MODELING THE BENEFITS OF TOWING DURING ADVENTURE RACING, RUNNING WITH APPLIED HORIZONTAL FORCE

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INTRODUCTION

Adventure races are typically self-supported, multi-sport, team (3-5 people) races with a wilderness aspect. A team must stay together at all times; therefore, the slowest team member determines overall performance. Adventure racers have used towing as a technique to increase overall team speed during the running portions of a race. Mechanically, towing is accomplished by attaching an elastic cord from the waist of one racer (tow-er) to the waist of a teammate (tow-ee). In theory, the most aerobically fit racer should tow a less fit teammate so that the racers run at the same relative level of exertion (%VO_{2max}), thus achieving a faster speed than the less fit runner could accomplish solo. Our purpose was to predict the optimal towing forces between two runners that would result in the best overall race performance.

METHODS

We used previously established equations [1,2] to model 10, 20, and 42.2 km race distances on a flat course, assuming a constant towing force and negligible aerodynamic drafting. We calculated towing forces and amount of time saved for different combinations of VO_{2max} (ml/kg*min) and body mass. The relationship between $VO_{2submax}$ and running speed established by Daniels and Gilbert [1] is:

$$\mathbf{VO_{2submax}\ (ml/kg{*}min) = 0.3744V^2 + 10.93548V - 4.6}$$

(V=velocity in m/sec)

The %VO_{2max} that can be sustained for a defined time [1] is:

$$\mathbf{\%VO_{2max} = 80 + 18.94393{*}e^{(-0.012778T)} + 29.89558{*}e^{(-0.1932605T)}}$$

(T=time in min)

We normalized the equation of Chang and Kram [2] to calculate changes in $VO_{2submax}$ due to aiding or impeding towing forces:

$$\mathbf{\%\ Change\ VO_{2submax} = 0.155(AHF)^2 - 4.420(AHF) - 0.0000153}$$

(AHF=Applied Horizontal Force in % body weight)

We determined theoretical time saving by combining equations, solving iteratively, and using curve-fitting techniques.

RESULTS AND DISCUSSION

Our model predicts that towing can improve overall running performance by more than 10min in a 10km race (Fig.1, Table1). The effectiveness of towing depends on differences in VO_{2max}; a tow-er must have a higher VO_{2max} than a tow-ee. For a given VO_{2max} difference, performance can be further improved when a tow-er has greater body mass than the tow-ee. However, with optimal towing force, performance may also improve when a tow-ee is heavier than a tow-er. Additionally, towing may improve relative performance more as the race distance increases (Fig.2). Optimal towing force for best overall performance during running depends on runners' VO_{2max}, body mass, and distance. The strongest determinant of running performance due to towing is the VO_{2max} of each runner. Body mass differences and race distance can also influence running performance, but have smaller effects.

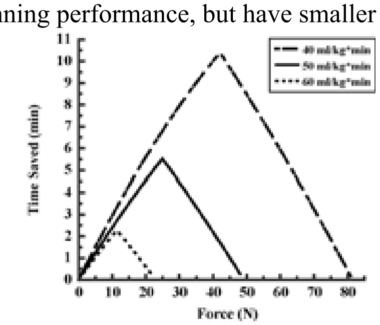

Fig. 1: Time saved in 10km race due to towing force. Tow-er's VO_{2max} = 70ml/kg*min, body mass = 70kg; Tow-ee's VO_{2max} = 40, 50, or 60 ml/kg*min, body mass = 70kg.

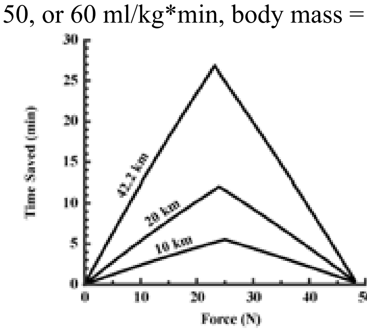

Fig. 2: Time saved in 10, 20, & 42.2km races due to towing force. Tow-er's VO_{2max} = 70ml/kg*min, body mass = 70 kg; Tow-ee's VO_{2max} = 50 ml/kg*min, body mass = 70 kg.

REFERENCES

1. Daniels J & J Gilbert, *Oxygen Power: Performance Tables for Distance Runners*, 1979.
2. Chang Y-H & R Kram, *Journal of Applied Physiology* **86**(5), 1657-1662

Table 1: Solo race times for 10km based on runners' VO_{2max}. Optimal tow force, maximum time saved, & optimal race time based on tow-ees' VO_{2max} & body mass. Tow-er always had VO_{2max} = 70 ml/kg*min, body mass = 70 kg.

VO_{2max} (ml/kg*min)	Body Mass (kg)	Race Dist (km)	Solo Race Time (min)	Optimal Tow Force (N)	Maximum Time Saved (min)	Optimal Race Time (min)
40	70	10.0	50.01	42.1	10.4	39.61
50	70	10.0	41.33	24.9	5.5	35.83
60	70	10.0	35.37	11.4	2.3	33.07
70	**70**	**10.0**	**31.02**	———	———	———