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Parasympathetic decreases immediately following self-reported cannabis smoking among adults living with cannabis use disorder

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ABSTRACT

The purpose of the current study was to determine the difference between heart rate variability levels before and after self-reported non-medical cannabis use within a sample of African American young adults living with cannabis use disorder. The sample included 31 self-identifying African American undergraduate students (Women = 83.87 %), with a mean age of approximately 19.71 (SD = 1.49) years. After giving consent, the participants were administered a semi-structured interview that included the Mini International Neuropsychiatric Interview (MINI) to determine cannabis use disorder (CUD) status. If a participant met the criteria for CUD, they were instructed to wear a Garmin smartwatch for three consecutive days. The Garmin smartwatch collected interbeat intervals via photoplethysmographic measurement. Participants were also instructed to complete a survey each time they smoked cannabis, a survey that asked for the start and stop times for each cannabis smoking session. Employing mixed ANOVA and Multilevel models, results suggest a significant difference in HRV levels before and after self-reported cannabis smoking. Specifically, both time and frequency domain HRV metrics are significantly lower than levels prior to smoking cannabis. Further, we see a significant increase in average heart rate from before to after cannabis smoking. The current findings identify cannabis' acute autonomic cardiac influence among individuals living with CUD. Future research should elucidate the impact of repeated cannabis exposure and their long term autonomic implications, including more cannabis ingestion modalities.

1. Introduction

State legislatures across the United States are rapidly becoming less restrictive and are voting in favor of recreational cannabis smoking (Orenstein and Glantz, 2020). Despite non-medical cannabis legalization being associated with increases in emergency department visit rates (Nguyen et al., 2024; Shelton et al., 2020), the increase in social acceptance has empowered many who believe cannabis smoking is not addictive or deleterious to health. Recently, cannabis use disorder (CUD) prevalence has increased (Lapham et al., 2023; Mattingly et al., 2024). Cannabis is the most commonly used illicit drug among college students, reaching historically high levels (National Institutes of Health, 2021; National Institute on Drug Abuse, 2022). College students' cannabis use is associated with various harmful effects, including substance use disorders (Arria et al., 2015; Suerken et al., 2014) and cardiovascular alterations (Subramaniam et al., 2019).

For more than five decades, researchers have examined the cardiovascular effects of cannabis smoking (Dornbush et al., 1971). However, there are few rigorous studies determining cannabis' cardiovascular effects (DeFilippis et al., 2020). Much of this literature reports case studies, connecting the acute cannabis exposure to a subsequent cardiovascular event that brought an individual to the hospital (Chaphekar et al., 2019). Heart attack (Wengrofsky et al., 2018), stroke (Zachariah, 1991; Keskin et al., 2016), asystole (Brancheau et al., 2016), tachycardia (Rezkalla et al., 2003; Hendrickson et al., 2021), and acute cardiovascular death (Bachs and Mørland, 2001) are all represented in this literature. Recently, researchers reported a relationship between daily cannabis use and the likelihood of stroke, myocardial infarction, and other cardiovascular risk factors in a sample of adults in the United States (Jeffers et al., 2024). Further, researchers have suggested that there is a direct influence on heart rate, functioning as a cardiac compensatory mechanism for cannabis smoking (Gómez et al., 2019).

Many researchers and clinicians have identified heart rate variability as a transdiagnostic measure of autonomic nervous system risk

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(Agorastos et al., 2023). Heart Rate Variability (HRV) is a non-invasive assessment of autonomic activity and has been explored extensively in the scientific literature. Higher HRV levels are associated with decreased likelihood of developing cardiovascular disease (Kubota et al., 2017). Much of the literature employs linear metrics from the time or frequency domains. The frequency spectrum of electroencephalographic data provides information about vagally mediated autonomic activity (Reyes del Paso et al., 2013). High frequency HRV is negatively associated with cardiovascular risk (Thayer et al., 2009) and is utilized clinically in mortality and cardiovascular risk stratification (Heldeweg et al., 2016). Given the dubious nature of other frequency domain metrics (i.e., very low and low), many researchers focus on high frequency HRV (HF-HRV) as a proxy for parasympathetic activity. Concerning the time domain metrics, Root Means Square Difference of Successive Differences (RMSSD) in R-R intervals reflects parasympathetic activity (DeGiorgio et al., 2010; Spinella et al., 2021). This vagally mediated metric is also associated with cardiovascular risk (Jarczok et al., 2019). Recent research has identified rostral central autonomic pathways (e.g., the pathway from amygdala to prefrontal cortex) associated with parasympathetically mediated HRV from both time and frequency domains (Ma et al., 2024). These pathways have neuroanatomical overlap with cannabinoid receptor-saturated brain areas, presented within the endocannabinoid system (Mechoulam and Parker, 2013).

There is limited published research determining the association between cannabis use and HRV (Schmid et al., 2010; Nayak et al., 2017; Nayak et al., 2020; Pabon et al., 2022; Glodosky et al., 2024). In a recent study of self-reported chronic cannabis smokers, there was no difference in HRV levels when compared to healthy controls (Glodosky et al., 2024). In a community sample of self-identified African American young adults, HRV was not associated with cannabis smoking (Cavanagh and Obasi, 2022). However, it should be noted that cannabis smoking was measured via timeline follow-back 90 days after the autonomic measurement. Nayak et al. (2017, 2020) reported decreased HRV among regular cannabis smokers (at least 6 times daily for two years or more) compared to non-cannabis users. In line with these subjective reports, other studies have identified that self-reported cannabis intoxication is negatively associated with HRV (Pabon et al., 2022). In contrast, urine testing positive for tetrahydrocannabinol was associated with increases in HRV (Schmid et al., 2010). Though the findings in Schmid et al.'s (2010) study were unexpected, the human body may be attempting to compensate for the cannabis use through homeostatic modulation. Cannabis may elicit an increase in sympathetic activity and may also be an increase in parasympathetic activity (Middlekauff et al., 2014).

Overall, there is a dearth of literature examining cannabis use and acute autonomic alterations. Specifically, there is little evidence of natural setting exploration of the potential autonomic shifts from before to after cannabis smoking. This notion is noticed when searching PubMed for keywords "cannabis" and "heart rate variability", which yields 39 results (as of June 6, 2025). These results vary widely in their inclusion of longitudinal study design, young adults, or how people represent the various ethnic groups among participants. The current study looks to elucidate the autonomic alterations immediately following cannabis smoking within a sample of young adults. Specifically, the purpose of this study is to determine the difference between HRV levels before and after self-reported cannabis smoking sessions in a sample of African American or Black young adults. We hypothesize that there will be a significant decrease in HRV when comparing HRV levels ten minutes before the smoking session to the ten minutes after the smoking session. Additionally, we hypothesize that the before and after HRV levels will vary by the frequency of sessions, resulting in decreases in parasympathetic activity. Specifically, more frequent cannabis smoking will be associated with larger decreases in HRV.

2. Methods

2.1. Participants

Participants were 31 (83.87 % female) undergraduates living with CUD. The average age for the participants was approximately 19 years (m = 19.71 ± 1.49), and the average age of cannabis use onset was nearly 14 years (m = 14.01 ± 2.71). These undergraduate students were recruited from a Historically Black University in central Virginia, enrolled in the parent study, "*The Cannabis Nexus Initiative*". These data were collected from January 2022 through January 2025. Participants were recruited on campus through flyers, the use of the SONA System (Sona Systems, https://www.sona-systems.com), and professor referrals. The SONA System is an online participant recruitment platform designed for universities and other academic institutions. As an investigator posts their study to the software, including potential time slots, participants will have the choice to sign up to receive credit or compensation. To participate in the parent study, participants needed to be between the ages of 18 and 25 years, identify as Black or African American, self-report no history of a cardiovascular event (e.g., heart attack, stroke, etc), and be an undergraduate student at the university. Only those with complete demographic, cannabis use, and resting HRV data were included in the current analyses. This study has received annual approval from the local Institutional Review Board. See Table 1 for other sample characteristics and Table 1 in the appendix.

2.2. Procedure

Upon entry into the lab, participants' temperature was taken, and a trained research assistant asked the Centers for Disease Control and Prevention standard COVID-19 screening questions. Once participants completed the COVID-19 screening, a trained research assistant obtained the participants' informed consent to proceed with the rest of the study protocol. Once informed consent was obtained, participants' height was measured and their weight was taken via the TANITA body composition scale (Jebb et al., 2000). Participants then took part in the Qualtrics online survey, which lasted approximately 30–45 min. The survey included measures of demographic information, brief medical history, and substance use. After completion of the online survey, participants were administered the Mini International Neuropsychiatric Interview (Sheehan et al., 1998) as a part of a semi-structured interview. Participants who responded "yes" to two or more symptoms for cannabis use disorder items and met the requirements for any other substance use disorder were referred to Phase II of the study. At the end of the semi-structured interview, the trained research assistant addressed any questions posed by the participant. Participants were given a $25 VISA gift card as compensation.

If participants agreed to participate in the second portion of the study, participants were presented with the informed consent form for Phase II and briefed on the study protocol. Once informed consent was

Table 1
Demographic descriptive table (n = 31).

Variable description	n (%) or mean ± SD	
Sex		
Male	5.00	(16.13)
Female	26.00	(83.87)
CUD severity status		
Mild	10.00	(32.26)
Moderate	10.00	(32.26)
Severe	11.00	(35.48)
Age	19.71	±1.49
Age of cannabis use onset	14.01	±2.71
BMI	28.86	±8.67
Rest Mean HR	92.55	±12.98
Rest Mean HF	328.7	±165.41
Rest Mean RMSSD	30.60	±9.92

obtained, participants were given a Garmin SQ watch and asked to download the Garmin and Labfront applications on their smartphones. The participants were asked to put the watch on their non-dominant arm. Participants were then briefed on how to report their cannabis use via the Labfront application and to sync the heart rate data for the Garmin application. The participants were instructed to only report their cannabis smoking behaviors. The trained clinical research assistant then instructed the participant to wear the watch for three full days. This includes when bathing, working out, or sleeping. Once a day, the participant receives a text message reminding them to sync their data and report any cannabis use in the Labfront application. Participants returned the watch on the fourth day at a pre-scheduled time. After debriefing and addressing any questions posed by the participants, the trained research assistant thanked the participant and gave them a $50 Visa gift card.

2.3. Measures

2.3.1. HRV Calculation

The Garmin Venu SQ watch collects beat-to-beat data for each participant. Interbeat intervals obtained using photoplethysmographic measurements are called Beat-to-Beat Intervals (BBI). The photoplethysmographic signal generated BBI data measures the time interval between two successive pulse pressure waves of the capillary arterial blood flow in the sensor field of view (which, in the case of Garmin wearables, is the wrist). Root Mean Square of Successive Differences was calculated using the formula RMSSD = $\sqrt{(1/(N-1)\sum_{j=1}^{N-1}(RR_{j+1}-RR_j)^2)}$. We then applied the piecewise cubic Hermite interpolating polynomial method to transform an original series of BBI vs. beat number into a new series of BBI time vs. time at a sampling frequency of 4 Hz. Apply a Hamming window to the BBI time series obtained to minimize the discontinuities of truncated waveforms, thus reducing spectral leakage. The discrete Fourier transformation is then applied to the BBI time series obtained. The frequency-domain HRV indices are obtained according to the power in the corresponding frequency ranges. The bands for each HRV are as follows: very high frequency (0.4 Hz to 0.9 Hz), high frequency (0.15 Hz to 0.4 Hz), low frequency (0.04 Hz to 0.15 Hz), and very low frequency (0.0033 Hz to 0.04 Hz). The current study focused on the parasympathetically mediated high-frequency HRV. Root Mean Square of Successive Differences and high frequency HRV were derived from the interbeat interval data analyzed for 10 min before and the 10 min immediately following the self-reported cannabis use.

2.4. Covariates

2.4.1. Demographic covariates

Age (in years) and sex were collected via the demographic questionnaire. The relationship between age and HRV suggests a linear decrease in HRV with increases in age (Umetani et al., 1998; Garavaglia et al., 2021).

2.4.2. Cannabis use disorder severity

The Mini International Neuropsychiatric Interview (Sheehan et al., 1998) is a widely used assessment of psychological disorders that includes cannabis use disorder (CUD) and cannabis use disorder severity (CUD severity). The MINI is a semi-structured interview administered orally, with a response choice of "yes" or "no." Participants are asked 10 response questions based on cannabis use in the past 12 months to determine CUD or non-CUD. If there are at least two responses with "yes," participants are classified as having CUD severity. Cannabis Use Disorder severity is categorized into four categories: none, mild, moderate, and severe, which are determined by the number of symptoms each participant answers "yes" to during the MINI. Individuals who develop substance use disorder, including CUD and CUD severity, are linked to self-dysregulation and emotional distress, lowering HRV in those individuals (Moon et al., 2024).

2.4.3. Age of onset

A 41-item DFAQ-CU subset questionnaire was developed to measure frequency, age of onset of cannabis use, among other cannabis metrics. Four items were used to measure the age of onset of cannabis use. The age of onset items are probes for age of first use, age of regular cannabis use, age of daily or near daily cannabis use, and frequency of cannabis use before the age of 16 (Cuttler and Spradlin, 2017). Age of onset, similarly to age, has a negative relationship with HRV, suggesting HRV decreases with increases in age of onset (Jandackova et al., 2016). The age of onset subscale yielded a Cronbach's alpha of 0.64.

2.4.4. Ecological Cannabis use measurement

Participants were to self-report their cannabis smoking occasions while wearing the Garmin smartwatch for three (3) days. To report smoking cannabis, the participant needed to open the Labfront application and select a start and end time for their cannabis smoking session. There were no instructions for the participant to limit or expand their normal cannabis usage, nor were they compensated per use report. These start and end times were counted as individual sessions and added up to reflect cannabis use frequency by the participant.

2.4.5. Sex

Sex was dummy coded where males were represented by "0" and females were represented by "1". The variation between males and females in autonomic activity may further characterize the connection between cannabis use and HRV. Additionally, previous research posits significant sex differences in autonomic control of the heart (Koenig and Thayer, 2016; Garavaglia et al., 2021). Specifically, women are more likely to have higher resting heart rates, yet have lower cardiovascular risk than their male counterparts (Cordero and Alegria, 2006). Given that greater HRV is associated with great cardiovascular health (Young and Benton, 2018), increases in cannabis use may further exacerbate the sex differences already present between males and females.

2.4.6. Body Mass Index

Body Mass Index (BMI) is determined using the TANITA Body Composition Analyzer model SC-331 s (Jebb et al., 2000; Webster et al., 2021). The TANITA Body Composition Analyzer SC-331 is a single-frequency bioelectrical impedance assessment device that requires the following data inputted before weight assessment: estimate of clothing weight, sex, height in inches, and age. After data input, the user steps onto the scale with four-foot contacts, and the machine then measures the user's body weight. The TANITA scale then calculates the BMI based on the World Health Organization's recommended formula (World Health Organization, 2024). Individuals with a higher BMI are likely to develop cardiovascular disease and have pathologically decreased HRV (Indumathy et al., 2015; Strüven et al., 2021; Yadav et al., 2017).

2.5. Data analysis

R statistical software was used for the analysis (R Core Team, 2021). The data for this study were collected from a sample of ($n = 31$) participants whose heart rate and HRV (time and frequency domains) were measured before and after each occasion they used cannabis. The data was changed to a long format (i.e., the information/variables were represented in a column for each participant) for all 11 measurement times/events ($n = 214$). Data visualizations for all the different outcome variables (HR, HF-HRV, and RMSSD) were obtained (see Figs. 1, 2, and 3). Other figures can be found in the supplementary materials (Figs. 1s to 3s). Due to the nature of the data (repeated data), both mixed ANOVA and Multilevel models were performed.

Given the small sample size and to test for overall mean differences between pre- and post-scores, especially for the first occasion with complete participant data (n = 31), and the interaction between pre- and

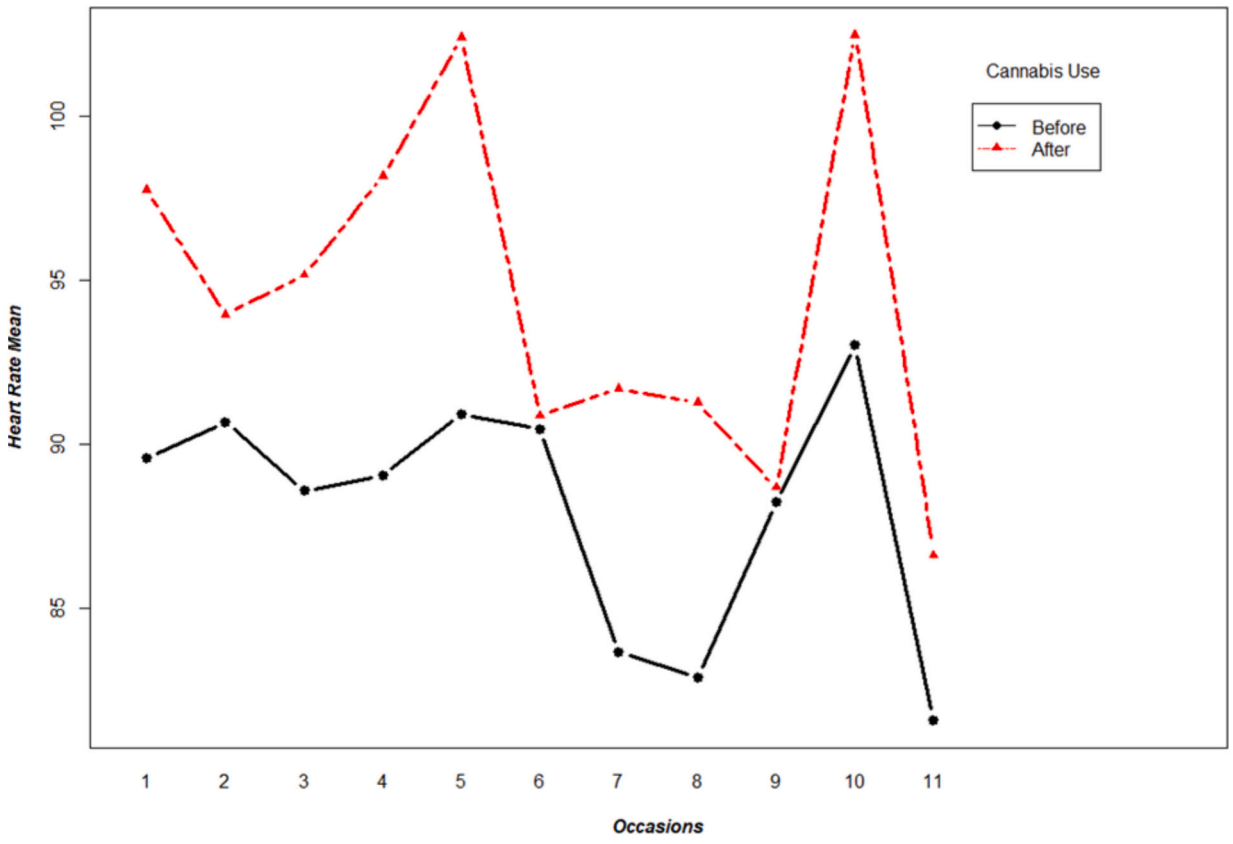

Fig. 1. Heart rate average across each time cannabis was used.

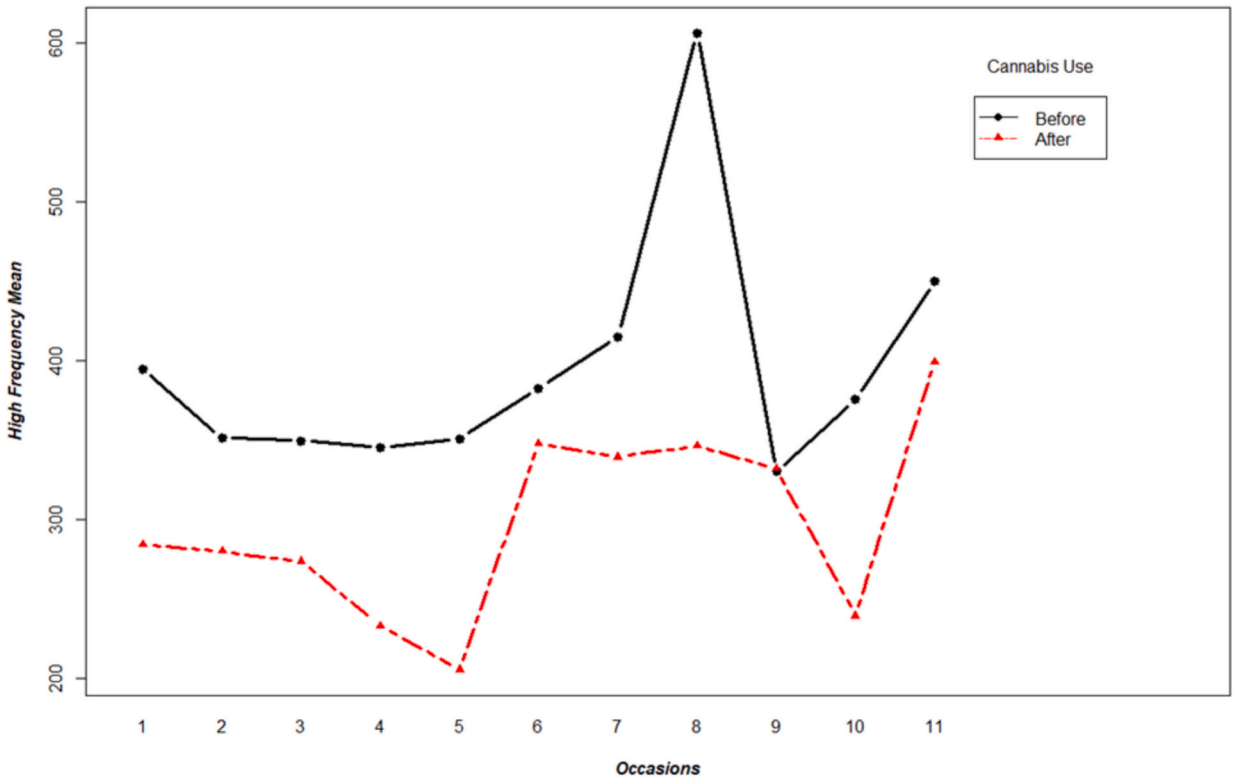

Fig. 2. High frequency heart rate variability across each time cannabis was used.

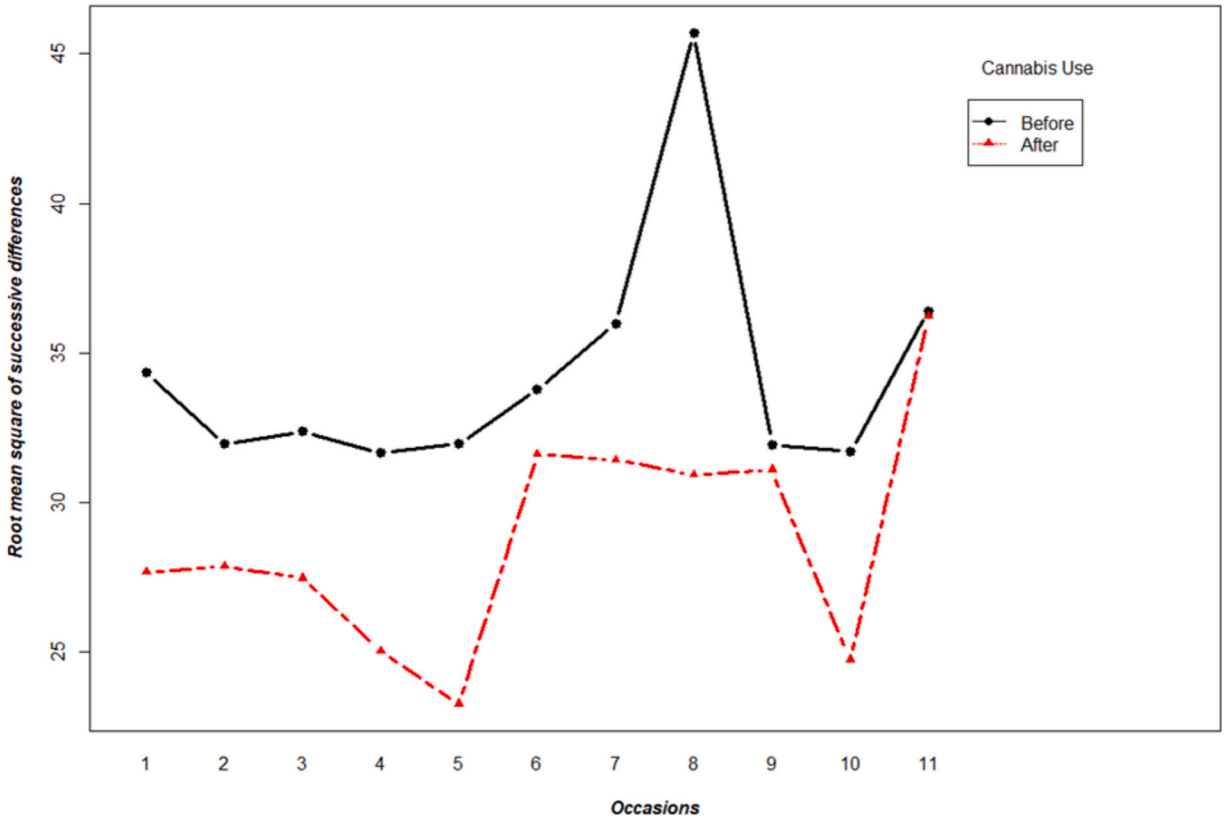

Fig. 3. Root mean square of successive difference scores across each time cannabis was used.

post-scores and occasion, a preliminary analysis of repeated measures ANOVA was performed. The analyses included interaction terms between within-level variables of occasions (the number of events or measurements) and Cannabis use (Pre-Post) for the three outcome variables. Then, three Multilevel models were performed, mean Heart Rate (HR), mean High Frequency (HF-HRV), and mean Root mean square of successive differences (RMSSD) were the outcome variables for each model. For all the models, fixed effects of the predictor variables were estimated. The main predictor was a grouping variable of before and after cannabis use, while occasions (the number of events or measurements) were entered into the model as a linear covariate. Between-level variables of sex, age, age of onset of cannabis use, Cannabis severity disorder, and BMI were controlled for in the model. For multilevel models, the time variable was considered a linear (continuous) variable.

Multilevel models with fixed effects were performed to account for between-person variance. Given the number of the clusters (within each participant), the Restricted Maximum Likelihood (REML) estimator was used instead of Maximum Likelihood (ML) since it provides more unbiased estimates for smaller designs than ML for mixed linear models (Lee, 2017). Additionally, a mixed linear model takes into account unequal data (Jennrich and Schluchter, 1986) and enables the handling of missing data compared to ANOVA. The multilevel models were performed using an R package-lme4 (lmer) (Bates et al., 2015), which uses *t*-test and Satterthwaite degrees of freedom (Satterthwaite, 1946) to adjust the degrees of freedom based on the number of individuals in the data to provide more accurate *p*-values from the t distribution. Additionally, with a small sample size or groups, Satterthwaite corrections have better Type I error rates (Manor and Zucker, 2004).

3. Results

3.1. Analysis of variance

For all of the outcome variables (e.g., HR, HF-HRV, and RMSSD), repeated measure ANOVA results indicated no significant interaction terms between occasions and cannabis use (before VS after), while the main effects of cannabis use were statistically significant. For heart rate, there was a statistically significant difference between the before and after mean heart rate scores. The pairwise comparison results indicated that the after (Mean = 95.82, SD = 13.33) was statistically significantly higher than the before mean score (Mean = 89.27, SD = 11.80) ($p < .01$). For HF-HRV, there was a statistically significant difference between before and after mean HF-HRV scores. The pairwise comparison results indicated the after-mean score (M = 281.22, SD = 132.52) to be statistically significantly lower than the before mean score (M = 376.18, SD = 181.29) ($p < .01$). For RMSSD, there was a statistically significant difference between before and after RMSSD mean scores. The pairwise comparison results indicated the after-mean score (M = 27.77, SD = 8.18) to be statistically significantly lower than the before-mean score (M = 33.42, SD = 10.72) ($p < .01$).

Figs. 1 to 3 and Table 2 further break down the means for each occasion before and after use for all the participants. The first occasion had all the participants ($n = 31$), and the 11th occasion had only one participant. For HR, for all 11 occasions (see Fig. 1 and Table 1), the before means were lower than the after. For example, for the first occasion, the before HR mean score (M = 89.60, SD = 12.12) was lower than the after mean score (M = 97.76, SD = 17.85). For all 11 occasions for HF, the before means scores were higher than the after means. For instance, for the first occasion, the before HF mean score (M = 394.57, SD = 209.92) was higher than the after score (M = 283.85, SD = 163.35). Similarly, for all 11 occasions, the RMSSD before means scores were higher than the after means. For instance, for the first occasion, the

Table 2
Pre- and post-means scores for different time points.

n	Occasions	Before HR (mean ± SD)		After HR (mean ± SD)		Before HF (mean ± SD)		After HF (mean ± SD)		Before RMSSD (mean ± SD)		After RMSSD (mean ± SD)	
31	1	89.60	±12.12	97.76	±17.85	394.57	±209.92	283.85	±163.35	34.34	±11.86	27.68	±10.58
21	2	90.68	±11.96	93.96	±9.05	351.31	±162.55	279.81	±137.27	31.97	±9.66	27.87	±7.51
14	3	88.59	±12.20	95.17	±13.45	349.42	±162.56	273.49	±100.59	32.38	±10.37	27.48	±6.81
11	4	89.05	±10.46	98.18	±10.89	345.38	±130.15	232.52	±95.801	31.66	±7.74	25.03	±5.94
8	5	90.93	±9.53	102.40	±9.82	350.85	±122.05	205.18	±82.72	31.96	±8.50	23.28	±5.70
8	6	90.48	±13.74	90.89	±13.60	382.58	±197.75	347.59	±139.71	33.79	±11.83	31.62	±8.43
5	7	83.67	±5.55	91.70	±7.82	414.96	±109.40	339.16	±80.16	35.98	±6.03	31.42	±4.73
3	8	82.90	±24.43	91.28	±6.07	606.24	±426.28	346.02	±122.17	45.70	±25.52	30.93	±6.25
3	9	88.24	±17.96	88.69	±14.06	329.95	±196.62	331.92	±164.50	31.94	±14.82	31.10	±9.22
2	10	93.03	±9.28	102.47	±11.40	375.24	±161.43	238.96	±59.38	31.71	±8.21	24.75	±3.35
1	11	81.61	NA	86.61	NA	450.05	NA	399.00	NA	36.41	NA	36.23	NA

RMSSD before mean score (M = 34.34, SD = 11.86) was higher than the after score (M = 27.68, SD = 10.58).

3.2. Multilevel models

For all outcome variables, multilevel regression models with only random intercepts specified were conducted. For the outcome variable heart rate, the intraclass correlation coefficient (proportion of variance between people) was 0.437, indicating that 43.7 % of the variance in the mean heart rate scores is attributed to the person. There were no significant interactions between before and after cannabis use, and occasions. The main effect of before and after cannabis use was statistically significant. The results indicated that using cannabis was expected to significantly increase heart rate by 7.03 units after controlling for other variables in the model (B = 7.03, $p < .01$) (see Table 3). Variables of occasions, sex, age, age of onset, BMI, and cannabis use disorder severity were not statistically significant.

For the HF-HRV, the intraclass correlation coefficient (proportion of variance between people) was 0.572, indicating that 57.2 % of the variance in mean HF-HRV is attributed to a person. There were no significant interactions between before and after cannabis use, and occasions. The main effect of before and after cannabis use was statistically significant. The results indicated that using cannabis was expected to significantly decrease HF mean by 96.68 units after controlling for other variables in the model (B = -96.68, p < .01) (see Table 3). Variables of occasions, sex, age, age of onset cannabis use disorder, and BMI were not statistically significant.

Lastly, the RMSSD's intraclass correlation coefficient (proportion of variance between people) was 0.526, indicating that 52.6 % of the variance in RMSSD mean scores is attributed to a person. The main effect of before and after cannabis use was statistically significant. There were no significant interactions between before and after cannabis use, and occasions. The results indicated that using cannabis was expected to significantly decrease RMSSD mean by 5.91 units after controlling for other variables in the model (B = -5.91, $p < .01$) (see Table 3). Variables of occasions, sex, age, age of onset cannabis use disorder, and BMI were not statistically significant.

4. Discussion

The current study sought to determine autonomic differences between 10 min before and 10 min after cannabis smoking among individuals living with cannabis use disorder. Autonomic shifts or alterations were measured using heart rate, RMSSD, and HF-HRV. Employing multilevel modeling and statistically adjusting for covariates, 10 min before levels of each autonomic measure were significantly lower than the 10 min after levels. In our second hypothesis, the before and after HRV levels would vary by the frequency of cannabis smoking sessions. However, there was no cumulative effect across the time points, nor did HRV vary by the cannabis smoking frequency. In line with previous research that examined cannabis smoking's acute effects (Hendrickson et al., 2021), these analyses suggest a sympathetic shift immediately following cannabis smoking. This is in line with previous combustion-based research examining cigarette smoking (Hayano et al., 1990; Kobayashi et al., 2005; Karakaya et al., 2007). Both acute and chronic tobacco or nicotine exposure contribute to progressive damage to the cardiovascular system (Benowitz and Burbank, 2016) and reduce HRV, specifically high-frequency HRV (Bodin et al., 2017).

Very few studies have examined cannabis use and autonomic activity. Among this dearth of literature, researchers have examined the use of cannabis products on autonomic activity, suggesting cannabis smoking is associated with tachycardia after inhalation (Hendrickson et al., 2021). Our findings are more consistent with experimental studies, which show a dose-response relationship with heart rate in the first hour and beyond (Schlienz et al., 2020). Specifically, even the smallest doses of tetrahydrocannabinol showed increases in heart rate when compared to their placebo counterparts. However, there may be a ceiling for these effects, as increases in additional oral tetrahydrocannabinol doses for a cannabis smoker may mediate the connection between cannabis smoking and increases in heart rate (Vandrey et al., 2013).

The second hypothesis sought to examine the influence of cannabis

Table 3
Models for heart rate, high frequency heart rate variability, and root mean square of successive differences (n = 214 for 31 participants).

Moderate CUD (VS severe CUD)	−1.75	5.46	37.78	74.56	1.40	4.37
Female (Vs Male)	5.08	4.80	−73.66	66.13	−4.81	3.83
Variables	HR		HF		RMSSD	
	B	SE	B	SE	B	SE
Cannabis Use (After VS Before)	7.03**	2.28	−96.68**	24.45	−5.91**	1.5494
Occasions	−0.01	0.52	4.35	4.74	0.25	0.30
Age	8.59	5.29	7.12	19.02	0.41	1.10
Age of cannabis use onset	−0.61	1.37	−8.56	11.93	−0.48	0.70
BMI	0.35	0.88	1.80	3.48	0.07	0.19
Interaction (Pre-Post*Occasions)	−0.12		0.50	5.79	0.08	0.37
(Intercept)	−0.14**	0.54	416.85	393.34	35.48	23.13
Mild CUD (VS Severe CUD)	−0.37	0.44	−97.90	73.69	−6.03	4.28

*significant at $p < .05$, **significant at p < .01, HR, HF, and RMSSD are independent variables.

smoking frequency (occasions) on heart rate and HRV. In the presence of substance use and anthropometric covariates, cannabis smoking frequency was not associated with autonomic activity. Of the scientific literature that identifies a connection between cannabis (or its components) and autonomic activity, none focus on cannabis use frequency. These are focused on experimental designs where the protocol includes administering tetrahydrocannabinol or a type of cannabis to participants in various dosages (Pabon et al., 2022; Hendrickson et al., 2021) or creating groups based on drug testing results (Schmid et al., 2010). The epidemiological literature speaks to the likelihood that cannabis users also have cardiovascular events or conditions (Mondal et al., 2024). However, the current study is the first to report cannabis frequency temporally paired with autonomic data collection.

The connection between cannabis use and heart rate modulation may be event-based, and not a function of tolerance or cannabis use frequency. This notion is supported by our findings that suggest neither cannabis use disorder severity nor the number of cannabis usage occasions were predictors of sympathetic shifts in heart rate or HRV. Further, previous research suggests that neither cannabis use frequency nor cannabis concentration levels in smoked flower products were associated with heart rate when comparing cannabis users to healthy controls (Limbacher et al., n.d.). This increase in heart rate after using cannabis was also reported in a young healthy sample of cannabis users who also experienced cardiovascular dysfunction, including arterial thickness and blood pressure alterations (Cheung et al., 2024). The event-based (i.e., each cannabis smoking session) sympathetic increase in young adult African American/Black college students may not seem deleterious at first glance. But given that African American or Black adults are exceedingly high risk for cardiovascular disease (Mensah, 2018) and cardiovascular events (Carnethon et al., 2017), this presents an interesting risk factor for individuals living with CUD in middle and older age groups.

The sympathetic shifts associated with cannabis smoking are in line with previous research reporting a dose-response relationship between cannabis use via combustion modalities, including smoking (Zamarripa et al., 2022) and vaping (Sholler et al., 2021). Though many studies examining the association between cannabis use and heart rate are in experimental studies, no study has sought to examine individuals living with CUD 10 min before and after smoking cannabis. The current findings extend previous findings that identify an immediate increase in heart rate after smoking cannabis (Kayser et al., 2020) by further exploring the nature of the autonomic shift. Specifically, the current findings not only suggest an increase in heart rate but also a decrease in parasympathetic metrics in both time and frequency domains. These results provide further context to the autonomic shift that is seemingly antagonistic, coupling the parasympathetic and sympathetic nervous system responses. The reciprocal nature between parasympathetic and sympathetic nervous systems allows for more sophisticated targeting for future interventions, including just-in-time text message-based interventions that may be based on increases or decreases in heart rate.

The current findings are the first to examine cannabis use and autonomic activity in African Americans or Black young adults living with CUD. Specifically, the sample consisted of individuals living with cannabis use disorder. Chronic cannabis use is associated with deleterious cardiovascular alterations (DeFilippis et al., 2020). However, the cardiovascular risk increases if an individual is African American or Black, younger, and suffers from cannabis use disorder (Chouairi et al., 2021). Through ecological momentary assessment-based design, this study plants the seed for future research in this area to explore individual-level autonomic shifts in cannabis smokers. Employing these analyses will allow for a more detailed determination of cannabis's autonomic influence in real-world settings. Specifically, designing a study to account for psychosocial perceptions and awareness of the participant before cannabis would be truly informative.

These results of the study should be considered in light of some limitations. First, the cannabis usage data collected were self-reported, in natural settings. Data collection procedures could benefit from multi-method (e.g., diary, urine drug tests) approaches to validate cannabis usage. Moreover, we did not collect data on the context of the cannabis smoking session, whether the participant was alone or with a group. Thirdly, we did not collect concomitant substance use in addition to the cannabis smoking events. This includes the assessment of nicotine, which could be used in conjunction with cannabis when smoking. Fourth, though an underrepresented sample in the scientific literature, we recruited young adult undergraduates. Future research should replicate this study in a community-based sample or a sample of middle-aged adults for contrast. Further, researchers should consider these effects in sex-balanced samples to elucidate potential biological differences that would influence the prevalence of cannabis use or autonomic function. This variation in study samples would include the statistical adjustment for menstrual cycle phase, as previous research has suggested its influence on autonomic activity (Simon et al., 2021). Fifth, the current study did not assess cannabis use modalities outside of smoking cannabis. Though we employed cannabis use disorder as an inclusion criterion, we did not assess if they also used edibles or topical oils during the longitudinal data collection. Lastly, future research should also look to examine larger samples, including individuals living with and without cannabis use disorder. This would allow for possible elucidation or etiology of cannabis influence on the peripheral components of the autonomic nervous system.

5. Conclusion

In conclusion, the present study begins to further elucidate the autonomic shifts that may occur among individuals who live with CUD each time they smoke cannabis. Results indicated that when compared to the 10 min prior to use, there is a significant parasympathetic decrease and sympathetic increase 10 min after smoking cannabis. However, there is no cumulative or additive effect based on the number of times cannabis was used that influenced autonomic activity. Cannabis use disorders associated with internalizing symptoms (Keen et al., 2023) and cardiovascular risk (Schermitzler et al., 2023) may be linked to this habitual sympathetic shift after smoking cannabis. With more rigor and replication, service providers may find these results informative concerning medicinal medication usage or for patients with cardiovascular dysfunction.

CRediT authorship contribution statement

Larry Keen: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Caroline Bena Kuno:** Writing – original draft, Visualization, Software, Formal analysis, Data curation, Conceptualization. **Alexis Morris:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation.

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Appendix A

Table 1s
Pre- and post-means scores for different time points.

n	Occasions	Before HR (mean ± SD)		After HR (mean ± SD)		Before HF (mean ± SD)		After HF (mean ± SD)		Before RMSSD (mean ± SD)		After RMSSD (mean ± SD)	
31	1	89.60	±12.12	97.76	±17.85	394.57	±209.92	283.85	±163.35	34.34	±11.86	27.68	±10.58
21	2	90.68	±11.96	93.96	±9.05	351.31	±162.55	279.81	±137.27	31.97	±9.66	27.87	±7.51
14	3	88.59	±12.20	95.17	±13.45	349.42	±162.56	273.49	±100.59	32.38	±10.37	27.48	±6.81
11	4	89.05	±10.46	98.18	±10.89	345.38	±130.15	232.52	±95.801	31.66	±7.74	25.03	±5.94
8	5	90.93	±9.53	102.40	±9.82	350.85	±122.05	205.18	±82.72	31.96	±8.50	23.28	±5.70
8	6	90.48	±13.74	90.89	±13.60	382.58	±197.75	347.59	±139.71	33.79	±11.83	31.62	±8.43
5	7	83.67	±5.55	91.70	±7.82	414.96	±109.40	339.16	±80.16	35.98	±6.03	31.42	±4.73
3	8	82.90	±24.43	91.28	±6.07	606.24	±426.28	346.02	±122.17	45.70	±25.52	30.93	±6.25
3	9	88.24	±17.96	88.69	±14.06	329.95	±196.62	331.92	±164.50	31.94	±14.82	31.10	±9.22
2	10	93.03	±9.28	102.47	±11.40	375.24	±161.43	238.96	±59.38	31.71	±8.21	24.75	±3.35
1	11	81.61	NA	86.61	NA	450.05	NA	399.00	NA	36.41	NA	36.23	NA

Model specification.
$y_{it} = \beta_0 + \beta_1 time_{it} + \beta_2 txtime_{it} + u_{oi.}$
$y_{it} = \beta_0 + \beta_1 tx_{it} + \beta_2 time_{it} + \beta_3 txtime_{it} + \beta_3 controls_{it} u_{oi}$
β_0 = the mean score for each participant
β_1= estimate for the average Cannabis use effect (is the difference in the Cannabis use(before VS after).
β_2 = estimate for the average time effect (change over time)
β_3 = interaction effect
u_{oi}=the error term capturing participant-level deviation in mean score

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpsycho.2025.113211.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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