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Differences between male and female university students in sleepiness, weekday sleep loss, and weekend sleep duration

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ABSTRACT

Introduction: Women and men experience sleep differently and the difference in intrinsic desire for sleep might underlie some of the observed male-female differences. The objective of this cross-sectional questionnaire study of university students was to determine male-female differences in self-reported sleepiness and sleep-wake patterns.
Methods: Five questionnaires were completed by 1650 students at four Russian universities.
Results: Compared to male students, female students reported a lower subjective sleep quality score, had a higher morning sleepability score and lower nighttime and daytime wakeability scores. They more often reported excessive daytime sleepiness and expected to be sleepier at any time of the day with the largest male-female difference around the times of sleep onset and offset. On free days, they reported a longer sleep duration and an earlier sleep onset. Free-weekday difference was larger for sleep duration and smaller for sleep onset. Such male-female differences showed similarity to the differences observed in university and high school students from different countries around the globe. There was no significant male-female difference in weekly averaged sleep duration, weekday sleep duration, hours slept, midpoint of sleep on free days, free-weekday difference in sleep offset, social jetlag, and morningness-eveningness score. Therefore, when studies rely on these self-reports, the most salient male-female differences might not be immediately evident.
Conclusions: It seems that the intrinsic desire for longer sleep duration might contribute to a higher susceptibility of female students to weekday sleep loss. Among these students, negative effects of reduced sleep duration might be more common and more detrimental.

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1. Introduction

Young adults and late adolescents are often forced to wake up early in the morning on weekdays to attend university/college/school. They do not fully compensate such earlier wakeups by the proportionally similar shift of bedtimes on early hour. Therefore, they don't get sufficient amount of sleep at weekday nights. The comparison of weekday and weekend sleep times suggested that people at this age are mostly late risers and they usually lose a much larger fraction of their sleep on weekdays than people of younger and older ages (Crowley et al., 2018; Gradisar et al., 2011; Liu et al., 2008; Putilov et al., 2020; Putilov & Verevkin, 2018; Short et al., 2013; Thorleifsdottir et al., 2002; Urner et al., 2009). It remains to be explored whether female adolescents and young adults suffer more than male adolescents and young adults from such earlier weekday wakeups.

In overall, women's sleep differs from men's sleep in many respects. Consistent across the studies are the findings indicating that, compared to men, women have better objective sleep quality, i.e., a shorter sleep-onset latency and a better sleep efficiency, a larger amount of deep sleep, a longer total sleep time and a smaller amount of total wake time. Despite this, women report more subjective complaints of non-refreshing sleep and a greater need for sleep than men (e.g., reviewed by Mallampalli & Carter, 2014; Mehta et al., 2015; Mong & Cusmano, 2016). Moreover, women report a higher level of daytime sleepiness (e.g., Concepcion et al., 2014; de Souza et al., 2017; Tran et al., 2014) and they more frequently than men report excessive daytime sleepiness (Doi & Minowa, 2003; Larsson et al., 2003; Meyer et al., 2019; Ohayon et al., 2013). However, such reports were not supported by the studies applying the Multiple Sleep Latency Test. These studies suggested that the gender difference in subjective sleepiness is not always reflected in objective sleepiness measurements, e.g., in such sleep propensity measure as mean latency to sleep onset (e.g., Chervin & Aldrich, 1999; Ye et al., 2009). Women might report their sleepiness differently, e.g., they might tend to emphasize fatigue, tiredness, or lack of energy more than sleepiness (Baldwin et al., 2004; Chervin, 2000). On the other hand, latency to sleep onset reflects the strength of wake drive, while the difference in self-assessed daytime sleepiness might be related to another objective marker representing the sleep drive (Dorokhov et al., 2021).

Lindberg et al. (1997) showed the association of female gender with a greater difference between needed and actually obtained sleep (despite a longer reported total sleep duration). When the abilities to wake and sleep at different times of the day were compared in 3402 males and 4063 females using the Sleep-Wake Pattern Assessment Questionnaire (SWPAQ), female gender was associated with a lower wakeability both in the morning and in the evening, i.e., with a higher score on Morning Lateness scale but a lower score on Evening Lateness scale (Putilov et al., 2008). Since gender gap in self-reported mean sleep duration was not found, women were concluded to desire but not actually obtain more sleep than men (Putilov et al., 2008). This conclusion was simultaneously supported by the results of Tonetti et al. (2008) showing that, across most of ages, females reported a longer ideal sleep duration than males as indicated by responses to the open questions of the Morningness-Eveningness Questionnaire (MEQ) asking about preferred bed- and risetimes (Horne & Östberg 1976).

Experimentally documented larger fraction of sleep in free-running condition (Wever, 1984a,b) might be a plausible explanation for women's higher desire for sleep, lateness in the morning, and earliness in the evening. Wever (1984a,b) reported that, when the sleep-wake cycle remains synchronized with the body temperature rhythm in a "free-running protocol" (self-selected light-dark and wake-sleep cycle), the fraction of sleep is larger by 18% and the sleep-wake cycle is shorter by 28 min in women than men. Such experimental findings allow the suggestion that the negative effects of sleep reduction might be more common and more detrimental among women, and, therefore, it is necessary to suggest tailoring treatments based on their individual weekday sleep loses.

However, the fundamental biological differences might not be clear evident in real-life condition due to the mentioned above influence of the psychological difference in subjective perception of sleep and sleepiness as well as due to the influence of differences in social, cultural and environmental determinants of women's and men's sleep. For instance, although in overall and at most life course stages, women slept more than men, much of the gap was explained by gendered time tradeoffs and work and family responsibilities (Burgard & Ailshire, 2013). Therefore, it remains to be clarified whether, despite the evident psycho-sociological differences between genders, the underlying biological differences between men and women can underlie the differences in everyday sleepiness levels and sleep timing.

In the present study, we applied a larger set of different questionnaires for testing whether, in real-life condition, women's sleep-wake pattern and sleepiness levels would be interpreted as reflecting their intrinsic desire of getting a longer sleep compared to men and whether they fail to actually obtain a higher amount of sleep compared to men. Male and female university students were invited to participate in this cross-sectional questionnaire study because they represent a group of young adults at the same life course stage and with a relatively small gender gap in social, cultural and environmental determinants of sleep. They also represent the age group that, compared to younger and older age groups, suffers most from weekday reduction of sleep due to early morning awakenings, and, therefore, a disproportion between desired and actually obtained sleep might be easier detected in this particular age group.

Consequently, the objective of this cross-sectional questionnaire study was to evaluate the female-male differences in self-reported sleepiness and sleep-wake patterns in a larges sample of university students with minimal gendered time tradeoffs and relatively small gender gaps in social, cultural and environmental determinants of sleep. We hypothesized significant difference between these young men and women in self-reported characteristics of sleepiness and sleep pattern. In the light of the other findings, such a difference might be interpreted as reflecting the difference in intrinsic desire for sleep.

2. Materials and methods

2.1. Sample and procedure

Students attending physiology/psychophysiology classes at four Russian universities were invited by the lectures to voluntarily participate in this survey by responding from their smartphones to the questions about their sleep and sleepiness. To collect their responses, the web page of this study was designed (https://docs.google.com/forms/d/e/1FAIpQLSdIEeg00XFqmoULmKjXMqGI9rtMwpPD4HVwv5ZqYtH-BDMd3A/viewform). Demographic information on the whole sample and on subsamples from four universities is reported in Table 1.

The study was approved by the ethics committees of each of the universities and was performed in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

2.2. The list of five questionnaires

The questionnaires (Tables 2–4 and Figs. 1–3) were designed for self-assessments of sleep timing and quality, sleep- and wake-abilities, and sleepiness. Each participant completed: 1) the Munich ChronoType Questionnaire (MCTQ) for separate self-reporting times of sleep onset and offset on free and weekdays (Roenneberg et al., 2003), 2) the Pittsburgh Sleep Quality Index (PSQI) that includes the self-assessments of hours slept, subjective sleep efficiency, and subjective sleep quality (Buysse et al., 1989), 3) the reduced (50-item) version of Sleep-Wake Adaptability Test (SWAT) for self-assessing abilities to sleep or wake on demand at different times of the day (Putilov, 2016; Putilov et al., 2021), 4) the 8-item Epworth Sleepiness Scale (ESS) for reporting excessive daytime sleepiness (Johns, 1991), and 5) the visuo-verbal judgment task (VJT) for rating levels of sleepiness expected for different clock times on the 1.5-day interval of permanent wakefulness (Marcoen et al., 2015; Putilov et al., 2021).

2.3. Assessments: sleep timing and quality

The MCTQ (Roenneberg et al., 2003) was used to collect self-reports on sleep onset (bedtime + sleep latency) and sleep offset on weekdays and free days. Additional calculations provided such estimates as sleep duration (i.e., sleep offset-onset difference) and midpoint of sleep on these days (sleep onset plus a half of sleep duration), as well as the free-weekday differences in these sleep times. Previously we demonstrated that, after averaging over many samples, such self-reported sleep times are almost identical to the times predicted by a sleep-wake regulation model (Putilov & Verevkin, 2018; Putilov et al., 2020). The results of these simulations suggested a possibility to estimate weekday sleep loss from data on weekday and weekend sleep times. This estimate can serve as an indicator of the degree of reduction in sleep duration due to early wakeups on weekdays (Putilov et al., 2020).

Additionally, the responses to several questions (1–4 and 9) of the PSQI (Buysse et al., 1989) provided the estimates of sleep efficiency, subjective sleep quality score, and hours slept for the previous month.

2.4. Assessments: sleepabilities and wakeabilities

The 168-item SWAT (Putilov, 2016) was designed for testing the predictions of a three-dimensional model of individual variation in sleep-wake adaptability. It includes abilities to sleep or wake on demands at different times of the day (e.g., in the morning, in the afternoon, and in the evening and at night). Unlike chronobiological questionnaires for the assessment of either a trait-like or a state-like individual variation (e.g., either the MEQ or the MCTQ, respectively), the SWAT and SWPAQ assess an ability-like individual variation (see Putilov, 2017). For implicating the SWAT into the questionnaire surveys (Putilov et al., 2021), the questionnaire was reduced to 50 items by merging two closely inter-correlated scales (Nighttime and Evening Wakeability scales) and by excluding the items with relatively low item-scale correlations in accord with the result of the analysis of the previously collected samples of school and university students (n = 1048). In the sample of 1650 university students of the present study, Cronbach's Alphas were 0.817,

Table 1
Ages of male and female university students.

	University	Peoples'		Pirogov		Ryazan		Surgut		Whole sample	
	Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
n		213	413	75	239	131	353	68	158	487	1163
Age, years	≤19	155	301	59	186	97	271	27	69	338	827
	>19	58	112	16	53	34	82	41	89	149	336
	Mean	19.1	19.0	19.2	19.2	19.2	19.2	20.3	20.2	19.3	19.3
	SD	1.5	1.5	0.9	1.0	1.3	1.2	1.6	1.6	1.4	1.4

Notes. Peoples', Pirogov, Ryazan, and Surgut: Four Russian university subsamples from Medical Institute of the Peoples' Friendship University of Russia, Moscow, Pirogov's Russian National Research Medical University, Moscow, Ryazan State Medical University, Ryazan, and Medical Institute of the of Surgut State University, Surgut. Whole sample: Total number of survey participants (*n*) in two (male and female) subsamples; Age, years: Age characteristics of survey participants; ≤19 and > 19: Adolescence and youth age categories, respectively; Mean and SD: Subsample-averaged age and its Standard Deviation.

Table 2
Significance of main effect of fixed factor “Gender” in three MANOVAs.

Dependent Variable	MANOVA	One-way		Two-way		Three-way		#
		$F_{1,1647}$	*p*	$F_{1,1646}$	*p*	$F_{3,1634}$	*p*	
MCTQ:	weekday	0.063	0.803	0.023	0.878	0.000	0.986	1a
Sleep Onset, h	free day	15.81	<0.001	11.07	0.001	10.56	0.001	
Sleep	weekday	13.32	<0.001	7.947	0.005	0.567	0.451	1b
Offset, h	free day	0.234	0.628	0.605	0.437	0.939	0.333	
Sleep	Weekday	5.919	0.015	3.364	0.067	0.191	0.662	1c
Duration, h	free day	20.28	<0.001	17.52	<0.001	17.10	<0.001	
Free-weekday	for Sleep Onset	16.18	<0.001	11.03	0.001	9.619	0.002	1d
difference, h	for Sleep Offset	6.207	0.013	5.314	0.021	1.771	0.183	
	for Sleep Duration	29.96	<0.001	22.53	<0.001	12.81	<0.001	
Weekly sleep estimates	Weekly Sleep Duration, h	0.379	0.538	0.038	0.845	1.040	0.308	2a
	Sleep loss, %	26.66	<0.001	19.17	<0.001	9.518	0.002	
MidPoint of sleep, h	free day	2.564	0.110	1.590	0.207	1.983	0.159	2b
	free-weekday difference	4.148	0.042	2.175	0.140	1.409	0.235	
	Weekday	0.944	0.331	0.401	0.527	0.149	0.700	2c
PSQI	Sleep %	2.350	0.126	1.560	0.212	0.000	0.994	
	Subjective Sleep Quality score	26.14	<0.001	21.81	<0.001	10.81	0.001	2d
	Hours slept, h	0.019	0.891	0.219	0.640	0.233	0.629	
SWAT’s scale score	Morning Sleepability	74.92	<0.001	74.56	<0.001	47.96	<0.001	1e
	Nighttime Wakeability	46.42	<0.001	35.87	<0.001	34.14	<0.001	
	and sum of these two scores	2.511	0.113	4.355	0.037	1.043	0.307	
	Daytime Wakeability	105.0	<0.001	86.75	<0.001	66.25	<0.001	1f
	Daytime Sleepability	0.001	0.982	0.019	0.89	0.000	0.994	
	Daytime Sleepability	2.822	0.093	1.276	0.259	1.376	0.241	
	Epworth Sleepiness Scale score	17.60	<0.001	18.51	<0.001	17.96	<0.001	2e
Karolinska Sleepiness Scale (KSS)	Mean score (19 clock times)	115.4	<0.001	98.70	<0.001	101.1	<0.001	
	Score at 08:00	35.51	<0.001	38.63	<0.001	29.80	<0.001	1g
	Score at 11:00	4.706	0.030	4.413	0.036	9.544	0.002	
	Score at 02:00	56.40	<0.001	47.80	<0.001	45.34	<0.001	
	Score at 09:00	10.33	0.001	12.55	<0.001	13.63	<0.001	–
	Score at 10:00	8.527	0.004	5.369	0.021	10.83	0.001	
	Score at 12:00	14.18	<0.001	10.11	0.002	15.19	<0.001	

Notes. *F* and *p*: F-ratio with degree of freedom and level of significance (*p*) for main effect of fixed factor “Gender” in the results of MANOVAs. In One-, Two- and Three-way MANOVAs, age was the covariate (in years), the 2nd and the 3rd fixed factor (ages either ≤19 or >19 years, see Table 1), respectively. Three-way MANOVA included additional fixed factor “University” (four Russian universities, Peoples’, Pirogov, Ryazan, and Surgut, see Table 1 for their full names); h: Decimal hours or decimal clock hours; #: Results on each of subsamples are illustrated in Figs. #1 and #2. See also the confirmation of the significance of these F-ratios by results of further analysis reported in Table 3.

0.733, 0.769, 0.767, and 0.733 for 5 10-item scales named Morning Sleepability (MS), Nighttime Wakeability (NW), Daytime Wakeability (DW), Daytime Sleepability (DS), and Nighttime Sleepability (NS), respectively. A negative score on each scale indicates inability to sleep/wake on demand in the morning (MS), in the afternoon (DS/DW), and in the evening and at night (NS/NW, respectively).

2.5. Assessments: sleepiness

The ESS (Johns, 1991) was used in many somnological and chronobiological studies to quickly determine excessive daytime sleepiness. The scale scores subjective sleepiness defined as the propensity to fall asleep in 8 different daily life situations. When a score calculated by summing the responses to its 8 items is above 10, it indicates mild excessive daytime sleepiness (Johns, 1991). In the whole sample of the present study, Cronbach’s Alpha attained the value of 0.697.

The 19-time point VJT (Marcoen et al., 2015) evaluates how sleepy a survey participant thought to be at different randomly presented times after having habitual night sleep terminated at approximately 7:30. The time cues from 8 a.m. to midday and from 8 p.m. to midnight are presented with 1-h intervals, while time cues between midday and 8 p.m. and after midnight are presented with 2-h intervals (19 clock times in total). The proposed setting further evoked a pictured sleepiness-neutral situation (i.e. “sitting and reading”), and the participants would see on the screen a visual aid. It consists of clock times along the scale illustrating the daily variation in the outdoor illumination level and indicating the duration of the waking period (for the illustrations and other details see Marcoen et al., 2015).

To ask about sleepiness level, we utilized in this survey the Karolinska Sleepiness Scale (Åkerstedt & Gillberg, 1981). In this version of the VJT, the KSS is verbally anchored Likert scale with 10 levels of alertness-sleepiness: 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. The randomly collected KSS scores (https://docs.google.com/forms/d/e/1FAIpQLSdIEeg00XFqmoULmKjXMqGI9rtMwpPD4HVwv5ZqYtH-BDMd3A/viewform) were then subsequently ordered for constructing the anticipated sleepiness curve consisting of 19 time points.

Table 3
Confirmation of significance of male-female difference with Student's t-test.

Dependent variable	Mean values with SD						Statistical tests				#
	Difference		Male		Female		Levene's test		Student's test		
	Mean	SEM	Mean	SD	Mean	SD	F	p	t_{1648}	p	
MCTQ: Sleep Onset, free day, h	0.39	0.10	1.52	1.99	1.12	1.77	9.336	0.002	3.778	<0.001	1a
and free-weekday difference, h	0.41	0.10	1.02	2.03	0.61	1.86	0.193	0.661	4.016	<0.001	1d
Sleep Offset, weekday, h	0.21	0.06	6.81	1.27	6.60	1.00	5.849	0.016	3.319	0.001	1b
Sleep Duration, free day, h	−0.43	0.10	8.86	1.89	9.29	1.72	4.711	0.030	−4.35	<0.001	1c
and free-weekday difference, h	−0.68	0.12	2.54	2.32	3.22	2.26	0.123	0.726	−5.49	<0.001	1d
Sleep loss, %	−6.24	1.20	26.6	24.1	32.8	21.5	3.747	0.053	−5.181	<0.001	2a
MidPoint of sleep, free day, h	0.18	0.09	5.95	1.83	5.77	1.55	13.03	<0.001	1.869	0.062	2b
PSQI: Subjective Sleep Quality score	0.21	0.04	1.87	0.78	1.65	0.77	10.28	0.001	5.103	<0.001	2d
SWAT: Morning Sleepability score	−2.45	0.28	0.78	5.43	3.23	5.16	3.697	0.055	−8.66	<0.001	1e
Nighttime Wakeability score	1.77	0.26	0.39	4.66	−1.38	4.89	2.563	0.110	6.81	<0.001	
Daytime Wakeability score	2.73	0.27	2.79	4.84	0.06	4.97	0.121	0.728	10.25	<0.001	1f
Epworth Sleepiness Scale score	−0.91	0.22	8.21	4.12	9.12	3.94	1.655	0.199	−4.201	<0.001	2e
Mean KSS score	−0.67	0.06	5.10	1.24	5.76	1.11	6.141	0.013	−10.28	<0.001	
Score at 08:00	−0.75	0.13	5.08	2.42	5.82	2.26	5.526	0.019	−5.807	<0.001	1g
Score at 11:00	−0.23	0.11	3.51	1.99	3.74	2.00	0.195	0.659	−2.173	0.030	
Score at 02:00	−0.93	0.13	6.39	2.43	7.31	2.22	11.47	0.001	−7.243	<0.001	

Notes. A variable showing significant main effect of "Gender" in the results of MANOVAs (Table 2), was included in this table with results of applying *t*-test and results of averaging within male and female subsamples; Mean and SD or SEM: Sample- or subsample-averaged estimate with Standard Error of Mean or Standard Deviation, respectively; h: Decimal hours or decimal clock hours. Levene's test: Degree of freedom for *t*-test was corrected when the null hypothesis that the variances for male and female are equal was rejected; #: See results on each of four university subsamples in Figs. #1 and #2.

Table 4
Male-female difference in sleep times on free days and in free-weekday differences.

Three sets of sleep times	This study, $n = 8$				12 studies, $n = 12$				Gariepy et al., $n = 20$				#
	Difference		Student's test		Difference		Student's test		Difference		Student's test		
Sleep time	Mean	SEM	t_7	p	Mean	SEM	t_{11}	p	Mean	SEM	t_{19}	p	
Free days:													
Sleep Onset, h	0.39	0.13	2.94	0.022	0.43	0.09	4.99	<0.001	0.23	0.02	9.33	<0.001	3a
Sleep Midpoint, h	0.15	0.12	1.26	0.247	0.24	0.07	3.39	0.006	0.08	0.03	2.83	0.011	3b
Sleep Offset, h	−0.12	0.13	−0.91	0.393	0.05	0.08	0.57	0.578	−0.08	0.04	−2.26	0.035	3c
Sleep Duration, h	−0.48	0.13	−3.71	0.008	−0.39	0.09	−4.28	0.001	−0.32	0.03	−9.82	<0.001	3d
Free-weekday difference:													
Sleep Onset, h	0.39	0.10	4.06	0.005	0.20	0.06	3.30	0.007	0.16	0.02	8.45	<0.001	3a
Sleep Midpoint, h	0.12	0.11	1.14	0.294	0.03	0.06	0.56	0.587	0.00	0.02	−0.17	0.868	3b
Sleep Offset, h	−0.17	0.12	−1.48	0.183	−0.13	0.09	−1.45	0.175	−0.18	0.03	−5.12	<0.001	3c
Sleep Duration, h	−0.54	0.10	−5.61	0.001	−0.41	0.35	−1.15	0.275	−0.35	0.03	−11.3	<0.001	3d
Weekly Sleep Duration	−0.10	0.11	−0.89	0.403	−0.15	0.06	−2.78	0.018	−0.06	0.02	−4.15	0.001	

Notes. Difference: Mean difference between male and female subsamples. Either t_7 or t_{11} or t_{19} and p in paired Student's test: t-statistic and level of significance for pairwise comparisons of mean sleep times for either a set of 8 subsamples of this study or a set of 12 samples from 12 studies of high school/university students or a set of 20 samples from the study of Gariepy et al., 2020. See Supplementary Table in Appendixes A and B for sleep times in each of 8 subsamples of university students from Peoples', Pirogov, Ryazan, Surgut universities with ages either ≤19 or >19 years, in each of 12 published samples of university or high school students with mean ages between 16 and 22 years from Lithuania, Finland, Norway, Italy, Croatia, Lebanon, Korea, Taiwan, Australia, Canada, USA, and Brazil, and in each of 20 samples of younger students from European and North American countries (mean age 13.5 years) from the study of Gariepy et al. (2020); #: see Fig. #3 for the results on each of 8 subsamples and for the results obtained by averaging within each of the sets (over 8 subsamples, over 12 samples from 12 studies, and over 20 samples from different countries of the study of Gariepy et al., 2020).

In the whole sample, Cronbach's Alpha attained the value of 0.856 for a set of 19 KSS scores. Recently, the 50-item SWAT and 19-item VJT were cross-validated and validated against several other self-assessments, including the MCTQ and the ESS (Putilov et al., 2021).

2.6. Statistical analyses

The $SPSS_{23.0}$ statistical software package (IBM, Armonk, NY, USA) was used for all statistical analyses. First, MANOVAs (Table 2) with the fixed factor "Gender" (male vs. female) were applied for testing significance of the main effect of "Gender". In one-way MANOVA, age was the covariate. In two- and three-way MANOVAs, additional fixed factors were "Age" (ages either ≤19 or >19 years, see Table 1) and "University" (four Russian universities, Peoples', Pirogov, Ryazan, and Surgut, see Table 1 for their full names). To confirm those of results that suggested the statistically significant difference between male and female students (Table 2), the

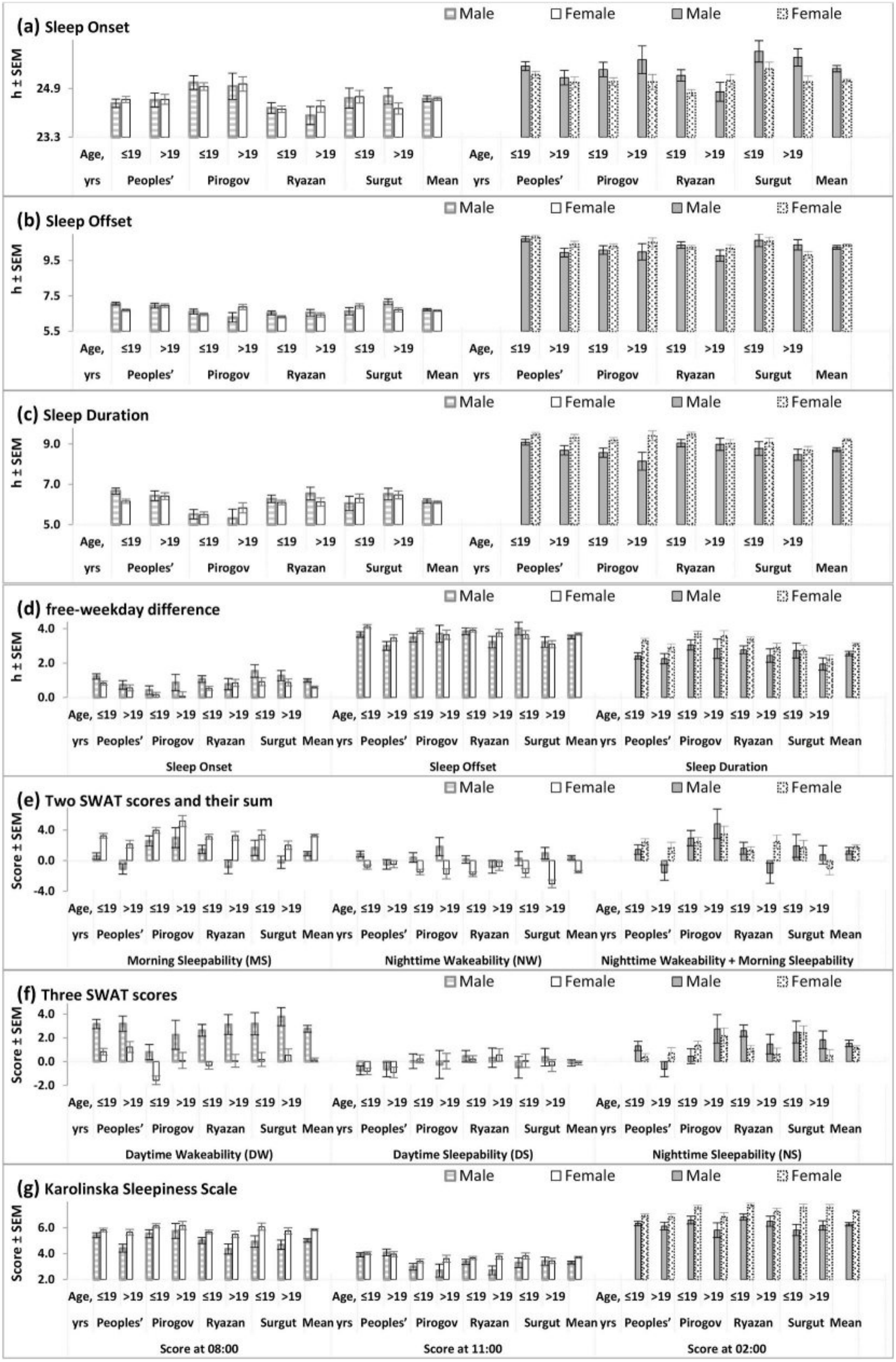

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Fig. 1. Values averaged either over each of 8 subsamples or over the whole sample. (a, b, c, and d) Sleep Onsets, Sleep Offsets, Sleep Durations for weekdays and free days and free-weekday differences for them from the answers to questions of the MCTQ; (e and f) Each score on 5 10-item scales of the SWAT varies from −10 to 10 with positive or negative score indicating the presence or lack of ability to sleep or wake on demand at certain time of the day. Additionally, scores on MS and NW scales were summarized; (g) Karolinska Sleepiness Scale score (varies from 1 to 10) was expected at certain clock hour (the VJT). SEM: Standard Error of Mean; h: Decimal hours or clock hours. See Tables 2 and 3 level of significance for male-female difference.

significance of each of such differences was additionally checked by applying the independent Student t-test to the whole dataset (Table 3).

To demonstrate generalizability of some of the results (i.e., on sleep times), we applied paired Student's t-tests to 1) the estimates obtained for 8 subsamples of male and female university students of our study (ages of students at four universities either ≤19 or >19 years, see Tables 1) and 2) the estimates obtained for 12 samples of male and female university or high school students from 12 different countries (Lithuania, Finland, Norway, Italy, Croatia, Lebanon, Korea, Taiwan, Australia, Canada, USA, and Brazil, - all we can find in the existing literature), and 3) the estimates obtained for 20 samples of younger students from different European and North American countries from the publication of Gariepy et al. (2020). The lists of data for this analysis and the list of references of 13 previously published studies can be found in Supplementary Table (Appendixes A and B). The results on the paired Student's tests are reported in Table 4 and illustrated in Fig. 3. Finally, two-way rANOVAs were applied to check significance of interaction of "Gender" with "Set" (8 subsamples of the present study vs. 12 vs. 20 samples from the previous publications).

3. Results

3.1. Difference between male and female subsamples: negative results

For a minority of variables, two- and three-way MANOVAs failed to reveal significant and consistent over universities and ages differences between male and female students (Table 2). The list of these variables included the self-assessments of weekday sleep duration (Fig. 1c, left), weekly averaged sleep duration (Fig. 2a, left), free-weekday difference in sleep offset (Fig. 1d, middle, and Fig. 3c, right), free-weekday difference in midpoint of sleep that is known as "social jetlag" (Figs. 2b and 3b, right), sleep percentage and hours slept (Fig. 2c and d, right, respectively), ability to sleep on demand, either during the day or at night (Fig. 1f), and such an ability-like measure of morningness-eveningness as the sum of scores on Morning Sleepability and Nighttime Wakeability scales (the combination of two abilities, the ability to sleep/inability to wake up on demand in the morning and the ability to remain awake on demand in the evening and at night; Fig. 1e, right).

Moreover, most of statistical analyses did not suggest significance of male-female difference in such a state-like measure of morningness-eveningness as midpoint of sleep on free days (Fig. 2b, left, Fig. 3b, left, and Tables 2–4). Finally, not all statistical analyses confirmed significance of male-female difference in weekday sleep onset (Fig. 1a, left, and Tables 2 and 3).

3.2. Difference between male and female subsamples: positive results

Male-female difference was found to be significant for the remaining (the vast majority of) variables (mostly with $p < 0.001$) and such a difference demonstrated consistency across four universities, two age categories, and several methods of statistical analyses (Tables 2–4). Namely, compared to male students, female students had a lower subjective sleep quality score (Fig. 2d, left, and Tables 2 and 3). Their score on Morning Sleepability scale was higher and their score on Nighttime and Daytime Wakeability scales was lower. In other words, they were neither more morning-oriented in the morning nor more evening-oriented in the evening/at night compared to male students (Fig. 1e, left and middle, Fig. 1f, left, and Tables 2 and 3).

They scored higher on such a trait-like measure of sleepiness on the ESS (Fig. 2e, left, and Tables 2 and 3), the result suggesting that female students suffered from excessive daytime sleepiness more frequently than male students. The female students also scored higher on such a state-like measure of sleepiness as KSS score in VJT, both on average and at any of 19 clock times (Figs. 1g and 2e, right, and Tables 2 and 3). The largest male-female difference in KSS score was noted for clock times around sleep onset and offset, while the lowest but still significant difference was found for the late morning hours (Fig. 1g and Tables 2 and 3).

As compared to male students (Tables 2 and 3), female students had 1) a longer sleep duration and 2) an earlier sleep onset on free days (Fig. 2c, middle, and 2a, right), 3) a larger free-weekday difference in sleep duration and 4) a smaller free-weekday difference in sleep onset (Fig. 2d, right and left, respectively). The sample-averaged male-female differences were 1) +26, 2) −23, 3) +41, and 4) −25 min, respectively (Table 3).

3.3. Confirmation in analyses of previously reported sleep times

Very similar results were provided by the analyses of sleep times from 12 previously published reports on university/high school students (12 samples) and on students of younger age (20 samples). Again, the male-female differences were found to be significant for the free day sleep times and for the free-weekday difference between these times (Table 4 and Fig. 3). The estimates obtained for differences between female and male students from subsamples of our study, and from 12 to 20 samples of the previously published studies were the following: 1) +29, +23, and+19 min for a longer sleep duration on free days, 2) −23, −26, and −14 min for an earlier

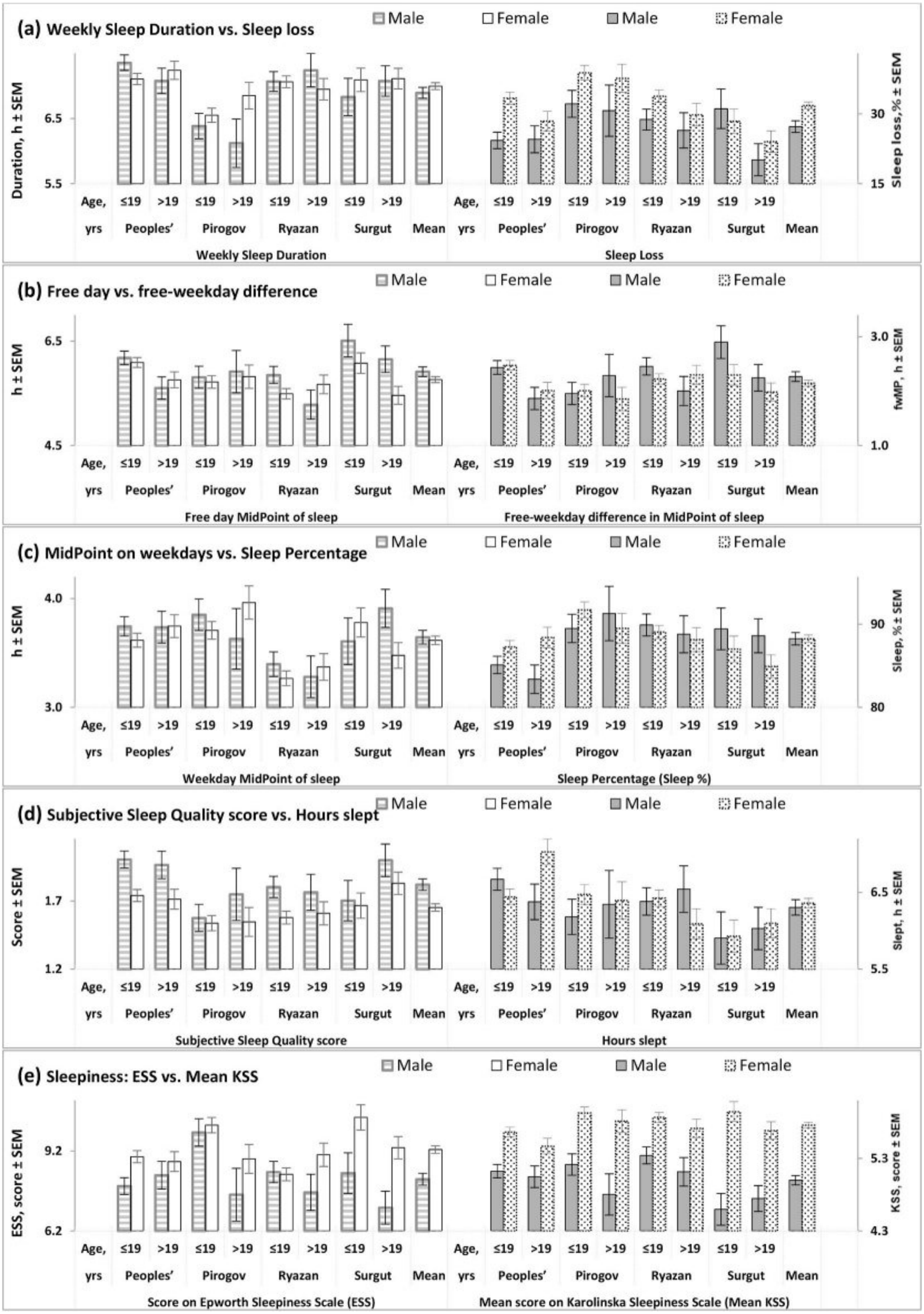

Fig. 2. Paired variables in each of 8 subsamples and in the whole sample. (a) Weekly Sleep Duration vs. Sleep loss, %; (b) MidPoint of sleep on free day and free-weekday difference; (c) MidPoint of sleep on weekdays and Sleep percentage; (d) Subjective Sleep Quality score: Answer to the question 9 of the PSQI with responses ranging from 0 to 3 (0- Very good, 1-Fairly good, 2- Fairly bad, 3-Very bad); Hours slept: Answer to the question 4 of the PSQI; (e) ESS score varies between 0 and 24 with a score above 10 indicating mild excessive daytime sleepiness; Mean KSS score was calculated by averaging over KSS scores expected for 19 different clock times, from 8:00 to 12:00 next day. See Tables 2 and 3 for level of significance of male and female difference.

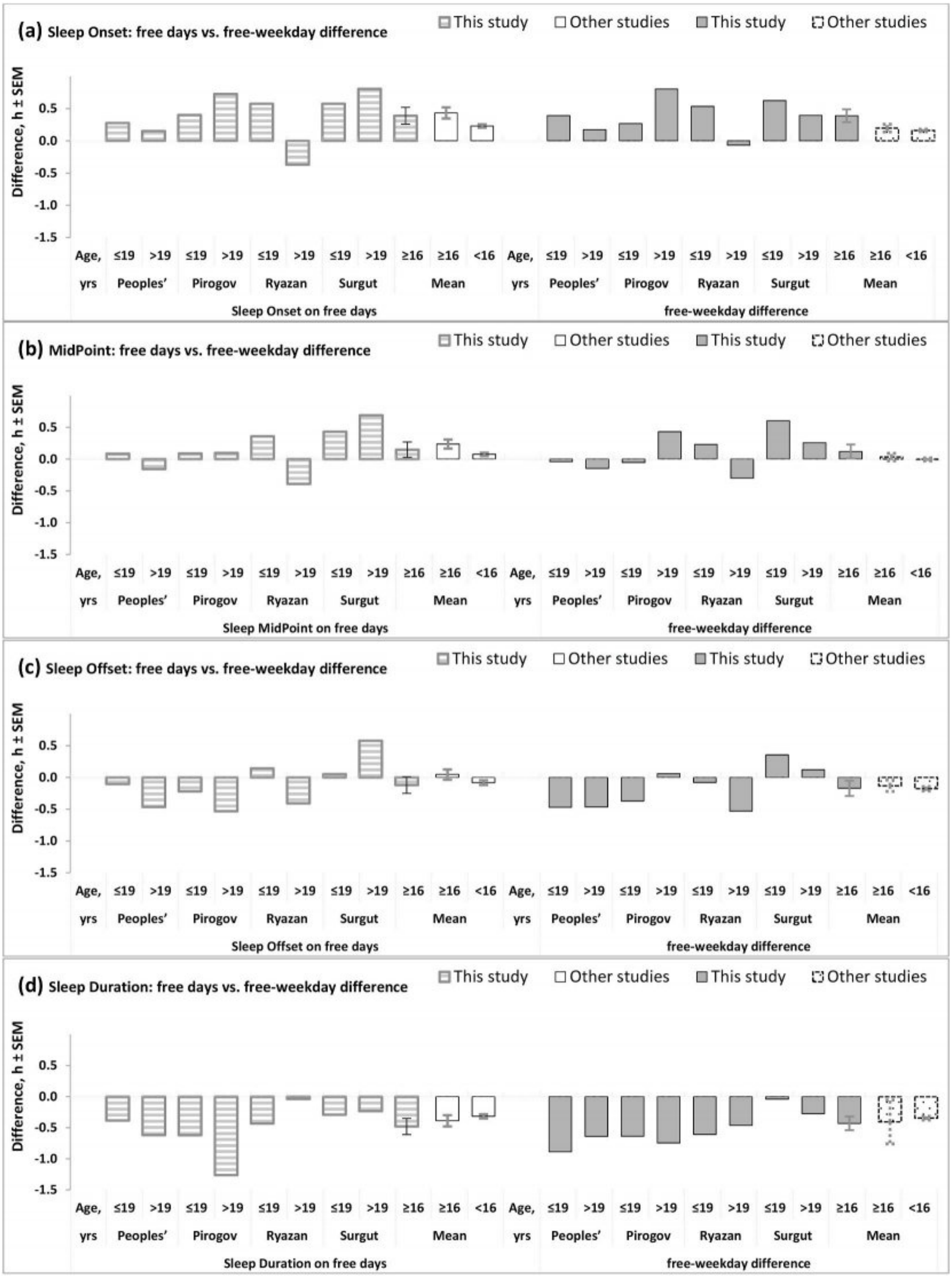

Fig. 3. Male-female difference in sleep times in 8 subsamples, and 12 and 20 other samples.

sleep onset on free days, 3) +32, +25, and +21 min for a larger free-weekday difference in sleep duration, and 4) −23, −12, and −10 min for a smaller free-weekday difference in sleep onset (Table 4 and Fig. 3, and see also the datasets in Supplementary Table).

Two-way rANOVAs of these sleep times did not yield significant interaction between "Gender" (male vs. female) and "Set" (the sets of 8 subsamples of this study vs. 12 samples vs. 20 samples of previously published samples). Thus, the results suggested close similarity of male-female differences revealed among Russian university students with those revealed among students of other countries around the globe.

Importantly, a longer sleep duration on free days resulted in a higher susceptibility of female students to weekday sleep loss (Fig. 2a, right, and Tables 2 and 3).

3.4. Interaction of factor "gender" with other between-subjects factors

One-, two- and three-way MANOVAs failed to reveal significant interaction of factor "Gender" with "Age" as a factor or covariate in the sample of students from 4 Russian universities.

Moreover, three-way MANOVA did not yield significant interaction of "Gender" with additional fixed factor "University" for the vast majority of analyzed variables listed in Table 2. The exceptions were sleepiness scores ($F_{3,1634} = 2.767$, $p = 0.041$ and $F_{3,1634} = 3.774$, $p = 0.01$ for ESS and mean KSS score, respectively) and percentage of sleep ($F_{3,1634} = 3.186$, $p = 0.023$).

4. Discussion

4.1. Positive results

Women and men seem to experience sleep differently and some of the particular differences in men's and women's sleep in real-student-life condition were previously documented (Krishnan, Collop, 2006; Mallampalli & Carter, 2014; Mehta et al., 2015; Mong, Cusmano, 2016). Moreover, solid evidence for fundamental biological differences between men and women was obtained in the experiments with isolation of study participants from external time cues (Wever, 1984 ab). However, it remains explored whether the male-female differences in real-life situations reflect the intrinsic biological differences between men and women in, for instance, biological need for sleep and sleep-wakeabilities before and after sleep. Although in overall and at most life course stages, women slept more than men, much of the difference was explained by work and family responsibilities and gendered time tradeoffs (Burgard & Ailshire, 2013). A study of university students might help in providing evidence for a link of such a difference to the underlying male-female difference in intrinsic sleep desire because 1) these students represent a group of young adults at the same life course stage and with a relatively small gender gap in social, cultural and environmental determinants of sleep, and 2) they represent the age group with most drastic weekday reduction of sleep due to early morning awakenings. The results of the present study suggested that the most salient male-female difference seemed to be manifested in a longer free day sleep duration and a larger free-weekday difference in sleep duration in female students. As a result, female students demonstrated an enlarged susceptibility to weekday sleep loss. Such male-female differences in self-reported sleep times were similar to the differences found for the students from various countries around the globe. Moreover, our findings on such differences in sleep times (assessed with the MCTQ) were supported by the results on subjective sleep quality (assessed with the PSQI), on wake-sleepability (assessed with the SWAT), and on state- and trait-like characteristics of sleepiness (assessed with the ESS and KSS in the VJT, respectively). These results indicated a higher proneness of female students to reporting excessive sleepiness (on the ESS), to anticipating higher sleepiness levels, especially before and after sleep time (on the KSS in VJT), to experiencing a lower wakeability both in the morning and in the evening or at nighttime (on SWAT's scales).

The differences between male and female students remained statistically significant when different methods of statistical analysis were applied to data collected from students of two ages (adolescence and youth) at four different universities. Moreover, the generalizability of the results was additionally demonstrated for sleep times by the comparison of our results with the results on the samples (32 in total) from the existing literature, including the results on samples of younger students representing 19 European and North American countries. In overall, the present results supported our expectation that the patterns of sleep and sleepiness in female students reflect the experiencing a longer sleep desire and suffering from reduction of weekday sleep. This was, in particular, evident from their longer sleep duration on free days, greater free-weekday difference in sleep duration, and lower wakeability/higher sleepiness both before and after sleep.

4.2. Interpretation of positive results

The study results on male-female difference in some of self-reported characteristics of sleep and sleepiness might be interpreted as reflecting the difference in intrinsic desire for sleep. Any significant male-female difference might be explained in the light of the major positive finding suggesting the difference in free day sleep duration that, in turn, led to the difference in weekday sleep loss. Namely, a higher level of sleepiness in female students might be a consequence of insufficient duration of weekday sleep. Moreover, such insufficient sleep might be a cause of a lower subjective sleep quality scoring. Importantly, the male-female difference revealed as a higher KSS score in female students cannot be regarded as reflecting just a state-like difference originating from the necessity to reduce sleep for attending early morning class. This was also found to be a trait-like difference (exemplified by a higher ESS score) and an ability-like difference (manifesting in a higher score on the SWAT's scale for assessment of morning sleepability/wakeinability and the lower scores on the scales for assessment of daytime and nighttime wakeabilities). Such state-, trait-, ability-like difference seems to predispose young women to use the opportunities of lengthening sleep duration on free days and vacations.

The results on the SWAT fully confirmed the previously reported results on male-female difference in the scores on Morning and Evening Lateness scales of another questionnaire, the SWPAQ (Putilov et al., 2008). Moreover, these and other results might be interpreted as reflecting a stronger intrinsic desire for sleep in females. They corroborated several previously reported findings, such as a longer ideal sleep duration in females (Tonetti et al., 2008), a greater difference between needed and actually obtained sleep reported by females along with reporting a longer total sleep duration (Lindberg et al., 1997), a relatively small but significant gender gap in total sleep time favoring women that was found both in analysis of big samples in questionnaire studies (Krueger & Friedman, 2009;

Burgard & Ailshire, 2013) and in analysis of objective measurements, e.g. obtained by wrist activity monitoring (Lauderdale et al., 2006) and using home polysomnography (Walsleben et al., 2004). Any of these results seems to be in full agreement with the experimental findings demonstrating the difference between men and women in the fraction of sleep and in the length of self-selected sleep-wake cycle in free-running condition (Wever, 1984 ab). Therefore, in the light of the present and previously reported findings, the observed difference between male and female students in sleepiness and sleep-wake pattern might be linked to the biological difference in intrinsic desire for sleep.

4.3. Negative results and their explanation

More striking were the results suggesting the lack of significant male-female difference in hours slept, percentage of sleep, weekday sleep duration, weekly averaged sleep durations, free-weekday difference in sleep offset, midpoint of sleep on free days, social jetlag (free-weekday difference in midpoint of sleep), and morningness-eveningness score (the sum of scores on Morning Sleepability and Nighttime Wakeability scales). Such negative results supported our expectation that, in the real-student-life condition, it is not easy for young females to satisfy their intrinsic desire for sleep.

Moreover, any of such negative results can be explained from the positive findings of the male-female difference in weekday sleep loss. For instance, a longer free day sleep duration that might reflect a higher sleep desire is expected to contribute (positively) to the male-female difference in weekly averaged sleep duration and to hours slept while a larger reduction of weekday sleep duration due to this higher sleep desire is expected to contribute in the opposite direction (negatively) to this male-female difference in weekly averaged sleep duration and hours slept. A longer free day sleep duration in female students that might reflect a higher sleep desire did not allow the delay of their fee day sleep onset, but, on the other hand, it also did not allow the advance of free day sleep offset. As a result, male-female difference was not clearly documented for midpoint of sleep on free days, social jetlag, and free-weekday difference in sleep offset. Finally, a lower wakeability in the morning was counterbalanced by a lower wakeability in the evening to result in indetectable male-female difference in the summing morningness-eveningness score (a score on Morning Sleepability scale plus a score on Nighttime Wakeability scale).

Therefore, the present results suggested that most salient differences between male and female students would not be immediately evident in a questionnaire study relying on such widely used self-reports on the sleep-wake patterns as weekday sleep duration, weekly or monthly averaged sleep duration, hours slept, midpoint of sleep on free days, free-weekday difference in sleep offset, social jetlag, and morningness-eveningness score. For instance, genders did not differ in mean sleep duration despite the highly replicable over samples and ages result suggesting the lowered morning and evening wakeabilities in female study participants (Putilov et al., 2008). The male-female differences became much clearly evident and much easily interpreted in the light of experimental findings (Wever, 1984a,b) in the present study because the set of applied questionnaire tools provided a possibility of simultaneous analysis of much larger number of self-assessments, e.g., both weekday and weekend sleep times, both sleep amount and quality, both current sleepiness level and wake-sleepabilities, both morning and evening components of morningness-eveningness, etc.

4.4. Implications and limitations of the study

Sleep seems to be of great importance for promoting optimal health and avoiding negative health outcomes. Mounting evidence suggests that a reduced sleep duration is a risk factor across diverse health and functional domains (see, e.g., Lauderdale et al., 2006; Itani et al., 2017, for review). The negative effects of sleep reduction might be more common and more detrimental among young women due to a significantly larger weekday sleep loss. Therefore, the accounting for significantly greater sleep loss on weekdays is necessary for designing preventive measures and interventions purposed on reduction of sleep and health problems. Particularly, it might be recommended for female university students with a large weekday sleep loss and excessive daytime sleepiness to take measures for protecting their natural right to stay somewhat longer in bed in the weekday mornings. In addition, it might be recommended to suggest tailoring treatments based on their individual sleep-wake timing.

There are limitations to our dataset. The major limitation is that it includes only self-reports that may not be accurate. Therefore, we emphasized as significant only those of the obtained positive results that demonstrated replicability over universities, ages, and methods of statistical analyses and that usually showed significance at $p < 0.001$. The profound change in sleep-wake pattern across ages does not allow the generalization of the results to the whole lifespan. Since all participants were Russian university students enrolled in physiology/psychophysiology courses, the present results require confirmation with samples representing university students of other faculties, school and college students, workers and other groups of young adults from different countries around the globe. Finally, the major limitation of our survey is the absence of data allowing the comparison of self-reports of male and female students with objective measures of daily changes in levels of alertness-sleepiness, a circadian phase of the sleep-wake cycle, the polysomnographic indicators of sleep quality, and the actigraphically recorded sleep times on weekdays and weekends.

5. Conclusions

In real-student-life condition, female students reported lower wakeability/higher sleepiness both before and after sleep, a longer sleep duration on free days with a greater free-weekday difference in sleep duration (due to an earlier sleep onset on free days). These results might be interpreted as reflecting intrinsic rather than socially imposed differences between young women and men in the desired amount of sleep and sleep-wakeability before and after sleep onset. Therefore, negative effects of weekday sleep loss might be more common and more detrimental among young women. The designing interventions purposed on reduction of sleep and health problems in university students can take into account their greater sleep loss on weekdays.

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Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.adolescence.2021.02.006.

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