THE RELATIONSHIP BETWEEN SHOT PUT TECHNIQUE AND MECHANICAL ENERGY OUTPUT OF CHINESE FEMALE SHOT-PUTT ATHLETES

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The purpose of this study was to examine the relationship between the shot-putt technique and the energy output in Chinese female shot-putt athletes. Three-dimensional photogrammetry and a video analysis system were used to study the shot-put technique from the perspective of the body's output of mechanical energy. It was found that, during the sliding phase, the main energy output was the kinetic energy of translation. During the transitional phase, the body expends the least energy in delivery of the shot. In the beginning of the push-off phase, the maximum amount of mechanical energy and kinetic energy was used. At the end of the push-off phase the energy output decreased. Otherwise, the relationship between the energy output with the shot putt result and technique indicated that the trunk's energy output were closely correlated with the shot putt result. Knowledge of the trunk's movement is of great importance to the shot-put technique.

KEY WORDS: three-dimensional video analysis, mechanical energy, kinetic energy of rotation, kinetic energy of translation, shot putt technique

INTRODUCTION: The back gliding shot put is a complex skill in track events. The influence of the shot putt technique on the success of the result is considerable. Many researchers on the shot putt technique have concentrated on kinematic analysis. There has been very little assessment of the contribution of the movements from each part of the body to the shot putt result. The purpose of this study was threefold: One, to find the relationship between the body's mechanical energy output and the technique. Two, to examine the effects of the magnitude of the mechanical energy output of each part of the body on the shot putt result; and finally to apply the results to teaching and training.

METHODS: The athletes selected for this study were 8 Chinese experienced female shot putters for whom the mean of their personal best shot put was 19.32 m. Close-range Dynamic Three- dimensional cinematogrammetry and 3 video recorders (M9000 Panasonic) were used to record the throwing actions. The Engine Sport Video Analysis system (Beijing Body Information Institute) was used to analyze the movements in three dimensions.

Analysis method. The shot putt technique was broken down into four phases and seven instantaneous positions as in Table 1.

The Machiyi's Japanese body model and the moment of inertia data published by National Technical Information Service on 03/1957 were applied to analyze the shot putt technique and to calculate the amount of mechanical energy that the athlete expends in the course of the throw.

Equation (1-1,1-2) is the mathematical statement of the calculation of the mechanical energy:

$$ME_i = m_i g h_{ci} + \tfrac{1}{2} m_i v_{ci}^2 + \tfrac{1}{2} I_i W_{ci}^2 \quad \textbf{(1-1)}$$

$$ME_{TOT} = \sum_{1}^{n} ME_i \quad \textbf{(1-2)}$$

$h_{ci}v_{ci}$ are the height and speed of the center of mass of each part of the body W_{ci} is the instantaneous angular velocity.

Table 1 The Phases and the Instantaneous Positions of Motion in the Shot Put

Phase	Instantaneous position	
Gliding phase	Upright position	T0
	The lowest drop position	T1
	Right foot leaves the ground	T2
	Right foot touches the ground	T3
Transitional phase	Right foot touches the ground	T3
	Left foot touches the ground	T4
The beginning of push-off phase	Left foot touches the ground	T4
	Shot and hand leave the shoulder	T5
The end of push-off Phase	Shot and hand leave the shoulder	T5
	The shot leaves the hand	T6

RESULTS: The potential energy (PE), kinetic energy of translation (KET), kinetic energy of rotation (KER) output during the course of a throw are shown in Figure 1 for the athlete who put the shot at 20.25 m.

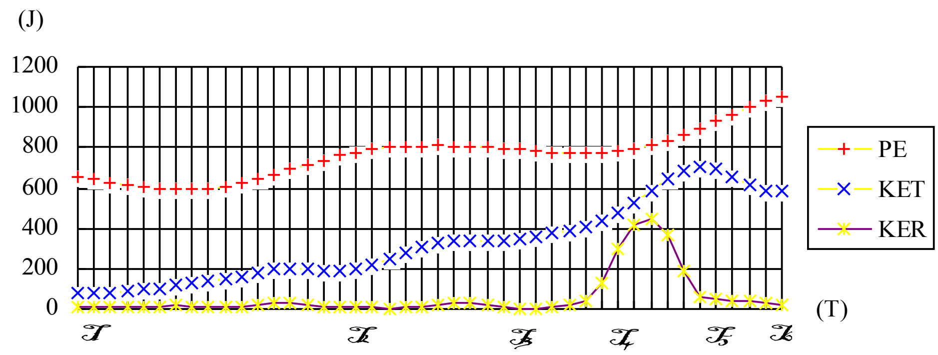

Figure 1 - Potential energy, kinetic energy of translation, kinetic energy of rotation during the course of the throw.

The average values of potential energy, kinetic energy of translation, kinetic energy of rotation and total mechanical energy (ME_{tot}) that 8 athletes produced at different instants are shown in Table 2.

Table 2 Average Values of Energy that 8 Athletes Produced at Different Instants (J)

Energy	T1	T2	T3	T4	T5	T6
PE	645	25.2	25.2	25.2	25.2	25.2
KET	86.8	323	294	418	682	577
KER	25.2	25.2	25.2	25.2	125.2	25.2
ME_{tot}	742	1135	1154	1325	1869	1734

The individual values of the kinetic energy of translation of the trunk per unit body weight correlated significantly with the individual values of the shot put result at T2 ($r=0.83$; $p<0.01$) and at T3 ($r=0.62$; $p<0.05$) as well as at T5($r=0.93$; $p<0.01$). The individual values of kinetic energy of translation of the throwing arm per unit body weight correlated significantly with the individual values of the shot putt result at T6 ($r=0.74$ $p<0.05$).

The total increase of the potential energy was 477 J from the lowest drop position until the shot release. The increase of potential energy from T1 to T2 was 33.3%, from T2 to T4 10.2%, from T4 to T5 36.5%, from T5 to T6 20.3%.

The total increase of the kinetic energy of translation was 625 J from the lowest drop position until the shot left the shoulder. The increase of the kinetic energy of translation from T1 to T2

was 37.9%, from T3 to T4 19.9% and from T4 to T5 42.2%. From T5 to T6 the kinetic energy of translation decreased by 105 J.
From Figure 1 and Table 2 it can be seen that only during the period from left foot touching the ground (T4) to the shot and hand leaving the shoulder (T5) did the kinetic energy of rotation increase significantly.

DISCUSSION: The individual values of kinetic energy of translation of the trunk per unit body weight correlated significantly with the individual values of the shot putt result at T2 ($r=0.83$; $p<0.01$) and at T3 ($r=0.62$; $p<0.05$) as well as at T5 ($r=0.93$; $p<0.01$). These findings can provide an evaluation criterion of motion skill or of training effectiveness of female shot putters to guide their training and competition.
The values of the mechanical energy are less in the transitional phase, but the values of the kinetic energy of translation increase consistently. This shows that maintaining reasonable motion is the main goal of this phase. From Figure 1 and Table 2, these results demonstrate that the gliding phase and the beginning of push-off phase are the main phases of energy output by the shot putter. In the gliding phase the potential energy and kinetic energy of translation respectively increase by 33.3% and 37.9%. This demands that the support leg works effectively with the free leg, and drives towards the stop board. In the beginning of push-off phase the potential energy and kinetic energy of translation respectively increase by 36.5% and 42.2% to reach the maximum 307 J (mean). Through stretching out the back leg and rotating the hip and trunk, the athlete produces the maximum amount of mechanical energy in this phase. This shows that the technique in this phase is most important and requires the maximum speed of the putter's upper body, and the maximum explosive power, speed and coordination. It is this specific "throwing strength" that the shot putt athlete and the coach are seeking.
The kinetic energy of rotation is equal to the pitching angular kinetic energy added to the twisting angular kinetic energy (about the vertical axis). In the beginning of push-off phase the ratio is 1:8.47. Reasonable rotation technique demands the coordination of pitching rotation and twisting rotation. This ratio provides a reference for evaluation of the rotational technique.

CONCLUSION: This study identified that the mechanical energy output by the putt in the course of the throw correlated significantly with the shot put result. The beginning of push-off phase is the most important technique phase; here, the maximum mechanical energy appears. The ratio of the pitching angular kinetic energy to the twisting angular kinetic energy provides a reference with which to evaluate the rotation technique. These energy values can provide an evaluation criterion of motion skill and the training effectiveness of female shot putt athletes. These findings provide some guidelines for women shot putt training and competition.

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