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Original Research Article

Assessment of Heart Rate Variability in Young Adults with Smartphone Overuse

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Abstract:

Background: Excessive smartphone use has emerged as a behavioral concern among young adults and may influence autonomic nervous system regulation. Heart rate variability (HRV) provides a noninvasive measure of cardiac autonomic function and can detect early autonomic imbalance before overt clinical disease. This study assessed HRV in young adults with smartphone overuse compared with non-overusers.

Material and Methods: A cross-sectional comparative study was conducted among 150 apparently healthy adults aged 18–25 years. Participants were categorized into smartphone overuse (n = 75) and non-overuse (n = 75) groups using the Smartphone Addiction Scale–Short Version. Short-term resting HRV was recorded under standardized conditions using a 5-minute supine protocol. Time-domain and frequency-domain HRV parameters were analyzed. Group comparisons were performed using appropriate parametric or nonparametric tests. Multivariable linear regression was used to examine independent associations between smartphone overuse and HRV indices after adjustment for potential confounders.

Results: Baseline demographic characteristics were comparable between groups; however, smartphone overusers had significantly higher resting heart rate and shorter sleep duration. Time-domain analysis showed significantly lower mean RR interval, SDNN, RMSSD, and pNN50 in the overuse group (all $p < 0.01$). Frequency-domain analysis demonstrated reduced total power and high-frequency power, along with a significantly higher LF/HF ratio among smartphone overusers ($p < 0.01$). After adjustment for age, sex, body mass index, sleep duration, physical activity, caffeine intake, and resting blood pressure, smartphone overuse remained independently associated with lower RMSSD, SDNN, and HF power, and a higher LF/HF ratio.

Conclusion: Smartphone overuse in young adults is independently associated with reduced heart rate variability, indicating diminished parasympathetic activity and altered sympathovagal balance, even in an otherwise healthy population.

Keywords: Smartphone Overuse; Heart Rate Variability; Autonomic Nervous System; Young Adults; Parasympathetic Activity.

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Introduction

Smartphones are now embedded in education, social interaction, and daily planning, particularly among young adults. Alongside these benefits, a subset of users develops a maladaptive pattern characterized by impaired control over use and continued engagement despite negative consequences—often described as problematic smartphone use or smartphone overuse. In university populations, systematic evidence indicates that problematic smartphone use is common and is consistently associated with adverse psychological outcomes, including depressive and anxiety symptoms [1]. Sleep disruption is another frequently implicated pathway: an updated systematic review and meta-analysis of electronic media use reported significant associations with poorer sleep outcomes, with problematic use showing stronger relationships with sleep problems than general use [2]. Given that sleep and affective states are tightly linked with autonomic regulation, these behavioral patterns may have measurable physiological correlates.

Heart rate variability (HRV) is a noninvasive marker of cardiac autonomic modulation, derived from the temporal variation between consecutive normal-to-normal heartbeats. Standardized guidance recognizes HRV as a practical tool for quantifying autonomic balance using time-domain and

frequency-domain indices [3]. Contemporary overviews further emphasize that short-term (≈5-minute) resting HRV can capture vagally mediated indices (e.g., RMSSD, HF power) relevant to stress regulation and health-related autonomic function [4]. As such, HRV offers a physiologically grounded approach to evaluate whether smartphone overuse is associated with autonomic shifts in otherwise healthy young adults.

Evidence linking excessive technology-related behaviors with autonomic dysregulation is accumulating. In school-aged children, internet addiction has been associated with lower parasympathetic indices (including reduced HF-related measures) and relatively higher sympathetic activity compared with nonaddicted peers [5]. In healthy adults, longer daily mobile phone use has been associated with reduced time-domain HRV indices (including RMSSD and pNN50) and a higher LF/HF ratio, suggesting altered sympathovagal balance [6]. However, data focused specifically on smartphone overuse as a behavioral phenotype—defined using validated screening instruments and examined in young adult cohorts under standardized short-term HRV conditions—remain comparatively limited.

The Smartphone Addiction Scale–Short Version (SAS-SV) provides a concise, validated measure with sex-specific cutoffs proposed for identifying individuals at higher risk of smartphone addiction/overuse [7]. Using this instrument, the present study aimed to assess resting HRV in young adults with smartphone overuse compared with non-overusers, and to determine whether observed HRV differences persist after accounting for key covariates known to influence autonomic measures.

Material and Methods

Study design and setting: A cross-sectional, comparative study was conducted among apparently healthy young adults. Data collection was performed in a quiet, temperature-controlled laboratory to minimize environmental influences on autonomic measurements.

Inclusion criteria:

- Age 18–25 years
- Regular smartphone user (≥1 year)
- Clinically stable at the time of assessment (no acute febrile illness in the preceding 2 weeks)

Exclusion criteria (to limit confounding on HRV):

- Known cardiovascular disease, diabetes mellitus, thyroid dysfunction, chronic respiratory disease, chronic kidney/liver disease
- Current psychiatric illness under active treatment or use of psychoactive medications
- Use of medications known to affect autonomic tone (e.g., beta-blockers, anticholinergics, stimulants)
- Current smoking or use of nicotine products; harmful alcohol use
- Shift work, transmeridian travel in the preceding 2 weeks
- Regular endurance training/competitive sports (as it can substantially elevate vagal indices)
- For females: pregnancy

Sample size determination: Sample size was planned to detect a moderate between-group difference in short-term resting HRV (primary metric: RMSSD) between smartphone overuse and non-overuse groups, consistent with effect sizes reported in behavioral-addiction/autonomic literature. Assuming a standardized effect size of 0.5, two-sided $\alpha = 0.05$, and power = 0.80, a minimum of 128 participants (64 per group) was required. To account for unusable HRV recordings (artefacts/ectopy) and incomplete questionnaires, the target enrollment was set at 150 participants.

Smartphone overuse assessment: Smartphone overuse was quantified using the Smartphone Addiction Scale–Short Version (SAS-SV), a 10-item instrument scored on a 6-point Likert scale (total score range 10–60). Participants were categorized using established sex-specific cutoffs: ≥31 for males and ≥33 for females to define the "overuse/high-risk" group; scores below these cutoffs comprised the comparison group. Additional smartphone exposure variables were recorded to support interpretation and sensitivity analyses:

- Average daily smartphone use (self-reported hours/day over the past week)
- Primary use pattern (social media, gaming, streaming, academic, mixed)
- Night-time use (use within 1 hour before sleep: yes/no)

Covariates: Potential confounders known to influence HRV were documented using standardized forms: age, sex, BMI, resting blood pressure, habitual physical activity (brief activity questionnaire), caffeine intake, sleep duration, and recent stress (single-item perceived stress rating).

Heart rate variability acquisition

Pre-test standardization: Participants were instructed to:

- Avoid vigorous exercise for 24 hours
- Avoid caffeine/energy drinks for 12 hours and alcohol for 24 hours
- Avoid heavy meals for 2 hours prior to testing
- Refrain from smartphone use for at least 30 minutes before recording to reduce acute arousal effects

All recordings were scheduled in the morning (08:00–11:00) to limit circadian variability.

Recording protocol: Short-term resting HRV was recorded using a validated RR-interval acquisition system (ECG-based or a clinically validated chest-strap sensor) while participants rested supine in a quiet room. After a 10-minute acclimatization period, a 5-minute continuous recording was obtained during spontaneous breathing, with participants instructed to remain still, relaxed, and silent. The 5-minute short-term duration aligns with established HRV measurement standards for time- and frequency-domain analyses [7,8].

Data quality and artifact handling: Recordings were visually inspected. Segments with excessive noise, ectopy, or movement artefacts were excluded. RR artefacts were corrected using standard threshold-based filtering, and participants with persistent artefacts that prevented reliable analysis were removed from the final HRV dataset.

HRV metrics and processing: HRV analysis was performed on normal-to-normal (NN) intervals using standard algorithms. Time-domain indices [Mean RR (ms), SDNN (ms), RMSSD (ms), pNN50 (%)], and frequency-domain indices [spectral analysis on 5-min recordings, LF power (0.04–0.15 Hz), HF power (0.15–0.40 Hz), LF/HF ratio, total power] were extracted. Frequency-domain parameters were expressed in absolute units (ms^2); log-transformation was planned if distributions were skewed.

Outcomes

Primary outcome: RMSSD (parasympathetic/ vagal modulation proxy in short-term resting recordings).
Secondary outcomes: SDNN, HF power, LF power, LF/HF ratio, and resting heart rate.

Statistical analysis: Data were analyzed using R software. Continuous variables were summarized as mean ± standard deviation for normally distributed data. Group comparisons between the overuse and non-overuse groups were performed using the independent t-test. Categorical variables were analyzed using the χ^2 test. Multivariable analyses were conducted using linear regression models to examine the association between smartphone overuse status and outcomes of interest, with the SAS-SV score additionally analyzed as a continuous variable while adjusting for relevant covariates.

Results

The two groups were comparable with respect to age, sex distribution, body mass index, and resting blood pressure (Table 1). Participants in the smartphone overuse group reported significantly greater daily smartphone exposure and shorter average sleep duration compared with the non-overuse group (both $p < 0.001$). Resting heart rate was significantly higher among smartphone overusers, suggesting a relative shift toward sympathetic predominance at baseline (Table 1).

Time-domain HRV indices demonstrated a consistent reduction in autonomic variability among participants with smartphone overuse (Table 2). Mean RR interval, SDNN, and RMSSD were all significantly lower in the overuse group compared with controls (all $p < 0.001$). The median pNN50 value was also markedly reduced among smartphone overusers, indicating attenuated parasympathetic modulation (Table 2).

Frequency-domain analysis revealed significantly lower total power and high-frequency (HF) power in the smartphone overuse group, reflecting reduced overall autonomic and vagal activity (Table 3). Low-frequency (LF) power was modestly but significantly lower among overusers ($p = 0.04$). The LF/HF ratio was significantly higher in the overuse group, indicating relative sympathetic dominance and altered sympathovagal balance (Table 3).

After adjustment for age, sex, body mass index, sleep duration, physical activity, caffeine intake, and resting blood pressure, smartphone overuse remained independently associated with adverse HRV parameters (Table 4). Smartphone overuse was associated with a significant reduction in RMSSD and SDNN, as well as lower log-transformed HF power. In contrast, the LF/HF ratio remained significantly elevated among smartphone overusers after adjustment, confirming a persistent shift toward sympathetic predominance independent of measured confounders (Table 4).

Table 1: Baseline demographic and clinical characteristics of the study participants

Variable	Smartphone overuse group (n = 75)	Non-overuse group (n = 75)	p value
Age (years)	21.3 ± 1.9	21.0 ± 2.1	0.38
Male/Female (n)	38 / 37	36 / 39	0.74
Body mass index (kg/m^2)	23.6 ± 2.8	22.9 ± 2.6	0.11
Resting heart rate (beats/min)	76.8 ± 7.4	72.1 ± 6.9	<0.01
Systolic BP (mmHg)	116.2 ± 9.1	114.7 ± 8.6	0.29
Diastolic BP (mmHg)	74.8 ± 6.5	73.9 ± 6.1	0.37
Average smartphone use (hours/day)	6.9 ± 1.4	3.2 ± 0.9	<0.01
Sleep duration (hours/night)	6.3 ± 0.8	7.1 ± 0.9	<0.01

Table 2: Comparison of time-domain HRV parameters between study groups

HRV parameter	Smartphone overuse group (n = 75)	Non-overuse group (n = 75)	p value
Mean RR interval (ms)	781.4 ± 92.6	835.9 ± 88.3	<0.01
SDNN (ms)	41.2 ± 11.5	49.8 ± 12.4	<0.01
RMSSD (ms)	29.6 ± 9.8	39.7 ± 11.2	<0.01
pNN50 (%)	12.4 (7.1–18.9)	21.8 (14.6–28.4)	<0.01

Table 3: Comparison of frequency-domain HRV parameters between study groups

HRV parameter	Smartphone overuse group (n = 75)	Non-overuse group (n = 75)	p value
Total power (ms²)	1765 (1210–2450)	2418 (1825–3120)	<0.01
LF power (ms²)	624 (430–895)	712 (498–1024)	0.04
HF power (ms²)	402 (255–612)	712 (480–1035)	<0.01
LF/HF ratio	1.62 ± 0.54	1.09 ± 0.41	<0.01

Table 4: Association between smartphone overuse and HRV parameters after adjustment for confounders

HRV parameter (dependent variable)	Adjusted β (95% CI)	p value
RMSSD (ms)	−8.4 (−11.9 to −4.9)	<0.01
SDNN (ms)	−6.7 (−10.4 to −3.1)	<0.01
HF power (log ms²)	−0.31 (−0.49 to −0.14)	<0.01
LF/HF ratio	+0.42 (0.21 to 0.63)	<0.01

Discussion

In this study of young adults, participants classified as smartphone overusers demonstrated an autonomic profile consistent with reduced parasympathetic modulation, reflected by lower time-domain indices (e.g., RMSSD and SDNN) and lower HF power, alongside a higher LF/HF ratio and higher resting heart rate (Tables 1–3). These group differences suggest relative sympathetic predominance and vagal withdrawal in the overuse phenotype. Similar patterns of diminished vagally mediated HRV have been reported in technology-related problematic behaviors; for example, individuals with problematic mobile gaming showed lower baseline RMSSD and lower HF-related metrics compared with non-problematic users and also exhibited elevated LF/HF during gaming-related conditions, indicating heightened autonomic arousal and impaired recovery [9].

A plausible pathway linking smartphone overuse to altered HRV is sleep disruption. Large-scale evidence using validated addiction measures and objective phone-use markers indicates that smartphone addiction and excessive screen time are associated with poorer sleep and shorter sleep duration among university students [10]. Experimentally, sleep curtailment has been shown to shift autonomic balance toward sympathetic dominance, with increases in heart rate and reductions in several HRV indices during restricted sleep [11]. Complementing these trial-level findings, a meta-analysis of randomized studies concluded that sleep deprivation decreases RMSSD and increases LF and LF/HF, supporting the interpretation that insufficient sleep can produce vagal suppression and sympathetic predominance [12]. Taken together, the shorter sleep duration observed among overusers in our cohort (Table 1) may have contributed to the lower vagally mediated HRV indices (Table 2).

Beyond sleep duration, dependence-like features may play a role. In a randomized controlled trial secondary analysis, reducing smartphone use to <2 hours/day was associated with a significant decline in wearable-derived HRV during the intervention phase, and HRV during the intervention correlated with craving and sleep quality—findings interpreted as consistent with a withdrawal-like physiological response in some participants [13]. While our design differs (cross-sectional comparison rather than reduction intervention), this literature supports the concept that problematic smartphone behaviors can be linked to measurable autonomic changes, potentially mediated by craving, arousal, and sleep-hygiene disruption.

Our multivariable analysis (Table 4) further indicates that the association between smartphone overuse severity (SAS-SV score) and vagally mediated HRV remained evident after adjustment for key covariates. This aligns with developmental/psychophysiological data suggesting that higher mobile phone addiction is associated with lower HF-HRV and altered HF-HRV reactivity in adolescents, implicating reduced parasympathetic flexibility in problematic use patterns [14]. Although direct causal inference is not possible in our dataset, the persistence of associations after adjustment supports the likelihood that smartphone

overuse is not merely a proxy for demographic differences.

It is also important to consider that acute proximity/exposure contexts might influence HRV measurements in some users (e.g., phone kept near the chest). Experimental work in medical students found that keeping a phone close to the heart in ring/vibration mode reduced several HRV indices and increased LF/HF, with more pronounced effects among obese participants []15. While our protocol assessed resting HRV under standardized conditions, unmeasured behaviors (device carriage patterns, notification load) could contribute to individual variability and should be captured in future studies.

Limitations and implication: The primary limitations include the cross-sectional design (precluding temporality), reliance on self-reported smartphone behavior for classification, and use of short-term resting HRV which, while widely used, can be influenced by recent caffeine intake, physical activity, stress, circadian timing, and (in females) menstrual cycle phase. Residual confounding related to mental health symptoms, academic stress, and unmeasured sleep parameters (e.g., sleep regularity, bedtime procrastination, and nocturnal awakenings) is also possible. Nonetheless, the consistency of our findings across time-domain and frequency-domain metrics (Tables 2–3) and their alignment with mechanistic sleep/behavioral literature suggest that smartphone overuse may be associated with clinically relevant autonomic shifts in otherwise healthy young adults, supporting the need for longitudinal studies incorporating objective phone-use logs and actigraphy-based sleep measures.

Conclusion

Smartphone overuse among young adults is associated with a significant reduction in heart rate variability, characterized by diminished parasympathetic activity and a relative shift toward sympathetic dominance. Both time-domain and frequency-domain HRV indices were adversely affected in individuals with smartphone overuse, and these associations persisted after adjustment for key demographic, behavioral, and physiological confounders. The findings suggest that excessive smartphone use may exert measurable effects on cardiac autonomic regulation even in otherwise healthy young adults, highlighting the potential relevance of smartphone use patterns as a modifiable behavioral factor with implications for long-term cardiovascular and autonomic health.

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