Journal of Exercise Physiologyonline

Volume 14 Number 5 October 2011

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

JEPonline

Ventilatory and Respiratory Muscle Function at Rest and During Exercise Across the Menstrual Cycle

James S. Williams[1], S. Megan Parsons[2]

[1]Exercise Physiology Lab, Texas State University, San Marcos, TX
[2]Applied Physiology Lab, Texas Tech University, Lubbock, TX

ABSTRACT

Williams JS, Parsons, SM. Ventilatory and Respiratory Muscle Function at Rest and During Exercise Across the Menstrual Cycle. JEPonline 2011;14(5):109-117. The purpose of this study was to compare ventilatory responses and inspiratory muscle strength at rest and during incremental exercise during the follicular and luteal phases of the menstrual cycle. Subjects were healthy females (18 to 25 yrs) with a normal menstrual cycle during the 4 months prior to the study. None was using birth control medication. Standard pulmonary function testing was performed followed by a graded exercise test (GXT) to assess ventilatory responses to exercise. All subjects performed a maximal inspiratory pressure (MIP) maneuver to assess inspiratory muscle strength before and immediately following the GXT. Spirometric flow rates and capacities were not significantly different (P>0.05) between the follicular and luteal phases. There were no significant differences (P>0.05) in resting, submaximal, or maximal ventilation (V_E, V_E/VO_2, and V_E/VCO_2) across the menstrual cycle. No significant differences within or between conditions (P>0.05) were found in MIP before and after exercise. These results indicate that the menstrual cycle phase had no influence on the subjects' ventilatory responses at rest, during submaximal exercise or maximal exercise. Additionally, there were no differences in inspiratory muscle strength at rest or following exercise between the follicular and luteal phases of the menstrual cycle.

Key Words: Spirometry, Ventilation, Inspiratory Muscle Strength, Hormones

INTRODUCTION

Although the influence of menstrual cycle hormones on exercise performance have been studied previously, the results remain controversial and the ventilatory responses to progressive intensity exercise have shown inconsistent results (21). Several studies show higher exercise minute ventilation (V_E) during the luteal phase compared to the follicular phase (17,20,21,23) while other studies show no difference (4,9,12,14). The luteal and the follicular phase have shown differences for maximal V_E as high as 12 $L \cdot min^{-1}$ with no influence on VO_2 max (3,21). Numerous studies have also suggested that the impact of menstrual cycle hormones on VO_2 max or exercise performance appears to be minimal (8,9,12,14,16,18,21).

There are inconsistent reports in the literature on the effect of sex on the ventilatory equivalent for oxygen (V_E/VO_2) and ventilator equivalent for carbon dioxide (V_E/VCO_2) during exercise. Some have demonstrated no differences (6,21) while others have reported a significantly higher V_E/VCO_2 in women compared to men (15). Neither the Blackie and colleagues (6) nor the Habedank et al. (15) studies accounted for menstrual cycle phase. The differences in V_E/VCO_2 can be greater during the luteal phase (14), but this is also controversial (3).

Only one study has demonstrated the influence of menstrual hormones on inspiratory muscle fatigue (RMF) and spirometric flows and capacity (7). The Bruno da Silva et al. (7) study suggested that spirometric variables did not change during the menstrual cycle. However, the correlations observed between sexual hormones and respiratory muscle function variables suggested a positive influence of sexual female hormones controlling the thoracic pump muscles in the luteal phase.

Accordingly, the purpose of the present study was to compare ventilatory responses and inspiratory muscle strength at rest and during incremental exercise in both the follicular and luteal phases of the menstrual cycle in healthy females that reported a normal menstrual cycle and were not using birth control medications.

METHODS

Subjects

Recruitment was limited to young (18 to 25 years) healthy female subjects with no known history of cardiopulmonary, metabolic, or musculoskeletal disease. All subjects demonstrated a normal menstrual cycle during the previous 4 months as determined by a health questionnaire, and none was currently using birth control medications. This study was approved by the local institutional review board and written informed consent was obtained from each subject.

Testing Procedures

Once the inclusion criteria were met, the subjects were scheduled for experimental testing according to the timing of their menstrual cycle phase (days 5 to 10 following menses-follicular; days 20 to 25 following menses-luteal). All testing was performed at the same time of the day. Standard pulmonary function testing (FVC, FEV_1, PF, and FEF) was performed (MedGraphics CPX/D) in accordance with American Thoracic Society Guidelines (1,2). The pneumotach was calibrated to the manufacturer's specifications prior to each test. An incremental graded exercise test (GXT) was conducted on a cycle ergometer (Lode-Corvial) where the subject warmed-up at 0 watts for 3 min and the workload was, then, increased to 75 watts and increased by 25 watts every 3 min until volitional fatigue. Baseline data collection for resting gas exchange values lasted 5 min. Expired respiratory gases were collected (MedGraphics CPX/D) during the GXT for the determination of metabolic and ventilatory parameters (VO_2, VCO_2, V_E, and other resultant variables).

Blood pressure was monitored during the GXT via auscultation. Heart rate and rhythm were monitored continuously (EKG- Quinton 4500) throughout the GXT. The subjects performed a maximal inspiratory pressure (MIP) maneuver via a differential pressure transducer before and immediately following the GXT (Validyne) in accordance with the procedures of Black and Hyatt (5). Visual feedback of the pressure signal was provided on a computer screen and the transducer was calibrated prior to each maneuver. The MIP maneuver (an index of global inspiratory muscle fatigue) determined the maximal sustained mouth pressure that can be generated from residual volume. To ensure repeatable results, numerous trials were performed with at least 30 sec of rest between each trial to prevent testing-induced resting muscle fatigue. The greatest negative inspiratory pressure recorded (cmH_20) from at least 5 trials was used for data analysis.

Statistical Analysis

The pre-post data were analyzed with paired t-tests (spirometric and maximal exercise values). A 2 x 4 repeated measures ANOVA was used to determine the differences in V_E, V_E/VO_2, and V_E/VCO_2 during the follicular and luteal phases at rest, during submaximal exercise, and maximal exercise. A 2 x 2 repeated measures ANOVA was used to determine differences in MIP during the follicular and luteal phases at pre- and post-exercise. If significant differences (P=0.05) were found, a Bonferroni correction was applied. Data were analyzed at rest (R), unloaded cycling (0L), 75 Watts, and relative maximum (RM) for V_E, V_E/VO_2, and V_E/VCO_2. Relative maximum was the highest workload achieved for both exercise tests. All statistical analysis was performed utilizing SigmaStat V2.03. An alpha level of P=0.05 was considered significant.

RESULTS

The subject characteristics are presented in Table 1. No significant differences (P>0.05) were found between the follicular and luteal phases of the menstrual cycle for any spirometric variables (Table 2). The subjects presented no pulmonary impairments as indicated by the % predicted FVC (>94), the % predicted FEV_1 (>88), and the FEV_1/FVC (>80).

Table 1. Subject Characteristics (n = 9)

Variable	Mean	±SD
Age (yrs)	22.33	2.35
Ht (in)	65.79	3.60
Wt (kg)	59.80	6.04
BSA	1.67	0.12

Gas exchange parameters at maximal exercise included in the analysis are presented in Table 3. No significant differences (P>0.05) were found between the follicular and luteal phases of the menstrual cycle for any of these variables. No significant differences (P>0.05) were found between the follicular and luteal phases of the menstrual cycle at rest, during exercise for V_E, V_E/VO_2, and V_E/VCO_2 (Figures 1 and 2). Figure 4 shows MIP values before and after exercise during the follicular and luteal phases of the menstrual cycle. No significant differences (P>0.05) were found before or after exercise for MIP.

DISCUSSION

The findings of this study suggest that menstrual cycle phase did not influence ventilatory responses at rest, during submaximal or maximal exercise, or respiratory muscle function. Additionally, there were no significant differences in gas exchange variables during a maximal GXT between the follicular and luteal phases of the menstrual cycle.

Table 2. Spirometry Variables (mean ± SD)

	Condition	
Variable	**Follicular**	**Luteal**
FVC (L)	4.01 ± 0.54	4.00 ± 0.53)
FVC % pred	104.67 ± 10.72	104.78 ± 12.60
FEV_1 (L)	3.38 ± 0.51	3.33 ± 0.47
FEV_1 % pred	102.67 ± 12.63	101.33 ± 13.11
FEV_1/FVC	84.33 ± 4.58	83.44 ± 4.28
FEF25-75 (L/sec)	3.67 ± 0.93	3.48 ± 0.73
FEF25-75% pred	94.00 ± 25.61	89.22 ± 20.44
PEF (L/sec)	6.60 ± 1.33	6.71 ± 0.93
PEF % pred	102.89 ± 19.92	104.56 ± 13.92

Values are means ± SD. No significant differences (P>0.05)

Table 3. Maximal Exercise Test Variables (mean ± SD)

	Condition	
Variable	**Follicular**	**Luteal**
V_{Th} (%VO_2 max)	55.78 ± 4.94	57.00 ± 6.19
VO_2 ($ml \cdot min^{-1}$)	2039.00 ± 298.00	2027.00 ± 411.13
VCO_2 ($ml \cdot min^{-1}$)	2216.78 ± 289.35	2232.56 ± 295.30
TV (L/br)	1730.67 ± 293.91	1759.56 ± 306.80
V_E ($L \cdot min^{-1}$)	85.86 ± 14.59	86.63 ± 14.68
F_b ($br \cdot min^{-1}$)	50.59 ± 10.32	49.87 ± 9.47
HR ($beats \cdot min^{-1}$)	187.38 ± 11.86	189.67 ± 7.14
RER	1.08 ± 0.08	1.11 ± 0.10
Power Output (W)	152.78 ± 23.19	158.33 ± 21.65
Total Exercise Time (sec)	13.31 ± 2.44	13.73 ± 2.71

Values are means ± SD. No significant differences (P>0.05)

Spirometry Variables

Our results are similar to those of Bruno da Silva et al. (7). They reported that spirometry variables were not influenced by phases of the menstrual cycle. Other studies have also reported that FVC and FEV_1 do not change during the menstrual cycle phases, despite elevated progesterone levels in the luteal phase (3,11). However, the results of Williams and Krahenbuhl (23) showed variation in respiratory function during the menstrual cycle. Resmi et al. (19) showed a significant decrease in FEV_1/FVC and FEF75% and a significant increase in peak expiratory flow rate (PEF) in subjects using oral contraceptives when compared to controls. This discrepancy in results could be due to experimental design. For example, Williams and Krahenbuhl (23) divided the cycle into 5 phases. The current study divided the cycle into 2 phases. Another possible explanation for the variability in results in the different phases could be associated with both inter-subject hormonal variations among the cycles and intra-subject variation when taking into account the same menstrual cycle phases (7).

Gas Exchange Variables

In agreement with our study, Casazza et al. (9) showed that in the absence of oral contraceptives, the menstrual cycle phase did not influence peak exercise capacity or the cardiorespiratory variables during exercise. Furthermore, the Dean et al. (13) study is similar to our study in which they showed lactate threshold as a $\%V0_2$ max did not significantly differ across the menstrual cycle. Also, VO_2 max,

HR max, final workload, time to exhaustion, and RER did not change across the menstrual cycle in this study. Additionally, Schoene et al. (20) observed no difference between the follicular and luteal phases in the onset of the anaerobic threshold.

Ventilatory Responses

The menstrual cycle phase did not influence the subjects' ventilatory responses at rest, during submaximal exercise, or at maximal V_E. These results are in agreement with numerous earlier studies (3,4,9,12,13,16,18,22). In contrast, other studies have shown significant differences in exercise V_E during the luteal phase of the menstrual cycle (17,20,21,23). The varying results between these studies and the current study could be related to individual responses and the differences in progesterone receptor sensitivity (3).

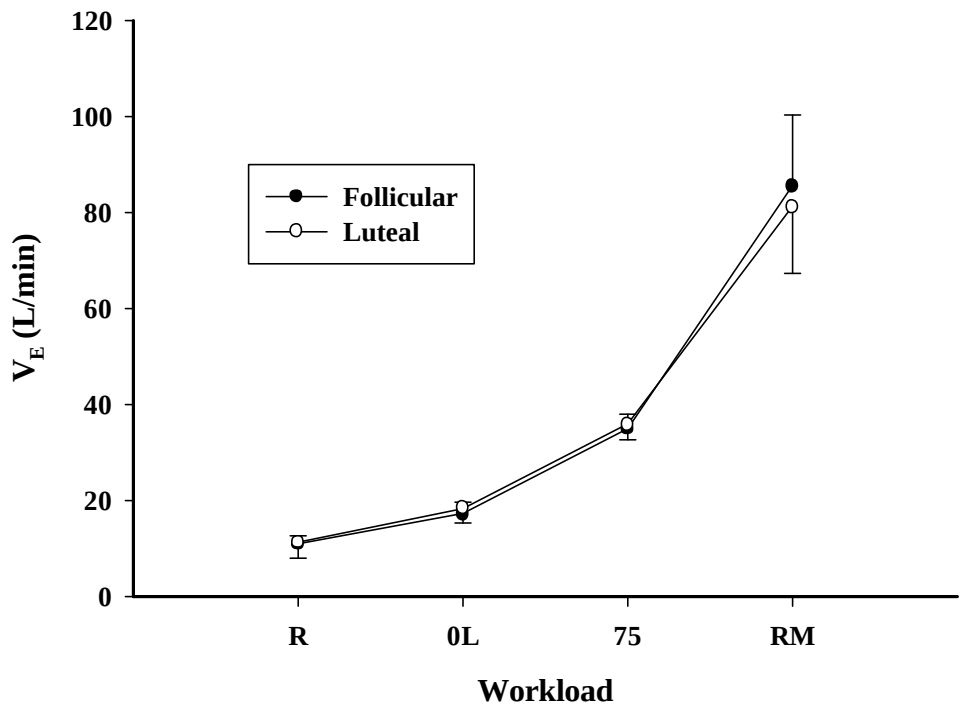

Figure 1. Minute ventilation (V_E) at rest and during exercise during the follicular and luteal phases of the menstrual cycle. Values are means ± SD. R = rest; 0L = unloaded cycling; RM = relative maximum. No significant differences between conditions (P>0.05).

In addition, it is widely accepted that the ventilatory measures demonstrate large within-subject daily variability. The ventilatory equivalents (V_E/VO_2 and V_E/VCO_2) were not elevated during the luteal phase at rest and during incremental exercise compared to the follicular phase in the present study. Our study is one of the few studies to determine ventilatory efficiency in relation to the menstrual cycle phase. Beidleman et al. (3) and Bemben et al. (4) also reported no significant differences in the ventilatory equivalents in the follicular and luteal phases of the menstrual cycle. Nonetheless, the results of Schoene and colleagues (20) demonstrated that V_E/VO_2 was significantly greater at all levels of exercise in the luteal phase. However, their study did not show a significant correlation between respiratory variables and plasma progesterone. It is not surprising that V_E/VO_2 and V_E/VCO_2 were not elevated in the current study since V_E, VO_2, and VCO_2 were not different between menstrual phases at submaximal and maximal levels of exercise.

Respiratory Muscle Function

The MIP values before and after exercise during the follicular and luteal phases of the menstrual cycle were not significantly (P>0.05) different in our study. Bruno da Silva et al. (7) and Chen and Tang (10) reported similar results. The evaluation of the MIP is an index of global respiratory muscle fatigue (5). The literature on static respiratory pressure generation across the menstrual cycle is limited. The study by Bruno da Silva et al. (7) demonstrated a weak (r=0.32) yet significant association between MIP and menstrual hormones. This suggests that the menstrual hormones may have an influence on thoracic pump muscles during the luteal phase. However, again, the correlation was weak and does not suggest cause and effect.

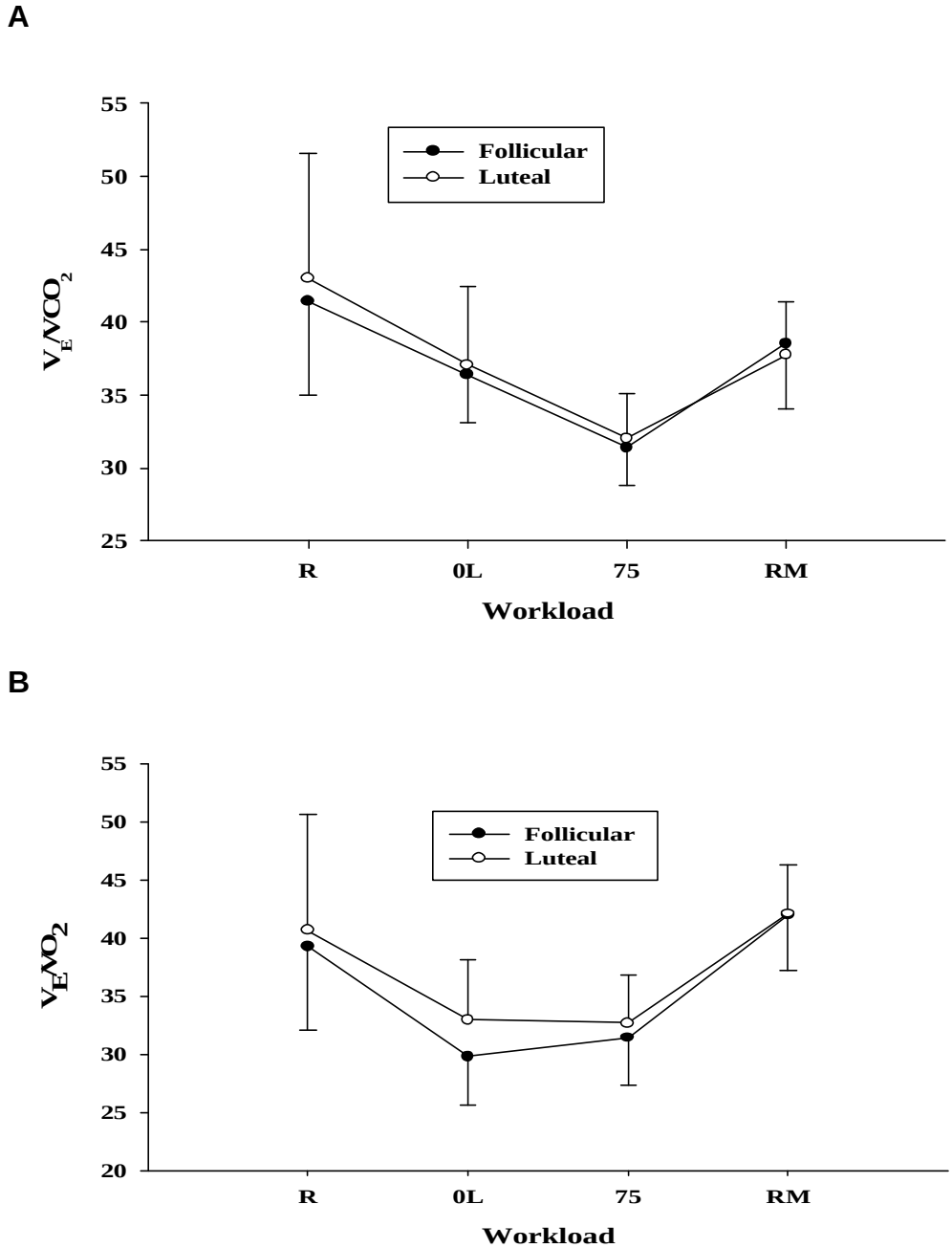

Figure 2. (A) Ventilatory equivalents for dioxide production (V_E/VCO_2) and (B) oxygen consumption (V_E/VO_2) at rest and exercise during the follicular and luteal phases of the menstrual cycle. Values are means $\pm$ SD. R = rest; 0L = unloaded cycling; RM = relative maximum. No significant differences between conditions (P>0.05).

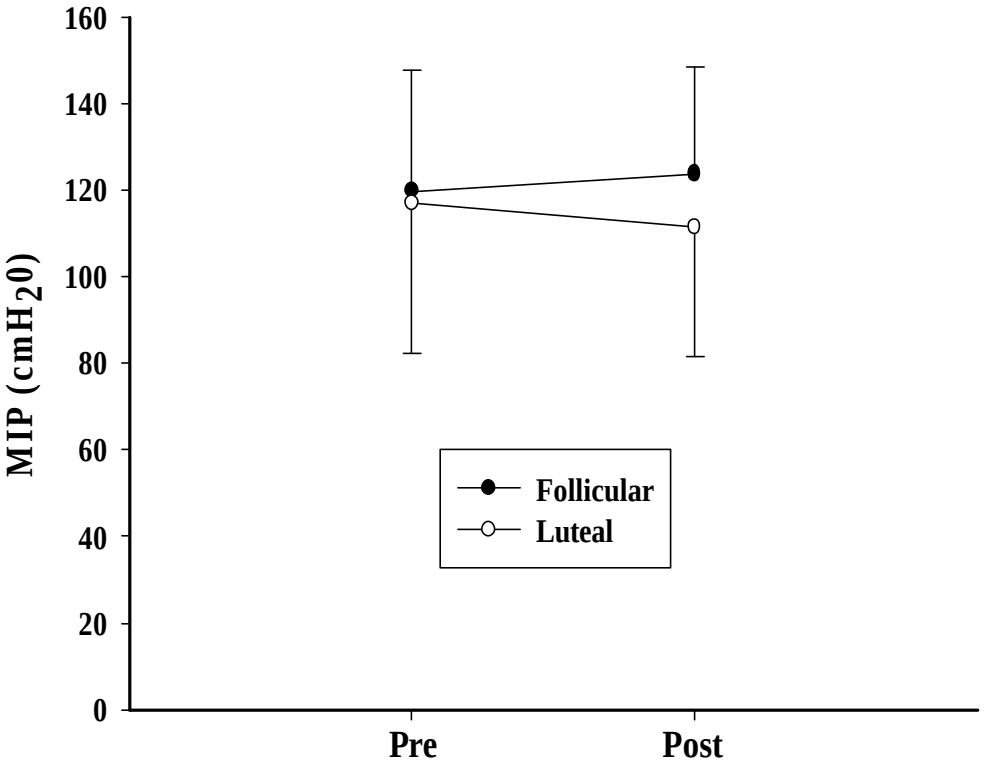

Figure 3. Maximal sustained mouth pressure (MIP) values before and after exercise during the follicular and luteal phases of the menstrual cycle. Values are means ± SD. No significant differences between conditions (P>0.05).

CONCLUSIONS

Our results indicate that the menstrual cycle phase did not have an influence on the spirometric or ventilatory responses at rest, during submaximal exercise, or maximal exercise. There were no differences in the maximal exercise test variables and respiratory muscle function between the follicular and luteal phases of the menstrual cycle. These results provide additional data that indicate the timing of the menstrual cycle phase may not be as critical as once believed when designing exercise ventilation or respiratory muscle function studies.

A limitation to the present study is that the ovarian hormones were not measured during the menstrual cycle phases. However, all the subjects reported a normal menstrual history and none were taking oral contraceptives.

Address for correspondence: Williams JS, PhD, Department of Health and Human Performance, Texas State University, San Marcos, Texas. (512) 245-1970; jw88@txstate.edu

REFERENCES

1. American Thoracic Society. Standardization of spirometry. ***ARRD*** 1987;136:1285-1298.

2. American Thoracic Society. Lung function testing: selection of reference values and interpretative strategies. ***ARRD*** 1991;144:1202-1218.

3. Beidleman BA, Rock PB, Muza SR, Fulco CS. Forte VA, Cymerman A. Exercise V_E and physical performance at altitude are not affected by menstrual cycle phase. ***J Appl Physiol*** 1999;86:1519-1526.

4. Bemben DA, Salm PC, Salm AJ. Ventilatory and blood lactate responses to maximal treadmill exercise during the menstrual cycle. ***J Sports Med Phys Fitness*** 1995;35:257-262.

5. Black LF, Hyatt RE. Maximal expiratory pressures: Normal values and relationship to age and sex. ***ARRD*** 1969;99:696-701.

6. Blackie SP, Fairbarn MS, McElvaney NG, et al. Normal values and ranges for ventilation and breathing pattern at maximal exercise. ***Chest*** 1991;100:136-142.

7. Bruno da Silva S, de Sousa Ramalho Viana E., Cordeiro de Sousa M. Changes in peak expiratory flow and menstrual respiratory strength during the menstrual cycle. ***Respir Physiol Neurobiol*** 2006;150:211-219.

8. Bryner RW, Toffle RC. Ullrich IH, et al. Effect of low dose oral contraceptives on exercise performance. ***Br J Sports Med*** 1996;30:36-40.

9. Casazza G, Sang-Hoon S, Miller B., Navazio F, Brooks G. Effects of oral contraceptives on peak exercise capacity. ***J Appl Physiol*** 2002;93:1698-1702.

10. Chen H, Tang Y. Effects of the menstrual cycle on respiratory muscle function. ***ARRD*** 1989;140:1359-1362.

11. Das TK. Effects of the menstrual cycle on timing and depth of breathing at rest. ***Indian J Physiol Pharmacol*** 1989;42:498-502.

12. De Souza MJ, Maguire MS, Rubin KR, et al. Effects of menstrual phase and amenorrhea on exercise performance in runners. ***Med Sci Sports Exerc*** 1990;22:575-580.

13. Dean TM, Perreault L, Mazzeo RS, Horton TJ. No effect of menstrual cycle phase on lactate threshold. ***J Appl Physiol*** 2003;95:2537-2543.

14. Dombovy ML, Bonekat HW, Williams TJ, et al. Exercise performance and ventilatory response in the menstrual cycle. ***Med Sci Sports Exerc*** 1987;19:111-117.

15. Habedank D, Reindl I, Vietzke G, et al. Ventilatory efficiency and exercise tolerance in 101 healthy volunteers. ***Eur J Appl Physiol*** 1998;77:421-426.

16. Hackney AC, Curley CS, Nicklas BJ. Physiological responses to submaximal exercise at the mid-follicular, ovulatory, and mid-luteal phases of the menstrual cycle. ***Scand J Med Sci Sports*** 1991;1:94-98. :

17. Jurkowski JE, Jones NL, Toews CJ, Sutton JR. Effects of menstrual cycle on blood lactate, O_2 delivery, and performance during exercise. ***J Appl Physiol*** 1981;51:1493-1499.

18. Lebrun CM, McKenzie DC, Prior JC, et al. Effects of menstrual cycle phase on athletic performance. ***Med Sci Sports Exerc*** 1995;27:437-444.

19. Resmi SS, Samuel E, Kesavachandran C, Shashidhar S. Effect of oral contraceptives on respiratory function. ***Indian J Physiol Pharmacol*** 2002;46:361-366.

20. Schoene RB, Robertson HT, Pierson DJ, Peterson AP. Respiratory drives and exercise in menstrual cycles of athletic and nonathletic women. ***J Appl Physiol*** 1981;50:1300-1305.

21. Sheel AW, Richards JC, Foster GE, Guenette JA. Sex differences in respiratory exercise physiology. ***Sports Med*** 2004;34:567-579.

22. Stephenson LA, Kolka M, Wilkerson JE. Metabolic and thermoregulatory responses to exercise during the human menstrual cycle. ***Med Sci Sports Exerc*** 1982;14:270-275.

23. Williams TJ, Krahenbuhl GS. Menstrual cycle phase and running economy. ***Med Sci Sports Exerc*** 1997;29:1609-1618.