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*Chest* 1991;100:1229-1234
DOI 10.1378/chest.100.5.1229

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The Effect of Body Posture on Exercise- and Hyperventilation-induced Asthma*

Omri Inbar, Ph.D.; Shachar Naiss, M.Sc.; Etai Neuman, M.D.; and Jonathan Daskalovich, Ph.D.

Recent studies have shown that swimming is of relatively low asthmogenicity, even under conditions of high respiratory heat (and/or water) loss (RHL). It has been suggested that the horizontal body position may contribute to swimming’s low asthmogenicity. We studied the effects of upright and prone body postures on pulmonary function following exercise (EIA) and after noneexercise hyperventilation (HIA). Twelve asthmatic boys (aged 12 to 16 years) underwent two 8-min exercise sessions of shoulder flexion-extension and two 8-min isocapnic hyperventilation treatments, in a counterbalanced order, either while lying prone or standing upright. All tests were carried out in a climatic chamber at 10 ± 1°C and 31 ± 2 percent relative humidity. Minute ventilation (VE) was kept constant at a predetermined individual level during all treatments. No differences were observed in pulmonary functions between the prone and upright postures following either exercise (FEV1 = 20.5 ± 18.7 percent vs 22.2 ± 18.7 percent, respectively) or hyperventilation (FEV1 = −29.6 ± 19.0 percent vs −29.1 ± 29.2 percent). We conclude that body posture on land has no meaningful effect on the severity of bronchoconstriction in asthmatic children; however, in view of some conceivable physiologic benefits of the prone position in water, an interactive effect on swimming-induced asthma (SIA) of body posture and water immersion cannot be ruled out.

Material and Methods

Subjects

Twelve boys participated in this study. They were all diagnosed as having extrinsic perennial asthma for at least five years. EIA was reported by the child and/or the parents and was verified by a standardized exercise provocation test prior to this study. All subjects showed a reduction of at least 25 percent in FEV1, with group mean reduction of 31.4 percent.

Their mean (± SD) age was 14.67 ± 1.72 years and they were within age-related normal body height (166 ± 12.21 cm), weight (54.61 ± 12.09 kg), and adiposity (14.5 ± 3.2 percent).

All children were kept symptom free by maintenance of hyposensitization and required either round-the-clock bronchodilators or local beclomethasone dipropionate inhalations.

Testing was performed during the summer months of 1989. The summer season was selected to reduce the likelihood of seasonal allergic effects. The children were tested following discontinuation of treatment with all medications for 12 hours. All testing sessions for a given child were completed within five to ten days.

Experimental Procedures and Conditions

Each child underwent four testing sessions. Testing included the following: (1) shoulder extension-flexion exercise while in the prone position (EX-P) (Fig 1, B); (2) shoulder extension—flexion exercise while standing upright (EX-U) (Fig 1, C); (3) isocapnic hyperventi-
Body Posture and Asthma (Inbar et al)

Ficuisx 1. Schematic illustration of the exercise and hyperventilation set-up employed in this study.

IN OWS

FIGURE 2. Scheme of a testing session protocol. Arrows denote time of pulmonary function testing (PFT).

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**Table 1—Individual Resting Pulmonary Functions***

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subject</th>
<th>Meas</th>
<th>%Pred</th>
<th>Meas</th>
<th>%Pred</th>
<th>Meas</th>
<th>%Pred</th>
<th>Meas</th>
<th>%Pred</th>
<th>Meas</th>
<th>%Pred</th>
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<td>1</td>
<td>3.60</td>
<td>103</td>
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<td>81</td>
<td>73</td>
<td>81</td>
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<td>56</td>
<td>2.40</td>
<td>55</td>
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<td></td>
<td>2</td>
<td>4.59</td>
<td>107</td>
<td>2.75</td>
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<td>60</td>
<td>67</td>
<td>1.84</td>
<td>44</td>
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<td>4</td>
<td>4.49</td>
<td>130</td>
<td>2.96</td>
<td>93</td>
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<td>67</td>
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<td></td>
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<td>78</td>
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<td>74</td>
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<td>1.97</td>
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<td>8</td>
<td>4.15</td>
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<td>4.29</td>
<td>100</td>
<td>4.83</td>
<td>97</td>
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<td>9</td>
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<td>104</td>
<td>1.89</td>
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<td>71</td>
<td>81</td>
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<td>1.69</td>
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<tr>
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<td>2.62</td>
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<td>1.62</td>
<td>39</td>
<td>1.75</td>
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<td>2.93</td>
<td>110</td>
<td>2.27</td>
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<td>2.48</td>
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<td>4.72</td>
<td>109</td>
<td>3.58</td>
<td>89</td>
<td>76</td>
<td>83</td>
<td>3.10</td>
<td>73</td>
<td>3.40</td>
<td>71</td>
</tr>
<tr>
<td><strong>Mean ± SD</strong></td>
<td></td>
<td>3.99</td>
<td>106.5</td>
<td>2.78</td>
<td>80.8</td>
<td>70.3</td>
<td>78.4</td>
<td>2.26</td>
<td>59.3</td>
<td>2.58</td>
<td>60.2</td>
</tr>
</tbody>
</table>

*Values are means of baseline testing prior to each of the four treatments. Meas = measured; % pred = percent predicted. FVC = forced vital capacity; FEV = forced expiratory volume in 1 s; FEF25-75% = mean forced expiratory flow during middle half of FVC; PEF = peak expiratory flow. Predicted values are taken from Polgar and Promadhat,* 1971.

**RESULTS**

Individual resting pulmonary function is given in Table 1. Most patients had mild air-flow obstruction with slight reductions in expiratory flow rates. Mean (±1SD) of exercise 

\[
\text{VE}, 
\text{breathing frequency (BR), tidal volume (VT), VO}_2, 
\text{and HR by treatments are presented in Table 2.}
\]

It is apparent that despite a somewhat higher metabolic level (\(\text{VO}_2\)) during the upright than the prone exercise (18.1 ± 3.4 vs 15.1 ± 2.3 ml/kg-min, respectively (p<0.05), all other variables (\(\text{VE}, \text{VT}, \text{BR}\)) were similar in the four treatments, suggesting equal RHLs, since inspired air conditions were identical during all treatments.

Figure 3 displays the mean changes (± SEM) in FVC, FEV, FEF50, and FEF25-75 (posttreatment minus pretreatment − Δ) in all treatments.

There were no significant differences in pulmonary function within a given treatment (exercise or hyperventilation) (p>0.05), between the prone and the upright postures, suggesting no posture effects on either small- or large-airway patency following either exercise or hyperventilation.

**DISCUSSION**

In an attempt to elucidate possible mechanisms operating during swimming that protect against EIA, body posture (prone) was isolated using simulated swimming exercise on land. The major finding of this study is the similar pulmonary response of asthmatic children following both exercise and isocapnic hyperapnea under upright and prone positions. This suggests that posture per se (assuming similar RHL) has little or no protecting influence against bronchoconstriction following both exercise and/or isocapnic hyperventilation.

RHL was not directly measured in this study. However, the tight control of ambient temperature and humidity within the climatic chamber, on the one hand, and on the other hand, the constant 

\[
\text{VE} \text{and breathing pattern in all four treatments, strongly suggest comparable RHL in all sessions.}
\]

**Table 2—Selected Cardiopulmonary Variables during Exercise and Hyperventilation under the Two Body Postures***

<table>
<thead>
<tr>
<th>Treatment</th>
<th>(\text{VO}_2, \text{ml/min·kg})</th>
<th>HR, Beats/min</th>
<th>(\text{VE}, \text{L/min})</th>
<th>(\text{VT}, \text{L})</th>
<th>BR, BR/min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoulder Flex-Ext</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prone</td>
<td>(\bar{x})</td>
<td>15.15</td>
<td>142.4</td>
<td>41.73</td>
<td>0.966</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.30</td>
<td>18.2</td>
<td>10.86</td>
<td>0.230</td>
</tr>
<tr>
<td>Upright</td>
<td>(\bar{x})</td>
<td>18.1</td>
<td>147.2</td>
<td>42.19</td>
<td>1.056</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>3.4</td>
<td>18.7</td>
<td>10.62</td>
<td>0.247</td>
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<tr>
<td><strong>Hyperventilation</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Prone</td>
<td>(\bar{x})</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upright</td>
<td>(\bar{x})</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>F</td>
<td>7.59</td>
<td>1.396</td>
<td>1.571</td>
<td>0.729</td>
<td>1.895</td>
</tr>
<tr>
<td>P</td>
<td>0.02</td>
<td>0.265</td>
<td>0.215</td>
<td>0.542</td>
<td>0.159</td>
</tr>
</tbody>
</table>

*Flex-Ext denotes flexion and extension arm exercise.*
The results of this study are somewhat surprising in light of some physiologic "advantages" associated with the prone position when compared with the upright one. Of those physiologic differences, some are considered beneficial to the exercising asthmatic. It is well established that central blood flow is significantly increased when body position is shifted from upright to recumbent.\textsuperscript{10,15} Such an increase may result in improved gas diffusion efficiency and ventilation-perfusion matching,\textsuperscript{16,17} as well as in a reduction in airway cooling during and following exercise.\textsuperscript{18,19} A possible explanation for the observed similarities in bronchoconstriction in the upright and prone positions, following either exercise or hyperventilation, could be the following: (1) changes in central blood flow or volume associated with the prone position do not affect RHL under this study's conditions; (2) reduction in RHL, if indeed occurred in association with either exercise or hyperventilation while in the prone position, only negligibly affects postexercise pulmonary function under the present study's conditions.

Furthermore, a recent study\textsuperscript{15} demonstrated that stroke volume and blood flow differences in favor of the supine compared with the upright position disappear during exercise.

Tidal volume and breathing frequency, which under certain conditions could affect RHL,\textsuperscript{20} and thereby the severity of EIA,\textsuperscript{20-22} were similar in the present study, among all treatments, thus excluding breathing pattern as a possible confounding factor in our results.

To apply these results to actual swimming and thus exclude horizontal body position as a factor in swimming's low asthmogenicity, one must assume similar physiologic responses to swimming and to prone exercise on land. Such an assumption, however, seems, at least partially, unwarranted in light of some evidence pointing to a greater ventilatory efficiency and improved gas-exchange and pulmonary diffusion during horizontal exercise in water when compared with horizontal exercise on land.\textsuperscript{23} Furthermore, during immersion in water of less than 35°C, there is a peripheral vasoconstriction and consequent increase in central blood volume,\textsuperscript{24} which in turn may reduce respiratory heat loss and thus SIA.\textsuperscript{19} Finally, swimming was shown to increase catecholamine levels more than comparable exercise on land.\textsuperscript{25} Such a response is known to advantageous affect bronchial vasomotor tone.\textsuperscript{26}

Therefore, exclusion of the horizontal body position as a protective factor in actual swimming is not conclusive, since factors associated with water immersion per se may interact with body posture to alleviate SIA in some as yet unknown ways.

This study's design offers an opportunity to touch on yet another controversial issue related to mechanisms operating during EIA.

Many investigators believe that increased ventilatory effort may produce acute episodes of bronchospasm in asthmatics, either through mechanical stim-
ulation or irritation of the tracheobronchial tree,\textsuperscript{27-29} or through the hyperventilation-induced reduction in alveolar CO\textsubscript{2} tension (hypocapnea).\textsuperscript{30,31}

Others,\textsuperscript{21,22} however, believe that hyperventilation triggers events leading to bronchoconstriction solely through airway cooling.

Studies dealing with this topic, carried out prior to the formulation of the RHL theory (1977 to 1978), were typically lacking control of RHL. Most later studies overlooked the control of alveolar CO\textsubscript{2} tension.

In the present study, a comparison between EIA and HIA could be made with equated VE, inspired air conditions, and alveolar CO\textsubscript{2} tension.

Under those conditions and across body posture \((n = 24)\), we found hyperventilation more asthmogenic than exercise (Fig 4). Our results are in line with those of Noviski et al\textsuperscript{34} who reported that under equal VE and RHL conditions, more severe bronchospasm occurred following isocapnic hyperventilation than following exercise.

In conclusion, this study demonstrates the following: (1) body posture on land does not influence the severity of bronchoconstriction in asthmatic children; (2) in view of the mentioned physiologic benefits of the prone position in water, our results do not rule out the possibility that under aquatic conditions (but not on land), body posture may indeed play a protective role against SIA.

ACKNOWLEDGMENTS: The writers thank Dina Figenbaum for her technical assistance, Dr. G. Tenenbaum and Niva Belinko for their help in statistical analysis, and Rafi Dotan for his editorial assistance. Most importantly, the authors are grateful to the children who participated in this study and to their parents for their efforts and cooperation.

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