The effects of posture on the metabolic and ventilatory response to low level steady state exercise

CHARLES WEISSMAN, JEFFREY ASKANAZI, S. H. ROSENBAUM, ALLEN I. HYMAN, J. MILIC-EMILI AND JOHN M. KINNEY

Departments of Anesthesiology, Medicine and Surgery, College of Physicians and Surgeons, Columbia University, New York, U.S.A. and Meakins-Christie Laboratories, McGill University, Montreal, Quebec, Canada

(Received 5 March 1986; accepted 13 June 1986)

Summary

1. Low level exercise is frequently used to assess cardiac and pulmonary function. This study examines the differences in both metabolic and respiratory patterns between the sitting and supine position.

2. Six normal male subjects were studied in both positions during four levels of exercise (12.5, 25, 37.5 and 50 W). Oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$) and minute ventilation ($V_E$) were greater when sitting as were the ventilatory equivalents to $O_2$ ($V_E/\dot{V}O_2$) and $CO_2$ ($V_E/\dot{V}CO_2$).

3. Respiration was compared at equivalent workloads; the greater minute ventilation observed during sitting was due to greater tidal volumes ($V_T$) and mean inspiratory flows ($V_{Ti}/T_i$). Expiratory time ($T_E$) was longer and inspiratory duration shorter under most conditions when sitting.

4. When breathing patterns were compared at similar degrees of minute ventilation, $V_T$, $T_E$ and $V_{Ti}/T_i$ were greater when sitting, while respiratory frequency ($f_R$) was slower.

Key words: carbon dioxide production, oxygen consumption, posture, steady state exercise.

Introduction

Exercise at low workloads is used increasingly to assess cardiac and pulmonary function. Assessment of cardiac function after myocardial infarction is often performed using low levels of sitting exercise.

Cardiac radionucleotide studies, such as stress-thallium scans, often involve low levels of either supine or sitting exercise. A comparison of the metabolic and respiratory patterns of such workloads in the supine and sitting position is therefore of clinical as well as basic physiological interest. Such a comparison will also allow for a better understanding of the differences between the results of studies performed in the two positions. Previous studies have demonstrated that at equal submaximal workloads, minute ventilation, oxygen consumption, and carbon dioxide production are higher in the sitting than in the supine position [1-5]. This study extends these previous observations by examining in detail the differences in the pattern and timing of ventilation between the sitting and supine position at four levels of low level steady state exercise. Three of these workloads were lower than those studied previously [2-4] and thus this study also allows for analysis of respiratory changes at very low exercise loads. In addition, since a canopy-spirometer-computer system [6] that allows for continuous non-invasive measurements of both gas exchange and breathing patterns was employed, the results were not affected by facial attachments such as a mouthpiece plus noseclip.

Methods

Six normal male subjects were each randomly studied in both the supine and the sitting position. The subjects were untrained, non-smoking healthy males between the ages of 23 and 34 years, without any abnormalities on pulmonary function testing. Written informed consent was obtained from all subjects. None was aware of the intent of the study.
This study was approved by the Institutional Review Board of Columbia University, Health Sciences.

All studies were performed in the morning after an overnight fast. Each subject was studied on two consecutive mornings, once supine and once sitting. The order was determined randomly.

The respiratory and metabolic measurements were made using a canopy-spirometer-computer system [6]. Exercise was performed using a bicycle-ergometer (Physiologically Paced Ergometry System, Warren G. Collins, Braintree, MA, U.S.A.) specifically modified for low level exercise. For supine exercise, the ergometer was attached to the footboard of a bed; for upright exercise it was attached to a bicycle frame.

After the subject was placed in the canopy and oxygen consumption ($\dot{V}_{O_2}$) and carbon dioxide production ($\dot{V}_{CO_2}$) had been stabilized, measurements were begun. An initial 17-min rest period was followed by 10-min exercise periods at a workload of 12.5 W. The initial exercise period was followed by a second rest period of 15 min, and then by a second 10-min exercise period at a workload of 25 W. This pattern of rest and exercise was repeated for workloads of 37.5 and 50 W. Pedalling rate was a constant 40 cycles/min. Heart rate was measured in four of the subjects.

The canopy–computer–spirometry system used in the present study has been described in detail previously [6]; it is composed of a head canopy connected to a spirometer (Med-Science model 470) and a Prime 300 computer. The canopy is a rigid transparent head chamber with a neck seal, ventilated by a continuous air-stream. The spirometer connected to the canopy provides a breath-by-breath record of changes in lung volume. Gas composition in the canopy is continuously sampled and analysed by means of a LIRA CO$_2$ analyser (model 200 F) and a Servomex O$_2$ analyser (model OA 250). Spirometry and gas exchange data are acquired and processed by the digital computer. Airflow to the canopy is set at 40 litres/min and is controlled to provide a stable spirometer baseline. Computer executed algorithms quantify each breath and determine minute ventilation ($\dot{V}_E$), tidal volume ($VT$), frequency ($f_b$), CO$_2$ production, O$_2$ consumption, peak inspiratory and expiratory flows (PIF, PEF) and inspiratory ($TI$) and expiratory ($TE$) time.

The computer algorithm analysed each half breath. Therefore, mean inspiratory flow ($\dot{V}_{TI}/TI$) was calculated from inspiratory tidal volume and $TI$, while mean inspiratory flow ($\dot{V}_{TI}/TE$) was calculated from expiratory tidal volume and $TE$. Tidal volume for each breath is an average of inspiratory and expiratory tidal volume. $TI$ and $TE$ were defined as the periods of active flow for inspiration and expiration and $T_{TOT}$ as the total interval between the beginning of inspiration and the start of the subsequent inspiration. Therefore, at rest, because of significant periods of no flow (dwell or pause time), $TI$ plus $TE$ does not equal $T_{TOT}$. During the higher levels of respiration the difference between the sum of $TI$ and $TE$ and $T_{TOT}$ diminishes as dwell periods decrease.

The ventilatory equivalents for O$_2$ and CO$_2$ ($\dot{V}_E/\dot{V}_{O_2}$, $\dot{V}_E/\dot{V}_{CO_2}$) were also calculated. An accuracy of $\pm$ 10 ml in $\dot{V}_E$ measurements is achieved for breathing frequencies in the range of 5–40 breaths/min. The program excludes all tidal volumes less than 40 ml, as these have been considered too small to represent a breath. The measurements made during min 5 to min 12 of the initial rest period and those made during min 4 to min 10 of each exercise period were used for comparison. This part of each steady state exercise period represents the plateau phase [7]. Heart rate, $\dot{V}_E$, $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ all returned to baseline levels by the end of each exercise period.

Statistical analysis was performed, using repeated measures analysis of variance to examine the changes between different levels of exercise within each posture and paired Student’s r-test to examine differences between the postures.

Results

Oxygen consumption (Fig. 1) and carbon dioxide production (Table 1) were greater throughout studies performed in the sitting position than during those performed supine. Resting $\dot{V}_{O_2}$ was 23% greater while $\dot{V}_{CO_2}$ was 27% greater when sitting as compared with lying in bed. At a workload of 25 W, $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$ were 25% and 28% larger, respectively, when seated. The slope of the $\dot{V}_E$–$\dot{V}_{O_2}$ relationship was $38 \pm 9$ (SD) when supine and $51 \pm 12$ when sitting ($P<0.050$). The ventilatory equivalents for O$_2$ and CO$_2$ were significantly greater when sitting ($P<0.05$) than when supine (Fig. 2).

In the supine position, the increases in minute ventilation observed with increasing workloads were primarily due to increases in $VT$ (Table 2), with increases in $f_b$ contributing to a lesser extent. Mean inspiratory flow also increased, while $VT/VT_{TOT}$ did so but to a lesser extent. Increases in mean expiratory flow ($VT/TE$) and peak inspiratory and expiratory flows (Table 1) were seen with increasing workload. Frequency increased from 17 breaths/min at rest to 21 breaths/min at workloads of 12.5 and 25 W ($P<0.05$). At workloads of 37.5 and 50 W, the frequency increased further, to 23 breaths/min and 24 breaths/min, respectively ($P<0.05$). These increases in frequency were due to decreases in both $TI$ and $TE$; the decreases in $TE$
Posture and response to exercise

were larger than those in $T_1$ (Fig. 3). This is reflected in $T_1/T_{TOT}$ which increased in two stages: from $0.37 \pm 0.04$ (SE) at rest, to $0.44 \pm 0.04$ and $0.45 \pm 0.05$ during the first two exercise levels and then to $0.47 \pm 0.04$ and $0.48 \pm 0.03$ during the highest two exercise loads (Table 2).

In the sitting position, the increases in $V_E$ seen with increasing exercise were accompanied by significant increases in $V_T$, $V_T/T_1$, $V_T/V_E$, PIF and PEF (Tables 1 and 2). Frequency increased from 18 breaths/min during rest to 21 breaths/min during

![Graph 1: Minute ventilation ($V_E$) plotted against oxygen consumption ($V_O_2$). Values are means ± SE for all six subjects. Posture: ---, supine; ----, sitting. Level of exercise: ●, rest; ○, 12.5 W; ×, 25 W; □, 37.5 W; ■, 50 W.](image1)

![Graph 2: Ventilatory equivalents for oxygen and carbon dioxide ($V_E/V_O_2$, $V_E/V_CO_2$) plotted against workload. Values are means ± SE for all six subjects. Posture: ---, supine; ----, sitting.](image2)

Table 1. Effect of posture on mean expiratory flow, peak inspiratory and expiratory flow, heart rate and carbon dioxide production

<table>
<thead>
<tr>
<th>Posture</th>
<th>$V_T/T_E$ (ml/s)</th>
<th>PIF (ml/s)</th>
<th>PEF (ml/s)</th>
<th>Heart rate (beats/min)</th>
<th>$V_CO_2$ (ml min⁻¹ m⁻²)</th>
<th>$V_O_2$ (ml min⁻¹ m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td>216 ± 60</td>
<td>373 ± 105</td>
<td>321 ± 95</td>
<td>65 ± 6</td>
<td>112 ± 31</td>
<td>128 ± 18</td>
</tr>
<tr>
<td>12.5 W</td>
<td>399 ± 72</td>
<td>718 ± 306</td>
<td>510 ± 93</td>
<td>79 ± 12</td>
<td>178 ± 49</td>
<td>222 ± 57</td>
</tr>
<tr>
<td>25 W</td>
<td>470 ± 171</td>
<td>862 ± 403</td>
<td>622 ± 110</td>
<td>83 ± 12</td>
<td>213 ± 51</td>
<td>266 ± 57</td>
</tr>
<tr>
<td>37.5 W</td>
<td>687 ± 255</td>
<td>1163 ± 404</td>
<td>898 ± 196</td>
<td>90 ± 5</td>
<td>282 ± 69</td>
<td>350 ± 90</td>
</tr>
<tr>
<td>50 W</td>
<td>1100 ± 417</td>
<td>1892 ± 727</td>
<td>1261 ± 312</td>
<td>106 ± 5</td>
<td>402 ± 94</td>
<td>485 ± 133</td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td>322 ± 54</td>
<td>542 ± 110</td>
<td>612 ± 59</td>
<td>82 ± 4</td>
<td>142 ± 31</td>
<td>168 ± 28</td>
</tr>
<tr>
<td>12.5 W</td>
<td>616 ± 131</td>
<td>1109 ± 339</td>
<td>957 ± 213</td>
<td>90 ± 11</td>
<td>237 ± 62</td>
<td>294 ± 98</td>
</tr>
<tr>
<td>25 W</td>
<td>703 ± 300</td>
<td>1308 ± 430</td>
<td>1085 ± 191</td>
<td>89 ± 12</td>
<td>275 ± 59</td>
<td>332 ± 97</td>
</tr>
<tr>
<td>37.5 W</td>
<td>978 ± 263</td>
<td>1591 ± 382</td>
<td>1415 ± 331</td>
<td>91 ± 11</td>
<td>346 ± 53</td>
<td>405 ± 92</td>
</tr>
<tr>
<td>50 W</td>
<td>1504 ± 494</td>
<td>2309 ± 704</td>
<td>1684 ± 257</td>
<td>118 ± 7</td>
<td>500 ± 84</td>
<td>510 ± 84</td>
</tr>
</tbody>
</table>

Values are means ± SD, $n = 6$, except for heart rate measurements ($n = 4$). Significantly different from supine values: $^aP < 0.050, ^bP < 0.025, ^cP < 0.010, ^dP < 0.001$. Significantly different from resting values: $^eP < 0.050, ^fP < 0.025, ^gP < 0.010, ^hP < 0.001$. Significantly different from 12.5 W values: $^iP < 0.050, ^jP < 0.025, ^kP < 0.010$. Significantly different from 25.0 W values: $^lP < 0.050, ^mP < 0.025, ^nP < 0.010, ^oP < 0.001$. Significantly different from 37.5 W values: $^pP < 0.050, ^qP < 0.001$. Significantly different from 50 W values: $^rP < 0.050, ^sP < 0.025, ^tP < 0.010, ^uP < 0.001$. Significantly different from 22 W values: $^vP < 0.050, ^wP < 0.025, ^xP < 0.010, ^yP < 0.001$. Significantly different from 18 W values: $^zP < 0.050, ^{1P} < 0.025, ^{2P} < 0.010, ^{3P} < 0.001$. Significantly different from 14 W values: $^{4P} < 0.050, ^{5P} < 0.025, ^{6P} < 0.010, ^{7P} < 0.001$.
TABLE 2. Effect of posture on ventilatory parameters in six subjects

<table>
<thead>
<tr>
<th>Posture</th>
<th>( V_E ) (litres/min/m^2)</th>
<th>( V_T ) (ml)</th>
<th>( T_i/T_{TOT} ) (s)</th>
<th>( T_r/T_{TOT} ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td>2.6 ± 0.92 ( ^{a,b} )</td>
<td>167 ± 48 ( ^{a} )</td>
<td>3.5 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
<tr>
<td>Rest</td>
<td>4.5 ± 0.61 ( ^{ac} )</td>
<td>167 ± 48 ( ^{a} )</td>
<td>3.6 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
<tr>
<td>25 W</td>
<td>7.4 ± 0.68 ( ^{ac} )</td>
<td>167 ± 48 ( ^{a} )</td>
<td>3.6 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
<tr>
<td>50 W</td>
<td>9.8 ± 3.69 ( ^{ac} )</td>
<td>167 ± 48 ( ^{a} )</td>
<td>3.6 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
<tr>
<td>Sitting</td>
<td>6.5 ± 0.30 ( ^{ac} )</td>
<td>167 ± 48</td>
<td>3.6 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
<tr>
<td>25 W</td>
<td>16.5 ± 0.30 ( ^{ac} )</td>
<td>167 ± 48</td>
<td>3.6 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
<tr>
<td>50 W</td>
<td>16.5 ± 0.30 ( ^{ac} )</td>
<td>167 ± 48</td>
<td>3.6 ± 0.16 ( ^{ac} )</td>
<td>0.7 ± 0.14 ( ^{ac} )</td>
</tr>
</tbody>
</table>

The first three exercise loads \((P < 0.05)\) and to 26 breaths/min at loads of 50 W \((P < 0.05)\). \( T_r \) decreased more than did \( T_i \) (Fig. 2), resulting in increases in \( T_i/T_{TOT} \) from 0.39 ± 0.05 during rest to 0.43 ± 0.04 during loads of 12.5 and 25 W \((P < 0.05)\) and to 0.46 ± 0.04 and 0.47 ± 0.04 during the two highest exercise loads studied (Table 2).

Contrasting the supine with the sitting position, during rest and at the four levels of exercise studied, \( V_E \), \( V_T \) and \( V_i/T_i \) were significantly greater in the sitting position (Table 1). The mean resting \( V_E \) was 2.6 ± 0.92 litres min\(^{-1}\) m\(^{-2}\) when supine and 4.5 ± 1.1 litres min\(^{-1}\) m\(^{-2}\) in the sitting position. The difference in minute ventilation between the two postures was mainly due to larger tidal volumes and greater mean inspiratory flows rather than differences in frequency and \( T_i/T_{TOT} \). Interestingly, \( T_r \) was longer and \( T_i \) was shorter at most conditions while sitting (Fig. 3). Mean expiratory flow, as well as PIF and PEF, was greater sitting than supine both at rest and at all four levels of exercise studied (Table 2). At rest and during exercise at workloads of 12.5 and 25 W, heart rate was significantly greater in the sitting position (Table 1).

Breathing patterns were compared at similar degrees of minute ventilation. Two points of comparison were used: (a) supine, 25 W \((V_E = 7.0 ± 4.4 \text{ litres min}^{-1} \text{ m}^{-2})\) vs sitting, 12.5 W \((V_E = 7.6 ± 3.7 \text{ litres min}^{-1} \text{ m}^{-2})\); (b) supine, 50 W \((V_E = 16.5 ± 6.3 \text{ litres min}^{-1} \text{ m}^{-2})\) vs sitting, 37.5 W \((V_E = 15.4 ± 3.4 \text{ litres min}^{-1} \text{ m}^{-2})\)
litres min$^{-1}$ m$^{-2}$); and (c) supine, 12.5 W ($V_E = 5.4 \pm 2.0$ litres min$^{-1}$ m$^{-2}$) vs sitting, at rest ($V_E = 4.5$ litres min$^{-1}$ m$^{-2}$). Comparison (a) revealed that when sitting, $V_T$ ($P<0.01$), $T_E$ ($P<0.05$), $V_T/T_i$ ($P<0.001$) and $V_T/T_E$ ($P<0.025$) were greater than when supine. Comparison (b) demonstrated that $V_T$ ($P<0.05$) and $T_{TOT}$ ($P<0.05$) were larger in the sitting than in the supine position. Comparison (c) revealed that $V_T$ ($P<0.01$), $V_T/T_i$ ($P<0.025$), $T_E$ ($P<0.025$) and $T_{TOT}$ ($P<0.01$) were greater sitting than supine.

Discussion

This study demonstrates that there are substantial differences in the pattern and timing of respiration between the sitting and supine positions at the four rather low levels of steady state exercise. In addition to extending previously published observations [1–5, 8] by including measurements of inspiratory flow and inspiratory duty cycle [9], the study was performed using a non-invasive system so that respiratory pattern was not affected by facial attachments such as a mouthpiece plus noseclip or mask [10]. The use of four levels of exercise allowed us to compare the difference between sitting and supine patterns not only at equivalent workloads but also at similar levels of minute ventilation.

At equal workloads, minute ventilation, tidal volume and mean inspiratory flow were consistently greater in the sitting position while frequency and inspiratory duty cycle were relatively unaffected. This is in agreement with a number of published observations [3, 4] that at equal submaximal workloads, minute ventilation is higher in the sitting than the supine position. Others [2] have observed that at maximal work rate, minute ventilation is greater in the sitting position. McGregor et al. [3] observed that both at rest and at workloads of 50 and 93 W of bicycle-ergometry, minute ventilation was higher in the sitting position; this was due to a higher respiratory frequency, while tidal volume remained unchanged. This is in variance with our observations that tidal volume was greater sitting than supine. However, the studies performed by McGregor et al. [3] utilized a mouthpiece plus noseclip while our study used a canopy-spirometer–computer system which requires no facial attachments [6]. Sackner et al. [10] examined the influence of a mouthpiece plus noseclip on respiratory patterns at rest and during exercise. At rest, the mouthpiece plus noseclip caused an increase in tidal volume and minute ventilation, but not in frequency. However, during a 5-min exercise period at a workload of 130 W, frequency, mean inspiratory flow and minute ventilation were greater with the use of a mouthpiece plus noseclip while $V_T$ was unaffected. Thus, the difference between our observations and those of McGregor et al. [3] may be due to differences in measurement techniques.

Analysis of breathing patterns at equivalent workloads in terms of the duration of inspiration and expiration demonstrated that during both sitting and supine breathing the increases in frequency were due to a greater shortening of $T_E$ than $T_i$, resulting in an increase in $T_i/T_{TOT}$. This is consistent with our previous observations [11]. Comparing supine with sitting values at the same workloads demonstrated that in the sitting posture $T_E$ was longer and, in most instances, $T_i$ was slightly shorter. Thus the higher $V_T/T_i$ observed when sitting was due mainly to a larger $V_T$. During exercise, there was little difference in $T_i/T_{TOT}$ between the two postures since the relative changes in $T_i$ and $T_E$ were similar in the two postures. These results can be compared with results obtained when the effects of posture (sitting vs supine) on breathing pattern during the administration of 2% and 4% CO$_2$ was examined [12]. In that study, in the seated position, $T_i$ was consistently lower and the $V_T$ was larger so that $V_T/T_i$ was increased. Unlike exercise, during CO$_2$ stimulation $T_E$ was not longer when sitting. Thus, it appears that in the sitting position, $T_i$ is shorter during CO$_2$ administration, while during exercise $T_E$ is altered more than is $T_i$.

Comparison of breathing patterns at similar minute ventilations revealed some interesting trends. When the patterns of respiration at a sitting workload of 12.5 W were compared with those at a supine workload of 25 W, an instance where mean $V_E$ was 0.6 litre min$^{-1}$ m$^{-2}$ greater sitting, tidal volume ($P<0.01$), inspiratory flow ($P<0.01$), $T_E$ ($P<0.05$) and $T_{TOT}$ (NS) were greater in the sitting position. At another point of comparison, supine at 50 W vs sitting at 37.5 W, mean $V_E$ was 0.9 litre min$^{-1}$ m$^{-2}$ greater than supine. In this situation, $V_T$ was $0.05$), $T_{TOT}$ ($P<0.05$) and $T_E$ (NS) were greater sitting. Sitting at rest ($V_E = 4.5$ litres min$^{-1}$ m$^{-2}$) was compared with lying while exercising at 12.5 W ($V_E = 5.4 \pm 2.0$ litres min$^{-1}$ m$^{-2}$). In this instance we again see that despite a lower $V_E$ sitting $V_T$, $V_T/T_i$, $T_E$ and $T_{TOT}$ were all significantly greater sitting. These observations suggest that at similar degrees of minute ventilation, $V_T$, $T_{TOT}$ and $T_E$ are larger in the sitting position, while $T_i$ is unchanged. It therefore appears that under the conditions studied here, rest and four low levels of exercise with minute ventilations of 2.6–16.5 litres min$^{-1}$ m$^{-2}$, at similar minute ventilations the pattern of respiration is one of a larger tidal volume and slightly lower frequency in the sitting position than in the supine one. One possible explanation is that in the supine position caudal movement of the diaphragm is encumbered by abdominal contents.
This is not the case in the sitting position. For example, in the supine position the compliance of the total respiratory system is lower in the sitting position and there are differences in ventilation-perfusion relationships between the postures. Therefore, a number of mechanisms may account for these changes. Thus, when supine, it is probably more efficient to increase frequency rather than tidal volume. Other mechanisms may also be operative.

At rest and during the four levels of exercise studied, both $\dot{V}CO_2$ and $\dot{V}O_2$ were lower when the subjects were supine. This has been observed by others [1, 5] and has been attributed to the fact that arm and trunk muscles are relatively immobilized during supine exercise, in contrast to their contribution to total body metabolism in the sitting position [2]. Convertino et al. [2] observed that immobilization of the arm and trunk muscles in the sitting position abolished the difference between supine and sitting maximum $\dot{V}O_2$. We also noted that the ventilatory equivalents for both $CO_2$ and $O_2$ were lower in the supine position. There is thus more effective ventilation in the supine position. This may be due to a lower anatomical and alveolar dead space in the supine position [8, 9]. We also observed that there were no significant differences in the slope of the $\dot{V}e-\dot{V}CO_2$ relationships, but like McGregor et al. [3] noted that the slope of the $\dot{V}e-\dot{V}O_2$ relationship was greater in the sitting position.

In summary, this study demonstrates that there are significant differences in breathing patterns and metabolic parameters between the sitting and supine positions both during rest and low levels of steady state exercise. Therefore, when examining breathing patterns it is important to consider the influence of posture.

Acknowledgment

This work was supported by National Institutes of Health Grants GM-14546 and HL-23975 (U.S. Army Contract no. DA-MD-17-81-C-1048).

References


