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Original articles

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DAILY PATTERN OF BREATHING IN HEALTHY YOUNG MEN

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Daily changes in the pulmonary function indices were examined in 30 healthy young men. The breathing pattern technique (Lungtest system, MES, Cracow) was used to measure daily changes in basic ventilatory parameters every 3 hours during a 24-hour period. The results revealed significant daily variables in VT (tidal volume), MV (minute ventilation), VT/TI (mean inspiratory flow), and the ratios of MV/P0. 1, (minute ventilation/mouth occlusion pressure) and P0.1/VT/TI. There was lack of significant variations in the other variables. The daily minima in the variables occurred during the usual sleep period at 2:00, 5:00 and also at 8:00 hours. The results of this study demonstrate that healthy adults have small, but significant, daily variations in some of the breathing parameters, although, overall, the breathing pattern remains relatively stable around the clock.

Key words: *breathing pattern, daily rhythm, ventilation, hypoxia*

INTRODUCTION

It is well established that numerous aspects of respiratory control, mechanics, and gas exchange follow the circadian pattern. Some of the circadian fluctuations are determined by changes in the state of arousal, whereas others, *e.g.*, in airway dynamics, are independent of the sleep-wake cycles (1). Respiratory pattern undergoes changes in both circadian and ultradian cycles. During the course of a day circadian variations in breathing pattern are observed. At the same time, periodic changes in ventilatory gas exchange also are observed (2). The mechanisms responsible for the daily pattern of changes in airway and lungs mechanics are unknown. Some of these variations may be due to thermoregulation or to circadian oscillations in metabolism.

To estimate the respiratory pattern, breath-by-breath measurements are required. It is well known that many physiological parameters oscillate over the 24-hour period. Vargas *et al* (3) and Stephenson *et al* (4) showed that breathing rate exhibits a low amplitude circadian oscillation. The temporal correlations between the circadian fluctuations of breathing and other physiological variables (blood pressure, steroid hormones) are the subject of investigations.

Changes in breathing pattern are of consequence for medical sciences. It has been proposed that the breathing pattern assessment may be useful in patients being weaned from mechanical ventilation. The measurement of occlusion pressure (which is measured at zero flow and thus is independent of respiratory system compliance and resistance) allows estimating the neuromuscular drive to breathe. An increase in P0.1 values reveals an increased neuromuscular activation of the respiratory system and is a sign of inspiratory muscle fatigue (5). Measurements of respiratory pattern changes may also be of value for reference purposes in patients suffering from diseases affecting the respiratory system. The lung volume recording is a standard method of estimation of respiration in such patients (6). The current study focuses on daily changes in volume and airflow parameters.

MATERIAL AND METHODS

The study was approved by a local Ethics Committee and was conducted according to the Declaration of Helsinki for Human Research. The study group consisted of 30 healthy adult men, who were nonsmokers, aged 18-28. Before the experiment, all subjects were asked to abstain from caffeinated drinks, alcohol, and food for at least 12 h. The subjects did not regularly take any medications, and they were free from medications for at least 1 week before the start of study. All subjects were placed on a modified constant-routine protocol for 24 h as described elsewhere (7). They were studied in a laboratory room isolated from sunlight and external time cues. Laboratory temperature was maintained at approximately 22°C. A small meal was served every 3 h, with a total energy content of 1500 kJ. The routine protocol permitted different forms of moderate activity, the participants were allowed to move, read, and watch movies.

The breathing pattern and P0.1 (occlusion pressure) were measured every 3 h during a 24-h period. All measurements were performed in the seated position after a short rest. The test of quiet breathing of atmospheric air lasted 6 min. Lung function was measured with the MES Lungtest 1000 system (MES, Cracow, Poland). The breathing pattern test was used for the analysis of VT (tidal volume), BF (breath frequency), MV (minute ventilation), TI (inspiratory time), TE (expiratory time), TTOT (total time of cycle inspiration-expiration), P0.1, and the respiratory ratios: VT/TI, TI/TTOT, P0.1/VT/TI, and MV/P0.1. The breathing pattern was recorded in real time. The set-up used for the measurements consisted of a computer, pneumotachograph, and a shutter with electromagnetic valve closing every 5 breaths at 100 ms from the beginning of inspiratory movement (8).

All values were presented as means ±SD. Nonparametric Friedman test was used for the statistical data analysis. Multiple Comparison Student-Newman-Keuls test was used to assess the significance of differences between the mean values of ventilatory parameters. The results were considered statistically significant at $P<0.05$.

RESULTS

Thirty subjects were eligible for the study. The results of daily changes in respiratory variables for all subjects are shown in *Table 1* and illustrated in *Figs. 1, 2 , 3, 4,* and *5*. No significant differences in daily fluctuations were found in the main values of BF, TI, TE, P0.1, TTOT, TI/TTOT mean values measured in eight breathing pattern tests during 24 h (*Table 1*).

Table 1. Mean values of breathing pattern variables obtained from eight breathing pattern tests during 24 hours.

	Time of day							
	8:00	11:00	14:00	17:00	20:00	23:00	02:00	05:00
BF (breaths/min)	16.83 ±6.41	17.24 ±3.73	17.45 ±5.33	17.23 ±6.12	17.34 ±5.61	17.33 ±5.49	17.29 ±6.34	17.11 ±6.46
TI (s)	1.76 ±0.51	1.72 ±0.51	1.76 ±0.51	1.80 ±0.64	1.83 ±0.65	1.75 ±0.53	1.77 ±0.61	1.74 ±0.49
TE (s)	2.21 ±0.66	2.04 ±0.61	2.02 ±0.55	2.14 ±0.73	2.12 ±0.70	2.06 ±0.59	2.15 ±0.71	2.21 ±0.73
TTOT (s)	4.01 ±1.09	3.81 ±1.02	3.81 ±1.00	3.98 ±1.34	3.98 ±1.32	3.85 ±1.10	3.96 ±1.28	3.99 ±1.16
TI/TTOT (%)	0.45 ±0.06	0.46 ±0.07	0.47 ±0.05	0.46 ±0.04	0.46 ±0.04	0.46 ±0.04	0.45 ±0.04	0.59 ±0.77
P0.1 (kPa)	3.04 ±1.94	3.16 ±2.19	3.26 ±2.19	3.23 ±2.45	3.25 ±2.45	3.32 ±1.86	3.12 ±1.83	2.94 ±1.64

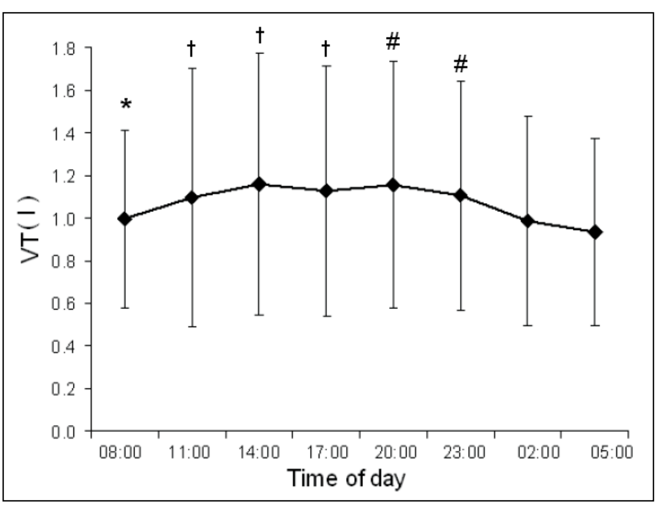

Fig. 1. Daily changes in breathing pattern presented as mean values of VT (n=30). The VT value recorded at 8:00 (*) was significantly different from all others values. The 11:00, 14:00, and 17:00 values (†) were significantly different from those at 20:00, 02:00 and 05:00 hours. The 20:00 and 23:00 values (#) were different from those at 02:00 and 05:00 hours each ($P<0.05$).

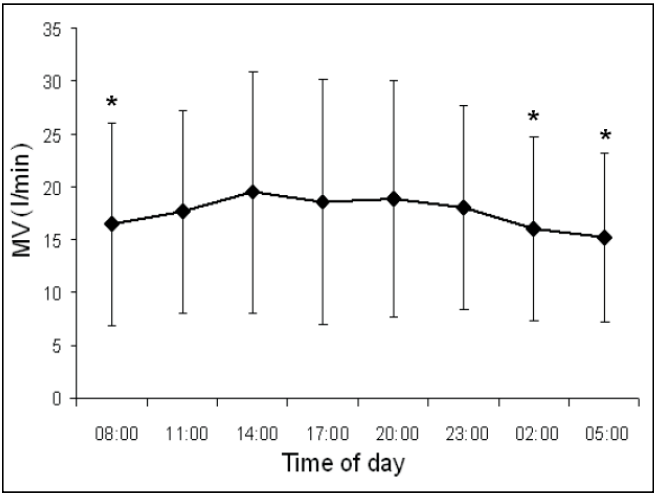

Fig. 2. Circadian changes in breathing pattern presented as mean values of MV. The values measured at 2:00, 5:00, and 8:00 (*) were significantly lower than those at 11:00, 14:00, 17:00, 20:00, and 23:00 hours (P<0.05).

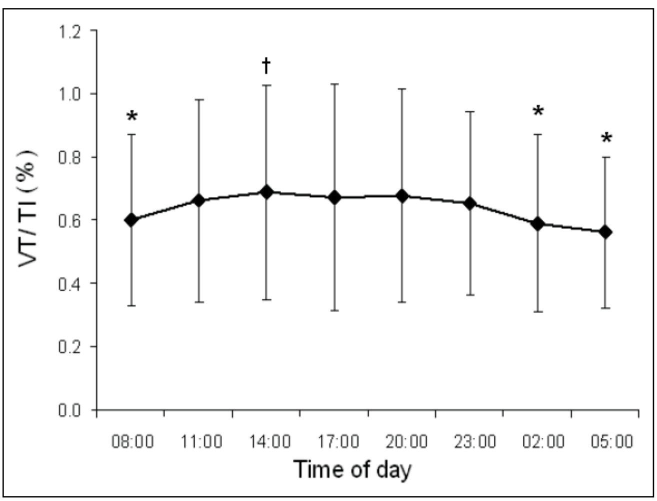

Fig. 3. Daily changes in breathing pattern presented as mean values of VT/TI (n=30). The 8:00, 02:00, and 05:00 values (*) were significantly different from those at 11:00, 14:00, 17:00, 20:00, and 23:00 hours. Moreover the 14:00 value (†) was significantly different from the value at 17:00 hours (P<0.05).

Daily variations of VT are presented in *Fig. 1*. VT values decreased at 2:00, 5:00, and 8:00 hours. An increase in VT values was recorded at 11:00, 14:00, 17:00, 20:00, and 23:00 hours. Those changes were significant (P<0.05). The mean values of MV and VT/TI are given in *Fig. 2* and *Fig. 3*. Both indices were significantly lower at 8:00, 2:00, and 5:00 in comparison with the values at 11:00, 14:00, 17:00, 20:00, and 23:00 hours (P<0.05). There was also a significant increase in both indices at 14:00 compare with those at 17:00 hours.

Daily changes in the MV/P0.1 ratio are shown in *Fig. 4*. At 23:00, 5:00, 2:00, and 8:00, this variable was lower than the values at 11:00, 14:00, and 17:00. Moreover, MV/P0.1 at 2:00, 8:00, and 23:00 were lower than that at 20:00 hours (P<0.05).

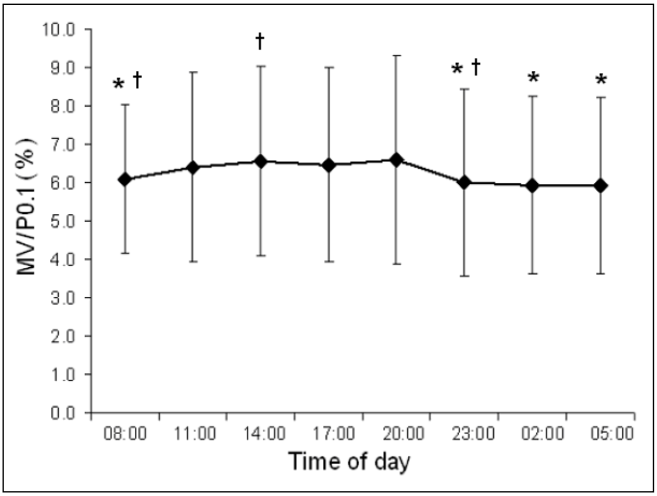

Fig. 4. Daily changes in breathing pattern presented as mean values of the MV/P0.1 ratio. The 23:00, 2:00, 5:00, and 8:00 values (*) were significantly lower than those at 11:00, 14:00, and 17:00 hours, and the values at 2:00, 8:00 and 23:00 (†) were different *vs.* 20:00 hours (P<0.05).

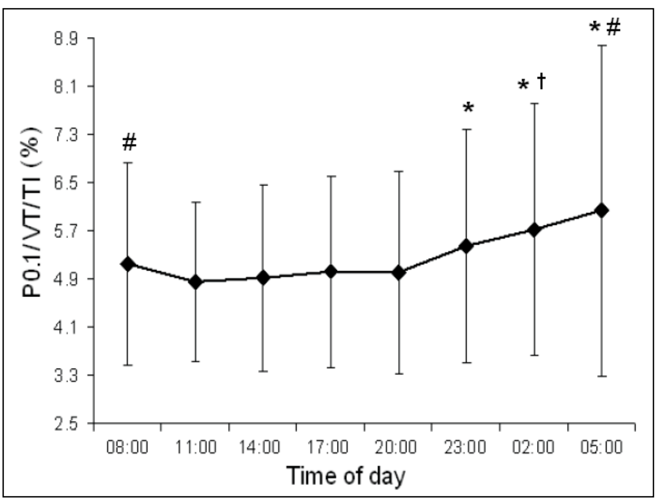

Fig. 5. The daily variations of breathing pattern presented as mean values of the P0.1/VT/TI ratio. The 23:00, 2:00, and 5:00 values (*) were significantly different vs. 11:00 and 14:00 hours. The value at 2:00 (†) was significantly different *vs.* 5:00, 8:00, 17:00, 20:00, and 23:00 hours. The values at 5:00 (#) *vs.* 23:00, and 8:00 (#) *vs.* 11:00, 14:00, 20:00 hours also were significantly different (P>0.05).

The P0.1/VT/TI values at 23:00, 5:00, and 2:00 were significantly different from those at 11:00 and 14:00. The values at 2:00 were significantly different *vs.* 5:00, 8:00, 17:00, 20:00, and 23:00 hours. There also were significant differences between the values at 5:00 *vs.* 23:00, and 8:00 *vs.* 11:00, 14:00, and 20:00 hours (P>0.05).

DISCUSSION

Several studies have demonstrated that the human respiratory system function varies depending on the time of day (9). Great variability of breathing patterns among healthy subjects is also well documented (10). Spengler and Shea (11) have demonstrated that healthy adults have a small but significant circadian variation in FEV1 (forced expiratory volume in 1 second) and a ratio of FEV1/FEVC (FEVC - forced expiratory vital capacity). Similar tendency has been observed for another ventilatory variable - PEF (peak expiratory flow). However, fluctuations in this parameter do not reach statistical significance when the influence of core temperature was taken into account.

In the current study, we observed the daily breathing pattern, having a 'constant routine protocol' (7). Numerous studied investigating daily changes in breathing pattern used incompatible protocols. The introduction of a "constant routine protocol" as an investigation schedule allows avoiding some limitations which could influence the circadian patterns (11, 12). Banzett *et al* (13) have shown that breathing pattern alters during spirometry, so that a method estimating lung volumes during resting breathing pattern seems more appropriate.

In our previous study, we have shown daily changes in the ventilatory response to progressive isocapnic hypoxia (14). Czeisler *et al* (15) have demonstrated that hypoxia resulted in significant alterations of normal oscillations in body temperature in both humans and rats (16). As the rhythm of body temperature is important for the duration and organization of sleep, alterations of body temperature could be responsible for sleep disturbances during hypoxia (17) and in patients with cardio-respiratory diseases (18). Therefore, the relationship between the hypoxic ventilator response and circadian patterns may have clinical implications. Circadian oscillations in body temperature and oxygen consumption are influenced by circadian changes in thermoregulatory mechanisms (19). It is of interest to consider the possibility that pulmonary ventilation may change throughout the 24 hour period. The majority of available studies on the subject come from animal models (20). Askenezi *et al* (21) have shown that hypobaric hypoxia in humans has a very short effect on the thermoregulatory aspects of circadian rhythmicity.

In the present study, significant daily fluctuations of breathing pattern were observed in the volume components (tidal volume, minute ventilation), but not in the time components (expiratory time and total breath duration). The data of the present study indicate that sleep deprivation did not have an independent effect on pulmonary function. In a group of healthy young adult men, there were small, but significant daily variations in VT, MV, VT/TI, MV/P0.1, and P0.1/VT/TI relations. We observed increases in ventilatory variables during daytime and decreases during the usual sleep period. The mean values of VT, MV, VT/TI, and MV/P0.1 were significantly lower at 2:00, 5:00, and 8:00 hours.

The ventilatory changes noted in the present study are similar to those observed previously in a study on changes in the ventilatory response to progressive isocapnic hypoxia (14). The daily breathing pattern variability does not seem mediated by hypoxia. Therefore, distribution of breathing pattern, with depression of some respiratory variables at night, may reflect the presence of circadian oscillation.

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Conflicts of interest: The authors report no conflicts of interest in relation to this work.

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