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EFFECT OF 4-7-8 BREATHING EXERCISE ON HEART RATE VARIABILITY IN PARTIALLY SLEEP-DEPRIVED YOUNG ADULTS- AN INTERVENTIONAL STUDY

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ABSTRACT

Background: Heart Rate Variability (HRV) is defined as the fluctuation in the time interval between successive heartbeats. It is an important indicator of autonomic imbalance and cardiovascular health. Research studies have shown that the effect of partial sleep deprivation on HRV has yielded inconclusive results. Our Objectives were to determine whether the HRV parameters in the morning following partial sleep deprivation were different from those following normal 7-8 hours of sleep at night in the same participants and to determine the acute effect of the 4-7-8 breathing exercises on HRV in partial sleep-deprived subjects when practiced for 20 mins.

Methods: Twenty subjects were screened with the Pittsburgh Sleep Quality Index Scale (PSQI) and Epworth Sleepiness Scale (ESS) and were recruited based on inclusion-exclusion criteria. Baseline HRV was recorded by using PPG (Photo plethysmography). After 3 nights of sleep less than 5 hrs per night, on the morning following the 3rd night, PPG was again recorded. HRV [Total power (TP), Low-frequency power (LF), High-frequency power (HF), LFnu, HFnu, and the LF-HF ratio)] were derived from PPG. Then, subjects were taught 4-7-8 breathing exercises and asked to practice the same for 20 minutes following which HRV was recorded again.

Results: HRV following Partial sleep deprivation when compared to baseline showed a significant change in total power. [TP, baseline (5880.55 ± 2095.988), partial sleep deprived (4435.15 ± 1782.604) (P = 0.036). The 4-7-8 breathing exercises intervention after partial sleep deprivation did not show a significant change (P< 0.05) in HRV parameters in the participants compared to the HRV after PSD.

Conclusion: PSD showed an impact on HRV parameters mainly showing reduced parasympathetic activity in healthy young adults. However, 4-7-8 breathing exercises for 20 minutes improved the parasympathetic activity following partial sleep deprivation but it was not statistically significant. Future studies need to be conducted in this area.

Keywords: PSD (partial sleep deprivation), Heart rate variability, 4, 7, 8 breathing exercise

INTRODUCTION:

Sleep is required for physical and mental well-being and for the recovery from damages caused due to daytime stress.(1) The National Sleep Foundation (NSF) recommends that young adults require seven to nine hours of sleep at night. Total sleep deprivation has deleterious effects and its ill effects are well-researched.(2,3) However, it is Partial Sleep Deprivation(PSD) that we come across more often than total sleep deprivation on a day-to-day basis. Those who restricted their sleep to 2 hours less than their regular sleep hours, for 3 consecutive nights can be defined as having partial sleep deprivation. Research studies have shown that sleep deprivation causes increased inflammation, increased oxidative stress, and increased insulin resistance.(4,5)

Heart Rate Variability (HRV) is defined as the fluctuation in the time interval between successive heartbeats. HRV assessment gives the measure of the degree of autonomic modulation rather than the level of autonomic tone.(6) Research studies have shown that partial sleep deprivation is associated with increased LF (low-frequency band) and decreased HF (high-frequency band).(7) However, Vierra et al. showed no differences in HRV between those who slept less than 7 hours and those who slept more than 7 hours the previous night.(8) Laborde et al. reported that there was a significant increase in RMSSD and absolute LF during voluntary slow breathing practice. This study concluded that voluntary slow breathing showed significant increases in HRV and increased vagal-mediated parasympathetic activity. (9)Research studies on slow deep breathing have shown that TP, HF, and HF nu increased with slow deep breathing exercises.(10)4-7-8 Breathing exercise, a form of

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Pranayama has been used as an intervention and it has been found that it has no acute effects on HRV when practiced for 9 minutes in partial sleep-deprived subjects.(8)

We hypothesized that HRV parameters following PSD would significantly increase in LF and LF nu and decrease in TP, HF and HF nu from the baseline HRV. Our second hypothesis was that there would be a significant increase in TP, HF, and HF nu following 4-7-8 breathing exercises for 20 minutes compared to HRV following PSD.

Objectives of the Study:

1) To determine whether HRV parameters on the morning following 3rd consecutive night of partial sleep deprivation were different from the HRV at baseline.
2) To determine the acute effect of the 4-7-8 breathing exercise on HRV in partial sleep-deprived participants when practiced for 20 mins

METHODOLOGY:

Participants:

Ethical clearance was obtained from the Institutional Ethical Committee. The study design was an experimental study. Written informed consent was obtained from each of the participants. Recruitment of participants was done by convenient sampling and the study was conducted between April and June 2024 in the Physiology Research Lab, Department of Physiology.

Twenty young adult men in the age group of 20-35 years were included in this study after checking the inclusion and exclusion criteria. Inclusion was limited to participants who gave informed consent and who had normal PSQI score of less than 5 and ESS equals zero in the screening test. Those who were regular yoga practitioners, smokers, those who had consumed alcohol in the last 24 hrs or those suffering from any acute or chronic condition, any neuro-muscular disorder/ skeletal deformities, those who had taken antihistamines during the period of the study were excluded from the study. If a participant felt uncomfortable during the experiment, he was given the option to opt out of the study.

Sample size:

The sample size was calculated based on a previous study by Bourdillon et.al (7)
According to the formula:

$n = Z_\alpha^2 \sigma^2 / d^2$

Z_α= Standard table value for 95% CI = 1.96
σ = Standard deviation = 2028
d = effect size = 962

$n = (1.96)^2 \times (2028)^2 / (962)^2 = 17.07$

After adding the dropout rate (10%) the sample size was estimated to be 20.

Instruments:

Screening tools:

1. Pittsburgh Sleep Quality Index (PSQI): It is a self-report questionnaire. It measures sleep quality and disturbances over a one-month period. It has a total of 19 questions, and the sum of the scores were global scores ranging from 0-21. A score of less than 5 was considered to be healthy.
2. The Epworth sleepiness scale (ESS) was a subjective measure of daytime sleepiness. It was an open-source self-assessment scale. It has a total of 8 situations in which you rate your tendency to sleepiness. Each question score ranged from 0 to 3, 0 showed no chances of dozing, 3 showed a high chance of dozing and the sum of scores ranged from 0 to 24. A score of 1 to 24 showed daytime sleepiness.

Instruments:

Recording of Photoplethysmogram (PPG)

Photoplethysmogram (PPG) was recorded using the PowerLab system by AD instruments (model number – PL 15T02 and S.NO 15T2-0862). The PowerLab system is a 15T multichannel recording unit. The pulse transducer used for the PPG recording was TN1012/ST. The Power Lab system acquires, stores, and analyzes the data. The raw input signal acquired by the system undergoes signal conditioning (amplification and filtering and also removal of unwanted noise). This signal is converted to digital form and then sent to the attached computer. The computer displayed the data directly and the HRV software (v8.1.24) analyzed the data.

HRV Analysis: AD Instruments Lab Chart Pro (v8.1.24) software was used for HRV analysis.

Methodology:

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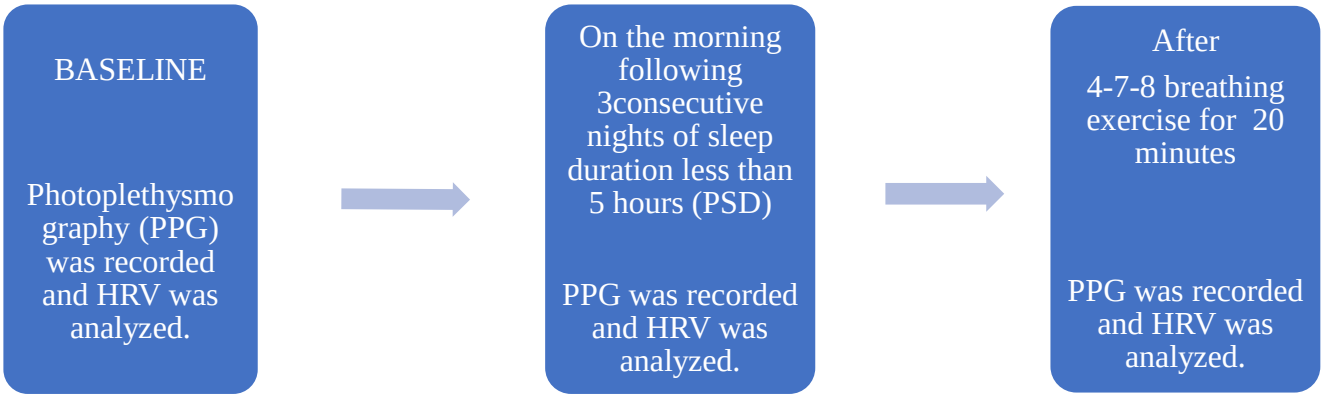
Participants were recruited after screening with inclusion and exclusion criteria and the screening tools. Each of the participants was instructed to maintain a sleep diary and to note the time of going to sleep and waking up till the study was completed. The participants were instructed to maintain constant bedtime as far as possible. For the baseline recording, participants were instructed to come in the fasting state between 8 to 10 AM in the morning and the ppg was recorded for a duration of 10 mins after giving each of them 30 mins of supine rest.

Participants were then instructed to sleep for 2 hrs less than their usual sleep duration for 3 consecutive nights without taking any naps in between and to report to the physiology research lab in the fasting state in the morning following 3 nights of 5 hrs of sleep. Following PSD (as described above), PPG was recorded for 10 minutes after 30 mins of supine rest.

Then, 4-7-8 breathing was taught to the participants by a yoga teacher and participants were instructed to practice that for 20 minutes following which PPG was again recorded for 10 minutes period. Each of the three PPG recordings were screened for any artifacts manually and was subjected to HRV analysis by using AD Instruments Lab Chart Pro (v8.1.24) software.
The power spectral analysis of the PPG yielded the following outcome measures:
Frequency domain measures:

a. Total power (TP) in ms2
b. Low-frequency power (LF) in ms2
c. High-frequency power (HF) in ms2
d. Low-Frequency nu (LF nu)
e. High-frequency nu (HF nu)
f. The ratio of LF nu to HF nu (LF-HF ratio)

Protocol:



Statistical analysis:
Data were entered in Microsoft Excel2010 and were analyzed by using Jamovi (version 2.4.8). Descriptive statistics were done and data were represented as Mean±Standard Deviation. Inferential statistics was done using paired t test to compare means in HRV parameters between baseline and following PSD and also to compare the means between HRV parameters following PSD recording and after the 20-minute practice of 4-7-8 breathing exercises.

RESULTS:
Table 1 shows that TP in ms^2 was significantly lower after the PSD when compared to baseline. The other parameters LF, and LF nu were higher and HF and HF nu were lower following PSD compared to baseline but they were not statistically significant.
When comparing HRV following PSD and HRV after 20 mins of 4-7-8 breathing exercise, LF in ms2 and LF nu decreased but TP, HF in ms^2 and HF nu increased. None of the P values obtained while comparing the means of HRV after PSD to that after 4-7-8 breathing exercise were statistically significant.

Table1: Comparing the heart rate variability parameters measured at base line and after partial sleep deprivation and after 4-7-8 breathing exercise

[a] paired t test - baseline vs after partial sleep deprivation
[b] paired t test - after partial sleep deprivation vs after 4-7-8 breathing

HRV parameter	Baseline (n=20)	After PSD(n=20)	P value[a]	After 4-7-8 breathing	P value[b]

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TP (ms^2)	5880.55 ± 2095.988	4435.15 ±1782.604	0.036 *	5220.85 ± 2342.951	0.223
LF (ms^2)	1506.235 ± 1118.743	2104.15 ±1577.307	0.215	1782.185 ± 1193.805	0.487
LF (nu)	42.168 ±15.14	43.968 ± 17.675	0.71	42.451 ± 19.531	0.733
HF (ms^2)	2904.81 ± 2224.317	1766.73 ±1110.086	0.07	2272.57 ± 1635.596	0.295
HF (nu)	55.608 ± 14.097	52.903 ± 15.878	0.558	53.727 ± 15.819	0.813
LF/HF Ratio	0.9 ± 0.833	1.058 ±0.892	0.571	1.054 ± 1	0.986

DISCUSSION

Our findings were that the HRV parameter total power (TP) showed a statistically significant decrease after partial sleep deprivation compared to baseline. There was no statistically significant change in other HRV parameters compared to baseline. 4-7-8 breathing intervention did not show significant improvement in HRV parameters in partially sleep-deprived subjects.

Role of HRV parameters in Autonomic modulation:

The activity of the efferent vagus nerve is a key contributor to the high frequency (HF) component. This has been evidenced in clinical and experimental studies involving autonomic maneuvers such as electrical stimulation of the vagus nerve, blocking of muscarinic receptors, and surgical vagotomy.(11,12)The LF component, when expressed in normalized units, is an indicator of sympathetic modulation.(13,14)However, others view it as a parameter that influences both sympathetic and vagal influences.(11,15)

Factors that affect HRV:

HRV parameters are influenced by several factors like age, gender, circadian rhythm, autonomic regulation, and respiration. However, the study design, and collection of data at the same time of the day controlled for these factors.(16) Research studies have reported a decrease in parasympathetic activity and an increase in sympathetic activity in HRV following partial sleep deprivation. (7,17,18)

Our study finds that partial sleep deprivation decreases Total power (TP) significantly (P value = 0.036) compared to baseline. Although there were no statistically significant changes observed individually in sympathetic activity (LF) or parasympathetic activity (HF), an increasing trend in LF and LFnu and a decreasing trend in HF and HF nu were observed. These results are in line with the findings reported by Schlagintweit J et al.(17)and Bourdillon et al.(7) Our findings indicate that sleep deprivation was not intense enough to inhibit vagal modulations to the heart significantly.

A low inhale-to-exhale ratio significantly increases vagal activity, leading to an improvement in parasympathetic function.(10) Additionally, holding one's breath after inhalation can increase arterial oxygen saturation, which in turn reduces stimulation of peripheral chemoreceptors, further promoting parasympathetic activity.(8)

Magnon et al. showed in 2021 that there was a significant increase in Total Power (TP) and High Frequency (HF) following the practice of deep slow breathing.(10) Even though the 4-7-8 breathing is a subtype of deep slow breathing our study did not find any significant difference in HRV parameters. Our finding that there is no improvement in HRV parameters following 20 minutes of 4-7-8 breathing in PSD subjects is in accordance with Vierra et al.(8)

We hypothesized that HRV parameters following PSD would be significantly different from the baseline HRV. This hypothesis was partially fulfilled as we found the total power was significantly decreased following PSD. However, even though there was a trend, the other HRV parameters were not statistically different. Our second hypothesis was that there would be a significant improvement in TP, HF, and HF nu following 4-7-8 breathing exercises for 20 minutes compared to HRV following PSD. This hypothesis was rejected.

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Strength and limitations:
Our study controlled for several confounders that affect HRV. Gender and age were controlled for because of study design. A standardized instrument was used for recording HRV. Despite the strengths of the study, the current findings can be attributed to PSD which was not intense enough to affect other HRV parameters other than TP, and acute intervention of 4-7-8 breathing due to its short duration probably did not yield significant findings.

CONCLUSION

PSD impacted HRV parameters mainly showing reduced parasympathetic activity in healthy young adults. However, 4-7-8 breathing exercises for 20 minutes improved the parasympathetic activity following partial sleep deprivation but were not statistically significant. Future studies need to be conducted in this area.

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Conflict of interest -none

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