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Mathematical simulation analysis of optimal testing of shot putter's throwing path

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Abstract

Objective: To study the mathematical simulation analysis of shot-putter throwing optimal path.

Methods: Shot put was simplified as a parabolic motion of a particle, the corresponding mathematical model was established, and the mathematical relationship between the throwing distance and the initial velocity of shot put, the shooting Angle and the shooting height was defined.

Results: The fitting formula between shooting speed and shooting Angle was obtained by using the fitting method, and the quantitative relationship between them and the ideal shooting Angle was identified.

Conclusion: The mathematical principle of shot put is revealed through the process of building a model from simple to complex. However, there are still many problems to be solved, among which the height problem is a complex one. At the present level, it is not possible to find a reasonable height, because it involves many factors. However, the development of grey mathematics will provide a beneficial attempt for it to establish a reasonable and scientific model.

Keywords: shot put, optimal path, mathematical simulation analysis.

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1 Introduction

In the training practice of shot put, it is generally found that the principle of mechanics based on the projectile motion in physics has great limitation and inaccuracy in the practical application. This not only caused people to put the shot mechanics of the foundation in doubt, but it also made some people to begin to deny the mechanics of the foundation. In fact, the shot-put movement is the projectile point higher than the falling point of the projectile movement of the fact is objective, is undeniable. The crux of the problem is that people who are involved in the process of application look only from the perspective of physical exercise awareness and make an analysis of the characteristics of the shot put movement, without applying the conditions of the sports mechanics

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principle itself. Therefore, in the projectile motion, based on the principle of mechanics of physics, there are many limitations in practical application and accuracy. Through the mathematical analysis of the principle of mechanics of shot put, this paper aims to explore the reasons for the inaccuracy of the principle of mechanics of shot put in practice and provide a reference for further improvement of the same [1].

2 Experimental methods

2.1 Research premises

When we study the shot put movement, we can separate the movement process before and after shooting, and only in this way can we understand the characteristics and rules of the shot put movement. But it's important to note that this separation must be conditional, and that's the premise of any process.

2.2 Find data for comparison

From a set of outstanding women far mobilisation in China from a group of outstanding women's shot put data of the athletes in China (Table 1), by establishing a mathematical correlation analysis model [2], seeking and shoot height, Angle velocity v T h three factors of the effect of throwing distance s size, in training and competition for athletes and coaches have certain theoretical guiding significance.

2.3 Mechanical basis of shot put

The throwing distance of the ball depends on the speed, Angle and height of the ball when it is thrown. Among them, the initial speed has the biggest impact on the throwing distance. For professional athletes after hard training, the shooting speed of the ball can be stable at a higher level, and the shot put speed is generally 11.0–15.0 m/s because it cannot be increased at will. The shooting height is also relative to a certain amount. Therefore, to find the best shot Angle, it imperative to improve the shot putting technology to get the longest distance. Next, we build a mathematical model of the problem.

2.4 Logical relation before and after shot put

Shot put before and after the movement from the surface form is relatively independent. The movement before the hand is a biological movement based on the characteristics and laws of human body movement, while the movement after the hand is a projectile movement. But because the shot speed, shot Angle and shot height from the shot before the movement process, and shot before and after the shot is a continuous uninterrupted process, the shot before the movement is the basis and condition of the shot after the shot after the movement is the continuation of the shot before the movement and effect. In this sense, the shooting movement after the shot put is not a simple shooting movement, but it is a shooting movement that includes the law of biological movement. Although these two movement processes have their own relatively independent movement rules, the basic conditions, continuity and effect between the movement before and after the shot put shooting determine that the movement before and after the shot put shooting is closely linked, restricted and influenced by each other [3]. This shows that there is a significant causal relationship between the two movement processes before and after shot putting.

3 Research methods

3.1 Calculation process and method of the best theoretical shooting Angle of shot put

According to the data sequence of shot put score, shooting speed, shooting Angle and shooting height in Table 1, as the behavior data sequence, let's call each of them x_0, x_1, x_2, x_3 , calculate the mathematical model of

Table 1 Shot put data of an elite athlete in China

Speed of delivery V (m/s)	Handle angle T (degree)	Height of hand H (m)	Shot put S (m)
13.51	28.69	2.00	20.30
14.08	35.13	1.95	21.76
13.82	30.80	2.1	20.49
13.40	36.02	2.11	20.24
13.77	34.64	2.01	20.84
13.41	38.74	1.92	20.02
13.56	35.33	1.77	20.10
14.08	34.60	1.89	21.58
13.23	39.13	2.10	19.84
13.35	34.08	1.89	19.26
13.07	39.68	1.97	19.17
13.39	34.14	1.83	19.62
13.30	37.74	1.76	19.76
13.58	37.75	2.02	20.76
13.48	40.56	2.00	20.33
13.39	34.67	2.01	19.85
13.35	39.27	1.91	19.81
13.37	36.98	1.95	19.62
13.46	38.68	1.83	19.59
13.20	42.48	1.98	19.58
13.18	38.62	1.89	19.36
13.21	41.32	2.03	19.82
13.38	36.10	1.94	19.71

x_1, x_2, x_3 vs. . First, we initialize it

$$x_i = \frac{x}{x^i(1)} (i = 0, 1, 2, 3) \quad (1)$$

The infinite toughening sequence x_0, x_1, x_2, x_3 is obtained by

$$V_{0i} = \frac{1}{3} \sum_{k=1}^3, V(x_0(k), x_i(k)), V(x_0(k), x_i(k)) = \frac{m = {}^a M}{W(k) + {}^a M}, \quad (2)$$

Where $W(k) = |x_0(k) - x_i(k)|$, $m = \min_{i,k} W(k)$, $M = \max_{i,k} W(k)$. a is the resolution coefficient, here, $a = 0.5$ is substituted into the data and the following calculation can be obtained:

$$V_{01} = 0.886V_{02} = 0.6710V_{03} = 0.7678$$

Therefore, it can be seen that the distance of the shot put is most closely related to the shooting speed, followed by the height of the shot, and finally the Angle of the shot. However, it must be noted that the effect of the Angle of the shot on the throwing distance is >0.6 . Therefore, to improve the performance of shot put, we should first improve the speed of shooting, then consider the selection of athletes with the height advantage, do not deliberately pursue the Angle of shooting; But on the other hand, for well-trained athletes, the speed and height of their shots tend to be a stable state, at this time to improve sports performance, it is necessary to consider the choice of an ideal shot Angle [4].

3.2 Model establishment and solution

Model building and solution Suppose the initial velocity of the shot put shooting is T , the shooting height is h , the Angle between the initial velocity T and the ground is a , the flight trajectory of the ball is shown in Table 2, then the flight time of the ball from the shooting point A to the highest point B is taken

$$V_{AB} = \frac{T_2}{g} = \frac{1}{g} V \sin a \quad (3)$$

The height of the ball

$$h_1 = \frac{1}{2} g V_{AB}^2 = \frac{1}{2g} V^2 \sin^2 a \quad (4)$$

So B, the highest point of the ball, is going to be zero

$$H = h_1 + h \quad (5)$$

If the shot is moved from B to C (landing point) in time V_{BC}

$$H = \frac{1}{2} g V_{BC}^2 \quad (6)$$

Substitute (4) and (5) into (6) to obtain

$$V_{BC} = \frac{1}{g} \sqrt{V^2 \sin^2 a + 2gh} \quad (7)$$

Thus, the total time of the shot in the air is

$$V = V_{AB} + V_{BC} \quad (8)$$

Throwing distance

$$S = V_1 = TV_{caso} \quad (9)$$

Substitute (3), (7) and (8) into (9) to get

$$S = \frac{1}{g} V \cos a \cdot \sqrt{V^2 \sin^2 a + 2gh} + \frac{1}{2g} V^2 \sin 2a \quad (10)$$

This is the analytical expression of the relationship between the throwing distance S and the shooting speed V , the shooting height h and the shooting Angle a . It can be seen that S increases and decreases with the increase and decrease of V . S goes up and down with h . Therefore, we see the elite shot putters, are basically tall and strong (to get a larger V) players. It can be seen from Eq. (8). The ball shooting Angle a has a direct relationship with the throwing distance S , but S may not increase or decrease with the increase or decrease of a . If V and h are regarded as constants, S is a function of a . So if you want to get the maximum throw distance S , when a is equal to $ds/da=0$, that's equal to

$$T \cos 2a - \sin a \sqrt{T^2 a + 2gh} + \frac{T^2 \sin a \cos^2 a}{\sqrt{T^2 \sin^2 a + 2gh}} = 0 \quad (11)$$

Equation (9) determines an implicit function $F(v,h,a) = 0$. If v and h are regarded as independent variables, then a is a binary function of them. Table 1 is the optimal value of a and corresponding maximum throwing distance s of (v,h) at different levels determined from this. Athletes can choose the corresponding throwing Angle according to their shooting height H and shooting speed V [5].

3.3 Conditions for the application of the theoretical function relation of the best shot put angle

The theoretical basis of the optimal shooting Angle is based on the projectile motion which is higher than the landing point in physics. It is based on the movement index (shooting speed V , shooting Angle T , shooting height H) and the movement effect (shooting point and landing point projection J in the horizontal plane) function relationship, through mathematical operations.

Formula (1) is the function relation between the shooting speed V , the shooting Angle T , the shooting height h and the projection J of the shooting point and the landing place on the horizontal plane

$$J = \frac{V \cos T}{g} (V \cos T + \frac{\sqrt{V^2 \sin^2 T + 2gh}}{g}) \quad (12)$$

The operating conditions assume that the velocity of the shot is V and the height of the shot is known.

According to the differential function relation, the derivative of function formula (12) is made equal to 0. Through calculation, the function relation (14) between the optimal shooting Angle T , the shooting speed V and the shooting height H is obtained.

$$\sin T = \frac{V}{\sqrt{2V^2 + 2gh}} \quad (13)$$

$$T = \arcsin \frac{V}{\sqrt{2V^2 + 2gh}} \quad (14)$$

Shot put the conditions of the function relation between the best Angle for theory application in the process of the above calculation assumptions to speed where V_0 , shoot height H is known, this means (14) is the function relation between the two movements before and after the shot put out process to separate, and set out velocity V , Angle for T , shoot height h is under the condition of three independent variables. Thus we can conclude that the application of the functional relation (14) must satisfy two conditions. First, there are two independent processes before and after shooting the shot. Second, release speed V , release Angle T , release height H in numerical changes are independent of each other's three physical quantities. And these two conditions are necessary and sufficient conditions for the application of the functional relation (14).

3.4 Analysis of the relationship and characteristics of movement indexes in shot put

Shot speed V , shot Angle T , shot height H are the three instantaneous movement indicators of shot put shot. But these three indexes are not suddenly obtained at the moment of the shot, but through the unified movement process of the shot and the human body before the shot. In the movement process of the shot and the human body, through the movement process of the human body, the speed of the shot from 0 to the instantaneous speed when the shot is shot; The height of the hand is also from a certain height (lower than the height of the hand) to the height of the hand; The hand Angle is the movement effect of the joint coordination of the human body. This shows that the shooting speed V_0 , the shooting Angle θ and the shooting height H are determined by the human movement process before the shot put is shot, and they are the three effect indexes of human movement. At the same time, the movement after shooting is the continuation of the movement effect before shooting. Shot put speed of the size of the shot put mainly depends on the contraction of the muscle and speed of the human body before the shot. Shot put shooting Angle and shooting height mainly depend on the movement form of the human body [6].

3.5 Analyse by line chart

When the height of the hand is 2 m, the calculation results in Figure 1 can be obtained. In the figure, T represents the Angle, Y represents the angular module, and Z represents the descent Angle. R stands for the corner of the ground. The simulation results show that the optimal shooting Angle T and landing Angle R are complementary angles to each other. This result is in good agreement with the conclusion from the literature that

Fig. 1 Relationship between various angles and firing speed.

when the shot is shot at the best Angle of release, the velocity vector of release and velocity vector of landing are perpendicular to each other.

Like the best shot Angle, the best shot Angle varies with the speed of shot put. When the speed is small, the optimal landing Angle is close to 90° , which means that 90° is the asymptotic Angle of the optimal landing Angle at a small speed (it can be an Angle that is infinitely close but never reached). As the velocity exceeds 14 m/s and increases, the Angle of impact decreases gradually, as it approaches at 45° , which is another asymptotic Angle at the maximum velocity.

When the speed becomes very small, since the optimal hand Angle tends to 0° , and the deflection Angle of the hand is equal to 45° minus the optimal Angle of the hand, it gradually approaches 45° , that is to say, 45° is the asymptotic Angle of the deflection Angle of the hand at a small speed.

When the speed increases gradually, the optimal Angle of release gradually tends to 45° , so the deflection Angle of release gradually tends to 0° , which is the asymptotic Angle of release Angle under the maximum speed.

4 Results and analysis

4.1 Analyse the change rule of data in the table

The initial speed V is the most important factor affecting the throwing distance. If the initial speed increases by 1 m/s, the throwing distance will be increased by 2–3 m. Therefore, athletes should do everything possible to improve the throwing technique, strengthen strength training, and try to improve the initial throwing speed. Under the condition of constant initial velocity, the throwing distance increases with the height of the shot. For every 5 cm increase in the height of the hand, the throwing distance will increase by about 4.5 cm. Therefore, when selecting materials, athletes should pay attention to both strength and height. In the case of similar strength, tall people should be chosen first.

There is an important relationship between throwing Angle and throwing distance. The throwing distance in the table is the maximum distance achieved under the optimal throwing Angle. Take the throwing height of 1.90 m and the throwing speed of 14.5 m/s for example, the optimal throwing Angle of $42^\circ 40'$ is 4240', and the corresponding distance is 23.28 m, if the ball is thrown from either $4140'$ or $4340'$, the throwing distance will

not be >23.26 m. The difference of 2 cm is extremely precious for high-level athletes, which often determines whether they can win the championship in major competitions. The only reason is the difference of 1° of ball shooting Angle, so it can be seen the importance of serious training and strengthening skills [7]. For a certain height of the ball, the Angle of the ball will increase with the increase of the initial velocity. For professional players, the Angle of the ball should be between 41° and 43° .

Table 1 can provide reference for athletes to find personal gap and improve throwing technique. Shot put height can be easily measured by taking the average height of a number of effective throws. Shot put speed can be measured by the velocimeter, or by the following methods. It can be obtained from Eqs. (3), (7), (8) and (9)

$$T = \frac{1}{g}(V \sin a + \sqrt{V^2 \sin^2 a + 2gh})$$

$$S = TY \cos a \quad (15)$$

Figure out the release velocity V of several effective throwing groups, and take its mean value as the athlete's release velocity. According to the athlete's release height and initial velocity, the athlete's maximum throwing distance can be predicted by looking up Table 1. If there is a big difference between the actual throwing distance and the distance shown in the table, it is probably due to the bad Angle of throwing the ball. Players should adjust the Angle of throwing the ball.

4.2 The results

There is an optimal shot Angle, and it can be calculated mathematically. But the precondition is to first determine the changing relationship between the Angle of the hand and the speed of the hand, the height of the hand (the speed of the hand has little influence on the height of the hand, if ignored, can only determine the changing relationship between the Angle of the hand and the speed of the hand). In this way, we can use the method of conditional extremum problem to calculate the best shooting Angle. When the functional relation (11) is applied to study the influence of shooting Angle and shooting speed on the shot put distance, the effect of index change on the shot put distance should be considered first [8]. When the shot putting Angle reaches a certain value, every increase of 10 will have little effect on the shot putting distance, and the effect will be smaller and smaller with the increase of shot putting Angle.

The contribution of shooting speed V to S is much greater than that of T and H , so we must strengthen this aspect of training in training and competition, that is, we must strengthen the training of arm strength, especially the explosive power, to maximise the speed of shooting. Release speed and release Angle restrict each other, there is an obvious dependence relationship. Therefore, when improving the speed of shooting, the shooting Angle should be considered comprehensively to adjust to the ideal state of the athletes. The height of the hand influences the throwing distance, which can be controlled by selecting the athletes with the height advantage, which is a difficult factor to control in the throwing process [9, 10].

5 Conclusion

Through the process of building a model from simple to complex, the mathematical principle of shot putting is revealed. However, there are still many problems to be solved, among which the height problem is complex. At the current level, it is not possible to find a reasonable height, because it involves many factors. The movement of the shot can be decomposed into the implicated movement of the human body centre of mass and the relative movement of the human body centre of mass. The motion of the shot meets the law of progressive speed, progressive energy and abrupt energy and the transmission law of moment of momentum. In the process of pushing the ball, the principle of maximum work, maximum impulse and maximum moment of momentum must be followed. However, the development of mathematical correlation will provide a useful attempt to establish a reasonable and scientific model. To improve and perfect the

shot put sports technology, we should not only take the physical movement characteristics of the shot as the basis but also consider the characteristics of the biological movement process before the shot is shot. It is more meaningful to give full play to the maximum biomechanical effect of the human body to get good results.

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