Biomechanics of the shot put
Application of module content

This application has been adapted from the following two papers:


Biomechanics application

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The first step to describing the biomechanics of a skill is to define the relevant terminology. For the shot put throw the relevant terminology is as follows:

1. The **flight phase** occurs when the athlete is moving from the back of the throwing circle towards the front and has no contact with the throwing surface.

   In the glide technique, the flight phase occurs the instant the rear foot breaks contact with the throwing surface until it makes contact with the throwing surface again.

2. In the rotational style, the flight phase begins when the front foot leaves the throwing surface and ends when the rear foot makes contact with the throwing surface.
2. The **power position** is achieved when the front foot touches down and the athlete has both feet in contact with the throwing surface in preparation for the delivery of the throw.

3. The **rear foot** is the foot towards the rear of the throwing circle when the athlete is in the power position.

4. The **front foot** is the foot closest to the toe board when the athlete is in the power position.

5. **Rear-foot touchdown** occurs when the thrower’s rear foot contacts the throwing circle following the flight phase.

6. **Front-foot touchdown** occurs when the thrower’s front foot contacts the throwing circle following the flight phase.

7. The **transition phase** is time between rear and front foot touchdown following the flight phase.

8. **Shoulder-hip separation** is the orientation of the hips relative to the orientation of the shoulders. A neutral position (zero degrees of separation) occurs when the shoulders and hips are aligned with one another as is the case in anatomical position. A positive angle occurs when the throwing side shoulder is posterior to the throwing side hip. A negative angle occurs when the throwing side shoulder is anterior to the throwing side hip.
9. **Release** is the instance the shot leaves the thrower's hand.

10. **Release velocity** is how fast the shot is moving at the moment of release.

11. **Release angle** is the angle at which the shot is released relative to horizontal.

12. **Release height** is the height of the center of the shot above the surface of the ring at the moment of release.

13. **Horizontal release distance** is the horizontal distance between the center of the shot and the innermost edge of the toe board at the instant of release.

14. **Projected distance** is the horizontal displacement of the shot beginning at the hand and ending at the landing point.

15. **Measured distance** is the horizontal displacement of the shot measured from the innermost edge of the toe-board and ending at the landing point of the shot. This is the official recorded result. The measured distance is the projected distance plus the horizontal release distance.
Now that we have defined the terminology we can begin to think about what parameters are critical to maximizing the measured distance of the throw. A parameter can be altered to vary the measured distance.

Recall that the measured distance of a shot put throw is the sum of two distances: the horizontal release distance plus the projected distance.

Projected distance contributes 97% to the measured distance, and the horizontal release distance contributes the remaining 3%. Wind resistance and aerodynamic factors are insignificant in the shot put throw.
Parameters affecting projected distance

Projected distance depends on three parameters: the height of release, angle of release, and velocity of the shot at the instant it is released.

The final release velocity of the shot is the culmination of all the movement units across the circle up to, and including the power position. Poorly executed movement units across the circle negatively affect the final release velocity.

Release velocity and release angle are inversely related. As one parameter increases, the other decreases. Release angle can be manipulated depending on the thrower’s strength and anthropometrics. The goal is to determine the release angle that optimizes the total distance for the release velocity attained for the thrower. For the shot put, the optimum angle of release is between 31° and 36°.

Release velocities in excess of 13 m/s are necessary for elite-level throws. The velocity a thrower can attain depends on his or her capacity to handle the forces associated with the velocity. A velocity that is beyond the thrower’s strength can result in instability, technical problems, and inefficient sequencing of muscle contractions.

Keep in mind that the relative importance of the three release parameters will vary depending on gender, their body proportions, strength, whether they use a slide or spin throwing technique, and individual style.

Parameters affecting horizontal release distance

Horizontal release distance depends on a full arm extension at the optimum projection angle.

The athlete's trunk and limb lengths largely determines horizontal release distance. When the arm is correctly extended the only variable that can affect release height is the angle of release.

The optimal horizontal release position is between 0.2m and 0.5m in front of the toe board. A long horizontal release distance provides a longer path for the application of force on the shot.
Therefore, the horizontal release position is significant for two reasons.

- It determines whether the release of the shot is at an advantageous or disadvantageous angle of projection.
- It adds to the time the force can be applied to the shot.
Kinematics describes movements of the body without considering the forces causing those movements. A coach typically evaluates technique in terms of kinematics because forces are too difficult to measure.

There are six critical kinematic parameters in the shot put throw. Some are relevant to the rotational technique and some to the linear technique.

**Long Sweeping Free Leg (Rotational Technique)**

One purpose of the spin is to build up a high rotational speed. At the beginning of the spin the thrower makes a long sweeping movement of the free leg. The wide swinging free leg helps to maximize the rotational inertia of the thrower.

\[\text{Toe-to-toe distance}\]

It also assists in developing greater positive separation between the shoulders and hips at rear-foot touchdown.

Characteristics of a good free leg include:

- a great toe-to-toe distance, a wide radius about the free-leg hip axis,
- a sweep that is low enough to the throwing surface so balance is not disturbed but high enough to optimize the radius of the leg.
High COM during Flight Phase (Glide Technique)

It was once thought that the ideal path of the athlete’s center of mass (COM) and the shot across the circle was a linear path, with the lowest point being at the beginning of the throw and the highest point being at release. Current thinking is that an S-shaped path, as viewed from the sagittal plane, activates the stretch reflex upon landing after the flight phase. This, in turn, increases muscle activation in the legs.

Recall that the stretch reflex is an involuntary contraction of a muscle in response to the rapid stretching of the muscle-tendon unit. This rapid reflex creates more forceful and powerful muscular contractions than would be possible under voluntary control alone.

In the shot put, the rate of stretch can be enhanced by maximizing the vertical velocity of the athlete when he/she lands following the flight phase. This can be achieved by increasing the maximal height of the athlete’s center of mass during this period. The higher the apex of the center of mass during the flight phase, the greater the athlete’s vertical velocity will be upon landing.

The optimal height for the flight phase is primarily determined by the athlete’s eccentric muscle strength and the ability of the
nervous system to respond to sudden changes in muscle length. It is believed that a higher COM during the flight phase is advantageous.

**Rear-Knee Flexion at Rear-Foot Touchdown**

A greater rear-knee flexion at rear-foot touchdown is one of the best indicators of success in the shot put. The ideal rear-knee angle at rear-foot touchdown is approximately 100°. However, this value depends on the leg strength of the athlete.

Most throwers land with a rear knee joint angle that is much bigger than 100°. Aiming for more flexion of the rear knee at rear-foot touchdown may provide these throwers with the opportunity to function with favorable leverage. This would result in greater implement acceleration.

Knee flexion beyond the proposed optimal value will negatively affect the throw.

**Greater Shoulder-Hip Separation at Rear-Foot Touchdown**

Positive shoulder-hip separation has long been advocated by throws coaches. A greater degree of separation is advantageous to maximize throwing distance. This is probably due higher pretension in the abdominal musculature and a longer path around which the shot can travel before being released. This provides the opportunity to increase the time of force application to the implement resulting in a higher acceleration of the shot.

At release, a neutral position is favorable to a negative shoulder-hip orientation.
Rear-Knee Flexion at Release

Greater rear-knee flexion at release is a significant predictor of the measured distance. This is in contrast to the recommendation that complete or near complete extension of the rear or both legs is crucial for achieving maximum distance.

The reason for this discrepancy may lie in the fact that the rear-knee angle at release may not be a critical factor in and of itself but rather an indication or effect of the extreme power and explosiveness needed to be an elite level shot putter.

A similar phenomenon has been seen in sprinting, jumping for height, and Olympic weightlifting. In such a case, the initial force generated by the legs accelerates the athlete and shot system with such rapidity that the shot is either released prior to the point of complete extension of the legs or the athlete breaks contact with the ground making further extension of the legs inconsequential.

It may be advisable to instruct athletes to strive for complete extension of one or both legs but those athletes who are very explosive may never have the opportunity to even approach full extension.

Neutral Shoulder-Hip Orientation at Release

A neutral shoulder-hip orientation at release helps maximize throwing distance. A small or nonexistent shoulder-hip separation at release indicates a strong non-throwing side block. Such a block, results in a transfer of momentum from the non-throwing side to the throwing side which would in turn increase the velocity of the throwing side and implement.

TEMPORAL PARAMETERS

Only one temporal parameter appears to have any effect at all on the distance achieved. This involves the transition time for the glide technique.

The transition time is time between rear- and front-foot touchdown following the flight phase. A short transition time appears to be beneficial for throwers using the glide technique, but has no benefit for rotational throwers. A near simultaneous rear- and front-foot touchdown may either allow for force application from both legs sooner in the throw, or permit the athlete to vault over an extended front leg depending on the technique being used.
The shot has a very high inertia and for this reason it has a strong "desire" to remain at rest. Overcoming this inertia requires the application of a very high force. The equation \( F = ma \) explains why the shot put requires a high level of strength and power. The shot putter only has 2.135 metres (7.00 ft) to accelerate the shot from zero m/sec to as high a velocity as possible. Throwers use one of two techniques to accomplish this - the glide and the rotational style.

In both cases, the ability to accelerate the shot faster depends on the size of the force the athlete can apply. The only way to apply a bigger force is to enhance strength and power. When athletes enhance their strength and power also the also increase their muscle mass. Therefore, it is not surprising that shot putters are rather big and muscular.

In addition to muscle mass, a thrower must be fast. Quickness depends on fast twitch muscle fibers, enhanced power and a highly tuned quick activation of the fast twitch muscle fibers.

For throwers using the glide technique there is a close correlation between muscle strength, lean body mass and measured distance. In other words, the glide technique favors thrower who are very big and very strong but are perhaps have a lower ability to move their limbs and body rapidly in a complex movement pattern.

The rotational style is thought to favor athletes who can produce a very high speed after taking the power position. Power production while performing the rotational technique appears to rely on speed of movement (coordination under time pressure) to produce force and slightly less on muscle mass and strength. In other words, strength and power appear to be more important to rotational throwers rather than their LBM.

When the athlete executes the spin, the upper body is twisted hard to the right creating a wide shoulder-hip separation. This action builds up torque, and stretches the muscles, creating an involuntary elasticity in the muscles, providing extra power and momentum. When the athlete prepares to release, the left foot is firmly planted, causing the momentum and energy generated in the body to be transferred to the shot.
Another purpose of the spin is to create the ‘ice-skater’ effect. The long swinging free leg creates a high rotational inertia. Then when the thrower brings all the limbs in tight the effect is similar to a figure skater bringing in their arms to increase their rotational speed. The fast rotational speed is transferred to the shot at the release.

The answer to the question: Which technique is better? is that, it depends on the elastic tissue component in the chest area allowing a rapid ‘uncoiling’ effect so that the energy stored in the chest is transferred to the shot.