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The energy consumption and velocity model assist the cyclists to win the road race

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Abstract: This paper studies the relationship between the position of road cyclists on the track and the energy exerted by cyclists. The research on this problem has guiding significance for the competition scheme of cyclists. We explored various factors affecting the riding speed and energy in the process of road cycling. According to the characteristics of the real scene and the relevant knowledge of physics, we established the energy consumption and velocity model. Finally, the relationship between the position of cyclists on the track and the energy exerted by cyclists is determined.

1. Introduction

To assist cyclists to win in the road race scientifically, we need to establish the relationship between the position of cyclists in the field and the energy consumed during cycling. In the process of competition, the energy consumed by athletes is determined by external and internal factors. The analysis of external factors requires us to use the relevant knowledge and empirical rules of physics to study the resistance of cyclists in the process of cycling, while the analysis of internal factors requires us to use the relevant knowledge of biology and chemistry to better understand the law of internal energy consumption of athletes.

2. Model establishment and solution

2.1 Definition of energy consumption (*C*)

In 1986, Di Prampero of Italy first put forward the concept of energy consumption C based on previous studies, which refers to the additional energy consumed per unit distance higher than the quiet level, expressed by "C", and the unit is J / m or kJ/km. Therefore, we can equivalent the energy applied by cyclists in the forward unit distance to energy consumption. The energy consumed by an athlete when riding a bicycle is expressed by $C=E/V$, where C (kJ/m) refers to the energy consumption for completing the unit distance, E (kJ/s) refers to the energy metabolism rate, V (m/s) is the speed.

Because when the energy metabolic rate reaches the maximum, the speed will also reach the maximum. Currently, to have the maximum speed, you need to have the minimum energy consumption. In the cycling road race, the size of time determines the ranking of athletes, so it is necessary to use the minimum energy consumption to achieve the maximum speed to complete the race. For athletes, the difference in individual energy consumption plays a decisive role in sports whose performance is determined by speed, such as road bicycle time trial.

According to the literature, the rate of energy metabolism. We have collected many data, which comprehensively shows that the average heart rate of men is 165-168b / min and that of women is 170-180 b/min. We take the heart rate of male athletes as 166.5 b/min and that of female athletes as 175b/min.

2.2 Decisive factors affecting energy consumption (C)

The energy consumption in the process of cycling is composed of the total power per unit distance and sports efficiency, which is expressed by the formula $C = W/\eta_L$, where η_L refers to the motion efficiency, that is, the ratio between energy output and energy input. In general, the exercise efficiency of male time trial specialists is 0.985 and that of timber is 0.87; The exercise efficiency of women's time trial specialists is 0.810, and that of the chamber is 0.775.

W includes work W_A to overcome air resistance and work W_{NA} to overcome non air resistance, expressed by formula $W = W_A + W_{NA}$.

Among them, work is done to overcome air resistance $W_A = kV^2 = \frac{1}{2}AC_d\rho V^2$, where A is the area of the front part of the body (cyclist + CAR), C_d is the air resistance coefficient, ρ is the air density, V is the speed. It can be seen from the formula that under normal conditions, the size of air resistance is directly proportional to the air resistance coefficient and windward area, and directly proportional to the square of speed. Air density at normal temperature (20 ℃) and standard atmospheric pressure are ρ=1.266kg /m^2. At the same time, according to the research of Wilson, in modern racing bicycles, A = 0.36 m^2, C_d = 0.88.

Overcoming non-air resistance to do work is to do work in addition to overcoming air resistance. It mainly includes external work and internal work. $W_{NA} = W_{ext} + W_{int}$.

External work includes work done by bicycle rolling friction and work done against gravity. The work done by rolling friction is affected by the total weight of people and bicycles, gravitational acceleration, and rolling friction. Expressed by the formula: $W_{ext} = \mu(m+M)g\cos\theta$, where θ is the angle between the ground and the horizontal plane. The weight m of the racing bike is about 6-8kg, and 7kg is taken here. Statistics show that among cyclists, the average weight of men is and that of women is 60 ± 8kg. In the preliminary establishment of the model, we set the weight value of male athletes M = 72.73 kg and that of female athletes M = 60 kg. Rolling friction of athlete's bicycle tire on asphalt road μ = 0.004.

The work done by overcoming gravity in the internal work is affected by the weight of people and vehicles, gravity acceleration, and riding slope. Expressed by formula: $W_{int} = (m+M)g\sin\theta$. Internal work includes internal work, muscle contraction caused by maintaining body posture, and the movement of respiratory muscles and the heart. Here, we ignore the muscle contraction caused by maintaining body posture and the work done by the movement of respiratory muscles and the heart.

Combined with the above formula, we can get the energy consumption and velocity model.

$$\frac{W}{\eta_L} = \frac{W}{V} \tag{1}$$

$$\frac{1/2AC_d\rho V^2 + \mu(m+M)g\cos\theta + (m+M)g\sin\theta}{\eta_L} = \frac{-11.009656 + 0.257245 \times \text{Average heart rate}}{V} \tag{2}$$

θ is the angle between the ground and the horizontal plane. θ= 0 indicates that the athlete is driving on the flat ground currently. θ>0 indicates that the athlete is in the uphill state. θ<0 indicates that the athlete is in a downhill state.

2.3 Speed curve of different types of athletes of different genders during competition

Let's first analyze men's time trial specialists. According to equation (2), we can make the curve of V and θ as shown in Figure 1.

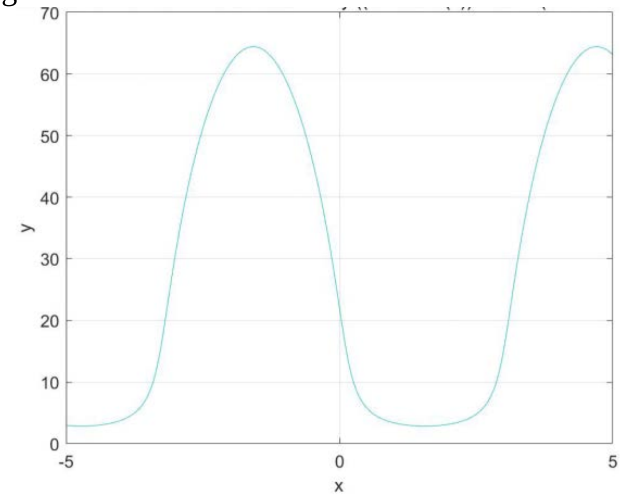

Figure 1: V-θ of men's time trial specialist

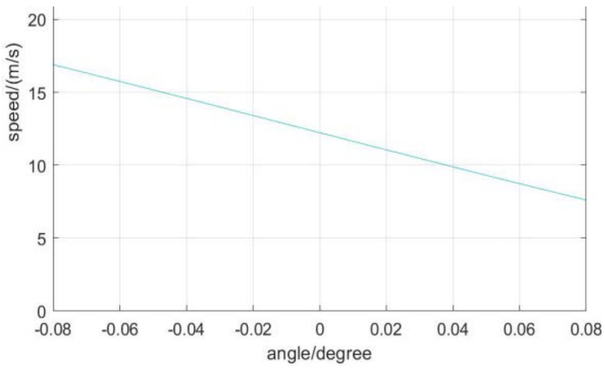

Figure 2: V-θ of men's time trial specialist -0.08<θ<0.08

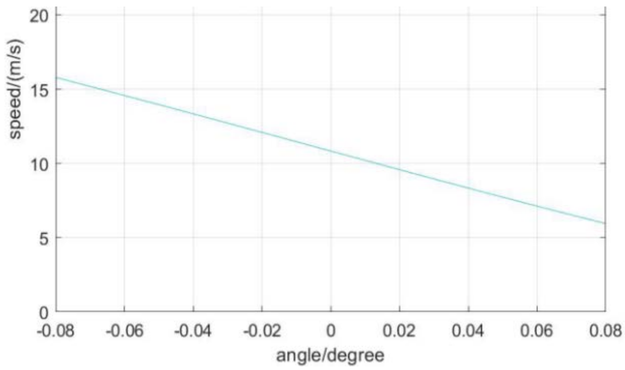

Figure 3: V-θ of women's time trial specialist -0.08<θ<0.08

Since the maximum inclination of ordinary highways is not greater than 8%, we take $-0.08<\theta<0.08$, as shown in Figure 2. The speed is 12 m/s on a flat road, 7.56 m/s on an uphill slope, and 16.8 m/s on a downhill slope, which can minimize the energy consumed by athletes when moving forward per unit distance.

Similarly, for women's time trial specialists, we can make Figure 3. The speed is 10.8 m/s on a flat road, 5.88 m/s on an uphill slope, and 15.72 m/s on a downhill slope, which can minimize the energy consumed by athletes.

For the men's climber, Figure 4 is made. The speed is 11.4 m/s on a flat road, 6.36 m/s on an uphill slope, and 15.96 m/s on a downhill slope, which can minimize the energy consumed by athletes.

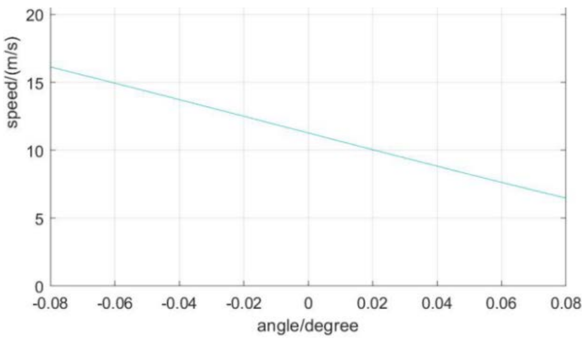

Figure 4: V-θ of men's climber, $-0.08<\theta<0.08$

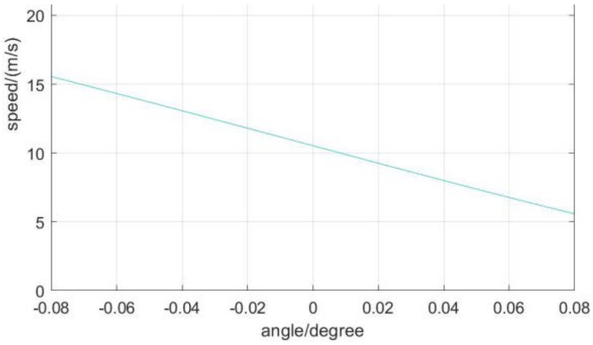

Figure 5: V-θ of women's climber, $-0.08<\theta<0.08$

For the women’s climber, Figure 5 is made. The speed is 10.44 m/s on a flat road, 5.64 m/s on an uphill slope, and 15.48 m/s on a downhill slope, which can minimize the energy consumed by athletes.

3. Model Evaluation

We creatively analyzed the relationship between the energy consumed by cyclists in the process of riding and speed and constantly verified the possibility and operability of its implementation.

To simplify the model, our cyclist's riding speed slope model only considers the factors with great influence and ignores the influence of the total air resistance, moment of inertia, and wheel radius when the front and rear wheels rotate. Therefore, the model has limitations to a certain extent.

In the model of the position of cyclists on the track and the energy applied by cyclists established by us, if we add relevant variables and functions, we can also study the influence of the energy supply changes of anaerobic exercise and aerobic exercise on cyclists based on the original model, such as the relationship between the speed and distance of cyclists and aerobic exercise and anaerobic exercise, to calculate the energy curve more accurately.

Our model is combined with relevant knowledge to meet the general mathematical principles and physical laws. Although the values of various parameters at any time can not be accurately known, the relationship model between the position of cyclists on the track and the energy applied by cyclists can solve the problems of energy distribution and speed control of cyclists in road races.

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