Original Studies

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On the influence of the day of the week on objective and self-rated sleep quality of adults

It is common knowledge that most adolescents and adults have trouble falling asleep on Sunday nights and feel less refreshed on Monday mornings than on other days of the week. In a sleep health program developed and conducted for the German Armed Forces [25], several participants felt significantly impaired by these weekly recurring problems, which was also reflected in their sleep log data (unpublished data). The possible reasons are not just preoccupation with the upcoming work or school week, but also the changes in the timing of going to bed and getting up from weekends to weekdays. These differences in the sleep–wake rhythm between weekdays and weekends are attributed to the so-called "social jetlag" [28]. Social jetlag is characterized by a misalignment between the social and the biological clock, and it usually results in a phase delay of sleep–wake timing on work-free days as compared to weekdays [22, 28]. Several studies have shown that social jetlag has negative impacts on the school performance of children and adolescents [8, 9] as well as on productivity in industry, and might lead to detrimental health effects, e.g., metabolic changes and adiposity [21, 26, 27]. Whereas these negative consequences have been well studied, only few data are available on objectively derived sleep quality from adult populations across different weekdays. Most studies on social jetlag applied questionnaires and/or used retrospective evaluation for self-rated parameters [10, 15, 22]. Only a few studies applied objective data gathered by actigraphy [20, 27, 30]. To the best of our knowledge, no study has applied ambulatory polysomnography across different nights of the week in the general adult population to look for effects of different weekdays on different sleep quality measures. In the present study, objective as well as self-reported sleep data from an experimental field study on the impact of mobile phone base stations were reanalyzed with regard to effects of weekday, age, gender, and employment status in a rural adult population.

Materials and methods

Study design

For the present analysis, data were derived from a double-blind randomized cross-over study on possible effects of electromagnetic field (EMF) exposure from mobile phone base stations on sleep [5]. In ten different small German villages without any network coverage and a mean number of 286 inhabitants, an experimental mobile phone base station was set up for a study period of 2 weeks. In total, 397 residents (18–81 years, 50.9% female) participated in the study. All individuals were randomly exposed to EMF from Global System for Mobile Communications (GSM; 900 MHz and 1800 MHz) and sham for a total number of 5 nights each, while sleep was recorded at their homes.

Questionnaires prior to experimental procedures

In the runup to the study, the following questionnaires were completed by participants: Pittsburgh Sleep Quality Index (PSQI [3]), the Epworth Sleepiness Scale (ESS [17]), morningness–eveningness questionnaire (MEQ [12]), self-rat-

Table 1	Definitions of objective and self-rated sleep parameters	
	Objective sleep parameter (polysomnography)	**Self-rated sleep parameter (evening/morning protocol)**
Time in bed (TIB)	Time period from "lights off" to "lights on" (oTIB, min)	Time period from "lights off" to "lights on" (TIB, min)
Total sleep time (TST)	Time period from "lights off" to "lights on" minus wake (oTST, min)	Estimated total sleep time (sTST, min)
Sleep efficiency index (SEI)	(oTST/oTIB) × 100; (oSEI, %)	(sTST/sTIB) × 100; (sSEI, %)
Sleep onset latency (SOL)	Sleep onset latency stage 1: time period from "lights off" to stage 1 (oSOL, min)	Estimated time from "lights off" to falling asleep (sSOL, min)
Wake after sleep onset (WASO)	Wake after sleep onset (oWASO, min)	Estimated total time awake during night (sWASO, min)
Restlessness (VAS)	–	Visual analogue scale (VAS, morning): low values indicate high restfulness (0 = very restful, 100 = not restful)

Table 2 Characteristics of all participants of the study ($n = 397$), for the subgroup in which objective and self-rated sleep data were available ($n = 335$), and of those who dropped out or were excluded ($n = 62$)

Parameter	Total sample ($n = 397$)	Analysis group ($n = 335$)	Dropouts/excluded ($n = 62$)	Analysis group vs. dropouts/excluded
	Median (IQR)	Median (IQR)	Median (IQR)	p-value[a]
Age (years)	45.0 (35.0, 55.5)	45.0 (35.0, 56.0)	41.0 (34.0, 55.3)	0.426
BMI kg/m^2	26.2 (23.6, 29.3)	26.2 (23.6, 29.3)	25.9 (23.3, 29.8)	0.836
PSQI score	5.0 (3.0, 6.0)	5.0 (3.0, 6.0)	4.0 (3.0, 6.0)	0.816
ESS score	8.0 (5.0, 10.0)	7.0 (5.0, 10.0)	9.0 (5.0, 10.3)	0.224
SDS score	32.0 (27.0, 36.0)	32.0 (28.0, 36.0)	31.0 (26.0, 35.5)	0.633
SAS score	30.0 (26.0, 34.0)	30.0 (26.0, 34.0)	29.0 (25.0, 34.3)	0.467
	n (%)	n (%)	n (%)	p-value[b]
Female	202 (50.9)	175 (52.2)	27 (43.5)	0.209
PSQI score >5	129 (32.5)	108 (32.2)	21 (34.4)	0.737
ESS score >10	81 (20.4)	66 (19.7)	15 (24.2)	0.420
SDS score >40	37 (9.3)	27 (8.1)	10 (16.1)	0.045
SAS score >35	76 (19.1)	62 (18.5)	14 (22.6)	0.454
MEQ—definite evening type (<31)	1 (0.3)	1 (0.3)	0 (0.0)	0.365
MEQ—moderate evening type (31–41)	17 (4.3)	13 (3.9)	4 (6.5)	
MEQ—indifferent type (42–58)	178 (44.8)	146 (43.6)	32 (51.6)	
MEQ—moderate morning type (59–69)	158 (39.8)	135 (40.3)	23 (37.1)	
MEQ—definite morning type (>69)	43 (10.8)	40 (11.9)	3 (4.8)	
Employment status				
Employed (fulltime)	161 (40.6)	129 (38.5)	32 (51.6)	0.054
Part-time/not employed/training/school	236 (59.4)	206 (61.5)	30 (48.4)	

BMI body mass index, *ESS* Epworth Sleepiness Scale, *IQR* interquartile range, *MEQ* morningness–eveningness questionnaire, *PSQI* Pittsburgh Sleep Quality Index, *SAS* self-rating anxiety scale, *SDS* self-rating depression scale
[a]Mann–Whitney U test
[b]Chi-squared test

ing depression (SDS [31]) and anxiety scale (SAS [32]), the NEO personality inventory (NEO-PI [2, 4]), and a questionnaire on attitude towards mobile communication [14]. Only results from PSQI, ESS, SDS, SAS, and MEQ are reported here, since they are closely related to sleep quality.

Ambulatory sleep recordings

Objective sleep quality was monitored at the homes of the study participants by an ambulatory device which tracks frontal electroencephalography (EEG) and electrooculography (EOG; SOMNOscreen Neuro-Kombi™ by SOMNOmedics, Randersacker, Germany). The first night (Sunday) served as an adaptation night, and sleep was also recorded in the following nights until Friday. After a break on Saturday, sleep was monitored for another 6 nights (Sunday to Friday), resulting in a maximum of 12 nights per individual. In half of the nights, the experimental base station was operating in verum mode (GSM). Prior to unblinding of the data, the quality of all sleep recordings was visually controlled for artifacts resulting from wrong handling of the recording system or other technical problems. If artifacts did not allow correct automatic scoring, recordings were omitted. In a next step, sleep onset was determined according to the criteria of the American Academy of Sleep Medicine [13] in terms of the appearance of the first epoch of any sleep stage. The time of awakening (first epoch "awake" after the last stage of sleep) was manually determined and scoring of sleep in between was performed automatically with the DOMINO software from SOMNOmedics. The definitions of the five selected objective sleep parameters are shown in ◘ **Table** 1.

Self-rated sleep parameters

Participants filled in the evening and morning protocol (sleep diary) of the German Sleep Research Society [11] parallel to the ambulatory sleep recording to assess parameters of self-rated sleep quality. The evening protocol comprises eight items and the morning protocol 11 sleep-related items. Six parameters of self-rated sleep quality corresponding to the five objective sleep parameters were considered, and their definitions are shown in ◘ **Table** 1.

Statistical analysis

Since EMF did not have any effect on the objectively derived and self-rated sleep quality parameters [5], data of all nights were analyzed, except for the adaption night. For each of the other days of the week, the data of the 2 weeks were averaged separately per day. Since data were

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Abstract

Background and objective. The extent to which adult sleep varies depending on the day of the week has not yet been systematically investigated with electroenzephalography (EEG) data. Whether such effects exist and whether they are related to age, gender, and employment status was retrospectively analyzed based on data from an experimental double-blind cross-over study in which effects of electromagnetic fields of a cell phone base station on the sleep of a general rural population had been examined.
Methods. The sleep of 397 adults (age 45.0 ± 14.2 years, range 18–81 years; 50.9% women) from ten different rural German villages was recorded for 12 nights with ambulatory devices. Self-reported sleep quality was recorded in morning and evening protocols. Friedman tests were used for statistical analysis of the comparison between the days, and the Kruskal–Wallis and Mann–Whitney U tests were used for pairwise comparisons of independent parameters between groups.
Results. For the present analysis, data from 335 participants were considered. Overall, the differences between nights were small and the quality of sleep was good. Three of the five objective and all six self-rated sleep parameters differed significantly between the days of the week. While the objective and the self-estimated total sleep time were longest on Sunday nights, the qualitatively poorest values occurred on Monday nights. People who worked fulltime had the longest sleep latencies on Sunday nights. Friday nights were rated the best.
Conclusion. The objective and self-rated sleep quality varied relatively little in a rural adult population over the course of the week, being worst on Monday nights and best on Friday nights.

Keywords

Social jetlag · Sleep latency · Subjective sleep quality · Polysomnography · Sleep log

Einfluss des Wochentags auf die objektive und selbst bewertete Schlafqualität von Erwachsenen

Zusammenfassung

Hintergrund und Ziel. Inwiefern Schlaf von Erwachsenen in Abhängigkeit vom Wochentag variiert, wurde bisher nicht systematisch mittels auf Elektroenzephalographie (EEG-)basierten Daten untersucht. Ob es solche Effekte gibt, und ob diese mit Alter, Geschlecht und Beschäftigungsstatus zusammenhängen, wurde auf der Basis von Daten einer experimentellen doppelblinden Cross-over-Studie, in der der Einfluss elektromagnetischer Felder einer Mobilfunkbasisstation auf den Schlaf einer ländlichen Allgemeinbevölkerung untersucht wurde, retrospektiv analysiert.
Methoden. Der Schlaf von 397 Erwachsenen (Alter: 45,0 ± 14,2 Jahre, Spannbreite: 18–81 Jahre; 50,9 % Frauen) aus 10 verschiedenen ländlichen deutschen Orten wurde über jeweils 12 Nächte mit ambulanten Geräten untersucht. Die selbst eingeschätzte Schlafqualität wurde mit Morgen- und Abendprotokollen erfasst. Für die statistische Analyse des Vergleichs zwischen den Tagen wurden Friedman-Tests verwendet, für paarweise Vergleiche unabhängiger Parameter kamen der Kruskal-Wallis-Test und der Mann-Whitney-U-Test zum Einsatz.
Ergebnisse. Für die vorliegende Analyse wurden Daten von 335 Personen berücksichtigt. Die Unterschiede zwischen den Nächten waren sehr gering und die Schlafqualität sehr gut. Ein signifikanter Unterschied zwischen den Wochentagen bestand bei 3 der 5 objektiven und bei allen 6 subjektiven Schlafparametern. Während die objektive und die selbst geschätzte Gesamtschlafzeit in den Sonntagnächten am längsten waren, traten die qualitativ schlechtesten Werte in den Montagnächten auf. Personen, die einer Vollzeitbeschäftigung nachgingen, zeigten am Sonntagabend die längsten Einschlaflatenzen. Am besten bewertet wurden die Freitagnächte.
Schlussfolgerungen. Die objektive und selbst bewertetete Schlafqualität variierte relativ geringfügig in einer erwachsenen ländlichen Population im Laufe der Woche und war in Montagnächten am schlechtesten und in Freitagnächten am besten.

Schlüsselwörter

Sozialer Jetlag · Schlaflatenz · Subjektive Schlafqualität · Polysomnographie · Schlaftagebuch

not normally distributed, only non-parametric statistical analyses were applied. The Friedman test was applied to test for differences in parameters across the 6 days. Mann–Whitney U tests were used for pairwise comparisons. Chi-squared tests were used to analyze the distribution of categorized data between groups. All tests were performed with a two-tailed $p < 0.05$. Statistical analyses were conducted with SPSS IBM SPSS Statistics 26 (IBM Corp., Armonk, NY, USA).

The study protocol was approved by the ethics committee of the Charité, Universitätsmedizin Berlin, and all participants gave written informed consent. The study was performed according to the Declaration of Helsinki.

Results

Characteristics of participants

From 397 residents included in the study, 21 dropped out voluntarily (10 due to issues with recording, five each due to work-related reasons and health issues, and one for unclear reasons). Data of 11 study participants had been excluded because the individuals did not live close enough (i.e. in a distance >500 m) to the mobile phone base station, finally resulting in data of morning and evening protocols of 365 individuals. For analysis of objective sleep data, data from seven individuals were omitted because a different recording system was used, and for 23 individuals the quality of recordings was not sufficient in at least 50% of all nights, resulting in a total number of datasets from 335 participants.

Fig. 1 ▲ Median bedtimes and getting up times across the two study weeks. **a** Median bedtimes of all participants. In **b** median bedtimes of only fully employed participants are shown. **c** Median getting up times of all participants and **d** of the fully employed only. Note that getting up times refer to the morning of the next day, e.g., getting up times of Sunday nights refer to Monday mornings. *Sun* Sunday, *Mon* Monday, *Tue* Tuesday, *Wed* Wednesday, *Thu* Thursday, *Fri* Friday

The characteristics of the originally included participants ($n = 397$) are shown in ▣ **Table 2**. The subgroup analyzed here ($n = 335$) did not differ from the voluntary dropout and excluded participants ($n = 62$), except for the number of individuals with elevated SDS scores, which was slightly higher among the participants not considered, while the median did not differ between groups. Fully employed participants ($n = 129$) were significantly younger (median: 44.0 years; interquartile range: 35.0, 51.0 years) than the not fully employed individuals (median: 47.0 years; interquartile range: 36.0, 59.0 years). Within the fully employed subsample, 75.2% were males and 24.8% were females.

Bedtimes and getting up times

To get a picture of clock times across the different nights, all 12 study days were

considered. In ▣ **Fig. 1a** median bedtimes of all 12 nights for all participants and for the fully employed subsample separately (▣ **Fig. 1b**) are displayed. Median getting up times are shown in ▣ **Fig. 1c, d**. Median bedtimes were earliest on Friday nights and getting up times were latest on Friday nights, i.e., Saturday mornings, in both samples. Whereas bedtimes were the same in both groups in 8 of the 12 nights (22:30), the fully employed showed earlier getting up times on all working day mornings.

Objective sleep parameter across weekdays

Three of the five objective (o) sleep parameters varied statistically significantly across the 6 days in all participants (▣ **Table 3**). The median oTIB (▣ **Fig. 2a**) as well as oTST (▣ **Fig. 2b**) were longest on Sunday nights. Median oSOL was

longest on Monday nights and shortest on Thursday and Friday nights (▣ **Fig. 2c**). There were no significant differences between the nights in terms of oSEI and oWASO (▣ **Table 3**). In the subsample of the fully employed participants, two parameters varied significantly across the week (▣ **Table 4**). The oTIB was shortest on Monday nights and longest on Friday nights. The median oSOL was longest on Sunday nights and shortest on Thursday nights (▣ **Table 4**).

Self-rated sleep parameters across weekdays

All six endpoints from the self-rated (s) evening- and morning protocols differed statistically significantly between the days, with the longest sTIB (▣ **Fig. 3a**) and highest sSEI (▣ **Fig. 3c**) on Friday nights, and the longest sTST (▣ **Fig. 3b**) on Sunday nights (▣ **Table 3**). All self-re-

Table 3 Results of objective and self-rated sleep parameters for 6 different weekdays of all participants of the analysis group

	Sun	Mon	Tue	Wed	Thu	Fri	
	Median [IQR]	*Median [IQR]*	*Median [IQR]*	*Median [IQR]*	*Median [IQR]*	*Median [IQR]*	*p-value*[a]
Objective sleep parameters							
Time in bed (oTIB, min)	447.6 [389.4; 492.6]	432.4 [391.6; 476.6]	438.1 [392.0; 480.2]	432.0 [392.4; 473.7]	432.9 [389.8; 477.5]	439.9 [396.4; 476.7]	<0.0001
Total sleep time (oTST, min)	414.5 [360.0; 458.5]	400.5 [359.3; 441.0]	402.0 [360.3; 437.3]	402.3 [359.5; 437.0]	399.0 [361.0; 443.0]	404.3 [363.8; 441.8]	0.0151
Sleep efficiency index (oSEI, %)	93.0 [90.3; 95.2]	93.0 [90.0; 94.8]	93.3 [90.7; 95.0]	93.5 [90.6; 95.1]	93.3 [90.5; 95.1]	93.3 [90.3; 95.1]	0.1786
Sleep onset latency (oSOL, min)	9.8 [4.8; 18.7]	10.4 [6.4; 16.2]	9.9 [6.4; 15.6]	9.9 [6.3; 15.3]	8.7 [5.4; 16.5]	8.7 [5.3; 14.3]	<0.0001
Wake after sleep onset (oWASO, min)	23.7 [14.2; 36.3]	22.4 [14.9; 36.4]	23.7 [15.1; 33.8]	21.3 [14.4; 33.4]	21.4 [13.9; 32.8]	22.0 [14.9; 35.2]	0.2692
Self-rated sleep parameters							
Time in bed (sTIB, min)	445.0 [389.5; 502.0]	433.5 [391.3; 479.0]	436.5 [388.0; 482.5]	435.0 [390.0; 475.0]	434.0 [389.3; 477.5]	446.0 [397.5; 490.0]	<0.0001
Total sleep time (sTST, min)	410.0 [360.0; 450.0]	390.0 [360.0; 435.0]	390.0 [360.0; 435.0]	405.0 [360.0; 445.0]	405.0 [360.0; 437.5]	405.0 [360.0; 450.0]	<0.0001
Sleep efficiency index (sSEI, %)	92.6 [83.5; 97.5]	92.5 [86.3; 97.1]	92.9 [86.4; 96.8]	93.4 [87.9; 97.8]	93.3 [88.5; 97.3]	93.8 [88.1; 98.0]	0.0110
Sleep onset latency (sSOL, min)	10.0 [5.0; 22.5]	12.5 [7.5; 25.0]	12.5 [7.5; 22.5]	10.0 [5.0; 21.3]	10.0 [5.0; 20.0]	10.0 [5.0; 17.5]	<0.0001
Wake after sleep onset (sWASO, min)	10.0 [5.0; 30.0]	12.5 [7.5; 30.0]	12.5 [6.0; 22.5]	10.5 [6.4; 22.5]	10.3 [5.4; 20.0]	10.0 [5.0; 22.8]	0.0157
Restfulness (VAS)	33.0 [22.0; 52.0]	37.5 [26.3; 51.3]	35.0 [24.0; 47.0]	31.0 [21.0 45.5]	33.0 [22.3; 45.5]	31.0 [21.3; 43.5]	<0.0001

IQR interquartile range, *Sun* Sunday, *Mon* Monday, *Tue* Tuesday, *Wed* Wednesday, *Thu* Thursday, *Fri* Friday
[a]Friedman test

ported parameters were rated worst on Monday nights (and also on Tuesday nights in sTST, sSOL, and sWASO; see ◘ Fig. 3a–f) by all participants and by the subsample of the fully employed only (◘ Table 4). In addition, in the fully employed (◘ Table 4) sSOL was of equal length on Sundays and Tuesdays, and sSEI was of equal magnitude on Sundays and Mondays.

Effect of gender

The durations of oTIB and oTST were longer in female participants than in males on all nights and differed statistically significantly on Sunday and Friday nights (◘ Fig. 4a, b); oTIB also differed statistically significantly on Wednesday nights. Objective SOL was significantly longer in females on all nights, except for Monday nights. None of the other objective sleep parameters differed between women and men.

In the self-rated sleep variables, only time in bed and sleep onset latencies indicated significant differences between female and male participants (◘ Fig. 5a, b). The results were similar to those of the objective parameters and the direction was the same, with longer estimated sSOL in females in nearly all nights, except for Thursday nights, and significant differences with regard to sTIB on Sunday and Friday nights and also on Wednesday nights.

Effect of employment status

The differences in objective sleep parameters between participants who were fully employed and those who were not are shown in the ◘ Fig. 6a–e. While oTIB (◘ Fig. 6a) and oTST (◘ Fig. 6b) in the fully employed were significantly shorter, in particular at the beginning of the week, oSEI was always significantly higher (◘ Fig. 6c), except for Sunday nights. Objective WASO (◘ Fig. 6e)

was significantly shorter on all nights in the fully employed. On weekdays, oSOL (◘ Fig. 6d) was significantly shorter on all nights in the fully employed subsample, except for Thursday and Sunday nights.

Self-rated sleep parameters show a similar picture to the objective ones in sTIB (◘ Fig. 7a) and sTST (◘ Fig. 7b), but just one significant difference in sSEI on Thursdays (◘ Fig. 7c) and sWASO on Tuesdays (◘ Fig. 7e). The sSOL (◘ Fig. 7d) was rated significantly shorter on all nights in fully employed participants in contrast to on 4 nights in oSOL (◘ Fig. 7d). The fully employed participants rated sleep of Wednesday nights as significantly less restful than the other participants (◘ Fig. 7f). There were no significant differences in all other nights with regard to the degree of restfulness of sleep.
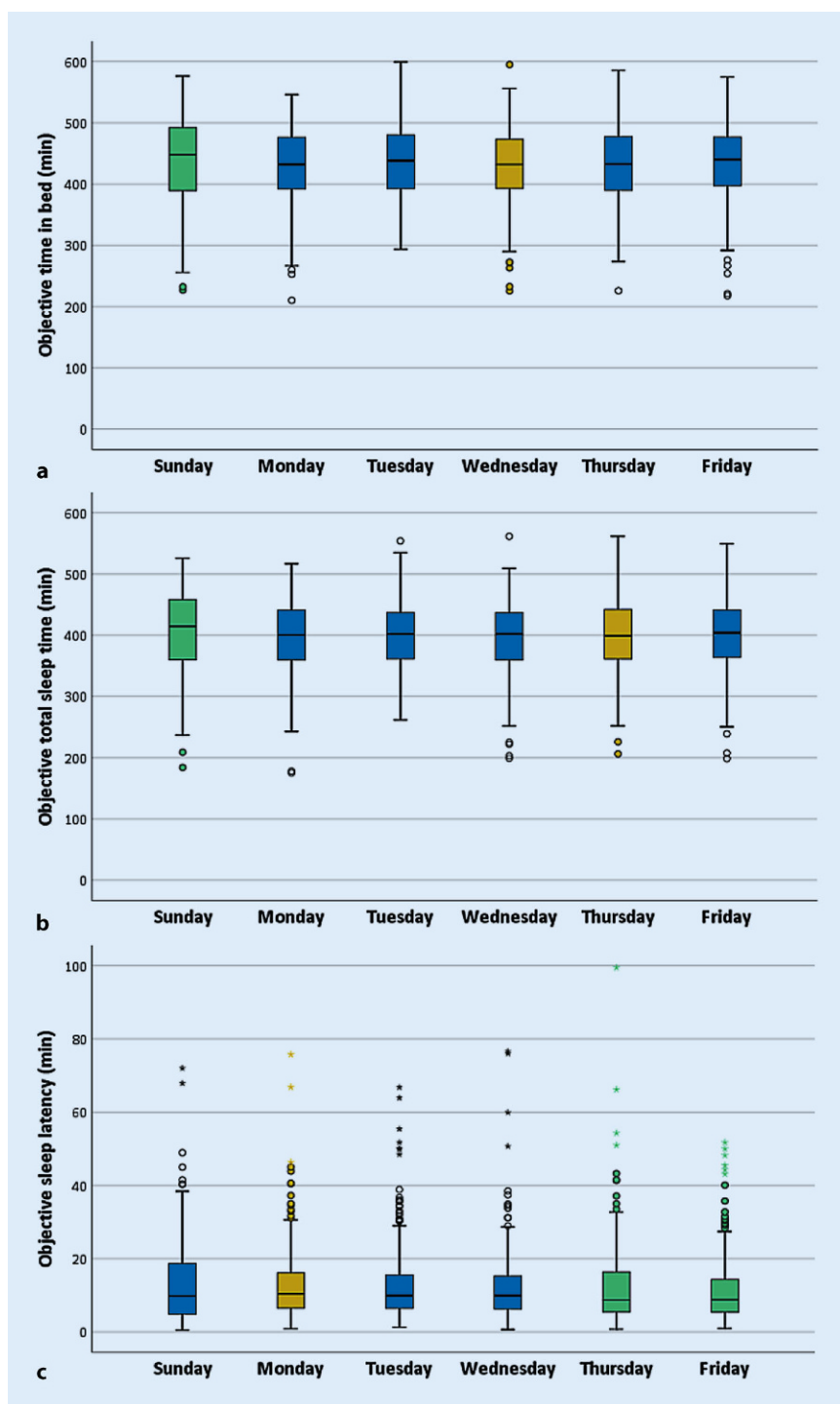
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Fig. 2 ▲ Objective sleep parameters which vary significantly between the 6 days are shown for all participants. Results of Friedman tests and descriptive values are shown in ◻ **Table 3**. The respective most positive values in terms of sleep quality are colored in *green* and the parameters with the least sleep quality across 6 days are colored in *orange*

Discussion

The present study provides data on ambulatorily recorded and self-rating-derived sleep parameters of a large sample of the rural German population. Bedtimes and getting up times followed a similar pattern in the two study weeks, with earlier bedtimes on Friday nights and clearly later getting up times on Saturday mornings. These findings were independent of whether individuals were fully employed or not. Sleep recordings in this rural population of a broad age range indicated short median sleep latencies ≤10 min. The median sleep duration of all participants was about 7 h in all nights. Median sleep efficiency indices varied between 93.0 and 93.5%, which is quite high when compared to age- and sex-specific reference values [6]. Whereas the sleep latencies were shorter in the present sample than in the reference study, which is based on data of laboratory nights with polysomnography [6], a higher sleep efficiency in the present sample might at least in part result from shorter TIB as compared to the given 8 h TIB in the reference study.

In general, differences in sleep parameters between weekdays in the present sample were quite small. This finding is in agreement with the American time use survey [1], in which 47,731 respondents older than 14 years answered questions on sleep time and waking activities. The differences in average sleep time were larger between weekdays and weekend days than between weekdays (Monday to Friday).

In a study on the contribution of various types of activities to recovery, 28 women and 18 men of different working populations (with a mean age of 34.93 years) completed a diary for 7 days and nights [24]. Sleep duration, sleep quality, and feelings of being refreshed increased at the weekend, which is consistent with our findings of the highest self-rated sleep duration and level of restfulness on Saturday mornings in the fully employed sample. In the latter cited study [24], Sunday nights were rated worst, which was not the case for most of the sleep parameters in our study. Interestingly, in our study,

Table 4 Results of objective and self-rated sleep parameters for 6 different weekdays of fully employed participants of the analysis group

	Sun Median [IQR]	Mon Median [IQR]	Tue Median [IQR]	Wed Median [IQR]	Thu Median [IQR]	Fri Median [IQR]	p-value[a]
Objective sleep parameters							
Time in bed (oTIB, min)	422.9 [374.4; 458.6]	414.5 [369.6; 460.3]	429.4 [368.6; 462.5]	416.0 [369.6; 460.3]	421.8 [377.6; 460.4]	428.2 [386.3; 474.0]	0.0304
Total sleep time (oTST, min)	387.0 [349.6; 422.5]	383.3 [345.8; 421.4]	391.3 [347.3; 430.3]	384.1 [345.5; 427.8]	389.1 [353.1; 427.5]	393.0 [356.8; 431.5]	0.1062
Sleep efficiency index (oSEI, %)	93.4 [90.8; 95.7]	93.5 [90.9; 95.3]	94.0 [91.9; 95.5]	94.0 [92.0; 95.7]	94.0 [91.7; 95.2]	94.2 [91.4; 95.2]	0.1186
Sleep onset latency (oSOL, min)	9.0 [4.7; 16.6]	8.4 [6.2; 14.0]	8.1 [5.2; 13.1]	8.4 [5.8; 11.8]	7.4 [5.0; 11.8]	7.6 [5.0; 11.3]	0.0097
Wake after sleep onset (oWASO, min)	20.8 [12.0; 33.0]	19.0 [13.6; 29.3]	18.6 [12.3; 28.5]	18.1 [12.1; 24.7]	17.7 [11.3; 28.3]	18.4 [13.1; 28.2]	0.0894
Self-rated sleep parameters							
Time in bed (sTIB, min)	420.0 [374.0; 465.0]	413.5 [372.0; 462.0]	415.0 [370.0; 454.5]	419.0 [380.0; 463.8]	419.5 [372.5; 464.3]	428.5 [391.8; 483.5]	0.0197
Total sleep time (sTST, min)	390.0 [348.8; 420.0]	382.5 [345.0; 420.0]	387.5 [345.4; 427.5]	390.0 [345.0; 427.5]	390.0 [338.8; 420.0]	400.0 [360.0; 450.0]	0.0145
Sleep efficiency index (sSEI, %)	93.3 [87.3; 97.9]	93.3 [87.5; 97.4]	93.7 [87.4; 97.3]	94.8 [89.4; 98.0]	94.1 [90.3; 97.2]	93.9 [89.2; 97.9]	0.1702
Sleep onset latency (sSOL, min)	10.0 [5.0; 20.0]	10.0 [5.0; 20.0]	10.0 [5.0; 15.0]	7.5 [5.0; 13.8]	7.5 [5.0; 12.5]	7.5 [4.0; 12.5]	<0.0001
Wake after sleep onset (sWASO, min)	10.0 [5.0; 30.0]	12.5 [7.5; 22.5]	10.0 [5.7; 17.5]	10.0 [5.9; 25.0]	10.0 [5.0; 20.0]	8.8 [5.0; 22.0]	0.1070
Restfulness (VAS)	34.0 [24.0; 51.8]	39.8 [26.5; 51.5]	37.2 [23.6; 49.1]	34.5 [21.5 46.9]	32.0 [22.0; 46.0]	31.0 [22.1; 42.0]	0.0001

IQR interquartile range, *Sun* Sunday, *Mon* Monday, *Tue* Tuesday, *Wed* Wednesday, *Thu* Thursday, *Fri* Friday
[a]Friedman test

Monday nights appeared to be the least refreshing nights and ranked last in all of the self-rated outcome parameters.

In the fully employed subsample, the objectively measured time to fall asleep was longest on Sunday nights. This would corroborate findings of social jetlag, since later getting up times on Saturday mornings and strict bedtimes on all nights before working days may induce prolonged times to fall asleep on Sunday nights. Furthermore, in the fully employed individuals, sleep latencies decreased significantly across the weekdays, possibly due at least in some part to a higher sleep pressure as a consequence of accumulated sleep debt during the week [16, 23]. A high sleep pressure might additionally have led to the observed earlier bedtimes on Friday nights and to later getting up times on Saturday mornings. The observed longer time in bed and total sleep time on Sunday nights in the total group might also reflect such an accumulated sleep debt [7] with subsequent recovery sleep, a phenomenon which is observed in many adolescents and adults [1, 23]. Similar to the present findings, in the American time use survey, sleep duration was also longest on Sundays nights [1].

In the present study, the fully employed individuals had significantly shorter TST during most of the weekdays compared to the not fully employed. These results could be attributed to the higher prevalence of male participants and the younger age in the fully employed sample, in which the oldest was 60 years old compared to 20.4% in the not fully employed sample who were 60 years or older. In the American time use study, participants aged ≥65 years slept longer during weekdays, whereas those <35 years showed longer weekend sleep times, especially on Sundays [1].

Female study participants in our study had longer TIB and TST as well as longer sleep latencies on all days except Mondays. These findings match with the results of other studies that have shown that on the one hand, women have longer sleep durations and sleep latencies [5, 19], and on the other hand, are more prone to insomnia disorders [29].

A limitation of the present study was that Saturday nights were missing, and only half of the available Sunday nights could be used, since the first nights were always adaption nights and were therefore excluded from further analyses.

A strength of the study is the large population and the objective data of several nights recorded in the participants' familiar surroundings. In addition, observational studies are usually prone to the Hawthorne effect, i.e., individuals who participate in a study are informed about the topic and aim of the study, which might bias their behavior and self-reporting [18]. This effect was not applicable to the present study since the original objective was to evaluate the possible impact of electromagnetic fields of a base station on sleep. Therefore, a retrospective anal-
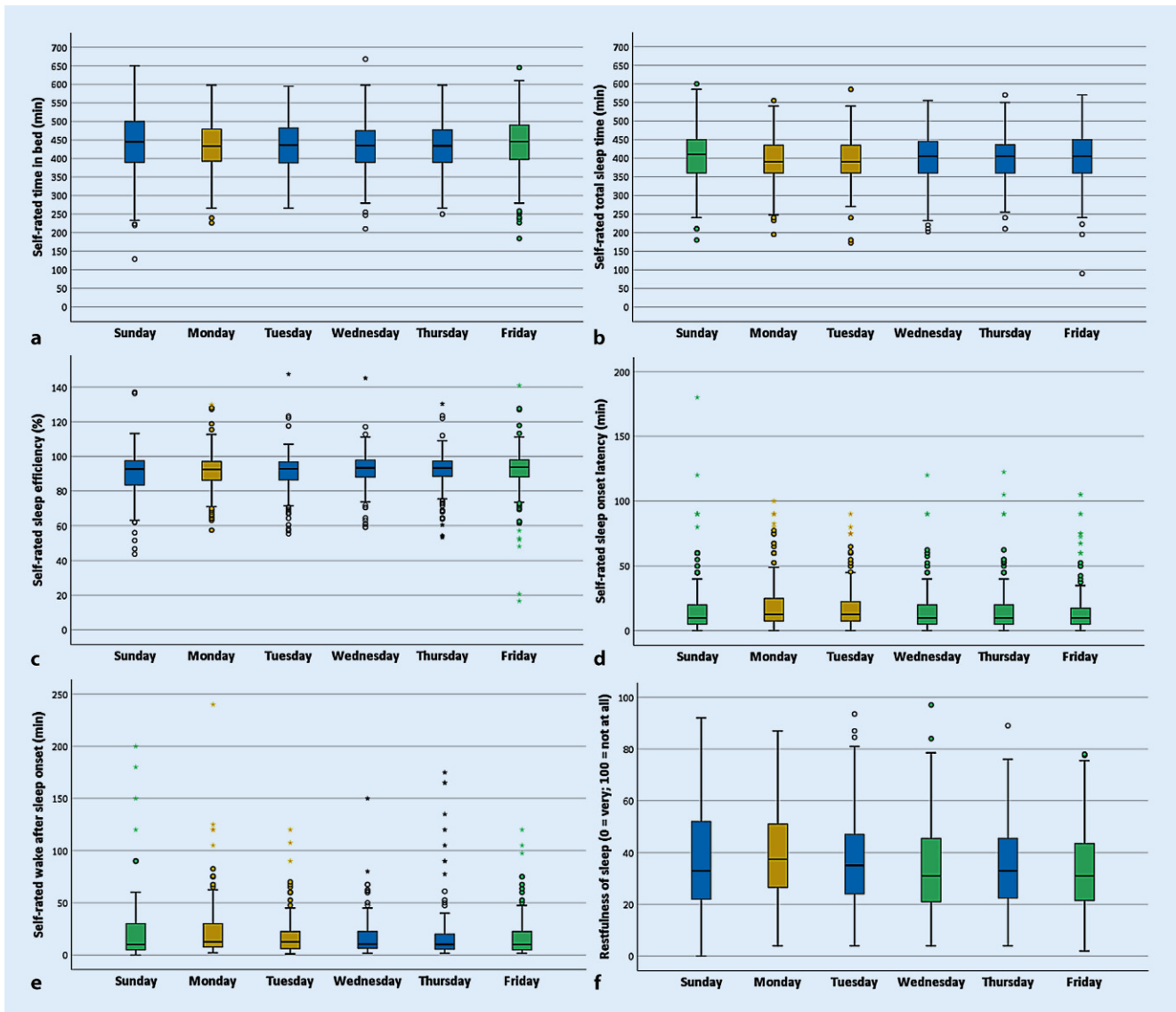
Fig. 3 ▲ Self-rated parameters which vary significantly between the 6 days are shown for all participants. Results of Friedman tests and descriptive values are shown in ◻ **Table 3**. The respective most positive values in terms of (sleep) quality are colored in *green*, and the parameters with the least quality across 6 days are colored in *orange*
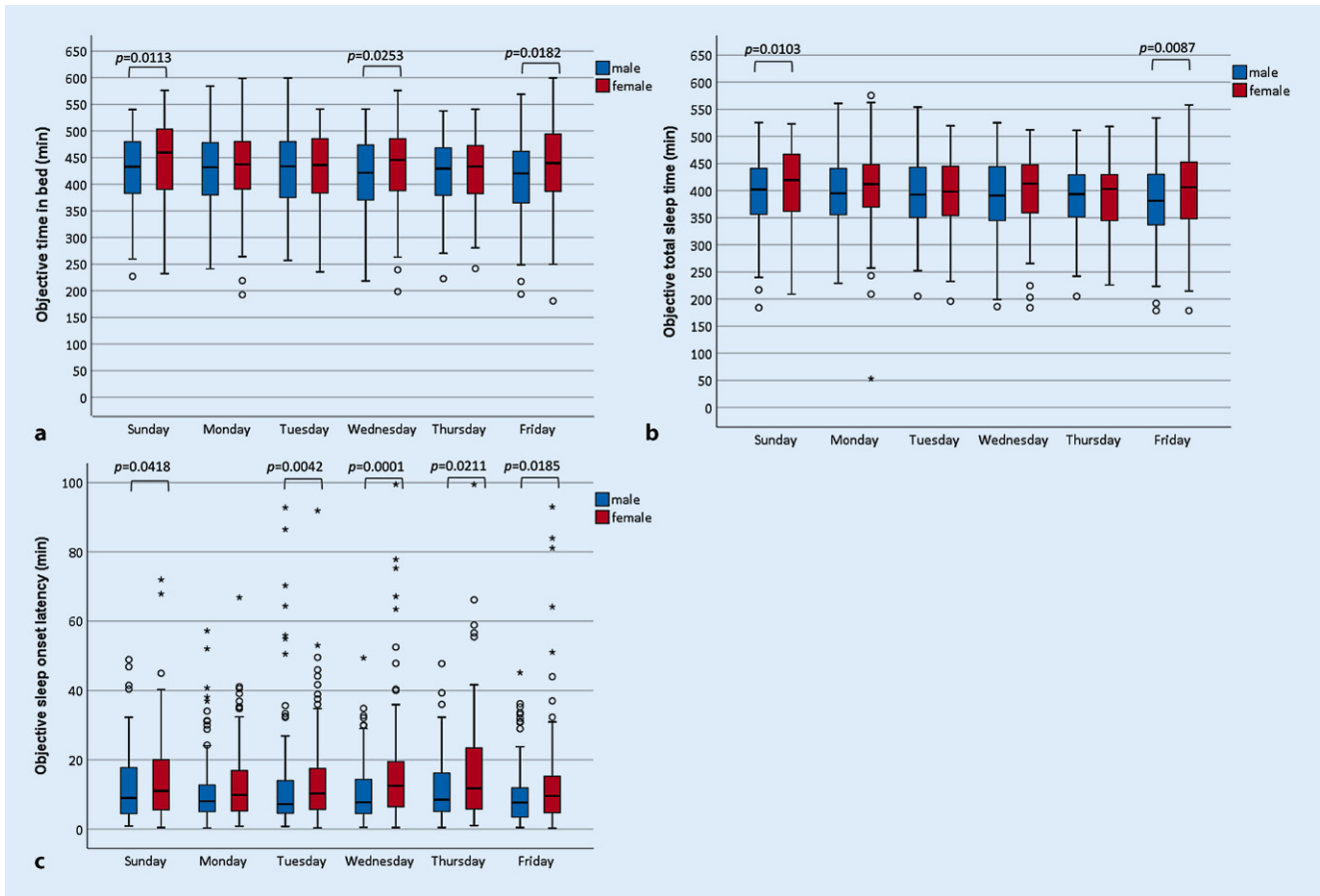
Fig. 4 ▲ Objective sleep parameters for 6 days/nights that differ significantly between female and male participants are shown. Only significant *p*-values are indicated
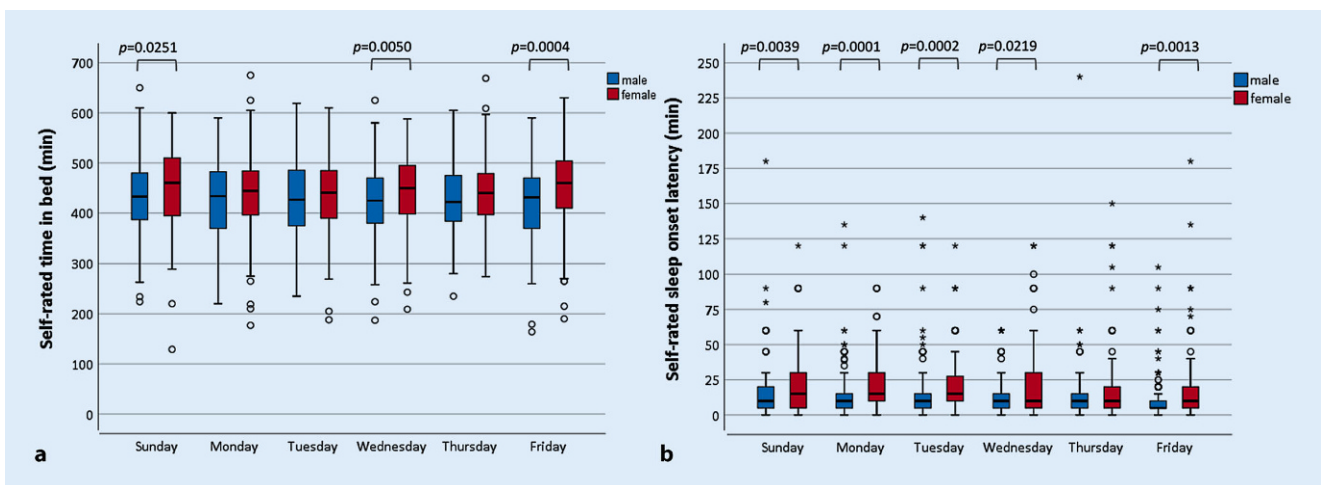
Fig. 5 ▲ Self-rated sleep parameters for 6 days/nights that differ significantly between female and male participants are shown. Only significant *p*-values are indicated
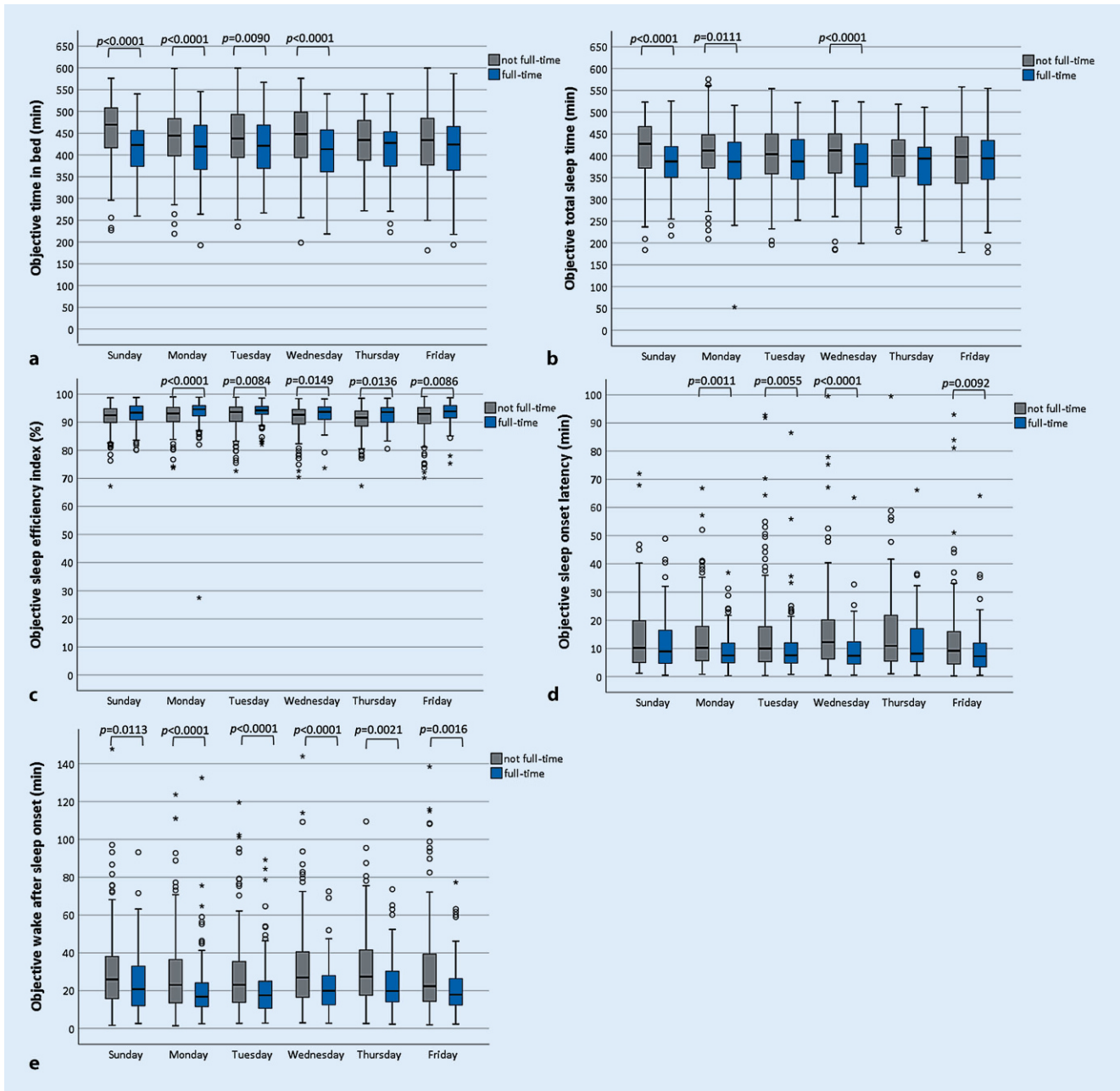
Fig. 6 ▲ Objective sleep parameters for 6 days/nights: differences between fulltime employed participants and not fully employed participants. Only significant *p*-values are indicated
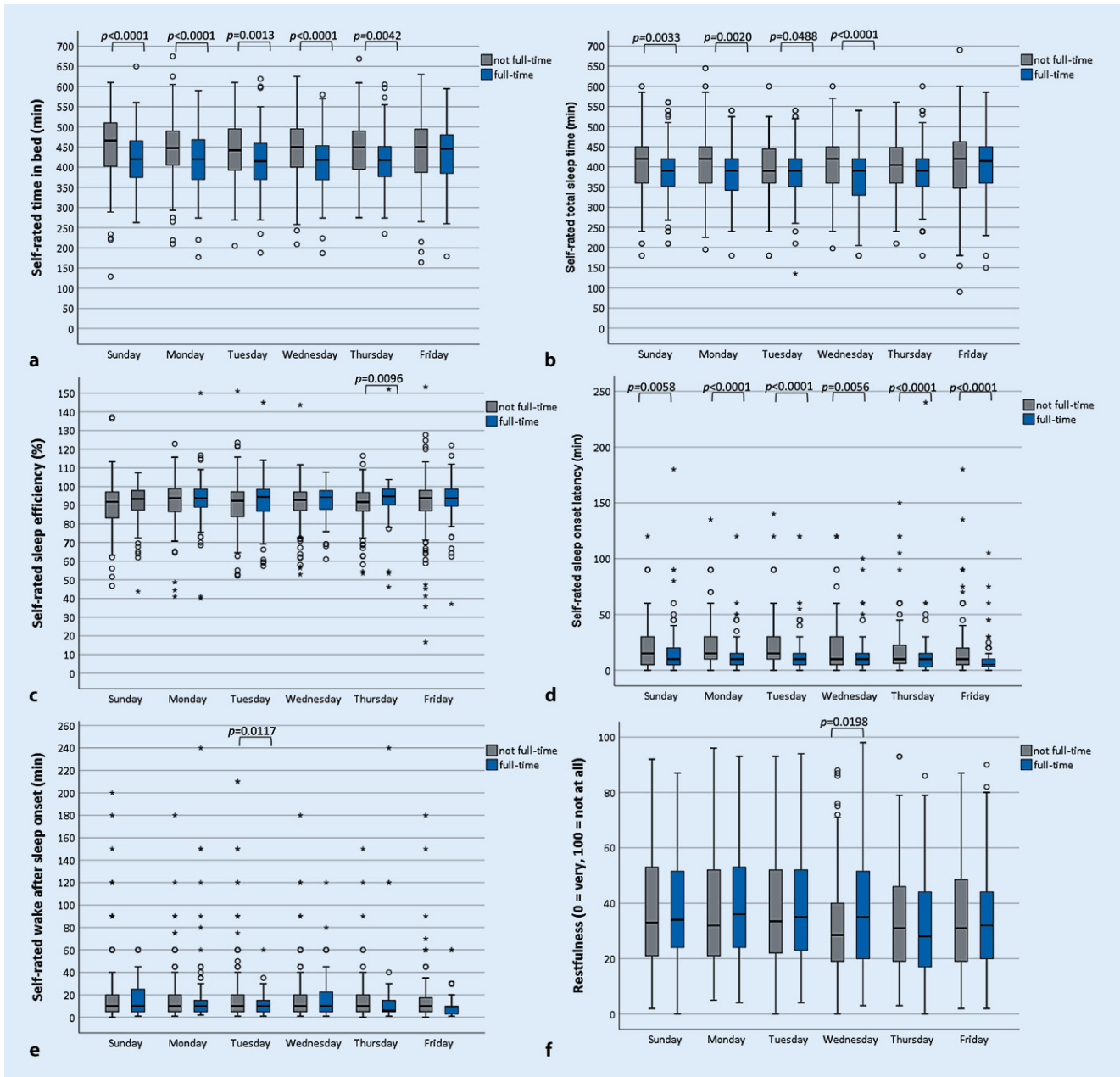
Fig. 7 ▲ Subjective sleep parameters for 6 days/nights: differences between fulltime employed participants and not fully employed participants. Only significant *p*-values are indicated

ysis of data with regard to the effects of day of the week on sleep is not affected by this kind of bias.

Conclusion

The present study shows that in a rural adult population, social jetlag and negative consequences on objective and self-rated sleep quality are small. Nevertheless, accumulated sleep debt across the week may lead to more pronounced negative effects on sleep and wakefulness than possible effects of social jetlag.

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Compliance with ethical guidelines

Conflict of interest. C. Sauter, H. Dorn, and H. Danker-Hopfe declare that they have no competing interests.

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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