THE BIOMECHANICAL DIAGNOSIS OF TRIP-PUTTING TECHNIQUE

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The purpose of this paper was to apply biomechanical analysis to the shot put technique of a Chinese high performance athlete. The data collected on trip-putting technique was recorded with fixed-spot method using PANASONIC DP200 Professional Camera, with a speed of 50 fields/second. The AIJIE 2D Analysis System was used to analyze the images, collect relevant kinetic data. In order to determine the cause of an unsatisfactory performance, the focus of the study was on the technique during the transition phase. During transition phase the interval between landings is too long, the distance between two feet after landing is too small. In addition, it was important to determine the main reason for an apparent loss of power in this phase.

KEY WORDS: shot put, sport biomechanics, 2D analysis, technical

INTRODUCTION: This study was undertaken in order to improve the performance of a young male shot put athlete with considerable championship potential. This is reflected in his record of 18.04 m in the fixed-put event in 1997 at the National Young Championships. Even in training he achieved 18.30 m which was the best record ever in China's history. However, because of problems in coordinating trip-putting technique and in the final toss, his performance in the trip put event is even worse than in fixed-putting. Normally an elite athlete's performance in trip-put is 2-2.5 m farther than it wold be in the fixed-put event. If the trip-putting technique could be improved, this athlete would be able to advance to the high performance level of shot put athletes in China. To address this problem, the athlete's technique and movement were recorded using fixed-spot camera recording method in competition during the National Track & Field Championships in Shijiazhuang on April 25, 1999. At that time, the techniques and movements of the two of the best male shot put athletes in China, were also recorded using the same recording method. Using the results of two-dimensional analysis from the AIJIE 2D Analysis System, comparison analysis was made of all the technique indicators from three athletes. The purpose of this study, therefore is to find the discrepancies in the athlete's technique and thus help him improve his trip-putting technique.

METHODS: The subject of our research is an experienced shot put athlete. The main research is based on his performance during the National Track & Field Championships in Shijiazhuang, where he had a performance of 16.48 m. Because most data of other shot put athletes covered in previous research are from film analyses, instead of the analysis from AIJIE 2D Analysis System, data comparison is hard to perform. Thus data from the controls that were chosen were analyzed using the same system and same method. The controls are two of the best male shot put athletes in China. Their techniques and movements were recorded at the National Track & Field Championships' Shijiazhuang Stop, with performances of 18.69 m and 18.93 m.

Table1 Subjects' Physical Profile

Name	Height	Weight	Age	Performance
Liu Yu	1.94 m	130 kg	21	16.48 m
Liu Hao	1.96 m	136 kg	31	18.69 m
Wen Jili	1.92 m	140 kg	27	18.93 m

The subject and controls' front and side images were recorded in movement with fixed-spot method using PANASONIC DP200 Professional Camera, with a speed of 50 fields /second, mirror main ray axis vertical to the movement plane, a distance of 18 m, and a camera height of 1.2 m. AIJIE 2D Analysis System was used to analyze the images, collect relevant kinetic data, and digital wave filtering method to smooth the data, with a cutting-through frequency of 8. The data was analyzed using biomechanics, shot put kinetics, and with consideration of coaches' opinion.

To facilitate analysis, based on the current conventional method widely used in the world, the whole shot put technique was divided into three phases (right-handed shot put as an example):

1. Tripping: from right foot leaving the ground to right foot landing;
2. Transition: from right foot landing to left foot landing;
3. Final toss: from left foot landing to ball leaving the hand.

RESULT AND DISCUSSION: 1. Tripping. This phase requires that human gravity point is moved rapidly toward the direction of the ball, so that human body and the ball instantaneously leave the inert state and achieve parallel and vertical speed.

Table 2 Subjects' Technique Indicators in Tripping Phase

Name	Time Used	Tripping Distance	Gravity Point Height	Ball Height	Gravity Point Speed	Ball Speed
Liu Yu	0.2 s	0.72 m	1.01 m	1.24 m	2.03 m/s	2.24m/s
Liu Hao	0.12 s	0.63 m	0.95 m	1.17 m	2.35 m/s	2.43 m/s
Wen Jili	0.2 s	0.78 m	0.91 m	1.15 m	2.31 m/s	2.39 m/s

Based on the technique indicators in the Table 2, there is not much difference between the athletes' time elapsed and tripping distance. At the end of the tripping phase, the gravity point's speed and ball speed of the less experienced athlete are much smaller than those of the high performance athletes. This is especially relevant to gravity point's speed, which is related to the fact that the swing of the less experienced athlete is not adequate at the start of the tripping phase. Furthermore, the difference between the less experienced athlete's ball speed and gravity point speed is 0.21 m/s, while that of the high performance athletes are both 0.08 m/s. Some related articles (Jianchen Li, 1993; Judge.L.W., 1994) have concluded the closeness of ball speed and gravity point speed before conversion is an important measure in evaluating an elite shot put athlete's tripping phase.

From the images obtained in competition and from recording coaches' direct judgments, it was determined that the less experienced athlete is not able to keep an optimal body gesture during the tripping phase. In addition, his gravity height and ball height, are both higher than the other competitors. This is not advantageous for connecting to the next phase.

2. Transition. The transition phase is a crucial technique part of the whole shot put technique, and it has the important function of connecting the first and third phase, and thus directly affects the result of final toss.

The main task of transition phase is to maintain or properly increase the ball's speed acquired during the tripping phase, quickly convert double-side support to single-side support, and form a good position for the final toss.

Table 3 Subjects' Main Technique Indicators in Transition Phase

Name	Time Used	Foot-to-foot Distance	Gravity Point Height	Ball Height	Gravity Point Speed	Ball Speed
Liu Yu	0.2 s	0.99 m	1.00 m	1.26 m	1.98 m/s	2.70 m/s
Liu Hao	0.16 s	1.19 m	1.01 m	1.26 m	2.60 m/s	3.24 m/s
Wen Jili	0.16 s	1.07 m	1.00 m	1.27 m	2.38 m/s	3.04 m/s

In this phase, except gravity point height and ball height, all the other indicators are worse for the less experienced athlete than for the high performance athletes. First of all, the time interval between two feet land is 0.2 s, which is slower than the high performance athletes of 0.16 s. The time interval between two feet hitting the ground is another important kinetic indicator. Normally, under the condition of maintaining the ball's parallel speed and forming proper preparation gesture, the shorter the time interval between the two feet land, the better the performance.

On the indicator of foot-to-foot distance, the less experienced athlete's was 0.99 m, much less than 1.07 m recorded for the high performance athletes. Short distance between the two feet usually means harder to prepare for a "ahead-of-ball" gesture. Therefore, coxa axis and shoulder axis could not tighten maximally, and relevant body muscle group could not get enough stretch and thus failed to generate maximal power.

While watching the technique tape with his coaches, it was found that instead of actively stretching forward and hitting the ground at the instant of landing, the less experienced athlete's left foot has an almost imperceptible motion of withdrawal, and it does not hold to plank at all. Because of the maximum forward parallel speed of the ball and body, the withdrawal of left foot makes it hard to form a firm support before final toss and to pass the force generated from the body fully on to the ball. In this process, a lot of energy is lost. Viewed from the technique indicators, during the transition phase, body gravity point's speed and ball speed of the less experienced athlete are both less than those of the high performance athletes. For the former, this is even less than it is in the tripping phase. Also due to the short distance between the two feet, firm "left-side support" is not formed, and thus the final working distance on the ball is shortened. It has been established that improving working distance on the ball can significantly increase the its speed leaving the hand. Xing Wei & Fulin Kan (1991) found that when the initial speed is only 13 m/s, the working time is maintained. If the working distance on the ball is increased by 0.01 m, the speed of the ball leaving hand could increase by 0.13 m/s, which gives the ball 0.30 m more in distance.

After having discussion with coaches, it was concluded that the discrepancies in transition phase, is the key reason that caused the less-than-optimal performance in trip-put event for the less experienced athlete.

3. Final toss. Final toss is the most important step in the whole technique of shot put and it is composed of preparation phase and final acceleration phase.

Acceleration preparation phase is from final toss start to the working arm's acceleration of ball. The main task is to maintain the ball's original speed, and prepare muscles and nervous system for the working arm's final toss acceleration.

Table 4 Subjects' Technique Indicators in Acceleration Preparation Phase

Name	Time Used	Gravity Point Height	Ball Height	Gravity Point Speed	Ball Speed
Liu Yu	0.08 s	1.10 m	1.44 m	2.67 m/s	4.05 m/s
Liu Hao	0.08 s	1.13 m	1.48 m	3.30 m/s	3.89 m/s
Wen Jili	0.08 s	1.08 m	1.44 m	2.56 m/s	3.65 m/s

According to Table 4, there is not much difference in the three athletes' ball height, gravity point height, and time used. The less experienced athlete's ball speed of 4.05 m/s is even more than 3.89 m/s and 3.65 m/s recorded for the high performance athletes. But this does not demonstrate better technique. From the technique tape, it was found that due to the inappropriate technique during transition phase, the less experienced athlete could not generate the satisfactory "ahead-of-ball" gesture. The relevant muscles could not stretch enough, and thus generate power passively by momentum from the past phase, which is the so called "advanced exert".

Table 5 Subjects' Technique Indicators in Final Acceleration Phase

Name	Time Used	Angle Leaving Hand	Gravity Point Height	Ball Height	Gravity Point Speed	Ball Speed
Liu Yu	0.16 s	37.3°	1.31 m	2.25 m	1.37 m/s	11.05 m/s
Liu Hao	0.16 s	39.8°	1.34 m	2.33 m	1.52 m/s	12.13 m/s
Wen Jili	0.16 s	41.4°	1.32 m	2.32 m	1.99 m/s	12.15 m/s

It has been established that the main factors determining the ball's flying distance are ball's initial speed, angle, and height when leaving hand. The ball speed of the less experienced athlete is only 11.05 m/s when leaving hand, which is much lower than that of the high performance athletes of 12.13 m/s and 12.15 m/s. Also the ball angle leaving the hand of the less experienced athlete is 37.3° which is a lot lower than 39.8° and 41.4° recorded for the high performance athletes. Chao Wen's (1994) found that if ball height is 2.20 m and speed is 11 m/s when leaving hand, the optimal angle should be 40.6°. If speed is higher, optimal angle should be higher as well. A ball angle of 2.25 m when leaving hand is too low for the 1.94 m achieved by the less experienced athlete.

Almost all of the technique indicator values in the final toss phase of the less experienced athlete were inferior to that of the controls. Although these data show us the direct reasons that caused the unsatisfactory performance, the primary reason is the inability of the athlete to coordinate the techniques during the transition phase. It was concluded that the technique details during transition phase must be improved before addressing the technique in the final toss phase.

CONCLUSION:

1. During tripping phase optimal technique, could not be maintained. The difference between the ball speed and gravity point speed is too large.
2. During transition phase the interval between landings of two feet is too long. The distance between two feet after landing is too small, which might be the main reason for power loss.
3. During accelerate preparation phase, the advantageous "ahead-of-ball" gesture, could not be accomplished. The athlete tends to toss beforehand, which negatively affects the final acceleration.
4. His ball angle and height leaving hand are low.

SUGGESTION: Although performance is less than optimal, the most noteworthy advantage of this athlete is that he is very young. He has the task of preparing for the 9th National Olympic Games in 2001 and the 14th Asian Olympic Games in 2002. It is hoped that this promising young athlete will be able to improve his technique and performance in his training. According to this study, the following suggestions are made:

1. Maintain the harmony of body and ball; avoid body's twist during tripping.
2. During transition, try to move left foot forward to hit the ground, avoid withdrawal action, shorten the time between the two feet hitting the ground, widen the distance between feet, stick left foot to plank, and form firm left-side support.
3. Pay attention to the execution of "ahead-of-ball" movement. Under the condition of not affecting the rhythm of whole body movement, stretch related body muscle group, increase the working distance on the ball, and prepare for the final toss.

4. Appropriately increase ball angle and height leaving hand.
5. Consider training to improve the body's coordination.

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