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ROTATIONAL VS. GLIDE REVISITED

COMPARING SHOT TECHNIQUES

ANDREAS V. MAHERAS, PH.D.

Although the rotational style appeared almost sixty years ago, it started establishing itself as a legitimate way of putting the shot in the early 70's when national and world records were set employing this technique. The two most prominent proponents of the early era of the rotational style were Brian Oldfield of the U.S. and Alexandr Baryshnikov of what used to be the Soviet Union. It is currently the dominant style of throwing among American male shot-putters while it is rapidly gaining ground across both sexes in both domestic and international shot-putters. Albeit its increasing popularity, the rotational style of putting the shot has not completely dominated the technique of that event. Some coaches and athletes may be proficient and favor one style over the other while others may be apt towards either style. In this narrative, an overview of the various aspects of those two techniques is presented in a comparative fashion in an effort to elucidate some known similarities and differences between the two.

SHOT VELOCITY

In both the rotational and the glide techniques the velocity of the shot varies during the course of the throw. Initially there is an increase, followed by a decrease culminating in a final and dramatic increase at release (Ariel et al., 2004). In the glide, the shot reaches velocities between 2.0 and 4.0 m/sec., in the early stages of the throw decreasing slightly to 1.5 to 3.5 m/sec., when the back leg touches down in preparation for the power position. Following a small increase during the transition to the front leg in the power position, there is a dramatic increase of the shot velocity as it attains its maximum speed at release which is usually no less than 13m/sec., in high caliber throws. In the rotational technique, the shot velocity during the preparation for the transition from double to single support over the front foot in the back of the circle was reported close to 4.0 m/sec., in Lanka (2000). Coh & Stuhec (2005) reported a maximum velocity of 3.5 m/sec during the same phase. Generally, higher maximum value velocities are observed in

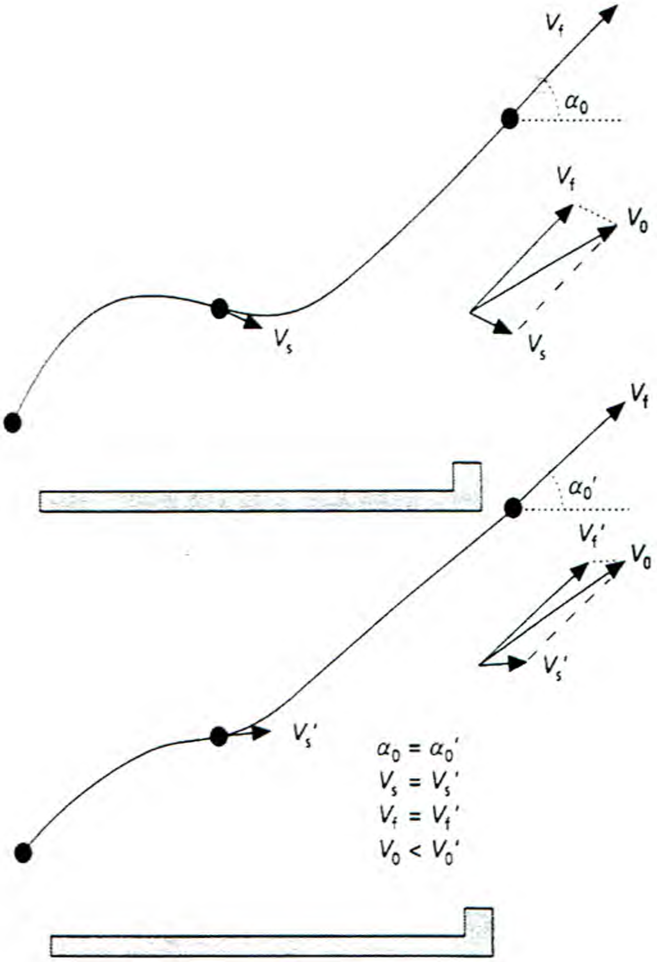

Figure 1. Graphic representation of the summation of the start (Vs) and final (Vf) velocities in the glide shot putting. Note, a) the different direction of the start velocity, and b) the differences in the magnitude of the resultant velocity. (From Lanka, 2000).

rotational shot putting up to the moment when the back foot lands in the middle of the circle (Susanka & Stepanek, 1988). At that moment, the shot velocity was reported at 1.38 m/sec. in Coh & Stuhec (2005) and no higher than 1.2 m/sec., in Stepanek (1990) for the rotational style. For the glide style, this value was about 1 m/sec., more as reported in Susanka & Stepanek (1988). Therefore, the velocity of the shot, at the moment the back foot lands in the circle to initiate the final double support, a decisive moment in shot putting, is quite higher in the glide as compared to the rotational style of throwing the shot. The significant drop in the velocity of the shot in rotational shot putting is due to the fact that in the airborne phase, the shot moves opposite to the direction of the throw, and also due to the presence of centripetal forces (particularly if a large loop forms) which at that particular moment resist the movement of the shot horizontally.

HORIZONTAL PLANE PATH

There has been an ongoing discussion as to the optimum shape of the path of the shot during the glide technique, as it advances from the back of the circle to its point of release. In this style, a curved path is observed. Due to the position of the shot in the start of the glide, the quantities of the velocities during the glide itself and that during the delivery phase, point in different directions (see Figure 1). This results in an inability to sum up all the velocities developed during the various phases of the throw no matter what method is used to lessen that effect. For example, if the velocity of the shot is around 2 m/sec., at back foot landing in the middle of the circle, and assuming that a shot putter can put the shot around 20 meters without gliding, which requires a release speed around 13 m/sec., then a total velocity of around 15 m/sec., would result in throws in excess of 24 meters, something that would not be the case if the same thrower were to actually glide and throw.

It seems that with the rotational style, the issue of better aligning the initial and final velocity directions can be better resolved and make it possible to increase the path of force application during the final effort (Lanka, 2000). For this to occur, the shot will move at the end of a large radius (make a loop) during the rotation in the middle. Assuming that the angular velocity is the same as in a smaller or no loop condition, this will result in higher linear velocity of the shot. Also, a larger loop will increase the load on the muscles, in the form of additional resistance, so that a higher level of strength may be necessary (Tutevich, in Lanka, 2000). Similarly, too large of a loop may decrease the velocity of the extension of the throwing arm. The shot can indeed be moved on a large or a small loop, or the athlete can move around the shot (see Figure 2). In throws with a larger loop, maintaining the direction of the shot may be problematic as it happens when the shot lands out of the sector to the right, due to great centripetal forces.

Regarding the importance of the tangential velocity (i.e., the linear speed of something moving along a circular path), during the second single support, Gutierrez-Davila et al. (2009), mentioned that their results confirmed that this is a critical point in the course of a rotational

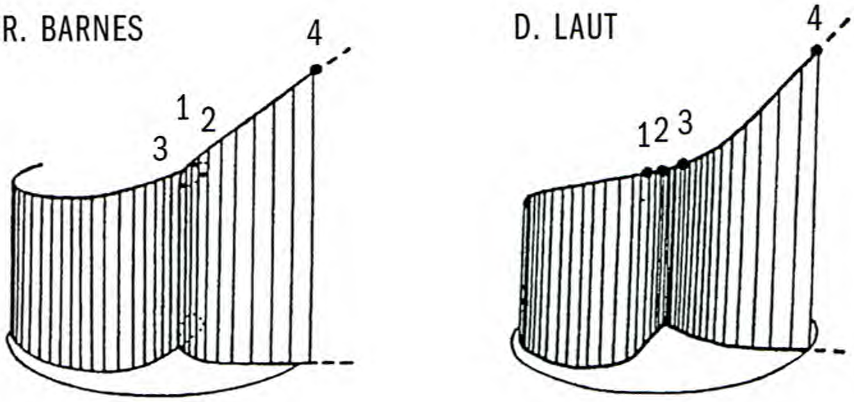

Figure 2. Path of the shot with (left) and without a loop (right). Instance (1), take off from front foot in the back of the circle, (2), landing of the back foot, (3), landing of front foot for the power position, (4), release. (From Bartonietz, 1994a).

shot put, but they could not confirm that the tangential velocity of the shot at the moment of the second single support is related to the release tangential velocity of the shot or whether it is actually problematic to keep the shot in the proper direction.

TOTAL ACCELERATION PATH VS. DELIVERY PATH

The lengthening of the acceleration path has been a common argument for the rotational shot technique. Bosen (1985) reported the length of implement trajectory to be around 2.4 meters for the glide technique and 4.8 meters for the rotational. Because of the emphasis placed on a greater path of acceleration, Hay (1993), throwers in both techniques should lower the torso in the initial stages of the throw so the shot is outside the confines of the ring in an apparent effort to lengthen the horizontal and vertical displacements of the shot.

Bartonietz (1994b), however, suggested that although indisputably the shot covers a longer overall path during the rotational technique, the path that matters is what he termed the "delivery" path which is not longer in the rotational as opposed to the glide technique. Analyzing two top throwers of the time he found that the glide thrower had a 12% longer "final" path. Stepanek (1987), reported a 0.3 meter longer delivery path for a glider compared to a rotational, when he compared two junior throwers.

The relationship though between the velocity of the shot and the distance over which force is applied on the shot during the final drive and effort, needs to be better appreciated from a mathematical perspective also. That is, we can generally say that the greater the distance of the acceleration path, the higher the final velocity. However, the underlying assumption for this to be true is that this occurs only when acceleration is constant. This probably is not the case in shot putting and the other throwing events. In those cases, the thrower utilizes a time of acceleration that is related to their individual capacity to apply force which is usually the result of the thrower's particular technique and anthropometric characteristics. Gutierrez et al. (2009), reached the conclusion that, to the extent that the distance of the acceleration is reduced, up to certain minimum values, the force applied to the shot increases. This fact is based on the Hochmuth's theories on the optimum distance of acceleration for the high jump (as reported in Gutierrez, 2009) and those developed by Perrine & Edgerton (1978), on the individual capacity of the muscles to develop force.

Obviously the reason for the claims pertaining to the relative importance of the final path as opposed to the total path, are twofold. First, as mentioned above, the velocity of the shot drops significantly during both styles and more dramatically in the rotational style, at the back foot landing in the middle of the circle. In addition, accelerative forces cannot be applied on the implement during the flight phase which precedes the delivery phase. World class shot putters employ longer delivery paths which are between 1.6 and 1.8 meters.

Moreover, differences between the two techniques as far as the distance between the point of release of the shot and the stop board should be taken into account. This because both the acceleration path itself can potentially become longer and also the shot is released further to the front of the circle in relation to the point of distance measurement. Bosen (1985) illustrated a greater distance between the stop board and the point of release for the rotational technique in the order of 0.3 meters. Kerssenbrock (1974) reported a distance of 0.4 vs 0.1 meters for the rotational and the glide styles respectively.

THE SECOND SINGLE SUPPORT

As the back foot lands in the circle to establish the second single support, the torso should be comparatively more erect in rotational throwers than for gliders (Oesterreich, 1997). With a position like this, the goal will be for the athlete to be able to rotate easier due to the shorter radius of rotation such a position allows. However, as the torso becomes taller, there is a shortening of the trajectory along which the shot can be accelerated during the final effort. In turn, however, this position, compared to that during the glide technique, can lead to a greater shoulder-hip separation and greater knee flexion (both good criteria for efficient shot putting) at the moment the back foot lands on the ground for the second single support. Another effect mentioned by Jarver (1976) is that the shoulder axis of rotational shot-putters slows down more in relation to the hip axis, leading to a more torqued power position.

Moreover, regarding the implement velocity at the second single support, although rotational shot-putters experience lower velocities, they also experience greater shoulder axis to hip axis torsion while at the same time the shot's position is located at greater lateral distance from the direction of the throw (Lindsay, 1994), leading to an increase of the angular trajectory of the shot during the delivery phase. From a physiological point of view, the observed increase in the torsion angle between shoulders and hips, also creates a beneficial pre-tension of the torso musculature.

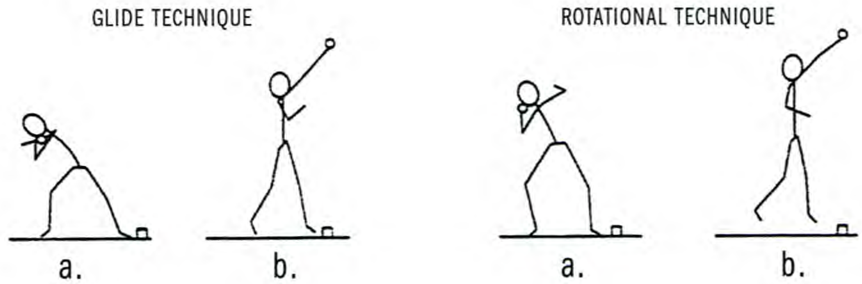

Figure 3. Schematic representation of the differences between the two techniques during the front foot landing by the stop board (a), and at release (b).

THE TRANSITION TO THE FRONT FOOT

The time between the landing of the back foot on the ground for the second single support, and the landing of the front foot in the front of the circle expresses the transition phase. During this phase there is a deceleration of the shot in rotational shot putting which reaches the level of about 1 m/sec., according to Coh & Stuhec, (2005). On the other hand gliders to not experience such a loss in the shot's velocity at this particular phase.

According to Lindsay (1994) and McCoy et. al (1984), at least part of the reason for the shot's deceleration during the transition phase, can be attributed to longer transition times when employing the rotational technique which can be twice as long as those of the gliders. Short transition times are linked to longer throws in the rotational technique (Young, 2006) and the glide technique alike. It may be that shorter transition times may actually enhance a greater shoulder to hip axis torsion. According to Goss-Sampson & Chapman (2003), longer transition times, smaller maximal shoulder-hip torsion during the transition phase and smaller shoulder-hip torsion at the end of the transition phase were linked to shorter throws. Along the same lines, Heger (1974) suggested that shorter transition times minimize the shot's deceleration before the final double support. He also implied that longer transition times was one of the rotational technique's disadvantages.

SECOND DOUBLE SUPPORT

For the majority of the athletes, there is a significant difference between those employing the rotational and the glide techniques. Those who throw rotationally use a shorter base (distance between the feet) compared to those who glide (Bartonietz, 1994a; Bosen, 1985), in the order of 0.2 to 0.5 meters. This seems to be a disadvantage, due to the increased chances for fouling during the final effort. Bosen (1985) assigned a net benefit to the rotational technique with its narrow stance, commenting that longer contact is maintained beyond the stop board so that the delivery path varies between 1.7 and 1.8 meters as compared to between 1.5 and 1.6 meters during the glide. Another potential mechanical beneficial element of the narrow stance has to do with the creation of a double leg lift for the final effort. Lindsay (1994) reported that the shoulder to hip torsion achieved by rotational shot putters during the second single support, is lost by the time the front foot touches down for the second double support. Apart from being a disadvantage, however, this could indicate that rotational shot putters are accelerating the shot more efficiently during the transition phase by "untorquing" their shoulder to hip torsion angle before the front foot touches the ground in the front of the circle. This effect was coined as the rotational pre-acceleration by Oesterreich at al., (1997), who speculated that it was one of the main advantages of the rotational technique.

FINAL EFFORT

The role of both legs during the final effort is of paramount importance in both styles of shot putting in the sense that they are very active and contribute significantly to a successful completion of the throw. However, their actions could be quite different between the two styles. In the glide technique, the majority of the body weight is initially over the back leg before there is a transfer over the front leg. In the rotational technique, throwers often push simultaneously with both legs with minimal weight transfer from back to front (Figure 3). Heger (1974) commented that such an execution is not as effective as that of the glide, while others (Oesterreich at al. 1997), made the argument that according their rotational pre-acceleration theory (also see above), the shot putter while still in the second single support over the back leg, is able to begin rotational acceleration and successfully continue it through the release of the shot, thus enabling the thrower to more efficiently accelerate the shot in the final effort. The same authors suggested that to maximize the distance thrown, rotational shot putters should actually attempt to jump upwards for the delivery of the shot. This way, vertical acceleration is generated by the activity of the legs with horizontal acceleration being the result of the arm strike and the horizontal component of the rotational acceleration. Regarding the vertical jump, Bartonietz & Borgstom (1995), mentioned that the position for the final effort should be such so the thrower will be able to place the shot directly over the right thigh, pelvis and shoulder so that there is an efficient and most direct application of force to be transmitted on the shot itself.

Gutierrez-Davila et al. (2009), and Luhtanen et al. (1997) found that the great acceleration observed in both styles of shot putting during the delivery effort, was achieved by the rotational shot putters right after the landing of the front foot to complete the power position (Figure 4). On the other hand, the gliders exhibited a definite acceleration of the shot a bit later following the left foot

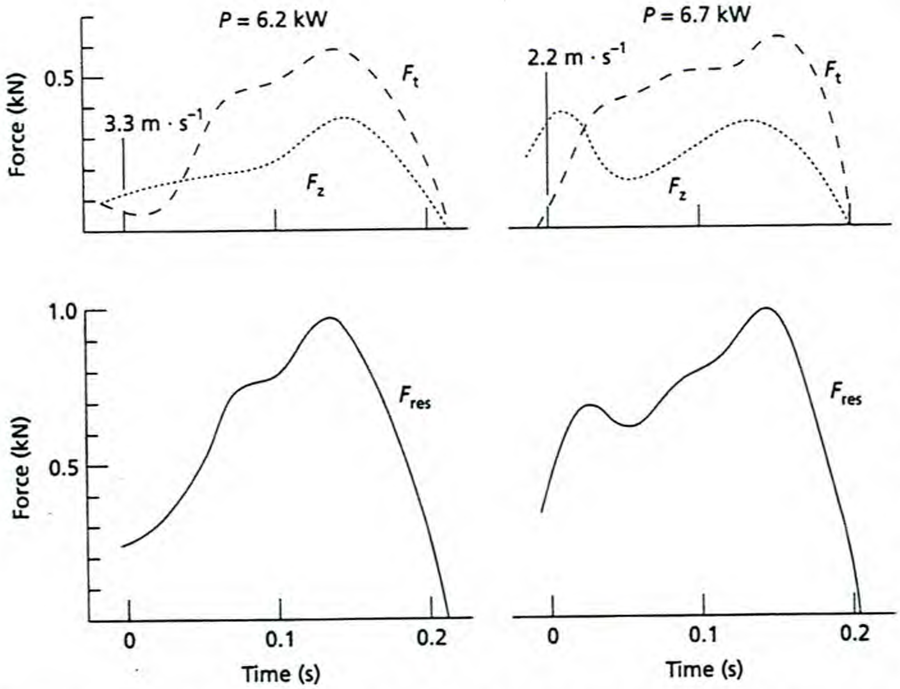

Figure 4. The force acting on the shot in the course of the throw following left foot landing in the power position, to release. Glide technique left, rotational technique right. Top graphs, (Ft) is the tangential component (changes in velocity), (Fc) is the centripetal component (changes in direction). (P) is the maximum power in kW, or 8.3 and 9.0 HP for the glide and the rotational technique respectively. Bottom graphs, (Fres) is the resultant force. (From Lanka, 2000).

landing (Gutierrez-Davila et al. (2009). Among the women gliders they analyzed, only two of the eight, were able to demonstrate a clear acceleration at front foot landing. The authors though noted that although their data showed that it may be easier to accelerate the shot during the final delivery of the shot with the rotational technique, their results do not necessarily show that the delay in the definitive acceleration observed in the glide technique is due to only one factor. Other factors related to the velocity of the body segments and the body positions themselves, are factors that cause the differences found in the final acceleration of the shot.

SHOT RELEASE

During the completion of the delivery phase, assuming that the lower extremities have contributed maximally in the course of the throw, it is essential that the non throwing side provides a solid support so that the throwing side can indeed act optimally also. That support of the left side is in the form of an active stop or block at least during the exact moment of release. It has been suggested that it is easier to stop the non throwing side during the glide as compared to the rotational technique, further suggesting that the thrower should attempt to essentially prevent the non-throwing side from decelerating/blocking (Goss-Sampson & Chapman, 2003). It has also been suggested that the difficulty of effectively blocking the non throwing side is a disadvantage of the rotational technique because it prevents the active stretching of the chest area and may also cause the forward movement of the trunk to be stopped prematurely (Heger, 1974).

On the other hand, there are some advantages of the rotational technique that may "make up" for such presumed shortcomings. For example, it has generally been accepted, and indeed for some is necessary, as in Oesterreich at al. (1997), that the thrower should be airborne during release if the rotational technique is used, something that it is not exactly and clearly the case in the glide technique. Indeed, an airborne delivery is observed in the majority of high level rotational shot putters. The short base of support, the reduced weight transfer from the back leg to the front, and the coordinated two-leg push during the release phase, actually necessitates an airborne release. Bartonietz & Bogstrom (1995) and Oesterreich et al. (1997), reported that the front foot comes off the ground before the back foot in all the athletes they studied, and it also reaches a higher point above the ground. This observation may provide evidence of the thrower's intention to "jump" upwards with a powerful action of the back leg. In the former authors' study, there was an implication that the higher the front foot is off the ground the better the back leg action may be. Arrhenius (2014), suggested that optimally, if the shot putter can produce greater peak force into the ground with he right leg during the delivery phase, this will cause the shot putter to come off their front leg sooner, resulting in greater velocity of release.

In addition, the narrow base and the two-leg push observed during the rotational technique may lead to a posture at release where the hips are more forward. This allows rotational shot putters to release the shot with the hips over the front foot thus enabling them to push and release the shot further in front of the stop board. Gliders on the other hand release the shot with the hips behind the front leg. (Kerssenbrock, 1974).

GROUND REACTION FORCES, EFFICIENCY, AND ENERGY DEMANDS

Ground reaction forces show a similar general pattern of the interaction of the feet in relation to the ground in both techniques in the phase following the second single support over the back foot, until the moment of release (Bartonietz, 1994a). Also, the data from Bartonietz (1994b) showed that rotational shot putters exhibit larger maximum ground reaction forces but directed steeper. Pagani (1985) addressed that the front leg of rotational shot putters applies up to three times as much force as the back leg and this exceeds the force exhibited by the front leg of glider shot putters, suggesting the different role of the front leg between the two shot put styles. Arrhenius (2014), found that indeed both absolute peak force values and peak force values as percentage of the body weight were higher for the front leg but only 6% and 11% respectively. Peng et al. (2008), reported that the braking force of the front leg was greater than that of the back leg, the maximal vertical force of the front leg was smaller than that of the back leg, and the total impulse of vertical force of the front leg was smaller than that of the back leg.

Bartonietz (1994b), reported that it is more difficult to produce early accelerating power output from the right leg in rotational shot putting, due to the longer transition times observed. His data indicated that the increase of the velocity of the center of gravity, as a result of the back leg's push only, in rotational shot putting, reaches only one third of that of the glide's value. However, this absolute right leg force value acting on the center of gravity should be evaluated not as just a brute force but as power, a fact that necessitates the consideration of the quantity of velocity (P= F x v). In other words, what matters is how fast the center of gravity moves when it really counts, which is during release. In that case, in the rotational technique, the velocity of the center of gravity increases as the thrower decreases the momentum of inertia and rotates faster (also in Stepanek, 1990), past the phase of the take off from the back leg. This increase can reach 0.8 m/sec. This value could probably not be obtained from the work of the right leg of a glider who can increase the velocity of the center of gravity by no more than 0.3 m/sec. (Bartonietz, 1994b).

Along the same lines, the power demands of the rotation technique are about 20% higher for comparable ranges, because the path of the shot and the thrower's body during the delivery is shorter and the velocity of the shot is lower at the start of the delivery. However, as hinted previously, the thrower using the rotational technique can create a high level of power with the help of the explosive leg thrust which in turn creates an explosive angular acceleration and a very high muscular pretension (Bartonietz,1994c)

Bartonietz (1994b) further reported that, a) the relative physical work to accelerate the shot is slightly higher in the rotational than the glide shot, however, there is more relative work required to lift the shot in the glide technique; b) the relative potential for increase of the shot's velocity during the delivery phase is higher in the rotational shot, as is also the relative potential to increase the shot's velocity from the shot's minimum velocity; and c) the relative physical power demand to accelerate the shot during delivery is higher in the rotational shot putting, which shows that the mechanical efficiency, in attaining a given performance, is not as good as that of the glide. Rotational shot putters must perform more work for the same result, which implies that they need a higher level of power in the form of specific strength. The specific strength will lead to an improved muscular pre-tension which together with the powerful back leg extension, creating vertical lift, result in a velocity of the center of gravity which is more than double that of the gliders.

Bosen (1985) addressed the efficiency of the two techniques in regards to the difference in distance between the execution of a standing throw and that of a full throw. In that respect, gliders generally expect 1.5 to 2.0 meters to be added to their standing throw as opposed to 2.75 to 3.0 meters, for their rotational counterparts. Bartonietz (1994c) also mentioned that training practice suggests a high efficiency of the rotational technique when taking into account the distance achieved by given abilities and the anthropometric data. That is, smaller and may be less strong throwers may be able to achieve better performance when employing the rotational technique.

Further illustrating the overall efficiency of the rotational shot, Stepanek (1990) compared two very high caliber throwers (the current two best of all time), who had exhibited similar performances (0.08 m. difference). He reported that the glider increased the velocity of the shot in the final effort, from 2.6 to the final 14.2 m/sec. along a delivery path of 1.99 meters, while the rotational shot putter increased the velocity from 0.5 to 14.25 m/sec., along a path of 1.75 meters. The author suggested that because of such observations the rotational technique may yield better performances. Other reasons for using the rotational technique were the enabling of achieving a better and more "natural" position of the body during the delivery phase and that it also allows for better utilization of the swing movements of the extremities.

CONCLUSIONS

According to Oesterreich et al. (1997), the most prominent advantage of the rotational technique over the glide, is that it allows for more favorable conditions for the final acceleration of the athlete-shot system. As Palm (1990), suggested, the essence of the rotational acceleration of the shot cannot be determined only by simply observing the values of the shot velocity and its trajectory in the course of a throw. In that sense, although the velocity of the shot may seem very low, (as it happens in the second single support, before the final effort), the quantity of motion and kinetic energy do not decrease, they remain high, and contribute significantly towards a maximum release velocity.

There is an observed rotational pre-acceleration of the thrower and the shot along with a highly efficient redistribution of the rotational energy between the lower extremities the torso and the throwing arm. In the rotational technique the optimal use of the inertia of the torso and the shot results in a clearly higher amount of tension in the muscles involved, and consequently to a more effective impulse buildup in the final effort phase. During the rotational technique, the shot putters may, on average, utilize shorter acceleration paths in the delivery phase, but they can compensate for this by utilizing higher angular velocity of the right side (hip) the throwing shoulder and elbow.

The start of the rotation itself is generally a more natural movement than gliding backwards. However, in competition, a disadvantage of the rotational technique is that it allows for inconsistent performance. Executing a good throw using the rotational technique without fouling, is generally more challenging as compared to the glide technique. The high rotational velocity which is twice that of the glide, along with the short duration of the delivery usually require more coordination. The rotational technique is a comparatively more complex and difficult technique to perfect and is subject to flaws. Tiny imperfections can shave distance off the throw.

Selection of rotational shot putters should be based on the same criteria as those for the gliders. However, shorter but more powerful throwers have a better chance for better individual performances with the rotational style. The rotational technique could also be better suited for those throwers who lack what is called "starting" strength something which is more prevalent during the static start of the glide technique.

Because of the pattern of the acceleration path of the shot which is characterized by a reduction of the velocity of the shot to 1m/sec. or less, at the moment the back foot lands somewhere in the center of the circle, the power requirements for the final acceleration of the shot are higher in rotational shot putting as compared to the glide. One also needs to take into consideration that the stance during the power position is shorter than the glide, the torso is more erect at back foot landing in preparation for the power position, both contributing to a shorter acceleration path of the shot. In the case of comparable achieved distances, the assumption is that the force exerted can be 8% greater than in the glide. This power must be generated by the leg, the torso, the shoulders and the arm musculature. It can be produced by employing the driving forces of the skeletal and motor systems, that is, the rotational acceleration of the body and shot system, with the resulting buildup of tension in the final position and drive. It is at this decisive moment that the rotational technique, although a technique that requires more power and skill, may have a clear advantage over the glide technique.

REFERENCES

Arrhenius, N. (2014). Ground forces impact on release of rotational shot put technique. Masters thesis, Brigham Young University, Provo, UT.

Ariel, G., Penny, A., Probe, J., Buijs, R., Simonsen, E., Finch, A., & Judge, L. (2004). Biomechanical analysis of the shot-put event at the 2004 Athens Olympic Games. Accessed from the public domain.

Bartonietz, K. (1994a). Rotational shot put technique: Biomechanic findings and recommendations for training. Track and Field Quarterly Review, 93(3), 18-29.

Bartonietz, K. (1994b). The energy relationship in rotational and glide shot put techniques. Modern Athlete and Coach, 32(2), 7-10.

Bartonietz, K. (1994c). Training of technique and specific power in throwing events. Modern Athlete and Coach, 32(1), 1-16.

Bartonietz, K., & Borgstöm, A. (1995). The throwing events at the World Championships in Athletics 1995, Goteborg - Technique of the world's best athletes. Part 1: shot put and hammer throw. New Studies in Athletics, 10(4), 43-63.

Bosen, K.O. (1985). A comparative study between the conventional and rotational techniques of shot put. Track & Field Quarterly Review, 85(1), 7-11.

Coh, M., & Stuhec, S. (2005). 3-D kinematic analysis of the rotational shot put technique. New Studies in Athletics, 20(3), 57-66.

Goss-Sampson, M.A, & Chapman, M. (2003). Temporal and kinematic analysis of the rotational shot put technique. Journal of Sports Sciences, 21, 237-238.

Gutierrez-Davila, M., Rojas, J., Campos, J., Gamez, J., & Encarnacion, A. (2009). Biomechanical analysis of the shot put at the 12th IAAF world indoor championships. New Studies in Athletics, 24(3), 45-61.

Hay, J.G. (1993). The Biomechanics of Sports Techniques (4th ed.). Englewood Cliffs, NJ: Prentice Hall.

Heger, W. (1974). Is the rotation technique better? Track Technique, 58, 1849.

Jarver, J. (1976). Discus-style shot put. Track Technique, 66, 2097-2098.

Kerssenbrock, K. (1974). Potential of the rotation shot put. Track Technique, 58, 1848.

Lanka, J. (2000). Shot Putting. In V. Zatsiorsky (Ed.), Biomechanics in Sport (pp. 435-457). London: Blackwell Science Ltd.

Lindsay, M.R. (1994). A comparison of rotational and O'Brien shot put techniques. The Thrower, 63, 12-17.

Luhtanen, P., Blomqvist, M., & Vanttinen, T. (1997). A comparison of two elite shot putters using the rotational shot put technique. New Studies in Athletics, 12(4), 25-33.

McCoy, R.W., Gregor, R.J., Whiting, W.C., Rich, R.G., & Ward, P.E. (1984). Kinematic analysis of elite shot-putters. Track Technique, 90, 2868-2871.

Oesterreich, R., Bartonietz, B., & Goldmann, W. (1997). Rotational technique: A model for the long-term preparation of young athletes. New Studies in Athletics, 12(4), 35-48.

Pagani, T. (1985). The "spin" shot put style. Track & Field Quarterly Review, 85(1), 15-16.

Palm, V. (1990). Some biomechanical observations of the rotational shot put. Modern Athlete and Coach, 28, 15-18

Peng, H., Peng, H., & Huang, C. (2008). Ground reaction force of rotational shot put-case study. ISBS conference, July 14-18, 2008, Seoul, Korea.

Pierrine, J., & Edgerton, V. (1978). Muscle-force-velocity and power-velocity relationships under isokinetic loading. Medicine in Science and Sport, 10, 149-156.

Stepanek, J. (1990). Kinematic analysis of glide and spin shot put technique. Biomechanics in Sports, Proceedings of the VIII international symposium on biomechanics in sports.

Stepanek, J. (1987). Comparison of the glide and the rotation technique in the shot put. Paper presented at the biomechanics in sport V: Proceedings of the fifth international symposium of biomechanics in sport, Athens: Hellenic sports research institute.

Susanka, P., & Stepanek, J. (1988). Biomechanical analysis of the shot put. In Scientific Report on the Second IAAF World Championships in Athletics. Rome: H1-H77.

Young, M. (2009) Development and application of an optimization model for elite level shot putting. Doctoral dissertation, Baton Rouge, LA, Louisiana State University.

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