Biomechanical Analysis of the Back Sliding Techniques of Li-jiao GONG

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Abstract. The main technical factors affecting the shot-putter’s performance are studied from the biomechanical perspective with emphasis on the speed rhythm. Li-Jiao GONG, the silver medal winner of the women's shot put at 2015 World Championships in Athletics, is chosen as the research object. The results show that the sliding initiation technique of GONG is good with a desirable angle between the leg and the ground (ALG); in the transitional stage, the shot velocity increases but the barycentric velocity decreases owing to too long a supporting time caused by her poor concession capability and the ability to quickly transfer to the forward acceleration; in the last exertion, GONG’s distinct acceleration point (exerting point) leads to significant increase of shot velocity.

Object and Methods

Object

The silver medal winner of the women's shot put at 2015 World Championships in Athletics Li-Jiao GONG is chosen as the research object. The basic information is listed in Table 1.

| Name       | Test Score(m) | Birthday(a) | Height(m) | Weight(kg) | Level      |
|------------|---------------|-------------|-----------|------------|------------|
| Li-Jiao GONG | 20.30         | 1989.01     | 1.75      | 110        | International |

Methods

This study used a single NV-S850 camera designated on the right side of shooting (the athlete throws with the right hand) 14 m away from throwing the center working at the frequency of 50/s and height of 1.15 m with the main optical axis perpendicular with the throwing direction to obtain 3 valid samples. Video parsing is performed using the Agile Movement Measurement and Analysis System by sites parsing each try from sliding to the shot. (Note: The speed in this paper refers to the combined speed of the throwing direction if not in special version.)

Results and Analysis

Sliding Phase

Technical features of the sliding phase. The angle between the leg and the ground (ALG) is an important parameter to evaluate the sliding technique, which should not be too large \cite{2}. A large ALG may cause a beating phenomenon in the sliding phase due to vertical speed over the athlete and equipment. Meanwhile, it should not be too small. Otherwise the friction force would be too large to complete the landing. The world's elite athletes have an average ALG of 53°, and Li-Jiao GONG’s ALG is 53.24°, indicating her good sliding technique.

The main driving force of sliding is the left-leg swinging and right-leg kicking. In terms of the swing-kick coordination technique required by inertia force, the timing of the maximum left-leg swinging speed imposes an influence on the right-leg kicking speed and power. The maximum
speed of GONG’s left-leg swing appears when the right foot steps off the ground (see Table 2),
which is conducive to the right-leg speed and kicking power. Statistical analysis shows a significant
correlation between the maximum speed of left-leg swing and BM and SM ($\gamma_1 = .865$, $\gamma_2 = 0.787$, P
<0.05). It means that the left leg swing is one of the main factors that affect the shot speed and the
barycentric speed at the sliding phase.

Table 2. Major Speed Parameters of Sliding Stage.

| Name     | Score(m) | BM (m/s) | SM (m/s) | LKM (m/s) | LHM (m/s) | ALG     | T (s) | D (m/s) |
|----------|----------|----------|----------|-----------|-----------|---------|-------|---------|
| Li-Jiao GONG | 20.30    | 3.224    | 3.435    | 4.287     | 2.983     | 53.24º  | 0.10  | 0.211   |

Note: BM- Barycentre; Maxv; SM- Shot Maxv; LKM- Left-knee Maxv; LHM- Left-hip Maxv;
ALG- Angle between the right leg and ground; T- time difference between the left-knee Maxv and
the right foot leaving ground; D- D-value of the barycenter Maxv and shot Maxv

**Speed change of barycentric velocity and shot velocity in the sliding phase.** The major
criterion for the evaluation of elite shot-putters is the difference between the barycentric speed and
the shot speed (D-value) in the sliding phase [3]. Table 2 shows that Li-Jiao GONG has a D-value of
0.211m/s. In comparison, China’s other two elite female shot putter Zhi-Hong HUANG (21.52m)
and Xin-Mei SUI (21.66m) have a BM of 2.17m/s and 2.13m/s, respectively at an SM of 2.23 m/s,
their D-values being 0.08m/s and 0.10m/s, respectively, indicating perfect techniques. It is shown
that Li-Jiao GONG needs further improvement in her sliding technique.

**Transitional Phase**

**Speed change of hip and knee joints in the transitional phase.**

Table 3. Major Speed Parameters of Transitional Stage.

| Name       | Score(m) | LHV (m/s) | RHV (m/s) | LKV (m/s) | RKV (m/s) | Time (s) |
|------------|----------|-----------|-----------|-----------|-----------|----------|
| Li-Jiao GONG | 20.30    | 2.5       | 3         | 1.91      | 2.21      | 2.34     | 2.62     | 1.78     | 3.89     | 2.84     | 0.12     |

Note: LHV- left hip velocity; RHV- right hip velocity; LKV- left knee velocity; RKV- right knee velocity

With the right foot landing on the ground, GONG’s LHV is larger than RHV, as a continuation of
the sliding action, and a higher LHV is beneficial for the left leg to quickly insert in the direction of
the touch-plinth. With the left foot landing on the ground, RHV is greater than LHV, indicating
immediate acceleration of the right part with the left foot landing on the ground, which is conducive
to the hip axis quickly moving from vertical into throwing direction. Analysis shows a significant
correlation between the score (20.30m) and LHV and RHV ($\gamma_L=0.5012$, P < 0.05; $\gamma_R=0.5231$, P <
0.05), so the hip joint is an important part in the transitional phase.

GONG’s LKV decreases in the second half of the transitional phase after an upward trend in the
first half. The upward trend is due to the down swing plug with vertical negative velocity of the left
knee rising in the former half. The horizontal velocity of the right knee increases quickly after a
slight downward trend ($\bar{v}_R=2.283\pm0.178$, $\bar{v}_L=2.557\pm0.054$). RKV decreases with the right foot
landing on the ground, but the horizontal velocity rises sharply with the rotation of the right knee
and the acceleration of the lower limbs, indicating the rotation and timely forward movement
compensates for the loss of speed.
**Speed change of barycentric velocity and shot velocity in the transitional phase.**

**Table 4. Byrycentric Velocity, Shot Velocity and their difference in the Transitional Stage.**

| Name         | Score (m) | Shot Velocity (m/s) | Barycentric Velocity (m/s) | Difference (m/s) |
|--------------|-----------|---------------------|---------------------------|------------------|
| Li-Jiao Gong | 20.30     | 2.18 2.33 0.15      | 2.02 1.98 -0.04           | 0.16 0.35        |
| Zhi-Hong Huang| 20.40     | 2.21 2.47 0.26      | 2.04 2.08 0.04            | 0.17 0.39        |
| Xin-Mei Sui  | 21.52     | 2.27 2.71 0.44      | 2.16 2.06 -0.04           | 0.09 0.65        |

The barycentric velocity (BV) of Li-Jiao GONG increased by 0.15 m/s, while the shot velocity (SV) decreased by 0.04 m/s in the transitional stage. In the shot of 20.88m by Xin-Mei SUI, the SV and BV increased by 0.29m/s and 0.20m/s respectively; in Zhi-Hong HUANG’s shot of 20.40m the SV and BV increased by 0.26m/s and 0.04m/s, and in her shot of 21.53 m the SV increased by 0.44 m/s while BV decreased by 0.12m/s[6]. It is shown that our athletes should maintain optimal force posture so that the BV and SV increase at the same time to achieve better results.

The greater the difference between BV and SV is in the transitional stage, the more the athletes will fully transcend the equipment with more reverse forces generated by the shoulder and torso [6]. The D-value of elite shot putters in China is more than 0.5m/s [7], but the D-value of GONG is smaller (0.35 m/s). Compared with European and American athletes, Chinese shot putters need to improve the SV and the D-value in the transitional phase to lay the foundation for the last exertion.

**Changes in the Last Exertion**

Most coaches and researchers believe that the shot speed should increases without interruption during the entire shot process, which is also considered as an important basis for the evaluation of the athletes’ performance. Our study shows that in the period from the left foot landing on the ground to the horizontal axis turning to be parallel to the throwing direction, Li-Jiao GONG’s SV increased stably with a sharp upward trend afterwards until the velocity curve reached its highest point. It indicates that GONG did not act with undue haste with focus primarily on the forward action of the hip joint. Although the SV shows a slight decline after the left foot landing on the ground, the hip could move to form a firm anchor of the waist and torso muscles. Thus, the main force is more significantly effective with a upward trend of the speed curve.

According to the above analysis, the force posture formed when the left foot lands on the ground is the first anchor which cannot show good effects if the trunk and upper limbs are eager to force. After the left foot lands on the ground and the hip is fixed for the trunk and upper limb movement, it will form the second anchor for the whole body muscle groups to be fully mobilized. The last exertion at this point will lead to the best shot.

**Conclusion**

Effective swing of the left leg can increase the kicking power and the sliding speed. The maximum speed of GONG’s left-leg swing appears when the right foot steps off the ground, which effectively enhances the right-leg speed and kicking power, indicating good sliding techniques of Li-Jiao GONG in the initiation stage.

The quick insertion of the left leg in the transitional phase is conducive to the recovery of the BV with less supporting time and forward movement of the hip joint. The concession ability of Li-Jiao GONG is too poor to be quickly transferred to the forward acceleration. Then with long supporting time, the BV and SV decreased to hamper the acceleration of the last exertion.

In the final stage, sudden braking and quick kicking after the left foot landing on the ground
could better transfer power to enhance athletic performance in the last exertion. Li-Jiao GONG demonstrates quick shot with clear accelerating point and a sharp rise of SV.

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