ISSN : 0974 - 7435 Volume 10 Issue 7

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(7), 2014 [1927-1933]

# Quantitative analysis of athlete technical feature affecting shot performance based on matlab simulation

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## ABSTRACT

By establishing shot throwing mathematical model, regard shot as a particle, ignoring air resistance. In case it researches landing point and throwing point in the same horizontal line, use Newton mechanics and relative physical knowledge making force analysis of shot,only suffers gravity $G$, it is clear that it makes constant movement in horizontal direction and makes constant decelerated movement in vertical direction, and so it can get $L$ and $v$, $\alpha$ relationships. And it researches landing point and throwing point are not in the same horizontal line status according to practice, finally it gets $L$ and $v$, $\alpha$ as well as $h$ quantitative correlations, and according to searched data, use quantitative analysis method, through Matlab programming, it gets correlation simulation figure, respectively gets corresponding best release speed, release angle and release height.

## KEYWORDS

Force analysis; Quantitative analysis; Shot technique; Biomechanics.

## INTRODUCTION

Sports as a kind of culture, it has already become indispensable part of society and individual, it represents a country and nation development level, especially for present competitive sports which is not only a fiercely sports competition but also a science and technology combating. This paper analyzes shot movement from mechanical perspective, solves cast distance and release height, release speed as well as release angle relationships.

From oblique object mechanical principle formula $L = \frac{v^2 \sin 2\alpha}{g}$, it is clear that distance $L$ is equal to release initial speed square $v^2$ and release angle sine $\sin 2\alpha$ product divides gravity accelerated speed $g$ apparatus flying distance is mainly up to release speed. It provides scientific applying evidence for us improving throwing technique and development sports results in physical education and sports training. Practice proves that in shot putting, due to people's height, arms lengths and other factors are not totally the same, ball release point and landing point are not in the same horizontal plane, it exists a release height, and release point heights differences let sports parabola changes on the original basis. When there is a certain release initial speed, release angle and release height, it will produce a fixed movement trajectory. Therefore in the three basic factors, if one factor changes, movement trajectory will change accordingly.

For relative influence factors quantitative analysis, it can provide reference data for undertaking shot teaching and sports training, applying mechanical principle and practice combined development throwing distance can make sports training more scientific and effective. It provides theoretical basis for shot putting establishing a set of theory system, looking for maximum flying distance initial conditions as well as shot talents selection and training.

## SHOT THROWING MODEL

Due to shot mass is large, volume is small, initial speed is relative small, it can regard it as particle and can ignore air resistance.

### Landing point and throwing point in the same horizontal line

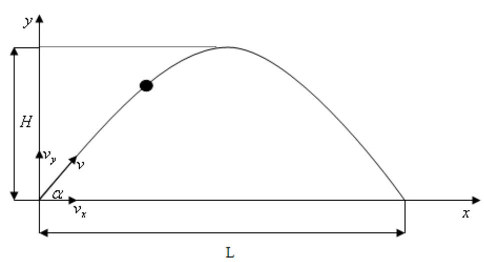


**Figure 1 : Same horizontal line movement trajectory**

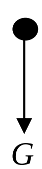


**Figure 2 : Mechanical analysis**

Make force analysis of shot:

As Figure 2 show, its vertical direction accelerated speed $a = -g \; m \cdot s^{-2}$, its horizontal movement is constant movement, its vertical movement is constant decelerated movement, therefore its trajectory is as Figure 1show.

Make decomposition to initial speed as Figure 1:

$$\begin{cases} v_x = v\cos\alpha \\ v_y = v\sin\alpha \end{cases} \quad (1)$$

Speed in movement process:

$$\begin{cases} v_{x1} = v_x \\ v_{y1} = v_y - gt \end{cases} \quad (2)$$

Journey in movement process:

$$\begin{cases} L = v_{x1} \cdot t \\ 0 = v_{y1} \cdot t - \frac{1}{2} gt^2 \end{cases} \quad (3)$$

Therefore its kinematic equation is:

$$L = \frac{v^2 \sin 2\alpha}{g} \quad (4)$$

From equation formula (4),it is clear that $L$ is in direct proportion to $v$ quadratic that $v$ increases a little, $L$ increases by square times, so $v$ is the first factor deciding $L$. On the other hand, when sine function value arrives at maximum, $\alpha = \pi/4$, therefore when $\alpha$ is equal to 45°, $L$ is the maximum.

For shot throwing distance, many coaches also use formula (4) to explain that is to improve shot performance, release speed improvement is the first element. Because shot throwing has an initial height, use 45°casting is not the best,it should less than 45°.

## Landing point and throwing point are not in the same horizontal line

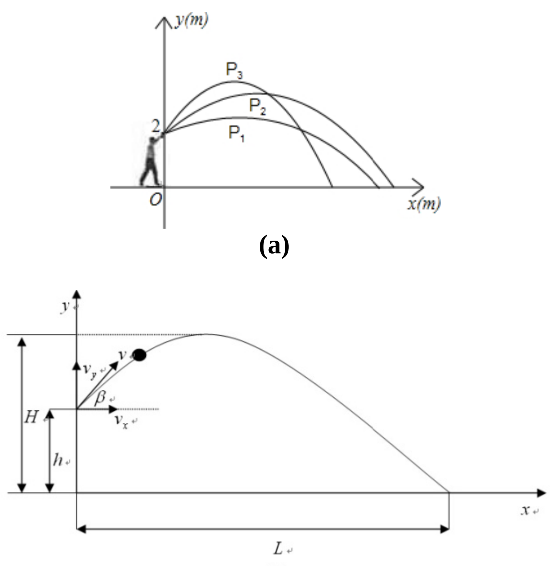


**Figure 3 : Movement trajectory not in the same horizontal line**

Shot vertical direction accelerated speed $a = -g\ m \cdot s^{-2}$, its horizontal movement is constant movement, its vertical movement is constant variable movement, so its trajectory is as Figure 3 show. Speed equation formula in movement is:

$$\begin{cases} v_{x2} = v\cos\beta \\ v_{y2} = v\sin\beta - gt \end{cases} \quad (5)$$

Given shot arriving at top point time to be: $t_1$;
Shot arriving at ground time as: $t_2$
Therefore:

$$t = t_1 + t_2 \quad (6)$$

$$\begin{cases} t_1 = \dfrac{v\sin\beta}{g} \\ t_2 = \sqrt{\dfrac{2H}{g}} \end{cases} \quad (7)$$

And

$$H = h + v\sin\beta \cdot t_1 - \frac{1}{2}gt_1^2 \quad (8)$$

Then:

$$t = \frac{v\sin\beta}{g} + \sqrt{\frac{2h}{g} + \frac{v^2\sin^2\beta}{g^2}} \quad (9)$$

Displacement equation formula in movement is:

$$\begin{cases} L = v\cos\beta \cdot t \\ -h = v\sin\beta \cdot t - \dfrac{1}{2}gt^2 \end{cases} \quad (10)$$

It solves:

$$L = v\cos\beta\left(\frac{v\sin\beta}{g} + \sqrt{\frac{2h}{g} + \frac{v^2\sin^2\beta}{g^2}}\right) \quad (11)$$

According to formula (7), by quantitative analysis method, it is clear when shot gets maximum throwing journey:

By data searching,it gets TABLE 1, assume that the release height is between1.75-2.10 $m$, throwing shot speed is between 13.2-14.2 $m \cdot s^{-1}$, $g = 9.8\ m \cdot s^{-2}$. By Matlab programming, it can get $L$ and $\beta$ image relationships (horizontal axis is $\beta$, and define it value range is $(0, \pi/3)$, vertical coordinate is $L$ ),respectively takes release height and release speed two extremes. Figure 4 used release speed $v$ is13.2 $m \cdot s^{-1}$, release height $h$ is 1.75 $m$, it gets maximum cast distance $L = 19.442m$, corresponding $\beta$ is converted into angle that is 40.19°;Figure 5 release speed $v$ is14.2 $m \cdot s^{-1}$, release height $h$ is 2.10 $m$, it gets maximum cast distance as $L = 22.85m$ ,corresponding $\beta$ is converted into angle that is 42.2°. Therefore, if it want to achieve extraordinary performance, release angle $\beta$ practical value should around 41° that is the best.

**TABLE 1 : Different release speed best projection angle**

| Release speed v (m/s) | Releas angle β (°) | Release height h (m) | Shot performance L (m) |
|---|---|---|---|
| 13.51 | 38.69 | 2.00 | 20.30 |
| 14.08 | 35.13 | 1.95 | 21.76 |
| 13.82 | 30.80 | 2.10 | 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 | 39.93 | 2.05 | 19.50 |
| 13.86 | 39.06 | 2.04 | 19.83 |
| 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 |
| 13.95 | 39.06 | 2.04 | 21.66 |
| 13.95 | 36.13 | 1.88 | 20.40 |
| 13.45 | 38.15 | 2.06 | 20.43 |
| 13.76 | 34.38 | 1.97 | 20.90 |
| 13.58 | 37.75 | 2.02 | 20.78 |
| 13.48 | 40.56 | 2.00 | 20.33 |
| 13.39 | 34.67 | 2.01 | 19.85 |

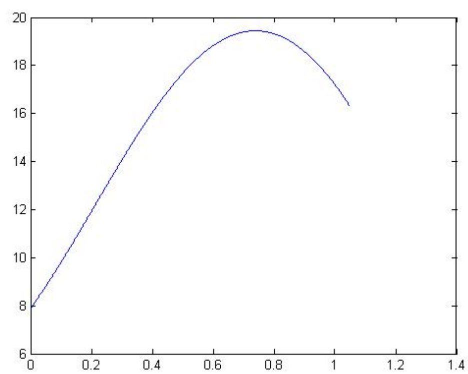


**Figure 4 : Release speed v is 13.2 $m \cdot s^{-1}$**

By data searching, assume that release angle is 41°, throwing shot speed is between 13.7 $m \cdot s^{-1}$, $g = 9.8\, m \cdot s^{-2}$. By Matlab sequence, it can get $L$ and $h$ image relationship (horizontal axis is $h$, vertical coordinate is $L$). It gets Figure 6, as following show: $L$ and $h$ have increasing relations as following (Because $h$ coefficient is quite small, and considering release height will less or equal to 2.5 $m$, during $h$ interval $L$ and $h$ are almost in linear).

By data searching, assume the release angle is 41°, release height is 2.0 $m$. Use Matlab to get $L$ and $h$ image relations (horizontal axis is $v$, vertical coordinate is $L$). It gets Figure 7, as following show: $L$ and $v$ are increasing quadratic.

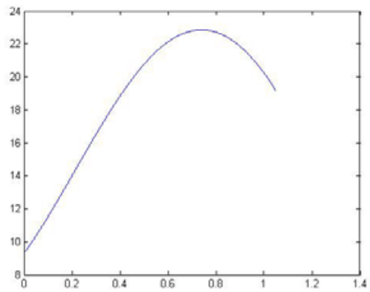


**Figure 5 : Release speed $v$ is $14.2\,\mathrm{m \cdot s^{-1}}$**

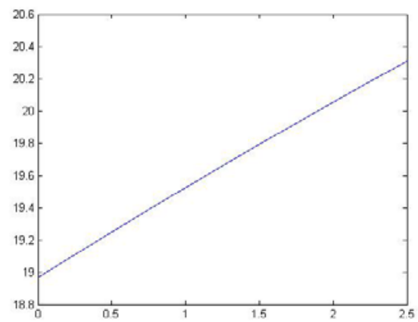


**Figure 6 : L and h image relations**

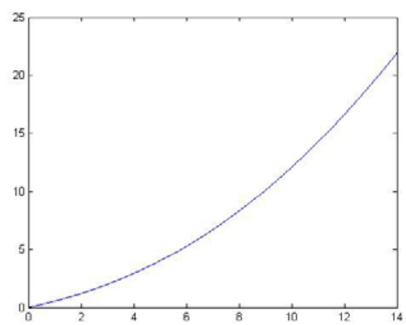


**Figure 7 : L and v quadratic increasing**

## CONCLUSIONS

From formula (7), it is clear that shot event main influence factors are release speed $v$, release angle $\beta$, release height $h$. By Figure 4 and Figure 5,it can get best release angle is 41°, athlete can master roughly release angle by short-term training, and when release height and release speed are fixed, as well as release angle gets close to 41°, from TABLE 2, it is clear certain angle deflecting has no great influences on cast distance. And when athletes take training, $v$ and $h$ are stable, they can make gradual improvements on the original release angle.

**TABLE 2 : When release height, speed are fixed, different release angles influences on performance**

| | | | $h = 2\,\mathrm{m}$ | $v = 10\,\mathrm{m \cdot s^{-1}}$ | | | |
|---|---|---|---|---|---|---|---|
| $\beta$ | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| $L$ | 10.12 | 10.894 | 11.499 | 11.892 | 12.038 | 11.916 | 11.514 |
| % | | 1.08 | 1.06 | 1.03 | 1.05 | 0.99 | 0.97 |

By comparing Figure 7 with Figure 6, it is clear that $v$ has larger influences on $L$, so athletes should increase their explosive force, taking more training on gliding and turning to improve release speed. As for $h$, it is a fixed quantity to athletes, because it is up to their own height and arms lengths, which can be regarded as excellent athletes' one selection criterion

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