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Time to rethink sleep quality: PSQI scores reflect sleep quality on workdays

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Abstract

The Pittsburgh Sleep Quality Index (PSQI) is the most common measure of sleep quality. Its questions refer to "usual" sleep habits during the last month. Considering how different sleep–wake behavior can be between workdays and work-free days, we hypothesized that sleep quality should show similar differences. We investigated these potential differences in a cross-sectional online study using the original and two adapted versions of the PSQI that replaced "usual" by explicitly referring to sleep on workdays or work-free days. Additionally, we investigated how these scores relate to chronotype and social jetlag assessed by the Munich ChronoType Questionnaire. Participants were recruited online, they had to be older than 18 years, following regular weekly work schedules, and they should not be shift workers. Repeated-measures analysis of variance was used to compare the three different versions of the PSQI (usual, work, and work-free). To find out whether PSQI score differences could be predicted by chronotype and/or social jetlag a mediation analysis was carried out. Workday PSQI scores were similar to the original "usual" scores, two points higher than the PSQI score on work-free days and above the cutoff designating poor sleep quality. PSQI components and time variables also differed between workdays and work-free days. Chronotype correlated with the difference between PSQI scores on workdays and on work-free days, an association mediated by social jetlag. Our results suggest that the original PSQI predominantly reports sleep quality on workdays and that work schedules may affect sleep quality. The mediation of social jetlag on the association of chronotype and PSQI score differences could mean that not chronotype per se, but rather the collision of an individuals' chronotype with fixed work schedules explains the differences between sleep on workdays and work-free days. Understanding how sleep quality differs between workdays and work-free days, how this difference can adequately be assessed through directing participants to focus on their sleep specifically on workdays vs. work-free days, and how circadian factors modulate this difference, is crucial to improve sleep quality.

PSQI, sleep, sleep quality, sleep timing, work-free days, workdays, MCTQ, social jetlag, chronotype

Statement of Significance

About one-third of all studies on sleep quality use the Pittsburgh Sleep Quality Index (PSQI)—a questionnaire asking for "usual" sleep—as a primary tool for assessing subjective sleep quality. Here, we compared two modified versions: one for workdays and one for work-free days, with the original PSQI. Our results show that the original PSQI reflects mainly sleep quality on workdays, and that participants sleep significantly better on work-free days. Additionally, circadian factors influence the differences in PSQI scores from workdays to work-free days. Understanding how sleep quality differs between workdays and work-free days, and how circadian factors modulate this difference, is crucial to adequately assess and, finally, improve sleep quality.

Introduction

The Pittsburgh Sleep Quality Index (PSQI) was developed in 1989 to provide a reliable and standardized measure discriminating “good” from “poor” sleepers with the help of a simple index. The PSQI was also designed to evaluate a range of sleep disturbances that affect sleep quality. It assesses different aspects of sleep quality representing the past month [1] and is currently the most common measure of sleep quality [1, 2]. Since 2007, the number of published studies that mention “Pittsburgh Sleep Quality Index” represents more than a quarter of the number of studies mentioning “sleep quality,” reaching a noteworthy 34.5 per cent in the last year (as assessed in Pubmed, on April 12, 2017).

Although the PSQI correlates significantly with sleep log data and subjective measures like symptoms of insomnia, depression, and anxiety [3–5], its comparisons with objective sleep parameters obtained by polysomnography or wrist actimetry yield heterogeneous results: Spira et al. found only moderate correlations between the PSQI score and actimetric parameters (longer napping, more time spent awake after sleep onset) [6], and Grutsch et al. found that in a patient group lower sleep quality correlates with lower general activity as well as with more time spent asleep (actimetry)—but only in outpatients and not in inpatients [7]; finally, several other studies found no correlations between PSQI scores and objective measures from actimetry and polysomnography (i.e. sleep latency, sleep efficiency, wake after sleep onset, time spent asleep, and time spent in REM sleep) [3, 4, 8].

This inconsistency may reflect the fact that the PSQI addresses *usual* sleep summarized over the course of a month and not a specific night as measured by the objective instruments. Participants might base their responses about usual sleep on either what they do most frequently (i.e. workdays) or on a “weighted average.” Results obtained with the Munich ChronoType Questionnaire (MCTQ) have shown that sleep duration and timing vary substantially between workdays and work-free days [9, 10]. One reason is that more than 80 per cent of the population in Western countries uses an alarm clock on workdays, whereas sleep timing on work-free days (i.e. chronotype) is mainly influenced by the biological clock [11, 12]. This characteristic so-called chronotype is normally distributed and spans from extremely early sleep times to extremely late sleep times [9]. Late chronotypes suffer from early work start times and have to get up way before their internal clock wakes them up. This discrepancy between internal time (defined by chronotype) and external time (defined by work schedules) was coined social jetlag [12, 13] and is associated with a variety of health risks and diseases (smoking and alcohol consumption [13], obesity [12], depressive symptoms [14], and metabolic disorders [15, 16]).

Here, we investigated whether PSQI scores differ between workdays and work-free days, and what the original PSQI (asking for *usual* sleep habits) actually represents. Additionally, we explored whether the original and the day-specific PSQI scores depend on chronotype and/or social jetlag. For this purpose, in a cross-sectional study, participants filled out three online versions of the PSQI: the original version (asking for *usual* sleep-behavior; $PSQI_u$,) and two adapted day-specific versions (asking for sleep-behavior on workdays, $PSQI_W$; and work-free days, $PSQI_f$) as well as the MCTQ. We hypothesize that “usual” sleep quality reflects sleep quality on workdays, and that sleep quality on workdays is worse compared with sleep quality on work-free days. We also hypothesize that a higher difference in sleep quality between workdays and work-free days is associated with a later chronotype and a higher social jetlag.

Methods

Participants

Between June 11 and July 30, 2015, 341 participants took part in our multilingual study (questionnaires were available online in English, German, and Portuguese). One hundred forty-seven participants filled out the English version, 125 the Portuguese version, and 69 the German version. Participants were between 18 and 74 years old (mean 35 ± 12 years): 236 were female and 105 male. Average height was 1.69 ± 0.09 m, average weight was 67 ± 17 kg, and average number of workdays per week was 3.8 ± 2.3 days. Tables 1 and 2 show how relevant variables varied according to age, sex, and language.

Table 1.

PSQI general scores

					Comparisons		
	n	$PSQI_u$	$PSQI_w$	$PSQI_f$	$PSQI_u$	$PSQI_w$	$PSQI_f$
Sex							
Male	105	5.00 (2.42)	5.02 (2.77)	3.50 (2.46)	$t_{248.96} = -3.46$	$t_{239.44} = -3.52$	$t_{336} = -2.04$
Female	233	6.08 (3.05)	6.24 (3.34)	4.16 (2.87)	$p < 0.01$	$p < 0.01$	$p < 0.05$
Age							
18–30 y	158	6.15 (2.87)	6.33 (3.16)	4.03 (2.64)	$F_{(3, 334)} = 2.17$	$F_{(3, 334)} = 2.82$	$F_{(3, 334)} = 1.16$
31–40 y	88	5.20 (2.66)	5.14 (2.89)	3.61 (2.74)	$p = 0.09$	$p < 0.05$	$p = 0.32$
41–50 y	39	5.72 (2.67)	6.03 (3.24)	3.77 (2.37)	—	18–30 vs. 31–40 y	-
>50 y	53	5.49 (3.43)	5.57 (3.72)	4.47 (3.36)		($p < 0.05$)	
Language							
English	146	5.54 (2.91)	5.68 (3.38)	3.83 (3.00)	$F_{(2, 335)} = 0.97$	$F_{(2, 335)} = 0.71$	$F_{(2, 335)} = 0.32$
German	69	5.68 (2.79)	5.75 (2.84)	3.96 (2.26)	$p = 0.38$	$p = 0.49$	$p = 0.73$
Portuguese	123	6.03 (2.96)	6.14 (3.23)	4.11 (2.74)	—	—	—

Descriptive statistics and comparisons of PSQI general scores ($PSQI_u$, $PSQI_w$ and $PSQI_f$ [mean, standard deviation in brackets]) by sex, age, and language groups. Results from *t*-tests or ANOVA followed by Tukey post hoc tests. Out of $n = 341$, $n = 338$ are analyzed and $n = 3$ are excluded due to invalid or incomplete datasets.

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Table 2.

PSQI Score differences, chronotype and social jetlag by sex, age and language

					Comparisons		
	n	$PSQI_{diff}$	Chronotype	Social jetlag	$PSQI_{diff}$	MSFsc	SJL
Sex							
Male	88	1.51 (2.22)	4:50 (1:41)	1:23 (1:06)	$t_{262}= -1.96$	$t_{139.68}= -1.96$	$t_{262}= -0.37$
Female	176	2.12 (2.12)	4:38 (1:17)	1:26 (1:00)	$p = 0.05$	$p = 0.33$	$p = 0.71$
Age							
18–30 y	110	2.34 (2.46)	5:01 (1:31)	1.44 (1:07)	$F_{(3, 260)} = 3.38$	$F_{(3, 260)} = 5.53$	$F_{(3, 260)} = 8.65$
31–40 y	74	1.55 (2.19)	4:45 (1:15)	1:21 (0:53)	$p < 0.05$	$p < 0.01$	$p < 0.001$
41–50 y	34	2.29 (2.76)	4:21 (1:10)	1:18 (0:58)	18–30 vs. >50 y	18−30 vs. >50 y	18−30 vs. >50 y
>50 y	46	1.22 (2.15)	4:06 (1:30)	0:52 (0:45)	($p < 0.05$)	($p < 0.01$)	31–40 vs. >50 y ($p < 0.001$, $p < 0.05$)
Language							
English	113	1.81 (2.45)	4:44 (1:35)	1:15 (0:53)	$F_{(2, 261)} = 0.22$	$F_{(2, 261)} = 1.52$	$F_{(2, 261)} = 4.11$
German	48	2.00 (2.31)	4:22 (1:19)	1:23 (1:03)	$p = 0.80$	$p = 0.22$	$p < 0.05$
Portuguese	104	2.00 (2.43)	4:48 (1:18)	1:38 (1:07)	—	—	en vs. pt

Descriptive statistics and comparisons of PSQI differences ($PSQI_{diff}$, difference between the score on workdays and work-free days), chronotype (MSF_{SC}), and social jetlag (mean, standard deviation in brackets) by sex, age, and language groups. Results from *t*-tests or ANOVA followed by Tukey post hoc tests. Out of $n = 341$, $n = 264$ are analyzed for $PSQI_{diff}$, $n = 3$ are excluded due to invalid or incomplete datasets, $n = 264$ are analyzed for chronotype and social jetlag, $n = 76$ use alarm clocks on work-free days, i.e. chronotype could not be calculated, and $n = 1$ is excluded as an outlier: more than 3 IQR above Q3 for social jetlag.

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The study was approved by the ethics committee of the Medical Faculty of the Ludwig Maximilian University Munich and was conducted in accordance with the Declaration of Helsinki. All participants provided their informed consent by clicking a statement before proceeding to the survey data collection.

Procedure

We used nonrepresentative snowball sampling and recruited participants through social media, e-mails to personal contacts, and posts on discussion boards and mailing lists. Inclusion criteria were being at least 18 years old, following a regular weekly work schedule and not being a shift worker. When accessing the webpage, participants were informed about the study terms, including confidentiality and data handling policies, as well as ways to contact the research team if they had any further questions. After accepting the study terms, participants were directed to the questionnaires. At first, all participants filled out the original version of the PSQI asking for usual sleep behavior ($PSQI_u$), followed by the two modified versions for workdays ($PSQI_W$) or work-free days ($PSQI_f$) in a randomized order, and finally the MCTQ. All questionnaires had to be completed in one session. On average, participants needed 29 min to fill out all questionnaires. Only fully completed questionnaires were saved to the online database.

Materials

Pittsburgh Sleep Quality Index

The PSQI was developed by Buysse et al. [1]. It is a self-report on subjective sleep quality over the last 4 weeks with 18 questions. The first four questions enquire about times (bed time, number of minutes it took for the participant to fall asleep, get up time, and hours of sleep per night).

The next 10 questions ask how often the participant had trouble sleeping because of different reasons (e.g. woke up in the middle of the night, need to go to the bathroom, cough, and bad dreams). Each of these questions must be answered on a 4-point scale ranging from “never” to “three times or more a week.” Additional questions include a subjective rating of the participants’ sleep quality (4-point scale from “very good” to “very bad”), the use of sleep medication, and trouble staying awake during the day (4-point scale ranging from “never” to “three times or more a week”). The final question asks if it has been a problem for the participant to keep up enough enthusiasm for getting things done (4-point scale ranging from “no problem at all” to “a very big problem”).

The 18 items of the PSQI form seven-component score ranging from 0 to 3 (sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, sleep medication, and daytime dysfunction) that can be summed up to a general score. Higher scores represent worse sleep quality [1]. The psychometric properties of the English version [1], as well as the German [5] and the Portuguese version [17], are good.

In our study, we used the original PSQI that states, “The following questions relate to your usual sleep habits during the past month only.” We added two modified versions, one for workdays, stating “The following questions relate to your sleep habits on *workdays* during the past month only,” and one for work-free days, stating “The following questions relate to your sleep habits on *work-free days* during the past month only.” In the modified versions, we added the term “workdays” (or “work-free days,” respectively) to every single question. The words “workdays” and “work-free days” were highlighted in the questionnaires, and attention was drawn, in the instructions, to the fact that there were versions for each one of them.

Munich ChronoType Questionnaire

The English, German, and Portuguese core versions of the MCTQ for non–shift workers were used to assess sleep–wake behavior on workdays and work-free days (see https://www.thewep.org/documentations/mctq). The MCTQ asks, separately for workdays and work-free days, at what time people go to bed and are ready to sleep, how long it takes them to fall asleep, at what time they wake up and get up, and if they use an alarm clock.

The MCTQ was designed to assess chronotype based on the phase of entrainment (relationship between internal and external days). Chronotype is not a score, but a local time (MSF_{SC}: midpoint between sleep onset and sleep offset on work-free days, corrected for oversleep if individuals sleep longer on work-free days than on workdays, see Ref. 11 for exact calculations). Additionally, variables like sleep duration and social jetlag (absolute difference between mid-sleep on workdays and work-free days) can be derived from the MCTQ [11, 13].

Chronotype calculations were considered only if the participant reported not to use an alarm clock on work-free days.

Sample size calculation

Roenneberg et al. [10] compared sleep parameters on workdays and work-free days, and the smallest significant effect size was 0.27. To achieve a statistical power of $1-\beta = 0.95$ with an $\alpha < 0.05$ and an effect size of at least 0.2, we needed to recruit 327 participants to compare workdays and work-free days.

Data analysis

Statistical analysis was performed using SPSS Statistics 23 (IBM SPSS), Excel 2011 for Macintosh, and Prism 6. To confirm data validity, we only included data following a 24 h time format. Three hundred forty-one participants completed the questionnaires, and three were excluded due to invalid or incomplete datasets on one of the PSQIs. All variables followed a normal distribution determined by visual inspection of histograms. We used repeated-measures analysis of variance (ANOVA) with the three different versions of the PSQI (usual, work, and work-free) as a within-participant factor. If the assumption of sphericity (Mauchly’s test) was violated, the Greenhouse-Geisser correction was applied. Bonferroni tests were used as post hoc tests. We used paired sample *t*-tests to analyze the differences between MCTQ timing variables between workdays and work-free days. Linear regressions were used to determine whether there were associations between PSQI scores, chronotype, and social jetlag. To find out whether PSQI score differences could be predicted by chronotype and/or social jetlag, we carried out a mediation analysis as described by Preacher and Hayes. Additionally, we calculated a “time-free” PSQI score (i.e. the sum of component 1: sleep quality, component 5: sleep disturbances, component 6: sleep medication, and component 7: daytime dysfunction) to make sure that potential relations between chronotype, social jetlag, and PSQI scores were not only due to the fact that PSQI scores also include variables that are derived from information about sleep timing and sleep duration (i.e. component 2: sleep latency, component 3: sleep duration, and component 4: sleep efficiency). We then calculated an additional mediation model with the “time-free” PSQI score. In multiple regressions, tolerance tests were used as indicators of colinearity. Seventy-six of 341 participants reported alarm clock usage on work-free days; therefore, chronotype could not be calculated. We excluded one extreme outlier (social jetlag 3 times the interquartile range higher than 75th percentile). Participants who used alarm clocks on work-free days did not differ from the whole sample in terms of age and sex.

Results

Differences between $PSQI_u$, $PSQI_w$, and $PSQI_f$

Internal consistency

The internal consistency for $PSQI_u$ (α = 0.62), $PSQI_w$ (α = 0.67), and $PSQI_f$ (α = 0.68) was considered acceptable. The largest item-total correlation coefficients were found for component 1: sleep quality (*r* = 0.56, 0.56, 0.61), the smallest for component 6: sleep medication (r = 0.14, 0.11, 0.21).

General PSQI score

As shown in Figure 1 and Table 3, $PSQI_u$, $PSQI_w$, and $PSQI_f$ scores differ significantly. Post hoc comparisons revealed a significant difference between $PSQI_u$ vs. $PSQI_f$ and $PSQI_w$ vs. $PSQI_f$, but not between $PSQI_u$ and $PSQI_w$. Neither of the three PSQI general scores differed between participants who used and who did not use an alarm clock on work-free days ($PSQI_u$: $p = 0.533$; $PSQI_w$: $p = 0.551$; $PSQI_f$: $p = 0.312$).

Table 3.

PSQI general scores, PSQI component scores, and PSQI time variables

				ANOVA			Post hoc comparisons (Bonferroni)		
							usual* work	usual* free	free* work
	Usual	Workdays	Work-free days	*F* (*df*)	*P*	η2p	*P*	*P*	*P*
PSQI general score	5.75 (2.91)	5.86 (3.22)	3.96 (2.76)	204.7 (1.53, 518.4)	<0.0001	0.38	0.3885	<0.0001	<0.0001
Components									
1 – Sleep quality	1.11 (0.68)	1.21 (0.75)	0.83 (0.71)	94.76 (1.51, 510.3)	<0.0001	0.22	<0.0001	<0.0001	<0.0001
2 – Sleep latency	1.02 (0.93)	0.92 (0.96)	0.64 (0.79)	72.07 (1.66, 558.0)	<0.0001	0.18	0.0002	<0.0001	<0.0001
3 – Sleep duration	0.52 (0.71)	0.64 (0.85)	0.15 (0.50)	92.21 (1.61, 543.6)	<0.0001	0.21	<0.0001	<0.0001	<0.0001
4 – Sleep efficiency	0.38 (0.78)	0.43 (0.81)	0.26 (0.62)	11.52 (1.94,652.7)	<0.0001	0.03	0.6706	0.0021	<0.0001
5 – Sleep disturbances	1.14 (0.45)	1.09 (0.46)	0.98 (0.48)	32.58 (1.77,595.2)	<0.0001	0.09	0.0089	<0.0001	<0.0001
6 – Sleep medication	0.31 (0.82)	0.30 (0.81)	0.24 (0.75)	5.30 (2.69, 570.4)	0.0081	0.02	1.0000	0.0015	0.0937
7 – Daytime dysfunction	1.27 (0.81)	1.28 (0.84)	0.87 (0.77)	97.50 (1.57, 530.2)	<0.0001	0.22	1.0000	<0.0001	<0.0001
Time variables									
Bedtime (hh:mm)	23:43 (01:26)	23:36 (01:17)	00:28 (01:31)	112.9 (1.93, 651.1)	< 0.0001	0.25	0.1850	< 0.0001	< 0.0001
Latency (min)	19.35 (18.28)	19.89 (19.99)	16.52 (16.67)	15.16 (1.49, 501.6)	< 0.0001	0.04	0.6274	0.0002	< 0.0001
Get up (hh:mm)	07:32 (01:45)	07:17 (01:32)	09:17 (01:42)	318.4 (1.87, 630.4)	< 0.0001	0.49	0.0026	< 0.0001	< 0.0001
Sleep Duration (hh:mm)	07:01 (01:07)	06:52 (01:29)	08:11 (01:17)	187.8 (1.60, 538.9)	< 0.0001	0.36	0.0686	< 0.0001	< 0.0001

Descriptive statistics and comparisons of PSQI general score, PSQI components scores, and PSQI time variables (mean, standard deviation in brackets). Results from repeated measures ANOVA followed by Bonferroni's multiple comparisons tests. Out of $n = 341$, $n = 338$ are analyzed and $n = 3$ are excluded due to invalid or incomplete datasets.

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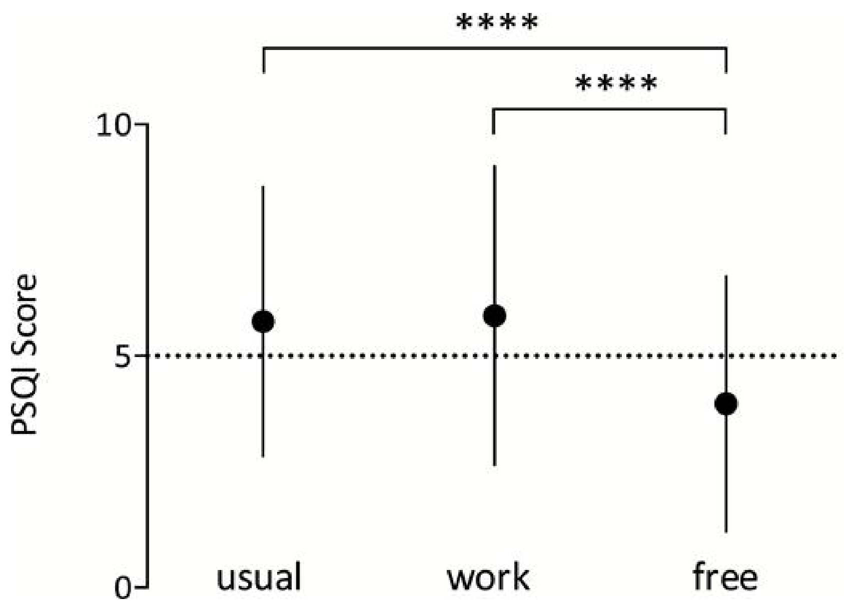
Figure 1.



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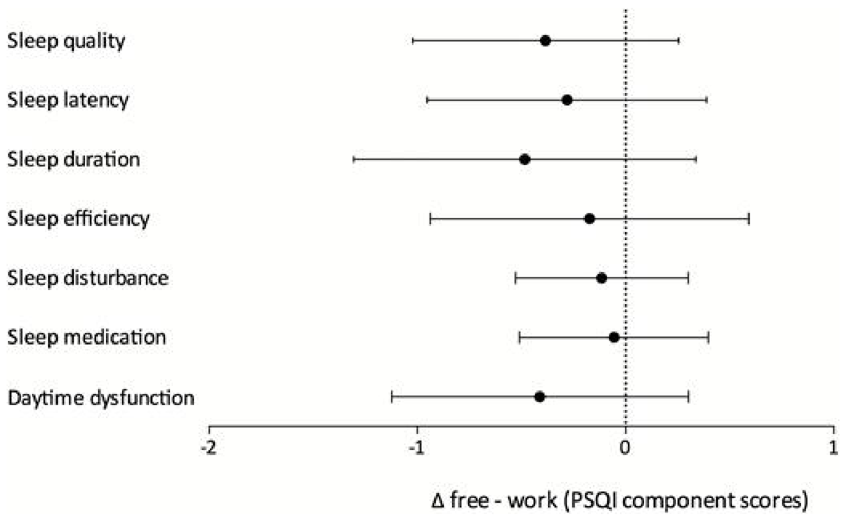
PSQI score differences between “usual,” “workdays,” and “work-free days.” Black dots show means and whiskers show standard deviations. ****$p < 0.0001$.

PSQI component scores

PSQI component scores and comparisons between conditions are shown in Table 3. Apart from component 6: sleep medication, all component scores (that are summed up to the general PSQI score) differ between “usual” and “work-free days” as well as between “workdays” and “work-free days.” Figure 2 displays the differences between PSQI component scores on workdays and work-free days, showing a higher sleep quality, a reduced sleep latency, a longer sleep duration, a higher sleep efficiency, and less sleep disturbances and less daytime dysfunction on work-free days compared with workdays.

Figure 2.



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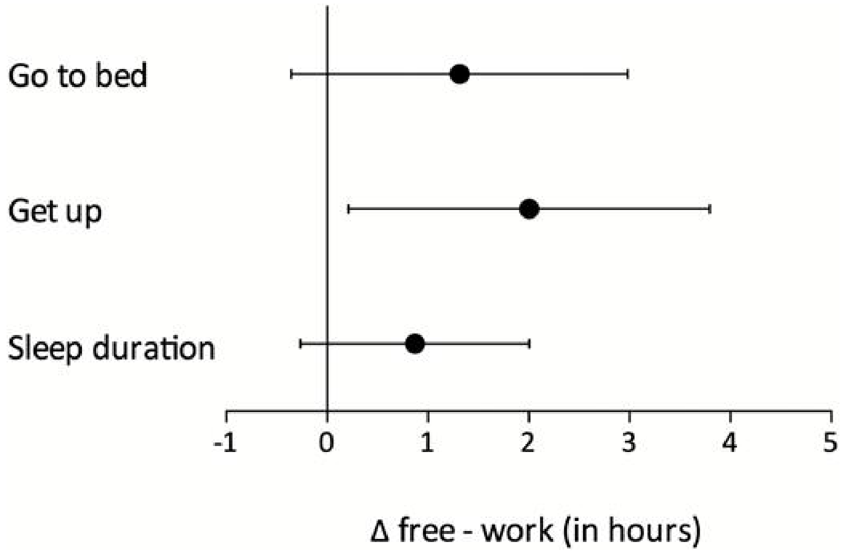
Differences in PSQI component scores between workdays and work-free days. Component scores ranging from 0 to 3. Black dots show mean differences and whiskers show standard deviations. Note: the higher the component scores, the worse the sleep.

PSQI time variables

Table 3 shows that all PSQI variables asking for answers on a time scale (i.e. bedtime, sleep latency, get up time, and sleep duration) differ significantly between “workdays” vs “work-free days” and between “work-free days” vs “usual,” but only get-up time differed between “usual” vs “work-free days.” Figure 3 shows that participants go to bed and get-up later and sleep longer on work-free days compared with workdays.

Figure 3.



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Differences in PSQI time variables bedtime, get-up time, and sleep duration between workdays and work-free days. Black dots show mean differences and whiskers show standard deviations.

PSQI score differences, chronotype, and social jetlag

Descriptive statistics from the MCTQ can be seen in Table 4. Chronotype predicts PSQI score differences ($PSQI_{diff}$: $r = -0.159$, $p = 0.010$; $\beta = 0.140$, $p = 0.025$) in a linear regression model adjusted for age ($\beta = -0.114$, $p = 0.066$) and sex ($\beta = 0.121$, $p = 0.046$). Also social jetlag predicts $PSQI_{diff}$ ($r = -0.221$, $p < 0.0001$; $\beta = 0.193$, $p \leq 0.0001$), adjusted for age ($\beta = -0.106$, $p = 0.052$) and sex ($\beta = 0.098$, $p = 0.062$).

Table 4.

MCTQ variables

			Comparisons	
	Workdays	Work-free days	*t* (*df*)	*P*
Bedtime (hh:mm)	23:29 (01:14)	00:25 (01:36)	−13.62 (340)	<0.0001
Being ready to sleep (hh:mm)	23:49 (01:15)	00:43 (01:38)	−14.38 (340)	<0.0001
Sleep latency (min)	20 (25)	17 (16)	3.09 (340)	0.002
Sleep onset (hh:mm)	00:09 (01:24)	01:00 (01:42)	−12.75 (340)	<0.0001
Sleep end (hh:mm)	07:14 (01:31)	09:02 (01:47)	−19.20 (340)	<0.0001
Sleep inertia (min)	23 (64)	33 (70)	−3.79 (340)	<0.0001
Getting up (hh:mm)	07:37 (01:51)	09:35 (02:12)	−19.02 (340)	<0.0001
Sleep duration (hh:mm)	07:04 (01:27)	08:02 (01:42)	−9.81 (340)	<0.0001
Total time spent in bed (hh:mm)	08:07 (01:44)	09:09 (02:05)	−9.69 (340)	<0.0001
Chronotype (MSFsc), (hh:mm)	04:43 (01:28)			
Social jetlag (hh:mm)	01:25 (01:05)			

Descriptive statistics and comparisons of MCTQ timing variables, chronotype, and social jetlag. Results from *t*-tests. *N* = 341 are analyzed for MCTQ time variables; *n* = 264 are analyzed for chronotype and social jetlag, *n* = 76 use alarm clocks on work-free days, i.e. chronotype could not be calculated, and *n* = 1 is excluded as an outlier: more than 3 IQR above Q3 for social jetlag.

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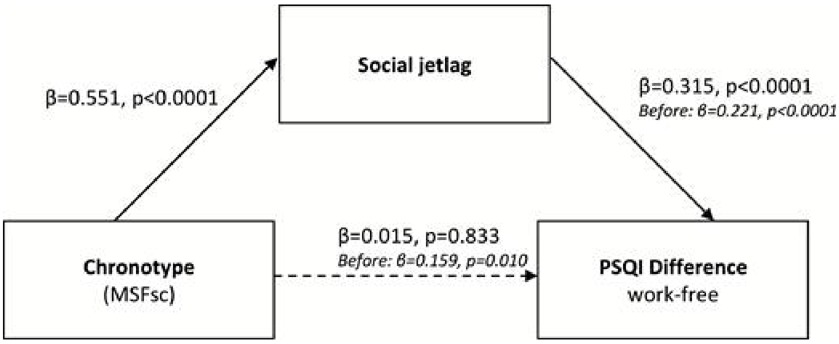
In a mediation model, $PSQI_{diff}$ could be predicted by chronotype (as an independent variable, β = 0.159, $p = 0.010$) and by social jetlag (as mediator, β = 0.221, $p < 0.0001$). Chronotype also predicted social jetlag (β = 0.551, $p < 0.0001$). When social jetlag and chronotype were entered into the model, social jetlag predicted $PSQI_{diff}$ (β = 0.315, $p < 0.0001$), whereas chronotype did not predict $PSQI_{diff}$ anymore (β = −0.015, $p = 0.833$) (Figure 4). The Sobel test showed a significant mediation effect ($Z = 4.136$, $p < 0.0001$) of social jetlag on the relationship between chronotype and $PSQI_{diff}$.

Figure 4.



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The relationship between PSQI score difference (work-free days minus workdays) and chronotype is mediated by social jetlag.

A mediation model calculated with PSQI scores excluding all sleep timing–related variables (i.e. component 2: sleep latency, component 3: sleep duration, and component 4: sleep efficiency) yielded similar results: $PSQI_{diff}$ without time variables could be predicted by chronotype (as an independent variable, β = 0.124, $p = 0.044$) and by social jetlag (as mediator, β = 0.238, $p < 0.0001$). In a regression with both chronotype and social jetlag, only the latter predicted $PSQI_{diff}$ without time variables (β = 0.346, $p < .0001$; chronotype: β = −0.066, $p = 0.345$). Also for $PSQI_{diff}$ without time-related variables, the Sobel test showed a significant mediation effect ($Z = 4.150$, $p < 0.0001$) of social jetlag on the relationship between chronotype and $PSQI_{diff}$.

In both models (e.g. with the PSQI score difference between workdays and work-free days and with PSQI scores' difference excluding timing-related components 2–4 as dependent variables), tolerance was greater than 0.10 (0.737) and the variance inflation factor was lower than 10 (1.36), indicating that colinearity does not account for our results.

Discussion

To the best of our knowledge, the PSQI has never before been asked in the form of day-specific versions, i.e. separately for workdays and work-free days. Our results show a substantial difference between workdays and work-free days in terms of sleep quality in a general population. $PSQI_w$ was two points higher than $PSQI_f$ and above the cutoff for poor sleep quality (>5), suggesting that beyond the impact on sleep timing and duration, the effects of imposed work schedules extend to sleep quality. *Usual* PSQI scores were indistinguishable from workdays' scores, suggesting that the $PSQI_u$ mainly assesses workdays' sleep quality. The difference between $PSQI_w$ and $PSQI_f$ scores was not a direct effect of sleep duration and timing (influencing the total score), as the difference also pertained when analyzing the difference in separate components other than sleep duration and timing (i.e. sleep quality, sleep disturbances, and daytime dysfunction), suggesting that other aspects are affected as well. We also found that the later the chronotype, the higher the difference between $PSQI_w$ and $PSQI_f$ scores, and that this association was mediated by social jetlag.

In our study, chronotype correlated with the difference between $PSQI_w$ and $PSQI_f$ scores. Previous studies found that chronotype has a significant effect on sleep quality as measured by actigraphic measures. Evening types were reported to have decreased sleep quality and shorter sleep duration when compared with morning and intermediate types during the week, reaching the same levels in the weekend [18]. Alternatively to a direct effect of chronotype on the PSQI differences, we have shown that this relationship is mediated by social jetlag. That means that possibly it is not being a late chronotype per se that explains the association with higher PSQI differences, but rather the collision of a late chronotype with time constraints of the external word, which can be quantified by social jetlag. Late chronotypes often need to adapt to conventional early work schedules, so the later the chronotype, the greater the social jetlag and so the difference between sleep quality on workdays compared with work-free days. Two studies that lead into that direction were conducted in shift workers—a group of people that is highly affected by social jetlag: the interaction of chronotype and shift modulated sleep disturbances [19] and tailoring work schedules to reduce social jetlag improved sleep quality [20].

One could argue that the relationship between chronotype/social jetlag and PSQI difference was only due to components overlapping, since variables such as sleep duration are used for the calculation of both chronotype or social jetlag and PSQI scores. However, the result of the mediation model was similar after removing the variation in sleep quality due to sleep timing and duration. Additionally, PSQI scores and sleep duration (as measured by sleep logs) were previously reported to overlap only to a small extent in a nonclinical population, and sleep quality components other than duration were suggested to be widely responsible for the association between sleep quality and measures of health and wellbeing [21]; besides, a variety of studies presents evidence on the association between poor sleep and health problems [22, 23]. A recent meta-analysis on the relationship between sleep and work suggests that sleep quality has been examined more often than sleep quantity, was only modestly related to it, and was significantly associated with more correlates (e.g. trait negative affect, workload, perceived control, depression, fatigue, general strain, and work-family control) and with larger average sizes, especially for variables related to the employees' perceptions or emotions [24].

Other factors related to the work life beyond social jetlag and sleep duration probably contribute to the observed differences between workdays and work-free days. Stress and strain at the workplace have been associated with poor sleep quality [25, 26]. Among work stressors related to disturbed sleep are high demands, persistent thoughts about work, low social support at work, and high physical work [27]. All these factors could be working together, as it has been proposed that circadian misalignment could render the organism to an allostatic overload and therefore reduce the ability to cope with stress [28].

Our results should be interpreted with caution, because a conclusion about causality between social jetlag and sleep quality cannot be taken in a cross-sectional study. Colinearity could have also influenced our results; however, tests for colinearity indicated that it was not large enough to affect the predicted values. It should also be noted that the PSQI cutoff score of 5 has been debated in the literature, and some authors suggested higher thresholds to classify "good" and "poor" sleepers [29, 30]. The study design could be subject to recall bias, i.e. participants usually work more days per week than they have work-free days, which might have led to a more accurate representation of sleep on workdays compared with work-free days. Additionally, all three versions of the PSQI were completed in one session which might have influenced our results, i.e. subsequent tests might have been affected by earlier responses and participants might have over- or underestimated the differences between workdays and work-free days. However, our main aim was to assess data on sleep quality regarding the previous month to make it as comparable as possible to the original PSQI. At least we randomized the order of completion of the PSQI for workdays and for work-free days to counterbalance any effects due to sequence.

Since this was an online-advertised survey, it was subject to volunteer bias (i.e. people particularly interested in sleep could be more prone to participate and to perceive differences between workdays and work-free days) and the sample was quite heterogeneous (e.g. from different countries and cultural backgrounds), which could compromise internal validity. However, chronotype in our sample followed a normal distribution and was similar compared with the large MCTQ database [11]. Additionally, the online survey allowed us to reach a geographically diverse sample, potentially increasing the study external validity. We did not use any objective measurement, which might be seen as a limitation. However, sleep quality can, by definition, be considered as a subjective perception, with still no consensus on what good sleep in fact implies [31]. Objective measurements refer to the assessment of behaviors that are considered to be correlates of sleep quality. When comparing the relationship with work-related outcomes of subjective and objective measurements of sleep quality, Litwiller et al. have seen that the latter were used in fewer studies, showed a small nonsignificant correlation with the subjective measurements, and were not as strongly correlated to variables related to perception and emotions [24]. One possible explanation is that the rating of subjective sleep quality is influenced by negative affect, which could confound the impact of its relationship with health outcomes. However, it has also been suggested that objective and subjective measures appraise different aspects of sleep quality and that one cannot function as a surrogate for the other [32, 33]. In that case, it would be interesting to see whether objective sleep quality measures also differ when comparing workdays and work-free days.

Our study showed that if we aim to assess sleep quality as correctly as possible, we should start by asking separately for workdays and work-free days. To understand the discrepancy between them, we still need to uncover how chronotype and social jetlag as well as other factors contribute to poor sleep quality. Further studies using objective measurements of sleep quality could be a next step to understand how these relationships are intertwined. Additionally, studies in sleep disorders patients investigating how sleep quality differs on workdays when compared with work-free days might help us to understand how these patterns might be clinically relevant. Finally, this understanding might foster purposeful solutions, e.g. the use of chronotype-based work schedules, to improve sleep quality and health.

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Notes

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