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Evaluation of Smartphone Usage as a Predictor of Social Jetlag in University Students

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Abstract

Background: Individual sleep and activity patterns show large variations and are interfered considerably by social schedules. Social jetlag (SJL) is the difference between intrinsic circadian rhythm and extrinsically enforced sleep-wake cycle. However, little is known about the variables affecting the severity of SJL. **Methodology:** We evaluated whether sleep- or smartphone-related variables affected the severity of SJL among college students in India. A total of 1175 students from medicine, dental, engineering, paramedical, and other colleges in Gujarat, India, completed a web-based survey. The survey included demographic questions and questions from the Smartphone Addiction Scale-Short Version (SAS-SV), reduced Horne and Ostberg Morningness-Eveningness Questionnaire (rMEQ), and Munich Chronotype Questionnaire (MCTQ). The responses to the MCTQ determined SJL scores. **Results:** Outcomes from multiple linear regression analysis indicated that the sleep length on free-day (B = 0.42), chronotypes (B = 0.44, B2 = 0.40) maximum smartphone usage time after waking up (B = 0.92), smartphone addiction severity (B = –0.01) and free-day sleep onset range (B = –0.02) significantly predicted SJL scores ($P < 0.03$). The SJL severity was 0.42 and 0.40 units greater in individuals with morning-type and evening-type, respectively, compared to the neutral-type rMEQ category. The SJL severity was 0.92 units greater in individuals whose smartphone usage was maximum right after waking up compared to those whose usage was maximum during other times of the day. Every unit increase in SAS score decreased SJL by 0.01 units. **Conclusion:** These results indicate that SJL severity is affected by several factors, which can be targeted for developing interventions for reducing SJL among college students in India.

Keywords: Chronotype, circadian misalignment, smartphone addiction, social jetlag

Introduction

The circadian rhythm is a natural, self-sustaining oscillating cycle of physiological processes that functions in anticipation of temporal variations in environment occurring with the 24-h rotation of Earth.[1,2] This cycle is entrained to the external environment by numerous natural and artificial time-giving cues namely "zeitgebers" like light, sound, etc.[3] This circadian rhythm of an individual manifests as his "chronotype" and it determines the phase of entrainment of the body clock during any time of the day. Humans show well-documented inter-individual differences in organizing their behavior within the 24-h day, cardinally in their preference of timing of sleep and wakefulness; in accordance with their chronotypes.[4]

The modern human environment contains many zeitgebers such as artificial lights, presence of personal use electronics like smartphones, tablets and computers, haphazard eating habits, social and professional obligations. These serve as circadian disruptors and are proven to adversely impact our sleep cycles.[5] The discrepancy between the natural sleep-wake cycle as manifested by a person's chronotype and that dictated extrinsically by environmental pressures and disruptors was defined as social jetlag by Wittman *et al.* in 2006.[6] It is a chronic stress factor linked to a variety of adverse health states such as excessive daytime sleepiness, depression, insomnia, obesity, metabolic syndrome, accelerated atherosclerosis, and cardiovascular diseases.[7]

The smartphone is a crucial component of today's lifestyle, serving as an important tool of round-the-clock connectivity,

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productivity as well as offering a mode of entertainment in the form of gaming, surfing, streaming, etc. The use of smartphones is thereby, a complex activity motivated by social, professional as well as pleasure-seeking behaviors with an addictive potential. Therefore, problematic smartphone use in terms of time spent and increasing frequency of use may tend to a behavioral disorder like smartphone addiction.[8] The smartphone screens emit significant quantities of short-wavelength "blue-light" radiation known to adversely impact sleep.[9,10] The smartphone is thus a significant source of artificial light with an addictive potential whose overuse may add to a person's social jetlag.

It is well established that young adults studying in professional courses are exposed to a psychosocial milieu that makes them susceptible to sleep- and addiction-related disorders.[9] Roberts *et al*. in 2014. found that college students spent up to 9 h daily on their cell phones. This may place them in the group whose social jetlag is highly affected by this modifiable risk factor.[11]

Therefore, our objective was to conduct a proof of concept study to assess the magnitude of social jetlag in college students and to analyze the role of Smartphone use pattern as its predictor using relevant questionnaires.

Methodology

This study was approved by Institutional Ethics Committee with reference number NHLIRB/2019/October/16/no. 11 obtained on October 16, 2019.

The study was conducted in accordance with the Declaration of Helsinki. In a cross-sectional design, a digital questionnaire was personally administered to our subjects, from February 1st to 5th 2020. Target population consisted of 17–25-year-old college students studying in professional undergraduate courses in Ahmedabad city. Those volunteers understanding English and possessing smartphones were included while those who self-reported as diagnosed cases of any sleep/substance abuse disorder or those giving incomplete entries were excluded. Before administering the questionnaire, participants were briefed about the aims of the study, verbal consent was taken and anonymity was assured to all.

The survey consisted of 30 questions, including 2 subjective questions and other standardized questionnaires namely the Smartphone addiction Scale-Short version (SAS-SV),[12] Reduced Morningness-Eveningness Questionnaire (rMEQ)[13] and 4 questions derived from the Munich Chronotype Questionnaire (MCTQ).[14] It was prevalidated in our target population by a pilot study of $n = 10$ students.

Questions derived from MCTQ were used for calculating Social jetlag (SJL).[14] Participants were asked to select the range of their sleep onset and offset times for work days and free days. Midpoints of these ranges were calculated, and the time intervals between them taken as the respective sleep durations for those days. Midpoints of respective sleep intervals on work (MSW) and free (MSF) days were thus obtained, and their difference was considered as SJL (in hours).[14]

SAS-SV consists of 10 questions, each scored on a Likert scale from 1 to 6; its total score ranges from 10 to 60, which positively correlates with a propensity to develop smartphone addiction.

RMEQ is a 5-item questionnaire used to assess a person's chronotype. The cut-offs for chronotype were as follows: evening type: <12; neutral type: 12–17; morning type: >17. Thus higher score implies greater "morningness."[13]

SAS-SV score, rMEQ score, chronotype, SJL, sleep length (in hours) on free and workdays were thus obtained. This dataset was analyzed using IBM-SPSS (New York, United States).

To limit the impact of selection bias, students across professional disciplines were included. In addition to the use of standardized tools, students were assured of anonymity and counseled that there were no "correct" answers in the survey to limit measurement bias. The assessment of subjects' chronotype by rMEQ and addition of subjective questions with open-ended options in the survey was done to account for potential confounders.

Utilizing Kwon *et al*. the mean of SAS-SV scores was taken as 25.26 with a standard deviation of 10.78 and assuming the population mean of 26.1 for 5% level of significance and 80% power, the required sample size was 1033.[12]

Considering a dropout of 10%, the sample size of $n = 1150$ was arrived upon.

Statistical analysis

Paired t-test was done to assess for a significant difference in sleep lengths on free and working days. ANOVA test was done to assess the distribution of rMEQ and SAS-SV scores with respect to age.

A direct entry strategy was used for building and assessing the multivariable linear regression model. Model fit was assessed using the F test, and its level of significance set at $\alpha = 0.05$

The model had SJL as the dependent variable respectively. Sleep Length on Free day, Sleep length on Workday, Morning chronotype, Evening chronotype, Gender, Sleep onset and offset ranges on workdays and free-days, Self-reported Maximum smartphone usage immediately upon waking-up were the independent variables used.

Results

A survey was conducted on $n = 1279$ students of which 104 forms were excluded; hence final data analysis was conducted on $n = 1175$ entries, of which 474 were males (40.34%) and 701 were females (59.66%). The distribution of demographic details is given in Table 1.

A total of 1132 participants reported an inability to follow their desired sleep routines. Figure 1 illustrates the reasons reported by these students for the same. Of these, 63.52% felt a single factor was responsible while the rest felt a combination of factors prevented them from desired sleep routines. Overall, 499 (42.4%) students reported Smartphone/electronics usage interfered with their sleep routines.

Neutral chronotype was the most common followed by extreme chronotypes [Table 1].

The mean SAS-SV score was 29.98 ± 9.84. Using the cut-off score of 31 for male and 33 for female, we found that $n = 448$ students (38.12%) maybe classified as addicted to smartphone. Neither SAS-SV nor rMEQ scores were differently distributed across age (Kruskal–Wallis test, $P > 0.05$).

Sleep lengths were found to be significantly lower in work-day as compared to free days (Wilcoxon's $P = 0.0001$). Mean free-day sleep was 8.4 ± 1.65 h while that on work-day was 7.19 ± 1.55 h. Four hundred and six students (34.5%) were found to over-sleep (>9 h) on free-day while 525 (44.7%) students reported under-sleeping (<7 h) on work days. Total 1157 subjects had social jetlag; mean SJL was 1.45 ± 0.93 h with $n = 757$ students having an SJL ≥1 h.

SAS-SV score was found to be significantly and positively correlate with Self-reported maximum smartphone use on waking up, sleep onset and offset ranges for both freeday and workdays, evening chronotype and sleep length on workdays but not with workday sleep length or morning chronotype [Table 2].

Regression model for predictors of social jetlag

Table 3 presents the multiple linear regression calculated to predict social jetlag severity based on sleep lengths on workday and freeday, smartphone addiction severity, maximum smartphone usage time, chronotype, gender and sleep onset and offset range. A significant regression was found ($F_{11,174} = 28.178$, $P < 0.00001$), with an R^2 of 0.21. The sleep length on freeday, rMEQ categories, maximum smartphone usage time after waking up (self-reported), freeday sleep onset range, and smartphone addiction severity score significantly predicted social jetlag score ($P < 0.03$). There was no significant difference in the social jetlag severity between the sleep length on workday, men and women, workday sleep onset and offset range and freeday sleep offset range.

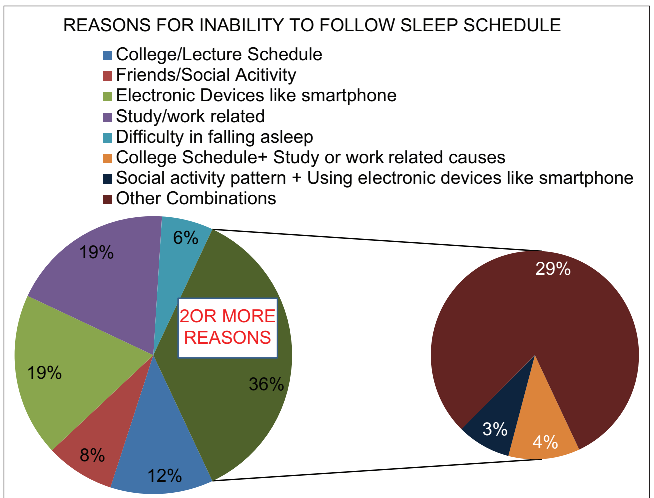

Figure 1: Students' reasons for their inability to follow a desired sleep schedule

Discussion

Most of the students expressed inability to follow desired sleep schedule; Smartphone usage and work-related causes being reported as the leading causes for the same. Effects of artificial light exposure on human circadian rhythm are well established[15] and our study highlights the disruptive potential of light-emitting electronics as artificial zeitgebers. Furthermore, professional rather than social commitments appear to be playing a subjectively more prevalent role in disrupting the college students' sleep schedules. This brings

Table 1: Demographics

	Males	Females
n	474	701
Mean age	19.76±1.62	19.52±1.59
rMEQ category		
Morning type	105	157
Neutral type	307	481
Evening type	62	63
rMEQ score	15.12±3.12	15.36±3.00
SAS-SV score	31±9.50	29±9.74
SJL (h)	2.04±1.78	2.20±1.69
Sleep length workday (h)	7.10±1.65	8.20±1.70
Sleep length freeday (h)	7.26±1.48	8.58±1.60
Sleep onset range (min)		
Workday	120.80±84.40	118.65±86.27
Freeday	120.82±87.21	113.13±82.70
Sleep offset range (min)		
Workday	90.39±93.13	78.69±84.87
Freeday	118.37±96.45	106.87±98.16
Percentage addicted to smartphone	45.30	33.38
<7 h workday sleep (%)	46.60	20.20
>9 h freeday sleep (%)	38.20	30.50

rMEQ: Reduced morningness-eveningness questionnaire, SAS-SV: Smartphone Addiction Scale-short version, SJL: Social jetlag

Table 2: Results of Pearson's correlations with Smartphone Addiction Scale-short version score

	r	*P* (one-tailed)	Inference
Maximum smartphone usage time	0.195	0.000	Significant
Freeday sleep onset range	0.092	0.001	Significant
Workday sleep offset range	0.086	0.002	Significant
Freeday sleep offset range	0.079	0.003	Significant
Evening type chronotype	0.076	0.005	Significant
Sleep length weekend	0.056	0.028	Significant
Workday sleep onset range	0.051	0.04	Significant
Sleep length workday	−0.016	0.291	Not significant
Morning type	−0.002	0.478	Not significant

into focus the need for personal and institutional interventions aimed at synchronizing the students' sleep cycles with the rigors of their professional demands.

Compared to neutral chronotypes, morning-type was a stronger predictor of SJL hours than evening-type [Table 3]. Most of the students surveyed belonged to the neutral chronotype [Table 1], usually entrained for a sleep offset time from 06.30 h to 08.30 h and sleep onset time from 22.45 h to 00.45 h;[16,17] allowing them to adapt most to the vagaries and demands of their daily schedules, thereby minimizing their social jetlag. Owing to their less versatile sleep-wake timings, extreme chronotypes are susceptible to disruptive zeitgebers and reflected in their lower prevalence overall [Table 1].

The young adults engage in a lot of activities later in the day such as night-time studying, late-night socializing, gaming, use of stimulants like caffeine, night-time alcohol use.[18] A shift toward "eveningness" is perhaps an adaptation by their circadian rhythm, enabling them to fulfill their social and professional roles with greater ease and thereby reducing their SJL as compared to morningness.

More than 38% of our sample were "addicted" to smartphones. While this prevalence is lower than that documented by Kumar *et al*. 2019;[19] the mean SAS-SV score was found to be 29.98 ± 9.84, close to the cut-offs qualifying as addiction, underlining how the target population maybe classified as "high risk" for Smartphone addiction and necessitating the dissemination of awareness regarding the same in them.

Age or gender did not affect rMEQ ($P > 0.05$), SAS-SV ($P > 0.05$) or SJL [Table 3]. This implies a homogenous impact and ubiquity of the given circadian stressors students within our sample.

Free-day sleep length correlated positively with SAS-SV score [Table 2]. Adverse effects of Smartphone overuse are mediated by impaired sleep quantity.[20] Thus, oversleeping on free-day appears to be a compensatory mechanism for the same.[21]

Free-day sleep length was a positive predictor of SJ [Figure 2]. Homeostatic sleep pressure modulates the phasic transition of the circadian rhythm[18] and this appears to drive oversleeping on free days in response to circadian misalignment.[21,22] Sleep onset and offset ranges on workdays did not predict SJL and despite the higher number of workdays compared to free days, work-day sleep length did not correlate with SAS-SV [Table 2], nor was a predictor of SJL [Table 3]. The impact of artificial zeitgebers and resultant daily sleep deficit may not be high enough per work-day causing it to manifest only upon accumulation to a certain magnitude on freedays. Besides, professional zeitgebers of workdays are likely to have consistent, uniform timings as compared to the vagaries of free-days.[22] Moreover, free-day offers an opportunity to recover from accumulated sleep deficit and to proactively correct circadian misalignment.[6,22] Hence, free-day sleep length appears to be a quantifiable marker of underlying SJL and SAS-SV score. The sleep onset range before freeday but not sleep offset range on the free-day was found to negatively predict SJL [Table 3]. Hence the above discussed compensatory effort may manifest as proactive modification of time of going to bed in anticipation of a free day rather than a reactive prolongation of time to wake up on free-day.

Over 98% of our sample suffered from SJL, with 64% reporting SJL ≥1 h (mean 1.45 ± 0.93 h). These values are greater than those reported by Sinha *et al*. 2020 in Indian subjects aged 18–31 years during the COVID-19 lockdown.[16] Rigorous schedules of the prelockdown era maybe implicated in causing a greater circadian misalignment than that under lockdown

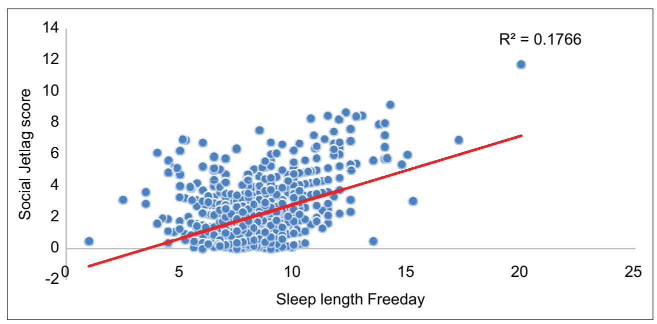

Figure 2: SJL scores as a function of sleep length on free-days

Table 3: Social jetlag severity multiple linear regression parameter estimate

	Unstandardized beta coefficient	SE	Standardized beta coefficient	*T*	*P*
Sleep length on freeday	0.42	0.03	0.40	14.59	0.0001
Morning type	0.44	0.11	0.11	4.01	0.0001
Max smartphone usage time after waking up	0.92	0.27	0.09	3.46	0.001
Evening type	0.40	0.15	0.07	2.63	0.009
Smartphone addiction severity score	−0.01	0.005	−0.06	−2.31	0.02
Sleep length on workday	0.04	0.03	0.03	1.22	0.22
Gender	0.001	0.09	0.000	0.01	0.99
Workday sleep onset range	0	0.001	0.02	0.73	0.48
Workday sleep offset range	0	0.001	0.02	0.60	0.55
Freeday sleep onset range	−0.002	0.001	−0.10	−3.05	0.002
Freeday sleep offset range	0	0.001	0.02	0.65	0.52

SE: Standard error

when people, largely free of extrinsic zeitgebers were enabled to exercise greater control over their sleep-wake cycle despite the disruptive psycho-social effects of the pandemic.

Sleep onset and offset ranges on all days correlated positively with SAS-SV score [Table 2]; leading to a vicious cycle of higher smartphone use inducing higher irregularity in sleep timings and vice-versa. This reinforces its previously established detrimental role on sleep.[23]

Participants who self-reported their maximum smartphone usage as just after waking up had higher SJL [Table 3] by 0.923 h (55 min) and higher SAS-SV [Table 2] score as compared to others. The use of smartphone earlier in the day, is perhaps a reflection of the salience and intensity of smartphone addiction.[24,25] Thus, the use of smartphone immediately upon waking up is a strong behavioral predictor of SJL and Smartphone addiction.

Majority of the students self-reported their time of maximum smartphone usage as that during the later half of the day during evening and night but not immediately prior to sleep [Figure 3]. By stimulating the retinohypothalamic tract, blue-light emitting electronics like smartphones are known to cause prolonged circadian disruption and suppress serum melatonin levels[26] for hours after their use.[1,27] This implies an entrained circadian shift toward eveningness due to smartphone use. The prevalence of higher SAS-SV score and addiction-related behaviors in evening types have been discussed elsewhere;[28] and we too found evening but not morning chronotype to correlate with higher SAS-SV score [Table 2].

SAS-SV was found to negatively predict SJL [Table 3] as well as to positively correlate with eveningness on rMEQ [Table 2]. As discussed above, the delayed phase of circadian entrainment in college students may serve to reduce their circadian misalignment. Thus we deduce that reduction in SJL by increased SAS-SV might be mediated by increased eveningness. Notwithstanding their detrimental effects on sleep,[23,29] smartphones appear to play the role of unique light-emitting zeitgebers in helping the students to adapt better to their social times.

Due to our large sample size and use of prevalidated standardized tools, our findings maybe applicable to the general population having a similar demographic profile.

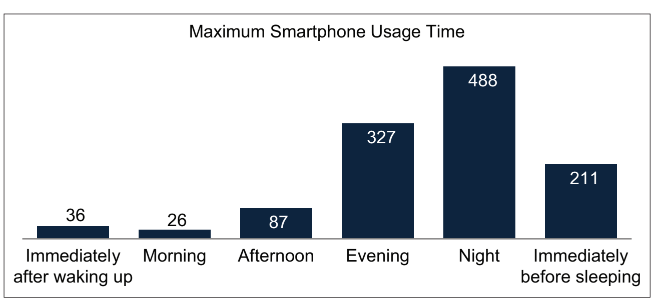

Figure 3: Maximum Smartphone Usage Time of the students during the day

However, our study was not without limitations. First, the concept of problematic smartphone use is itself debatable,[30,31] since they are considered essential components of our life whose use is complexly motivated by professional, personal, and pleasure-seeking reasons. Secondly, we did not account for the exact number of free days and workdays in our subjects, or any confounding effect it may have on SJL. Third, sleep disorders and substance abuse disorders may have been under-reported by the subjects. Finally, recall bias and personal errors by participants while interpreting questions are implicit to any questionnaire-based survey and may have affected our data.[32]

Conclusion

College students seem to adapt to their social times by increasing their "eveningness." Sleep habits on free days but not work days appear to predict SJL. The use of smartphone in the morning is a significant behavioral predictor of SJL and SAS-SV score. Smartphones are important zeitgebers and their use decreases circadian misalignment in college students by an increase in eveningness. These variables could be targeted for developing interventions for reducing SJL among college students in India.

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Conflicts of interest

There are no conflicts of interest.

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