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VENTILATORY RESPONSES TO EXERCISE WHILE ELICITING THE RELAXATION--ETC(U)

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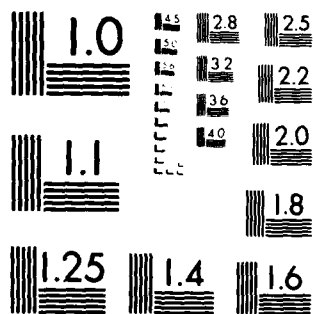


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VENTILATORY RESPONSES TO EXERCISE WHILE
ELICITING THE RELAXATION RESPONSE

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Running Head: Relaxation Response, Ventilatory Response, and Exercise

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Abstract

The effect of the elicitation of the relaxation response by use of a meditative technique on selected ventilatory variables was studied in eleven experimental (E) subjects who pedaled on an electrically-braked cycle ergometer at a low exercise intensity (50 W) while simultaneously eliciting this response. Thirteen control (C) subjects exercised at the same exercise intensity without evoking the response. Subjects in the E group had regularly elicited the relaxation response for a mean of 5.4 yrs (± 1.4 S.E.). Respiratory rate (breaths/min ⁺² 18.5C, 13.6E), minute ventilation (liters/min ⁺² 20.17C, 17.92E), and ventilatory equivalent for oxygen (26.06C, 23.16E) decreased and tidal volume (liters/breath ⁺² 1.15C, 1.49E) increased significantly ($p < 0.05$) during the relaxation response period in the E group. None of these ventilatory responses differed significantly ($p > 0.05$) between groups either before or after the meditation period. Differences seen in oxygen uptake and the respiratory exchange ratio between groups throughout exercise were not significant while the heart rate response was significantly higher for the E group throughout exercise. Rated perceived exertion significantly increased in the E group between the meditative (9.7) and post-meditative (11.0) period. These changes demonstrate that a voluntary wakeful mental activity that produces the relaxation response may alter ventilatory responses during exercise.

Index terms: cycling; meditation; perception of effort; physical exertion; pulmonary ventilation; respiratory rate; tidal volume; ventilatory equivalent for oxygen



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The relaxation response is believed to be an innate response associated with physiological changes consistent with decreased sympathetic nervous system activity and reduced responsivity to norepinephrine (1,3,7,14). When elicited at rest, it is characterized by decreases in oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide elimination ($\dot{V}_{CO_2}$), respiratory rate (f_R) and minute ventilation ($\dot{V}_E$), with no change in respiratory exchange ratio (R.E.R.) (2,14). In addition, there is a decrease in arterial blood pH and lactate and an increase in skin resistance (14). These changes which have been observed with the elicitation of the relaxation response at rest differ from those that occur during sleep or hypnosis (14).

The relaxation response can be elicited during exercise (3). The preliminary observations suggested that $\dot{V}_{O_2}$ decreased when subjects exercised at a steady state heart rate while eliciting the relaxation response (3). A voluntary, wakeful mental activity such as meditation has not been reported to alter other ventilatory responses to exercise. In the present paper, we present the results of further studies on ventilatory responses to exercise while eliciting the relaxation response.

METHODS

Twenty-four paid volunteers were divided into an experimental (N=11) and a control group (N=13). There were nine males in both groups with two females in the experimental group and four females in the control groups. The mean age ($\pm$ S.E.) in the control group was 27.9 ± 4.0 yrs. and in the experimental group was 31.8 ± 7.1 yrs. Subjects in the experimental group had 5.4 ± 1.4 yrs. experience in the regular practice of the relaxation response at rest. The control subjects had no experience with eliciting the relaxation response. Written, informed consent was obtained from each subject.

All subjects were asked to exercise on an electrically braked Quinton cycle ergometer at a constant, exercise intensity of 50 watts in a temperature-controlled room (21°C). Subjects pedaled continuously for a 40-minute session which was divided into three periods. The first period was ten minutes long and was called the "pre-intervention" period. The second period was 20 minutes in duration and served as the "intervention" period. During the "intervention" period, subjects in the experimental group continued to pedal and simultaneously practiced a meditative technique which elicited the relaxation response. Subjects in the control group simply continued to pedal. The third period, the "post-intervention" period, was ten minutes long.

Each subject was fit with a mask which covered their mouth and nose. The use of mouthpieces and noseclips would interfere with the elicitation of the relaxation response since nasal breathing is often considered to be necessary.

Two-minute-expired gas samples were collected with a Collins single J or a Mueller respiration gas-meter-breathing valve at minute three and seven of every ten minute interval. The EKG and heart-rate were continuously monitored using a Hewlett Packard Telemetry system. Oxygen and carbon dioxide fractions were measured on an Applied Electrochemistry S-3A oxygen analyzer and a Beckman LB-2 CO₂ analyzer. All gas volumes were determined using a Collins 120 liter, chain compensated Tissot gasometer.

Rated perceived exertion using the Borg category rating-scale (4), were assessed at each gas collection in the pre- and post-intervention periods and immediately after the 20 minute intervention period.

Statistical Methods

Results were analyzed using a mixed two factor (group x repeated

measures) analysis of variance (9). Critical differences were calculated by Tukey's method (8), or where there were group by time interactions, Cicchetti's method was used (5). Homogeneity of variance was tested according to Cochran (15). A probability level of 0.05 was chosen as the criterion for acceptance of statistical significance.

RESULTS

During the intervention period the respiratory rate (f_R , breaths·min⁻¹) for the experimental group (E) was 4.9 lower than controls (C) ($p < 0.01$) as illustrated in Figure 1. There were no significant differences in the f_R during the pre- (17.1, E; 17.0, C) or post- (19.4, E; 20.0 C) intervention period (Table 1). Several other respiratory parameters showed significant differences between the experimental and control groups during the intervention period. The tidal volume (V_T liters·breath⁻¹) of the experimental group was 0.341 liters greater than the control group ($p < 0.01$) (Figure 2). Pulmonary ventilation ($\dot{V}_E$, liters·min⁻¹) was 2.25 liters·min⁻¹ less for E than C ($p < 0.05$) (Figure 3). The ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}_{O_2}$) was 2.9 lower for E than C ($p < 0.05$), (Figure 4). No significant differences were seen between groups either pre- or post the intervention period for these three parameters (V_T , $\dot{V}_E$ and $\dot{V}_E/\dot{V}_{O_2}$). Differences between the two groups for oxygen uptake ($\dot{V}_{O_2}$, liters·min⁻¹) throughout the total exercise period were not significant (0.793, E; 0.773, C) (Figure 5). The respiratory exchange ratio did not differ between groups at any time (Table 1). Heart rate (beats·min⁻¹) was higher ($p < 0.05$) for E (101.5) than C (91.1) during the intervention period, but was consistently higher for E throughout the exercise period (Table 1).

Rated perceived exertion (RPE) did not differ between groups at any time, but the E group did show a significant ($p < 0.05$) increase in

the post-intervention period (11.0), compared to their own pre- (9.6) and intervention period (9.7) scores. The C group was significantly higher during the intervention period (10.6) and post-intervention period (11.1) than their own pre-intervention period (9.2) (Table 1).

DISCUSSION

The elicitation of the relaxation response at a fixed-exercise intensity was associated with changes in ventilatory variables similar to those found when elicited at rest (2,14). The decrease in f_T , $\dot{V}_E$, $\dot{V}_E/\dot{V}_{O_2}$ and increase in V_T observed in the experimental group during the intervention period did not occur in the control group. Since these ventilatory variables were not altered between groups both pre- and post-intervention, the changes observed in the experimental group can be ascribed to the practice of this mental process. In addition, the ventilatory variable alterations which were observed in our experimental group during the intervention period were not similar to those found with combined hypnosis and exercise (12). The change in rated perceived exertion in the experimental group with a higher post-intervention value might have been predicted considering this "quieting state" affects those respiratory sensations (f_T , $\dot{V}_E$, V_T) which are thought to provide central sensory cues for perception of effort because of their ability to be consciously monitored (11,13). Sensations from the exercising muscles and joints which are referred to as local cues are also thought to be important factors in the perception of effort during exercise particularly at higher exercise intensities (11,13). It is not known whether the elicitation of the relaxation response at higher exercise intensities will alter sensory input from these local muscular factors.

This study did not confirm previously reported significant decreases in oxygen consumption during exercise while eliciting the relaxation response (3) although there was a trend in the experimental group for $\dot{V}_{O_2}$ to decrease during the intervention period (Figure 5). However, an apparent reduction in the work of respiratory effort was observed in this group. This was implied by the finding of a relatively stable $\dot{V}_{O_2}$ in the face of a decreased $\dot{V}_E$ and increased V_T and is possibly the result of an increased alveolar - capillary exchange made possible by slower and deeper respirations.

The etiology of the heart-rate difference between the experimental and control groups throughout the experiment is not known. There may have been an element of performance anxiety in the experimental group related to eliciting the relaxation response while exercising. For some this was the first experience with combining exercise and the relaxation response. There was a variation in reported exercise activity among both control and experimental subjects (some jogged regularly, some were sedentary) which may have contributed to heart rate differences. Nevertheless, it has been shown quite clearly that heart rate is not a major perceptual input during exercise (11,13) and should therefore not have influenced the perceptual findings.

The development of a "hypoventilatory" state with exercise while practicing a mental process which produces the relaxation response is an observation which has not been reported previously. The mechanism of mediation of these ventilatory adaptations is not known and may have to await delineation of normal ventilatory mechanisms (6). It does not appear to be a fixed alteration in ventilatory responsivity as implied in studies on sympathetic-nervous-system responsivity and the relaxation

response (7) since the E and C groups did not differ before or after the intervention period. It may be related to cortical "appreciation" of exertion and cortical modulation of the "lower" respiratory centers. For example, low exercise $\dot{V}_E$ and $\dot{V}_E/\dot{V}_{CO_2}$ were found in endurance athletes when compared to non-athletes at equal relative exercise intensities. These differences were thought to be independent of training. It was suggested that the low exercise $\dot{V}_E$ might enhance endurance performance through an influence on the perceived effort of exercise, but the authors did not offer an explanation for how this state is attained. The endurance athlete exhibiting this low exercise ventilation might be spontaneously eliciting the relaxation response. While the benefit(s) of altering perception of the intensity of exertion may assist the endurance athlete, those alterations in ventilatory variables might also help to conserve ventilatory effort during exercise and aid performance. Increased ventilatory effort ($\dot{V}_E/\dot{V}_{O_2}$) during exercise at high altitude has been recently postulated as a dominant and possibly limiting perceptual cue in the effort sense.

Therefore, a wakeful mental activity which produces the relaxation response not only alters ventilatory variables at rest, but now appears associated with ventilatory alterations during exercise of constant low intensity.

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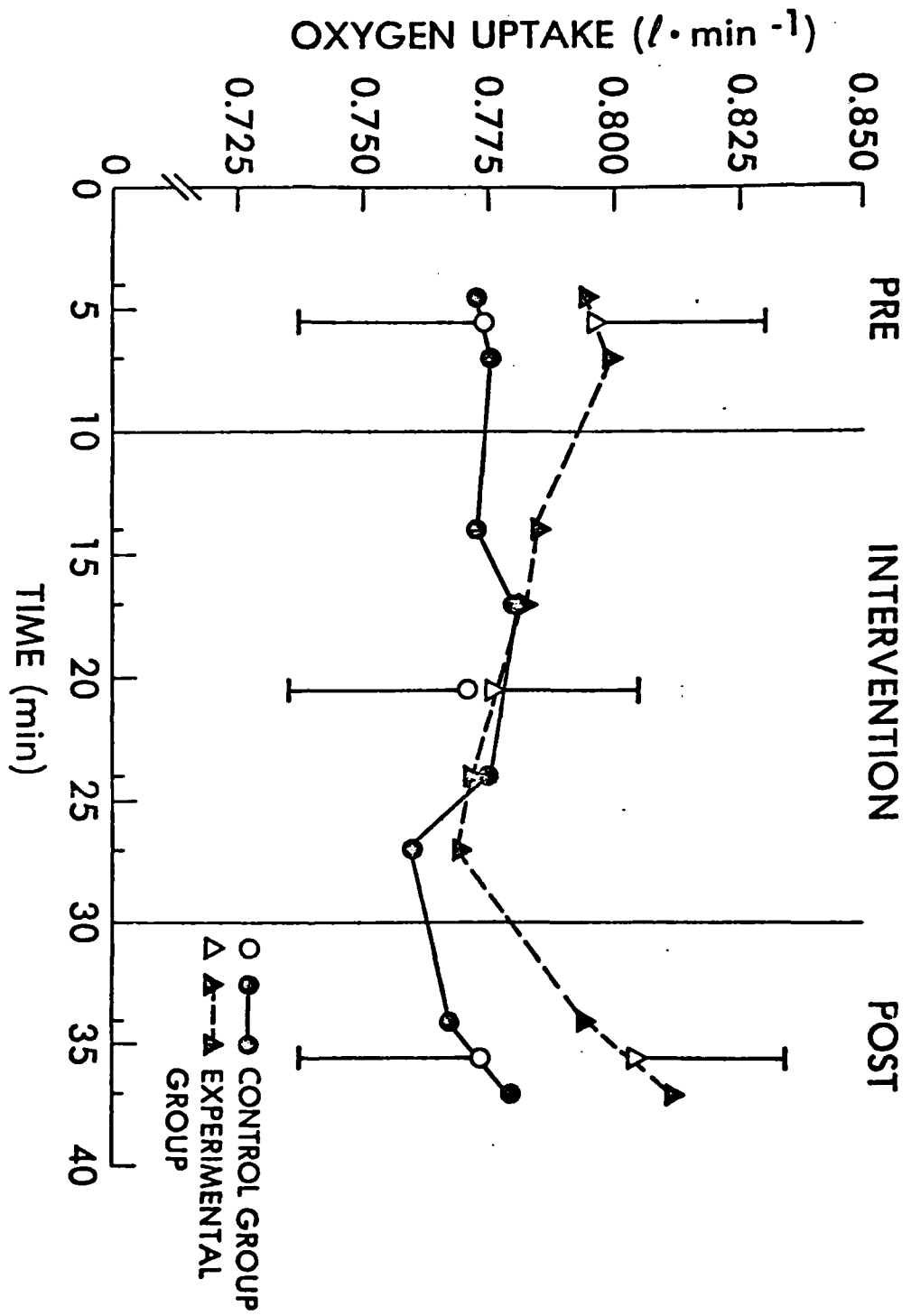
TABLE 1: VENTILATORY RESPONSES DURING EXERCISE WHILE ELICITING THE RELAXATION RESPONSE

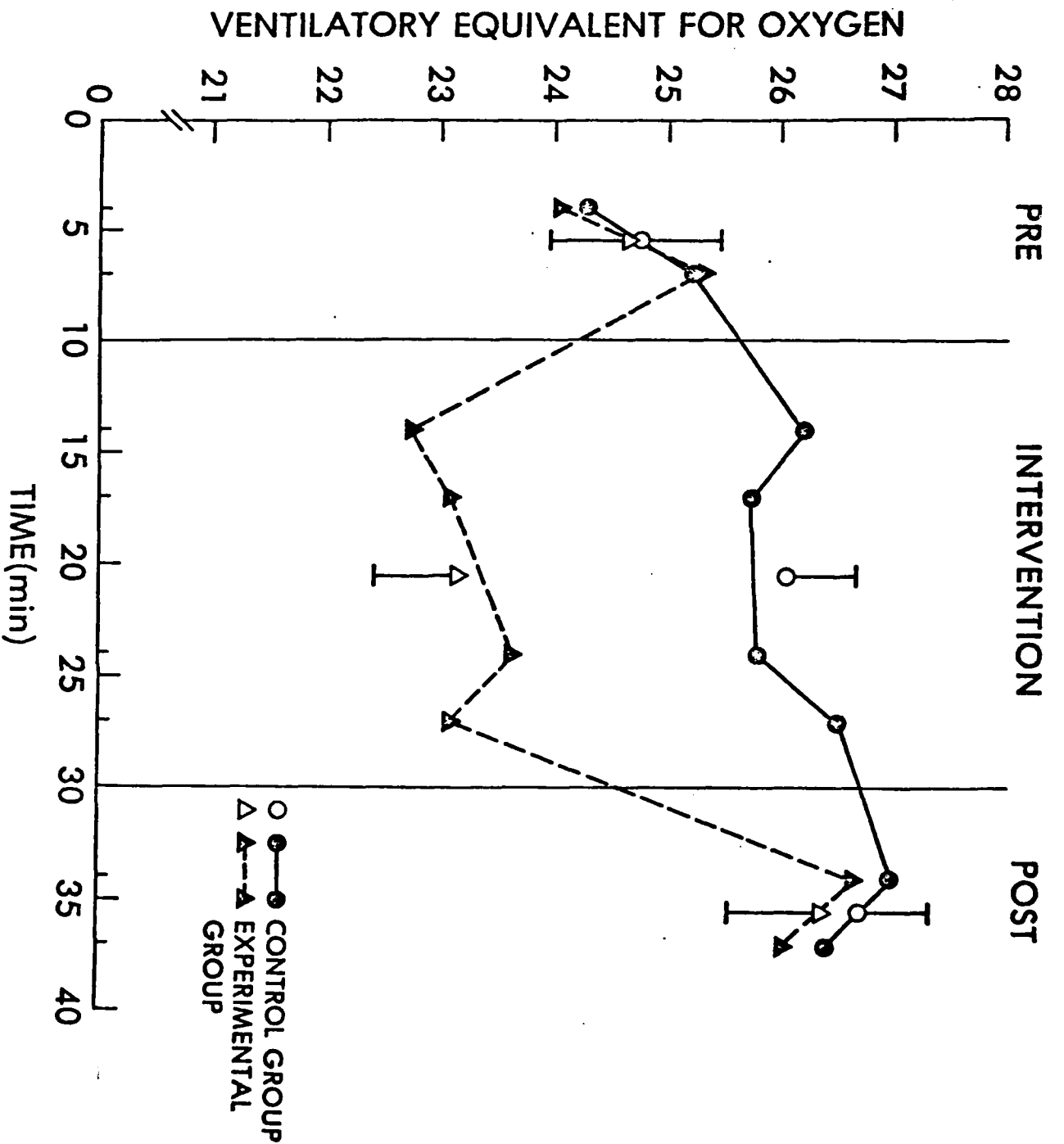
	Pre-intervention		Intervention		Post-intervention	
	Control	Experimental	Control	Experimental	Control	Experimental
Respiratory rate breaths·min ⁻¹	17.0 ± 1.2	17.1 ± 1.3	18.5 ± 1.3	13.6 ± 1.4*	20.0 ± 1.2	19.4 ± 1.5
Tidal volume liters·min ⁻¹	1.188 ± .081	1.209 ± .087	1.150 ± .087	1.491 ± .169*	1.082 ± .081	1.191 ± .129
$\dot{V}_E$ liters·min ⁻¹	19.15 ± 1.12	19.73 ± 1.03	20.17 ± 1.16	17.92 ± 0.79*	20.75 ± 1.23	21.15 ± 0.87
$\dot{V}_E/\dot{V}_{O_2}$	24.74 ± .70	24.68 ± .66	26.06 ± .63	23.16 ± .70*	26.69 ± .65	26.37 ± .79
$\dot{V}_{O_2}$ liters·min ⁻¹	.774 ± .037	.797 ± .032	.772 ± .036	.776 ± .032	.774 ± .037	.804 ± .029
Respiratory Exchange Ratio	.835 ± .012	.848 ± .016	.869 ± .012	.874 ± .012	.863 ± .012	.887 ± .013
Heart rate beats·min ⁻¹	87.7 ± 3.0	99.2 ± 3.4*	91.1 ± 2.5	101.5 ± 4.4*	91.4 ± 2.0	104.3 ± 4.0*
Rated perceived exertion	9.2 ± 0.4	9.6 ± 0.4	10.6 ± 0.4	9.7 ± 0.5	11.1 ± 0.5	11.0 ± 0.5

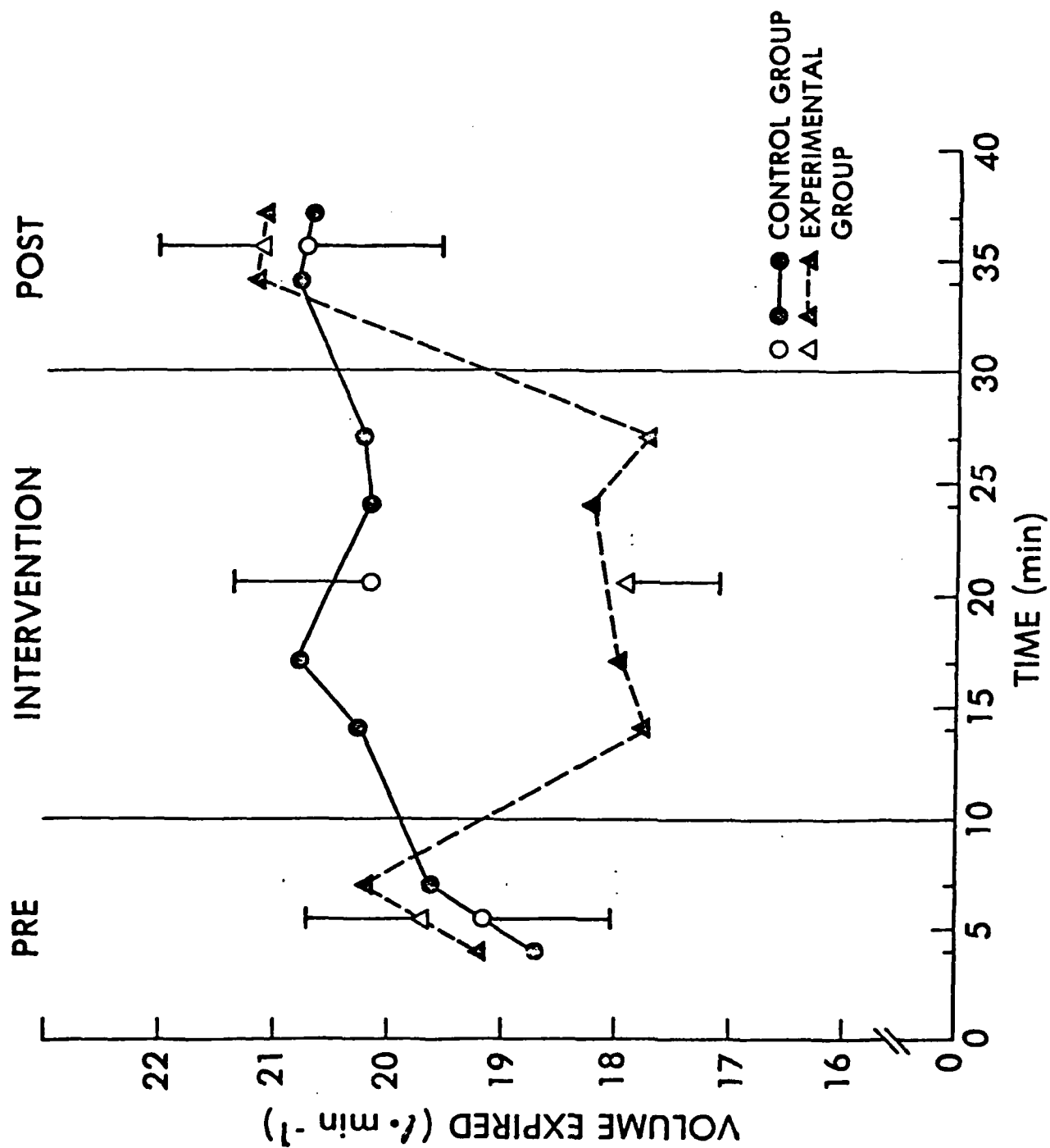
Each result is a mean (±S.E.) obtained during each gas collection period at minutes 3 and 7 (pre-intervention); minutes 13, 17, 23 and 27 (intervention); and minutes 33 and 37 (post-intervention). The results of rated perceived exertion during the intervention period was determined only once at minute 30. An asterisk denotes a significant difference ($p \leq 0.05$) between the experimental and control groups for the particular time period.

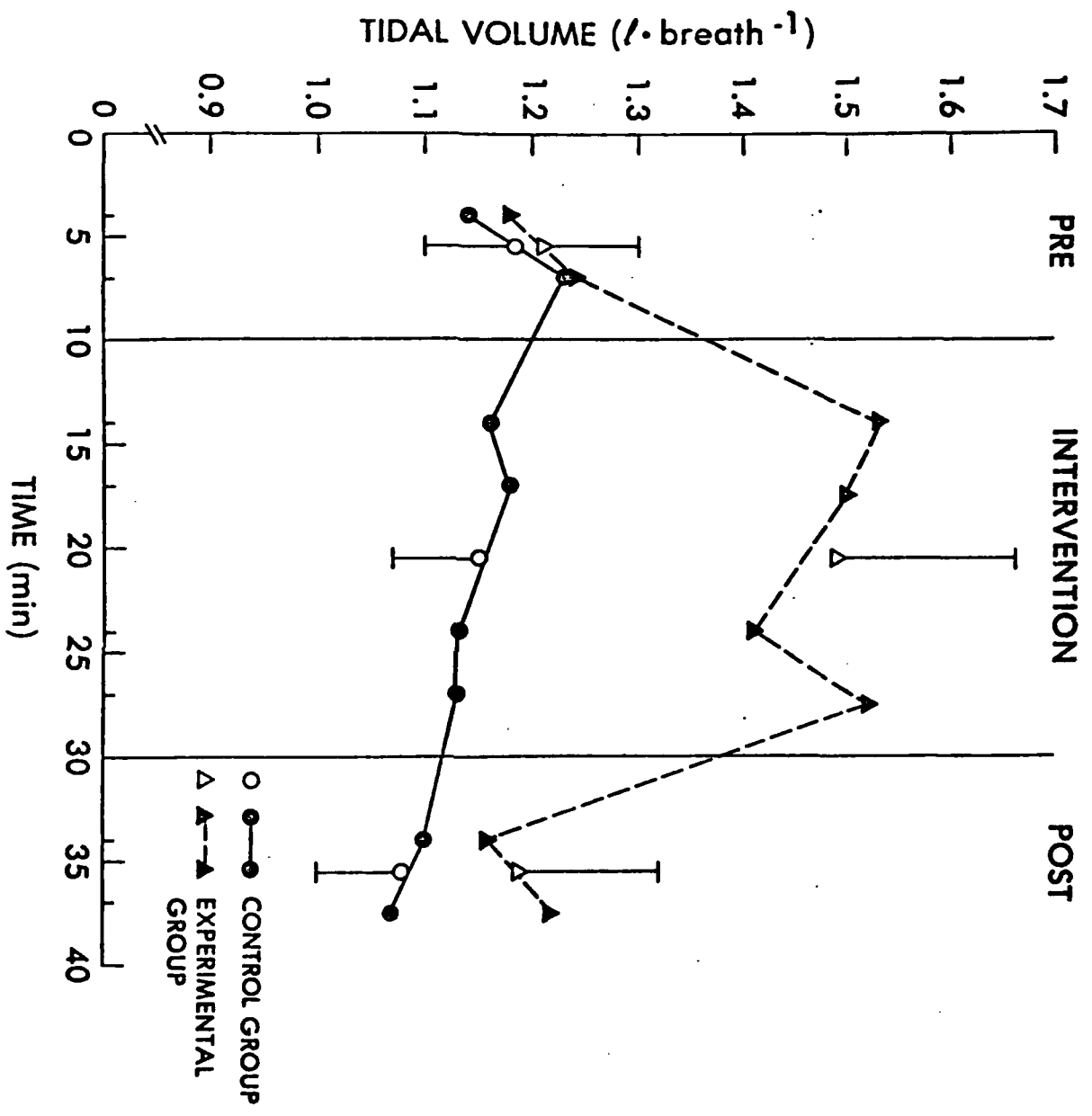
Figure Legends

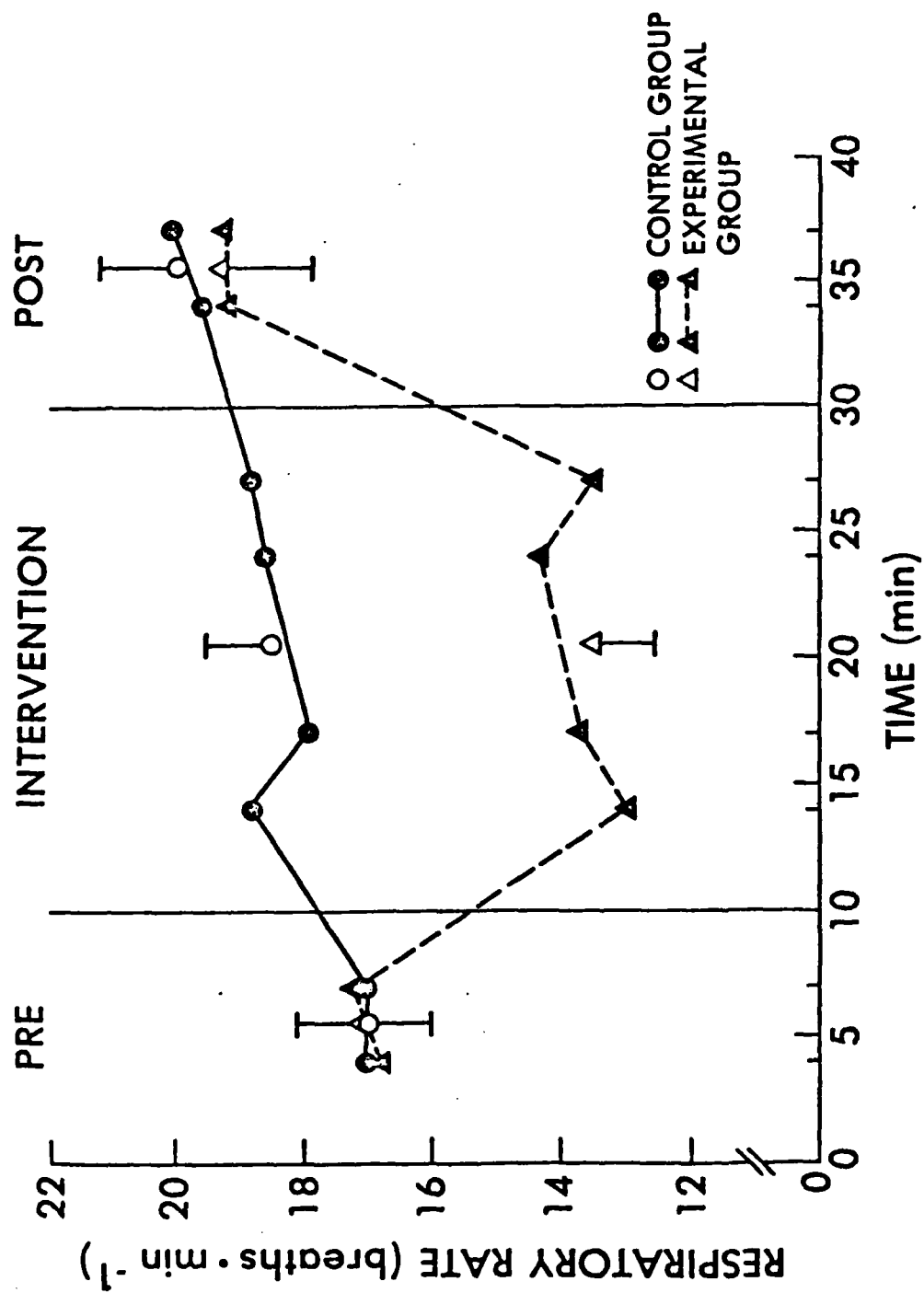
- Figure 1: Changes in respiratory rate (f_T) during exercise between control $\bullet\text{---}\bullet$ and experimental groups $\blacktriangle\text{---}\blacktriangle$. Each point represents the gas collection periods. The open symbols represent mean values.
- Figure 2: Changes in tidal volume (V_T) during exercise between control $\bullet\text{---}\bullet$ and experimental groups $\blacktriangle\text{---}\blacktriangle$. Each point represents the gas collection periods. The open symbols represent mean values.
- Figure 3: Changes in minute ventilation ($\dot{V}_E$) during exercise between control $\bullet\text{---}\bullet$ and experimental groups $\blacktriangle\text{---}\blacktriangle$. Each point represents the gas collection periods. The open symbols represent mean values.
- Figure 4: Changes in ventilatory equivalent for oxygen $\dot{V}_E/\dot{V}_{O_2}$ during exercise between control $\bullet\text{---}\bullet$ and experimental groups $\blacktriangle\text{---}\blacktriangle$. Each point represents the gas collection periods. The open symbols represent mean values.
- Figure 5: Changes in oxygen consumption $\dot{V}_{O_2}$ during exercise between control $\bullet\text{---}\bullet$ and experimental groups $\blacktriangle\text{---}\blacktriangle$. Each point represents the gas collection periods. The open symbols represent mean values.











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E₊ group had regularly elicited the relaxation response for a mean of 5.4 yrs (± 1.4 S.E.). Respiratory rate (breaths $\cdot$ min⁻¹ 18.5C, 13.6E), minute ventilation (liters $\cdot$ min⁻¹ 20.17C, 17.92E), and ventilatory equivalent⁻¹ for oxygen (26.06C, 23.16E) decreased and tidal volume (liters $\cdot$ breath⁻¹ 1.15C, 1.49E) increased significantly ($p < 0.05$) during the relaxation response period in the E group. None of these ventilatory responses differed significantly ($p > 0.05$) between groups either before or after the meditation period. Differences seen in oxygen uptake and the respiratory exchange ratio between groups throughout exercise were not significant while the heart rate response was significantly higher for the E group throughout exercise. Rated perceived exertion significantly increased in the E group between the meditative (9.7) and post-meditative (11.0) period. These changes demonstrate that a voluntary wakeful mental activity that produces the relaxation response may alter ventilatory responses during exercise.

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