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Analysis of Biomechanical Factors in Bend Running

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Abstract: Sprint running is the demonstration of comprehensive abilities of technology and tactics, under various conditions. However, whether it is just to allocate the tracks for short-distance athletes from different racetracks has been the hot topic. This study analyzes its forces, differences in different tracks and winding influences, in the aspects of sport biomechanics. The results indicate, many disadvantages exist in inner tracks, middle tracks are the best and outer ones are inferior to middle ones. Thus it provides references for training of short-distance items in biomechanics and psychology, etc.

Keywords: Bend running, biomechanics, factors

INTRODUCTION

At present, the 400 m semicircular track and field is constructed by 114.04 m long curving section and two 85.96 m long straight sections. The two curved segments are longer than the two straight segments, which are about 56.16 m. From the point of sport mode, bend running is a circumferential curve movement and in the projects of sprint which has bend running, the distance is longer than the straight. Therefore, the bend running projects should also be an important research subject in the theory of sprint technology. The theory and practice of modern sprint has proved that the technical characteristics and tactical approach are different in 100 and 200 m (Fenggang and Xiaolin, 1987). Generally speaking, the results of 200 m in the world are calculated by the average of 100 m, the former are close to or better than the latter. This force us to find out the theoretical basis of bend running from the principles of mechanics, in order to explore and solve the technical issues which existed in the bend running and achieve the purpose of improving the level of sports technology (Katharine, 1985). On the issues of different passes athletes whether have fair opportunity in the track and field competition; many scholars had some conclusions (Darren and Benno, 1998). But most of them described from one aspect, few real scientific experiments systematic and comprehensive study. The previous studies are focused on two aspects: one aspect is that different pass athletes has different results, even the same athlete will have different results when he at different passes. The other aspect is that the different passes have no influence on results, but the athlete's training habits and psychological orientation subjective factors take an important role on the results (Aki and Paul, 1998). In the process of competition, when the athletes are scheduled on the 3, 4, 5 passes which are believed the relative better passes, they always have good performance (Zhao, 2001).

According to the principle of biomechanics, the heretic's athletes should play more reasonable sports level and have good results because they have little influence by centrifugal force. But in the final competition of 200 m of Barcelona Olympic Games which was held in 1992, Michael Johnson broke the world record with the results 19 "72 and won the championship. Worth mentioning, he was at the eight pass. So, how the different passes influence the results in the end?

《COMPETITION RULES2012-2013》rules, the length of 400 m standard runway is 400 m. The best one is 36.5 m, which comprises of two 114.04 m curved sections and two 85.96-m straight sections. Besides, the curved sections are 56.16 m longer than straight ones. It also rules, for the four best athletes from different racetracks are allocated randomly at 1 track or 2 track.

The theory and practice of modern print running prove, 100 m straight track is largely different from 200, 400 m curved ones. The track for 400 m standard runway has two lines, one is lane line, also called as solid line, which divides track into various ones and the other is calculation line, also called as real line, which is to calculate perimeters of different tracks, real lines for athletes to run.

According to calculating methods, the perimeter formula for real running line in first track is (1):

$$C1 = 2\pi (R + 0.3) \tag{1}$$

From the second track to the eighth one, it is (2):

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Table 1: 400 m playground of various parameters

Track	Calculate the radius of semicircle arc length (m)	Drawing a line radius of the semicircle arc length (m)	Gap (m)	Motion radius increases 0.1 (m)	Drawing a line radius (m)
1	114.0398	113.0973	0.9425	0.315	36.3000
2	117.5584	116.9301	0.6283	0.315	37.4200
3	121.3911	120.7628	0.6283	0.315	38.6400
4	125.2239	124.5956	0.6283	0.315	39.8600
5	129.0566	128.4283	0.6283	0.315	41.0800
6	132.8894	132.2611	0.6283	0.315	42.3000
7	136.7221	136.0938	0.6283	0.315	43.5200
8	140.5549	139.9265	0.6283	0.315	44.7400

$$Cn = 2\pi\,[R + d\times(n - 1) + 0.2] \quad (2)$$

R is radius; n is different racetrack and d is width of racetrack (1.22 m). If calculate as 36 m inner arc radius, the results are shown as Table 1.

Using (1) as reference, the perimeter of first curved calculating line is (3):

$$2\times3.1416\times(36 + 0.30) = 228.08\ (m) \quad (3)$$

Then add the lengths of two straight lines (4):

$$85.96\times2 = 171.92\ (m) \quad (4)$$

Equaling to 400 m. Imagine athletes' running along inner 0.4 m arc, the length of calculation line in 200 m running is (5):

$$3.1416\times(36 + 0.4) = 114.355\ (m) \quad (5)$$

A adding a 85.96 m straight section, the result is 200.315 m. If he run along inners of outer 0.5 m arc, the result is 200.6284 and 1.26 m longer than 200 m one.

For athletes from different racetracks, if each athlete runs along calculation radius, from the aspect of distance, the allocation is fair. To sport biology, under the same wind speed, temperature and humidity, the conditions for athletes from straight racetracks are same, but discussion is essential for them from curved racetracks. This study analyzes the fair in racetrack allocation, advantages and disadvantages of inner track and outer track, in biomechanical models, in order to find its influential factors and to provide references for training (George *et al*., 2003).

BUILD A BIOMECHANICAL MODEL

Model hypothesis:

- Imagine each athlete conforming to regulations
- Due to force analysis, human is considered as a mass point, ignoring its shape and inclination of track field

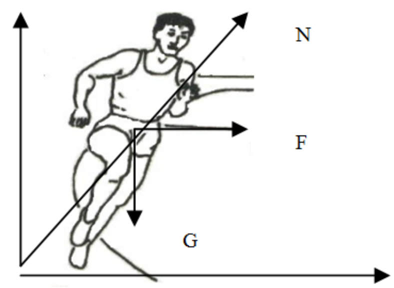

Fig. 1: The stress analysis of athletes in the bend running

- Imagine the climate conditions are about wind, temperature and humidity and wind speed is less than 2 m/s
- The following analysis is a 200 m running, which is a bend track and a straight track

Force analysis of bend running: When athletes are conducting bend running, their bodies are inclining to inner tracks. Meanwhile, the directions of gravity and ground reaction force are changing, thus they produce a resultant force directing to center point, which is the common conception of centripetal force F. Centripetal force is to overcome human's inertia, change the motion direction, to keep it properly going. When athletes are conducting bend running, human is inclining to center point. Meanwhile, human's gravity G is not in the same line with ground reaction force N, which are shown in Fig. 1, according to parallelogram rule. F is centripetal force.

However, the essence of centrifugal phenomenon is motion inertia, which is centrifugal inertia in sport biomechanics. If athletes run from outer line next to bend track closely or from outer line next to left line, the resistance must be produced. Such is the centrifugal force. The fast the athlete is, the bigger the centrifugal force is. To overcome centrifugal force, athlete has to achieve centripetal force by inclining to bend track. They are same in quantity and opposite in direction. To run in lanes, due to different radius produced by different tracks, imagine the gravity of athlete is 70 kg, if the speed is 10 m/s, then because of the formula (6):

Table 2: The centripetal force data of traffic separations

Track	1	2	3	4	5	6	7	8
Drawing a line radius (m)	36.300	37.420	38.640	39.860	41.080	42.300	43.520	44.740
Centripetal force (N)	192.837	187.065	181.159	175.614	170.399	165.484	160.845	156.459

Table 3: The acceleration distance of traffic separation from the straight-line

Track	1	2	3	4	5	6	7	8
Drawing a line radius (m)	36.0000	37.2200	38.4400	39.6600	40.8800	42.1000	43.3200	44.5400
The accelerated linear after the start (m)	9.4514	9.6076	9.7612	9.9126	10.0616	10.2084	10.3532	10.4960

$$F = \frac{mv^2}{R} \tag{6}$$

According to the formula (6), we conduct the data of Table 2.

The first track F = 192.8375N and the eighth one F = 156.4595N. As is shown, to athletes with same gravities and speeds, the centripetal force F of eighth track is 36.3780N less than that of the first track. In reality, radius R of band track decides the different centripetal forces of different tracks, which is adjustable. It changes with the changes of tracks. The outer ones have the smaller centripetal forces. Different tracks need different centripetal forces. Centripetal force is produced by changing athlete's body, whose value is positive to the magnitude of human's posture, direction is vertical to speed and points to center point.

The research shows, posture has an effect on performance. Therefore, seen from sport biomechanics, the athletes from inner tracks have bigger centrifugal forces and bigger centripetal forces are needed to keep balance, influenced largely. The athletes from outer tracks have small centrifugal forces, so they have to achieve fine performance by properly exerting. Therefore, they have more advantages (Scott *et al*., 2001). But, to an athlete, psychology is important. In general, the athletes next to the middle track are easy to get better performances, others have some bad influences. Therefore, to psychological factors, the athletes in middle tracks are likely to get better performances, with fine mood and enough confidences.

Advantages and disadvantages of inner and outer tracks: It has to be discussed from the three aspects such as sport biomechanics; differences of starting line in bend running and windy influences.

To the differences existing in starting line, athletes usually place the starting blocks outside the tracks, pointing to the cross point on the cross line, so as to have a straight section to benefit for speeding. It is very important. However, the inner and outer tracks have different effects on speed. Which are shown in Fig. 2.

N is the starting block point, the accelerated linear after the start MN can be calculated by formula (7):

$$MN = \sqrt{ON^2 - OM^2} \tag{7}$$

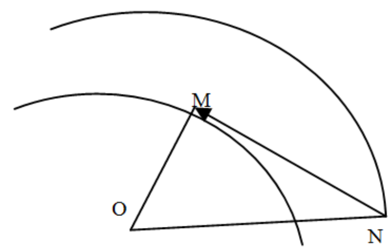

Fig. 2: The stress analysis of athletes in the bend starting

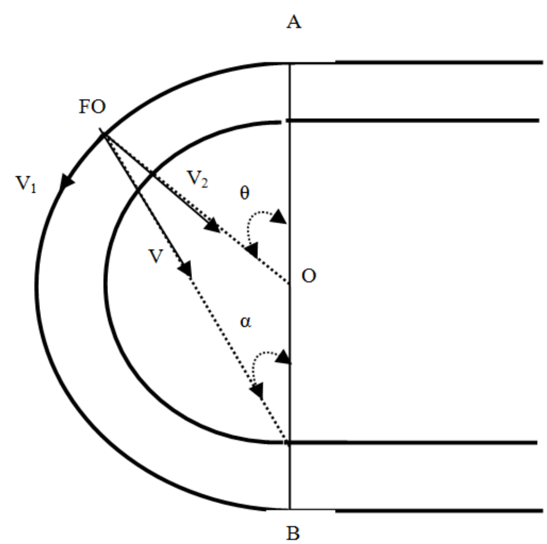

Fig. 3: The stress analysis of bend tangent wind speed

According to the formula (3), we conduct the data of Table 3.

Obviously, Table 3 shows that, the linear increases gradually from the first track to the eighth track. The eighth track has longer straight linear than that of the first one, with the advantage of 1.0446 m, which is good for accelerating to the maximum speed. The starts in outer tracks have more advantages. In other words, under such conditions, running in inner tracks have certain disadvantages.

Imagine wind speed is V, α angle with $\overline{AOB}$, athlete is at point F (F is at any point of arc AB). Connect OF, then (8):

Table 4: Mean cross wind speed

Track	R (m)	S (m)	β (°)	$\bar{V}_1$ (m/s)
1	36.30	0.00	0.0000	(Into β)
2	37.44	3.52	0.0940	(Into β)
3	38.66	7.35	0.1901	(Into β)
4	39.88	11.18	0.2803	(Into β)
5	41.10	15.02	0.3655	(Into β)
6	42.32	18.85	0.4454	(Into β)
7	43.52	22.68	0.5211	(Into β)
8	44.74	26.52	0.5928	(Into β)

Table 5: Unit wind speed $\bar{V}_1$ (m/s)

Track	$\bar{V}_1(0^0)$	$\bar{V}_1(30^0)$	$\bar{V}_1(45^0)$	$\bar{V}_1(60^0)$	$\bar{V}_1(90^0)$
1	0.637	0.551	0.450	0.318	0.000
2	0.655	0.580	0.480	0.354	0.030
3	0.671	0.613	0.520	0.391	0.063
4	0.686	0.643	0.554	0.427	0.098
5	0.697	0.667	0.583	0.459	0.128
6	0.705	0.689	0.610	0.489	0.158
7	0.713	0.712	0.638	0.521	0.190
8	0.780	0.731	0.663	0.549	0.220

$$\angle FOA = \theta \text{ (Fig. 3)} \quad (8)$$

Divide V at point F into cross wind speed V1 (the same as that of athletes) and V2 (Fig. 3), then (9):

$$V_1 = V.\sin(\theta - \alpha) \quad (9)$$

The bend mean cross wind speeds of eight tracks are:

The functional mean value in given section is the functional mean value produced by sectional length divided by definite integral in such section. Therefore, the mean cross wind speed $\overline{V}_1$ on the arc AB is (10):

$$\overline{V_1} = \frac{1}{\pi}\int_0^{\pi} V \cdot \sin(\theta - \alpha) d\theta \quad (10)$$

Imagine there are eight tracks and the starts for different tracks have angle β with arc $\overline{AOB}$, then (11):

$$\overline{V_1} = \frac{1}{\pi - \beta}\int_0^{\pi} V \cdot \sin(\theta - \alpha) d\theta = \frac{V}{\pi - \beta} \quad (11)$$
$$[\cos\alpha + \cos(\beta - \alpha)]$$

Besides (12):

$$\beta = S / R \quad (12)$$

S-arc length (200 m stagger) R-radius (real running radius)

The Table 4 and 5 shows, in the same wind directional angle α, although the wind speeds of straight tracks are same, the higher running track is, the bigger mean cross wind speed is.

Therefore, if the direction of $\overline{V}_1$ is same as that of running, the wind speed of outer track has bigger speed, which benefits for running and outer tracks have more advantages; if the direction of $\overline{V}_1$ is opposite to that of running (that is directional angle is from 90^0 to 180^0), the wind speed of outer track has bigger speed, which has bad effects on running and outer tracks have more influences. That is to say, under such environments, the inner track also has certain disadvantages (Tania *et al.*, 2004).

Analysis of best running route: In the course of running, to achieve best running route, out of climates, the best objects can be definite: short distance has small effects on geographic factors and large speed. Analysis is shown in the following:

The short-distance running longer than 200 m, the full distance at least has a bend track and a straight track. While conducting straight track, to achieve minimum distance, obviously, he should run along the inner track straightly. While conducting bend running, according to formula (13):

$$S = 2\pi(R + (n-1)d + 0.2) \quad (13)$$

(n = 2, 3, 4, 5, 6, 7, 8 d = 1.22 m)

The length of first bend track (14):

$$s_1 = 2\pi(R + 0.3) \quad (14)$$

(n = 1)

After accelerated running along the straight line, he runs into the bend track, to get the minimum S, he has to run along his inner track line. Otherwise, if athlete runs along 0.1 m outer line, his distance will increase by 0.315 m and if athlete runs along the outer line, his distance will increase by 3.843 m.

CONCLUSION

From the perspectives of such, the track allocation rule is: all the distances are fair; the biomechanical theory is, the innermost track has biggest effects, the outermost track has small effects and the middle one has general effects. The theory in psychology, the outermost track has biggest influences and the smaller ones of inner tracks.

All in all, the athletes in the middle tracks have small influences in all aspects and the athletes in the side tracks have larger effects. So allocate randomly the four best athletes at the middle tracks and fifth and sixth best ones are randomly at 7, 8 track and others are randomly at 1, 2 track. Such method is fair. General training has to be considered with mechanics and psychology, such as different inclination, wind speed should be applied differently to improvements.

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