Original Research Article

Cognitive performance and Heart rate variability: The influence of menstrual cycle in young subjects

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A R T I C L E   I N F O

A B S T R A C T

Introduction: Menstrual cycle characterized by various dynamic alterations in sex steroidal hormones not only alters the reproductive organs but also various systemic organs and hence higher functions are one among them. This study is an attempt to determine the influence of various hormones on cognitive function using short term heart rate variability analysis in different phases of menstrual cycle.

Materials and Methods: Thirty participants were subjected for the baseline recording of HRV and psychomotor vigilance test and short term memory test along with HRV recording in three subsequent numbers of times to study variations in three different phases of menstrual cycle. Both time domain and frequency domain parameters were studied during resting state and while performing psychomotor vigilance test and short term memory test.

Results: The time domain and frequency domain parameters on comparison with resting state to during psychomotor vigilance test and short term memory test parameters were statistically insignificant in all three phases recorded. Unlikely on comparison of heart rate variability parameters both times domain and frequency domain values of RRI, RMSSD and LF (nu) values were statistically significant across the different phases suggesting upper hand of sympathetic tone.

Conclusion: The present study indicated increased sympathetic discharge during follicular phase on comparison to luteal and menstrual phase. The results also indicated a change in cognitive functioning during different phases due to hormonal variations.

1. Introduction

Heart rate variability (HRV) is simple noninvasive measurement of interrelationship between the autonomic nervous system and cardiovascular system. The analysis of HRV which includes time domain and frequency domain measures provides indirect information about autonomic tone. In time domain measures of HRV, the interval between subsequent RR intervals obtained by electrical activity recording in ECG is used which helps in determining the neural effect on sinus rhythm. The recent evidence supports the use of HRV as an index for determination of regulating cardiovascular system by autonomic nervous system.[1,2]

Menstrual cycle is good model of ovarian steroid hormones effect on cognition, emotion and behavior. Direct measurement of these higher functions correlating hormone level will establish the interdependency among them. Autonomic nervous system and its functioning are closely related to these higher functions and their role as an important component needs to be disclosed.

Autonomic nervous system is integrated with cognition and emotion. The expression of advanced cognitive abilities in humans involving consciousness, language and emotions are due to complex social environment.

Homeostatic control of this autonomic nervous system is important as it affects social and emotional behavior along with various autonomic activities including hypothalamo-hypophysial pituitary axis which in turn regulates menstrual cycle. Brain and body a re coupled intrinsically which is

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dynamic. Cognition is one of the components among them which respond to the change in state of mind or body.[3] These interactions form the basis for the present study which incorporates to study cognition and its effect on heart rate variability during different phases of menstrual cycle.

Mental process can influence physical state of body directly by altering ANS or indirectly causing changes in respiration or skeleton-motor activity as intentional or incidental consequence of enacting behavioral decisions. Similarly internal physiological process of visceral organs can influence mental process like internal body state can grab attention, compete for cognitive resources and interrupt ongoing thoughts and feelings. Hence autonomic or visceral state acts as a variable context for emotional and cognitive process.[4]

2. Objectives

1. The influence of cognitive process on heart rate variability parameters.
2. To observe variation in cognitive process and heart rate variability during different phases of menstrual cycle.

3. Materials and Methods

3.1. Study design

Observational cross-sectional study

3.2. Study setting

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3.3. Sample size

30.

3.4. Sampling method

Purposive convenient sampling.

3.5. Inclusion criteria

18- 24 years female with normal menstrual cycle duration.

3.6. Exclusion criteria

Females with irregular menstrual cycle, history of drug intake in last seven days and chronic systemic illness.

3.7. Study duration

2 months (July-August 2018).

3.8. Study procedure

The study participants were informed about the study and after obtaining informed consent were included in the study; the participant decision to withdraw from study any time without explaining any reason was informed. All participants' basic profile was collected like age duration of menstrual cycle.

The participants were asked to report in recording laboratory between 10am-1pm on predetermined dates. To minimize external influence all subjects were made to lie down for 5 minutes before the start of recording. In resting state using audacity software five minute ECG recording was obtained and labeled which was free of artifacts. After five minutes of rest the participants w ere explained about psychomotor vigilance test and short term memory test by match to sample task. Both these tests we re carried for 5 minutes each and HRV recording was obtained during this period.

The participants were subjected for the baseline recording of HRV and psychomotor vigilance test and short term memory test along with HRV recording three subsequent numbers of time to study variations in different phases of menstrual cycle. Recording on 3-5th day of cycle (menstrual phase), 13-15th day of cycle (proliferative phase) and 22-25th day (luteal phase) subsequently.

3.9. Study tools (Audacity)5

Sound recording software was used in the study for recording and displaying the real-time ECG recording. It acts as an A/D converter, and an advantage of using the computer's sound card as an A/D converter is that it eliminates the additional requirement of an external microprocessor. Sound editing software was able to display the real-time signals with time and amplitude analysis solutions. A simple ECG analog amplifier was used to acquire the ECG signals. Digitalization of the analog signals was done using the sound card of a computer (laptop). Display of the data recording was done using Audacity sound editing software (version 1.2.2) in wave format. Electrical noise (50) Hz in the digital data was filtered using a low pass filter. R waves identified using beat-to-beat finder tool in the Audacity software by fixing the amplitude as 60 Hz, and if the amplitude of the waves was found to be low than it was increased to a desired amplitude by using the amplify option. Later, R peak, which was identified by beat finder, was converted into real-time RR interval data by exporting the labels option in the software which was stored in the notepad format. The RR intervals saved in the notepad format was fed into the Kubios HRV-software (version 2.2, Biosignal Analysis and Medical Imaging Group, Department of Applied Physics, University of Eastern Finland, Kuopio, Finland) to process for HRV analysis.[5]

The method of analysis of the HRV data used in this study was linear mathematical processes (i.e., time domain method). This method is based on the mathematical calculation of the variations in time occurring between

beats. The parameters planned to analyze the HRV within the time domain are mean R-R interval (RRI), standard deviation of R-R interval (SDNN) and the root-mean-square difference of successive normal R-R intervals (R MSSD). The definitions for the HRV parameters are as per the guidelines given in Task force of the European society of cardiology and the North American society of pacing and electrophysiology.[6]

3.10. Psychomotor vigilance test

The task was created and designed by Wikinson and Houghton[7] which was to measure sustained vigilant attention of participants. Reaction times to visual stimuli at random inter-stimulus interval w ill be recorded. In each trial a red circumference will appear on black background between 2000ms to 10000ms, the participants will be instructed to respond as fast as they could by pressing the space bar on keyboard. Feedback of the response time will be displayed on screen after each trial. The complete process will be carried using software Psychology Experiment Building Language (PEBL)[8] which stores the data in separate excel sheet with test details of reaction time which will be used for analysis.

3.11. Match to sample task

The task is carried out on software Psychology Experiment Building Language (PEBL).[8] The task was started with presentation of a sample stimulus in centre of screen for 1000ms followed by pause of 3500ms. Following two comparison stimuli was appearing on the lateral corners of the screen simultaneously. One stimulus will be identical to the test stimulus and the participant was asked to select the correct response by pressing the right or left shift key on the keyboard. 30 subsequent trails were followed and the data was stored about the duration taken for the response and result of the response as right or wrong was recorded.

3.12. Statistical analysis

Heart rate variability parameters are expressed in mean and standard deviation. The data collected were of HRV before cognitive process test and during test. One way analysis of variance (ANOVA) was performed to determine difference in HRV parameters during different phases of menstrual cycle. P value < 0.05 was considered as significant statistically.

4. Observation and Results

30 subjects with regular menstrual periods were included in the study with mean age group of 19.76 ±1.13 years and their mean menstrual cycle period of 28.36 ±1.40 days. As shown in Tables 1, 2 and 3 are the recordings of heart rate variability parameters both time domain

measures and frequency domain measures in three different phases of menstrual cycle that is during menstrual phase, follicular and luteal phase of menstrual cycle. The table also displays the heart rate variability measures at three different condition one during the resting state and other recordings during the psychomotor vigilance test and short term memory test being performed during the time of recording.

On analyzing the data of different values obtained during the events of psychomotor vigilance test and short term memory test, there was no such change in HRV parameters from that of the resting state during the same phase of menstrual cycle. Though in our observations the sympathetic activity inclined to be increased compared to parasympathetic as shown in the values of RRI and LF (nu) the difference in value obtained were not statistically significant.

The data expressed in Tables 4, 5 and 6 are to compare the heart rate variability parameters among different phases of menstrual cycle during resting state and during the performance of test which included psychomotor vigilance test and short term memory test.

In Table 4 heart rate variability parameters both time domain and frequency domain values of RRI, RMSSD and LF (nu) values were statistically significant across the different phases on ANOVA. It is observed that sympathetic activity was significantly altered in the resting state during different phases of menstrual cycle.

The data in Table 5 and Table 6 are almost similar values of heart rate variability parameters both during the psychomotor vigilance test and short term memory test. The parameter which showed a significant difference was RRI in time domain measure and Lf (nu) in frequency domain measures which had been different on comparison to different phases of menstrual cycle.

5. Discussion

The present design was to investigate the relation of cognitive ability and short term memory test in relation to different phases of menstrual cycle as measured in terms of heart rate variability which composed of both time domain and frequency domain parameters.

Our study results indicated a significant difference in the heart rate variability in different phases of menstrual cycle especially increased sympathetic discharge as noticed in follicular phase compared to menstrual and luteal phase, similar results were shown by Chung, M.-H et al.,[9] who showed significantly higher sympathetic component compared to parasympathetic in the follicular phase than in the luteal phase during sleeping periods after night or day work.

In contrast to our study Brar TK et al.,[10] and Tenan MS et al.,[11] have demonstrated that in their studies sympathetic discharge was at higher rate in luteal phase as compared

Table 1: HRV parameters during menstrual phase of menstrual cycle

HRV parameters	Resting state	Psychomotor vigilance test	Short term memory test
RRI(ms)	681.92±119.74	668.78±84.32	652.67±92.87
SDRR(ms)	46.49±14.19	42.55±17.76	40.23±14.77
RMSSD(ms)	39.67±20.29	37.96±18.24	34.38±15.73
LF(nu)	53.86±14.25	52.45±13.96	51.63±12.38
HF(nu)	45.61±12.36	44.87±11.83	42.91±13.51
LF/HF	1.4±0.93	2.58±1.02	1.21±0.88

Table 2: HRV parameters during follicular phase of menstrual cycle

HRV parameters	Resting state	Psychomotor vigilance test	Short term memory test
RRI(ms)	621.03±82.42	615.28±57.43	604.65±45.76
SDRR(ms)	41.27±16.5	40.65±14.87	39.82±11.81
RMSSD(ms)	29.32±19.12	27.92±18.24	26.28±17.99
LF(nu)	61.02±17.22	62.59±18.37	60.24±17.49
HF(nu)	38.04±15.84	39.74±14.88	39.81±15.38
LF/HF	2.25±1.84	1.59±1.24	1.51±1.18

Table 3: HRV parameters during luteal phase of menstrual cycle

HRV parameters	Resting state	Psychomotor vigilance test	Short term memory test
RRI(ms)	685.56±105.24	658.29±98.43	645±104.49
SDRR(ms)	48.37±18.09	44.71±17.49	42.35±19.87
RMSSD(ms)	40.32±19.25	36.26±18.38	34.88±15.79
LF(nu)	55.86±13.6	54.88±14.9	52.74±12.84
HF(nu)	45.72±19.11	43.25±18.42	41.38±16.38
LF/HF	2.13±1.84	1.85±1.36	1.26±1.04

Table 4: Comparison of HRV parameters in resting state during different phases of menstrual cycle

HRV parameters	Menstrual	Follicular phase	Luteal phase
RRI(ms)*	681.92±119.74	621.03±82.42	685.56±105.24
SDRR(ms)	46.49±14.19	41.27±16.5	48.37±18.09
RMSSD(ms)*	39.67±20.29	29.32±19.12	40.32±19.25
LF(nu)*	53.86±14.25	61.02±17.22	55.86±13.6
HF(nu)	45.61±12.36	38.04±15.84	45.72±19.11
LF/HF	1.4±0.93	2.25±1.84	2.13±1.84

*-p value <0.05 and statistically significant

Table 5: Comparison of HRV parameters during psychomotor vigilance test during different phases of menstrual cycle

HRV parameters	Menstrual	Follicular phase	Luteal phase
RRI(ms)*	668.78±84.32	615.28±57.43	658.29±98.43
SDRR(ms)	42.55±17.76	40.65±14.87	44.71±17.49
RMSSD(ms)	37.96±18.24	27.92±18.24	36.26±18.38
LF(nu)*	52.45±13.96	62.59±18.37	54.88±14.9
HF(nu)	44.87±11.83	39.74±14.88	43.25±18.42
LF/HF	2.58±1.02	1.59±1.24	1.85±1.36

*-p value <0.05 and statistically significant

Table 6: Comparison of HRV parameters during short term memory test during different phases of menstrual cycle

HRV parameters	Menstrual	Follicular phase	Luteal phase
RRI(ms)*	652.67±92.87	604.65±45.76	645±104.49
SDRR(ms)	40.23±14.77	39.82±11.81	42.35±19.87
RMSSD(ms)	34.38±15.73	26.28±17.99	34.88±15.79
LF(nu)*	51.63±12.38	60.24±17.49	52.74±12.84
HF(nu)	42.91±13.51	39.81±15.38	41.38±16.38
LF/HF	1.21±0.88	1.51±1.18	1.26±1.04

*-p value <0.05 and statistically significant

to other phases of menstrual cycle. There is also a study exception to observations as reported by Teixeira et al.,[1,2] that the different phases of the menstrual cycle did not alter the resting heart rate in healthy women hence no significant change recorded independent to the use of oral contraceptive.

The increase in sympathetic activity noted in follicular phase may be related to role of hormones and their effect on autonomic nervous system as reported by various studies that estrogen has a significant role in modulation of sympathetic and parasympathetic afferents to heart and alter its activity.[12–14] The parasympathetic withdrawal is considered to be an important component identified as a risk factor for various disorders associated with cardiovascular system.[14]

Our study results indicated significant difference in the parameters of RRI and LF (nu) on performance of short term memory tests across the different phases of menstrual cycle, as demonstrated by many studies that no association can be established with the menstrual cycle but at the same time possibility of estradiol influence on memory cannot be ignored as it has been proved by clinical trial that estrogen has some beneficial effect on memory when treated in postmenopausal women.[15]

We also observed that difference in time domain and frequency domain parameter of RRI and Lf (nu) was significantly different on compared to different phases of menstrual cycle and this was more noted in follicular phase with respect to menstrual and luteal phase. The results indicate that cognitive processing requires a high degree of attention and that was better possible during follicular phase due to increased sympathetic activity. However similar results were expressed by Pestana E R et al.,[16] in their study when they compared individuals in relation to fitness level at different period of menstrual cycle.

The menstrual cycle is a natural experiment with cyclical variation of sex hormones which has attracted many medical and psychological researchers to intrigue. There is evidence provided by many researchers which has linked the influence of sex hormones on neurobiology. However the definite link and its operational evidence are still not clear, our study is a small attempt in the direction to correlate the role of heart rate variability during menstrual cycle and effect on cognition. Though some evidence is exhibited in terms of variation the challenge lies ahead as this task to replicate will be highly challenging.

6. Conclusion

The present study in healthy subjects indicated that heart variability time domain and frequency domain measures in the resting state during different phases of menstrual cycle was significantly different and provided evidence for increased sympathetic discharge during follicular phase on compared to luteal and menstrual phase. The present study also found evidence that cognitive performance in form of vigilance and short term memory tests were also significantly different in different phases of menstrual cycle suggesting role of sex hormones in cognitive aspects.

The study helped in establishing the state of cognitive process during different phases of menstrual cycle in young females indirectly by measuring heart rate variability parameters. This also helped in understanding attention span and its nature in different phases of menstruation though its replication will be challenging. Learning is an important aspect in early life and learner's ability may be affected by the natural variations of menstrual cycle due its effect on cognition. Our study was not successful in establishing association between cognition and menstrual cycle using the tool of heart rate variability as indirect tool strongly as all the parameters were not correlating. Further studies are essential in larger population to have definite evidence correlating serum hormonal assay with cognitive tests and heart rate variability.

7. Source of Funding

None.

8. Conflict of Interest

None.

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