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ABSTRACT

This study examined the extent to which 10 minutes of prior exercise (PE) at a workload adjusted to maintain a heart rate (HR) of 140 beats per minute could facilitate the mobilization of the oxygen transport system in a strenuous criterion task (CT). The control treatment involved completion of the CT following 10 minutes of rest on the ergometer. Oxygen uptake was significantly higher following PE at every stage except the second 30-second period of the CT and the 60-second post-CT period. Ventilation was significantly higher following PE at every stage except the last 30 seconds of the CT and the 60-second post-CT period. HR was significantly higher following PE at every stage. Oxygen pulse was significantly higher following PE only during the 30-second pre-CT period and the first 30 seconds of the CT, indicating that the PE facilitated the mobilization of stroke volume (SV) and/or atrioventricular oxygen difference. The similar values for oxygen pulse during the last 90 seconds of the CT indicate that the higher oxygen uptake following PE was a function of higher HR, not higher SV or atrioventricular oxygen difference. (Author/JA)

OXYGEN CONSUMPTION IN THE FIRST STAGES OF

STRENUOUS WORK AS A FUNCTION OF PRIOR EXERCISE

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Abstract

This study examined the extent to which 10 minutes of prior exercise (PE) at a workload adjusted to maintain a heart rate (HR) of 140 bpm could facilitate the mobilization of the O_2 transport system in a strenuous criterion task (CT). The interval between the PE and CT was 30 seconds. The CT required the S to pedal for 2 minutes at a load of 1632 kpm/min. The control treatment involved completion of the CT following 10 minutes of rest on the ergometer. Comparisons between treatments were made during the 30 seconds between PE and CT, for four 30 second periods during the CT and for the 60 seconds following the CT. VO_2 was significantly higher following PE at every stage except the second 30 second period of the CT and the 60 second post-CT period. Ventilation was significantly higher following PE at every stage except the last 30 seconds of the CT and the 60 second post-CT period. HR was significantly higher following PE at every stage. And O_2 pulse was significantly higher following PE only during the 30 second pre-CT period and the first 30 seconds of the CT, indicating that the PE facilitated the mobilization of stroke volume (SV) and/or A-V O_2 difference. The similar values for O_2 pulse during the last 90 seconds of the CT indicate that the higher VO_2 following PE was a function of higher HR, not higher SV or A-V O_2 difference.

At the outset of strenuous exercise, there is often a metabolic demand for O_2 which is greater than the circulorespiratory system can immediately supply. This oxygen deficit results in the utilization of anaerobic reserves to meet the energy demand of the task. If the event requires total utilization of the anaerobic reserves, as would any event longer than 60 seconds in duration (1, p. 19), the amount of these reserves depleted in meeting the initial O_2 deficit might reduce the amount available for the rest of the event. Thus, if an individual mobilizes the circulorespiratory system prior to the event, reducing the initial time lag and O_2 deficit, he might improve his performance in tasks which exhaust the anaerobic capacity. Support for this line of reasoning was produced by Di Prampero, et al. (6), who found that the adjustments in O_2 uptake demanded by heavy exercise were faster when the heavy exercise was preceded by light exercise rather than rest, with no time elapsing between the light and heavy exercise. Starting from light exercise also resulted in a lower lactic acid concentration in the blood following the heavy exercise.

Since in competitive situations it is often not practicable to progress from light to heavy exercise without any interval between the two, this study examined the effect of prior exercise (PE) on the time course of O_2 adjustment to heavy exercise when 30 seconds elapsed between the PE and the heavy work.

Method

Subjects

The subjects were six male volunteers ranging in age from 22 to 45 with a mean of 30. Their weights ranged from 71 to 86 kg. with a mean of 78.

Apparatus and Tests

Both the PE and criterion task (CT) were performed on a Monark bicycle ergometer. The pace of pedaling was guided by an electronic metronome. A micro-switch was mounted so it would be tripped with each pedal revolution and the revolutions were counted on an electromagnetic counter.

Heart rate (HR) was obtained by counting all ECG R waves within a 30 second period and converting to bpm. The ECG was transmitted by radiotelemetry (Radiokardiogram 100 receiver), using a V5 lead, recorded on a Sanborn 100 Visc Cardiette and displayed on an oscilloscope (Electronics for Medicine).

Expired air was collected in 60 liter Douglas bags as subjects breathed through a low resistance Otis-McKerrow valve. Air samples were analyzed through a Beckman, model E2 O_2 Analyzer and a Godart O_2-CO_2 meter. Expired volume was measured by vacuum evacuation of the bags through an American gas meter and corrected to STPD.

All testing was conducted in a climate-controlled chamber at a temperature of 71 ± 2 degrees F and a relative humidity of 62 ± 1 per cent. Due to an electrical failure in the chamber on one day, the temperature was 75 degrees F and the humidity unknown for one subject under the mobilized condition.

The criterion task (CT) involved pedaling for two minutes at a load of 1632 kpm/min. (68 rpm and 4 kg resistance). Pilot work indicated that this would be a very heavy load for these subjects with the consequence that they might not be able to maintain the pace for the full two minutes. In that case, they were to keep going as fast as they could. The idea was to require a constant workload at the beginning so that differences in VO_2 could be attributed to the PE.

Design

The independent variable was presence or absence of PE. Each subject was tested both with and without PE on different days, with the order of the treatments counterbalanced.

The dependent variables were VO_2, HR, ventilation (Ve), Ve equivalent and O_2 pulse. These parameters were measured for the 30 second period between the PE and the CT, each 30 second period of the two minute CT, and for 1 minute following the CT.

Procedure

The subject reported to the laboratory in shorts and gym shoes, the electrodes were attached, the bicycle seat height was adjusted and he breathed through the gas collection system for several minutes to become familiarized with it.

The PE consisted of ten minutes of pedaling at 60 rpm with the resistance constantly adjusted to maintain the HR at 140 bpm, a value that is indicative of a VO_2 approximately 50-60 per cent of maximal (1, p. 165). Very little lactate accumulation would be expected during exercise at this intensity (9). The no PE treatment consisted of sitting quietly on the ergometer for ten minutes.

When two minutes remained in the PE or rest period, the subject began to breathe through the gas collection system and continued to do so throughout the rest of the protocol.

After the PE, the subject rested on the ergometer for 30 seconds and was then given a go signal to begin the CT. Gas was collected in 30 second periods during the rest interval and CT and a one minute bag was collected after the CT. HR was counted over the same stages and all measures were converted to minute values.

Results

A technical error in the gas collection procedure resulted in missing values for VO_2, Ve and O_2 pulse for one subject during stage 4 under the PE treatment. The missing values were estimated by the method described by Cox (4, p. 30) before proceeding with the analyses. A-tests for paired comparison and the .05 level were used in determining the significance of mean differences.

Figure 1 shows the stage by stage changes in VO_2 under the two PE conditions. VO_2 was significantly higher under the PE condition at every stage except the second 30 second period of the CT and the 60 second recovery period. Therefore, a clear cut mobilization effect was displayed as a result of the PE. Furthermore, the significant difference between the treatments during the last stages of the CT indicates that the VO_2 when starting cold did not fully catch up even after 90 seconds of exercise. Since the work done under the two conditions was almost identical (the mean difference was one revolution), more of the anaerobic reserves must have been utilized when starting in the cold condition. An estimate of the extent to which the PE reduced the initial O_2 deficit was made by assuming that the task was maximal or supramaximal and that after the PE, the subjects were approaching maximum VO_2 values toward the end of the CT. Astrand and Saltin (2) have shown that a supramaximal load can elicit close to maximum levels of VO_2 in two minutes. Then the peak value was extended back to the start of the CT and the O_2 deficits under the two conditions calculated and compared. When this was done, the O_2 deficit was 30.60 ml/kg after PE and 56.87 ml/kg without PE, a difference of 26.27 ml/kg. Thus, the O_2 deficit was 86 per cent higher when starting cold than when starting partially mobilized. Of course, since no clear-cut plateau in VO_2 was attained, these O_2 deficits are merely rough estimates.

Figure 2 shows Ve under the two conditions. The analysis revealed that Ve was significantly higher following PE at every stage of the CT except the last 30 seconds and the 60 second post-exercise period.

Figure 3 shows the stage by stage changes in HR under the two conditions. A very similar pattern to that seen for VO_2 and Ve is apparent with the exception that the HR under the PE condition was significantly higher at every stage of the CT as well as during the one minute post-exercise period.

The nature of the mobilization effect was examined further by analysis of the O_2 pulse as shown in Figure 4. Only during the 30 second rest interval and the first 30 seconds of the CT were the differences significant. The higher O_2 pulse at the first stage of the CT implies that HR did not completely account for the mobilization effect of the PE. Some contribution must be attributed to stroke volume (SV) and/or the A-V O_2 difference. Since SV ordinarily approaches maximum in bicycle exercise at a HR of 110-120 bpm (1, p. 164), it is likely that after PE the subjects were working at close to maximum SV at the very beginning of the CT. On the other hand, when starting cold, the HR over the entire first 30 seconds of the CT was 129 bpm. Since it was rising rapidly during this period, it is likely that for part of the period, the SV had not approached maximal values, thereby accounting to some extent for the lower O_2 pulse. It is not possible from this study to determine the extent to which shunting of blood and other factors which might contribute to an increase in A-V O_2 difference were involved in the mobilization effect. In any case, the fact that O_2 pulse was similar under the two conditions during the last three stages of the CT indicates that the contribution of SV and A-V O_2 difference was lost after the first 30 seconds of the CT. From then on, the higher VO_2 under the PE condition was related to the higher HR.

The Ve equivalents under the two conditions were significantly different only during the 30 seconds immediately prior to the CT. Since it was higher in the no PE condition, it appears that there was a pre-exercise anticipatory increase in Ve without a commensurate increase in VO_2. The similar Ve equivalents throughout the CT imply that the PE had no clear-cut effect on the efficiency of respiration.

Discussion

The results of this study agree with those of a recent study by Hermiston and O'Brien (8), who used a one minute rest interval between the PE and CT. The results also support the practices of those who utilize PE to shorten the adjustment period to exercise (2, 5, 7). For example, Astrand and Saltin (2) found that after ten minutes of PE at approximately 50 per cent of max VO_2, subjects could reach peak VO_2 in approximately two minutes of very heavy work. In this study, the VO_2 during the last 30 seconds of the CT was not significantly higher than that during the third stage of the CT in either the PE or no PE condition. This leveling does imply that peak values were being approached. The fact that PE is clearly capable of reducing the initial O_2 deficit would explain the results of Sucec (10), who found that a ten minute period of PE, followed by a 30 second rest period before the CT, improved performance on a ten minute endurance event.

Since O_2 pulse under the two conditions was very similar during the latter stages of the CT, it appears that this higher peak VO_2 was a result of higher HR rather than greater SV or A-V O_2 difference. The fact that O_2 pulse was similar after only 30 seconds of the CT also weakens the hypothesis that the core temperature increases elicited by the kind of PE used in this study (approximately .2 degrees F, unpublished data) can markedly increase the speed and amount of O_2 dissociation from hemoglobin (3). For if this were so, then the A-V O_2 difference and, as a result, the O_2 pulse would have been greater in the PE condition throughout the CT.

In summary, ten minutes of PE at a HR of approximately 140 bpm followed after 30 seconds rest by a two minute heavy work task produced a mobilization effect which reduced the initial O_2 deficit and enabled the subjects to achieve a higher peak VO_2. During the first stage of the task, the higher VO_2 was a result of a higher HR as well as a greater SV and/or A-V O_2 difference. The greater peak VO_2 was related to the higher maximum HR elicited following PE.

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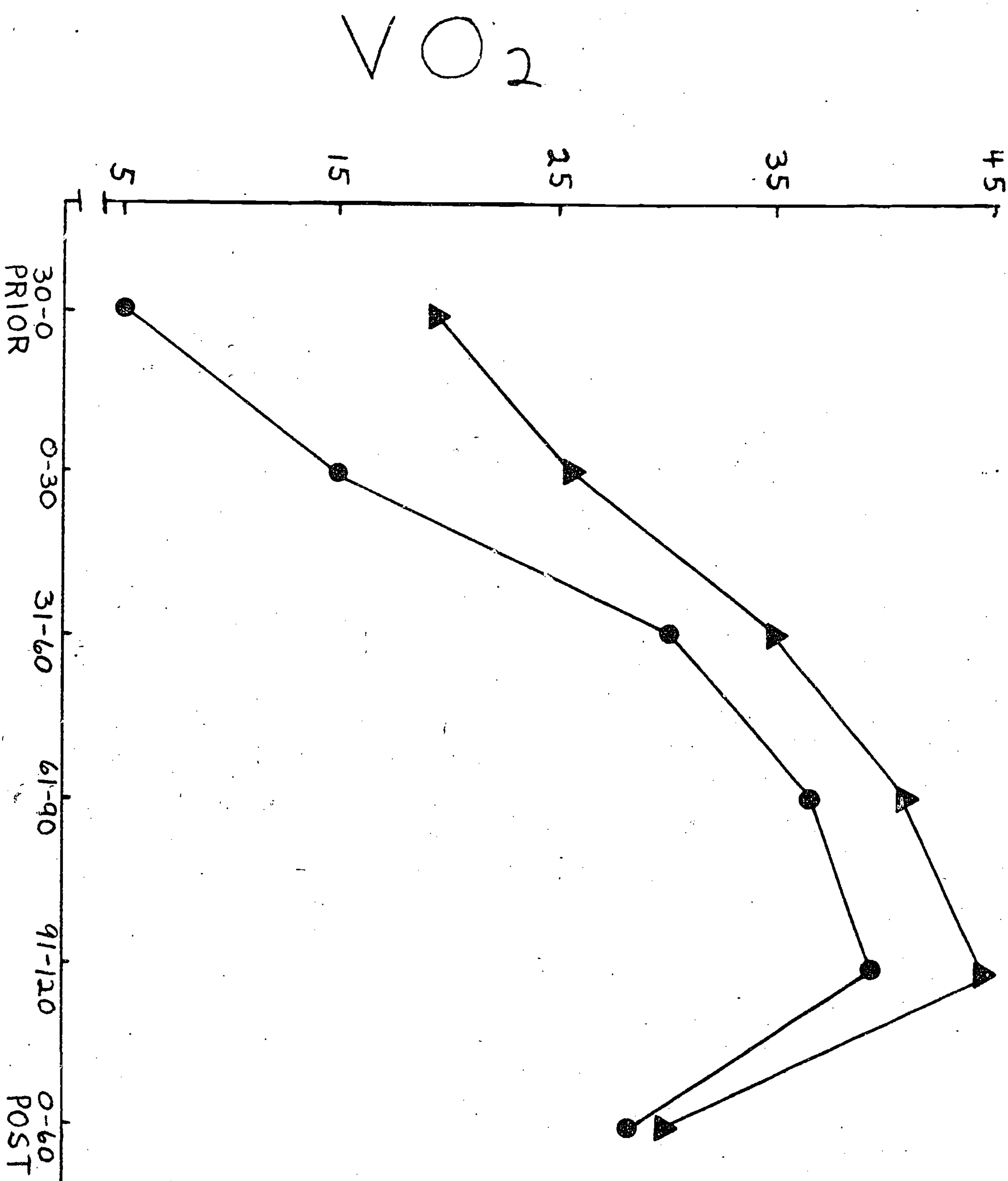

Figure 1.
VO2 (ml/kg/min) over the different stages of the experimental protocol (30 seconds prior to the CT, each 30 seconds of the CT, and 60 seconds following the CT). Triangles represent values following PE and circles denote values without PE.

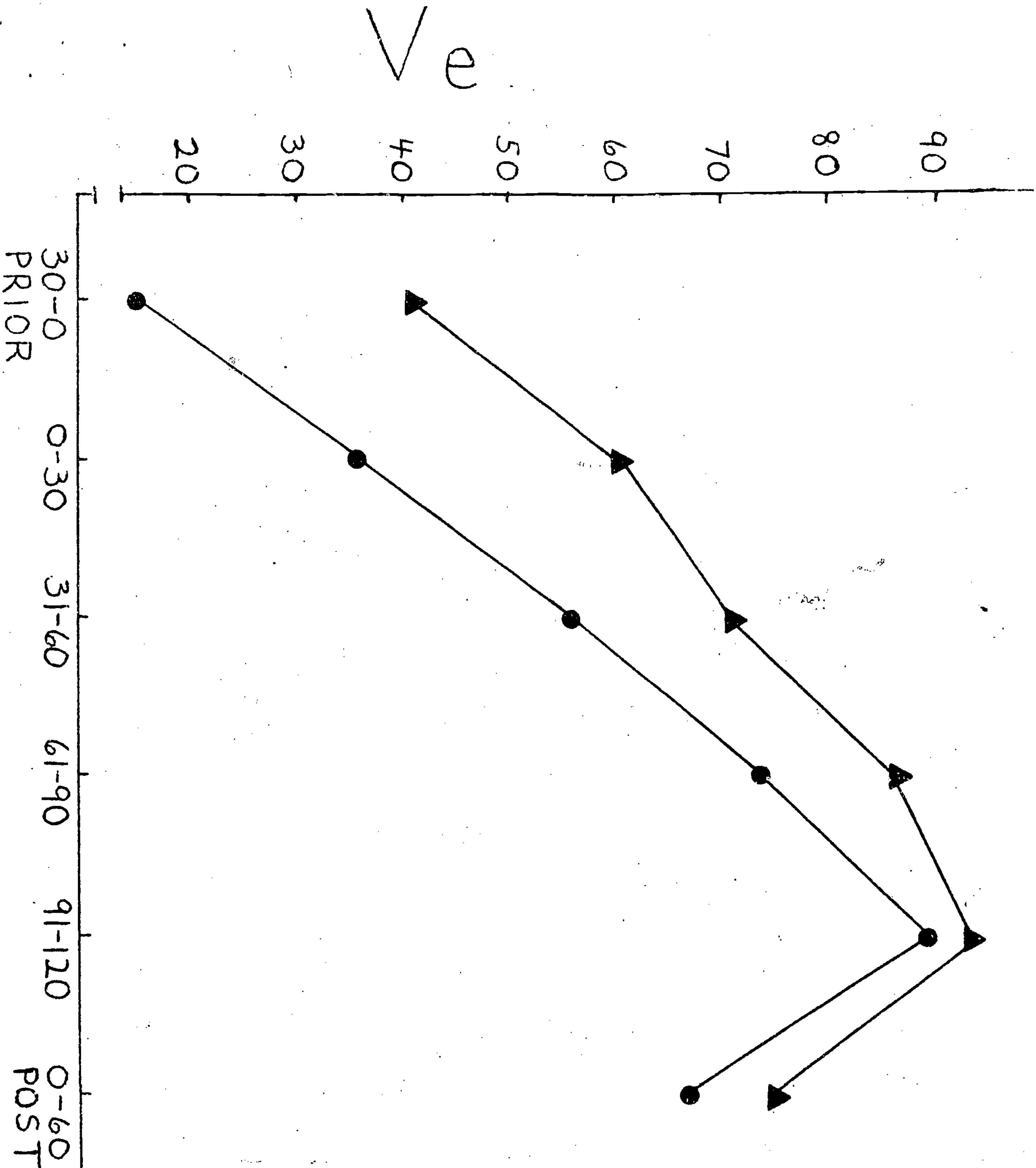

Figure 2.
Ve (l/min) over the stages of the experimental protocol. Legend is the same as in Figure 1.

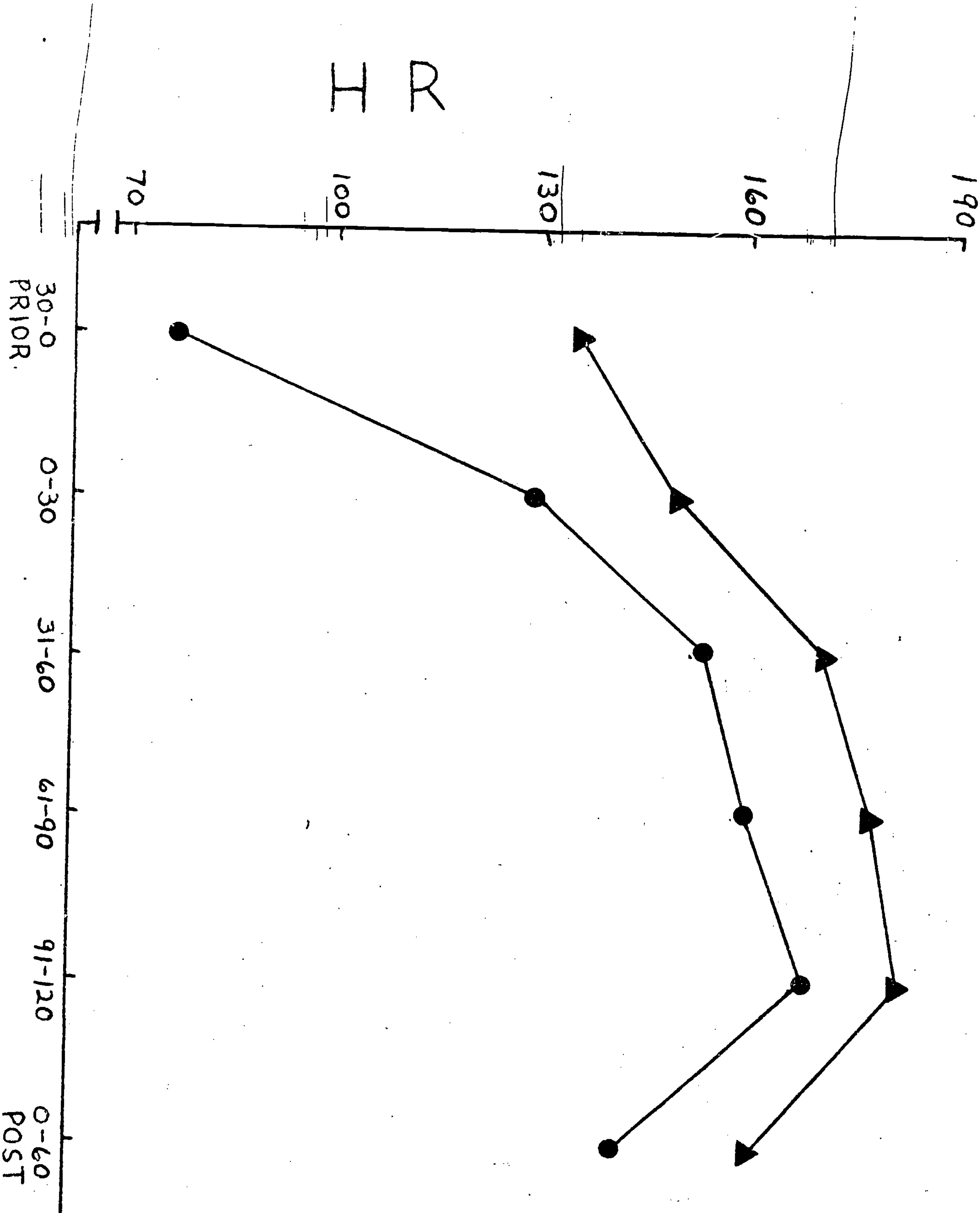

Figure 3.
HR (bpm) over the stages of the experimental protocol.
Legend is the same as in Figure 1.

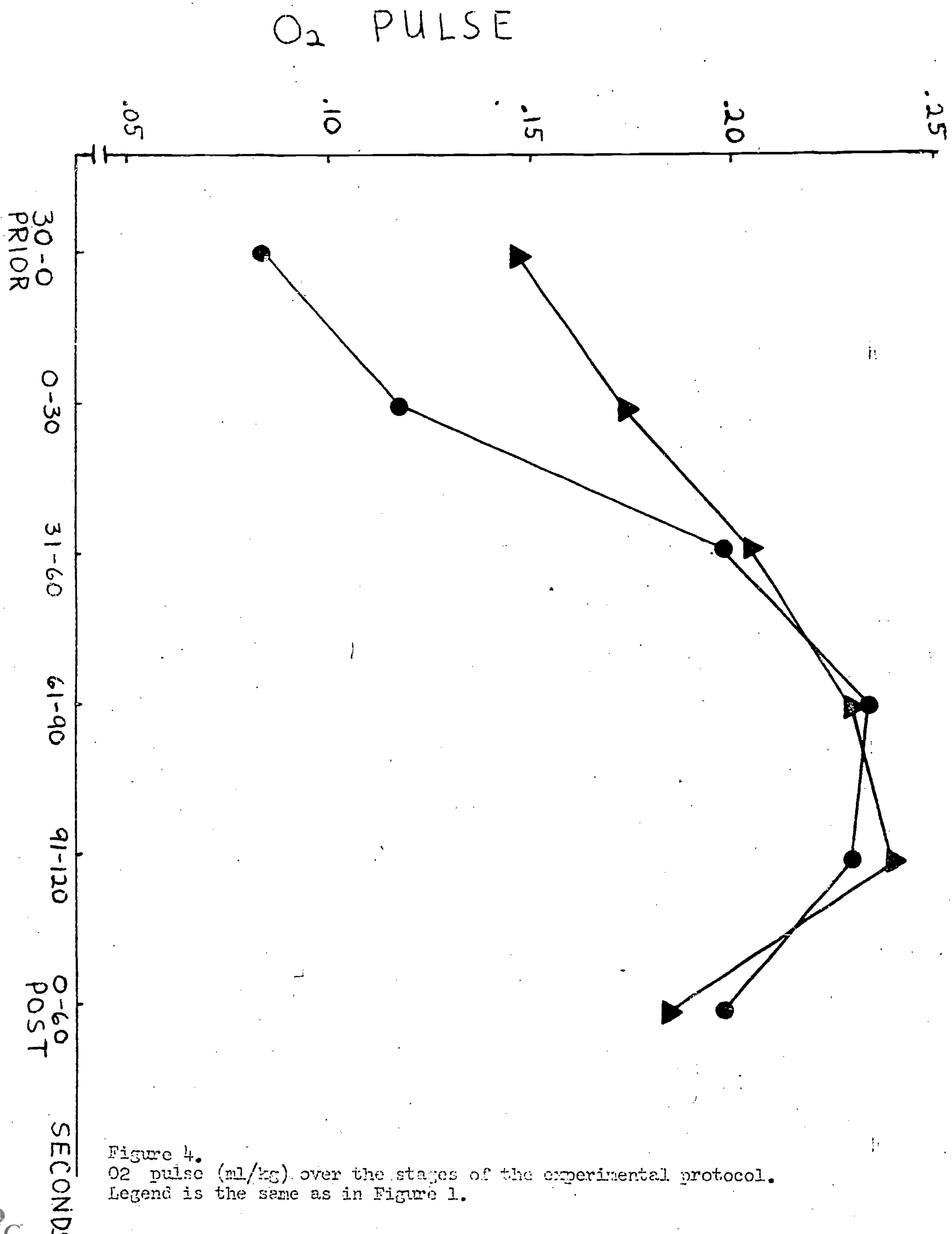

Figure 4.
02 pulse (ml/kg) over the stages of the experimental protocol.
Legend is the same as in Figure 1.