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Influence research on mechanics model-based athlete physical quality features affect shot

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ABSTRACT

Shot put as one of important composition items in athletics competition, throwing distance is main concerned problems by coaches and athletes. From general knowledge of throwing, it is known that there are mainly three factors affect throwing distance as initial speed when shot out of hands (m/s), throwing angle (angle) and throwing height (meter). By far, utilize physics kinematics knowledge researching shot put movement phenomenon is more, and less considering about throwing height influences when researching. The research on the basis of physics correlation knowledge, regard thrown shot as particle making projectile motion, and establish shot throwing distance mathematical model. Consider affect shot putter throwing main factors as shot throwing angle, shot initial speed and shot throwing height. According to model, it analyzes when throwing speed and throwing height are fixed, solve optimal throwing angle, let throwing distance be the maximum, it provides a basis for athletes scientific training. Carry out sensitivity analysis, it gets athletes' throwing distance key influence factor is throwing speed, therefore athlete in training process should more strengthen their throwing speed aspects training.

Key words: shot throw, throwing angle, mathematical model, throwing height

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INTRODUCTION

Due to computer technique rapidly development, it greatly increases mathematical practical problems solving abilities; due to computer technique fast development, it greatly increases mathematics solve practical problems ability. Make use of mathematical analysis and computer technique, it analyzes coach and athlete training influence factors, guide training with scientific and reasonable method. In practical training, athlete should positively play its own advantages and avoid its shortcomings, so that can achieve excellent results. Sai Qin-Bin in paper "World athletics throwing events sport performance situations as their causes primary investigation in 1987 to 1997, adopted grey modelling theory and normal mathematical statistics, and carried out systematically discussion on the time phase[1]. Dai Li-Qin in the article "Shot throwing angle and maximum performance function relationship", adopted projectile movement model and mathematical analysis exploring shot throwing distance and parabolic body maximum range function relationships, it got shot optimal performance theorem, shot optimal throwing speed and optimal throwing angle formulas[2]. Wang Wei-Guo in the article "Excellent throwing athletes special technical training", analyzed excellent throwing athletes special technical training from theoretical knowledge and practical operation, stated strength training method and way that should make simultaneously training on technique and strength[3]. Zhuang Ming-Qian, Yang Lei in article "Shot throwing process modelling and influence factor analysis", it adopted mechanics knowledge establishing shot throwing process models, carried out perfect analysis of models, and applied genetic algorithm solving throwing optimal angle, and carried out sensitivity analysis of each factor, finally defined each factor affects shot throwing distance master-subordinate relationships, it provided effective basis for athletes reasonable and scientific training plans making[4-6].

Shot throwing distance mainly is up to ball speed, angle and hands height. Among them, initial speed has the maximum effect on throwing distance, professional athletes by long-term hard training, ball out of hands speed

almost doesn't change, throwing height is also relative defined quantity, therefore, look for optimal throwing angle then becomes the most important path to improve shot throwing technique already achieved furthest throwing distance; throwing shot, angle, height release speed release point process has some connections with air resistance [7, 8]. To further understand every athlete respective throwing height, throwing speed to carry out throwing, what throwing angle should be adopted can fully play throwers' present physical condition and play their potentials to the greatest limits so that generate best throwing distance [9].

This paper by establishing mathematical model and computer simulation, it analyzes throwing distance and initial speed 、throwing angle and throwing height three factors relationships, it gets defined optimal throwing angle for different throwing speed, compares throwing result sensitivity degree to throwing speed and throwing angle. It is very important to guide throwing and training as well as further perfect throwing theory.

SHOT THROWING MATHEMATICAL MODEL

Shot throw competition requires that athlete in the circle with diameter of $2.135m$ throws shot with weight of $7.275kg$ (men), 4.0kg(female)shot to 34.92° fan region, as Figure 1 shows. Observe athletes competition videos, it finds their throwing angle are relative bigger, normally in 38^0-45^0, some arrives at 55^0 as highest, then how to throw shot further; For how to let shot throw furthest, it only needs to solve shot pace time in the air as well as shot speed in horizontal direction; shot pace time after throwing can be solved by after throwing shot vertical direction first moves with upward speed to static, then makes free falling and drops to the ground. This paper establishes model discussing following questions:

- Take throwing speed, throwing angle, throwing height as parameters, establish shot throwing mathematical model.
- Based on that, given throwing height, defines optimal throwing angle for different throwing speeds. Make comparison of throwing results sensitivities to throwing speed and throwing angle.

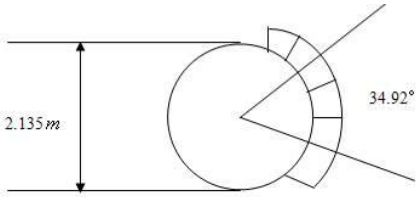

Figure 1: Shot throwing court

In case ignoring air resistance, regard thrown shot as a particle makes parabola movement, after shooting, shoot oblique projectile movement in a vertical plane, we shot vertical axis (is also called y axis), axis crosses ground shot drop point direction as transversal line(is also called x axis), rectangular plane coordinate system establishment is as Figure 2 shows.

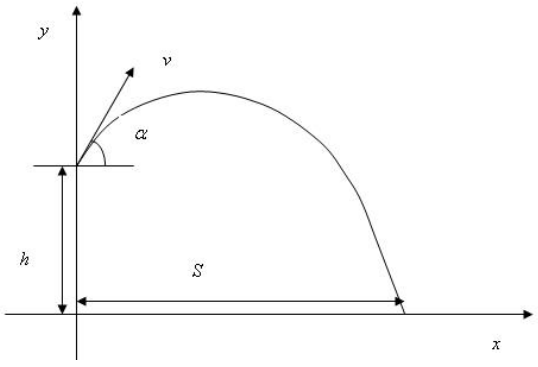

Figure 2: Shot rectangular plan coordinate system

Solve shot trajectory equation when it is out of hands. Given shot out of hands at time t moving point coordinate to be (x, y), shot throwing time to be t, shot throwing speed to be v, shot throwing angle to be α, by oblique up cast movement physics knowledge, it respectively lists shot movement equations in horizontal direction and value direction. It solves formula (1):

$$\begin{cases} x = v\cos\alpha \bullet t \\ y = v\sin\alpha \bullet t - \dfrac{1}{2}gt^2 + h \end{cases} \tag{1}$$

With simultaneous system of equations, it solves $y = h - \dfrac{gx^2}{2v^2\cos^2\alpha} + x \bullet \tan\alpha \quad (y \geq 0)$. When shot grounds that is $y = 0$, it has formula(2):

$$h - \frac{gx^2}{2v^2\cos^2\alpha} + x \bullet \tan\alpha = 0 \tag{2}$$

It solves:

$$x_1 = \sqrt{\frac{2hv^2\cos^2\alpha}{g} + \left(\frac{v^2\sin 2\alpha}{2g}\right)^2} + \frac{v^2\sin 2\alpha}{2g}$$

$$x_2 = -\sqrt{\frac{2hv^2\cos^2\alpha}{g} + \left(\frac{v^2\sin 2\alpha}{2g}\right)^2} + \frac{v^2\sin 2\alpha}{2g}$$

While due to $x_2 < 0$, get rid of x_2, it gets shot throwing distance mathematical expression (3):

$$S = \sqrt{\frac{2hv^2\cos^2\alpha}{g} + \left(\frac{v^2\sin 2\alpha}{2g}\right)^2} + \frac{v^2\sin 2\alpha}{2g} \tag{3}$$

From above formula, we can find that under certain circumstance, athlete increases shot throwing speed can let shot throwing distance be further, which is just match to our practical life scenes. Therefore, when coach selects athletes, he had better select robust with stronger explosive force athletes, because they can let shot achieve larger throwing speed in throwing process, which can better improve athletes' throw shot performance. In order to verify model rationality, we compare theoretical result with actual result by a group of data, and calculate theoretical result and actual result error percentage; if errors between theoretical result and actual result are getting bigger, then the model is more unreasonable, if errors between theoretical result and actual result are getting smaller, then the model is more reasonable; it is thought that in case theoretical error and actual error less than 5%, the model is regarded as reasonable. Athlete actual result and theoretical result comparative table is as Table 1 shows.

Table 1: Actual result and theoretical result comparative table

Staff	Throwing speed(m/s)	Throwing height(m)	Throwing angle$(°)$	Actual result(m)	Theoretical result(m)	error with actual
Athlete one	13.961	2.052	38.856	21.763	21.874	+0.11%
Athlete two	13.593	2.024	37.942	20.713	20.543	-0.98%
Athlete three	14.084	1.961	35.232	35.756	21.752	-1.25%
Athlete four	13.653	2.010	38.678	20.321	20.425	+0.54%
Athlete five	13.269	2.020	40.165	19.654	19.568	+0.81%

From Table 1 data, it is clear for us that within error permissible range (errors within 5% all regarded as reasonable), calculation results from shot throwing model and actual projection distance are relative matched.

For every shot putter, his v and h can approximately thought to be a constant. Therefore every athlete throwing shot distance S is mainly up to the sizes of shot putter throwing angle α, it can regard throwing angle α as throwing distance S function.

Make derivation on α from above equation two sides, it gets formula(4):

$$S' = \frac{1}{2g} \times \left[\frac{2\sin 2\alpha \bullet \cos 2\alpha \bullet 2v_0^4 - 8gHv_0^2\sin 2\alpha}{2\sqrt{\sin^2 2\alpha v^4{}_0 + 4gHv_0^2(1+\cos 2\alpha)}} \right] \tag{4}$$

According to differential equation solution conditions, let $S'=0$, that is formula(5):

$$\frac{1}{2g}\times\left[\frac{2\sin 2\alpha\bullet\cos 2\alpha\bullet 2{v_0}^4-8gH{v_0}^2\sin 2\alpha}{2\sqrt{\sin^2 2\alpha v^4{}_0+4gHv_0^2(1+\cos 2\alpha)}}\right]=0 \tag{5}$$

By sorting out, it gets formula(6)

$$-\cos 2\alpha=\frac{-2gh\sin 2\alpha+\sin 2\alpha\bullet\cos 2\alpha v_0^2}{\sqrt{\sin^2 2\alpha v^4{}_0+4gHv_0^2(1+\cos 2\alpha)}} \tag{6}$$

By simplifying, it gets formula(7)

$$\cos 2\alpha=\frac{\sqrt{v_0^4+4gH\left(v_0^2+gH\right)}-v_0^2}{2\left(gH+v_0^2\right)} \tag{7}$$

That is $\alpha=\frac{1}{2}\arccos-\frac{gH}{gH+v_0^2}$

When throwing angle is $\alpha=\frac{1}{2}\arccos-\frac{gH}{gH+v_0^2}$, shot throwing distance S exists maximum value, input existing extreme point α, it can work out $S_{\max}$ and get formula(8):

$$S_{\max}=\frac{v_0\sqrt{v_0^2+2gH}}{g} \tag{8}$$

MATHEMATICAL MODEL PARAMETER SENSITIVITY ANALYSES

Above shot throwing mathematical model has already discussed how athlete do can effective improve shot throwing distance from throwing height, throwing angle, throwing speed these three independent variables. It is normally thought that athletes' heights almost unchanged, so it can find out greatest impact factor from shot putter throwing angle and their throwing speed such two factors, which is to compare two sensitivity values.

Here, apply numeric analysis range size in comparing throwing speed v and throwing angle α sensitivity size, so that define throwing speed, throwing angle the two factors influences extents on shot throwing distance. We let putter throwing shot moment throwing height to be $2\,m$, throwing speed changes between $10\,m/s$ and $15\,m/s$, throwing angle changes between 37° and 43°. Use mathematical software MATLAB programming; it gets result as following Table 2 shows.

Table 2: Results achieved from mathematical software MATLAB

α / v	37	38	39	40	41	42	43	Range
10	11.97	12.02	12.04	12.05	12.06	12.03	12.01	0.05
11	14.12	14.16	14.19	14.20	14.22	14.21	14.19	0.12
12	16.41	16.47	16.52	16.54	16.57	15.56	15.57	0.16
13	18.91	18.98	19.05	19.11	19.12	19.13	19.14	0.24
14	21.57	21.72	21.78	21.85	21.89	21.90	21.91	0.31
15	24.48	24.62	24.71	24.82	27.84	24.87	24.89	0.43
Range	12.46	12.61	12.66	12.74	12.83	12.86	12.89	

From above Table 2 data, it can be found that athletes' throwing speed sensitivities change between 12.46 and

12.89 m . Athletes' throwing angle sensitivities change between 0.05 m and 0.43 m . It indicates v is affecting S uppermost factor, v sensitivity is higher than α sensitivity.

SHOT THROWING MECHANICS MODEL

In fact, above model only analyzes shot throwing instant and after shot throwing statuses, but to analyze shot throwing speed and shot throwing angle the two closely function relationship, we need to make physical mechanics analysis of shot throwing instant, it can establish following mechanical model.

Shot throwing process is completed through common acting form shot sliding phase and shot exerting phase. In these two phases, shot putter push force F in shot keeps constant, that is to say, shot force direction and throwing angle size are the same, as Figure 3 force analysis.

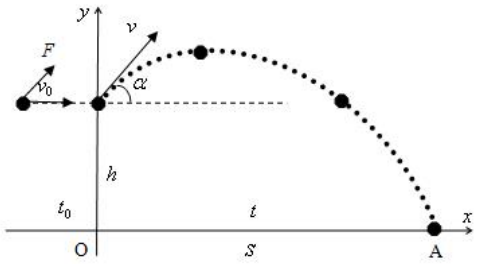

Figure 3: Force analysis

$x(t)$ is shot movement horizontal coordinate , $y(t)$ is shot movement vertical coordinate, and establish following equations as formula(9).

$$\begin{cases} mx''(t) = F\cos\alpha \\ my''(t) = F\sin\alpha - mg \end{cases} \tag{9}$$

F is push force, α is throwing angle, m is shot mass, make integration of formula and get formula(10):

$$\begin{cases} mx'(t) = Ft_0\cos\alpha + C_1 \\ my'(t) = Ft_0\sin\alpha - mgt_0 + C_2 \end{cases} \tag{10}$$

Input $C_1 = v_0, C_2 = 0$ into above formula(10), it gets formula (11):

$$\begin{cases} mx'(t) = Ft_0\cos\alpha + v_0 \\ my'(t) = Ft_0\sin\alpha - mgt_0 \end{cases} \tag{11}$$

Compound vertical direction speed and horizontal direction speed, then it get shot actual speed v, so that can get following equation (12):

$$v = \sqrt{x'(t)^2 + y'(t)^2}$$
$$v = \sqrt{\left(\frac{F^2}{m^2} + g^2 - \frac{2F}{m}g\sin\alpha\right){t_0}^2 + v_0^2 + \frac{2F}{m}t_0 v_0\cos\alpha}$$
$$s = \frac{v^2\sin 2\alpha + v\cdot\sqrt{v^2\sin^2\alpha + 4gh\cos^2\alpha}}{2g} \tag{12}$$

Calculate above formula, it gets formula(13):

$$v = \sqrt{\left(\frac{F^2}{m^2} + g^2 - \frac{2F}{m}g\sin\alpha\right){t_0}^2 + v_0^2 + \frac{2F}{m}t_0 v_0\cos\alpha} \tag{13}$$

It can get from it the shot throwing speed equation, by analyzing equation, we can know that shot joint speed size has connections with push force, throwing angle and shot mass as well as other factors.

CONCLUSION

From shot throwing mathematical model, it is clear that tall and strong as well as stronger explosive force athlete can get better results, but from another perspective, the two factors have limits in available improving extent. In practical life, change shot throw angles on the contrary will be more easily implemented which can better improve athlete throw shot performance.

For shot throw model listed shot joint speed equation, carry out differential solution. That is making use of $\frac{\partial s}{\partial \alpha}=0$ to solve α. It gets equation formula(14):

$$\cos 2\alpha=\frac{gh}{gh+v^2}=\frac{g}{g+\frac{v^2}{h}} \tag{14}$$

It is clear from it when v value keeps constant, the bigger h value is, the smaller α value would be; when h value keeps constant, the smaller h value is, the bigger α value would be. Due to $\alpha\in\left[0,\frac{\pi}{2}\right]$, when throwing height is equal to 0, shot throw furthest distance corresponding throwing angle is equal to 45° ($\alpha=45°$). But every athlete throwing height goes beyond 0(that is $h>0$); however optimal throwing angle is different between practical situation and theory.

After revising shot throwing mathematical model more conform to actual, we get shot throwing mechanical model formula, it states shot throwing moment initial speed v and throwing angle α function relations.

In formula $v=\sqrt{\left(\frac{F^2}{m^2}+g^2-\frac{2F}{m}g\sin\alpha\right)t_0{}^2+v_0^2+\frac{2F}{m}t_0v_0\cos\alpha}$, we can see that following by throwing speed v_0、time t_0 and push force F increasing, joint speed v will accordingly increase. Therefore, α and v mutual relation can be expressed like this:In practical life, it will appear approximate optimal throwing angle; on the contrary competition performance will reduce. Because shot throwing mathematical model got optimal throwing angle is on the condition that $h=0$ not $h>0$ special condition optimal throwing angle, actual optimal throwing angle is smaller than 45°.

From above formula, it can get following conclusions:

- Athlete throwing furthest distance has a direct relationship with athlete throwing speed, athlete throwing height(that is athlete height); when every shot putter throwing initial speed keeps constant, throwing distance will increase with throwing height increasing; when every putter throwing height keeps unchangeable, the larger throwing speed is, the further shot throwing furthest distance would be.
- Athlete optimal throwing angle is associated with athlete throwing speed, athlete throwing height (that is athlete height);when athlete throwing speed keeps constant, shot optimal throwing angle size will increase with shot throwing height decreasing, on the contrary, shot optimal throwing angle size will decrease with shot throwing height increasing; when every athlete throwing height keeps constant, shot optimal throwing angle will increase with shot throwing speed increasing, on the contrary, shot optimal throwing angle size will decrease with shot throwing speed decreasing.
- When athlete throwing angle α and throwing speed v keep constant, the taller athlete throws shot distance would be further. Therefore, when select throwing shot athletes, it should try to select tall athletes.
- Athlete in daily training process, increase throwing speed and explosive force training, can effective increase shot throwing distance, which is more helpful for improving athlete performance.

REFERENCES

[1] Sai Qing-bin. *Sichuan Sports Science*, **2000**, (1), 24-27.
[2] Wang Wei guo; Li Zhi hua; Xu Yi cheng. *Journal of Shanghai Physical Education Institute*, **2003**, 27(1),38-41.

[3] WANG Weiguo. *Journal of Chengdu Physical Education Institute*, **2004**, 30(3), 38-41.
[4] ZHANG Yong; WANG Yu-Feng. *Journal of Xi'an Institute of Physical Education*, **2011**, 28(6), 746-751.
[5] Li Chunlei. *Journal of Shanghai Physical Education Institute*, **2002**, 26(2), 51-57.
[6] Zhang B.; Zhang S.; Lu G.. *Journal of Chemical and Pharmaceutical Research*, **2013**, 5(9), 256-262.
[7] Zhang B.; *International Journal of Applied Mathematics and Statistics*, **2013**, 44(14), 422-430.
[8] Zhang B.; Yue H.. *International Journal of Applied Mathematics and Statistics*, **2013**, 40(10), 469-476.
[9] Zhang B.; Feng Y.. *International Journal of Applied Mathematics and Statistics*, **2013**, 40(10), 136-143.