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Modelling the oxygen cost of transport in competitions over ground of variable slope

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Summary

This study provides an objective method for estimating the oxygen consumption of horses while running on variable slopes so that realistic comparisons may be made of the locomotory transport cost involved in 3-day events, particularly the Speed and Endurance Test, at sites of differing terrain. A knowledge of the work profile over a particular course would enable competitors to plan speed and interval times appropriately along its length. We have developed a semi-empirical, but mechanistically based, model to calculate the oxygen cost of transport [COT_{path} in ml O_2/kg/m path] for running on the flat, up or down a slope of given gradient (from -0.3 to +0.3). The model is then used to calculate the overall effort of running on a number of 3-day event courses of differing standard; the model does not assess the energetic cost of jumping. The cost of transport over the range of gradient of -0.3 to +0.3 was modelled using the following equations:

On the flat or uphill: $COT_{path} = 0.123 + 1.561(\text{gradient})$

Downhill:

$$COT_{path} = 0.123 + 1.591(\text{gradient}) + 9.762(\text{gradient})^2 + 14.0(\text{gradient})^3$$

Introduction

A number of recent studies have described physiological and biochemical responses of horses competing in 3-day events, particularly the speed and endurance tests (Andrews *et al.* 1995; White *et al.* 1995; Marlin *et al.* 1995; Williamson *et al.* 1996). However, few have attempted to quantify the overall or progressive energetic cost of such exercise (Jones and Carlson 1995). The aim of this paper is to provide an objective method for estimating the oxygen consumption of horses while running on ground of variable slope so that more realistic comparisons may be made of the locomotory transport cost when competing at sites of differing terrain.

It is generally understood that competing on a relatively flat course demands a lower total effort than on a course of variable terrain. However, no requirements are laid down by the International Equestrian Federation (FEI) regarding the nature of the terrain of 3-day event courses for differing standards of competition, unlike the case for speed, distance and jumping effort. A knowledge of the profile of oxygen consumption over a particular course would also provide a means for competitors to plan speed and interval times to balance the effort appropriately over the length of a course.

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We present here a general model to calculate the oxygen cost of transport (the oxygen consumption to move 1 m: COT_{path}) for running on the flat and up, or down, a slope of given gradient. This model is then used to calculate the overall oxygen cost of running on a number of 3-day event courses in the UK, the 1995 Atlanta Cup (pre-Olympic trial) and the courses used for the 1996 Olympic Games in Atlanta, USA. The model does not assess the energetic cost of jumping, but the implications of cumulative energy expenditure on jumping ability are discussed.

Human and equine cost of locomotion

Running on the flat

The oxygen consumption of horses running on the flat, on the treadmill and other surfaces has often been quantified and is known to be approximately proportional to speed (Eaton 1994; Eaton *et al.* 1995; Schroter *et al.* 1996). The COT_{path} is, however, relatively insensitive to speed, provided gait can be freely chosen, and this is so for a range of both bipedal and quadrupedal species (Taylor *et al.* 1970, 1982; Fedak and Seeherman 1979); this is not so when gait is fixed (Hoyt and Taylor 1981).

When running up or downhill, the path travelled is longer than the projected horizontal distance and, therefore, the work done, or energy expended (COT_{path}) will be increased slightly. There is also a major difference due to the work involved raising or lowering the body up or down hill against gravity.

Running uphill

Eaton *et al.* (1995) studied the energetic cost of transport for horses exercising on a treadmill with an increasingly steep uphill gradient (from 0 to 0.1). They demonstrated that differences in COT_{path} with speed decrease and as the gradient is increased, these differences become effectively negligible. If the COT_{path} derived from the data of Eaton *et al.* (1995) is plotted against treadmill gradient for a range of speeds from 4 to 11 m/s, the slope for each speed is essentially linear, the differences between speeds being very small for gradients above 0.05 (Fig 1). The reported slightly curvilinear relationship is apparent at lower trotting speeds (Wickler *et al.* 2000). The approximately linear increase in COT_{path} with gradient reflects the increasingly dominant vertical workload to overcome gravity for a given distance covered along the path of the treadmill compared to the work required on the flat (Minetti 1995).