A New Method of Measuring and Evaluating the Shot Technique

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The purpose of this study was to show a new method of determining the result of shot putting. The technique can be evaluated by two biomechanical factors, Speed of Release and Angle of Release. Generally, there were several ways to obtain these these two factors, principally by the historical cinematographic analysis method in sports mechanics. The new method to be discussed was different from film analysis. It revealed that the shot technique could be measured by throwing flight time. An excellent technique has an optimum flight time. In this study the relationship between flight time, angle of release, height of release and throwing distance was determined by computer model calculations, and the measuring and evaluating method of the throwing technique was provided by mechanical laws and data which had been obtained.

METHODS

Two mathematical models had been used in this research. The program was constructed and then executed on an IBM-PC/XT 286 computer as follows:

1. Theory Model (the mechanical character of this model that of the particle model).

$V_{o.} = \sqrt{(gT/2-H/T)^2 + (S/T)^2}$
$\theta_{o.} = Arctg[(gT^2-2H) / (2S)]$
$V_{o.}$ - The speed of release
$\theta_{o.}$ - The angle of release
T - The shot flight time

S - The distance from release point to landing point
H - The height of point of release
g - Acceleration due to Gravity

The following formula were computed from the laws of projectile motion as follows (see Figure 1)

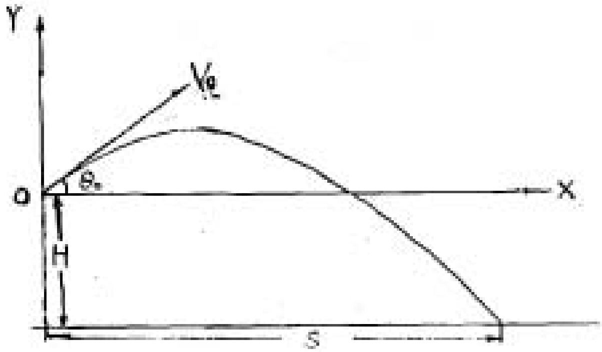

Figure 1

from: $-H = V_0 \sin \theta_0 . T - gT^2/2$

$S = V_0 \cos \theta_0 . T$

then: $V_0 \sin\theta_0 = gT/2 - H/T$

$V_0 \cos \theta_0 = S/T$

According to the vector quantities parallelogram:

$V_0 = \sqrt{(V_0 \sin\theta_0)^2 + (V_0 \cos\theta_0)^2} = \sqrt{(gT/2 - H/T)^2 + (S/T)^2}$

$\theta_0 = \text{Arctg}[(V_0 \sin\theta_0)/(V_0 \cos\theta_0)] = \text{Arctg}[gT^2 - 2H)/(2S)]$

2. Experimental Model (The mechanics of this model are those of a rigid body):

$S = M/(ckw).\ln[ckw/m.V_0\cos\theta_0(V_0\sin\theta_0 + \sqrt{V_0^2 \sin^2 \theta_0 - 2gH}/g + 1)]$

This formula was gained from an aerodynamic experiment of the shot put by the investigator. It can be changed as follows:

$S = M/(CKW).\ln[CKW/M.V. \cos \theta_0 . T + 1)]$

then:

$V_0 = \sqrt{(gT/2 - H/T)^2 + [M(CKW/T-1)/CKWT]^2}$

$\theta_0 = \text{Arctg}[(gT^2/2 - H)/(e^{(\frac{CKW}{M})S} - 1).\frac{CKW}{M}]$

S-distance from release point to landing

H-height of release

V_0-speed of release
θ_0-angle of release
T-shot flight time
C-resistance coefficient
W-area of cross section
K-air density of coefficient
M-mass of shot
g-acceleration due to gravity

Within a certain range of values which were given to S, H, and T, the result was calculated.

The **fixed** data given to S, H, T, were as follows:

S: 7-23m	AS = 1(m)
H:1.7 - 2.1(m)	AH = 0.05(m)
T: 0.5-4.5(sec)	AT = 0.1(sec)
M = 7.26(kg)	

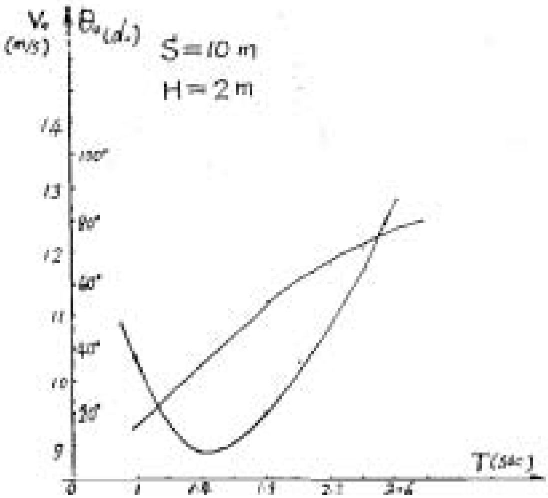

Figure 2

RESULTS AND ANALYSES

About 27,744 data were gained from calculations, some of these are represented in Table **1**. There were few differences between the theoretical model and experimental mode (see Figure 1). Results of the theory model were discussed in the variable analysis.

Table 1:

The speed and angle as related to the same distance, height and flight time.

S = **10m** H = 2m (notice: **T.M-Theory** Model **E.M-Experiment** model)

T(sec.)	V_o (m/sec)T.M	0_o(d.) TM	V_o (m/sec)E.M	0_o(d.)E.M
1.00	10.41	$16^{\circ}10'$	10.44	$16^{\circ}8'$
1.10	9.77	$21^{\circ}27'$	9.79	$21^{\circ}24'$
1.20	9.34	$26^{\circ}49'$	9.36	$26^{\circ}46'$
1.30	9.08	$32^{\circ}8'$	9.10	$32^{\circ}4'$
1.40	8.97	$37^{\circ}15'$	8.99	$37^{\circ}11'$
1.50	8.98	$42^{\circ}4'$	8.99	$41^{\circ}59'$
1.60	9.08	$46^{\circ}31'$	9.09	$46^{\circ}26'$
1.70	9.26	$50^{\circ}34'$	9.27	$50^{\circ}29'$
1.80	9.50	$54^{\circ}13'$	9.51	$54^{\circ}9'$
1.90	9.79	$57^{\circ}29'$	9.80	$57^{\circ}25'$
2.00	10.29	$60^{\circ}24'$	10.13	$60^{\circ}20'$
2.10	10.48	$62^{\circ}59'$	10.41	$62^{\circ}51'$
2.20	10.87	$65^{\circ}16'$	10.87	$65^{\circ}13'$
2.30	11.27	$67^{\circ}19'$	11.28	$67^{\circ}16'$
240	11.69	$69^{\circ}8'$	11.7	$69^{\circ}5'$
250	12.13	$70^{\circ}44'$	12.13	$70^{\circ}42'$

1. The Relationship Between Speed, Angle and Flight Under the Same Height of Point **of** Release **and** Same Distance.

It was observed that the angle became larger as the flight time increased, when the same height of point of release and same throwing distance were used. In other words, the Flight time would increase when the Angle of release increased. There was a positive and direct relationship between flight time and angle.

As illustrated in Figure 2 the speed emerged as a double curve law as flight time changed. At the lowest point of the V_o -T curve, **i.e.** the speed of release turned out to be larger when flight time increased, and was minimum at point T_o.

After point T_o had been passed, the speed increased as flight time increased. Height and distance had been observed, and it was implied that an optimum throwing technique can be gained whereby athletes throw the shot to certain distance with his maximum speed at the minimum speed on the curve.

2. The Relationship Between Speed, Angle and Flight Time Under Same Height and Different Distance.

It had been found from Figure 3, that in order to throw different distance with same flight time at the same height, the angle decreased when

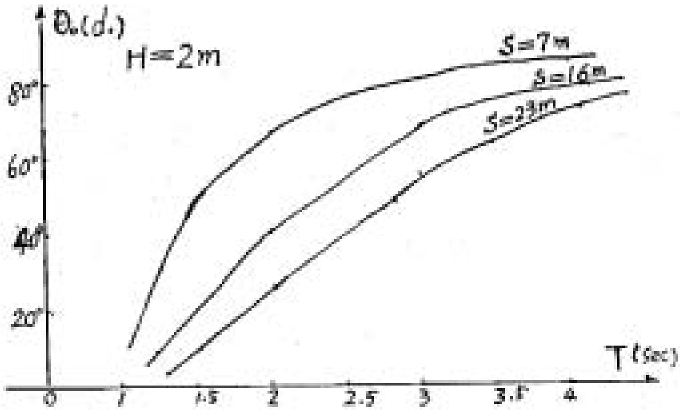

Figure 3

distance increased i.e. the relation curve (θ_0 -T) moved down as the distance increased. At the same time, the speed increased as the distance increased. The relative curve V_0 **-T** moved up as distance increased (Figure 4.) It can be seen that the relation curve moved toward the right when distance increased. This result agreed with the conclusion that distance was influenced by speed and angle of release, this conclusion was known in the throwing theory.

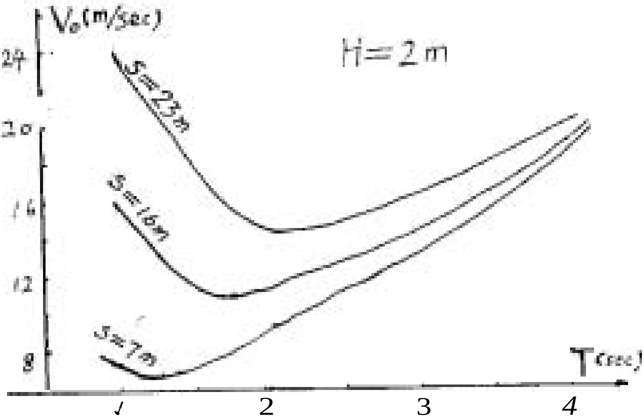

Figure 4

3. The Relationship Between Speed, Angle and Flight Time Under the Same Distance and Different Height of Point of Release.

The angle had a little decrease, as height increased under the same **dis**tance and different height, if flight time was the same (Figure 5). It was also found that the range decreased as the height increased under the same distance. It can be seen from Figure 6 that, if flight time is the same, the necessary speed has a little **decrease** as height increased. Meanwhile, the same changing range of up and down **parallely** was found in the calculations. Thus indicating that the influence uponthrowing distance by height is not obvious. This agreed with the conclusion we have drawn.

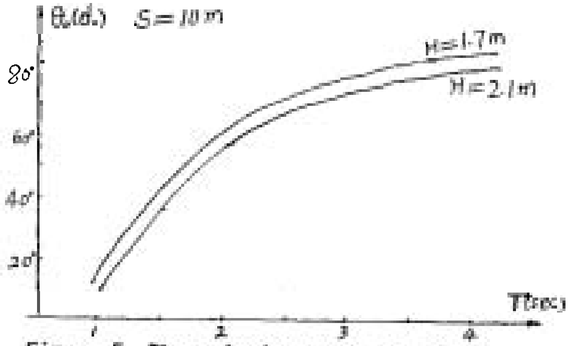

Figure 5. The relation curve of θ_0—T under the same distance and different height

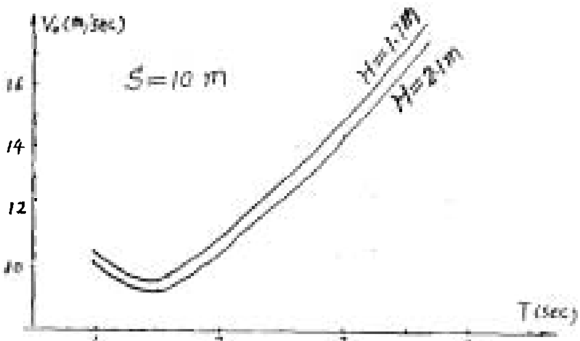

Figure 6. The relation curve of V_0 —T under *the* same *distance* and different height

DISCUSSION

1. The Optimum Flight Time

It has been known that there are many combinations between speed and angle of release under the certain height of release. Among them, there must be an optimum combination whose angle is defined as an optimum angle under this condition. Also, it can be stated that the speed related to optimum angle is a minimum among **all** combinations. The optimum angle related to minimum speed of any thrower can be calculated in order to get maximum distance when the maximum speed is to be handled as the minimum point of the curve **(V_o -T)**. This result is the target used in obtaining the optimum angle of throwing.

It is very clear that a flight time related to minimum speed and optimum angle exist and can be gained in any case. In other words, there is always a certain flight time T, which is related to the combination between minimum speed and optimum angle for any height and distance. This flight time is definited as optimum flight time in this study. If this optimum time is measured, the minimum speed and optimum angle needed in this case can be calculated (see Table 2 and 3).

There is also a point in the combination, where the optimum flight time is a fmed number, as the shot is thrown to a fmed distance from a different height of point of release (see Table 3). This will show that the optimum combination ,speed and angle, for a certain thrower whose point of release is not changed is a single value when he wants to throw the shot to a **fixed** distance.

Table 2.

The Data of Flight Time, Minimum Speed and Optimum Angle Under the Same height of Release and Different Throwing Distance.

H = 2m

		T.M		E.M	
S	T	V_o	θ_o	V_o	θ_o
9	1.38	8.41	39°10'	8.42	39°06
10	1.44	8.96	39°13'	8.98	39°08'
11	1.52	9.49	40°17'	9.50	40°11'
12	1.58	9.98	40°27'	10.00	40°22'
13	1.64	10.45	40°41'	10.48	40°35'
14	1.70	10.91	40°59'	10.93	40°52'
15	1.76	11.34	41°18'	11.37	41°11'
16	1.82	11.77	41°39'	11.79	41°32'
17	1.88	12.17	42°1'	12.20	41°53'
18	1.94	12.57	42°25'	12.60	42°16'
19	2.00	12.95	42°49'	12.98	42°49'
20	2.04	13.32	42°36'	13.36	41°50'
21	2.10	13.68	43°3'	13.72	42°53'
22	2.14	14.03	42°59'	14.08	42°08'
23	2.20	14.38	43°22'	14.42	42°37

Table 3.

The Relationship between Flight Time, Minimum Speed and Optimum Angle Under the Same Throwing Distance and Different Height of Release

S = 10m

	H(m)	1.7	1.75	1.80	1.85	1.90	1.95	2.00	2.05	2.10
	T(sec)	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
T.M	V_o(m/s)	9.1	9.01	9.03	9.01	8.99	8.96	8.96	8.94	8.92
	θ_o(d)	40°14'	40°4'	39°54'	39°44'	39°34'	39°23'	39°13'	39°2'	38°52'
E.M	V_o(m/s)	9.11	9.09	9.07	9.04	9.02	9.00	8.98	8.96	8.93
	θ_o(d)	40°10'	39°59'	39°49	39°39'	39°29'	39°19'	39°8'	38°58'	38°48'

2. The Significance of Optimum Flight Time

It had been seen from the above data that a certain flight time is related to a certain combination between speed and angle when height and distance are fmed. So the method of measuring flight can be adopted to **find** out an optimum combination between speed and angle of release **fordif-**ferent throwers. The nature of optimum flight time which is not changed in fmed height and fmed distance, and which is changing as the height and distance change provide us with the possibility to determine the throwing technique for different shot athletes.