ENERGY EXPENDITURE IN HORSES DURING SUBMAXIMAL EXERCISE

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Introduction

The horse is unique among domestic species in that its main productive function is work. This work may take many forms and can account for a large proportion of the horse's total energy expenditure. In spite of this, energy requirements for exercise in the horse are poorly defined. Other than the classic studies of Zuntz and Hagemann (1898) and Brody (1945) little has been done to quantify energy expenditures in the horse during work. Most recent studies have been feed and weight type trials using fairly subjective measures of exercise intensity (Hintz et al, 1971) or unnatural exercise environments such as inclined treadmills (Anderson et al, 1983). These types of experiments are subject to large error and are of limited usefulness under practical conditions. Therefore, the following experiment was conducted to measure the amount of energy expended by horses traveling at speeds up to 400 m/min. on a racetrack both with and without a rider, and to attempt to use these data to formulate a reasonable set of feeding standards for horses performing submaximal exercise.

Materials and Methods

The energy expenditure of horses during submaximal exercise was measured using a mobile modified open circuit indirect respiration calorimeter (figure 1). A total of 304 five-minute measurements were made on four geldings ranging in weight from 433 kg to 520 kg. Each horse's oxygen consumption and carbon dioxide production was measured at rest and over a range of speeds from 40 m/min. to 400 m/min. on an 800 meter oval track. The measurements were made on the horses both with and without a rider. The weight of the rider plus tack averaged 59 kg.

During a measurement the expired gas from the horse was collected using the face-mask shown in figure 2. This mask was held on the horse's head with a leather strap with velcro fasteners. An airtight seal was formed between the mask and the horse's muzzle with inflated blood pressure cuffs. The mask contained two one-way intake valves (V1 and V2) and one one-way outlet valve (V3). Outside air was drawn through the mask with a vacuum pump (figure 1) and all expired gases were directed through a four inch flexible hose into the calorimeter as indicated by the arrows in figures 1 and 2. A continuous aliquot of the gas passing through the calorimeter was collected and stored for analysis of oxygen and carbon dioxide concentration. The total volume of gas passing through the calorimeter was also measured along with its temperature and relative humidity. The gas volume was adjusted to standard temperature and pressure of dry gas, and multiplied by the change in composition of the collected gas from that of inspired (outside) air to obtain the amount of oxygen consumed and carbon dioxide produced during a measurement. Energy expended was calculated by multiplying the number of liters of oxygen consumed during a measurement by the oxygen's thermal equivalent (kcal/liter) at the respiratory quotient (RQ) calculated for each measurement (Brody, 1945).

The calorimeter was carried on a wagon pulled by a tractor. Electricity to power the pumps and clock on the calorimeter was supplied by a portable gasoline generator also carried on the wagon. The horse being measured walked or ran alongside the wagon attached to the calorimeter by an eight foot flexibile hose connected to the face-mask. During each trial the horse wearing the facemask was lead by another horse and rider to insure that it maintained a constant speed. The horse and wagon were brought to the speed to be measured in a particular trial about one minute before the five minute measurement period began. Total distance traveled during the five minutes was measured with an electronic bicycle odometer and this distance was used to calculate speed.

Results and Discussion

The results of measurements made on a 433 kg Quarter Horse gelding both with and without a rider are shown in figure 3. More energy was expended by the horse when carrying a rider than when unweighted. This was the case in all the horses measured. The amount of energy expended by the horses was related to speed and also appeared to be proportional to the body weight of the animal or the combined weight of the horse plus the rider. In other words, a 450 kg horse carrying a 50 kg rider would expend about the same amount of energy as a 500 kg horse carrying no weight. This agrees with work done by Taylor et al (1980) in rats, dogs, humans, and ponies in which oxygen consumption during exercise was found to increase in direct proportion to mass supported by the muscles.

In all horses measured the relationship between energy expended and speed (either with or without a rider) was best described by an exponential function. Figure 4 contains the results of all measurements made on the four horses. Energy expenditure measurements made without riders were divided by the horse's body weight, while those taken with riders were divided by the weight of the horse plus the rider. These data are best described by the equation $Y = e^{3.20 + .0065X}$ in which Y equals energy expended (cal/kg/min) and x equals speed (meters/min).

The efficiency of utilization of digestible or metabolizable energy by the horse for work must be known before feed energy requirements can be calculated. If the assumption can be made that fat is the primary substrate for energy generation in horses during low intensity work, then efficiencies of utilization of DE or ME for fat production can be used. Respiratory quotients measured in this experiment indicate that fat is indeed the major substrate for energy generation at slow speeds.

We have measured the efficiency of utilization of ME and DE for fattening in horses fed a 75% alfalfa-25% oat diet (Pagan and Hintz, 1985). These efficiencies were 60% and 55% respectively. Hoffman et al (1967) reported values of 66% and 59% for fat production from ME and DE in diets consisting of 60% meadow hay, 20% oats, 10% wheat bran and 10% flaxseed meal. It therefore appears that a value of between 55% and 60% can be used for the efficiency of utilization of digestible energy (DE) for submaximal work. These values can be used along with the equation from figure 4 to calculate the amount of digestible energy needed by a horse for submaximal work. This quantity can then be added to the amount of energy required by the horse when idle (the maintenance requirement) to obtain the overall digestible energy requirement. For example, a 450 kg horse with a 50 kg rider being ridden four hours per day at a medium trot (250 m/min) would be expected to expend 14.95 Mcal of net energy during exercise. If the efficiency of utilization of digestible energy (DE) for work is 58%, then this amount of work would require an intake of about 25.8 Mcal DE. The horse's maintenance energy requirement for the remaining twenty hours of the day can be calculated from the equation DE (kcal/day) = 856 + 22.04 (BW) and amounts to about 9 Mcal DE (Pagan and Hintz, 1985). The total DE requirement of this horse would therefore be 34.8 Mcal DE per day. With this method of calculation adjustments can be made to account for variation in feed quality, rider weight and maintenance energy requirement. This results in a much more flexible means of calculating energy requirements for work than is currently used by the NRC (1978).

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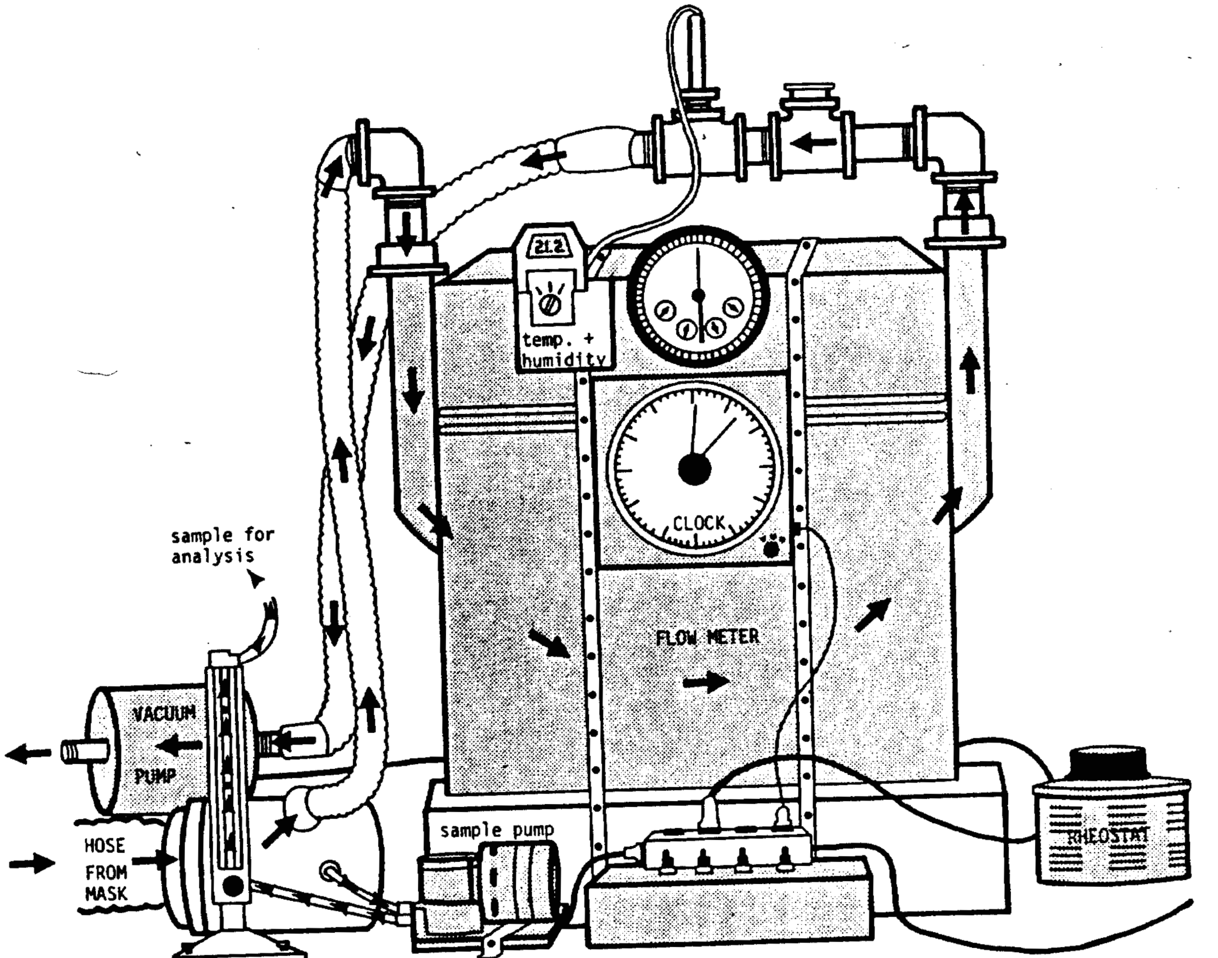

Figure 1. Modified open circuit indirect respiration calorimeter.

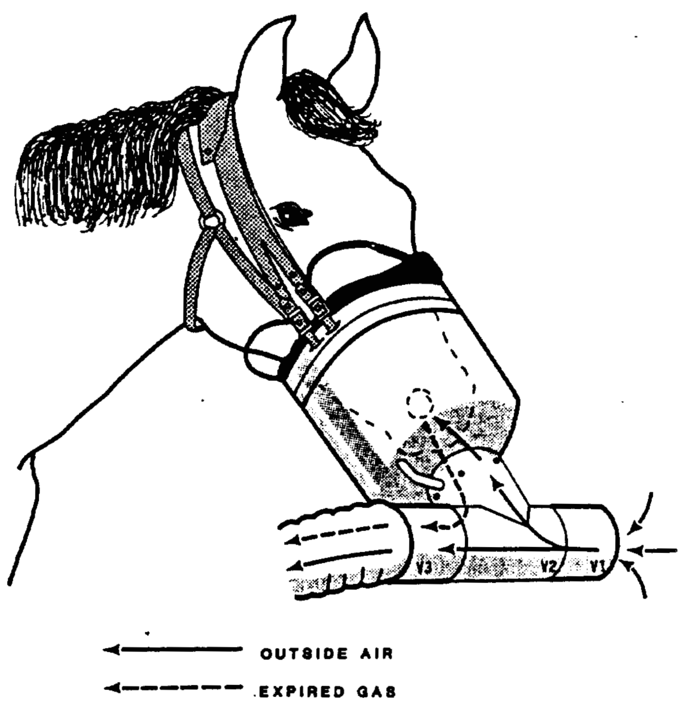

Figure 2. Face-mask used with respiration calorimeter.

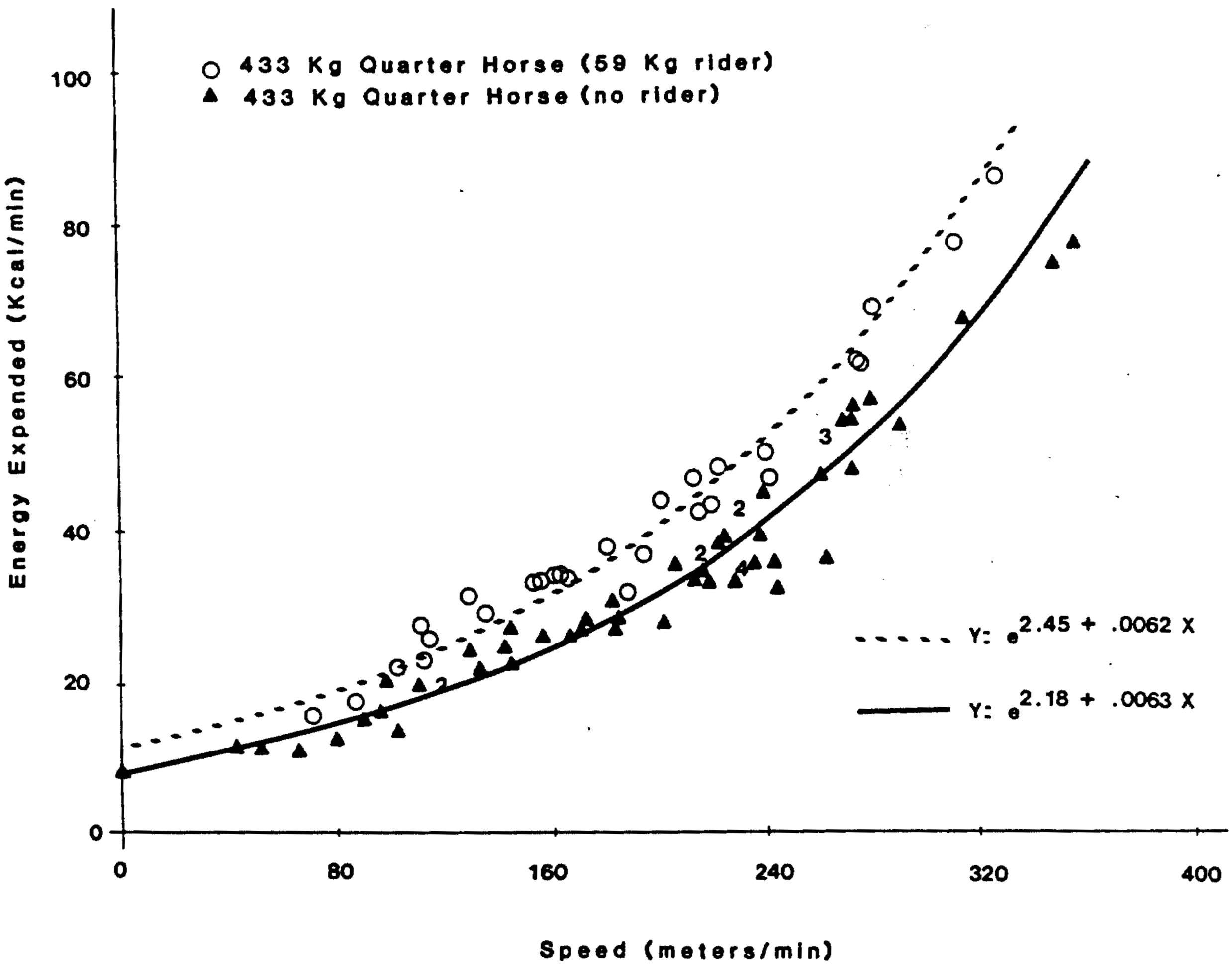

Figure 3. Energy expenditure in a 433 kg Quarter Horse gelding. 59 observations without a rider and 28 observations with a rider. Numbers represent more than one observation without a rider falling on the same location on the graph.

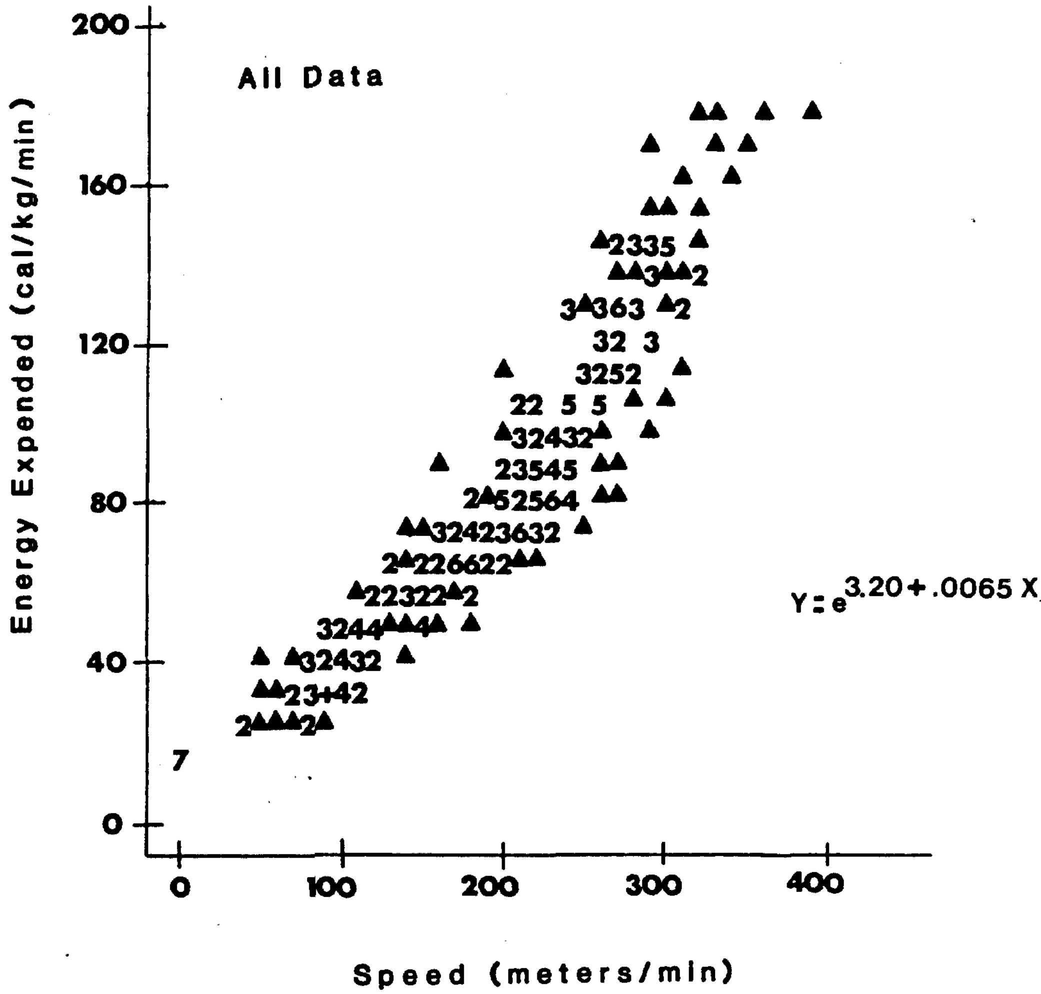

Figure 4. 304 energy expenditure measurements from four horses weighing 433 kg, 490 kg, 506 kg, and 520 kg. Each observation is from a five minute measurement. The measurements were made on the horses both with and without riders. Measurements without riders were divided by the horse's body weight, while those taken with riders were divided by the horse's plus the rider's weight. Numbers represent the number of observations falling on the same location on the graph. (+) represents more than 9 observations in the same location.