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The Function of the Extremities in Discus Throwing

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The Function of the Extremities in Discus Throwing

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THE ANGULAR MOMENTUM CONCEPT

Angular momentum, which is also called rotary momentum, is a mechanical factor in discus throwing that basically describes how fast the thrower+discus system is rotating (speed of rotation). In this respect, angular momentum is also related to how "spread out" the system may be with respect to the axis of rotation. The faster the system is rotating and the more spread out the system is with respect to the axis of rotation, the greater the angular momentum of the system. Changes in the angular momentum of the system can occur only when forces are exerted at a point off center to its center of mass (c.m). In turn, this is only possible when the system is directly affected by another system as, for example, the ground. In cases where the system is not in direct, physical contact with other systems, its angular momentum will remain constant. In discus throwing, when the thrower is airborne, as it happens in the phase between left foot takeoff and right foot touchdown in the middle of the circle, the angular momentum of the thrower+discus system will remain constant. Generally, engaging the "free" extremities quite aggressively toward the direction of the angular momentum that the thrower desires to achieve, enhances the generation of angular momentum in discus throwing. It is also possible to transfer angular momentum from one part of the system to another, while for any given amount of angular momentum that a part of the system has, the closer this part is kept to the axis of rotation, the faster it will tend to rotate around that axis.

In discus throwing, the thrower will acquire angular momentum, the discus will acquire angular momentum, and the combined thrower+discus system will acquire angular momentum. The force interaction between the thrower and the ground will determine the generation (or the loss) of angular momentum for the thrower+discus system, while the force interaction between the thrower and the discus will determine the transfer of angular momentum from the thrower to the discus or vice versa. In these terms, the angular momentum of the thrower+discus system is equal to the angular momentum of the thrower plus the angular momentum of the discus. In studying the angular momentum of the discus, one can gain an insight as to the actual speed of it because those two values are directly proportional. In other words, by examining the angular momentum of the discus we

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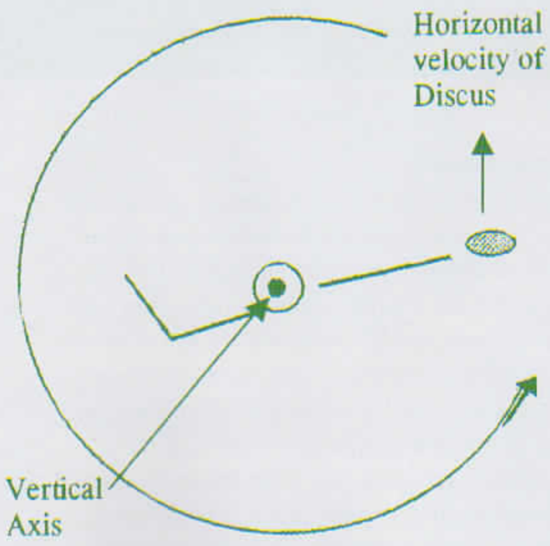

Figure 1. Angular momentum about the vertical axis (view from top. Curved arrow indicates direction of rotation).

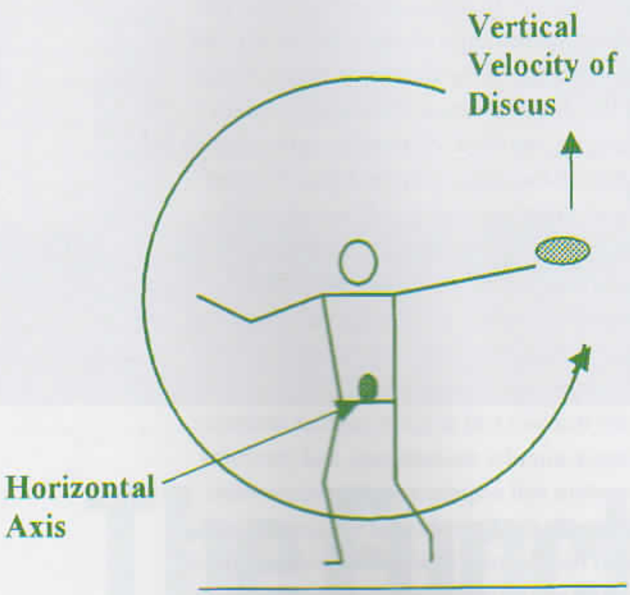

Figure 2. Angular momentum about the horizontal axis (view from the 0° azimuthal angle. Curved arrow indicates direction of rotation).

Figure 3. Forward linear momentum (transition to the middle of the circle).

can also tell whether the discus is moving fast or not. The ground reaction forces will produce the angular momentum in two directions. There is angular momentum about the vertical axis (figure 1) and there is also angular momentum about the horizontal axis (figure 2). A transfer of angular momentum about the vertical axis from the thrower to the discus imparts horizontal speed to the discus. A transfer of angular momentum about the horizontal axis from the thrower to the discus imparts vertical speed to the discus (Dapena, 1993; Maheras, 2007).

The contribution of the rotary momentum in discus throwing is greater than the contribution of the linear momentum in both the vertical and horizontal directions.

In discus throwing there is also linear momentum generation involved. Forward linear momentum (figure 3) will contribute approximately 6% to the horizontal speed of the discus at release with the angular momentum about the vertical axis contributing the remaining 94% of the horizontal speed. Upward linear momentum (figure 4) will contribute approximately 10% of the vertical speed of the discus at release with the angular momentum about the horizontal axis contributing the remaining 90% of the vertical speed (Dapena, 1993; 1994). Therefore, as a whole, the contribution of the rotary momentum in discus throwing (its contribution to the speed of the discus at release) is significantly greater than the contribution of the linear momentum in both the vertical and the horizontal directions. Given this fact, the action of the extremities as sources of rotary momentum generation is examined below.

PROPULSIVE ACTIONS OF THE RIGHT LEG AND THE LEFT ARM IN THE BACK OF THE CIRCLE

As soon as the right foot is lifted off the ground in the back of the circle, the right leg should make a rather wide counterclockwise rotation around the body as viewed from overhead. Following, it should be "thrust" very aggressively towards the front/middle of the circle. This thrusting action of the right leg enables the generation of angular momentum around the vertical axis due to the fact that it makes it easier for the left foot to exert on the ground the forces that are necessary for generating angular momentum. The right leg should be thrown around the body in a controlled but very fast way and over the longest range of motion possible. This dynamic action of the right leg can be experimentally evaluated with the larger values considered to be optimum in discus throwing (Dapena & Anderst, 1997). In case the right leg action seems to be less than optimum, two main factors can be the cause. First, the angular momentum of the right leg may be small or second, the duration of the sweeping of the right leg may be too brief.

In the case where the angular momentum of the right leg is small, this could be due to a slow speed of rotation of the leg or due to a short distance between the c.m of the leg and the c.m of the system (figure 5).

The activity of the left arm in the back of the circle is similar to that of the right leg. As soon as the discus reaches its furthermost position to the right during the winds, and until the lift off of the left foot, the left arm should execute a wide rotation around the body and towards the left. This sweeping action of the left arm enables the generation of angular momentum around the vertical axis following the same mechanism as during the action of the right leg. The left arm should be thrust in a controlled manner but at high speed, far from the middle of the body and over the longest possible range of motion. During the dynamic action of the left arm, larger values of angular momentum are considered to be optimum in discus throwing. If the left arm action seems to be less than optimum, either the angular momentum of the arm may be small, or the combined duration of the double support and single support over the left foot in the back of the circle may be too brief. In the case where the angular momentum of the left arm is small, this could be due to a slow speed of rotation of the arm or due to a short distance between the c.m of the arm and the c.m of the system (figure 6).

An important observation in comparing the momentum of the right leg and the left arm in the back of the circle is that the average angular momentum of the left arm is only about half of that of the right leg (Dapena & Anderst, 1997). However, the sweeping of the left arm lasts two and a half times longer than the sweeping of the right leg. Therefore, the longer duration of the sweep of the left arm allows the left arm to make a larger contribution to the rotation of the system. On average, the action of

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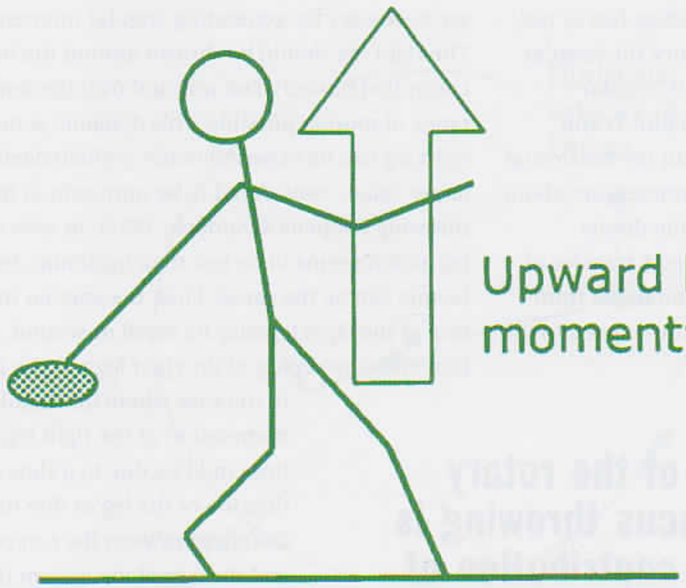

Figure 4. Upward linear momentum (final delivery).

The contribution of the rotary momentum in discus throwing is greater than the contribution of the linear momentum in both the vertical and horizontal directions.

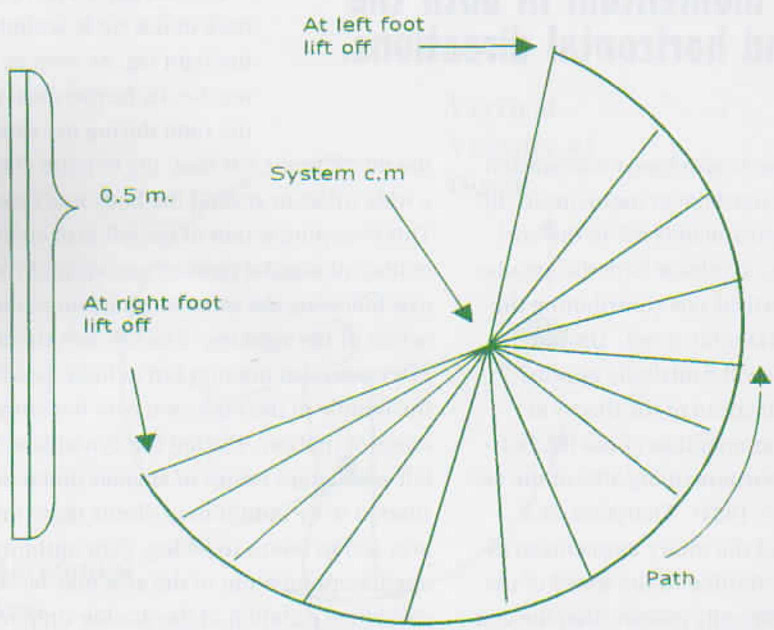

Figure 5. Approximate path of the c.m of the right leg during its drive. The larger the shaded area the better (adapted from Dapena & Anderst, 1997).

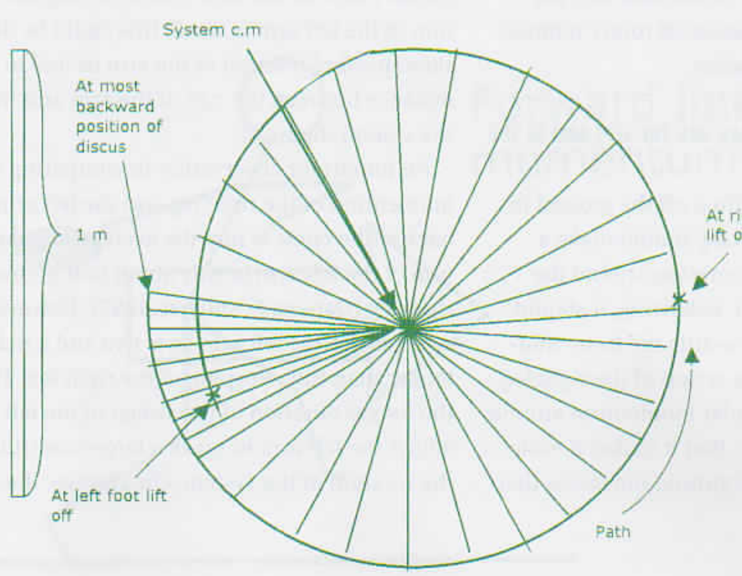

Figure 6. Approximate path of the c.m of the left arm during its initial drive. The larger the shaded area the better (adapted from Dapena & Anderst, 1997).

the left arm contributes about a third more than the action of the right leg to the rotation of the system.

RECOVERIES OF THE RIGHT AND LEFT LEGS

During the airborne phase immediately following the left foot push off in the back of the circle, when ground contact is lost, no more angular momentum can be produced and the legs cannot be used for the generation of such momentum. The new role of the legs during this phase is to increase their own speeds of rotation in relation to the upper body. This will allow for an early and quick planting of the left foot in the front of the circle – a beneficial action in discus throwing – (also see Maheras, 2008) and will also enable the thrower to assume a "wound-up" position in the middle of the circle, one where the lower body and hip axis are rotated significantly ahead of the upper body and the shoulder axis. To achieve a faster rotation of the legs, the thrower, during the non-support phase and the single support over the right foot, should decrease as much as possible the distance between the c.m of the right and left leg and the axis of the system. That axis passes through the system's c.m, is in line with the lower and upper part of the system and if the system tilts, it tilts also. During this airborne phase, the smaller the radius of the legs the better (figures 7, 8).

The thrower can transfer angular mometum to the legs...the slowing down of the left arm causes it to fall behind in its rotation with respect to the rest of the system.

RECOVERY OF THE LEFT ARM

As is the case with the right and left legs, the left arm is also unable to produce any additional angular momentum during the airborne phase after the left foot lifts off in the back of the circle. This is again due to the loss of ground contact. The function of the left arm during this airborne phase is to slow down its rotation and/or decrease its radius of rotation. This will cause the arm to use a smaller amount of the total angular momentum of the system and thus there will be more angular momentum available for the other parts of the system. Essentially, there is a transfer of angular momentum from the left arm to the rest of the system. There are two advantages of the mentioned slowing down of the left arm. First, the thrower can indeed transfer angular momentum to the legs where it is needed the most. That is, the slowing down of the left arm, in cooperation with the mid section muscles, contributes in speeding up the rotation of the legs which in turn results an earlier planting of the left foot in the front of the circle. Second, the slowing down of the left arm causes it to fall behind in its rotation with respect to the rest of the system. In turn, this makes it possible for the left arm to later execute another counterclockwise (towards the left) sweeping action as soon as ground support has been reestablished. This second sweeping action aids in generating additional angular momentum for the system during the single support over the right foot and the double support delivery phases.

If the angular momentum of the left arm is large during the period of the left foot takeoff in the back of the circle and the subsequent right foot landing, either the arm is rotating too fast or the radius of the arm is kept too long. It is not clear what would be the preferred method as the thrower attempts to keep the angular momentum of the left arm low. Does a thrower need to slow the arm down or does she need to shorten its radius of rotation? Both methods will be equally effective in helping the legs accelerate. However, the slowing down of the arm action offers the advantage of allowing the left arm to keep moving over a long range of motion in the ensuing single support and double support phases (Dapena & Anderst, 1997). If the left arm's radius is shortened, that short radius will cause the arm to keep moving to the left quite fast which will allow for a smaller range of motion available for the arm in the subsequent single and double support phase (figure 9).

SECOND PROPULSIVE DRIVE OF THE LEFT ARM

Following the right foot landing in the middle of the circle, the thrower should throw the left arm very dynamically to the left, far from the middle of the body and through the longest range of motion possible (figure 9). As a result, the c.m of the left arm obtains a significant amount of speed. This action aids in the generation of angular momentum for the thrower+discus system because it enables the right foot and, during the double support both feet, to exert on the ground the forces necessary for generating angular momentum. A characteristic of this part of the throw is that the thrower has an inclined position towards the back of the circle, which causes the axis to also have a backward incline. Due to that incline, the angular momen- →

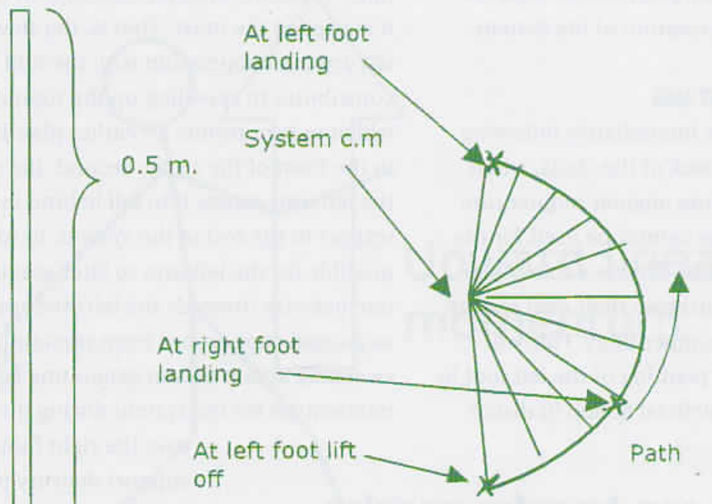

Figure 7. Approximate path of the c.m of the left leg during its recovery. The smaller the shaded area the better (adapted from Dapena & Anderst, 1997).

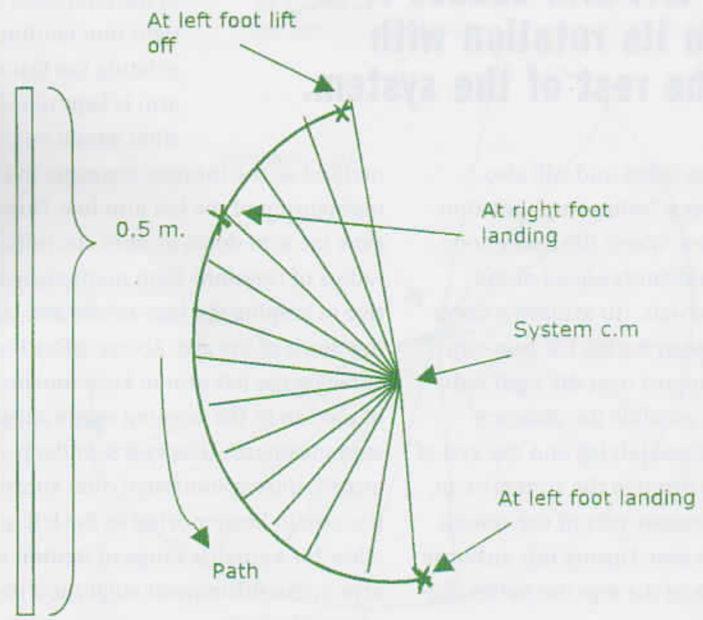

Figure 8. Approximate path of the c.m of the right leg during its recovery. The smaller the shaded area the better (adapted from Dapena & Anderst, 1997).

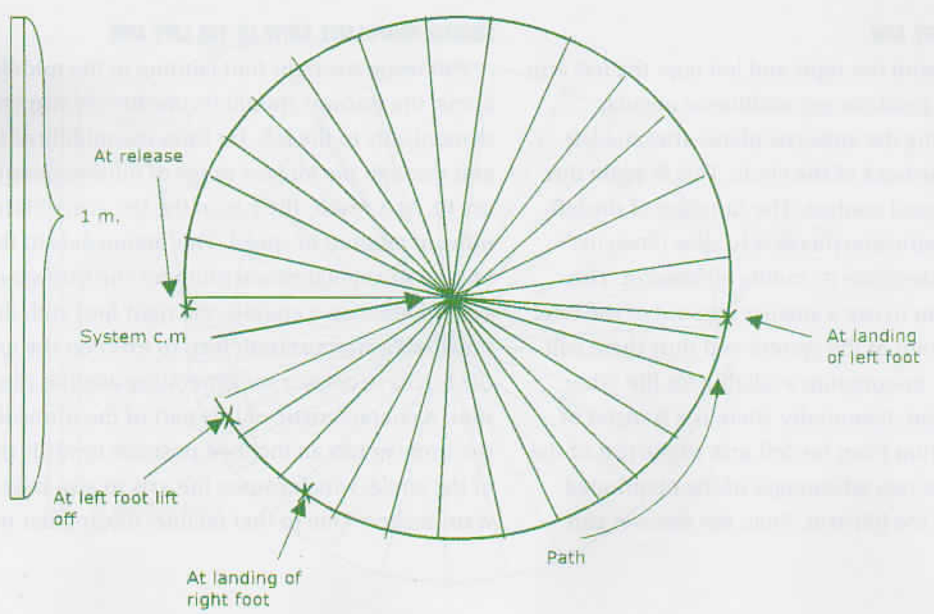

Figure 9. Approximate path of the c.m of the left arm during its initial recovery, during its second drive and, during its second recovery (adapted from Dapena & Anderst, 1997).

tum generated by the second propulsive action of the left arm is a combination of angular momentum around a vertical axis and angular momentum around a horizontal axis which is exactly what the discus thrower is after, since during that phase the thrower desires to develop both horizontal and vertical speed which will contribute to the final speed of the discus at release. If the thrower's second left-arm drive is less than optimum, that occurs because either the angular momentum of it is small or the combined duration of the single support on the right foot and the delivery phase is too short.

SECOND RECOVERY OF THE LEFT ARM

The second propulsive action of the left arm described above will help the thrower+discus system to acquire more angular momentum from the ground, which is very beneficial for the throw. Most of this angular momentum will be stored in the left arm itself. However, if the thrower keeps the momentum stored in the left arm throughout the delivery phase, then it will not do the thrower any good. That is why, before the release of the discus, it is necessary for the discus thrower to transfer as much of this angular momentum as possible to the discus she is holding. To do this, the thrower needs to reduce the angular momentum of the left arm during the final release phase by either slowing down the left arm or by reducing its radius of motion (figure 9). For a satisfactory transfer of angular momentum from the left arm to the rest of the system and the discus, the smaller the angular momentum of the left arm at the instant of release the better. It seems that most throwers slow down the left arm to reduce its angular momentum while a few others in addition to slowing the arm down will also progressively shorten its radius of rotation by bending the arm at the elbow.

SOME CONSIDERATIONS

It was mentioned earlier that rotary momentum contributes the great majority of the total momentum observed in discus throwing. Based on that, we can generalize and conclude that the discus thrower should make rotary momentum development the focus of her throwing and she should be devoting most of her efforts to maximizing the rotational part of her technique and the development of rotary momentum following the guidelines mentioned above. Many coaches and athletes may tend to overemphasize the linear momentum and the linear drive (sprint) from the back of the circle towards the center at the expense of rotary momentum. However, there is a caveat here. That is, paying attention to the linear drive from the back of the circle is not entirely a bad thing, because the ground reaction force that drives the thrower off from the back of the circle also contributes to the generation of a fair amount of the angular momentum about the vertical axis, due to the fact that (in the view from overhead) the force points off-center to the center of mass of the thrower-plus-discus system as it passes slightly to the right of the c.m (Dapena, 2009). If a thrower seems to be entirely ignoring the linear aspect of throwing then there is a need for the coach to address the issue and place the needed emphasis there. However, in the final analysis there is no question that the rotational effect is by far the more important of the two (rotational vs. translational). This should be clear in the coach's mind.

> **Many coaches and athletes tend to overemphasize the linear momentum and the linear drive from the back of the circle toward the center at the expense of rotary momentum.**

We also saw earlier that on average, the left arm contributes about a third more than the action of the right leg to the rotation of the system. For that reason, the role of the left arm needs to be better appreciated. We saw that the thrower needs to move the left arm aggressively and at high speed to the left and then stop it and "re-wrap" it clockwise prior to the start of the double-support. Finally, she should again move it aggressively and at high speed to the left during the final double support, and stop it (or bring it toward the body) just before release. So what the athlete needs to do is, two high-speed drives of the left arm and two "re-wrappings." However, contrary to those guidelines, many coaches have been encouraging the thrower to keep the left arm relatively inactive, particularly during the entry in the back of the circle. This encouragement may not be entirely incorrect. If the thrower allows the aggressively moving left arm to overly engage the upper body in leading the throw in the back of the circle, then there should be

a compromise and this arm needs to be restrained and be kept in check. The criterion for the dynamic or not involvement of the left arm, particularly in the back of the circle, is whether the athlete, following the drive from the back, is able to rotate the hips counter-clockwise relative to the shoulders so that the hips are again rotated markedly ahead of the shoulders before the start of the final delivery action. Even if the athlete were to allow the upper body (shoulders) to catch up with the lower body (pelvis) just before the takeoff from the back of the circle, this would not be a problem, again provided that the thrower is able to get "wound up" in the middle of the circle. Then the thrower would be OK. If the thrower could bring the shoulders back again after they have caught up with the pelvis, then it would actually be a good thing to allow the shoulders to "catch up" with the pelvis momentarily around the end of the takeoff from the back of the circle. Technical finesse comes into play here with the goal being for the thrower to take advantage of as much rotary momentum as possible from the left arm in the back of the circle without compromising the integrity of the ensuing throwing movement.

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