

**LUNGS AND LEGS:  
ENTRAINMENT OF BREATHING TO LOCOMOTION IN  
HIGHLY-TRAINED DISTANCE RUNNERS**

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Research has found that breathing is coordinated, or entrained, to the rhythm of locomotion, possibly conferring an economical advantage. Elite endurance athletes, whose ability to sustain high metabolic workloads sometimes results in exercise-induced hypoxemia (EIH) and expiratory flow limitation (FL), are a unique population in which to study this “lungs-legs” relationship.

**PURPOSE:** The purposes of this study were to examine the entrainment of breathing frequency to stride rate in elite distance runners during exercise at 70, 90, 100, and 110% of the ventilatory threshold (VT), to compare the degree of entrainment between % VT intensities, and to examine the relationship between entrainment and running economy. Given a sufficient number of entrained and non-entrained subjects, EIH and non-EIH subjects, and/or FL and non-FL subjects, secondary purposes were to compare economy at each intensity between entrained and non-entrained groups and to compare the proportion of subjects exhibiting entrainment and the percent entrainment between EIH and non-EIH groups and between FL and non-FL groups.

**METHODS:** Fifteen male distance runners performed a maximal oxygen consumption ( $VO_{2max}$ ) test and a locomotor-respiratory coupling test, during which running economy was also determined. EIH and FL were determined by pulse oximetry and flow-volume measurements during the  $VO_{2max}$  test, respectively.

**RESULTS:** Only 5 subjects exhibited EIH and 2 exhibited FL, precluding group comparisons regarding entrainment. All subjects entrained breathing to stride rate, precluding group comparisons regarding running economy. The step-to-breath ratio decreased with increasing intensity up to 100% VT ( $2.75 \pm 0.58$ ,  $2.32 \pm 0.52$ , and  $2.14 \pm 0.56$ ;  $p < 0.05$ ) but did not decrease further at 110% VT ( $2.16 \pm 0.48$ ). Subjects most often utilized 5:3 and 2:1 step-to-breath ratios. Percent entrainment during inspiration at 70% VT was less than at 100 and 110% VT ( $13.1 \pm 7.8$ ,  $23.1 \pm 14.5$ ,  $28.4 \pm 16.5$ , and  $30.8 \pm 14.9\%$  for 70, 90, 100, and 110% VT, respectively;  $p < 0.01$ ), but did not change with intensity during expiration ( $30.8 \pm 12.6$ ,  $27.9 \pm 10.0$ ,  $20.8 \pm 7.3$ , and  $25.7 \pm 11.2\%$ , respectively). At all intensities, percent entrainment was significantly greater than a chance occurrence. Correlations between the degree of entrainment and running economy were not significant at any intensity.

**CONCLUSION:** Entrainment of breathing to locomotion is a physiological phenomenon in elite distance runners, which is largely not influenced by intensity, but can differ between inspiration and expiration. Furthermore, running economy is not associated with entrainment. The methods used to quantify entrainment need additional research and critical reflection.

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