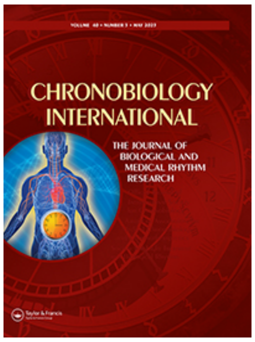

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ORIGINAL ARTICLE

Evening chronotype, insufficient weekday sleep, and weekday-weekend gap in sleep times: What is really to blame for a reduction in self-perceived health among university students?

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ABSTRACT
The association of insufficient sleep with reduced self-perceived health was previously well established. Moreover, it was sometimes shown that the indicators of poorer health were significantly related to chronotype and weekday-weekend gaps in sleep timing and duration. It remains to be elucidated, however, whether chronotype and these gaps can contribute to the reduced health self-ratings independently from shortened sleep duration or, alternatively, their relationship with health can be simply explained by their association with insufficient sleep on weekdays. In an online survey, we tested whether the self-rated health of university students can be predicted by several individual characteristics of the sleep-wake cycles, such as chronotype, weekday and weekend sleep times, weekday-weekend gap in sleep times, sleepability and wakeability at different times of the day, etc. Responses to a question about general health and to items of several questionnaires for chronobiological assessment were collected from smartphones of 1582 university students (mean age ± standard deviation was 19.5 ± 1.7 y). The results of regression analyses suggested that lower odds of having good self-rated health were significantly associated with an earlier weekday risetime, a later weekday bedtime, and, consequently, a shorter weekday time in bed. After accounting for weekday sleep, self-rated health showed significant association with neither chronotype nor weekday-weekend differences in sleep duration and timing. Besides, the adverse health effects of reduced weekday sleep were independent from the significant adverse effects of several other individual sleep-wake characteristics including poorer nighttime sleepability and lower daytime wakeability. We concluded that university students perceive the negative health impacts of losing sleep by waking up early on weekdays irrespective of their night sleep quality and daytime level of alertness. Their chronotype and weekday-weekend difference in sleep times might not be among significant contributors to this perception. It is of practical importance to consider the reduction of weekday sleep losses among the interventions aimed at preventing sleep and health problems.

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Sleep curtailment; sleep duration; sleep timing; self-rated health; chronotype

Introduction

Sleep curtailment negatively impacts safety, cognition, health, and longevity. In particular, short sleep durations were linked to the increased risk of serious accidents and injury (Gottlieb et al. 2018; Uehli et al. 2014), reduced ability to learn and retain information (Van Dongen et al. 2003; Williamson and Feyer 2000), bad mood (Medic et al. 2017; Orchard et al. 2020; Short et al. 2020), various problems with health including obesity and diabetes, cardiovascular and infection diseases, cancers (Buxton and Marcelli 2010; Morselli et al. 2010; Soucise et al. 2017; Thompson et al. 2011; von Ruesten et al. 2012) and even early mortality (Cappuccio et al. 2010; Grandner et al. 2010). The detrimental health impacts of insufficient sleep might be exemplified by a report showing that well-rested people were nearly three times less likely to develop a cold than those who slept less than 7 h (Cohen et al. 2009). In another publication, a dose – response relationship between sleep duration and self-rated health was found in a retrospective observational study of young adults in 24 countries, with the poor health

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category being more likely chosen by those who slept less than 7 h (Steptoe et al. 2006).

Adolescents and young adults prefer later sleep-wake timing (Carskadon 2011; Crowley et al. 2018; Gradisar et al. 2011; Jenni et al. 2005). Therefore, they suffer from a deficit of sleep during the weekdays with early morning wake-ups far more often than people of other ages (Becker et al. 2015; Millman 2005; Owens et al. 2014). Garmy et al. (2020) reported that fewer than 8 h of sleep duration before a school day was associated with poor self-reported health. However, Conklin et al. (2019) found that sleep deprivation was not associated with adolescent self-reported health, whereas chronic exposure to impaired quality of sleep was. Therefore, it is necessary to separate the potential health-reducing effects of low sleep quality and short duration of weekday sleep.

Research in the fields of sleep science and chronobiology distinguishes two distinct chronotypes: morning and evening (e.g. Adan 1994; Horne and Östberg 1976). Our work/study culture is biased towards the circadian clocks of the former types, and, in particular, working and school start times are traditionally set too early. In order to get to work/study, the latter types are forced to sacrifice a larger amount of sleep on weekdays than the former types. Although the association of poor self-perceived health with evening types and late sleep timing was reported (Mito et al. 2021; Yeo et al. 2022), little is known about its contribution to a larger weekday sleep insufficiency in evening types compared to morning types. Although the association of evening types with poorer health can simply be a consequence of the proneness of these types to unhealthy behavior (Fernando et al. 2022; Makarem et al. 2020; Merikanto et al. 2012; Patterson et al. 2016), one of the recently reported results suggested that both scheduled day sleep duration and chronotype play their significant roles in shaping health outcomes (Maultsby et al. 2022).

One particular example of sleep insufficiency in adolescents and young adults is a reduction of sleep duration after earlier risetimes on weekdays. These wakeups are mostly set by social clocks, while weekday bedtimes and weekend bed- and risetimes appear to be more strongly determined by people's biology (e.g. by timing of exposure of their circadian clocks to the 24-h light–dark cycle). Both evening chronotype and insufficient weekday sleep are expected to correlate with the gaps between weekday and weekend in sleep timing and duration. Usually, these gaps in timing and duration are described (e.g. Tonetti et al. 2022), as 1) delaying bedtime and get-up time during weekend days compared to weekdays, which is known as social jetlag (Wittmann et al. 2006) and 2) extending sleep duration during weekend days compared to weekdays, which is, sometimes, referred to as weekend catch-up sleep (Kim et al. 2011), respectively. Some studies suggested the significance of association of these gaps with health indicators. For example, Tamura et al. (2021) found that a larger social jetlag was related to elevated risk of irritable mood, daytime sleepiness, and poor academic performance. Zhang et al. (2017) reported that a longer weekend catch-up sleep was significantly associated with lower perception of mental and physical health.

Whether these gaps can contribute to health self-ratings independently from short weekday sleep remain to be elucidated. The results of examination of this possibility were inconclusive. For instance, it was observed that a longer weekend catch-up sleep was significantly associated with a lower well-being only in the group of sleep-deprived adolescents, and that the size of social jetlag was not significantly associated with well-being (Tonetti et al. 2022).

In this context, it is reasonable to ask:

(1) Can university students perceive the negative impact of weekday sleep deficiency on their health?

If the answer is yes (they can), it is also reasonable to ask:

(2) Can this perception be fully independent from the association of self-rated health with other individual characteristics of the sleep-wake cycle, such as sleep quality and excessive daytime sleepiness?

(3) Can this perception explain, at least partly, the association of self-rated health with chronotype and weekday-weekend gaps between sleep times?

Consequently, we analyzed data of an online survey of sleep-wake characteristics of university students to test the following hypotheses:

(1) Self-rated health can be significantly associated with weekday time in bed, thus indicating the ability to percept the detrimental health impacts of losing sleep by waking up earlier on weekdays.
(2) These impacts can be separated from the detrimental health impacts of several other individual characteristics of the sleep-wake cycle including poor sleep quality and reduced levels of alertness during the day.
(3) These impacts can explain, at least partly, the association of self-rated health with chronotype and weekday-weekend gaps in sleep timing and duration.

Methods

University lecturers invited their students to voluntarily respond from their smartphones to the questions of a survey of sleep-wake behavior and habits. Their responses were collected via a web-page. The mean ages ± standard deviations of 439 male and 1133 female university students were 19.7 ± 2.0 and 19.4 ± 1.5 y, respectively. Informed consent was obtained from each of the survey participants in the form of response "Yes" to the first question: "I give informed consent to voluntarily participate in this online survey of sleep-wake behavior and habits."

Students were asked to self-assess their health state (see the notes to Table 1), and their sleep and chronobiological characteristics were self-assessed with the following questionnaire tools (156 items in total): 1) the Single-Item Chronotyping (SIC) designed for self-choosing chronotype among seven options (Putilov et al. 2021c); 2) the 72-statement Sleep Wake Pattern Assessment Questionnaire (SWPAQ) for self-reporting sleep-wake adaptability (Putilov 2007); 3) the reduced (60-item) version (Putilov et al. 2022b) of the Sleep-Wake Adaptability test (SWAT) that was also designed for self-reporting sleep-wake adaptability (Putilov 2016); 4) a slightly modified version (Putilov et al. 2021a, 2021b, 2021c, 2022b) of the 19-time point Visuo-verbal Judgment Task (VJT) developed by Marcoen et al. (2015) for predicting sleepiness levels on the 1.5-day interval of permanent wakefulness; and 5) four questions about clock hours for rise- and bedtimes on weekdays and weekends.

This set of chronobiological tools allowed the assessment of different aspects of individual variation, state-like (sleep times), predicted state-like (VJT), trait-like (SIC), and ability-like individual differences (SWPAQ and SWAT). Previously, all these chronobiological instruments were cross-validated using students' samples (Putilov et al. 2021a, 2021b, 2021c, 2022a, 2022b). Here, they were also cross-validated, and the detailed description of the results of this cross-validation is included in the supplementary (Tables S1 and S2).

The $SPSS_{23.0}$ statistical software package (IBM, Armonk, NY, USA) was used for statistical analyses. Two-way ANOVAs were run to test whether three response options to the question about health were significantly related to sleep times and scores on chronobiological scales or subscales (Tables 1 and 2). The correlates and predictors of health were determined by applying correlation analysis (Spearman's rho, ρ), linear regression analyses, and binary logistic regression analyses (last column in Tables 1–4, respectively).

Additionally, three responses to the question about health and the dichotomized responses to the questions about weekday time in bed (≤6 h and >6 h) were

Table 1. Correlations and main effect of factor "health" in ANOVAs of sleep times and the SIC.

			Good		Intermediate		Bad		Statistics	
Variable	Health options		Mean	SEM	Mean	SEM	Mean	SEM	$F_{2/1576}$	ρ
Sex, %		(Sex%)	65.2		81.6		76.7			0.174***
Weekday	Risetime	(wRT)	7.18	0.04	7.03	0.06	7.13	0.21	2.24	−0.085**
	Bedtime	(wBT)	24.46	0.05	24.85	0.08	24.59	0.27	8.86***	0.138***
	Midsleep	(wMS)	3.82	0.04	3.94	0.05	3.86	0.19	1.56	0.050*
	Time in bed	(wTiB)	6.72	0.06	6.18	0.08	6.54	0.30	13.65***	−0.178***
Weekend	Risetime	(fRT)	10.04	0.06	10.35	0.09	10.06	0.30	4.53*	0.088***
	Bedtime	(fBT)	25.06	0.07	25.47	0.10	25.35	0.34	6.27**	0.106***
	Midsleep	(fMS)	5.55	0.05	5.91	0.08	5.70	0.27	7.69***	0.110***
	Time in bed	(fTiB)	8.98	0.07	8.88	0.10	8.71	0.36	0.52	−0.024
Difference in	Risetime	(fwRT)	2.85	0.06	3.32	0.09	2.93	0.31	9.87***	0.144***
	Bedtime	(fwBT)	0.60	0.06	0.62	0.09	0.76	0.31	0.15	−0.003
	Midsleep	(fwMS)	1.72	0.04	1.97	0.06	1.84	0.22	5.10**	0.088***
	Time in bed	(fwTiB)	2.25	0.08	2.70	0.12	2.17	0.42	4.88**	0.123***
LVEMAN Type	Morning	(MT)	0.89	0.05	0.56	0.08	0.26	0.28	7.51**	−0.111***
	Evening	(ET)	0.89	0.05	1.04	0.07	0.86	0.25	1.57	0.066**
	M-other-E	(MoET)	1.07	0.03	1.21	0.04	1.22	0.13	5.02**	0.103***
	Lethargic	(LT)	0.03	0.01	0.08	0.01	0.09	0.04	10.56***	0.100***
	Vigilant	(VT)	0.23	0.02	0.15	0.03	0.13	0.10	3.20*	−0.093***
	L-other-V	(LoVT)	1.09	0.01	0.99	0.02	0.97	0.06	10.71***	−0.130***
	Napping	(NT)	0.39	0.05	0.56	0.08	0.78	0.27	2.28	0.071**
	Afternoon	(AT)	1.20	0.09	1.25	0.12	1.75	0.44	0.74	0.009
	N-other-A	(NoAT)	0.88	0.02	0.90	0.03	0.87	0.10	0.29	0.029

In each of two-way ANOVAs, the independent factors were "Sex" (Male or Female) and "Health" (three possible answers to the question: "What is your health state?"); ρ: Spearman correlation coefficient with answers about Health scored as 2, 1, and 0 for Good, Intermediate, and Bad, respectively; to calculate ρ for Sex, responses were scored as 1 or 2 for male or female, respectively. Difference in: Difference in sleep time (fw) between Weekend (f) and Weekday (w); Midsleep: A halfway to a risetime from a bedtime. LVEMAN Type: Six of seven options for answering the only question of the SIC asking about chronotype. English names of seven chronotypes were abbreviated as "LIVEMAN" ("Lethargic," "Inconclusive," "Vigilant," "Evening," "Morning," "Afternoon," and "Napping"); a choice of a certain chronotype was coded as 1, while other six choices were coded as 0. MoET, LoVT, and NoAT: The answers were additionally paired to grade chronotypes from 0 (MT or LT or NT) via 1 (o – other options) to 2 (ET or VT or AT). Mean and SEM: Response-averaged value and Standard Error of this Mean; Level of significance for F-ratio or r: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 2. Correlations and main effect of factor "health" in ANOVAs of chronobiological scores.

	Variable	Health	Good		Intermediate		Bad		Statistics	
			Mean	SEM	Mean	SEM	Mean	SEM	$F_{2/1576}$	ρ
SWPAQ	Morning Lateness	(M)	1.43	0.20	3.01	0.29	1.25	1.03	10.35***	0.131***
	Evening Lateness	(E)	1.40	0.22	1.31	0.31	1.06	1.11	0.07	0.012
	Their difference	(E-M)	2.83	0.33	4.32	0.47	2.30	1.68	3.55*	0.099***
	Their sum	(E+M)	−0.03	0.26	−1.71	0.37	−0.19	1.34	6.83**	−0.089***
	Daytime Wakeability	(V)	0.32	0.19	−1.32	0.27	−2.60	0.95	15.75***	−0.214***
	Anytime Wakeability	(W)	0.64	0.20	−1.23	0.28	−1.44	1.00	15.99***	−0.180***
	Anytime Sleepability	(F)	1.11	0.21	0.69	0.30	−0.84	1.09	1.97	0.004
	Nighttime Sleepability	(S)	4.21	0.20	2.68	0.28	−0.27	1.01	17.41***	−0.154***
SWAT	Morning Sleepability	(MS)	1.18	0.18	2.75	0.26	1.39	0.91	12.88***	0.152***
	Nighttime Wakeability	(NW)	0.51	0.15	0.76	0.21	0.79	0.76	0.50	0.021
	Their difference	(N-M)	1.68	0.25	3.51	0.36	2.18	1.28	8.70***	0.124***
	Their sum	(N+M)	−0.67	0.21	−2.00	0.30	−0.60	1.08	6.55**	−0.117***
	Daytime Wakeability	(DW)	3.31	0.16	0.91	0.23	0.17	0.83	40.48***	−0.284***
	After 24 h Wakeability	(AW)	−3.27	0.16	−3.51	0.23	−4.00	0.83	0.64	−0.072**
	Daytime Sleepability	(DS)	−0.28	0.19	−0.25	0.27	−1.73	0.95	1.14	0.012
	Nighttime Sleepability	(NS)	1.18	0.17	0.25	0.24	−2.27	0.86	11.60***	−0.098***
VJT	KSS score, 8:00–11:00	(M)	3.89	0.06	4.51	0.08	4.87	0.28	25.48***	0.192***
	KSS score, 21:00–4:00	(N)	5.96	0.05	6.12	0.08	6.05	0.28	1.45	0.040
	Their difference	(M-N)	0.02	0.06	0.32	0.08	0.45	0.29	5.29**	0.074**
	Their sum	(M+N)	4.92	0.04	5.32	0.06	5.46	0.20	19.42***	0.152***
	KSS score, 12:00–20:00	(D)	3.87	0.05	4.20	0.07	4.42	0.25	8.75***	0.137***
	KSS score, 6:00–12:00	(M+)	7.48	0.08	7.68	0.11	7.40	0.38	1.22	0.045

SWPAQ (Putilov 2007): Scores on 6 12-item scales; SWAT (Putilov 2016; Putilov et al. 2022): Scores on 6 10-item scales; for any scale, a positive score denotes lateness or ability either to sleep or to remain awake at certain time of the day; VJT (Marcoen et al. 2015): Scores on the Karolinska Sleepiness Scale (Åkerstedt and Gillberg 1990) averaged over four time subintervals (Putilov et al. 2021a) of the whole 1.5-day interval of permanent wakefulness (i.e. a higher KSS score denotes a higher sleepiness level on verbally anchored Likert scale: 1- Extremely alert, 2- Very alert, 3- Alert, 4- Rather alert, 5- Neither alert nor sleepy, 6- Some signs of sleepiness, 7- Sleepiness, but no effort to keep awake, 8- Sleepiness, but some effort to keep awake, 9- Very sleepy, great effort to keep awake, fighting sleep, 10- Extremely sleepy, can't keep awake). See also notes to Table 1.

Table 3. Results of linear regression analyses aimed at predicting health score.

Variable			β	Variable		β
Sex		(Sex)	0.110***		(Sex)	0.106***
Weekday	Risetime	(wRT)	−0.094***	Midsleep	(wMS)	−0.013
	Bedtime	(wBT)	0.098**	Time in bed	(wTiB)	−0.127***
Weekend	Risetime^	(fRT)	0.021	Midsleep^^	(fMS)	0.045
	Bedtime^	(fBT)	0.035	Time in bed^^	(fTiB)	−0.003
LVEMAN	Morning	(MT)	−0.054	M-other-E	(MoET)	0.042
Type	Evening	(ET)	0.014			
	Lethargic	(LT)	0.087**	L-other-V	(LoVT)	−0.067**
	Vigilant	(VT)	−0.014			
	Napping	(NT)	0.039	N-other-A	(NoAT)	−0.002
	Afternoon	(AT)	0.032			
SWPAQ	Morning Lateness	(M)	0.007	Their difference	(E-M)	0.008
	Evening Lateness	(E)	0.007	Their sum	(E+M)	−0.003
	Daytime Wakeability	(V)	−0.103***		(V)	−0.100**
	Anytime Wakeability	(W)	−0.075*		(W)	−0.070*
	Anytime Sleepability	(F)	−0.017		(F)	−0.015
	Nighttime Sleepability	(S)	−0.174***		(S)	−0.171***
SWAT	Morning Sleepability	(MS)	−0.058	Their difference	(N-M)	−0.015
	Nighttime Wakeability	(NW)	0.024	Their sum	(N+M)	0.050
	Daytime Wakeability	(DW)	−0.172***		(DW)	−0.177***
	After 24 h Wakeability	(AW)	0.049		(AW)	0.053
	Daytime Sleepability	(DS)	−0.063		(DS)	−0.061
	Nighttime Sleepability	(NS)	0.051		(NS)	0.053
VJT	KSS score, 8:00–11:00	(M)	0.042	Their difference	(KSM-N)	0.022
	KSS score, 21:00–4:00	(N)	−0.030	Their sum	(KSM+N)	0.029
	KSS score, 12:00–20:00	(D)	0.015		(KSSD)	−0.010
	KSS score, 6:00–12:00	(M+)	0.058*		(KSSA)	0.056*

Results of two linear regression analyses aimed on prediction of health scored as 0, 1, and 2 (self-rated as bad, intermediate, and good, respectively). Right and left analysis: Either the same variables were included in both analyses or some variables on the left were replaced on the right by their sums or differences on the left. Explained variance (R^2) was 0.17 and 0.16, respectively ($p < 0.001$). Level of significance for β (standardized beta coefficient) calculated for each of predictors: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; ^ or ^^: When these two variables were replaced either by the differences in bedtime (fwBT) and risetime (fwRT) or by the differences in midsleep (fwMS) and time in bed (fwTiB), respectively, the predicting powers of these differences were also non-significant (either β = 0.031 and 0.022 or β = 0.038 and −0.004, respectively; $p > 0.05$). Moreover, this replacement of two variables did not alter the predicting powers of other predictors. See also notes to Tables 1 and 2.

Table 4. Results of binary logistic regression analyses aimed at predicting the dichotomized health score.

Variable			B	Exp(B)	−95% CI	+95% CI
Sex#		(Sex)	−0.677***	0.508	0.39	0.661
Weekday	Risetime	(wRT)	−0.189***	1.191	1.082	1.310
	Bedtime	(wBT)	0.174***	0.828	0.748	0.917
Weekend	Risetime^	(fRT)	0.028	1.050	0.976	1.131
	Bedtime^	(fBT)	0.049	1.029	0.948	1.116
LVEMAN	Morning#	(MT)	0.185	1.203	0.668	2.167
Type	Evening#	(ET)	−0.203	0.816	0.473	1.409
	Lethargic#	(LT)	−0.996**	0.369	0.175	0.782
	Vigilant#	(VT)	0.094	1.098	0.569	2.118
	Napping#	(NT)	−0.272	0.762	0.435	1.336
	Afternoon#	(AT)	−0.341	0.711	0.385	1.313
SWPAQ	Morning Lateness	(M)	0.008	1.008	0.979	1.038
	Evening Lateness	(E)	0.002	1.002	0.976	1.029
	Daytime Wakeability	(V)	−0.042**	0.959	0.935	0.984
	Anytime Wakeability	(W)	−0.034**	0.967	0.943	0.991
	Anytime Sleepability	(F)	−0.010	0.990	0.961	1.020
	Nighttime Sleepability	(S)	−0.070***	0.932	0.908	0.957
SWAT	Morning Sleepability	(MS)	−0.021	0.980	0.945	1.015
	Nighttime Wakeability	(NW)	0.007	1.007	0.969	1.046
	Daytime Wakeability	(DW)	−0.085***	0.919	0.889	0.949
	After 24 h Wakeability	(AW)	0.033*	1.034	1.002	1.068
	Daytime Sleepability	(DS)	−0.028	0.972	0.939	1.006
	Nighttime Sleepability	(NS)	0.028	1.029	0.996	1.062
VJT	KSS score, 8:00–11:00	(M)	0.049	1.051	0.962	1.148
	KSS score, 21:00–4:00	(N)	0.034	1.035	0.941	1.138
	KSS score, 12:00–20:00	(D)	−0.049	0.953	0.863	1.052
	KSS score, 6:00–12:00	(M+)	0.069*	1.072	1.007	1.140

Results of binary logistic regression analysis aimed on prediction of health self-rated as either good or lower than good (i.e. bad and intermediate). Cox & Snell R Square was 0.17 and 0.16, respectively ($p < 0.001$). Level of significance for B (beta coefficient) calculated for each of predictors of dichotomized health score: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Exp(B), −95% CI, +95% CI: The odds ratios for predictors (the exponentiation of regression coefficient) with 95% Confidence Intervals; #: Also analyzed as a categorical variable; ^: When these two variables were replaced by the differences in bedtime (fwBT) and risetime (fwRT), the predicting powers of these differences were also found to be non-significant. Moreover, the replacement of these two variables did not alter the predicting powers of other predictors. See also Table 3. The results on modified variables (i.e. those listed in the left part of Table 3) are shown in Figure 1.

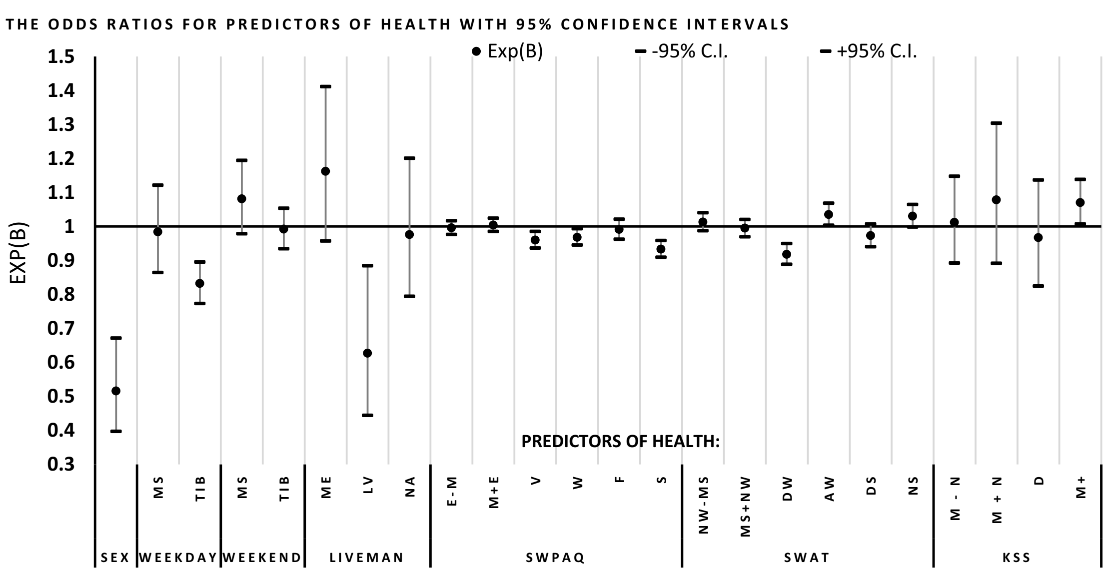

Figure 1. Characteristics of the sleep-wake cycle as predictors of health in university students. Results of the second binary logistic regression analysis aimed at prediction of self-rated health. Health was self-rated as either good or lower than good (i.e. bad and intermediate). Cox & Snell R Square was 0.16 ($p < 0.001$). Exp(B), -95% CI, +95% CI: The odds ratios for PREDICTORS of dichotomized health score (the exponentiation of regression coefficient) with 95% Confidence Intervals. The predicting powers of these differences were also non-significant after the replacement of two variables – weekend midsleep (fMS) and weekend time in bed (fTiB) – by the weekend-weekday difference in midsleep (fwMS) and time in bed (fwTiB), respectively. Moreover, such a replacement of two variables did not alter the predicting powers of other predictors. See also the right part of Table 3 for the full names of analyzed predictors.

distributed over six subsamples (three responses * two times in bed), and the Pearson Chi-Square test (χ^2) was applied to examine significance of deviation of an expected count from an actual count of a response to the question (i.e. when the random distribution of these responses over subsamples was expected).

Results

Correlation analysis and two-way ANOVAs yielded significant association of almost each of the examined variables with self-perceived health (Tables 1 and 2). Moreover, the level of significance for correlation coefficient and main effect of independent factor "Health" were found to be below 0.001 for most of these variables (Tables 1 and 2).

Notably, the list of such variables included bedtime and time in bed on weekdays, midsleep on weekends, and weekend-weekday differences in sleep times (Table 1). These variables also included such assessments of morning component of chronotype as morning lateness, morning sleepability, and sleepiness in the morning hours, 08:00h–11:00h (Table 2).

Since, as a rule, such variables (Tables 1 and 2) were significantly associated with each other, regression analyses were performed to confirm significance of their associations with health (Tables 3 and 4). The results on initial assessments are reported in the left columns of Tables 3 and 4. Some pairs of initial variables were used for the calculation of additional variables. They replaced these pairs of initial variables in the right columns of Tables 3 and 4 because both initial and additional variables – the derivatives of initial variables – cannot be included in the same analysis. The regression analyses did not confirm significance of association of health with any of the chronotypological differences between study participants (Figure 1 and Tables 3 and 4). Moreover, significant contribution of the differences between weekend and weekday in duration and timing of sleep also was not confirmed (e.g. see the legend to Figure 1 and the notes to Tables 3 and 4 on the results of regression analyses with the inclusion of weekend-weekday differences in these times instead of weekend sleep times).

The regression analyses supported the relationship of poorer self-rated health with the female sex, a larger weekday sleep loss due to a later bedtime and earlier risetime, self-rated lethargic chronotype, a lower daytime wakeability, and a poorer nighttime sleep (disturbed sleep corresponds to a lowered score on a nighttime sleepability scale).

These analyses also suggested that the associations of health with bedtime, risetime, and time in bed on weekday were independent from its associations with nighttime sleepability and daytime wakeability (Figure 1 and Tables 3 and 4). In other words, the analyses revealed that short duration of weekday sleep is a significant contributor to the decline of health self-scoring irrespective of some other negative health impacts, e.g. the effects of lowered sleep quality and lowered daytime alertness on health self-ratings (Figure 1 and Tables 3 and 4).

Figure 2 is designed to illustrate lower odds of having good self-rated health in those study participants who

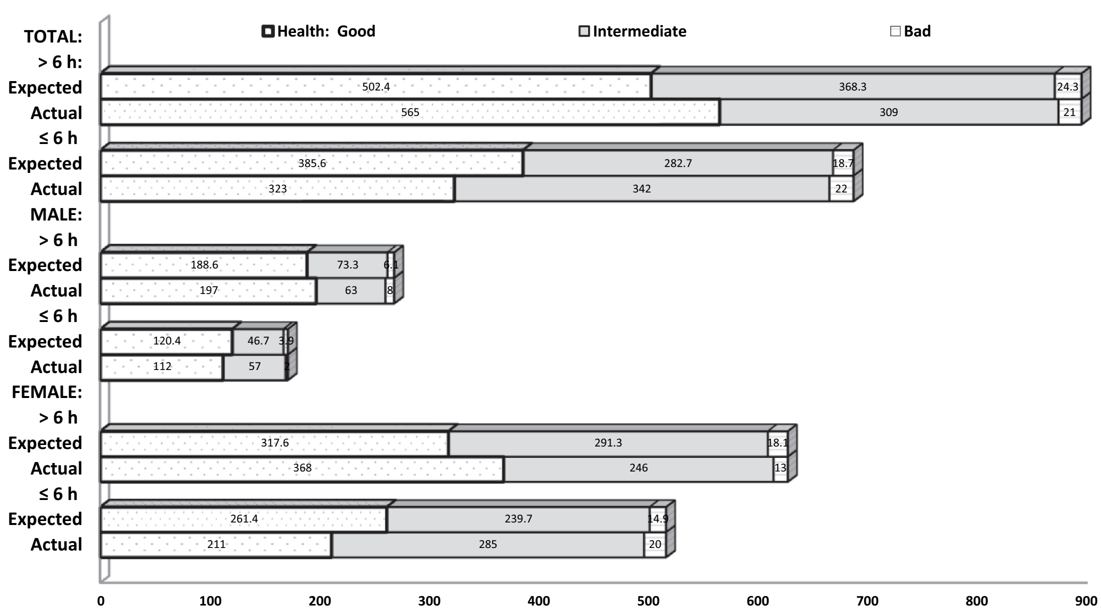

Figure 2. Health in university students with short (≤6 h) and longer time in bed (>6 h). Expected and Actual number of responses in subsamples obtained by subdivision in accord with the dichotomized weekday time in bed (≤6 h and >6 h). TOTAL: The whole sample; MALE and FEMALE: The subsamples of male and female students. For the whole sample, $\chi^2{}_2 = 41.01$, $p < 0.001$, and $\chi^2{}_2 = 6.15$, $p = 0.046$, and $\chi^2{}_2 = 36.49$, $p < 0.001$, for Male and Female students, respectively.

had a short weekday time in bed (6 h or even shorter). Given that, after the adjusting for contributions of other sleep-wake self-assessments, the association between self-perceived health and weekday sleep remained significant, the results supported the suggestion of ability of university students to perceive the negative impacts of losing sleep by waking up earlier on weekdays (Figure 1 and Tables 3 and 4). In contrast, the support was not provided, after such adjusting, for the associations of health self-perception with chronotype and weekday-weekend gaps in sleep timing and duration.

Discussion

It is well established that insufficient sleep duration is linked to lower health self-scorings (Andreasson et al. 2021; Garmy et al. 2020; Štefan et al. 2017; Steptoe et al. 2006). This link might be fully or partly explained by the association of lower health self-ratings with some other characteristics of the sleep-wake cycle, such as reduced night sleep quality, elevated daytime sleepiness, late chronotype, and large weekday-weekend gaps in sleep timing and duration. Therefore, we tested the associations of self-perceived health with these characteristics in a large sample of university students. The results of regression analyses suggested significance of the association of weekday sleep deficiency with lowered self-perceived health. Moreover, they indicated that the negative health effects of reduced weekday sleep were not overlapping with negative effects of several other sleep-wake characteristics of study participants, such as a lower nighttime sleepability and a lower daytime wakeability. Finally, the results suggested that the correlation of weekday sleep insufficiency with late chronotype and large weekday-weekend gaps in sleep timing and duration can explain their association with self-rated health.

It is not easy to compare the results on the association of self-rated health with weekday sleep insufficiency obtained in the present survey with the literature results due to the difference between our and previously published reports in the accounted covariates and variables used for assessments of weekday sleep loss. Steptoe et al. (2006) found an association of poorer self-rated health with short sleep duration, but Štefan et al. (2017) reported that not only short sleepers (<7 h) but also long (>10 h) sleepers have lower odds of having good self-rated health after adjusting for such potential covariates as age, gender, physical activity, smoking, alcohol consumption, sedentary behavior, body mass index, and psychological distress. In contrast, Andreasson et al. (2021) demonstrated that poorer self-rated health was associated with long sleep duration only in those individuals who also reported poor sleep quality, while poorer self-rated health in individuals with short sleep duration was largely independent of sleep quality. The present study results confirmed such an association of poorer self-rated health with lower nighttime sleepability, and, additionally, they suggested that this association is independent from the association with weekday sleep insufficiency.

If people tended to sleep a bit less when the social clocks were set earlier relative to the sun clocks, the detrimental health impacts of such relatively small reduction of sleep duration, e.g. approximately 20-min, were detectable (Giuntella and Mazzonna 2019; Gu et al. 2017; VoPham et al. 2018). Due to the age-specific features of their sleep-waking mechanisms, adolescents and young adults seem to be most vulnerable to sleep loss after an advancing shift of social clocks relative to the sun clocks (Putilov and Verevkin 2018; Putilov et al. 2020). Notably, a model of sleep-wake regulation predicted (Putilov, 1995; Putilov and Verevkin 2018) and simulations of empirical data confirmed (Putilov 2022, 2023; Putilov et al. 2022a) that, despite complete freedom to sleep in and nap during the two weekend days, the reduction in sleep during the week cannot be reversed by the extension of weekend sleep beyond its normal, adequate duration. In other words, the negative effects of skimping on sleep during the week cannot be reversed by the attempts to extend weekend sleep (Putilov 2022, 2023; Putilov et al. 2022a). Given that our work/study culture biased towards the circadian clocks of morning types, the irrecoverable loss of weekday sleep is usually larger in evening than morning types (Putilov et al. 2020, 2022a). Therefore, a larger deadweight sleep loss on weekdays in evening types might be one of the most common reasons for their lower odds of having good self-rated health.

In practical terms, the survey results suggested a potential influence of insufficient weekday sleep on health. Given the necessity to consider adequate sleep duration as one of the significant contributors to good health, it is of practical importance to consider the minimization of weekday sleep losses among other interventions designed to prevent and reduce problems with sleep and health in students.

Several limitations of the present study require acknowledgment. A list of analyzed covariates is far from being comprehensive. Possible influence of environmental, socio-economic, psychological, and cultural factors on health and sleep was not accounted for. For instance, self-perceived health was found to be strongly associated with socio-economic status. The studies consistently demonstrated that low self-perceived health and problems with sleep were strongly associated with low socio-economic status (Moore et al. 2002; Papadopoulos and Etindele Sosso 2023; Seo et al.

2017). Therefore, somewhat different results might be obtained after adding variables representing these factors in the regression analysis. Although it is important to recognize this limitation, our aim was not to evaluate the influence of environmental, socio-economic, psychological, and cultural factors on health self-ratings. Their potential health impacts do not seem to be critical for the achievement of the main goal of this study, i.e. to determine which of the various characteristics of the sleep-wake cycle can and cannot be associated with perceived health issues.

We also did not perform objective measurements of sleep time and quality, levels of alertness-sleepiness, physical and mental activity, etc. The advantage of the survey was its simplicity and swiftness that allow a relatively rapid collection of a large sample of data from university students who were ready to agree to voluntarily respond to the questions about their health and sleep-wake characteristics but were not ready to devote more efforts and time (at least, 1 week) on objective measurements of their sleep-wake cycles on weekdays and weekends. This can be, on the other hand, mentioned among the limitations of this study. Moreover, the most popular English-language morning-evening preference scales (e.g. [34]) were not administered to Russian university students. Therefore, future studies are required to support the present results and to confirm the association of health with weekday sleep duration using objective measurements, other chronobiological questionnaires, and a larger list of various confounding variables.

Conclusions

We found that the negative health impacts of the deadweight weekday losses in sleep might be self-perceived by university students. This effect did not overlap with other adverse effects of individual sleep-wake characteristics including poor nighttime sleepability and low daytime wakeability. A larger sleep loss after waking up earlier on weekdays can be an explanation of the association of poorer self-reported health with late chronotype and the enlarged weekday-weekend gaps in sleep timing and duration. It is of practical importance to consider the reduction of weekday sleep losses among the interventions aimed at prevention and treatment of problems with sleep and health in students.

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Author contributions

Conceptualization AAP; Funding acquisition AAP, DSS, and VBD; Data curation DSS, ZVB, ENY, YPS, VIT, EAT, MML, ZNL, EOG, and NVL, Resources AAP, DSS, and VBD; Project administration AAP, DSS, and VBD; Supervision AAP and VBD; Software AAP, DSS, and AAP; Investigation AAP, DSS, and ANP; Methodology AAP, DSS, and ANP; Validation AAP; Visualization AAP and DSS; Writing – review & editing AAP, DSS; DSS, ZVB, ENY, YPS, VIT, EAT, MML, ZNL, EOG, ANP, and VBD.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Availability of data and material

The survey dataset is available on reasonable request to the corresponding author.

Ethical approval

All procedures performed in this survey of human participants were in accordance with the ethical standards of the 2022b Helsinki Declaration and its later amendments and in accordance with the ethical standards of the institutional research committee (the Ethics Committees of the Institute of Higher Nervous Activity and Neurophysiology approved the experimental protocol in June 2019, Approval#12402-02-7112).

Informed consent statement

Informed consent was obtained from each of the study participants in the form of response "Yes" to the question of the survey saying "I give informed consent to voluntarily participate in this online survey of sleep-wake behavior and habits" (see the method section).

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