep quality is chronotype [21, 22]. Chronotype refers to an individual difference in circadian preference for sleep and activity, often mapped into the continuum of morningness-eveningness [23]. Individuals who prefer later than average sleep-wake times (i.e., evening types) are likely to experience circadian rhythm disruption due to the misalignment between their preferred sleep-wake times and normative social schedules, which create regulatory disadvantages in daytime functioning [24, 25]. Past research has linked early chronotypes (i.e., morningness) to better sleep quality and identified late chronotypes (i.e., eveningness) as a risk factor for sleep problems [26].

The relevance of chronotype for sleep hygiene is apparent, given the circadian preference and resultant irregular sleep patterns in evening types. Circadian misalignment experienced in evening types render them display behaviors indicative of self-regulatory failures (e.g., procrastination [22]). In addition, circadian misalignment causes difficulties in falling asleep in evening types when they intend to catch up normative schedules, increasing their vulnerability to developing improper sleep hygiene behaviors (e.g., bedtime media use) than morning types. Studies showed that evening types engaged in greater procrastinatory media use, as well as more bedtime procrastination, than morning types [20]. Thus, we hypothesize that bedtime media use would mediate the effect of chronotype on sleep quality.

Moreover, a meta-analytic report examining the link between chronotype and mental health outcomes indicated that eveningness was associated with maladaptive emotion regulation, and a higher level of anxiety and depression [4]. A study conducted among Chinese college students also found that maladaptive beliefs (such as worry) mediated between chronotype and sleep quality [28]. Taken together, these findings suggest that sleep hygiene behaviors, in particular regular sleep timing and pre-sleep stress management, may mediate between chronotype and sleep quality. Given that most of the aforementioned studies did not control for trait self-control, the present study aimed to examine sleep hygiene components as mediators between chronotype and sleep quality when controlling for self-control. Thus, we hypothesize that sleep hygiene behaviors, in particular pre-sleep stress management and sleep timing regularity, would mediate the effect of chronotype on sleep quality.

Whereas past research supported that chronotype and trait self-control served as determining factors for sleep hygiene behaviors and sleep quality, the present study aimed to complement this evidence by simultaneously examining and testing sleep hygiene components and bedtime media use as parallel mediators of the relations between chronotype, self-control and sleep quality. We hypothesized that morningness and higher self-control would be associated with better sleep quality. We expected that sleep hygiene components and bedtime media use would predict sleep quality and that they would mediate the associations between chronotype, self-control and sleep quality (see Fig 1 for the proposed multiple mediation model).

Methods

Participants and procedure

The present study draws on data from a cross-sectional study on Chinese adults' sleep behavior and sleep quality. Participants were 224 adults residing in Hong Kong recruited online by convenient sampling. Inclusion criteria was age 20 or older and Chinese language proficiency. Data were collected between 21 December 2020 and 15 January 2021. Every participant took part in this study on a voluntary basis. Participants completed the web-based survey administered in Chinese in approximately 25-35 minutes, and received a supermarket coupon of \$25 HKD (= \$3.22 USD) for their participation. Ethics approval was from the Human Research Ethics Committee of the Education University of Hong Kong. Written informed consent from each participant was obtained before the survey. The participants were predominantly women (83.5%), aged below 40 years old (75.4%). Specifically, 87 were 20-30 years old (38.8%), 82 were 31-40 years old (36.6%), 37 were

41-50 years old (16.5%), and 18 were 51 years old or above (8.0%). About half of participants were single (50.9%), whereas 46.0% of them were married and 3.1% were divorced or widowed.

Measures

The questionnaire consisted of the Chinese versions of the adult sleep-awake scale, the sleep hygiene index, the brief self-control scale, a measure of bedtime media use, the reduced Morningness-Eveningness Questionnaire (described in more details below) and demographic information, including age, gender and marital status. The first draft of the English to Chinese translation was done by the first author. Back translation was done by an independent research assistant. The Chinese translation was revised and polished with careful examination of the back translations by other members of the research team.

Sleep quality

Sleep quality was assessed using the Adult Sleep-Awake Scale [29]. Example items are “After waking up during the night, I roll over and go right back to sleep” and “After I fall asleep, but during the night, I toss and turn in bed” (reverse coded). The scale contains sleep behaviors on five dimensions—going to bed, falling asleep, maintaining sleep, reinitiating sleep, and returning to wakefulness. Participants rated each item on a 6-point scale from 1 “never” to 6 “always” with respect to how frequently each behavior occurred. The Chinese version of the scale showed good internal consistency ($\alpha = .90$). A higher mean score indicates better sleep quality.

Bedtime media use

Bedtime media use was measured with a set of questions developed by the authors to assess the frequency and duration of bedtime media use from Monday to Thursday night in the past month. Three items assessing the frequency of bedtime media use include “How often do you use social media (e.g., Facebook, Instagram or WhatsApp) for texting, surfing and other purposes with an electronic device including a laptop, tablet or mobile phone right before going to sleep?”; “How often do you watch videos/films/tv series or listen to music (e.g., Netflix or YouTube) with an electronic device right before going to sleep?”; “How often do you play games with an electronic device including a mobile phone or gaming console right before going to sleep?” (4-point scale from 1 “never” to 4 “almost everyday”). Two items assessed the duration of sleep delays due to media use, which read “For how many minutes do you think that you put off sleep due to social media use at bedtime?” and “For how many minutes do you think that you put off sleep to watch videos/films/tv series, listen to music, or play games at bedtime?”. Following Fossum et al.’s (2013) suggestion, the total time of sleep delays due to bedtime media use was then calculated by multiplying the frequency (the number of days) by duration (the minutes of bedtime delays on average) for each type of media [30]. The total sleep delay was then standardized, with a higher score indicating greater bedtime media use.

Chronotype

Chronotype was measured using the reduced Morningness-Eveningness Questionnaire (rMEQ) [31]. The 5 items assess participants’ typical rise time, morning freshness, typical retire time, subjective peak time (“at what time of the day do you think that you reach your feeling best peak?”) and their self-evaluation of chronotype (which reads, “One hears about

morning and evening types of people. Which one of these types do you consider yourself to be?") using a 4-point scale from 1 "definitely an evening type" to 4 "definitely a morning type". The total scores were computed following the guideline by Adan and Almirall [31]. The total scores ranged from 4 to 26, with higher scores indicating greater morningness preferences. The internal consistency of the Chinese version of the rMEQ was .61, similar to the scale reliability reported in past research [21].

Sleep hygiene behaviors

The 13-item Sleep Hygiene Index (SHI) [32] was used to assess sleep hygiene behaviors over the past month (e.g., "I get out of bed at different times from day to day", "I go to bed feeling stressed, angry, upset, or nervous"). Participants rated how often they have engaged in each behavior over the past month on a 5-point scale ranging from 1 "never" to 5 "always." The scores of all the items were reverse coded, with a higher score indicating better sleep hygiene. An exploratory factor analysis was performed using the principal component method and Oblimin rotation. Kaiser-Meyer-Olkin (KMO) measure and the Bartlett's test of Sphericity were used to detect sampling adequacy and data distribution, respectively. The KMO value was .77 and the Bartlett test reached significance ($p < .001$), indicating the suitability and adequacy of the sample for factor analysis.

A four-factor solution emerged. The factors cumulatively accounted for 60.6% of the total variance of item scores (Factor 1 = 27.9%, Factor 2 = 12.9%, Factor 3 = 11.5%, Factor 4 = 8.2%). Factors 1-4 are referred to as "pre-sleep stress management" ($\alpha = .72$); "sleep timing regularity" ($\alpha = .63$); "avoiding sleep-disrupting food or activities" ($\alpha = .60$); "comfortable sleeping environment" ($\alpha = .72$), respectively (see Table 1 for the items and factor loadings). A confirmatory factor analysis (CFA) was then conducted to verify the

factor structure. The fit indices used to assess model fit were the comparative fit index (CFI), Tucker-Lewis Index (TLI), the root-mean-square error of approximation (RMSEA) and standardized root mean square residual (SRMR). Values of CFI and TLI $> .90$, RMSEA $< .06$, and SRMR $< .08$ indicate a good fit with the data (Marsh, Hau, & Grayson, 2005). The results of CFA indicated that the four-factor model provided a reasonable fit for the data, CFI = .94, TLI = .91, RMSEA = .06, SRMR = .06. The mean scores of the items loaded on each factor were computed for mediation analysis.

Trait self-control

Trait self-control was measured with the 13-item brief Self-Control Scale [7], which assesses perceptions of self-discipline, impulsivity and resistance to temptation over the past month. Example items are “I am able to work effectively toward long-term goals” and “I wish I had more self-discipline” (reverse coded). The items were rated on a 5-point scale from 1 “not descriptive at all” to 5 “very much descriptive.” The Chinese version of the scale showed good internal consistency ($\alpha = .83$). A higher mean score indicates higher trait self-control.

Statistical analyses

Data analyses were performed using SPSS Version 26. Descriptive statistics were used to summarize demographic information, and Pearson’s r was used to assess the bivariate correlations between study variables. Additionally, Spearman’s ρ was computed to examine the associations between demographic characteristics and study variables. To test the main hypotheses, multiple mediation analyses were run using PROCESS macro for SPSS [34]. Chronotype and self-control were entered as independent variables, sleep

hygiene components and bedtime media use were entered as the mediators, and sleep quality was entered as the outcome variable. Age, gender and marital status were controlled for as covariates. Indirect effects of mediating effects were calculated using 5,000 bootstrap samples with 95% confidence intervals (CIs), whereby a significant mediating effect was determined by the exclusion of 0.

Results

Preliminary analyses

Table 2 presents the frequency and duration of bedtime media use by media type. As shown in Table 2, 80.4% of the participants reported to engage in social media surfing/texting before going to sleep almost everyday over the past month. Whereas 58.9% of the participants reported to watch films, videos or TV series, or listen to music at least 3 times per week, 21.9% of them reported to play games on electronic devices at bedtime at least 3 times per week. With respect to the average duration of media-related sleep delays, participants reported to put off their sleep due to social media use for 39.70 minutes ($SD = 31.94$ minutes) and due to other media activities (i.e., TV watching, listening to music, or gaming) for 40.01 minutes ($SD = 44.34$ minutes) on average.

Table 3 presents descriptive statistics and bivariate correlations between the study variables. Sleep quality, as predicted, was positively correlated to chronotype, self-control, all the sleep hygiene components ($r_s = .29 \sim .57, p_s < .0001$), but negatively correlated with bedtime media use ($r = -.36, p < .0001$). Chronotype was weakly and positively associated with self-control ($r = .22, p = .001$). Furthermore, chronotype was positively correlated with pre-sleep stress management ($r = .27, p < .0001$) and sleep time regularity ($r = .37, p <$

.0001), but was negatively correlated with bedtime media use ($r = -.28, p < .001$). On the other hand, self-control was weakly and positively correlated with all the sleep hygiene components ($r_s = .16\sim.22, ps < .02$), but was negatively correlated with bedtime media use ($r = -.15, p = .03$).

The results of the associations between demographic characteristics and study variables indicated that being younger (vs. older) was negatively correlated with pre-sleep stress management ($\rho = -.22, p = .001$), and sleep time regularity ($\rho = -.16, p = .01$), but was positively related to bedtime media use ($\rho = .15, p = .03$). Being married (vs. single) was positively correlated with chronotype ($\rho = .21, p = .002$), self-control ($\rho = .18, p = .008$), pre-sleep stress management ($\rho = .22, p = .001$) and sleep time regularity ($\rho = .17, p = .01$). None of the demographic variables were correlated with sleep quality ($\rho_s < .08, ps > .21$). Age, gender and marital status were controlled for as covariates in the mediation analyses.

Mediation analyses

The total effect of trait self-control on sleep quality was significant, with higher trait self-control predicting better sleep quality ($b = .32, SE = .08, p < .0001, 95\%CI = .17 \text{ to } .47$). As shown in Table 4, higher trait self-control significantly predicted better stress management ($b = .18, SE = .10, p = .05$), greater sleep regularity ($b = .17, SE = .08, p = .04$), and avoiding sleep-disrupting food or activities ($b = .15, SE = .07, p = .04$). Nonetheless, self-control was unrelated to bedtime media use ($b = -.18, SE = .12, p = .13$). Furthermore, among the sleep hygiene components, only pre-sleep stress management and comfortable sleeping environment had significant direct effects on sleep quality ($b = .32, SE = .05, p < .0001; b = .19, SE = .05, p < .0001$), whereas the direct effects of sleep timing

regularity and avoiding sleep-disrupting food or activities on sleep quality were non-significant ($ts < 1.00$, $ps > .31$). Bedtime media use also significantly and negatively predicted sleep quality ($b = -.08$, $SE = .04$, $p = .04$; see Table 4). Table 5 presents the bootstrapping results of the total, direct and indirect effects of the multiple mediation model. Results of the bootstrapped CIs for the indirect effects of self-control on sleep quality indicated significant mediation through pre-sleep stress management ($b = .06$, $SE = .03$, 95%CI = .001 to .13) and comfortable sleeping environment ($b = .03$, $SE = .02$, 95%CI = .003 to .08). After controlling for the mediators, the residual direct effect of self-control on sleep quality was still significant ($b = .19$, $SE = .06$, $p = .002$, 95%CI = .07 to .32).

There was also a significant total effect of chronotype on sleep quality, with greater morningness predicting better sleep quality ($b = .04$, $SE = .01$, $p = .001$, 95%CI = .02 to .07). As shown in Table 4, chronotype significantly predicted better pre-sleep stress management ($b = .05$, $SE = .02$, $p = .02$), greater sleep timing regularity ($b = .07$, $SE = .02$, $p < .001$), and less bedtime media use ($b = -.18$, $SE = .12$, $p < .001$), but chronotype was unrelated to avoiding sleep-disrupting food or activities, and comfortable sleeping environment ($ts < 1.48$, $ps > .14$). As shown in Table 5, the results of the bootstrapped CIs for the indirect effect of chronotype on sleep quality indicated significant mediation through pre-sleep stress management ($b = .02$, $SE = .005$, 95%CI = .01 to .03) and bedtime media use ($b = .006$, $SE = .003$, 95%CI = .001 to .01). After controlling for the mediators, the residual direct effect of chronotype on sleep quality was no longer significant ($b = .01$, $SE = .01$, $p = .29$, 95%CI = -.01 to .04).

Discussion

The main objectives of this study were to examine the distinctive roles of chronotype and trait self-control in predicting sleep quality and the mediating effects of sleep hygiene components and bedtime media use on the associations between chronotype, trait self-control and sleep quality in Chinese adults in Hong Kong. The results showed that morningness and higher trait self-control were related to better sleep quality. The multiple mediation analyses indicated unique and shared contributions of chronotype and trait self-control to sleep quality through the proposed mediators: the relationship between trait self-control and sleep quality was mediated by pre-sleep stress management and comfortable sleeping environment, whereas the relationship between chronotype and sleep quality was mediated by pre-sleep stress management and bedtime media use.

Findings concerning the associations between chronotype, self-control and sleep quality are in line with past research that identified eveningness and low self-control as risk factors for sleep problems and insufficient sleep [22, 35]. The present study advances the understanding of these associations by examining relative contributions of sleep hygiene components and bedtime media use as mediators. The finding that pre-sleep stress management mediated between both trait self-control and sleep quality and between chronotype and sleep quality indicates that morning types or people high in self-control had better pre-sleep stress management, which in turn promoted sleep quality. The results are largely consistent with research findings that a lack of stress management skills partly explained poor sleep quality in evening types or people low in trait self-control [27, 28], suggesting that pre-sleep stress management, including reducing worry and other arousing emotion before bedtime, is crucial for relieving sleep problems. In other words, in

accordance with the self-control strength model, the abilities to downregulate stress and emotion (e.g., self-regulatory abilities) underlie the differences in sleep quality between morning and evening types, and between people high vs. low in trait self-control [5, 13].

Bedtime media use, defined as sleep delay due to media use at bedtime, was found to mediate the link between chronotype and sleep quality, but not between self-control and sleep quality. In line with research that has linked eveningness to bedtime procrastination [22, 35]. This finding suggests that evening types were more inclined to spend time on media and put off their bedtime than morning types. It is important to note that the findings did not rule out other alternative explanations that bedtime media use also exacerbates disruption of circadian rhythm in evening types and causes sleep delay via other mechanisms. For instance, blue light emitted from electronic devices can inhibit melatonin production, and media activities increase cognitive and emotional arousals [17].

An unanticipated result of the present study was that bedtime media use did not mediate between trait self-control and sleep quality. This hypothesis was built up on a large body of research literature indicating that self-regulatory failures lie in the phenomenon of bedtime procrastination [19]. Although our finding was inconsistent with Exelmans and Van den Bulck (2021) [9] and Kroese et al. (2016) [19], it was corroborated by the findings of Kühnel et al. [22], where trait self-control was unrelated to bedtime procrastination after controlling for chronotype and state self-control. A possible explanation for this result was that the present study did not differentiate procrastinatory media use from recreational media use, as the two forms of media use are driven by different psychological mechanisms: “recreational media use represents strategic delay, whereas procrastinatory media use represents irrational delay” (p. 5) [36]. In Reinecke and Hofmann’s (2016) study,

trait self-control significantly predicted procrastinatory media use but not recreational media use. Therefore, the null effect of self-control on bedtime media use observed here may reflect the recreational nature of media use in the present study. Future research is needed to further test if recreational and procrastinatory media use would differently explain the relationship between chronotype and sleep quality.

This study has a number of strengths, as it is the first to examine the multiple mediation of sleep hygiene components in the relations between chronotype, trait self-control and sleep quality. It is also among the few studies that examined the effect of chronotype on sleep quality while controlling for trait self-control [22, 35]. However, there are several limitations to this study. First, this study relied on self-report, and thus the data may have been subjective to recall biases [37]. Although research has indicated that sleep habits can be studied reliably with self-report data as compared to sleep diaries [38], we are unable to assess the extent to which self-reported sleep behaviors reflected actual behaviors. Future research can consider different assessments of sleep habits and behaviors to replicate the current findings. Second, despite controlling for demographic characteristics as covariates (i.e., age, gender and marital status), other potential covariates were not controlled for, for instance, work schedule, shared bedroom, or presence of sleep problems, such as sleep apnea or insomnia. Third, this study uses a cross-sectional design. Therefore, given that this study was correlational in nature, we are unable to determine whether chronotype or trait self-control affected sleep hygiene or vice versa. Poor sleep hygiene and delay of circadian rhythm seem to be bidirectional, and jointly contribute to worse sleep quality [39]. Future research can employ a longitudinal design for further

understanding the associations between chronotype, self-control, sleep hygiene, bedtime media use and sleep quality.

In conclusion, the current investigation provided evidence that chronotype and trait self-control distinctively predicted sleep quality in Chinese adults in Hong Kong. Sleep hygiene was also found to be significant mediators, in parallel with bedtime media use, of the associations between chronotype, trait self-control and sleep quality. These results supported the protective effect of sleep hygiene that enables people to be less susceptible to poor quality of sleep. Furthermore, as sleep hygiene represents a behavioral aspect of sleep that can be ameliorated by goal-directed action, this study provides a rationale for improving sleep quality in evening types and people low in trait self-control by making them be aware of and purposefully adopt good sleep hygiene practices.

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Table 1. Items and factor loadings of the Sleep Hygiene Index (SHI).

Item Content	Factor Loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
1. I take daytime naps lasting two or more hours			.56	
2. I go to bed at different times from day to day		.46		
3. I get out of bed at different times from day to day		.40		
4. I exercise to the point of sweating within 1 h of going to bed			.31	
5. I stay in bed longer than I should two or three times a week		.78		
6. I use caffeine within 4 h of going to bed or after going to bed			.44	
7. I do something that may wake me up before bedtime		.43		
8. I go to bed feeling stressed, angry, upset, or nervous	.68			
9. I use my bed for things other than sleeping	.68			
10. I sleep on an uncomfortable bed				.66
11. I sleep in an uncomfortable bedroom				.70
12. I do important work before bedtime	.65			
13. I think, plan, or worry when I am in bed	.70			

All items were reverse coded, with higher scores indicating better sleep hygiene.

Table 2. Frequency and duration of bedtime media use by media type.

Media Type	<i>N</i>	Frequency				Duration (minutes per night)	
		Never	1-2 times per week	3-5 times per week	Almost everyday	<i>Mean</i>	<i>SD</i>
Social media surfing/texting (e.g., Facebook, Instagram, or WhatsApp)	224	2.2%	7.1%	10.3%	80.4%	39.70	31.94
Watching films/videos/TV series or listening to music (e.g., Netflix or YouTube)	224	17.4%	23.7%	21.9%	37.0%	40.01	44.34
Playing games on any electronic device	224	56.2%	21.9%	9.4%	12.5%		

SD = standard deviation.

Table 3. Bivariate associations between study variables.

	<i>N</i>	<i>Mean</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11
1 Age				-	-.03	-.20**	-.06	-.13	-.12	-.22**	-.16*	.04	.05	.15*
2 Gender					-	.07	.04	.07	.06	-.07	.01	.09	-.07	.01
3 Marital status						-	.08	.21**	.18**	.22**	.17*	.05	-.01	-.02
4 Sleep quality	224	4.24	.69				-	.30**	.36**	.57**	.38**	.29**	.46**	-.36**
5 Chronotype	224	13.22	3.36					-	.22**	.27**	.37**	.05	.12	-.28**
6 Trait self-control	224	3.09	.59						-	.20**	.22**	.16*	.16*	-.15*
7 SH1	224	3.32	.84							-	.42**	.23**	.33**	-.29**
8 SH2	224	3.26	.75								-	.28**	.20**	-.26**
9 SH3	224	4.45	.56									-	.33**	-.15*
10 SH4	224	4.08	.81										-	-.26**
11 Bedtime media use	207	274.29	221.09											-

Age was coded as 0 for age 41 years old or above, and 1 for aged 40 years old or below; gender was coded 0 for men and 1 for women. Marital status was coded as 0 for single/divorced and 1 for married. Spearman's rank order correlations were computed to assess the relationships between demographic covariates and key study variables, and Pearson's correlations were used to determine the relationships among key study variables. SH1 = pre-sleep stress management, SH2 = sleep timing regularity, SH3 = avoiding sleep-disrupting food or activities, SH4 = comfortable sleeping environment, *SD* = standard deviation. * $p < .05$. ** $p < .01$.

Table 4. Summary of regression coefficients for the multiple mediation model.

	M1: SH1		M2: SH2		M3: SH3		M4: SH4		M5: Bedtime media use		Y: Sleep quality	
Predictors	<i>B (SE)</i>	<i>p</i>	<i>B (SE)</i>	<i>p</i>	<i>B (SE)</i>	<i>p</i>	<i>B (SE)</i>	<i>p</i>	<i>B (SE)</i>	<i>p</i>	<i>B (SE)</i>	<i>p</i>
Constant	2.96 (.28)	< .0001	2.5 (.24)	< .0001	4.27 (.20)	< .0001	3.80 (.28)	< .0001	.92 (.34)	.008	1.71 (.35)	< .0001
Age	-.29 (.13)	.02	-.17 (.11)	.13	.04 (.09)	.65	.14 (.13)	.31	.18 (.16)	.27	.09 (.08)	.31
Gender	-.27 (.15)	.07	-.17 (.13)	.18	.08 (.11)	.48	-.17 (.15)	.27	-.15 (.18)	.40	.05 (.10)	.61
Marital status	.22 (.11)	.06	.10 (.10)	.30	.06 (.08)	.47	-.06 (.12)	.63	.20 (.14)	.14	-.06 (.07)	.40
Trait self-control	.18 (.10)	.05	.17 (.08)	.04	.15 (.07)	.04	.18 (.10)	.07	-.18 (.12)	.13	.19 (.06)	.002
Chronotype	.05 (.02)	.001	.07 (.02)	< .000	.01 (.01)	.70	.03 (.02)	.14	-.08 (.02)	< .0001	.01 (.01)	.29
M1: SH1											.32 (.05)	< .0001
M2: SH2											.05 (.06)	.41
M3: SH3											.07 (.07)	.32
M4: SH4											.19 (.05)	< .0001
M5: Bedtime media use											-.08 (.04)	.04
	$R^2 = .15$		$R^2 = .18$		$R^2 = .03$		$R^2 = .04$		$R^2 = .10$		$R^2 = .47$	
	$F(5, 201) = 7.13$		$F(5, 201) = 8.77$		$F(5, 201) = 1.41$		$F(5, 201) = 1.56$		$F(5, 201) = 4.64$		$F(10, 196) = 17.42$	
	$p < .001$		$p < .001$		$p = .22$		$p = .17$		$p < .001$		$p < .001$	

Age was coded as 0 for age 41 years old or above, and 1 for aged 40 years old or below; gender was coded 0 for men and 1 for women. Marital status was coded as 0 for single/divorced and 1 for married. SH1 = pre-sleep stress management, SH2 sleep timing regularity, SH3 = avoiding sleep-disrupting food or activities, SH4 = comfortable sleeping environment. M = mediator, *B* = unstandardized coefficient, *SE* = standard error.

Table 5. Bootstrapping results of the total, direct and indirect Effects of multiple mediation model.

	Unstandardized coefficient	<i>SE</i>	95%CI
Total effect of trait self-control on sleep quality	.32	.08	[.17, .47]
Direct effect of trait self-control on sleep quality	.19	.06	[.07, .32]
Total indirect effect of trait self-control on sleep quality	.13	.05	[.03, .23]
Through SH1	.06	.03	[.001, .13]
Through SH2	.01	.01	[-.01, .04]
Through SH3	.01	.01	[-.01, .04]
Through SH4	.03	.02	[.003, .08]
Through bedtime media use	.01	.01	[-.001, .05]
Total effect of chronotype on sleep quality	.04	.01	[.02, .07]
Direct effect of chronotype on sleep quality	.01	.01	[-.01, .04]
Total indirect effect of chronotype on sleep quality	.03	.01	[.02, .05]
Through SH1	.02	.005	[.01, .03]
Through SH2	.003	.004	[-.004, .012]
Through SH3	.000	.001	[-.001, .004]
Through SH4	.005	.003	[-.001, .013]
Through bedtime media use	.006	.003	[.001, .010]

SH1 = pre-sleep stress management, SH2 = sleep timing regularity, SH3 = avoiding sleep-disrupting food or activities, SH4 = comfortable sleeping environment, *SE* = standard error, *CI* = confidence interval.

Fig 1. Proposed multiple mediation model. Chronotype and trait self-control were considered as independent variables (X_1 , X_2), sleep hygiene components (M_1 – M_{n-1}) and bedtime media use (M_n) as mediators and sleep quality as outcome variable (Y). X can affect Y either directly (c') or indirectly through M_1 – M_n (a_1 – a_n , b_1 – b_n paths). Age, gender and marital status were included as covariates. N represents the number of mediators, and $n-1$ was determined by the number of sleep hygiene components derived from exploratory factor analysis of the item scores of Sleep Hygiene Index.