A Biomechanical Approach to Javelin

Blake Vajgrt

Concordia University

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Javelin is one of the four throwing events sanctioned by track and field governing bodies. The sport involves a spear-like implement that is thrown overhead into a sector from a runway. Javelin is performed for distance through three stages: the runway, drawback, and throw. The implement is influenced by projectile motion physics. Research has been performed regarding the optimal variables that are found in a good throw. Variables such as javelin release speed and angle, throwing mechanics, and strength all play an extremely important role in the throw.

Javelin is considered a highly dangerous sport in track and field due to the spear-like shape of the implement. The event is normally only legal at the collegiate and international levels of competition where athletes have more body control and awareness of their surroundings. Implements are made from lightweight metal alloys. They consist of a head, a shaft that can be hollow or solid, and a grip surface usually made from braided string (Rosenbaum, 2012). The article “Olympic Javelin Throw Rules” by Mike Rosenbaum states at the collegiate and international level, the men’s javelin mass is 800 grams and length is 2.6 to 2.7 meters long, and the women’s javelin mass is 600 grams and length is 2.2 to 2.3 meters long (2012). The metal tip of the javelin must stick into the ground for a throw to be considered legal, and the distance is measured from the throw line (Rosenbaum, 2012).

The convex shape of the javelin aids in its’ aerodynamic flight pattern, causing it to be twenty times more aerodynamic than the discus (Leigh, Liu, and Yu, 2010). When designing javelins, manufacturers seek to produce an implement with a high vibration frequency when in flight (Farjoun & Neu, 2005). Javelins often have hollow shafts, which help achieve the desired
vibration. Researchers Fossi Farjoun and John Neu found that a hollow implement will have a frequency of vibration five times greater when compared to a solid beam (2005).

When looking at the javelin throw, there are three distinct stages. The first stage is the runway. In this stage, athletes start from standing position and run forward with the implement in hand. The purpose of the runway is to develop linear velocity and momentum that can later be transferred to the javelin at the throw. The velocity built up in the runway works to increase the release speed of the javelin through relative means. For example, if an athlete is moving linearly at eighteen miles per hour, the javelin will already be moving at that speed and the angular velocity from the movements in the throw will be added to this translational velocity of the runway.

Movement in the sagittal plane characterizes the runway stage. The javelin is held in a static position at the shoulder during the run up. Athletes, with proper running mechanics, focus on accelerating down the runway while maintaining body control. High knee drive and foot contact underneath the center of gravity are key coaching points in a proper runway. The primary movements are flexion and extension in the hip and knee joints and plantarflexion and dorsiflexion at the ankle joint. The hip extensors (hamstring group and gluteus group), knee extensors (quadriceps group), and gastronemius all play a role in velocity development of the runway.

The next stage in the javelin throw is the pull or drawback. The purpose of this stage is to put the body in position to execute a throw. Motion transitions to frontal and transverse planes. During the pullback, the shoulder horizontally abducts and the elbow extends to bring the arm and javelin parallel to the ground at shoulder level or higher. This motion stores elastic potential
energy that is released during the throw. The body rotates during the pullback so that it is perpendicular to the throw line. The lower body transitions to crossover steps, which helps, maintain the translational speed of the turned body.

The crossover steps place the body in a position where the hips are able to rotate during the throw, transferring the translational speed of the runway to angular velocity in the body’s joints. The primary movements in the lower body of the pullback are abduction/adduction; flexion/extension of the hips, flexion and extension of the knee, and plantarflexion and dorsiflexion of the ankle joint. The same major muscle groups that were described in the runway stage are used in the pullback stage in the lower body.

The third stage is the throw. It is the most technical and well-researched stage. The purpose of the throw is to transfer the angular velocity and energy developed from movements at involved joints to the javelin upon release. Research has shown that the initiation and sequence of the throw in the lower and upper body is different for males and females. The throw exhibits a proximal to distal sequence in the upper body (shoulder to wrist) and deviations from the pattern leads to shorter throw distances (Liu, Leigh & Yu, 2010).

In males, the upper body sequence is as follows: trunk forward rotation, throwing shoulder horizontal adduction during final foot contact, throwing shoulder abduction, throwing elbow extension, throwing shoulder internal rotation, and wrist flexion (Liu et. al, 2010). Females exhibit a slightly modified throwing sequence. In females, the upper body sequence is contrasted by: trunk forward rotation, throwing shoulder abduction (after final foot contact), throwing shoulder horizontal adduction, elbow extension and shoulder internal rotation, and wrist flexion (Liu et. al, 2010). The differences between the sexes are that males begin the throw
at the shoulder with horizontal adduction while females begin with abduction. Males also begin the throw simultaneously with final foot contact. Movements of the upper body occur in all planes of motion and the body transitions from a perpendicular to parallel arrangement to the throw line.

At the throw, there is a plant foot (final foot contact) and non-dominant foot. The plant foot is on the opposite side of the body of the throwing shoulder. In males, the lower body sequence is as follows: non-dominant hip abduction and internal rotation, hip extension, non-dominant foot touchdown, knee extension, plantarflexion, pelvis forward rotation, plant leg hip adduction, plant foot contact, and plant hip extension followed by release of javelin (Liu et. al, 2010). The females perform this sequence: non-dominant hip internal rotation, hip abduction, foot contact, knee extension, ankle plantarflexion, pelvis forward rotation, plant hip adduction, plant foot contact, and plant hip extension (followed by release of the javelin) (Liu et. al, 2010). In females, non-dominant hip internal rotation and abduction are separate when comparing the motions found in males. Females also exhibit simultaneous forward pelvic rotation with non-dominant knee extension and ankle plantarflexion, while those motions are separate in males.

Liu et. al suggests that males are quicker with hip extension prior to non-dominant foot contact (2010). This quick hip extension is more efficient in helping to transfer angular energy to the javelin and maintaining the velocity accumulated during the runway and pullback. Males had an average hip extension time of -0.002 seconds (due to motion occurring prior to foot contact) compared to 0.046 seconds in females (Liu et. al, 2010). This difference can help explain why males are able to throw further than females.
Differences in the sequence and angles of the throwing motion lead to greater acceleration and distances when comparing javelin to other throwing sports. Javelin throwers exhibit a longer acceleration path of the upper body due to the sequence of the throwing motion (Tillar, 2005). These long accelerations and decelerations lead to greater torques and stress on the upper extremity joints, which can lead to injury in athletes. Greater distances are correlated with female throwers who have a more extended throwing elbow at non-dominant foot contact and in males whose throwing shoulder is more horizontally adducted and elbow is extended at plant foot contact (Leigh, Liu & Yu, 2010).

The javelin throw is to subject projectile motion physics. A throw’s distance is determined by the release speed, angle, and height of the javelin along with air resistance and drag. While release angle and height play important roles in the range of the javelin, but release speed is most the crucial factor in javelin throwing distance (Liu et. al, 2010). Javelin release speed is determined by the translational velocity built up during the runway and the transfer of angular velocities of the joints to the javelin upon release. In the throwing sequence, 70% of the release speed is built during the first 0.1 seconds (Forthomme, Crielaard, Forthomme & Croisier, 2007). The study “Neural Network Based Models of Javelin Flight: Prediction of Flight Distances and Optimal Release Parameters” that included data from elite throwers, showed the maximum release velocity was near 31.4 m/s (Maier, Wank, Bartonietz & Blickhan, 2000).

Javelin release angle is also important in determining the range of a throw. These angles often range between 25 to 42 degrees (Maier et. al, 2000). In the runway stage of a throw, the athlete holds the javelin in a static position. The angle of the javelin to the horizon during the runway is called the angle of inclination. The angle of inclination plays a role in determining the range of the javelin. The difference between the release angles to the angle of inclination is
called the attack angle. A larger angle of attack often leads to extra motion that decreases the rotational energy that can be transferred to the javelin upon release, but javelins with small angles of inclination and lower angles of attack correlate with further range of the javelin (Leigh et. al, 2010).

Projectile motion physics is determined by a continuum of interaction between the release speed, angle, and height variables. As one variable moves towards optimum, others move further away. Release speed as stated is the most important variable in determining the range of the javelin. In the interaction between release speed and angle, angles are often lower than 45 degrees to develop more speed upon release (Leigh et, al, 2010). The angle of attack plays a part in the interaction with release velocity. Higher release velocities should have angles of attack that are close to or slightly smaller than release angles (Maier et. al, 2000).

Javelin is a biomechanically complex sport. It involves all planes of motions and a wide array of joint motions. The sport consists of three stages: the runway, pullback, and throw. The purposes of each of these stages are to ultimately deliver the javelin with maximal release speed. Javelin is subject to projectile motion physics, and the implements range relies on release angle, height, and speed as well as air resistance.
References


