Method for Estimation of Quality Sports of Technique Diagnostics of Technical Mistakes

L. M. Raitsin and B. I. Prilutsky
Central Institute for Physical Education, Moscow, USSR

INTRODUCTION

In the present paper criteria of efficient running technique at a maximal speed have been determined. The authors assume as efficient the technique which provides the same performance by less mechanical energy cost. The purpose of the study is to answer the question about how to run (what kinematic, dynamic and energy characteristics should be) to provide an efficient running technique.

To investigate the efficiency of technique two methods — one of regression residuals and the other of discriminative features, are widely used. Regression residuals method [2] allows to differentiate between athletes «good at technique» and athletes «no good at technique»[1]. The merit of the method lies in the absence of motor potential influence on technique assessment. However the method does not provide technique criteria, i.e. biomechanical characteristics of the motion necessary for higher performance at the same motor potential level. The discriminative features method [1] allows to determine technique criteria by their comparison in highly- and low-qualified athletes with the same motor potential.

The authors suggest combination of the above methods for technique criteria determination. That will enhance their merits and eliminate drawbacks. At first, using the regression residuals method the subjects have been divided into groups of athletes good at technique and athletes

1. The term «good at technique» («no good at technique») means that technical mastery of an athlete is beyond (below) the average level in a given group.

no good at technique. Then the discriminative features method has been used, i.e. biomechanical motion characteristics have been compared in the groups of athletes good and no good at technique. Those characteristics that differe significantly in both groups have been taken for technique criteria, criteria choice being independent on athletes' motor potential.

METHOD

74 subjects aged from 18 to 25 qualified from the second grade to the International Master of Sport category, including 45 field-and-track athletes - 29 sprinters, 12 high jump and 4 long jump athletes, besides 4 wrestlers, 11 gymnasts, 6 volley-ball and 2 basket-ball players and 6 non-athletes, participated in the experiment. Some characteristics of the subjects are given in Table 1.

TABLE 1
Characteristics of the subjects

	Height, m	Weight, kg	Running velocity, m/s	Work used for lift of GCM during support, joule/kgm	Work used for down of GCM during support, j/kgm	Work used for increase of GCM horizontal velocity, j/kgm	Work used for decrease of GCM horizontal velocity, j/kgm
$\overline{X}$	1,750	69,5	8,35	0,187	0,117	0,774	0,358
σ	0,075	8,06	0,75	0,068	0,038	0,171	0,118

Note: $\overline{X}$ — mean
σ — standard deviation

The experiment consisted in running 60 meters at a maximal speed, trying to maintain it at the steady state level in the middle of the distance, where a force platform (measuring 0.75 × 0.75 m, own oscillation frequency 200 Hz, trade mark VISTI) was situated. Before the experiment the subjects performed several trial runs in order to plant a foot exactly on the platform. Using shelf oscillographer N-115 two components (horizontal and vertical) of ground reaction force have been registered. Besides, stride length and 3 m run time have been measured by 2 photocells placed in front of and behind the platform. Then velocity has been determined by the time. Digitized force platform data have been processed by Wang-2200 Computer using especially written programmes. As a result kinematic, dynamic and energy indices have been estimated. Some estimation formulae are presented in Table 2.

TABLE 2
Criteria of Efficient Sprinting Technique

Indices	Estimation Formulae	A group		B group		F-ratio
		M	SD	M	SD	
1	2	3	4	5	6	7
Horizontal displacement of the GCM during support period (m)	where $\int_x^{0,2} = \int_{t0}^{t0} V_x(t)dt$, where V_x — horizontal velocity of the GCM t_0, t_2 — instants of on-set and termination of support	0,987	0,026	0,917	0,023	4,726
Horizontal displacement of the GCM in amortization phase (m)	$\int_x^{0,1} = \int_{t0}^{t1} (X_x(t)dt$, where t_1 — instants of the end of amortization phase and on-set of take-off	0,417	0,031	0,380	0,033	13,598
Horizontal displacement of the GCM in take-off phase (m)	$\int_x^{1,2} = \int_{t1}^{t2} V_x(t)dt$, where (symbols see above)	0,569	0,030	0,591	0,037	4,790
Vertical displacement of the GCM in support period (m)	$\int_y^{1,2} = \int_{t1}^{t2} V_y(t)dt$, where V_y — vertical velocity of the GCM	0,034	0,012	0,050	0,013	17,379
Height of the GCM after the take-off (m)	$H = V_y(t_2)^2/2 \cdot g$	0,021	0,018	0,038	0,021	8,193
Amplitude of the maximum extremum of the horizontal component of force in the take-off phase, N.		338,5	65,3	423,3	99,6	11,307
Mean vertical force in the take-off phase	$F_y^{1,2} = \int_{t1}^{t2} (F_y - P)(t)dt)/(t_2 - t_1)$ where F_y — is the vertical component of the ground reaction force P — is body weight	543,0	178,9	731,8	200,5	10,601

Mean vertical force in the support period, N	$F_y^{0.2} = (\int_{t0}^{t2}(F_y - O)(t)dt) / (t_2 - t_0)$	763,1	168,0	906,7	176,3	7,417
Mean horizontal force in the take-off phase, N	$F_x^{1.2} = (\int_{t1}^{t2} F_x(t)dt) / (t_2 - t_1)$ where F_x — is the horizontal component of the ground reaction force	173,3	33,8	216,6	50,3	11,305
The percentage of contribution of the work used for increase of horizontal velocity of the GCM to the total positive mechanical work, %	$\frac{W^t_{h0r}}{W^t_{h0r} + W^{Vt}_{ver} + W^{St}_{ver}} \cdot 100$	75,7	8,8	69,6	7,3	5,727
The ratio of positive and negative work used for the displacement of the GCM in support period	$\frac{W^{St}_{ver}}{W^{S-}_{ver}}$	1,299	0,473	1,984	0,581	10,186

Note: M — the mean, SD — the standard deviation.
The data represented in the table are significantly different in groups A and B at the level of significance of 0,05; the critical value of F-ratio is 2,2.

Horizontal and vertical velocities of the GCM can be estimated as follows:

$$V_x = \frac{1}{m} \int_{t0}^{t2} F_x(t)dt + V_{x0}$$

$$V_y = \frac{1}{m} - \int_{t0}^{t2} (F_y - P)(t)dt + V_{y0}$$

where
V_x, V_y — horizontal and vertical velocities of the GCM
t_0, t_2 — instants of on-set and termination of support
F_x, F_y — horizontal and vertical components of ground reaction force
P, m — body weight and body mass
V_{x0}, V_{y0} — integration constants (or initial horizontal and vertical velocities of the GCM).

Initial horizontal velocity V_{x0} was calculated by G. Cavagna method (1975). The velocity value obtained from measured 3-m running time was used as V_{x0} (see above) (4). The initial vertical velocity V_{y0} was estimated on the basis of T. Fukunaga et al. findings (1980). The authors have demonstrated that in running the vertical velocity of the GCM amounts to zero at the transition of negative values of horizontal component of ground reaction into positive. It can be noted in different subjects running at different velocities (5). Displacement values were calculated by

$$S_x = \int_{t0}^{t2} V_x(t)dt$$
$$S_y = \int_{t0}^{t2} V_y(t)dt^*.$$

where
S_x, S_y — horizontal and vertical displacements of the GCM.

Values for kinetic and potential energies, as well as different fractions of mechanical work (positive and negative) used to change horizontal and vertical velocities and the height of the GCM over the ground were computed on the basis of velocity and displacement values. Each value of mechanical work fraction was reduced to a unit of distance covered in one stride and to a unit of body mass. Mechanical power output equals work times stride frequency.

To obtain technique criteria a regression equation was calculated. It integrated maximum running velocity recorded in experiment and mechanical work value used to increase the GCM horizontal velocity, reduced to a unit of time, path and body mass ($n = 0{,}550$, $p<0{,}05$). Those subjects were classified as technically skilled whose regression equation value exceeded the value of used mechanical work in running by 0,5 σ. Athletes were classified as technically poor if the mechanical energy expenditures exceeded the regression equation value by 0,5 σ. Thus the athletes were classified into two groups: athletes with good technical skill ($n = 24$; running velocity $8{,}408 \pm 0{,}455$ m/s, height $1{,}77 \pm 0{,}08$ m, mass $70{,}5 \pm 8{,}8$ kg) and athletes with poor technical skill ($n = 19$, running velocity $8{,}372 \pm 0{,}80$ m/s, height $1{,}74 \pm 0{,}07$ m, mass $67{,}0 \pm 7{,}4$ kg)[1]. The two groups of athletes produced smaller and greater mechanical work, respectively, at the same running velocity. After that the ANOVA was used to determine the biomechanical characteristics of motion if they differed significantly between the 2 groups of subjects. These were taken as technique criteria.

---

* Integration constants were assumed equal to zero.

1. Running velocity, height, body mass didn't differe significantly ($p = 0{,}05$, F - ratio, respect. 0,035; 2,160; 1,965).

RESULTS AND DISCUSSION

By means of statistic analysis we have singled out criteria of the efficient sprint technique represented in Table 2. They all can be classified into three groups: kinematic, dynamic and energetic ones. Horizontal displacement of the GCM in the support period and in the amortization phase, vertical displacement in the take-off phase, the height of the GCM after the take-off refer to the first group. All the above values, except horizontal displacement of the GCM in the support period and in the amortization phase, are lower with athletes of good technical skill. As the duration of amortization and take-off phases within two groups do not differ, it may be noted (see Table 2) that mean horizontal velocity in the amortization phase is higher and in the take-off phase is lower with athletes of group 1 (of good technical skill). It may be assumed that greater horizontal velocity in the amortization phase with athletes of good technical skill is connected with the plant of the take-off leg on the ground. A lower rise of the GCM in the take-off phase with athletes of good technical skill is an evidence of a «smoother» run of the athletes of this group. Vertical displacement of the GCM in the take-off phase is also indicative of this fact (0,021 ± 0,018 m in the first group and 0,038 ± 0,021 m in the second group). All this conforms to the modern concept of the correct sprint technique (3).

As far as the dynamic indices are concerned, it is necessary to note that it's exactly these indices that determine the kinematic and energetic criteria. They include mean vertical ground reaction forces during the support period and the take-off phase as well as mean horizontal force and the amplitude of the extremum of the horizontal component ground reaction force in the take-off phase. In the first group these indices are lower than in the second one.

In particular, the percentage of contribution of work used for horizontal velocity of the GCM to the total positive mechanical work refers to the energetic characteristics - technique criteria (see Table 2).

This value is by 6,1% greater in runners of the 1 group. This is indicative of a more effective distribution of mechanical energy expenditures with athletes of good technical skill, as this index is in a way analogous to efficiency, that is a ratio of useful work to the total mechanical energy expenditures. More rational technique of group 1 athletes is also manifested in other energetic characteristics, their values being lower within this group (see Table 2).

CONCLUSIONS

1. Efficient sprint technique criteria have been defined in this paper.
2. Efficient sprint technique has a «smooth» character, which results in lower vertical displacement of the athlete's GCM in the take-off phase and in flight period. Judging by the ground reaction, on the average, athletes of good technical skill make less effort in horizontal and vertical directions in take-off phase. Besides they produce less mechanical work in the vertical direction and the major portion of the total mechanical work falls on the work used for increase of horizontal velocity of the GCM.
3. The integration of the methods of regression residuals and discrimina-tive features has proved to be useful in research of biomechanics of sprint running.

REFERENCES

Zatsiorskii V. M., Cao Tan Thi «Teor. Prakt. Fiz. Kult». No 9, 14-18, 1971.

Zatsiorskii V. M. and Matveiv E. N., in: Mat. scientific confer. «Cybernetics and sport», 102-103, 1965.

Ozolin N. G. et al.: «Short running» (Text-book), 1977.

Cavagna G., «J. Appl. Physiol.», 39, 1, 174-179, 1975.

Fukunaga T. et al.: Effect of running velocity on external mechanical power output. «Ergonomics», 23, 2, 123-136, 1980.