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OXYGEN CONSUMPTION, HEART RATE AND THE ELECTROCARDIOGRAM OF PIGS DURING EXERTION

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Summary

Pigs were exercised for 5 minutes at five different treadmill speeds (1.0 - 1.8 m·sec⁻¹) (3° incline), while oxygen consumption ($\dot{M}O_2$), carbon dioxide production ($\dot{M}CO_2$), and the electrocardiogram (ECG) were continuously recorded. Data were taken at rest, during exercise, and at 2, 5, 15, and 30 minutes after exercise. $\dot{M}O_2$, $\dot{M}CO_2$, and heart rate (HR) showed progressive increases with increasing treadmill speed. The respiratory exchange ratio (R) increased during exercise and approached 1.0, but peak values were seen shortly after exercise. A high correlation between HR and $\dot{M}O_2$ was found in these animals. Prominent increases in T-wave amplitude of the ECG were associated with exercise and early recovery.

Introduction

Stress results in endocrine and physiological changes. Since the pig is very "stress susceptible", it may be more susceptible to disease. In the present investigation, our objective was to determine the effects of exercise stress on physiological function. Using techniques to continuously measure oxygen consumption ($\dot{M}O_2$), carbon dioxide production ($\dot{M}CO_2$), along with the electrocardiogram (ECG) in intact, running pigs, we examined dynamic changes that occur in these variables in association with exercise. These include changes in both $\dot{M}O_2$ and $\dot{M}CO_2$ during exercise, the time required to reach a steady-state during running exercise, the time course for recovery from exercise, and basic electrocardiographic changes associated with exercise. In addition, we determined the relationship between heart rate (HR) and $\dot{M}O_2$ in domestic pigs.

Experimental Procedure

Four white, crossbred, female pigs (3-5 months old) with a body mass of 47.1 ± 7.9 kg (mean $\pm$ SD) were used. Animals were housed in indoor stalls and fed a 14% protein commercial diet. $\dot{M}O_2$ and $\dot{M}CO_2$ were measured using an open flow method. External electrodes were placed on the frontal bone of the head, the left hip, and the right shoulder for electrocardiographic recordings on a Brush recorder. The electrocardiogram (ECG) was used to calculate HR.

Results and Discussion

Average resting $\dot{M}O_2$ and $\dot{M}CO_2$ in pigs lying on the treadmill were 0.34 ± 0.03 and 0.27 ± 0.04 mmol·min⁻¹·kg⁻¹, respectively. Oxygen uptake increased significantly during exercise and reached a steady-state 2 minutes after exercise.

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began. The highest $\dot{M}O_2$ we obtained in running pigs was $2.39 \text{ mmol} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ or $53.5 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$. Rates of $\dot{M}O_2$ during exercise continually increased with progressively higher treadmill speeds, and at all speeds reached a steady-state value by 2 minutes of exercise. $\dot{M}O_2$ returned to pre-exercise levels by 15 minutes post-exercise.

Like $\dot{M}O_2$, HR increased after the onset of exercise, reaching a steady-state within 2 minutes. Data from our tests indicate maximum HR to be about $280 \text{ beats} \cdot \text{min}^{-1}$ for our pigs. Thus, the range of exercise levels used in this study produced HR values from about 65% up to 100% of maximum. Heart rate returned to resting levels by 15 minutes post-exercise at all but the highest running speed, where complete recovery did not occur until 30 minutes post-exercise. A linear relationship between HR and $\dot{M}O_2$ was observed in the pigs and a high correlation between these variables was evident.

Alterations in the ECG pattern were consistently observed during and immediately after exercise. A large increase in T-wave amplitude began during exercise, but was most prominent shortly after exercise.

The electrocardiographic changes following exercise, involving large increases in T-wave amplitude, suggest that the exercising pig becomes hyperkalemic. Other investigators have measured blood potassium levels in exercising miniswine and found them to increase significantly. Interpretation of our ECG data further indicate that blood potassium levels may be changing rapidly shortly after exercise.

The present study describes the response to exercise and the time course for recovery from exercise in pigs. These animals are capable of reaching a steady-state, at least with respect to $\dot{M}O_2$, $\dot{M}CO_2$, and HR, within 2 minutes after the onset of exercise. A strong correlation between $\dot{M}O_2$ and HR during exercise, as well as significant alterations in the ECG, were observed.