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Time of day effect on oxygen uptake changes and lung function of active female

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Abstract

Various psychological and physiological functions have been shown to undergo changes within the 24-hour day. The purpose of this study was to compare the oxygen consumption changes, as well as lung function at three different times (09:00Am, 14:00 and 18:00 Pm) within the same day. Eleven female, physical education university students (age 22.27±.90 years, height 162.36± 4.20 cm and weight 56.82±6.60kg) took part in the study. The spirometric parameters (forced expiratory volume (FVC), forced expiratory volume in first second(FEV_1) FEV_1/FVC, peak expiratory flow (PEF), maximum expiratory flow($MEF_{25-75\%}$) as lung function indices determined before onset of exercise test, then progressive incremental cycle ergometer exercise test was performed until exhaustion in each time following one min of rest and two min of warm-up by cycling. The workload during the maximal test was increased 20 watts (W) every one minutes from an initial 45W until volitional subjective exhaustion. One-way repeated measures analysis of variance and bonferroni- corrected paired *t*-tests were used to test for differences between the times of day. Significance was set at $p \le 0.05$. A significant circadian rhythm was found for FEV_1 (p=0.05), FEV1/FVC (p=0.019), PEF (p=0.013) and $MEF_{25-75\%}$ (p=0.012) with the acrophases in evening. In contrast no significant circadian variation was observed for VO_2 at rest,VO_2 at 25, 45, 65, 85, 105, 125 watts, lactate threshold VO_2, VO_{2max}, slope of VO_2 changes curve and FVC between all measured time units (p>0.05). In summary, oxygen uptake changes didn't vary during the time frame within which exercise is normally conducted. In contrast time of the day effect existed for lung function and it was improved from morning until evening. Therefore, it is important for coaches and athletes to be aware of how the time of day will affect their function.

Key words: Circadian rhythms, lung function, oxygen uptake changes, active female.

INTRODUCTION

Today, experts have paid attention to various rhythms and using theses rhythms in enhancing human productivity on industry and sports. It is important to be aware of time dependent changes in physiological variables in response to physical activity both in professional sports in order to recognize the most optimal physiological time to acquire the highest efficiency and in unprofessional individuals to use the most physical activity benefits (5). In fact the sports science experts also have believed that in addition to various and important factors such as intensity, duration, type and exercise repetition, nutrition and environment which in the past received much attention, it is necessary to pay attention to an internal factor called biological clock and its effect on physiological condition and body function (12). It has been indicated that anal temperature diurnal rhythm remains constant under any conditions of various exercise activity intensities and peaks from 4 to 6 pm (8). The body temperature influences the soft tissues, thus changes resistance to movement and the energy cost of the activity (6).

The importance of oxygen consumption as indirect cell respiratory index, energy cost and motor economy (13) have caused that many researchers study it during different times of the day but previous findings were not reached to the consensus. For example, Deschenes et al showed that minute ventilation, oxygen consumption and respiratory exchange ratio, did not respond differently to exercise stimulus in four different times (7). Similarly Carter et al showed similarity of oxygen uptake kinetic to middle and intense exercise during different days and hours (6 Am, 12 and 6pm) (6). In contrast, Giacomoni et al. indicated that oxygen consumption, carbon dioxide consumption and the respiratory exchange ratio are greater in afternoon (8). Lung function indices (FEV_1, FVC, FEV_1/FVC, PEF, $MEF_{25\text{-}75\%}$) also have been studied due to their importance in lung function assessment and airway resistance (7-8). For example Spengler and Shea indicated significant diurnal changes in FEV_1/FVC and FEV_1 but no significant diurnal changes in PEF and FVC in healthy individual (19). So with regard to the importance of the so called variables in exercise performance and adaptations resulted from that and lack of a certain instruction on exercise response in different time of day in order to benefit from the most efficiency and designing the exercise more secure, this question arises that weather is different the oxygen uptake changes and lung function in active female at different time points selected for study? If yes, which time is better for exercise?

MATERIALS & METHODS

Study subjects

Eleven female physical education college students from Al-Zahra University who have practical classes 12 hours per week were included in our study. All of them had following conditions: 1) Except the university practical courses, they weren't any members of sports team. 2) All of them had almost regular menstruation. 3) During test session, they weren't on menstruation time.

Informed consent was obtained from all participants after completely awareness on the research goals, how the test implements and probably risks.

Oxygen consumption changes and lung function measurements

In order to examine the effect of Diurnal rhythms on oxygen consumption changes and lung function, each subjects should perform an progressive incremental cycle ergometer exercise test at three different times (09:00Am, 14:00 and 18:00 Pm) within the same day, before each test, lung function indices (FEV_1, FVC, FEV_1/FVC, PEF, $MEF_{25\text{-}75\%}$) measured by Spirometry at rest. Oxygen uptake measured by ergospirometry (ZAN model 680, Germany). To measure the oxygen consumption changes, the subject first did static and dynamic stretching for 5 minutes and then mask put on the subject mouth and nose, after doing spirometry test on standing position the subject sat on the cycle ergometry and the height of the saddle was adjusted to the subject height. At first, the subject information were recorded, including first and last name, birthday date, weight, height, gender and information on the subject (sick, healthy, active and …) and then exercise protocol was done as following: first 1 minute of unloaded pedaling as rest stage, 2 min pedaling at a work load of 25 W as warm up, and the work rate was increased by 20 W per minute in steps from an initial 45W until exhaustion was reached. Subject looked at the digital monitor across herself to maintain the pedaling rate as close to 60 rpm in all steps. This test continued until the subject felt tired and in despite of her effort and verbally encouragement could no longer maintain the required pedal rate. In this step the maximum consumed oxygen was determined. After finishing the test, the workload was returned to zero and recovery step continued for 2 min. During the exercise test, pulmonary gas exchange was determined breath by breath. Laboratory temperature was controlled for all testing sessions.

Statistical analysis

Descriptive analysis of variables was presented by means and standard deviation. After the normality of distribution of the parameters used in this study was verified using the Kolmogorov Smirnov test, One Way Repeated Measures Analysis of Variance was used to compare variables across the three time points (09:00Am, 14:00 and 18:00 Pm). When significant *F* ratios were established, a Bonferroni post-hoc analysis was used to determine pairwise differences. Statistical significant was set at $p<0.05$. All statistical analysis was performed by SPSS version 17 (SPSS Inc, Chicago, IL, USA).

RESULTS

Table 1 presents characteristics of the study participants. Pre exercise and during progressive incremental cycle ergometer exercise test data are given in table 2. In the present investigation there was no significant difference established in active rest Vo_2 (P=0.829), load 25watts (P=0.911), 45 (P=0.770), 65 (P=0.635), 85 (P=0.596), 105 (P=0.877), Lactate threshold oxygen consumption (P=0.598), maximum oxygen consumption (P=0.148), Slope of oxygen consumption changes curve (P=0.597) and forced vital capacity (FVC) (P= 0.07) during times of day that testing was performed (figure 1). In contrast, significant time of day effects were detected for Forced expiratory volume in first second (P=0.05), the ratio of the Forced expiratory volume in the first second to the forced vital capacity (P=0.019), Peak expiratory flow (P=0.03) and Maximum expiratory flow$_{25-75\%}$ (P= 0.043), with greatest on evening, and lowest on morning.

Table 1. Mean and standard deviation of characteristics of the study participants (n=11).

Variables	Mean ± SD
Age (year)	22.27±0.905
Body mass (kg)	56.82±6.60
Height (cm)	162.36±4.20
Body mass index (kg/m²)	22.25±2.55

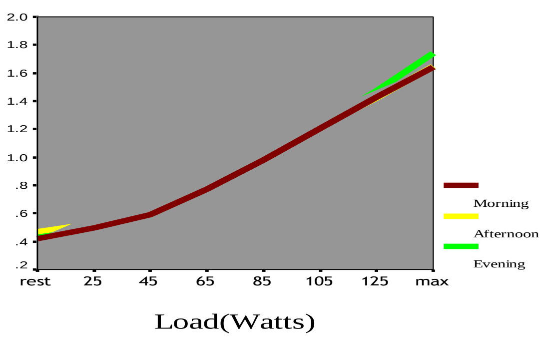

Figure 1. Oxygen consumption changes during progressive incremental cycle ergometer exercise test at three different times (09:00Am, 14:00 and 18:00 Pm).

Table 2. Mean and standard deviation of oxygen uptake changes and lung function indices at three different times (09:00 Am, 14:00 and 18:00 Pm).

Variables	Mean ± SD			F
	Morning	Afternoon	Evening	
Oxygen uptake at rest$_{(Lit/min)}$	0.42±0.21	0.47±017	0.45±017	0.192
Oxygen uptake at 25 watts	0.49±0.21	0.52±0.16	0.52±0.52	0.094
Oxygen uptake at 45 watts	0.59±021	0.63±0.18	0.65±0.18	0.270
Oxygen uptake at 65 watts	0.77±0.20	0.80±0.19	0.83±0.16	0.477
Oxygen uptake at 85 watts	0.98±0.22	0.99±0.17	1.03±0.15	0.548
Oxygen uptake at 105 watts	1.21±0.22	1.22±0.22	1.24±0.16	0.133
Oxygen uptake at 125 watts	1.43±0.19	1.42±0.22	1.47±0.17	0.516
Lactate threshold oxygen uptake	0.72±0.10	0.69±0.20	0.81±0.29	0.549
Vo_{2max}	1.64±0.24	1.65±0.18	1.74±0.20	2.378
Slope of oxygen uptake changes curve	0.01±0.0	0.01±0.0	0.01±0.0	0.547
$FEV_{1(Lit)}$	2.29±0.53	2.53±0.30	2.68±0.47	4.22*
$FVC_{(Lit)}$	2.48±0.50	2.75±0.38	2.80±0.50	3.58
$FEV_1/FVC_{(\%)}$	91.90±6.72	92.18±5.61	95.54±4.65	6.35*
$PEF_{(Lit/sec)}$	4.08±1.73	4.98±2.43	5.78±2.05	4.59*
$MEF_{25-75\%(Lit/sec)}$	3.01±1.25	3.64±2	4.31±2.07	5.02*

DISSCUSSIN

The present research findings indicated that active rest oxygen uptake in active female was not significant in various times of day (P=0.829). The research findings are consistent with reports by Deschenes et al. and was inconsistent with Carter et al, it's possible that the observed differences have occurred because of the differences in the resting conditions as rest step in the Carter research was standing while in present study was in form of pedaling for 1 min, and as mentioned in the researches, compared to rest state, oxygen uptake during middle intensity activity is of less fluctuation (15).

Similarly, there was no significant difference on oxygen uptake in the 25 (P=0.911), 45 (P=0.770), 65(P=0.635), 85(P=0.596), 105(P=0.877) and 105 (P=0.613) watts on various time of day. These findings were consistent with reports represented by Reilly and Brook (16), Deschenes et el. (7) and inconsistent with Cable & Reilly(4), Hill et al. (9), Giacomoni et al. (8) and Brisswalter et al. (3). In Cable & Reilly (4) and Hill et al. (9) the activity intensity was light that it's indicated that when activity intensity increases most of the body rhythms become weak except body temperature and it seems that compared to the rest state, the oxygen uptake during middle activity is of less fluctuation (15) and this fluctuation completely eliminate in high intensity above 40 to 50% of maximum oxygen uptake (16).

In Giacomoni et al. (8) research the test was done in three different days using treadmill with sub-maximal intensity (with intensity 7, 8, 9 km/h) that seems doing activity by treadmill is more sensitive to diurnal changes because in addition to bear weight, running activates more muscular mass than cycling. Also rate of the oxygen uptake during running is related to running economy which is influenced by step length, step frequency and joints and muscles flexibility (11) and although the gender, fitness level and age in Giacomoni et al. research are similar to the present study, the exercise protocol is different. In Brisswalter et al. (3) the oxygen uptake kinetic compared between morning and evening and the subjects were men, also there was at least 24 hours interval between tests, whereas in present study the subjects were female and all three tests were done in a same day. The research findings indicated that there was no significant difference in VO_{2max} in active females in various time of day (P=0.148). It is also worth to say that with regard to the maximum heart beat in three different times of day equal to 174, 178 and 180 beats in min respectively, it seems that the subject did the best and tiredness had no effect on their results. This research results was consistent with Reilly & Brooks

(16), Deschenes et al. (7) and were inconsistent with Hill (10) findings in which the comparison was done between morning and evening and the subjects were mixed.

The data also demonstrate that FEV_1, FEV_1/FVC, PEF and $MEF_{25-75\%}$ were influenced by time of day (P=0.05). The results represent higher amount in the evening than afternoon and afternoon than morning. But there was no significant difference between times of the day for FVC (P=0.07). The research findings were consistent with Silkoff & Martin (18) based on peak function on 4 pm and at least on 4 Am, Spengler & Shea (19) based on rhythm in FEV_1 and FEV_1/FVC and were inconsistent with Borsboom et al (2). Subjects of Borsboom study were 876 adults 30 to 60 years old, smokers and non-smokers and this research lasted three years, but in the present study the subjects were active and average age was 22 years and before doing spirometery test at afternoon and evening, the exercise activity was done.

From the results of this study it appears that oxygen uptake response and as a result economy in active females is not influenced by times of the day, so practically it seems that the oxygen uptake response to the activity and motor economy in various times of day, when physical activities such as exercise training and matches occur, almost remains constant. Also exercise habits in various parts of day in physical education students cause to reduce some fluctuations and maybe it is one of the reasons of not being significant the oxygen uptake changes in various parts of day. On lung function, the study findings indicate that the lung function is better in the evening than afternoon and afternoon than morning. So based on the present study results on diurnal rhythm in lung function and according to increasing Asthma prevalence in last 20 years in many countries (14) and the positive effect of exercise activities on improving lung function, patients with respiratory problem and young athletes are recommended to have sports training at noon for the purpose of maximizing training effectiveness.

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