UTILIZING THE STRETCH-SHORTENING CYCLES IN DISCUS TECHNIQUE (PART 1)

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THE STRETCH-SHORTENING CYCLE CONCEPT

An individually specific, optimal performance must successfully combine a large number of elements; one element of paramount importance is the ability to use the ***stretch-shortening cycle (SSC)*** to optimize power output, but first some explanation of the principle.

A ***stretch-shortening cycle*** starts with a rapid eccentric movement that stretches the muscle stimulating the ***myotatic stretch reflex***; this is immediately followed by a rapid concentric contraction in the lengthen muscle. In practical terms, it occurs whenever a movement sequence involves a rapid muscle stretch (eg. quadriceps in a sprinter's mid-support phase) followed by reversing the movement with a rapid concentric contraction (eg. drive phase/take-off), effectively shortening the muscle.

This is a natural mechanism that can be conditioned to achieve optimal performance for the greatest force and power, in a concentric phase. It is also variously described by coaches as the *reversibility of muscle action*, *elastic energy* and as a result of *pre-tensioning muscles*.

A familiar example occurs when a jumper invokes this principle in resistance conditioning by jumping down from a box and then immediately rebounding up onto another box. When landing, several extensors (including the calf muscles, quadriceps, erector-spinea, etc.) slow descent before reversing the motion (i.e. take-off). In this instance, power is augmented in these extensors by harnessing the stretch-shortening cycle. For the triple jumper, this natural stretch-shortening cycle occurs in every landing and take-off starting with every landing phase, including each run-up stride, and finally the hop, step and jump phases. With every ground contact, muscles eccentrically work to absorb the flight-landing impact and then respond utilising an augmented concentric contraction to drive each take-off.

In discus we also see stretch-shortening cycles repeating through the phases: i.e.

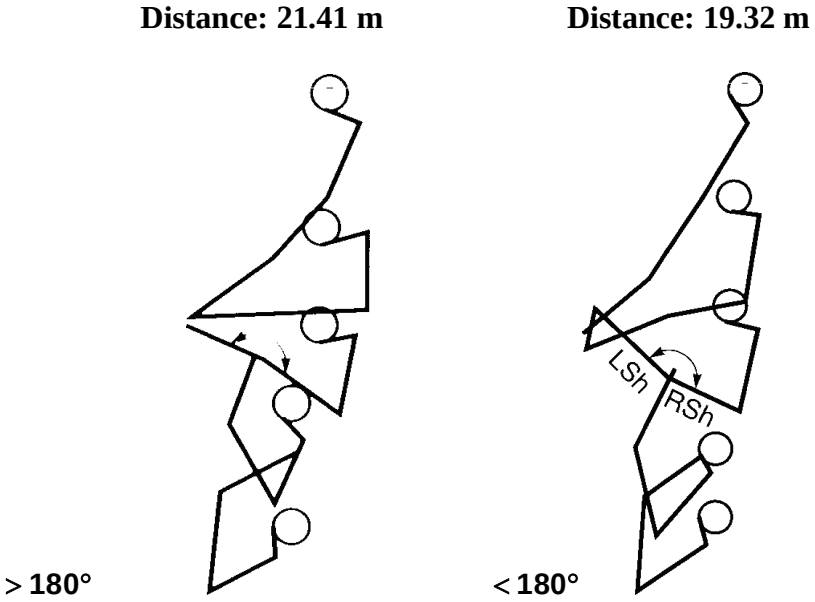
- During left leg-loading, the right leg's adductors and hip flexors are stretched and primed for the swing kick, then again
- as the left-foot loads and unloads to direct and launch into the brief airborne phase, then again
- during the right-leg landing to begin transition,
- and again as the left-foot grounds and weight shifts forwards while the hips and knees continue rotating against the inertia of the upper body, increasing torso-torque recognised by an increasing hip-shoulder-lines of separation.
- As the delivery phase progresses, the right pectorals are also stretched by the advance of the right-hip and inertia of the right shoulder and even further by the maximum separation of the advancing right-shoulder ahead of the trailing discus arm.

These cycles occur in all the throwing events, e.g. in figure 1 we see how a shot-putter successfully utilizes the *stretch-shortening cycle* for the chest and then in another attempt fails to establish pre-tension. In this example, the athlete's better throw shows that the pectoral muscles were initially stretched, with the shoulders appearing retracted (i.e. >180°) before the concentric contraction /shortening used to accelerate the distal end of the humerus.

In the first instant, the result is greater force in a given time (i.e. power) compared to the second release. If all other release parameters are the same greater power means a faster release velocity $\boldsymbol{V}$ and greater range $\boldsymbol{R}$ (range ***R,*** is directly proportional to the square of the release velocity **R**, i.e. $\mathbf{R} \propto \boldsymbol{V}^2$).

This example shows a significant difference of 2.09m (approximately 11%) and implies that the correct technical application of the SSC principle increases power, release speed and range.

The following 3 sections discuss how the SSC principle is invoked for discus technique and specifically, in the release phase.



The anterior angle between the left and right shoulders (i.e. LSh & RSh).

Figure 1 *Stick figure showing two attempts in shot putting with different results (**top view**). LSh and RSh are the left and right shoulders. In the successful attempt (result 21.4I m), the athlete managed to stretch the muscles of the shoulder girdle prior to delivery. In the less successful attempt (19.32 m), this element of technique was not properly executed. Note. Adapted from* ***S****port Technique, Elite* ***S****hot Putters by K. Bartonietz, 1990, June 7-9, paper presented at The First International Conference: Technique in Athletics, Koln. Reprinted in Science and practices of Strength training by Vladimir M. Zatsiorsky. Reproduced with permission by V. M. Zatsiorsky*

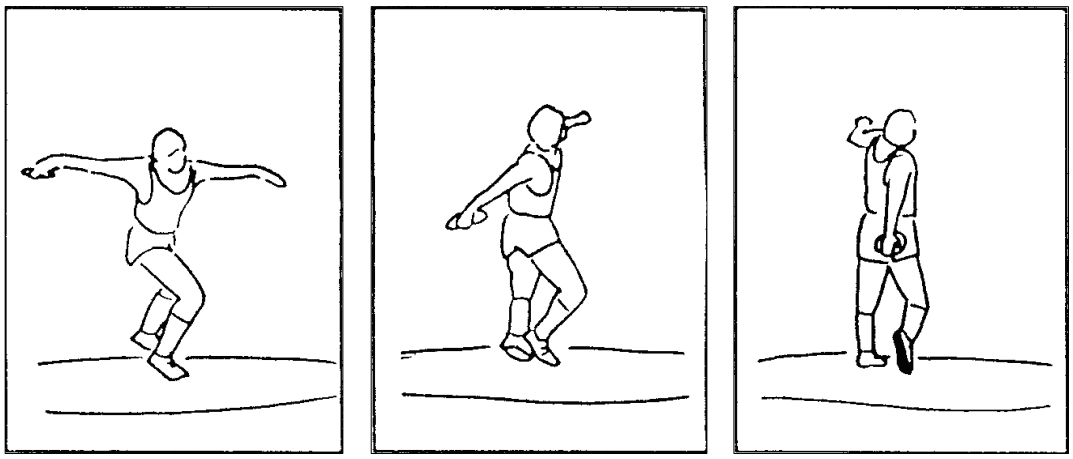


Figure 2. *These frames show the hips rotating rapidly to the front, with the shoulders and discus-arm passively trailing the shoulder. By the frame #9, the hips are almost square but the shoulders still have a significant distance left to unwind and the discus-arm is also well back. The athlete (Wolfgang Schmidt) now has excellent torso and shoulder arm muscle stretch. Sequence of Schmidt from* Nathan, S. (1990). Reproduced with permission by S. Nathan (UK).

In discus throwing, the most obvious SSC moment occurs during the delivery where the athlete is *torque-up* in the positions (figure 2) #7-9 with stretch in the torso (i.e. hip-shoulder separation) and between the alignment of the shoulder and arm, ready for the final unwinding, thigh-torso extension, pull and whip action to release.

These critical positions begin shortly after left-foot down (**L↓**) (figure 2, #7-8) while the discus is descending. Peak eccentric tension occurs as the hips spin through (#8-9), pushing well ahead of the shoulder-line, increasing the stretch in the torso, across the chest and shoulder joint.

It is here that the popular coaching tip of 'make a bow before you let it go' occurs. In this position the athletes feels considerable tension vertically as the hips press forwards (i.e. the archer's bow shape), and diagonal tension as the hips pull the shoulders towards the final ¼ turn that will complete delivery.

To successfully manage this sub-phase, the knees and hips must spin to the front (i.e. square to the release direction), to face the throwing direction. This is driven by the faster turning rate of the lower torso and limbs, which in turn are pulling around the more inert shoulders, for peak tension. Similarly stretch is increased in the right shoulder by the combined effect of the passive trailing of the discus arm and the rapid rotary acceleration of the lower body during transition that also accelerates the shoulder rotation. For optimum eccentric stretch in the throwing shoulder-arm muscles (i.e. pectorals) the throwing arm and discus must passively trail the shoulder following an orbit determined by the system's path and rotary acceleration through successive phases.

In brief:
During transition and early delivery phases, the momentum of the right leg is transferred to the lower-body, increasing the turning rate of the hips in the pivot. As the hips' rotation accelerates, they rotate slightly ahead of the shoulders and this difference in the alignment of the hips and shoulders increases the eccentric tension (think of it as stretch) in the torso muscles.

This action also increases the turning rate of the shoulders (i.e. rotary momentum of the lower torso and limbs being transferred upwards) because the hips are literally pulling the shoulders around and because the shoulders are leading the arm, the inertia (i.e. resistance of the passive discus arm) also increases the muscle stretch across the shoulder joint and chest.

Summary:
- The hips spin slightly faster than the shoulders;
- The hips pull the shoulders around creating torque (stretch) in the torso;
- The shoulders pull on the discus, stretching the right-shoulder, chest and arm muscles;
- The inertia of the discus trailing the shoulder while going downwards further increases the tension (stretch) in the throwing arm and shoulder as the rotating system moves forward and upwards.

If timed correctly, pulling the left-arm backwards, in-line with the throwing arm, also increases the tension in the chest, further augmenting the pectoral stretch (figure 3, frames 28-29), just prior to unleashing the powerful synchronised concentric contractions of the legs, torso, shoulder, chest and arm muscles.

When these combine, the athlete is set to synchronize and utilise forward and rotary momentum, vertical leg drive, extension and unwinding of the torso, the shoulder-pull and whip-arm delivery. However while positions and sequence of these parts can be practiced and applied in standing throws and full throws, more vigorous complex drills are required (e.g. South Africans) to hit these positions at close to actual competition speed, and to elicit and condition the SSC effect.

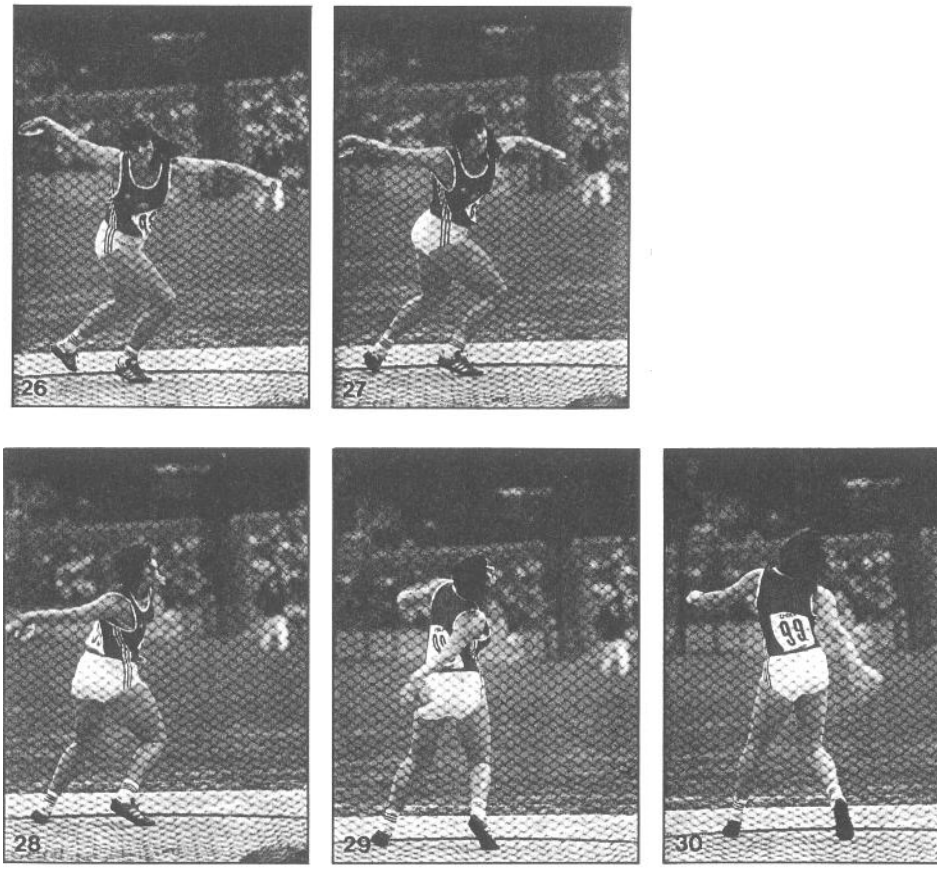


Figure 3. *Frames 28 & 29 show the upper body primed and ready for pull and whip release (thrower: Martina Opitz, GDR.) (Photographs: H. Payne, 1985).*

This series (figure 3, frames #26-30) shows excellent stretch in the muscles of the torso and shoulders indicated by the hip and shoulder-line separation (eg. #28), the shoulder-line and right arm separation (eg. 29) with the discus arm passively tracking well back behind the shoulder-line (#28-29).

These frames show the hips rotating rapidly to the front, with significant hip-shoulder separation and outstanding angle difference between the arm and shoulder-line (frames #28 & 29), with the discus still passively tracking behind the shoulder. By frame #29, the hips and knees have been allowed to spin through to the front, creating enormous tension between the hip and shoulder lines. The athlete is now primed and ready to powerfully unwind (*concentric phase*) allowing the right-shoulder to keep pulling on the discus before the pre-loaded (*stretched*) pectorals (aided by drawing the left-elbow down and back) and arm muscles to whip the discus through to complete release.

IDENTIFYING KEY STRETCH-SHORTENING CYCLES IN DISCUS TECHNIQUE (PART 2)

The following sections examine where SSC is involved and how the phases link to generate optimum power. No single section of discus technique can stand-alone; every phase affects the next. To understand this interdependence, the following discussion frequently revisits an earlier phase to link and elaborate upon successive phases.

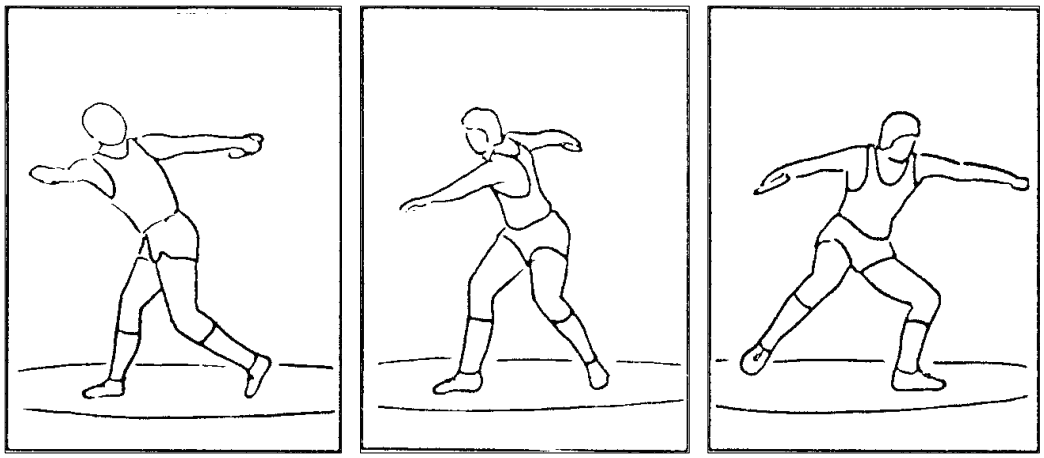
The thrower's action is universally considered as a series of separate key phases: preparatory, entry, transition and delivery. The instances that define these phases include:

P_0 Farthermost position and moment for the discus behind the thrower at the end of the last clockwise preliminary swing.
$R^{\uparrow}$ Moment at the rear of the circle when the right foot leaves the ground.
$L^{\uparrow}$ Moment at the rear of the circle when the left foot leaves the ground.
$R_{\downarrow}$ Moment near the centre of the circle when the right foot contacts the ground.
$L_{\downarrow}$ Moment at the front of the circle, when the left foot contacts the ground.
$O^{\uparrow}$ Moment when the discus leaves the thrower's fingers.

A key feature of differences in the alignment of the shoulders, hips and throwing arm with respect to each other axis is the ***angle of separation***

A general term to describe the angle between two axis or lines (i.e. between shoulders and hip lines; or between shoulders line and discus-arm).

Preparatory phase (P_0 - $R^{\uparrow}$)
This phase includes moving from the farthest clockwise position of discus, during the last preliminary swing (extreme clockwise limit of the wind-up) until the right-foot leaves the ground.



#1 (**P_0**) #2 #3 (**$R^{\uparrow}$**)

Figure 4. *Preparatory phase. In frame #1 Schmidt has stopped rotating away (winding-up) and is about to commence the counter-clockwise turn towards delivery.*

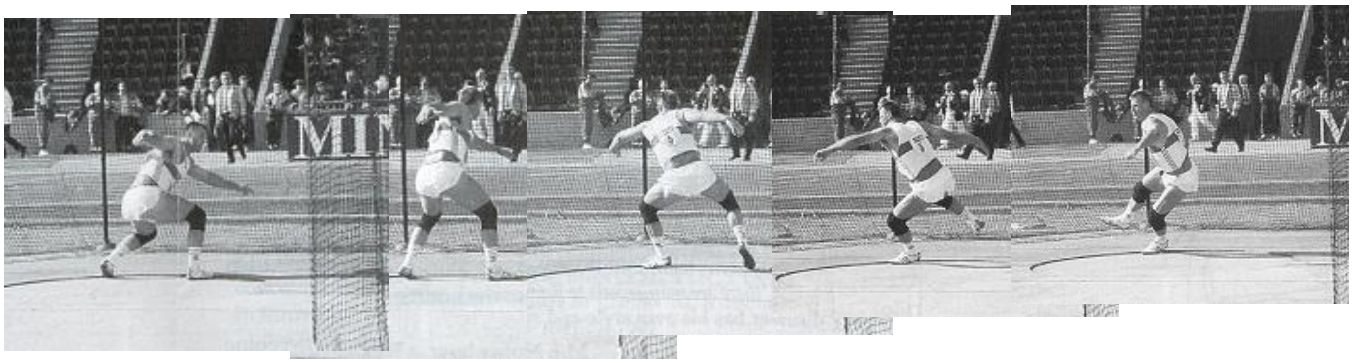
Action:
Movements include turning left, while loading the left-foot, lowering, sitting backwards, and leaning slightly left as preparation to counter to the right-leg action. Loading is usually complete by the time the chest has turned to face about 45° counter-clockwise from zero (#3 **$R^{\uparrow}$**). At that moment the right-foot will lift-off.

The preparatory phase starts (**P_0**) the instant the back-swing reaches its preferred limit. As soon the athlete senses this position, that moment should be used as a trigger point to commence loading on the left leg.

The combination of the subsequent weight shift to load the left foot and the movement of the right hip forward as a counter-clockwise movement to the clockwise momentum of the discus also serves to create the tension that maintains the position of the discus in the trailing right-hand.

As the system starts to turn towards entry, a natural pattern is for the discus arm's elbow to point backwards, increasing the range of the shoulder joint, effectively increasing the separation angle between the shoulder-line and trailing arm.

A correctly rotated humerus is evident by looking at the orientation of the elbow joint (see fig. 7 as examples). This orientation is critically important later in the delivery phase where optimal separation between the shoulder-line and the extended discus-arm will maximise the delivery path and final acceleration of the discus.



1 **2** **3** **4** **5**

Figure 5. Preparatory phase plus the acceleration of the right leg.
Note in the above sequence that as the athlete turns and loads the left-foot, he moves away from the right-foot creating stretch and hence tension in the adductors and hip flexors of the thigh and right hip. This stretch at the hip precedes the powerful concentric that drives the right-leg swing creating the lower limb momentum critical to increasing the rotary speed of the hips through transition and delivery. Note in figure 5 frames #3-5) that the discus is carried well back, palm down and behind the right hip with both shoulders rolled inwards.

As soon as entry begins, it is also important to allow the discus-arm to trail along behind the shoulder through the *preparatory, airborne, transition and the early part of the delivery phase*. Even though there is muscle tension and muscle stretch in the right-pectorals, shoulder and arm, due to the carry and the system's rotary motion, these muscle groups must not try to accelerate the discus until late in the delivery phase. To do so would move the discus arm alignment nearer to parallel and even beyond the shoulder-line, creating major problems later in delivery.

Athletes should regard the discus as '*a passenger, towed along behind the right-hip and right-shoulder'*. Similarly the shoulders and torso should also remain relatively passive, while turning, aided by the initial momentum of the system and being towed by the lower limbs.

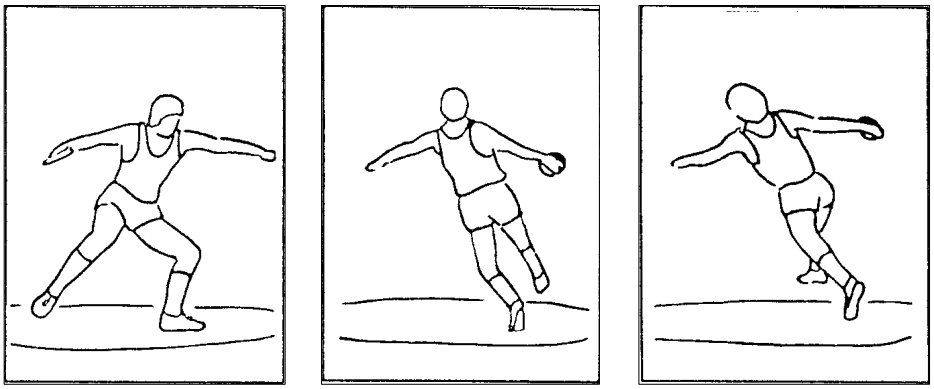
When examining the figure 5 sequence, this athlete can be seen starting to turn, to load the left-side, and in effect, moving away from the right-foot. By frame #3 the right-foot is about to leave the ground with tension in the right-hip and thigh created by the shift to the right, *stretching the right-hip flexors, adductors and quadriceps. This continues after the right-foot lifts until the heel is about knee height (frame #4). By this stage the required stretch has peaked and the reverse movement occurs: the right-leg's stretched muscles contract to sweep/ kick along a circular path powered by an augmented concentric contraction enhanced by SSC.*

This preparatory right-hip and thigh muscle stretch will be felt as a slight muscular restriction caused by moving left and is the '*pre-tension' used to accelerate the right-leg sweep.*

The angular momentum generated by the leg swing/ kick has a critical role in subsequent phases..

Entry phase **$R^{\uparrow}$ - $L^{\uparrow}$** (figure 6)

This phase commences the moment the right-foot leaves the round and ends when the left-foot also leaves the ground. This phase is of critical significance as it generates enormous angular momentum.



#3 **#4** **#5**

Figure 6. *Entry:* ***$R^{\uparrow}$ - $L^{\uparrow}$***

Action:

This sequence begins when the right-foot lifts off but in terms of timing, this is only possible when the left foot is fully loaded and the torso has turned to about 45° (i.e. counter-clockwise turn, measured from zero).

Even though the right foot is off the ground and will continue to rise to about knee height, the athlete will feel as it has been momentarily left behind (fig. 5, #4 / fig. 6, frame 3). So as the torso and hips turn away from the trailing right leg, this creates a passive *stretch in the upper-thigh and hip* (i.e. hip flexors and adductors), increasing and in a sense, priming the limb for a powerful rotary sweep/swing-kick.

The timing of the kick occurs only a moment after right-foot-off, and timed to occur as soon as the chest and hips have turned to about 90° left of zero.. The rotary acceleration of the right limb is concentrically driven by the pre-stretched right-hip flexors, thigh adductors and extensors *(i.e. SSC)*, that sweep the right-foot around, forwards, and towards the centre of the circle.

Correct timing is critical so between turning past 45° to reach a working peak at about 90°, athletes should feel as though they are momentarily 'waiting' until their chest faces 90° before the swing-kick / sweep commences.

The low, wide circular sweep of the right foot is best maintained by leading with the medial aspect of the ankle.

The angular momentum generated by the right leg will eventually be transfer up through the system to accelerate the rotary velocity of the hips, shoulders, arm and the discus. Optimum gains here substantially increase flight distance.

Coaching points might include:

- Turn as a unit and load the left foot;
- lift-off the right-foot relatively early (*spatial reference: when the chest has turned about 45°);*
- ***then wait*** until facing left (i.e. 90°) before *v*igorously swing-kicking towards the left.
- To maximise the angular momentum of the right limb, sweep wide, low and lead with the medial aspect of the knee and right-medial-malleolus (inside ankle-bone) (fig. 5, frames # 4-5) and definitely not with the toes.

When the athlete eventually turns to about 180°, the left-arm's rotary path reverses and swings forward into the running position

Preparation for take-off

While continuing to turn through the *preparatory and entry* phases, the left-hip and knee flex and the ankle dorsiflexs. While in this low position the gluteus, quadriceps and calf muscles are also *stretched.*

*At this point, a popular perception is that the athlete runs and drives h*owever the athlete does not require a powerful leap because the usual distance between the athlete's CG shift at take-off and touch-down is only about 0.3m and is completed in around 0.12s. This perception has more to do with the athlete's low position, body angle, the flexed knee, hip and ankle and the muscular tension felt maintaining balance through this phase.

Using the above figures, the flight's average linear velocity is only about 2.5m/s. So very little extra push is required given that athletes have already gained angular and linear velocity while loading, turning and leaning towards the sector-centre, and have also gaining momentum transferred from the leg-swing as muscle tension in the hamstrings and adductors start to slow the right leg at the front just before take-off (i.e. transfer of angular momentum and tangential velocity).

Nevertheless, there is some additional left-leg drive however the timing is critical just as it must be in the direction of the intended throw to increase forward directed linear momentum and ground reaction on touch down.

While still turning on the left-foot, and about to take-off, the *pre-stretched* left-hip, thigh and calf muscle tension is then *released* rather than augmented by a significant concentric contraction. It still feels like a leap but can be over-stated and detrimentally over emphasised as a contribution to both linear or angular velocity.

Mac Wilkins

Al Oerter

Figure 7*. Throwing legends Mac Wilkins and Al Oerter, showing their distinctive interpretations of the leg-sweep, mid-way through entry. While the degree of application is different, the principles are the same: during entry the lower limbs are actively generating angular momentum; the discus-arm tracks behind the shoulder, and the shoulders tracks behind the hips (e.g. Al Oerter). Note the orientation of the throwing arm-elbow: rearwards and upwards twist.*

Sub-phases:
A: *Descending path of discus to its lowest vertical position.*

Towards the lowest point, the discus should continue to be carried palm down (figure 7), with the humerus medially rotated, passively trailing well behind the right-shoulder-line well behind the hip-line.

Key features at lowest point (see figures 7) include:
- the discus-arm and discus tracking behind the right-shoulder and
- carried behind the right hip,
- close to the right buttocks when the chest facing 90-135°.

B: *The interval near the rear of the circle when the discus reaches its first minimum vertical height and continuing until the left-foot leaves the ground (i.e. take-off).*

During this sub-phase, the athlete ***must not deliberately swing the discus upwards*** and instead should continue to passively carry the discus so that it trails the shoulder-line.

From $\mathbf{P_0}$ to early in the delivery its orbit simply follows the circular and linear movements of the shoulders and hips., along a path determined by the inclination of the torso (main axis), shoulders and hips to the horizontal, speed of rotation and gravity. *Note in figure 7 how these discus legends Al Oerter (1956, 1960, 1964, 1968 Olympic discus champion and world record holder 4 times) and Mac Wilkins (1976 Olympic discus champion and world record holder 4 times) both carry the discus in a passive manner.*

These features dominate:
- the discus is a passenger, passively following the shoulder;
- it should not be allowed to move ahead of the shoulder-line or be deliberately swung up or down;
- the discus orbit and path radius are maintained by simply carrying it with an extended elbow and wrist, and towed on a path determined by momentum for the system and axis of the torso, hips and shoulders.

Flight (airborne phase /$L^{\uparrow}$ - R↓)

Commences the moment the left foot leaves the ground (**$L^{\uparrow}$**) and ends as the athlete's right-foot contacts the ground (**R↓**) near the centre of the ring.

This short leap involves very little extra thrust from the take-off foot, as it is already aided by the angular momentum of the right-leg swing and linear momentum of the athlete-discus system gained earlier while sitting backwards and later, by leaning towards the centre of the circle. However, correct timing for the take-off and direction remains critical to allow the athlete to land with the
- right-foot aligned towards 270°,
- the hips aligned to about 180°,
- the shoulders similarly aligned or just behind 180°,
- the discus arm continuing to track behind the shoulder-line and the right-foot landing under the right-shoulder (fig. 8).

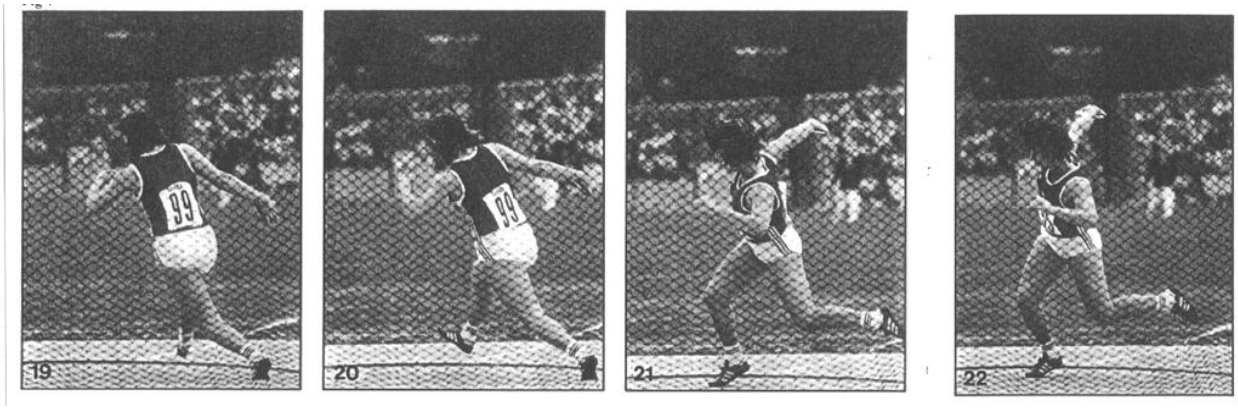


***Figure 8**. Airborne phase. Moment after take-off to the instant before touchdown (instant occurs between frames 20-21). Note: (#21) foot pointing towards 270°, hips 0°/180/360°, shoulders slightly behind hip alignment and the discus arm well behind and separated from the shoulder-line. Also visible is the orientation of the discus arm's humerus / elbow.*

At take-off, the hips should be turned to face slightly left of centre (i.e. towards the left-sector line) (figure 8, frame 20). During the flight, the hips should rotate through an angle of about 80-90° (see hip-line in frames 19 and 21) and finish the flight by striding around and down, with the angle between thighs being about 50-60°. It is important to avoid bringing the thighs *too close together before landing*, as the hips will rotate more quickly, causing excessive hip rotation.

These measures are critical features as excessive airborne rotation (i.e. if the right-foot were to land beyond 270° and similarly, for the hip-line to be turned well beyond 180°/ 360°) as this would cause the athlete to 'back' into transition and delivery.

When an athlete rotates and lands well beyond 270°, in effect backing the hips and torso into transition, the shoulders and discus arm have also turned closer to release and as a result, the remaining angular path for transition has also been reduced.

It is imperative that this sub-phase is well managed as it sets up the remaining rotary path where the stance is narrowed and rotary / angular momentum is transferred from the right thigh to the hips and torso. Transition enables the hips to accelerate ahead of the shoulders and discus arm, increasing the separation angles for the hip to shoulder-line and shoulder-line to discus arm so any excess airborne rotation will seriously compromise the SSC building through transition.

Similarly, if during take-off ($\mathbf{L}^{\uparrow}$) the athlete has already turned to face well beyond 90° before beginning the right-leg sweep, the athlete will also land too far around, and again the athlete will back into transition.

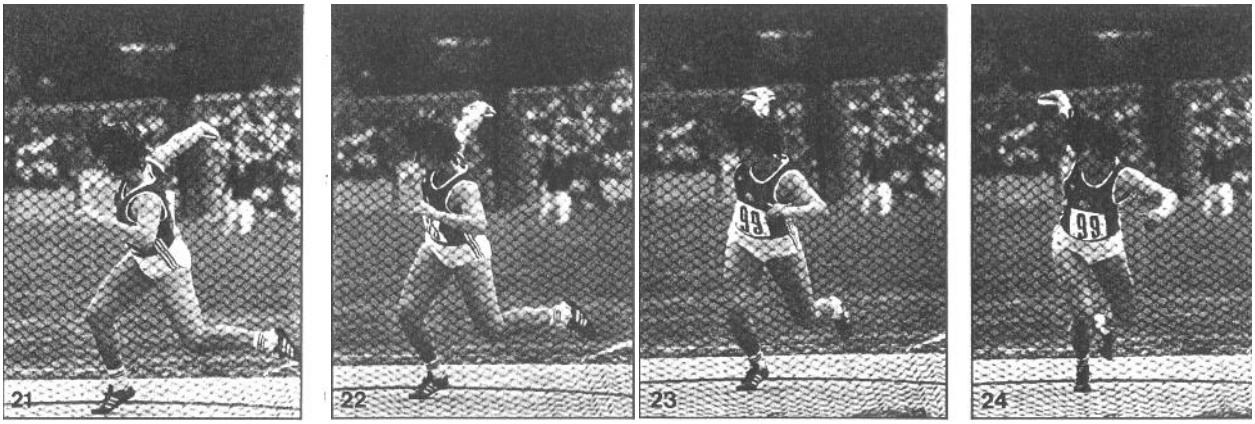
To avoid backing in to the transition phase, the flight's landing positions should include:

- the right-foot and knee should land pointing towards or close to 270° (frame 21), with
- the right-hip pointing slightly left of the sector centre (i.e. hip-line at about 180°/ 360°),
- the shoulder-line to be behind the hip-line (i.e. to feature hip-shoulder separation) and
- discus-arm and discus well behind the shoulder-line, at about shoulder height, with palm down.
- The right-shoulder should continue to feel like it is rolled inwards allowing the shoulder joint greatest range for near maximum shoulder-line and arm separation (frame 21).

Just before landing the right-forefoot should be pulled under the athlete so that the athlete's CG lands rearward of the forefoot, and allowing a slight lowering of the hips to absorb vertical and some forward speed (i.e. an eccentric muscle action) to begin the *next stretch-shortening cycle*.

Transition Phase ($R_{\downarrow}$ - $L_{\downarrow}$)

Commences the moment the right foot contacts the ground and ends as the left foot contacts the ground.



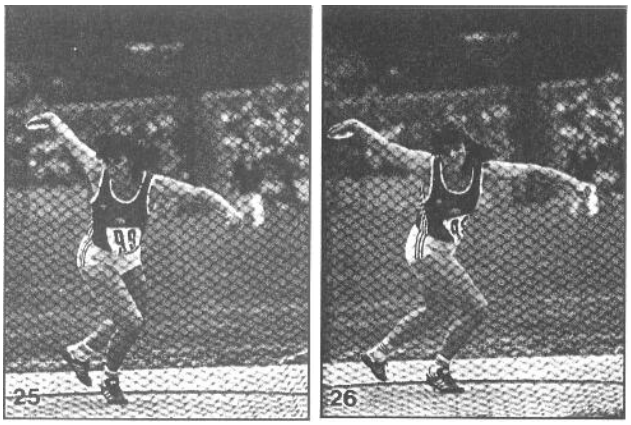


***Figure 9**. Transition. This athlete attains significant hip-shoulder separation, trailing the discus and maintains arm-shoulder-hip separation through transition.*

This phase includes a reducing the space between the thighs and feet to increase the angular (rotary) velocity of the hips, which also enables the hip-line to advance further ahead of the shoulder-line (i.e. eccentric muscle action of the torso), before once again moving the knees apart to ground the left-foot.

As soon as the athlete lands (**R↓)** the right-knee flexes slightly (*stretching the gluts, calves and thigh muscles ready for the vertical leg drive*) then pivoting both horizontally and forwards. The right-foot continues to turn on the ball of the foot, enabling the athlete to pivot into the delivery phase, avoiding any tendency to step backwards (**L↓)** into the delivery phase.

The pivot is an extremely fast phase and there is little time to do anything more than

- immediately settling (eccentric contraction / stretch phase of SSC),
- to 'close down' by 'wrapping' the right-arm close to chest and torso, while simultaneously reducing the thigh separation (reducing inertia),
- then almost immediately opening the knees again to allow the left-foot to touch down.

In the instant the system 'closes down' or 'wraps', the hips rotation will accelerate while the inertia of the discus arm and plate will keep it well back. This should be sufficient to improve hip-shoulder-line separation (*hence the stretch in torso and shoulder musculature*) before opening the knees to establish the throwing base.

Key features:

Landing:

- the right-foot and knee should land pointing towards 270° (figure 9, frame 21), with
- the hip-line pointing slightly left of the sector centre (180°/ 360°), and
- shoulder-line behind, and
- hip-shoulder separation and discus arm and discus well behind the shoulder-line, at about shoulder height, with palm down.
- Right leg to flex slightly to absorb downward momentum and to lower CG.

Pivot:

- On touch-down, momentarily adduct the thighs and
- then almost immediately open the knees for touch down of the left-foot.
- Athlete must pivot into double support for the delivery phase enabling the hip-shoulder-line separation to increase and to definitely avoid stepping backwards into double support.

Although popular, stepping backwards represents a major technical error,

- *causing* the *block to commence momentarily too soon. An early block causes the shoulder and arm to catch up to the hips too soon compromising the delivery's shoulder pull and whip action;*
- *Reduces forward momentum.*
- *Diminished transfer of angular momentum from the lower body to the upper body.*
- *Negative effect on shoulder-arm separation angle for the whip (arm catches up with shoulder-line).*

- *Limits the vertical leg-drive and hence the vertical component of the release velocity.*
- *Causes problems with the pull, leading to a tendency to release too steep because the athlete's CG remains is too far from the front of the base.*

Sub-phases:

A: R↓ to discus high point: Ascending phase of discus path to maximum in the vertical direction of its arc. While the discus will rise, it must remain behind the shoulder line, and at its maximum height, only rising to a point that is inline with the shoulder-line (fig.9, frame 23). A key feature here is that the discus is still being carried by a passive musculature. The lower limbs and torso are the only body sections actively involved in the acceleration of the system.

B: From discus high point to L↓

This is where the discus is still high but descending into the classic power position (figure 9, frame 26) and features *torso tension due to increasing* hip and shoulder-line separation; *this separation is an essential part of the muscle stretch* to feature later in the delivery.

Delivery phase (L↓ - O↑)

Commences the moment the left-foot contacts the ground and ends when the discus leaves the thrower's fingers.

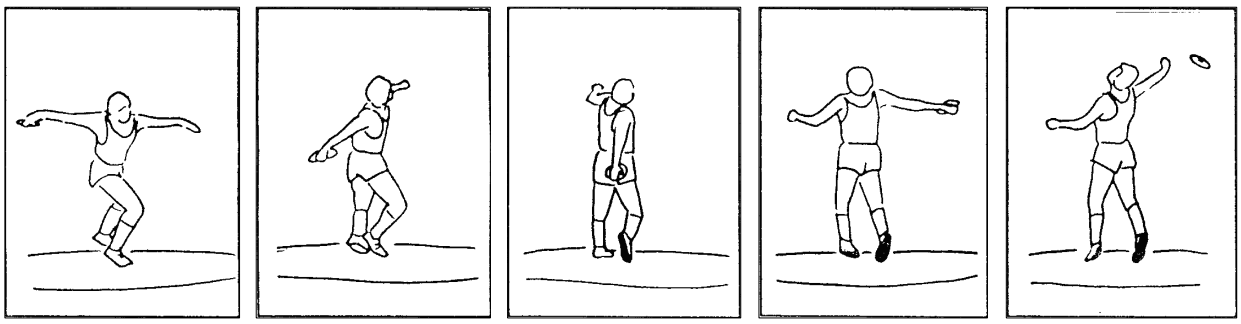


Figure 10*. Delivery phase commences with left-foot contact and ends with release of the discus.*

The left-foot is usually grounded at the front of the ring, slightly left of the sector centre. The off-set position of the left foot relative to the right foot should be just wide enough to allow the right hip to rotate forward and square to the *delivery direction.*

As the knees turn towards the front, the torso, hips and legs are beginning to drive upwards, the left-knee straightens and the left-heel drops, the left-foot pulling back against the ground *blocking the left side*, as the right-heel rises and turns outwards.

The vertical drive is aided by the *concentric contraction* of the muscles eccentrically stretched during the right-foot landing and the pivot into the delivery phase; i.e. the *eccentric stretching of the hip, thigh and lower leg extensors* before the muscles *concentrically contract* to impart a powerful upward acceleration.

The vertical drive also contributes to the block by stiffening the left-side.

The significance of the 'vertical drive' is that the legs are mechanically more effective for imparting a vertical-velocity component to the release velocity than adding to the horizontal velocity component. Conversely, the arm and unwinding torso are mechanically more effective imparting a horizontal velocity component to the release than their vertical velocity component.

To impart the most favourable source of vertical and horizontal velocity components, for the best release velocity and release angles, a preferred technical interpretation must reflect the individual's specific physical capabilities.

Athletes and coaches arguing the merit of variations that favour *a fixed foot delivery* or a more dynamic vertical effort by the legs (i.e. a *dynamic delivery*) loosely but popularly described as a *reverse technique*, should always consider whether their preferred model, generates an individually specific, optimum release speed and release angles.

This author favours a dynamic delivery.

Key features:

- The hips continue to turn, accelerating ahead of the shoulders, to face forwards, as do the knees.
- The hips are dragging the shoulders and trailing discus around behind the vertical line through the right hip.
- While both legs are turning to the front, the left-heel is grounded; however as the right-hip comes close to square, they begin to drive upwards.
- The right-heel rises further and turns outwards,
- allowing its hip to continue turning and to pull the right shoulder (and discus) forward and square for the whip delivery.

This continues to maintain the torso's eccentric stretch while also adding a centrally directed force (due to axis shift) adding to the tangential velocity of the discus.

The hips must keep turning to a position square with the sector, but the axis now changes from a central torso axis to a vertical axis through the left-side and a horizontal rotation axis about the left hip. So the right-hip now turns, accelerating to push forwards (Figure 10, frames #8-9) with tension peaking as the hips reach the limit of their pull on the more inert upper body. This is where the hips press forwards and around, maximizing tension ready to commence the *concentric phase of the stretch-shortening cycle in the torso* (frame #9).

A: Sub-phases: L↓ - to lowest discus position
Descending phase of discus path, commencing as the left-foot contacts the ground continuing until the discus reaches the lowest orbit position. In this phase the system's CG is continuing to move forwards while the discus is continuing down.

B: Lowest discus position until release (**O↑**)
Commences the moment the discus reaches the lowest orbit position and ends when the discus leaves the thrower's fingers.

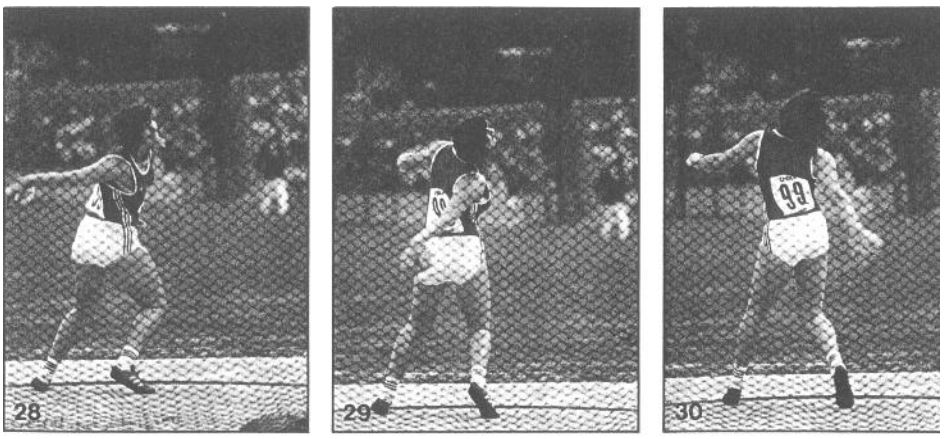


Figure 11 Delivery phase featuring the beginning of the final powerful whip

Since the hips are now well forwards and the arm is still tracking well behind the shoulder-line (figure 11, frames #29-30), this is where the hips ***'pull'*** the discus forward over the base, the torso unwinds (*concentric phase of torso musculature*), and the tension of the pull having *stretched the muscles of the chest and shoulder, also aided by the backward swing of the left-arm*, is now released, with a whip action, driven by the shortening phase of these muscle and groups.

The right-arm whips through using the *stretch-shortening cycle* across the chest, feeding in this augmented power to gain maximum release speed. This '***whip action'*** combines the rapid unwinding of the torso, the pull with the shoulder and the stretched pectorals along with the vertical leg drive to complete delivery.

SSC & DISCUS TECHNIQUE
SUPPLEMENTARY NOTES: INTERPRETATIONS (PART 3)
By ***Bryan Neighbour*** *- Senior throws coach (ATFCA: level 5), Mentone Athletic Club.*

The block

The idea of the block is to shift the system's rotary motion from around a central vertical axis to an axis around the left side by momentarily stopping the left-leg from continuing to turn. Since the body is not a rigid object, parts above the ground continue moving. In effect, creating a hinge movement around the left-side and accelerating the right-side and in particular, the right-hip and shoulder.

The left-foot contact simply limits the forward and rotary motion of the lower limbs, allowing the hips, torso and upper limbs to keep turning, winding to a maximum and then unwinding and extending. The vertical leg drive and hip extension also stiffens the lower limbs, forming a more rigid lower system as the hips turn square to delivery.

A partial block also occurs during transition when the right-foot touches down checking the degree of forward movement, loading the right-leg and as it yields, creating the stretch in the right-leg, hip and torso muscles.

Essentially, the role of the final block
- limits lower limb motion so the torso can continue to wind, gaining peak torque and then unwind,
- triggering the final stretch-shortening cycle phases,
- enabled by momentum transfers sequentially up through the hips (to increase hip-shoulder separation),
- changing the primary axes of rotation from within the length of the torso to the left-side, and round the left-hip and shoulder (i.e. pull), and finally back around the right-shoulder for the whip.

Timing is critical and must not happen too early or with the left-foot too far forward or left of the system's CG or it diminishes both forward and angular momentum, reducing the delivery to an off the right-foot release, well behind the optimum release position, negating any chance of utilizing the myotatic stretch response basic to the ***stretch-shortening cycle*** utilized in the ***pull and whip delivery***.

Torque created by hip and shoulder separation creates a rapid stretch (the eccentric contraction that triggers the myotatic reflex) in the abdominal, oblique muscle that is followed by a shortening or concentric contraction. This occurs because the hips are rotating fractionally faster than the upper-torso, in the pivot towards left-foot contact, further improving separation.

As soon as the left-foot blocks, the system also pivots forward, over its base, with the upper body still free to move forward (pull) and the right-hip still turning counter-clockwise. The weight shift forwards over its base, aided by the right-hip's forward rotation and inertia of the upper-limbs, creates the classic body 'bow' before it lets the discus 'go'.

The inertia of the trailing right-arm also resists the forward pivot and faster moving hips, adding stretch in the muscles of the shoulder and chest to that in the hips and abdominals.

At this point, the system is ready to deliver: unwind, continue driving upwards and finally the whip of the shoulder and arm.

The orientation of the discus arm

The discus should be oriented to be carried palm-down from $\mathbf{P_o}$ to release ($\mathbf{O\uparrow}$). While many athletes find it easier at the start, to carry the discus more vertically, shortly after the final back-swing, and as soon as practical, the discus should be realigned to a palm-down carry and remain palm down until released.

A *passive carry* enables the discus to trail the torso, and the torso to trail the active phases of the lower body (i.e. legs and hips).

Since the discus is carried rather than swung into positions, it moves down, up and down and finally up again on a path linked to the movements of the right shoulder. A simple movement concept is that for the first 2 steps the discus is 'just along for the ride', trailing behind the shoulder-line and when moving through the entry phase it is carried over the right buttocks.

While passive, the right-shoulder should feel rounded with the shoulder-joint and the humerus medially rotated. Medial rotation improves the separation angle between the arm's length and the shoulder-line, effectively improving the range of the final whip.

Controlling the hip rotation during the airborne and transition phases.

The rate at which the hips turn / rotate can be varied by changing the space between the legs. Increasing the space slows rotation and closing the space accelerates the rate of turning.

During entry, the right-leg sweep should be low and wide and not move closer to the opposite leg until the right-foot is pulled in just prior to touchdown to land with the right-foot beneath the right shoulder. Closing too early will cause the hips to turn excessively, leading to backing into the delivery, compromising transition and delivery range.

During transition, the thighs are much closer with the left-arm also wrapped / closer to the chest to keep the shoulders closed. The effect intended is to reduce lower body inertia and allowing the hips to turn faster than the shoulders. This is a very brief moment however it is critical that hips momentarily accelerate, to increase hip-lead (improving the torso muscle stretch), before opening the thighs again to step around and down into left-foot touchdown.

The feeling, during transition, should be *spinning through transition* and not *a stepping backwards through transition*. This sets-up the *power position*, where the hip-shoulder and shoulder-arm separation has stretch in their respective muscle groups.

As soon as the left-foot touches down, the right-hip and right-foot and both knees must keep turning towards delivery, maintaining and even increasing tension.

Controlling the upper-body during the airborne and transition phases.

An athlete holds the discus by relying on the initial tension in the arm and shoulder joint, created in the preliminary swings to hold the discus. This is aided, on entry, by allowing the shoulder to *pull the arm and discus*, and to simply *carry along*.

The shoulder, in-turn, should also remain relatively passive while also being pulled around by the angular and linear momentum of the hips and lower limbs generated during the preparatory and entry phases. Up until delivery, the torso, shoulder and arm should remain relatively passive.

The inertia of the arm and discus aids both arm-shoulder-line separation and hip-shoulder-line separation.

To maintain balance through the airborne phase, the left-arm balances and moves in counter-movements to the position of the discus-arm and the right-knee.

So during the entry when the left-arm swings left, at take-off the left-arm swing should suddenly reverse and assume a runner-arm position countering the position of the right-knee.

Final note

Of course few athletes ever achieve flawless technique (i.e. a technique where every phase contributes optimally to best distance). However, those who understand why and what to do and practice as perfectly as they can are going to be rewarded with far more of those special moments when after a really good release they think or exclaim ***'Wow! That was awesome'.***

Good luck.

Bryan R. Neighbour

Illustrations

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