ISSN : 0974 - 7435 Volume 8 Issue 10

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 8(10), 2013 [1319-1324]

Mechanics factor model of sprint scores improvement based on the correlation degree analysis

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ABSTRACT

The paper carries through force analysis to the athlete during the entire sprint process, and the whole process is divided into four phases. Studying how to match the step frequency and stride length in 100 meters is important factor in restricting the achievements; according to the appropriate step length and stride frequency it derives a computational model. For each 100m athlete one can get the best step length and stride frequency in the 100m way running according to the formula to achieve the best results. It uses correlation degree analysis method of the gray control systems theory to conduct quantitative analysis and research on improvement factors of the sprint performance, explores the interrelation between the sprint performances with various factors, finds out its internal relations, scientific laws and methods to improve sprinter results, and has guiding significance on the future teaching, science and training.

KEYWORDS

Correlation degree analysis method;
Sprint;
Fitting function;
Model.

INTRODUCTION

Speed constitutes the basis for the development of athletics, meanwhile also is the foundation of various sports development. Strengthening the student's sprint technique can not only improve the students' interest in learning, but also can make them capable when engaged in other sports. Sprint is to finish the maximum intensity work when human motion organs and offal system are in the extreme hypoxia condition, and belongs to limited movement; sprint is typical sports whose energy is mainly based on anaerobic metabolism.

The paper first carries through force analysis to the athlete during the entire sprint process, and the whole process is divided into four phases. Studying how to match the step frequency and stride length in 100 meters is important factor in restricting the achievements; according to the appropriate step length, stride frequency it derives a computational model. Innovations: using correlation degree analysis of the gray control systems theory, exploring the interrelation between the sprint performances with various factors, and finding out its internal relations and scientific laws and methods to improve sprinter results.

MODEL ASSUMES

Suppose that athletes suffer the same outside influence. Suppose that in the modeling process, athletes will not appear unwell. Suppose that athletes have no psychological factors during the game.

SYMBOL DESCRIPTION

Step length x; Air resistance f; Stride frequency y; The body weight of athletes m; Join force F_f;

Back kicking angle β; The inclination angle of the starting blocks θ; Flight angle α^0; The initial velocity when starting a race v_0; Jumping speed v; The horizontal distance in the flight phase B; Maximum speed G; The friction coefficient of the foot with the starting blocks μ_1; Acceleration time t; The horizontal displacement of the body center of gravity in the back kicking stage A; Instantaneous speed V_t; The distance from body center of gravity to the support points when back kicking stage finishes H.

MODEL BUILDING AND SOLVING

The sprint mechanics model (starting of a race phase)

The acceleration when starting a race: When starting a race, conduct force analysis of the body from the starting blocks, and obtain the maximum acceleration at start of a race. Suppose that the athlete's body weight is m, the friction coefficient of the foot with the starting blocks is μ_1, the inclination angle of the starting blocks is θ, and the join force is F_f, as shown in Figure 1:

$$F_f = mg\sin\theta + \mu mg\cos\theta\cos\theta \quad ;$$
$$a = g\cdot\sin\theta + \mu g\cdot\cos^2\theta$$

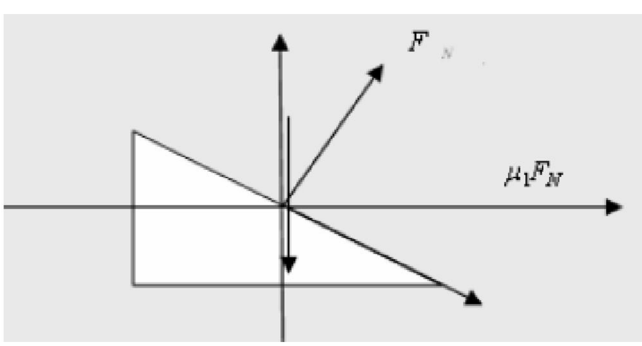

Figure 1 : Force analysis of human body when starting a race

The inclination angle of the starting blocks is related with personal habits. Generally the inclination angle of the front starting blocks is 30°, and the inclination angle of the back starting blocks is 45°. The acceleration of the front starting blocks is $a_1 = 4.9 + 7.35\mu$. The acceleration of the back starting blocks $a_2 = 6.86 + 2.45\mu$

The accelerated time when starting a race: For different starting ways, the time to achieve the maximum speed is also different. We find from the literature that when the set state of starting blocks is the long-form 70°, the force time is the longest; the time to achieve the maximum speed is also the maximum, shown as in TABLE 1.

TABLE 1 : The time needed to achieve the biggest force for the front and back starting blocks (ms)

Starting way	The back starting blocks	The front starting blocks
Short-form 300	64.7	97
Medium-from 300	80.7	116
Long-form 300	83.7	172.3
Short-form 500	89.3	127.3
Medium-from 500	73.7	100.3
Long-form 500	62.3	172.7
Short-form 700	81.7	114.7
Medium-from 700	116.7	249
Long-form 700	108	241.3

To achieve the maximum starting speed, we choose the long-form 70° starting way. The acceleration time of the back starting blocks is 0.108s, and the acceleration time of the front starting blocks is 0.241s.

The initial speed of at the start of a race:

$$\mathbf{v_0 = a\cdot t = 11.76t + 9.8\mu t} \quad \mathbf{(1)}$$

Formula 1 shows the instantaneous speed when leaving the starting blocks.

In the sprint process, there is acceleration ratio y, maximum speed G, acceleration time t, and instant speed V_t. During the whole process athletes suffer the influence of air resistance F, as shown in TABLE 1

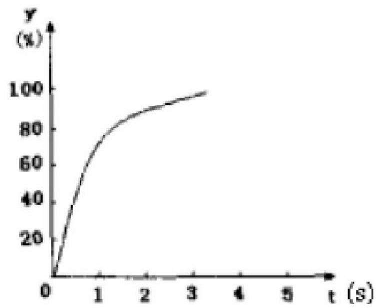

Figure 2 : The relationship of acceleration time and acceleration proportional

TABLE 2 : Acceleration proportion and time

Time	Acceleration proportion	Relevant factors
The second seconds	75-80	starting technique and muscles
The third second	87-90	starting technique and muscles
The fourth second	93-96	starting technique and stride frequency
The fifth second	98-100	starting technique and stride frequency

and Figure 2.

Instant speed:

$$V_{ti} = yG = \frac{t_i G}{0.8486 t_i + 0.8324} \quad (2)$$

Air resistance:

$$F = -c\rho s v^2 = -0.288 v^2 \quad (3)$$

The acceleration produced by the air resistance:

$$a = \frac{F}{m} = \frac{-0.288 v^2}{m} \quad (4)$$

The sprint mechanics model (back kicking stage)

Horizontal displacement of the body center of gravity in back kicking stage:

$$A: A = H\cos\beta \quad (5)$$

H is the distance from the body center of gravity to the support points after finishing the back kicking stage: β Is the back kicking angle: $\beta = 59.7^\circ \cos\beta = 0.5$; $A = 0.5H = t_i$

According to formula (2), the speed when finish the back kicking stage:

$$V_{t_i} = \frac{t_i G}{0.8486 t_i + 0.8324} = \frac{0.5HG}{0.4243H + 0.8324} \quad (6)$$

The horizontal acceleration of $0 - t_i$:

$$a_{t_i} = \frac{v_{t_i} + v_0}{t_i} = \frac{v_{t_i} + (g\sin\theta + \mu g\cos^2\theta)t}{t_i} \quad (7)$$

Since pedal ground angle when starting of a race is θ, then acceleration ability a_D along the angle θ of the body center of gravity is:

$$a_D = \frac{a_{t_i}}{\cos\theta} \quad (8)$$

Then:

$$a_y = a_D \sin\alpha \quad (9)$$

In the formula α is the angle between the ground and the ligature of body center to the contact point after landing on the ground. But, pedal against the ground don not start from α, but begins at the 1/2 of the back kicking stage. So in the first half of the pedal stage it moves forward by inertial force, that is to say pedal from 70° and end at α, within this range it is continuous pedal. Thus:

$$a_y = \frac{\int_\alpha^{70^\circ} a_D \sin d\alpha}{(70^\circ - \alpha)\times\pi/180^\circ} = \frac{180^\circ a_D}{(70^\circ - \alpha)\pi}\times(\cos\alpha - \cos 70^\circ) \quad (10)$$

Body running is a step-by-step acceleration process, so maximum speed is limited by the speed legs kicking on the ground. But why pedal speed get in the way running is greater than the pedal speed when starting? This is because starting running begins from leaving the run-up, and the acceleration at this time is the largest. The acceleration gets smaller and smaller with time increasing. According to $F = ma$ the pedaling force required is getting smaller and smaller with time increasing. So that, the load given on the skeletal muscle when contraction is small. According to skeletal muscle force-velocity relationship shown in figure 3, when the load is small, muscle contraction speed is fast. So in the way running pedal speed is greater than the starting speed. In order to obtain maximum speed, there must ex-

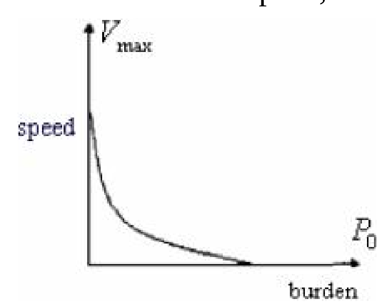

Figure 3 : Skeletal muscle force - velocity relationship

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ist $a_{t_i} = G$. The pedal acceleration in way running is:

$$a_t = G \times \frac{1}{\cos[\arcsin \frac{180(\cos\alpha - \cos 70^\circ)}{(70^\circ - \alpha)\pi}]} \tag{11}$$

The vertical acceleration in intermediate running stage:

$$a_y = a_t \sin \frac{180(\cos\alpha - \cos 70^\circ)}{(70^\circ - \alpha)} \tag{12}$$

$$v_y = a_y \times 1.7G \times \frac{H\cos\beta}{2G} \tag{13}$$

The sprint mechanics model (flight stage)

he flight stage is a parabolic movement, according to v_y 0 G the following is available:

Flight angle:

$$\alpha^0 = \arctan\frac{v_y \sin 90^\circ}{G + v_y \cos 90^\circ} = \arctan\frac{v_y}{G} \tag{14}$$

Flight speed:

$$v = \sqrt{v_y^2 + G^2} \tag{15}$$

The horizontal distance of the flight phase:

$$B = \frac{v_0^2 \sin 2\alpha^0}{g} \tag{16}$$

The sprint mechanics model (landing buffer phase)

The longer this stage is, namely the greater the distance from the landing point to the projection of body center, the greater the step length becomes. However, if the protrusion is too far, it will result in the formation of front landing, form resistance and result in performance declining. Only under the premise of no loss of stride length and velocity, it is desirable to consider the front pedal distance.

Generally the front kicking distance is one foot long. Suppose foot length is C, on the basis of the calculation of the above three stages, step length of sprint should be: $x = A + B + C$

Stride frequency in intermediate running stage is:

$$y = \frac{G}{x}$$

By the derivation of the above calculations, we can conclude that: the step length and stride frequency of sprint is not random combinations, but determined by the foot length, the highest horizontal speed and distance from the body center to the support points when finishing the pedal stage. For certain foot length, highest horizontal speed and distance from the body center to the support points, then there is a certain step length and stride frequency value which don not change. Artificially increase the step length can only lead to horizontal speed loss, resulting in performance decline. So in the application of the model established in this article, we should calculate the step length and stride frequency based on different parameters for each athlete. Only by analyzing the gap to the model, improving technology and developing physical fitness accordingly can one achieve one's best results.

RESULTS CORRELATION DEGREE ANALYSIS MODEL

By sprinter physical fitness analysis, elect 6physical quality indicators related with sprint performance in four stages. Then use the correlation degree analysis method to carry through quantitative analysis on the sprinter results and physical fitness tests (TABLE 3).

TABLE 3 : Sprint performance and physical fitness detection

Item	1	2	3	4
100m	14.86	14.7	14.63	14.51
30m march running	4.23	4.21	4.16	4.10
30m crouch start	4.93	4.81	4.74	4.65
Standing triple long jump	6.07	6.16	6.29	6.41
Standing 6 level leapfrog	12.71	13.44	13.98	14.45
300m	56.78	56.35	56.1	55.79
Standing 20 cross-jump	40.39	40.99	41.83	42.56

Set $y^0(k)$ as the reference sequence, standing for the sprint performance. The $x_1(k)$ 0 $x_2(k)$ 0 $x_3(k)$ 0 $x_4(k)$ 0 $x_5(k)$ 0 $x_6(k)$ are 6 comparative sequence, respectively, stand for the 30m march running (absolute speed), 30m crouch start (speed), standing triple long jump (explosive power), standing 6 level leapfrog (systemic coordination strength), 300m run (endurance of speed), standing 20 cross jump (endurance of strength). Ordinal number $k = 1\ 2\ 3\ 4$, respectively represent the four stages of teaching. In order to make the original data of indicators become comparable, we conduct the dimensionless treatment to the original data (see TABLE 4).

TABLE 4 : The initialization processing of the original data

Series name	1	2	3	4
$y_0(k)$	1	0.9919	0.9845	0.9764
$x_1(k)$	1	0.9953	0.9835	0.9693
$x_2(k)$	1	0.9757	0.9615	0.9432
$x_3(k)$	1	1.0148	1.0362	1.0560
$x_4(k)$	1	1.0574	1.0999	1.1369
$x_5(k)$	1	0.9924	0.9880	0.986
$x_6(k)$	1	1.0149	1.0357	1.0537

Calculate the absolute difference between the reference series and comparative series

The two-level minimum absolute difference $\min_i \min_k |y_0(k) - x_i(k)|$, the two-level maximum absolute difference $\max_i \max_k |y_0(k) - x_i(k)|$, as shown in TABLE 5:

TABLE 5 : The absolute difference between the reference series and comparative series

Differential	1	2	3	4
$\|y_0(k) - x_1(k)\|$	0	0.0034	0.001	0.0071
$\|y_0(k) - x_2(k)\|$	0	0.0162	0.023	0.03322
$\|y_0(k) - x_3(k)\|$	0	0.0229	0.0517	0.0796
$\|y_0(k) - x_4(k)\|$	0	0.0655	0.1154	0.1605
$\|y_0(k) - x_5(k)\|$	0	0.0005	0.0035	0.0062
$\|y_0(k) - x_6(k)\|$	0	0.023	0.0512	0.0773

Calculate the correlation coefficient

$\xi_{0i(k)} \frac{\Delta\min + P\Delta\max}{\Delta 0_i + P\Delta\max}$, Resolution factor $P = 0.5$, as shown in TABLE 6:

Calculate the correlation degree

$$r_{01} = \frac{1}{N}\sum_{\tau+1}^{n} \xi_{0i}(k)$$

$r_{01} = 0.9665; r_{02} = 0.8292; r_{05} = 0.9701; r_{06} =$

$0.7243; r_{03} = 0.7221; r_{04} = 0.5735$

In summary, the relationship between the six indicators and sprint performances is in line with the law of development of things. In these six indicators 30m stands for the march running, the 30m starting run stands for speed, standing triple long jump stands for explosiveness, standing 6 level leapfrog stands for the whole body's coordination ability, 300m stands for endurance of speed, standing 20 cross-jump stands for endurance of strength. The intrinsic link between physical fitness is extensive; the physical fitness does not exist in isolation. The correlation order of six indicators is $r_{05} > r_{01} > r_{02} > r_{06} > r_{03} > r_{04}$. We divide it into three categories: first category speed, second category endurance of speed, third category the strength of lower limb and trunk; and accordingly, it is easy to improve performance in sprint training.

TABLE 6 : Correlation coefficient

Correlation degree	1	2	3	4
$\xi_{01}(k)$	1	0.9594	0.9877	0.9187
$\xi_{02}(k)$	1	0.8320	0.7772	0.7074
$\xi_{03}(k)$	1	0.7780	0.6082	0.5021
$\xi_{04}(k)$	1	05506	0.4102	0.3333
$\xi_{05}(k)$	1	0.9938	0.9582	0.9283
$\xi_{06}(k)$	1	0.7772	0.6105	0.5094

CONCLUSIONS

Step length and stride frequency are the determinants of sprint speed. From the comparison of step length and stride frequency, as well as the comparison of step length index and stride frequency index, there is a great gap mainly in step length between our athletes with world excellent 100-meter athletes. Therefore, the main step is to improve the step length of our sprinter. In order to increase the step length of sprint and improve sprint speed, you first need to improve the muscle forces involved in the action, and then improve muscle groups' extensibility when in motion time. Only focus on professional quality training, strengthen the Special Forces and special flexibility exercises of sprint can achieve the purpose of increasing the step length and improving the running speed.

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