Influence of Cycle Menstrual Phases on Cardio-Respiratory Responses to Sub-Maximal Exercise Among Eumenorrheic Young Women.

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Abstract

Background: Exercising during different phases of the menstrual cycle may result in differential physiological responses due to differential concentrations of oestrogen and progesterone in these phases. However, there is a dearth of information on the influence of menstrual phase on physiological responses to sub-maximal exercise in eumenorrheic women. This study therefore examined the influence of menstrual phases on cardio-respiratory status in eumenorrhoeic women, and their cardio-respiratory responses to sub-maximal exercise. The methods used in this study involved: Quasi-experimental in which 110 eumenorrhiec undergraduates are involved. They performed sub-maximal exercise on a treadmill using Bruce Protocol. Axillary temperature, resting heart rate, blood pressure (BP), respiratory rate (RR), rate pressure products (RPP) body mass index and waist circumference were recorded pre and post exercise using standardised procedures. The results obtained were: Systolic BP, diastolic BP and body temperature did not differ ($p>0.05$) across the phases of the menstrual cycle except for heart rate ($p= 0.004$) and RPP ($p= 0.047$) that had the highest values in the luteal phase and the lowest value in the follicular phase. Menstrual phase showed no significant influence ($p>0.05$) on systolic BP, diastolic BP, heart rate, body temperature, and respiratory rate and RPP responses to sub-maximal exercise across phases of the menstrual cycle among eumenorrheic undergraduates. In conclusions, heart rate and RPP are lowest during the follicular phase of the menstrual cycle, and there is no difference in cardio-respiratory and body temperature responses to sub-maximal exercise across the phases.

Keywords: *Sub-Maximal Exercise, Menstrual Cycle, Cardiovascular System, Respiratory System, Body Temperature.*

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Introduction

Menstruation is a normal process in women of premenopausal ages that occurs monthly (Redman, Scroop & Norman, 2003). Eumenorrhoeic females have normal or regular menstrual cycle that lasts for an average of 28 days, which may range from 24 to 45 days. Adollaphor, Khosravi, and Zahra (2013) opined that the cyclic menstruation causes a periodic changes in the blood levels of female sex hormones. The four phases of menstrual cycle (the menstrual, the follicular, the ovulatory and the luteal) are based on ovarian function and are controlled by pituitary hormone signals (Redman et al., 2003).

Estrogen acts directly on blood vessels causing vasodilatation through an endothelial nitric-oxide-synthase-dependent genomic mechanism (Miller & Duckles, 2008). In addition, progesterone lowers blood pressure (BP) and blocks the response to angiotensin II, either independently or in conjunction with estrogen, by decreasing calcium L-currents, and hence, delays vascular smooth muscle contraction (Arifuddin , Hazari, & Redy, 2012). Progesterone receptors have also been localised in the myocardium and thus may have effect on cardiac contractility (Bargallo, Donenguez, Licata, Shan, Bing & Karpinski 2001). These direct vascular and neural actions explain the lower BP and increased renin- angiotensin system (RAS) activity during the secretary phase (Bargallo, et al., 2001).

Estrogen and progesterone fluctuate predictably across the menstrual phases in eumenorrheic women (Osthuyse & Bosch, 2010). These fluctuations are associated with corresponding significant changes in multiple neurohumoral homeostatic mechanism regulating the cardiovascular system (Hirshoren, Tzoran, Makrienko, Edoute, Plawner, Itskovitz-Eldor & Jacob, 2002). However, cardiovascular changes during normal menstrual cycle are not well documented and available studies have shown conflicting results (Arifuddin et al, 2012). In addition, only a few studies have reported influence of menstrual phases on cardiovascular changes during exercise (Redman et al, 2003, Tsai et al, 2003). Other than reproductive function, the ovarian hormones influence many other physiological systems and their actions during exercise may have implications for exercise performance (Osthuyse & Bosch, 2010). Exercising during different phases of the menstrual cycle may result in differential physiological responses due to differential concentrations of oestrogen and progesterone in these phases (Abdollaphor, et al., 2013). However, there is a dearth of information on these physiological responses to sub-maximal exercise in eumenorrhoeic women. This lack of information may have implications for the interpretation of cardio-respiratory responses to sub-maximal exercise. This study therefore examined the influence of menstrual phases on cardio-respiratory status in eumenorrhoeic undergraduates and their cardio-respiratory responses to sub-maximal exercise.

Method

This quasi-experimental study involved 110 eumenorrhiec undergraduates who were recruited through snowball sampling techniques. They were recruited consecutively through placement of advertisement on the campus detailing the nature of the study. The fitness and readiness of individual participants for exercise was ascertained through Physical Activity Readiness Questionnaire. Individuals who were having heavy or prolonged bleeding during menstruation; were having bleeding between periods; were having painful cramps, whose menstrual cycle varied by more than three days, or whose menstruation had stopped were excluded from these study. The details of the study were explained to each of the participants and their informed consent was obtained.

Approval of the procedures employed in this study was obtained from the Ethics Committee of Department of Medical Rehabilitation, Nnamdi Azikwe University. All the participants were prepared and familiarised with use of the treadmill. This study involved five research assistants who were students of the college and were knowledgeable in exercise physiology and the anthropometric and cardio-respiratory assessments employed in this study. Upon arrival at the study venue, each participant rested for five minutes to allow the physiological variables to fall to the resting level, after which axillary temperature, resting heart rate (HR), BP, respiratory rate (RR), body mass index and waist circumference were measured using standardised procedures as described below. In addition, information on age at the last birthday and date of the beginning of the last menstruation was recorded (to determine their menstrual phase status). All physiological measurements were taken with the participants comfortably seated and between 12 pm and 2 pm.

Menstrual Phase Status: Participants were categorised into different phases of the menstrual cycle, based on their date of commencement of the last menstruation as menstruation phase (days 1-4), follicular phase (days 5-13), ovulatory phase (day 14), and the luteal phase (days 15-28).

***Axillary Temperature**:* This was measured using calibrated mercury thermometer pre-exercise and post-exercise. The thermometer was cleaned with cotton wool dabbed with methylated spirit, was shaken to make mercury level fall below the calibrated portion. The Axillary temperature was taken by placing the thermometer bulb in the axilla for at least five minutes until the temperature stabilised. The axillary temperature was recorded, in ^{o}C by reading off the mercury level in the tube at the eye level.

The pooled (random effects) mean axillary temperature difference (rectal minus axillary temperature) for young people is reported to be 0.92^{o} (Craig, Lancaster, Williamson & Smyth, 2000).

***Blood Pressure and Heart Rate**:* BP and heart rate were measured, pre and post exercise, in the sitting using an automated BP device (Omron HEM-712, Bannockburn, China) following the recommended standards (Wilson, Kliewer, Pylobon & Sica, 2000). Three measurements, separated by two minutes, were taken for pre-exercise BP and HR, and the mean of the last two measurements was calculated and recorded, as systolic BP/diastolic BP in mmHg and HR in beats/minute. For the measurement at the end of the exercise, however, one measurement was feasible.

***Rate-Pressure Product**:* RPP was calculated using the formula; systolic BP x heart rate.

***Respiratory Rate**:* This was measured, pre and post-exercise, by visually observing the chest movement of participants in resting sitting position. The number of chest elevation in 15 seconds was counted and multiplied by four to record the RR in counts per minute.

Body Mass Index: This was calculated from body weight (kg) and height (m^2) using the formula body weight ÷ height^2. Body weight was measured using a bathroom measuring scale (Hana, Model BR9011; 120 x0.1 kg; China). The participants were measured bare footed and with minimal clothing. Height was measured using a height meter with participants bare-footed and erect on the platform of the scale and measurement was taken at level of the vertex.

Waist Circumference: This was taken at the level of the umbilicus using a non-elastic tape measure (Butterfly, China), and recorded to the nearest 0.1cm. The measurement was at the end of expiration.

Exercise Performance

Bruce protocol was employed in carrying out the exercise performance at the Gymnasium of the Department of Medical Rehabilitation, Nnamdi Azikwe University. After the participants had undergone the pre-exercise measurements and assessments, they performed exercise on a treadmill with an initial speed of 2.74km/hr and gradient (an incline) of 10% between 12 pm and 2 pm. After every three minutes, the gradient was increased by 2% while the speed was increased to 4.02Km/hr, 5.47KM/hr, 6.76KM/hr, successively. So, the exercise lasted for a maximum of 12 minutes for the participants. The time to exhaustion was taken using a digital stopwatch (Leap High-Point PC-396) and recorded as exercise duration in minutes. Also at the end of exercise session, the systolic BP, diastolic BP, HR, RR and body temperature were taken using the same procedures as the pre-exercise measurements. The RPP was calculated from the product of diastolic BP and HR on all participants. This procedure was carried out on all participants irrespective of the phases of their menstrual cycle.

Data Analysis

The data obtained from this research was summarised using descriptive statistics of mean and standard deviation. The inferential statistics of one-way ANOVA was used to determine statistical differences in cardio-respiratory variables and body temperature across phases of the menstrual cycle, at baseline and post-exercise. The significant differences in baseline heart rate and RPP were adjusted for in determining the influence of menstrual phase on post-exercise values of these variables using ANCOVA. Level of significance was set at 0.05.

Results

The participants' age, BMI and waist circumference in different phases of the menstrual cycle were as presented in table 1, and were not different across the phases. On average, participants fell within normal weight category of the BMI across phases of the menstrual cycle. Also, table 1 shows that systolic BP, diastolic BP and body temperature did not differ across the phases except for HR and RPP that had the highest values in the luteal phase and the lowest value in the follicular phase.

Table 1: *Demographic, anthropometric, cardio-respiratory and body temperature characteristics of participants*

	Luteal	Follicular	Ovulatory	Menstruation		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	F-value	p-value
Age(Years)	20.62±1.50	20.72±2.05	20.87±1.92	21.14±1.62	0.45	0.72
BMI (kg/m^2)	22.06±6.22	22.96±3.43	22.79±3.74	22.69±2.90	0.25	0.86
WC(cm)	75.51±6.45	75.67±8.35	75.09±6.40	75.14±6.94	0.33	0.80
SBP (mm Hg)	109.64±10.83	112.78±10.71	108.22±9.43	112.91±11.23	1.20	0.31
DBP (mm Hg)	68.80±10.17	68.67±8.24	69.43±12.18	71.71±7.78	0.49	0.69
HR (beats/min)	81.62±10.67	73.33±9.67	74.48±9.04	76.86±9.02	4.64	0.004*
Temp. (°C)	36.63±0.40	36.52±0.43	36.58±0.32	36.53±0.30	0.50	0.69
RR (counts/min)	28.26±3.55	28.04±3.09	28.35±2.67	27.05±3.77	0.74	0.53
Dura (min)	13.59±4.95	14.04±4.90	14.83±5.13	15.05±5.77	0.49	0.69
RPP	8934.54 ±1372.70	8248.59 ±1198.83	8059.00 ±1185.92	8704.14 ±1484.02	2.73	0.047*

BMI: Body Mass Index (Kg/m2); WC: Waist Circumference (cm); TEMP: Temperature(OC); SBP: Systolic Blood Pressure (mmHg); RR: Respiratory Rate; DBP: Diastolic Blood Pressure (mmHg); RPP: Rate Pressure Product; Dura: Duration (min)

In table 2 below, menstrual phase had no significant influence (p> 0.05) on systolic BP, diastolic BP, HR, body temperature, RR and RPP responses to sub-maximal exercise across phases of the menstrual cycle among eumenorrheic undergraduates.

Table 2: *Influence of Menstrual phases on cardiovascular, respiratory and body temperature Responses to sub-maximal exercise*

	Luteal	Follicular	Ovulatory	Menstruation		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	F-value	p-value
SBP (mm Hg)	146.82±2.49	147.12±3.12	147.98±3.33	143.62±3.51	0.31	0.82
DBP (mm Hg)	75.02±1.41	72.39±1.74	73.89±1.85	72.11±2.01	0.69	0.56
HR (beats/min)	178.58±2.51	178.10±3.08	177.43±3.18	178.35±3.40	0.03	1.00
Temp. (ºC)	37.17±0.10	37.32±0.13	37.16±0.13	37.32±0.14	0.53	0.66
RR (counts/min)	56.50±1.08	56.73±1.32	54.85±1.37	59.09±1.48	1.50	0.72
RPP	26034.08 ± 744.86	26361.35 ± 919.06	25135.78 ±965.95	25878.16 ±1029.94	0.35	0.79

TEMP: Temperature (OC); SBP: Systolic Blood Pressure (mmHg); RR: Respiratory Rate; DBP: Diastolic Blood Pressure (mmHg); RPP: Rate Pressure Product

Similarly, from table 3, below when the baseline differences in HR and RPP were adjusted for, the influence of menstrual phase on HR and RPP remained insignificant.

Table 3: *Baseline-Difference- Adjusted Influence of Menstrual phases on Heart Rate and Rate-Pressure Product Responses to sub-maximal exercise*

	Luteal	Follicular	Ovulatory	Menstruation		
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	F-value	p-value
HR (beats/min)	178.38±2.47	177.82±2.92	177.55±3.13	177.26±3.40	0.03	0.99
RPP	26276.74 ± 754.16	26279.61 ± 891.08	24864.71 ±954.83	25434.60 ±991.22	0.60	0.62

TEMP: Temperature (OC); SBP: Systolic Blood Pressure (mmHg); RR: Respiratory Rate; DBP: Diastolic Blood Pressure (mmHg); RPP: Rate Pressure Product

Discussion

This study explored the influence of menstrual phase on cardio-respiratory status and cardio-respiratory responses to sub-maximal exercise among eumenorrhiec undergraduates. This study has shown that only the resting HR and RPP differed across the phases of the menstrual cycle. However, no difference in resting systolic BP, resting diastolic BP, resting body temperature and resting RR was observed. In addition, there was no difference in systolic BP, diastolic BP, HR, RPP, body temperature and RR responses to a sub-maximal exercise across the phases of the menstrual cycle.

The findings that indicated that there is no difference in resting systolic BP and resting diastolic BP across the phases of the menstrual cycle confirm similar findings in a previous study (Arifudding et al, 2012). However, Moran et al (2000) reported higher resting SBP value in the ovulatory phase than in the other phases, but reported a similar finding as in this study for resting diastolic BP. Similarly, Tsai et al (2003) reported lower resting systolic BP in the follicular phase and lower resting diastolic BP in the menstrual and follicular phases. Furthermore, McFetridge and Sherwood (2000) reported that resting diastolic BP was lower during the luteal phase and higher during follicular phase, whereas systolic BP remained uniform across the menstrual cycle. In addition, the finding for the resting HR in this study is similar to the finding reported by Tsai et al (2003) that HR was lower during the menstrual follicular phase.

Differential concentrations of estradiol and progesterone are observed in different phases of the menstrual cycle; both are low during follicular phase, estrogen is high and progesterone is low during ovulatory phase and both are high in the luteal phase (Lebrun, Joyce & Constantini, 2013). Estrogen enhances vasodilation of the smooth muscle of coronary artery and peripheral vascular bed (Epstein, 1999). These vasodilating effects may be attributed to the production and release of nitric oxide, an endothelium-derived relaxation factor, in the presence of estrogen (Cicinelli, Ignaro & Lograno, 1996). The vasodilating effect of estrogen is expected to bring about reduced systolic BP and diastolic BP in the luteal and ovulatory phases. Finding of no significant influence of menstrual phases on the resting systolic and diastolic BP in this study may mean that there is another substance released during these phases that counteract the effect of estrogen. Comparing the findings in this study with those of a previous study is hardly possible due to dearth previous similar studies. However, findings of some previous related studies are discussed.

Mills, Nelesen, Ziegler, Parry, Berry, Dillon, & Dimsdale (1996) reported that African women in their study showed greater diastolic BP response to acute stress (speech making and mirror star tracing) during the follicular compared with the luteal phase of the menstrual cycle, whereas white women showed no significant changes in diastolic BP. It is difficult to understand the reason. A finding in the current study on a sample of African women has shown contradictions pertaining earlier finding on black women but conforms to that of white women in Mills et al's study. The intervention in Mills et al study involved speaking and mirror star tracing tasks as against sub-maximal exercise in the current study. In addition, while the participants in Mills et al study were exposed to acute stress at different phases of the menstrual cycle, participants in the current study were involved in the study based on phase of the cycle they were. These findings suggest that cardio-respiratory responses to exercise are expected to be the same regardless of the phase of menstrual cycle. These findings imply that menstrual cycle has no influence on cardio-respiratory responses to exercise in eumenorrhoeic females.

The findings in this study have clinical implications. The cardiovascular outcomes of exercise testing in menstruating women can be interpreted without being concerned about possible influence of menstrual phase. Secondly, respiratory rate and body temperature are not expected to differ regardless of the menstrual phase during sub-maximal exercise performance.

Limitation of the Study

The limitation of this study is the comparison of participants at different phases of the menstrual cycle rather comparing them across their phases of the menstrual cycle, and thereby, using them as their own control. In consideration of this limitation, it is recommended that further studies be carried out that will expose a group of eumenorrhiec women to sub-maximal exercise at different phases of their menstrual cycle, and then compare their cardiorespiratory/body temperature status and cardiorespiratory/body temperature responses to exercise across the phases. In conclusion, heart rate and RPP are lowest during the follicular phase of the menstrual cycle, and there is no difference in cardiorespiratory and body temperature responses to sub-maximal exercise across the phases.

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