ORIGINAL ARTICLE

Digital addiction, sympathovagal imbalance and neurophysiologic cognitive assessment using evoked potentials in medical students

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Abstract

Background: Digital addiction is becoming prevalent globally. Autonomic imbalance in the form of sympathetic dominance is observed among digital addiction. Correlation between sympathovagal imbalance and cognition using evoked potentials is least explored among medical students. *Aim and Objectives:* To evaluate and find the correlation between digital addiction, sympathovagal imbalance, and cognition among medical students. *Material and Methods*: The cross-sectional study was conducted in medical students after project approval from the Indian Council of Medical Research. Internet addiction was evaluated with Young's Internet Addiction Scale and smartphone addiction questionnaires. Sympathovagal balance was evaluated using the Heart Rate Variability (HRV) and cognition evaluated by evoked potential P300. *Results:* Out of 130 participants, smartphone addiction was prevalent among 51.54%, with no normal users based on internet addiction scores. Linear HRV analysis reported significant increase in LF/HF ratio among the Group II individuals (moderate and severe addicted) compared to Group I individuals (mild addicted) ($p = 0.01$). Nonlinear analysis of HRV reported a significant decrease in SD1 and SD2 among Group II participants, with $p = 0.01$ and $p = 0.02$ respectively. Cognition assessment using event related potentials P300 latency, reported significant increase ($p = 0.04$) among the Group II participants (295.70 ± 13.35) compared to Group I participants (290.39 ± 15.84). Correlation analysis among internet addiction and HRV analysis reported no significant association ($r = 0.02$ and $p = 0.8$). Similarly, cognition evaluated using P300 also showed no correlation with addiction ($r = 0.1$ and $p = 0.26$). *Conclusion:* The current study indicated an alarming rise in internet addiction, increase in P300 latency and autonomic imbalance among the students.

Keywords: Internet addiction, Heart rate variability, Cognition

Introduction

In 2020, World Health Organization (WHO) stated digital technology as a worldwide concern [1]. This is due to increasing usage of internet and online activity leading to a variety of abnormal behaviours. Digital addiction is an umbrella terminology, addressing not only internet addiction, but also refers to trending game addiction and digital media addiction [2]. As per the report of the Ministry of Information and Broadcasting in 2022, India had over 1.2 billion mobile phone users and 600 million smartphone users [3] and technology dependency has increased after the COVID-19 pandemic [4].

Medical college students use smartphones for information retrieval, interactive teaching-learning processes, social interaction, and for entertainment purposes. Digital addiction results in various adverse health issues like sleep disorders, depression, anxiety, and other behavioral disorders [5, 6]. Internet addiction can be evaluated by Young's Internet Addiction Test designed as per the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) [7]. Smartphone addiction

results in decreased academic activities, concentration, and overall performance of the students, and this can be measured with the Smartphone Addiction Scale [8].

Reports indicate that internet addiction affects the autonomic nervous system resulting in sympathetic dominance and a decrease in parasympathetic activity [9]. Heart Rate Variability (HRV) is a non-invasive tool that is widely employed to measure the sympathovagal balance. It is a physiological phenomenon representing time variation in consecutive heartbeats in milliseconds. Greater variation in beat-to-beat interval represents better health and parasympathetic dominance. Autonomic imbalance also is associated with the neural circuitry in the brain, responsible for various attitude and behavioural changes.

Internet addiction results in neurophysiological and characteristic changes in the cognitive domain but the mechanisms are not completely elucidated. These changes may be attributed to neuroplasticity, where rewiring of the neuronal structures in the brain happens due to the continuous assimilation of new information. Though social, attitude, and behavioural changes [10] due to internet addiction are widely explored, cognitive changes are the least explored areas in Indian medical students. So, evaluating subclinical cognition deficits using the neurophysiological marker, "P300", an event-related potential stands justifiable [11].

With these perspectives in mind, it was hypothesized that higher levels of digital addiction would be associated with autonomic imbalance (lower HRV, higher LF/HF) and impaired cognitive processing as reflected by prolonged P300 latency and reduced amplitude among medical students. The aim of the present study was to evaluate digital addiction, sympathovagal balance, and cognition using event-related potentials among medical students and to find the correlation between them.

Material and Methods

Study site and period

The study was undertaken in the research laboratory, Department of Physiology, of our institute.

Study design

It was a cross-sectional study in which MBBS students of age group 18-22 years, using smartphone were included as study participants. Students who do not use smartphones, had any form of mental illness, on regular medication intake (i.e. antibiotics, corticosteroids, antidepressants, benzodiazepines, prophylactic migraine drugs), history of neurological disease, primary or secondary headache were excluded.

Sampling

Sample size estimation was done with OpenEpi Info version 3.03, taking into account power 90% and 5% α error, with internet addiction prevalence from a previous study as 57%, [12] among medical students. The sample size was estimated as 121. With 10% non-response, the sample population was estimated to be 130.

Ethical consideration

Institutional ethical committee approval (SMVMCH-EC/ECO/IL/249/2023) and informed consent were obtained from all participants. A detailed review of medical history through a semi-structured questionnaire and physical examination were performed. Students were assured regarding the confidentiality of the data, and the information obtained pertaining to digital addiction, HRV, and cognitive assessment was used solely for research purposes. The study was approved by Indian Council of Medical Research as Short-Term Student project. (Reference ID: 2023-08086).

Methodology

Digital addiction

Young's Internet Addiction Test, an English version, self-report questionnaire designed by Dr. Kimberly Young was used to diagnose internet addiction. Participants who obtained total scores ranging between 80-100 represents severe addiction, 50-79 moderate addiction, 20-49 mild addiction, and < 20 represents normal users. The questionnaire has been used in the Indian context, has no copyright issues involved, and its reliability, and validity is tested [13].

Smartphone addiction was evaluated using the Smartphone Addiction Scale–Short Version (SAS-SV), which consists of 10 items scored on a Likert scale. The overall score ranges from 10-60. The cut-off value for males is 31 and females is 33. This scale is also pre-tested and validated in the Indian context [14].

HRV recording

The sympathovagal balance was recorded using the Recorders and Medicare System (RMS) Private Ltd., Chandigarh, India. The HRV was recorded for the study participants as per the task force guidelines [15]. After a 15-minute rest period, a 5-minute Electrocardiogram (ECG) was recorded using electrodes with a sampling rate of 500 Hz. The raw ECG data were bandpass filtered (2–40 Hz), and time and frequency domain parameters were evaluated using Kubios HRV analysis software (Finland). Also, non-linear analysis of HRV using Poincare Plot, Standard Descriptors (SD1 and SD2) were carried out.

Cognition assessment using auditory evoked potentials "P300"

P300 was evaluated using the Electromyograph Evoked Potentials machine, RMS private Ltd., Chandigarh, India. The subject was made to sit comfortably; scalp sites were cleaned with spirit and electrodes fixed using the 10-20 international system. Active electrodes were fixed on the vertex (Cz), the ground electrode to the Forehead (Fz) and reference electrodes to right and left mastoid (A1 and A2), respectively. Using headphones, each participant heard rare and frequent tones (1 Hz and 2 Hz, respectively) at 85 decibels in both ears, with frequencies of 20% and 80%. The participant was then instructed to count the rare stimuli loudly. Three hundred stimuli were applied at a rate of one stimulus per second. Two recordings were taken and averaged. P300 wave latency and amplitude were evaluated.

Data analysis

The data entry and statistical analyses were done with Microsoft Excel and OpenEpi Info Software, respectively. Quantitative data has been represented as means with standard deviations and analyzed using student's t-test. Qualitative data has been represented as proportions and analyzed by the chi-square test. The correlation between digital addiction, sympathovagal balance, and cognition were evaluated using Pearson's correlation test. A value of $p < 0.05$ was considered statistically significant.

Results

In the present study out of 130 participants, 67 (51.14%) were males and 63 (48.46%) were females. Participant's mean age was 20.41 ± 1.02 years. The reliability and validity of the questionnaires was confirmed by Cronbach's $\alpha = 0.91$ for Young's Internet Addiction Questionnaire and Cronbach's $\alpha = 0.83$ for Smartphone Addiction Scale.

Out of the 130 study participants, based on the Smartphone Addiction Scale defined cut off value

[14] for males as 31 and for females as 33, it was found that 30% of males and 24.62% of females were addicted. Based on the Internet Addiction Scale scores, it was found that there were no normal users, considering that all obtained scores were above 20. Mild addiction was reported among 71 (54.61%) participants and 56 (43.07%) had moderate addiction and 3 (2.31%) reported severe addiction. The participants were grouped as Group I, n = 71 (mild addiction) and Group II, n = 59 (moderate and severe addiction). (Table 1)

Mobile usage by the male and female participants in hours is represented in Table 2. Chi-square test reports value of 1.604 and p = 0.66 representing no association between mobile usage and gender.

Linear HRV analysis reported significant increase in LF/HF ratio among the Group II individuals compared to Group I individuals (p = 0.01). Non-Linear analysis of HRV reported a significant decrease in SD1 and SD2 among Group II participants, with p = 0.01 and p = 0.02 respectively (Table 3).

Cognition assessment using event related potentials P300 latency, reported significant increase (p = 0.04) among the Group II participants (295.70 ± 13.35) compared to Group I participants (290.39 ± 15.84) as represented in Figure 1. P300 amplitude expressed in millivolts showed no significant difference among the two groups, Group I (4.52 ± 2.79) and Group II (4.49 ± 2.92) with p = 0.95.

Correlation analysis among internet addiction and HRV analysis reported no significant association (r = 0.02 and p = 0.8). Similarly, cognition evaluated using P300 also showed no association with internet addiction (r = 0.1 and p = 0.26). (Table 4)

Table 1: Young's Internet Addiction Scale among the study participants (n = 130)

Groups	Young's Internet Addiction Scale	Number of students n (%)
Group I	**Normal Users**	0 (0%)
	Mild addiction	71 (54.61%)
Group II	**Moderate addiction**	56 (43.07%)
	Severe Addiction	3 (2.31%)

Table 2: Sex wise distribution of mobile usage among study participant

Mobile usage in hours	Males n (%)	Females n (%)	Total n (%)
Less than 4 hours	11 (8.45)	12 (9.23)	23 (17.69)
4-6 hours	32 (24.62)	28 (21.54)	60 (46.15)
6-8 hours	15 (11.54)	18 (13.85)	33 (25.38)
More than 8 hours	9 (6.92)	5 (3.85)	14 (10.78)

Chi square test =1.604, p value =0.66 (Not significant)

Table 3: Linear and non-linear HRV analysis among the study participants (n = 130)

Parameters	Group I (n = 71)	Group II (n = 59)	*p*
Mean RR	829.92 ± 75.64	788.38 ± 98.66	0.007*[S]
SDNN	67.54 ± 39.37	69.12 ± 52.87	0.8 [NS]
Mean heart rate	74.12 ± 9.45	78.27 ± 11.5	0.02*[S]
LF/HF ratio	0.96 ± 0.69	1.5 ± 1.78	0.01*[S]
SD1	55.64 ± 19.75	47.28 ± 18.39	0.01*[S]
SD2	81.4 ± 12.88	74.93 ± 19.38	0.02*[S]

RR: RR interval in ECG; SDNN: Standard deviation of normal-to-normal interval; LF: Low frequency; HF: High frequency; SD: Standard Descriptors

Table 4: Pearson's correlation among digital addiction, HRV and P300

Parameters	Young's Internet Addiction Scores	
	r	p
LF/HF ratio	0.02	0.8 NS
SD1	0.05	0.57 NS
SD2	0.04	0.65 NS
P300 latency	0.1	0.26 NS

LF: Low frequency; HF: High Frequency; SD: Standard Descriptors

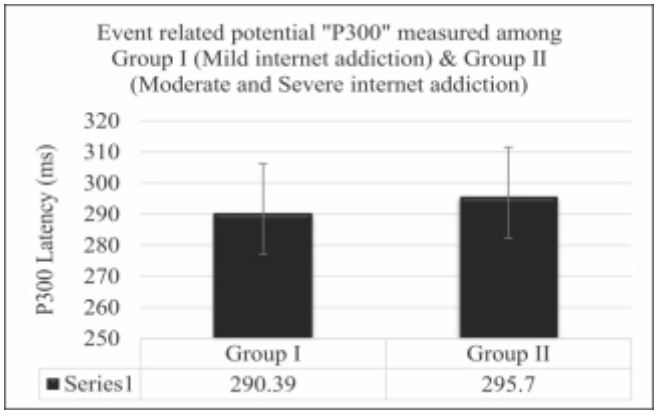

Figure 1: Cognition measured using "P300" among Group I and Group II participants (p=0.04)

Discussion

In our study the prevalence of mild internet addiction was reported as 54.61%, moderate addiction as 43.07% and severe addiction as 2.31% with mean age of the participants as 20.41 ± 1.02 years. In a previous study conducted in the same institute in 2015, there were 43.2% normal users, 32.8% had mild addiction, 20.8% had moderate addiction and 2% had severe addiction [16]. This study found that there are no normal users, which represents an issue of concern. Recent Indian and international data confirm that smartphone addiction has become highly prevalent among medical and university students with pooled estimates of 'addiction' often exceeding 40–50% depending on the scale and cut-off used. A 2025 systematic review of Indian MBBS students reported a high pooled prevalence of smartphone addiction and emphasized its association with sleep disturbances and academic difficulties, supporting the concern that our finding of 'no normal users' reflects a real epidemiological shift rather than a sampling artefact [17]. Smartphone addiction was observed in 40.5% of the students, with a significantly higher prevalence among males. Students with smartphone addiction exhibited poorer academic performance, disturbed sleep patterns, higher stress levels, and reduced overall well-being. Multivariate analysis revealed stress (AOR = 31.55) and poor sleep quality (AOR = 2.46) as the strongest predictors of smartphone addiction [18]. Continuous smartphone use was also found to be associated with various health problems, including headaches, eye dryness, earache, fatigue, and musculoskeletal manifestations [19]. The current study reports that there was no significant gender influence on the mobile usage. Based on the Smartphone Addiction Scale, 30% males and 24.62% females were addicted to smartphone. A recent study in Taiwan by Wu in 2023, reports no correlation between gender and smartphone addiction, but a positive correlation was seen between smartphone addiction and interpersonal attachment [20].

Linear HRV analysis showed a significant increase in mean HR and LF: HF ratio among the Group II (moderate and severe addiction group) compared to the Group I (mild addiction group) indicating sympathetic dominance in group II. Similarly, non-linear HRV analysed by Poincare plot descriptors, SD1 and SD2 showed a significant decrease among the Group II individuals compared to Group I reflecting sympathetic dominance and fall in vagal activity. Similar reports of sympathovagal imbalance are also reported by Lin *et al.* in 2014 among 240 school going children with digital addiction [21]. Other studies conducted in various population also reports of sympathetic overactivity and parasympathetic inhibition among internet addiction disorders [22-24]. Altered sleep behaviour and insomnia among internet addicts has been linked to autonomic imbalance [25].

Lower HRV and higher LF/HF ratios in our more addicted group are consistent with the broader literature linking digital overuse to sympathetic predominance and reduced vagal control. A randomized trial in university students showed that even reducing smartphone use can transiently lower HRV, interpreted as a physiological withdrawal-type response despite subjective improvement in stress and mood. Together with a 2024 case–control study in Chinese adults showing that habitual smartphone addiction was correlated with coronary

artery disease, plausibly mediated by chronic autonomic dysregulation and circadian disruption, our findings in young adults may represent an early functional stage of the same pathophysiological continuum [26].

In the current study, cognition assessment using auditory evoked potentials, P300 reported a significant increase in the latency among the Group II (moderate and severe addiction group) compared to the Group I (mild addiction group). P300 amplitude among the Group II was reduced though it was not statistically significant. The alterations observed in P300 latency and amplitude indicate a delayed processing of information in individuals with addiction. This delay may be from slower reaction times, possibly caused by increased difficulty in distinguishing between different stimuli. Another study conducted by Ge *et al.* in 2011 on internet addicts reported increased P300 latency which returned to normal values after they completed a three-month Cognitive Behavioural Therapy (CBT) program [27]. A review conducted by Hao *et al.* in 2023 showed that internet addiction caused abnormal changes in the brain structure and function, thereby reducing the dopaminergic system activity and limiting oxygen utilization and functional connectivity in brain [28]. A recent systematic review conducted by Mendez *et al.* in 2024 revealed that smartphone and internet addictions were associated with impairments in cognitive control related to reward processing (anterior cingulate cortex, insula, amygdala) and executive function (dorsolateral prefrontal cortex, frontal, parietal lobes) in adolescents and young adults [29].

Recent umbrella and systematic reviews indicate that existing interventions for digital addiction (CBT, psychoeducation, digital detox, and exercise-based programs) produce modest but significant improvements in addiction severity and can partly normalize autonomic and neurocognitive parameters, although the overall quality of evidence remains low. Incorporating screening for digital addiction, brief counselling, sleep hygiene, and structured physical activity into student wellness programs may therefore be a pragmatic strategy in medical colleges [30].

In our current study, no correlation was established between internet addiction and HRV parameters or P300 latency. The probable reason could be smaller sample size and moreover, this was a cross-sectional study so, the exact link and physiological basis of sympathovagal imbalance and cognition deficit among the internet addicts couldn't be established. Future studies with larger sample size, evaluating laboratory markers of oxidative stress and other neuroimaging studies can be planned to get a better understanding.

Conclusion

The study indicated an alarming increase in the internet addiction in the medical students. Deranged autonomic function and cognition among the addicted group require early planning of prevention and treatment strategies, as this may impair academic performance and learning abilities. The study will be extended to all medical students, and awareness sessions on "Digital Addiction" will be organized for them.

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