MODEL TECHNIQUE ANALYSIS SHEETS FOR THE THROWS PART IX: THE DISCUS THROW

By Günter Tidow

The ninth part of this series, dedicated to the analysis of model techniques in athletics, deals with the discus throw. The following movement phases are described in detail: (1) initial stance and preliminary swings, (2) double support starting phase, (3) single support starting phase, (4) flight (no support) phase, (5) single support delivery phase, (6) double support delivery phase. The concluding 'discus analysis sheet' is an attempt to integrate the elements of the phase structure in an ideal-typical way.

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1. Initial stance and preliminary swings

Since the early sixties, the 'open' sideward split position at the back of the circle has been preferred to the 'open' stride position, which was used before that time. Because of this stance, the thrower performs one and a half turns before the delivery of the implement. According to the rules, there is no limit to the number of turns allowed.

However, experiments conducted in the USA showed that two and a half turns, the first of which is made on the spot, do not guarantee longer throws. Instead, there is a higher risk of the implement landing outside the throwing sector (cf. NETT, 1961). Although several throwers have experimented with one and three quarter turns, the German thrower H.D. Neu has been the only one, during the last *25* years, to use this variation at international meetings (cf. STEINMETZ, 1978).

The main reason for not using this method of prolonging the acceleration path seems to be that it is also possible to achieve a maximum release velocity with a shorter acceleration path. There is presumably an optimal relationship between the length of the acceleration path, the thrower's maximum, controllable angular velocity and the resulting possibility of producing force in the final main acceleration phase. Taking the effectiveness and economy of technique as our criteria of validity, it therefore seems reasonable to choose the shorter path; at least as long as longer paths do not guarantee higher release velocities.

There is also another aspect, which is almost always overlooked: even with one and a half turns, acceleration paths of more than 10 m are possible (cf. KNICKER 1988 / SCHÖLLHORN 1989 / SUSANKA et al. 1988). The considerable range of this parameter from 7 to 11 meters, even in elite throwers, implies that the initial stance with the back turned to the throwing direction leads to a considerable ‘creative scope’. In other words, if a longer acceleration path led to better performances, elite throwers, at least, would show a trend to utilizing this acceleration path to the utmost limits.

As shown in Figure 1, the feet are parallel during the initial stance, in such a way that they are significantly more or less than shoulder width apart.

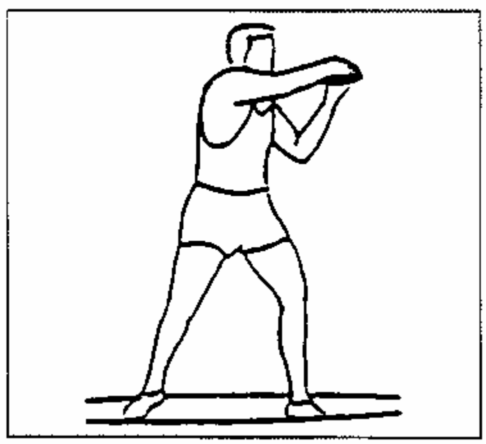


Figure 1: Initial stance of the discus thrower in the reverse phase of the swing, with the back turned to the throwing direction

The trend for a wide positioning of the feet is obvious. There are basically three, intermeshing reasons for this. The subsequent shift of the body weight can be carried out in an accentuated way and can lead fluently into the start of the turn (cf. SYLVESTER l986). Furthermore, the acceleration path of the discus is considerably prolonged and its course optimized. The acceleration path, looked at from above, has the form of a ‘pretzel’ (see Figure 2).

The course of the transition of the first part of the acceleration path (start section of the turn) to the second part of the acceleration path, leading into the release, is necessarily determined by the ‘carriage of the discus’ (close to or away from the body) and by the positioning of the ‘turning foot’ at the rim of the circle. A glance at Figure 3 will show that, in the case of a relatively wide positioning of the feet, the start, which must be oriented to the centre of the circle, is made from outside, as it were.

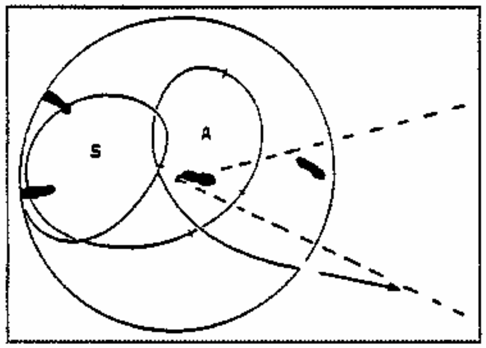


Figure 2: Acceleration path of the discus viewed from above
'S' = start loop; 'A' = release loop (Figure modified according to SCHÖLLHORN 1989)

Correspondingly, the push-off or impulse, which initiates the transition of the thrower-discus system, is not executed exactly in the throwing direction but diagonally to this direction. This leads to the advantage that the 'start loop' and the 'release loop' - i.e. the two parts of the 'pretzel' mentioned above - can be linked with one another without break, and with a wide rather than a narrow range.

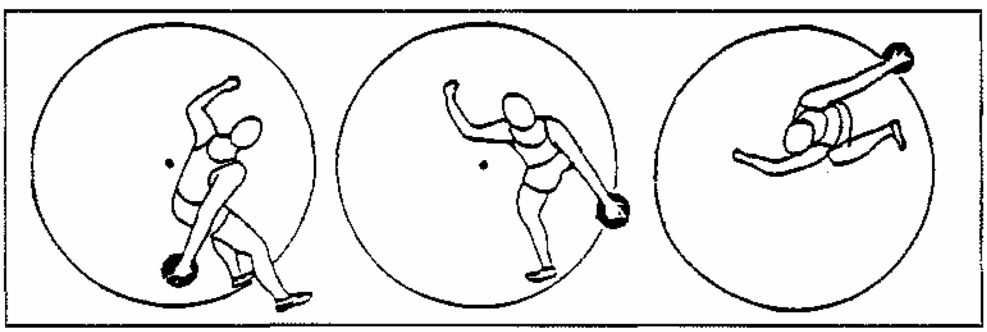


Figure 3: Three phases of the entry into the turn viewed from above
(Thrower: J. Schult; this Figure was made by copying video pictures directly from the screen.)

Additionally, especially if a wide initial stance is chosen, the off-centre positioning of the pivoting foot, as related to the throwing direction, leads to a slight shortening of the path of this foot to the front rim of the circle. This makes possible a faster take-up of the power position. This will be dealt with in detail later.

Of course, the thrower is not passive during the initial stance but prepares himself for the subsequent turn with a few preliminary swings. These swings can be divided into forward and backward movements. The forward swing is a relatively wide movement of the throwing arm and discus in the throwing or turning direction. The backward swing is performed in the opposite direction, after the reversal of the forward swing (see Figure 4).

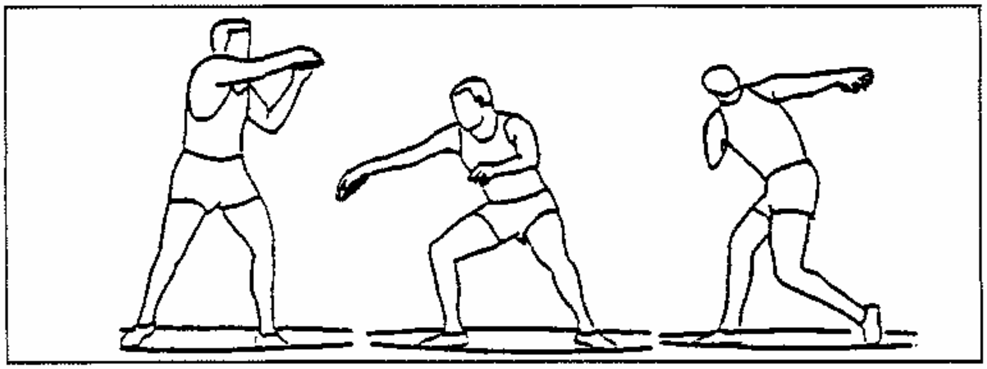
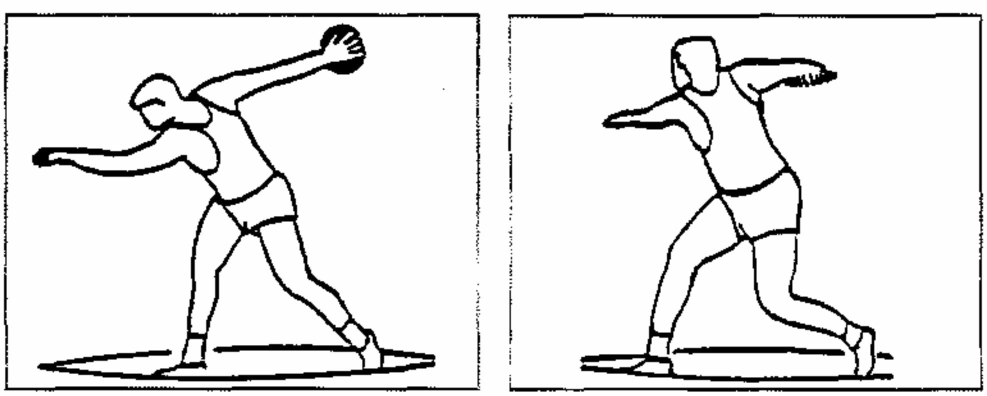


Figure 4: Initial stance with check of the forward swing (1), backward swing (2) and check of the backward swing (3)

Apart from the ‘preliminary butterfly swing’, in which the path of the discus looks like a figure eight lying on its side, there are several other variations of the preliminary swings. One of these can be seen in Figure 4. This type of preliminary swing has the advantage that, on the completion of the forward swing, the discus can be ‘put down’ again, as it were. This allows a short phase of concentration at the reverse point, with the discus resting on the palm of the swinging hand. However, the correct grip is not loosened.

The back-swing follows, with the discus being swung backward and upward as far as possible in a wide arc away from the body. The twist in the trunk, shoulder and arm area is primarily dependent on the thrower’s flexibility. At the moment of the reverse of the backswing, the discus travels up to shoulder height. This is the first high point of the discus path (cf. LINDNER 1962). Whether, at this moment, the discus is held in a vertical or horizontal position has no effect on performance. It is remarkable that the current world record holder, J. Schult, holds the discus in a vertical position at the reverse point. This makes possible an extremely smooth introduction to the turn (see Figure 5).



Figures 5 and 6: Completion of the backswing with a vertical position of the discus (left) and extreme twist

A discus, which is kept ‘flat’ and which is pressed against the tips of the fingers only by centrifugal force, demands a more continuous movement and allows only a minimum rest at the reverse point. A correspondingly ‘horizontal and flat’ alignment of the throwing hand and implement is shown in Figure 6. The thrower here demonstrates a wide backswing with an extreme twist. Such a twist is only possible if the thrower has great special flexibility.

Regardless of the position of the discus at the reverse point, the back-swing movement should not be hasty or jerky but controlled. This process is characterized by the fluent shift of the body weight from the pivot leg to the swinging leg. If the body weight is equally distributed on both legs during the backswing, the thrower, for a short time, goes through a ‘bridge position’, in a slightly sitting position (see Figure 4, phase 2).

Although this description sounds a bit elaborate, the movement is in fact a pendulum swing, which is performed (wide) in front of the body and goes from its starting point, at the reverse point of the forward swing, to the opposite reverse point of the backward swing. Gravity plays an important role during this movement; its effect is utilized or enforced by the slight give at the knee joints.

The head should follow this back swing until the line of vision runs parallel to the left sector line. The upper body is kept upright and the line of vision is kept approximately parallel to the ground. These instructions are also valid, if the thrower is extremely flexible and if the discus covers 810 degrees (two and a quarter turns) up to the delivery (see Figure 7).

In this case, regardless of the individual athlete’s degree of special flexibility, the feet are also involved in the action of the forward and backward swings, in that a turn, with the heel lifted, is also made on the non-weight bearing foot. However, the foot bearing the weight of the body does not change its position and keeps ground contact with the whole sole.

If the one and three quarter turn is preferred, both feet, which are placed on the bisector of the circle, remain almost stationary. The reason for this is that the pivoting foot, which, during this variation, is placed alone at the rim of the circle, makes a ‘heel-ball-turn’ immediately after the start of the movement across the circle.

Therefore, during the backswing, the pivot and shift of weight must also be performed on the heel. For purely anatomical reasons, this is difficult to do with the toe of the foot lifted and, since the acceleration path is already prolonged, it is not really necessary.

A problem of the one and three quarters turn, related to the initial position, has not yet been dealt with in the special literature. This problem is that the thrower’s position on the bisector of the circle actually means that a step backwards is taken, since this must necessarily lead to a ‘direct’ drive to the centre of the circle.

Strictly speaking this means that the advantageous, wide transition of the starting loop to the release loop, which results from a relatively broad initial stance when performing one and a half turns, cannot be achieved. Therefore, there is the possibility of further development in the one and three quarter turns technique, if the pivot foot is positioned diagonally to the centre of the circle. This would bring the movements of the entry into the turn into line with those of the one and a half turns technique.

2. Double support starting phase

Following BAUERSFELD/SCHRÖTER (1985) the discus technique is structured as follows:

- (1) double support starting phase
- (2) single support starting phase
- (3) supportless phase
- (4) single support delivery phase
- (5) double support delivery phase.

The double support starting phase begins with the check of the backward swing and ends when the swinging foot leaves the surface of the circle.

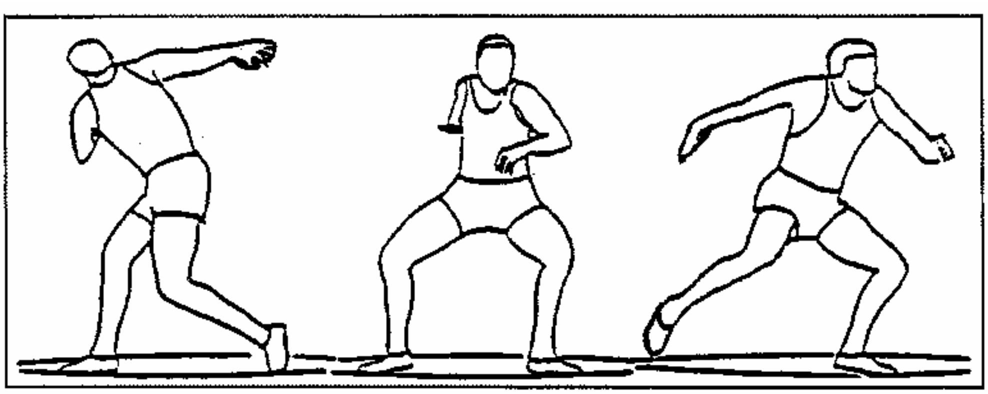


Figure 7: Double support starting movement in three phases, with accentuated V formation of the feet in the bridge position

As shown in Figure 7, the shift of body weight, which has already taken place during the preliminary swings, is repeated in the double support starting phase. If one looks at the course of the movement from the start to the delivery, it becomes clear that it can be described as a ‘running turn’, characterized by a rapid sequence of changes of support. These movements are anticipated during the preliminary swings. Here the shift of body weight and the body turn alternate from leg to leg. Therefore, the respective contact of the foot with the ground has been chosen as the differentiation criterion for the phase structure, used as the basis of this analysis.

The position at the end of the backward swing is repeated almost exactly in the 'power position'. Therefore, the end of the backward swing is used for the kinesthetic anticipation of the subsequent double support delivery phase. The changes of support during the turn are made from right to left (starting phase), then from left to right (push- off from the rear rim of the circle - flight - landing at the centre of the circle) and from right to left again (landing at the front rim of the circle). This is a description of the 'running turn' mentioned above.

The twist of the shoulder and arm is maintained as much as possible while the twist of the trunk is released to some extent, as the anticlockwise turn (right-handed thrower) is initiated at the end of the backward swing. This is the actual starting position. The body weight is now shifted smoothly from the right (swinging) leg to the left (pivot) leg. In doing so, the thrower moves through the 'bridge position' again for a short time.

During this phase the body weight is equally distributed on both legs. The feet show either a clear 'V position' (variation A – Figure 7), or the (left) turning foot, with the heel lifted, has already been turned outward in the turning direction, while the right foot, also with the heel lifted, remains as in the starting position (variation B: see Figure 8).

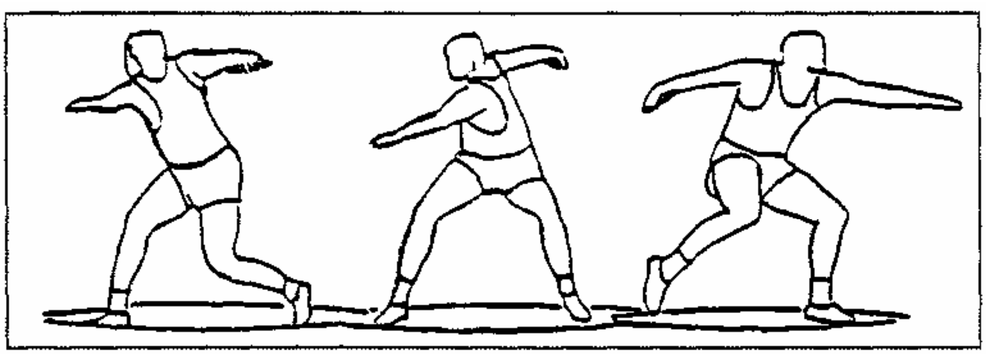


Figure 8: Double support starting position, in three phases (variation B, without specific V formation of the feet)

In the bridge position, the thrower 'sits' a little, with the knees pressed to the front, so that the pelvis is shifted, not towards the centre but towards the back of the circle. As viewed from behind the circle, the throwing arm is now behind the trunk. Whether it is visible, at this moment, or whether it is completely overlapped by the trunk, depends on the amount of twist the thrower is able to achieve.

In any case, it is important that the primary rotation of the trunk is produced not by an active opening or even ‘pull-open movement’ of the swinging arm but rather from the rotatory action of the (right) swinging leg, which is lifted from the ground after the weight of the body has been shifted to the left leg. As has been shown, this is the end of the double support starting phase.

It should be mentioned here that this phase has been considered by only a few authors and most of them are of the opinion that it is not relevant to performance (cf. STEPANEK & SUSANKA 1987 / SUSANKA et al. 1988 / KNICKER 1988 / SCHÖLLHORN 1989 / WARD 1981). The main reason for this is that, as far as correlational statistics is concerned, there is no evidence of any significant correlation between the parameters related to this phase and the performance. However, regardless of this, it must be mentioned that the main acceleration of the discus is achieved during the two double support phases (cf. SCHLÜTER & NIXDORF 1984). In this context, the movement segment discussed here has, as it were, a ‘push function’.

BARTLETT points out that HAY is the only one to emphasize the importance of the double support starting phase, because the execution of this phase has a direct influence on the positioning of the left foot in the power position (cf. BARTLETT 1990). There is no evidence to support this hypothesis. There can, however, be no doubt that raw beginners and advanced athletes alike often demonstrate an unstable bridge position, with an incomplete shift of the body weight to the left, pivoting leg. This leads to subsequent faults such as, for example, the late positioning of the left foot, when moving into the power position.

Therefore, it must be assumed that the importance of the double support starting phase decreases as the standard of performance increases and that its individual form is dependent on the athlete’s specific flexibility, ability to orientate in space and neuromuscular capacity.

3. Single support starting phase

A point of discussion, which is still of topical interest and which, at least indirectly, concerns the start of this phase, is the optimal time of lifting the foot of the swinging leg from the ground. While some authors favor a very early breaking of contact (cf. SYLVESTER 1986), other authors expressly recommend that contact with the ground should be maintained for as long as possible.

The main reason for these contradictory opinions is that the swinging leg can fulfill its function in many different ways. Some athletes - as for example Al Oerter (LISA), Ludvik Danek (TCH) or Imrich Bugar (TCH) - favor a ‘narrow’ movement of a bent swinging leg. In this case, a deliberately delayed lifting from the ground of that leg seems to be very sensible, in order to increase the pre-tension in the area of the adductor muscles of the right leg.

Other athletes, however, demonstrate a wide swinging movement with an almost straight swinging leg (see Figure 9), in order to move mass, at the beginning of the turn, away from the rotational axis (left leg) and then to decrease the moment of inertia of the whole system, during the ‘sprint across the circle, by moving the leg in again closer to the rotational axis (pirouette principle) (see Figure 9: phase 2 and 3).

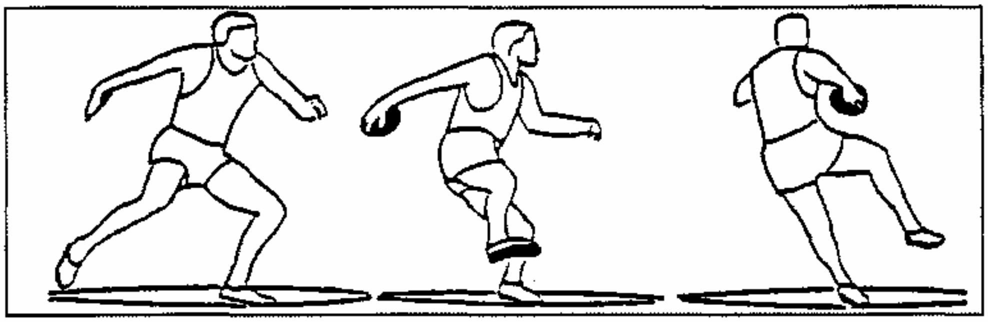


Figure 9: **Single support starting phase, with accentuated use of the swinging leg**

If one compares these two variations of the movement of the swinging leg, the latter appears to be more effective for the following reasons:

- An extended leg has a greater moment of inertia than a bent leg. So it is possible to produce an effective rotational impulse about the longitudinal axis of the body by a correspondingly powerful pull at the pelvis. A short delay of the bending of the hip towards the swinging leg during phase 2 (see Figure 9) increases the transmission of the swinging movement.
- The wide swinging, extended leg - which can be compared to an outrigger - facilitates a synchronous shift of the centre of gravity to the centre of the circle. This makes possible a fluent change of support from left to right, with a very short flight time and a shortened translation path of the CG (see Figure 10).
- By bending or moving the swinging leg toward the turning leg, the angular velocity can be effectively increased at a time when there seems to be no longer any possibility of rotational acceleration, namely at the beginning of and during the support-less phase.

In view of the advantages of the active use of an almost straight swinging leg, as shown above, the question arises as to why not all top discus throwers use this variation. Presumably the answer is that the individual turning rhythm, which is considerably influenced and even determined by the leg behavior discussed, eventually decides on the choice to be made.

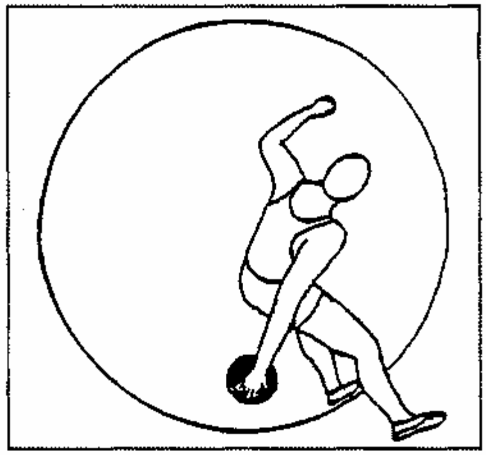


Figure 10: Extended swinging leg as 'outrigger' and shift of the CG to the opposite side, i.e. to the centre of the circle

Apart from the 'leg swing technique' presented here (cf. JONATH et al. 1976), the arm swing variation is also worth mentioning. Here, at the start of the rotation, the free arm is used in a horizontal and extended way in order to reduce the angular velocity.

During the subsequent support-less phase the arm is bent and moved in again towards the trunk. This variation of the utilization of the pirouette principle, as used, for example, by the four time Olympic champion Al Oerter (USA), is less effective than the use of the leg described above. The main reason for this ineffectiveness is the smaller moment of inertia of the arm compared to the leg (cf. Narr 1961). Furthermore, a closer look shows that the use of the free arm, as a swinging element, is useful only to a limited extent, because it would lead to a premature release of the twist of the trunk. So the extended arm has rather a steering function; it 'controls' the optimal angular velocity during each phase of the turn.

A combination of the use of the extended leg and extended arm at the beginning of the single support starting phase and the subsequent bending of the respective extremities at the end of the starting phase, must therefore be most effective from a theoretical point of view. As shown in Figure 11, attempts have actually been made at this solution to the problem.

Comparing this with the Sylvester technique, it can be seen that, during the push-off phase, the swinging leg moves closer to the pivot leg and the path of the swinging foot is flatter (see Figure 11, phases 4 and 5). This modification of the leg swing technique has recently become very popular. However, while the swinging leg is used actively, the free arm is not used as a 'swinging arm', but rather as an 'element of delay'. This is because the upper body must follow the leg action instead of running ahead of the legs. This establishes important prerequisites for the subsequent development of twist.

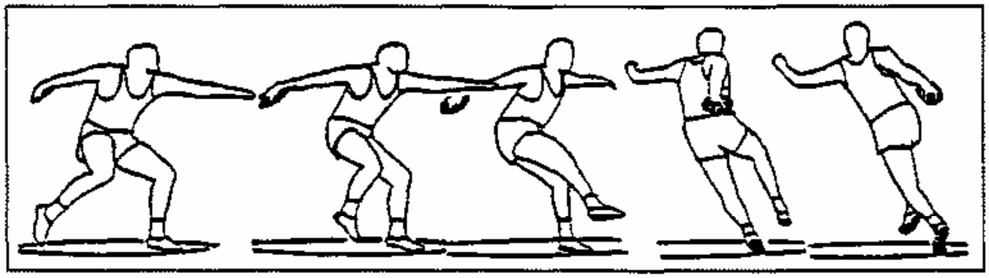


Figure 11: Single support starting phase with combined use of extended free arm and swinging leg
As compared to the Sylvester technique, the swinging leg passes the turning leg at a closer distance, and the foot is moved in a flatter way (see phases 4 and 5).

As far as the wide or narrow movement of the swinging leg is concerned, BARTLETT (1990) is presumably correct in pointing out that there is, as yet, no evidence of the superiority of the latter variation. Only SUSANKA et al. gives a reason for the narrow movement of the swinging leg: They prefer the narrow and flat movement of the swinging leg, because a swinging foot which is lifted high from the ground is disadvantageous for the other segmental movements (cf. SUSANKA et al. 1988).

If one takes up this idea, the flat and narrow path variation - as related to that section of the start which is turned in the throwing direction - can indeed be optimally combined with the intention to guarantee a maximally short support-less phase. In addition, the 'development of swing' with a wide swinging movement of the free leg should be completed before the thrower takes up the 'sprint start position'. In other words, the shift of mass from the rotational axis (left leg) is made so early that the development of swing is completed when the swinging foot is turned in the throwing direction. By moving the swinging foot along a flat, narrow and therefore 'straight' path, the moment of inertia of the whole system in this section of the movement is reduced more effectively than in the case of a high and wide movement of the leg from 'outward to inward'.

The synchronous flexion of the previously extended or almost extended swinging leg, as the thrower turns toward the centre of the circle, occurs in both variations. Apart from the utilization of the pirouette principle mentioned above, this flexion is also essential, because the optimal angle for the knee joint of the swinging leg, as it lands in the centre of the circle, must be 'adjusted' early.

The additional inclusion of the previously extended swinging arm, in this process of moving partial masses to the rotational axis, is demonstrated by only a few athletes using the 'leg swing technique' (as, for example. H.D. Neu). However, first signs of this can be frequently observed, such as the slightly bent swinging arm or the bent swinging arm held vertically (for example in L. Milde).

This aspect will be dealt with during the presentation of the following phase.

During the single support starting phase, which lasts about 350ms to 400ms, the discus covers about 2.40m to 2.80m (cf. KNICKER 1988 / SCHLÜTER & NIXDORF 1984 / SCHÖLLHORN 1989 / SUSANKA et al. 1988).

Here, the discus ‘follows’ the thrower, whose very active legs, at least to some extent, maintain the twist of the trunk achieved at the end of the backward swing. In any case the throwing arm and shoulder should be deliberately held back during the starting phase, instead of leading the movement. Thus, the ‘trailed’ discus travels through its first low point behind the thrower as it passes the bisector of the circle (as seen from above; see Figure 12).

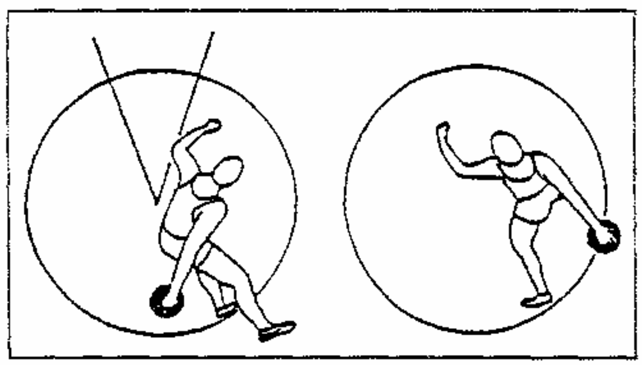


Figure 12: The ‘trailing’ of the discus as seen from above
The discus travels through its first low point as it passes the bisector during the starting phase.

4. Flight (no support) phase

The main function of the flight phase is to effect the change of support from the left to the right leg. Although it is possible to perform this translation even with no loss of ground contact, since a landing point at, or immediately behind, the centre of the circle involves covering a distance of only 1.25m to l.40m - as, for example, demonstrated by A. Wagner - this inevitably leads to a considerable reduction in the force of the primarily horizontal push-off of the left leg. The contribution of this leg to the acceleration of the whole system is often underestimated. A reason for this is that the rules forbid the use of the rim of the circle as a ‘starting block substitute’. When, at the beginning of the sixties, the then world record holder demonstrated his leg swing technique in Europe, the push-off from the rim of the circle, of which his opponents accused him and which at first was not noticed by the judges, was soon imitated. The gain in distance produced by this behavior was 1 to 2m, for a throwing distance of 50 to 55m. As the judges began to concentrate on this way of gaining a ‘push-off’ for the entry into the turn, this somewhat illegal method of achieving a longer throwing distance could no longer be used.

Nowadays most specialists utilize a push-off from the surface of the circle, which is - of course allowed by the rules. With a few exceptions, notably Wolfgang Schmidt, these throwers demonstrate a very short, flat turn (see Figure 13).

The ‘no support’ phase, which is characterized by a flight time of 60ms to 80ms and a distance of 0.8m covered by the discus, is the shortest of all five phases, in both space and time (cf. KNICKER 1988).

If one considers that the whole system cannot be accelerated when the thrower has no ground contact, but merely continues its translational and rotational movement, according to the law of conservation of momentum, the obvious aim to go through the flight phase as quickly as possible seems logical.

However, the law of conservation of momentum does not rule out a further acceleration of the discus. This possibility should, however, be used only to a very limited extent; otherwise the thrower will no longer be able to maintain the ‘trailing’ of the throwing arm and discus. (cf. BARTLETT 1990). Therefore the only useful alternative is to move the partial masses closer to the rotational axis (i.e. to the longitudinal axis of the body) during the flight.

Figure 13 shows that this alternative is employed only to a limited degree: for example a (right) swinging leg positioned directly under the body (Pachale and Schult), a swinging arm which is bent as it is lifted (Schmidt and Schult) or which is ‘angled’ as it is lowered (Schmidt and Schult) and a throwing arm moved slightly closer to the trunk (Schult). These actions lead only to an insignificant increase of the angular velocity of the system.

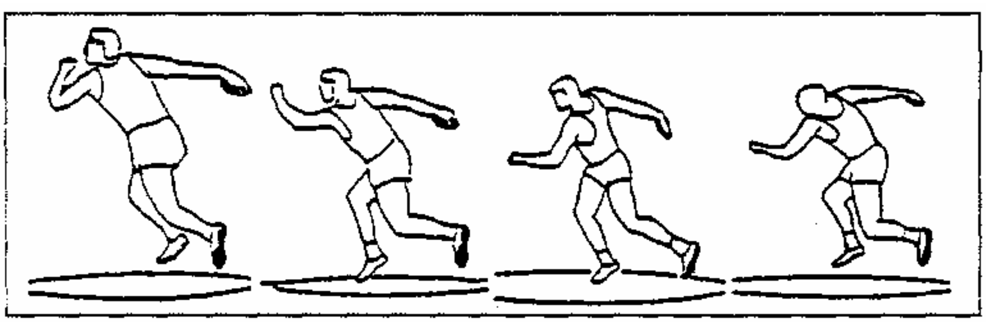


Figure 13: Flight phase in four world class athletes
(from left: Jay Sylvester (USA), Siegfried Pachale (GDR), Jürgen Schult (GDR/GER) and Wolfgang Schmidt (GDR/GER)

There are mainly two reasons why these possibilities are not used: firstly, there is too little time for such wide-amplitude changes and secondly, it is not very sensible to vary the plane of the discus a great deal. On close consideration, this argument also applies to the behavior of the swinging arm, which hardly changes its posture. The swinging arm has an important function during the single support phase which immediately follows. This function can be fulfilled only if the free arm is already in the optimal position, as the athlete moves into the single support phase.

5. Single support delivery phase

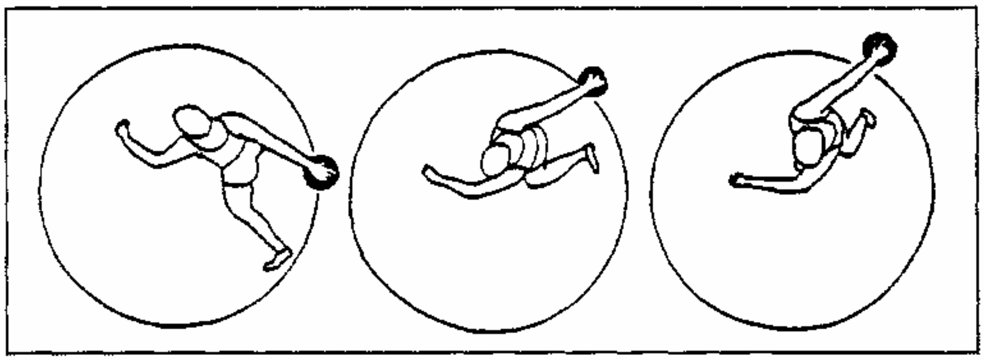


Figure 14: Push-off and landing, with delay phase for the build-up of twist, as seen from above
If the positions of the left arm during the three phases are compared with one another, the 'closing' against the throwing direction becomes obvious. One could say that the thrower 'winds' himself around the stationary free arm, with the elbow remaining approximately over the centre of the circle.

The aim of this phase is to develop torsion between the axes of the shoulder and pelvis. The free arm facilitates this by slowing down the rotation of the shoulder axis, while the pelvis continues to rotate. It seems remarkable that only SIMONYI & FELTON (1972) and BAUERSFELD & SCHROTER (1985) point out this very important aspect of technique: "The twist is supported by the left arm, which is deliberately held against the throwing direction and forms the 'opposite pole' of the turning extension movement of the right leg in the throwing direction" (BAUERSFELD & SCHROTER 1985, 312).

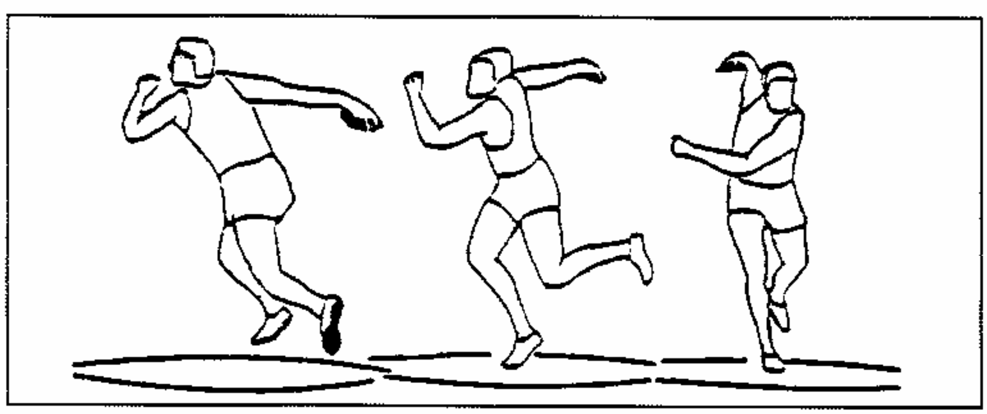


Figure 15: A 63m throw of the former world record holder Jay Sylvester in the year 1968
The three phases, which flow into one another, demonstrate a movement behaviour of the free arm clearly showing the intention of delay.

It is important that the right leg, immediately after landing, should not take over any extension function. Instead it performs a rotational movement, which is at first rather passive. The necessary rotational impulse has its origin primarily in the rotational start. However, immediately after the push-off of the pivoting foot from the back of the circle, this rotational impulse is continued and augmented by the contraction of the oblique trunk muscles. The fast and active positioning of the free (left) leg in the turning direction further increases the rotation of the lower extremities. The rotation of the trunk and throwing arm follows after these movements of the lower extremities.

In order to minimize the reduction of angular velocity through friction, a landing on the ball of the foot is essential and the sole of the right shoe should permit an easily executed pivoting movement. The delaying function of the free arm is by no means a new element. As Figure 15 shows, it was Sylvester, way back in the sixties, who was the main protagonist of this deliberate ‘closing’ action against the direction of rotation.

However, it must be said that the use of the left arm to hold back the upper part of the body, while the lower part is rotating actively, is possibly still the most effective method of achieving a high pre-tension of the trunk. Furthermore, this method makes it possible to prevent the discus from running ahead during the single support phase. In view of these advantages, it is surprising that, on an international level, very few athletes use the free arm in this way.

In the following series of figures, the movement pattern of Jay Sylvester may be compared with that of three other world-class athletes. The sequence shows the flight and landing configuration and ‘270° position’. In this position the throwing arm points in the throwing direction and, viewed from the back, the thrower demonstrates a definite vertical alignment of the trunk and limbs (see Figure 16).

A further advantage which can be derived from the ‘closing arm behavior’ is that the arm, because of its brief diagonal position in front of the body, can be used as an additional stimulus for the explosive delivery rotation, synchronous with the fast positioning of the free (left) leg. This is executed by a vigorous swinging or ‘pulling’ action of the arm diagonally upward, in an extended bent position. This ‘opening out’ action is carried out either directly (variation I), or indirectly (variation II).

In variation I, the free arm is immediately swung backwards and upwards towards the throwing direction (see Figure 17), while, in variation II, the arm is first lifted up to shoulder height. After this, the explosive ‘backward pull’ followed by a check at the shoulder joint or shoulder-blade/spinal area, produces a very effective rotational impulse (through transfer of momentum).

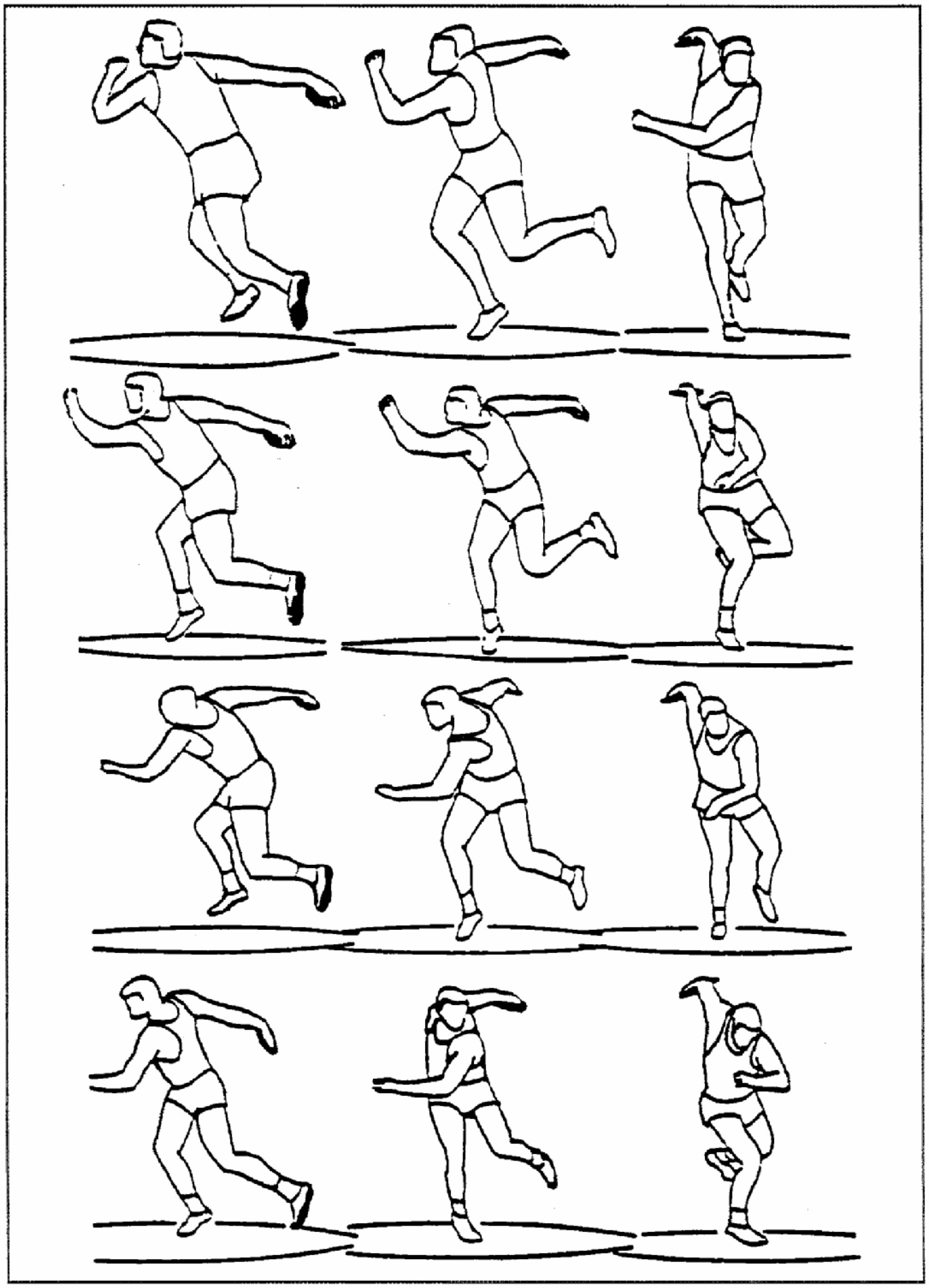


Figure 16: Comparison of the landing and flight behaviour of four athletes during three phases: flight, landing and the '270° position' (from left)

As already mentioned, the use of both variations is especially effective, if a 'stationary' free arm has been used to hold back the rotation of the upper body, up to the 270 position.

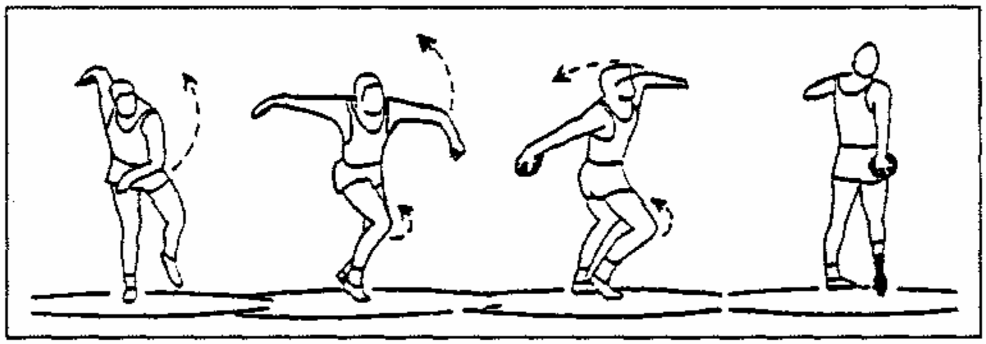


Figure 17: Rear view of a 68m throw, showing the active use of the free arm as a swinging element, during the single and double support delivery phase (variation I)
The extension movement is combined with the 'use of the hip'. The right 'flank' is swung vigorously against the resistance of the front leg, immediately after the left foot has been grounded. During this process the right leg is bent.

The question which of the two variations should be preferred can be answered theoretically, only if the individual rotational rhythm and the timing of the release are also taken into account. As shown in Figure 18, variation II has a comparatively long single support delivery phase.

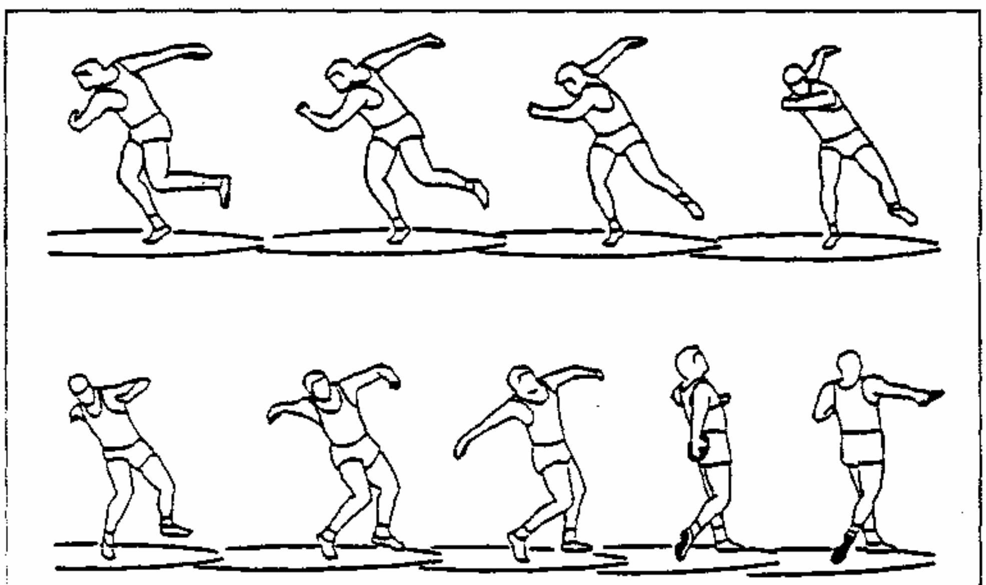


Figure 18: A side/oblique view of a 68m throw, showing variation II of the free arm behaviour
During the transition from phase 2 to phase 3, the free arm is first of all lifted and then actively rotated in the throwing direction, in the plane of the shoulder axis. As soon as the thrower reaches the frontal position, he blocks the left side of his body.

However, contrary to the opinion of STEPANEK & SUSANKA (1987), a longer duration of the single support release phase alone is not automatically a sign of an ineffective movement behavior.

For such a conclusion, an assessment of the whole movement process, and especially an analysis of the course of velocity of the implement during each phase, is essential. Although, according to SCHLÜTER & NIXDORF (1984), a sharp acceleration in the single support release phase is not useful, because this would lead to a too early release of the wind-up and, therefore, to a reduction of the effectiveness of the final double support phase, nevertheless it is a ‘generally accepted ideal’ to produce a positive acceleration of the discus from phase to phase during the whole rotational movement. Jürgen Schult, whose movement process is shown in Figure 18, indeed succeeds in achieving such an acceleration, in spite of a relatively long single support release phase (cf. KNICKER 1988).

Therefore, the orthodox opinion that the left (front) foot should be planted very rapidly and that the delivery should not begin until the power position is taken up, as demonstrated by the former Olympic Champion Rolf Danneberg, should at least be reconsidered. The very fact that the structural approach underlying this analysis, quite deliberately, divides the delivery process into a single and a double support release phase implies a rather different point of view.

However, the gradual increase of the velocity of the discus can be achieved only if the following preconditions are fulfilled:

- An attainment of a high angular velocity of the whole system, by means of an accentuated and dynamic leg action during the first single support starting phase.

- A delay of the trunk rotation during the flight phase and at the beginning of the first single support delivery phase. This causes an impulse to be transmitted to the lower extremities, which continue their rotation and thus produce an extreme twist of the trunk.

- An optimal landing position, with the longitudinal axis of the body leaning back against the throwing direction (the trunk first remains bent over the bent turning leg). The discus is trailed at, or slightly above, the height of the head at its second high point (‘kept back and high’).

- An active use of the free arm and free leg in the turning direction, while the throwing arm is deliberately (passively) ‘held back’ during the single support delivery phase.

- A good degree of flexibility and looseness at the throwing shoulder, so that the inertia of the trailed throwing arm / implement can be utilized by ‘the pull’ of the free arm. This prevents the discus from running ahead. At the same time, this leads both to the development of a high tension and also to such a great angular velocity, that centrifugal force keeps the discus on the widest path of acceleration, at the level of the second high point.

- An active turning thrust of the right leg, which causes the pelvis to run ahead and shift quickly in the throwing direction. This leads to an increase of tension in the trunk during the single support delivery phase and is an optimal preparation for the slinging movement.

This ‘slinging movement’ is the transition from the single support delivery phase, which lasts about l90ms and in which the discus covers a distance of 1.50m (cf. KNICKER 1988), to the double support delivery phase.

6 Double support delivery phase

According to BARTLETT (1990), 62% to 73% of the release velocity is produced during this main acceleration phase. Its duration is approximately 150ms, while the path of the discus is about 3m long (cf. SUSANKA 1988). If one compares the current delivery techniques, NETT’S (1970) analysis of the delivery behavior of the best throwers in the world is still valid. Depending on whether two feet, the front foot or no foot has ground contact, at the moment when the discus leaves the thrower’s hand, NETT speaks of a ‘single’ or ‘double support’ or of a ‘jump delivery’ of the discus. As far as the frequency of the use of the individual variations is concerned, there is evidence of a certain preference for the double support by female top-level throwers. With the men the picture is not so uniform. However, there is a trend towards the ‘jump delivery’.

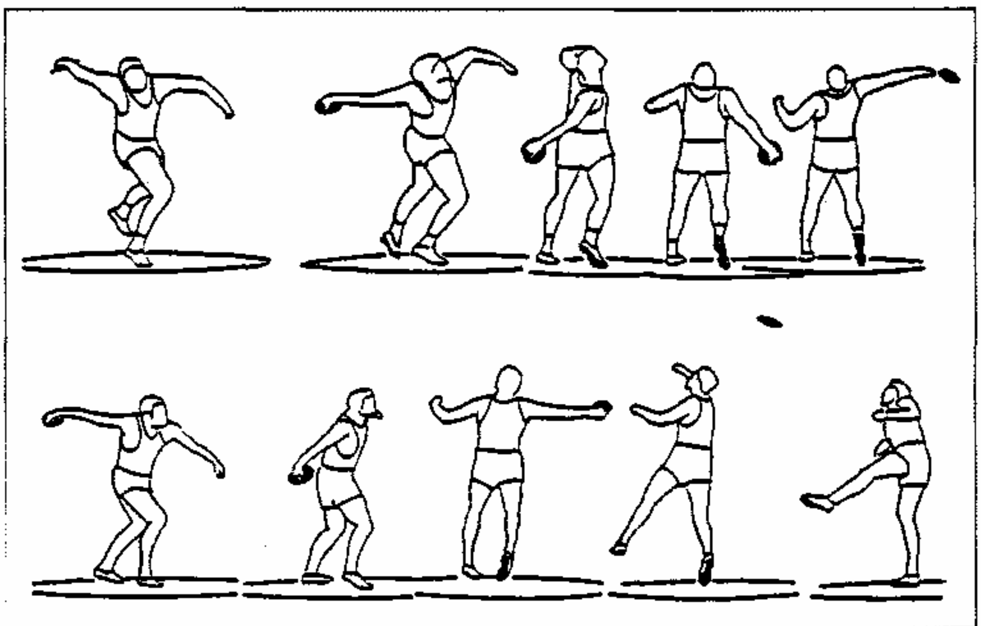
It is not possible to say which technique is more successful, because many top-level throwers change their delivery technique in the course of their career. This is, for example, the case with the current world record holder Jürgen Schult, who, although actually a ‘support thrower’, experimented with the ‘jump delivery’ in 1986. In that year he even achieved a world record, under very favorable wind conditions. However, in 1987 he returned to the ‘support’ throw (cf. BRANDT 1990).

From a biomechanical point of view, also, a final assessment of the relative effectiveness of these variations is difficult. It is possible that, apart from the influence of the teaching method and the coach, the eventual selection of any one variation depends on the different neuromuscular abilities of each individual, which should not be underestimated. Those throwers who opt for the ‘jump delivery’ stress the vertical acceleration component of the release velocity, which is only possible if there is very great explosive strength in the leg muscles, while those who prefer the double support put the emphasis rather on the rotational component. The optimal execution of this delivery variation also requires great leg strength. However, this strength is not only used at certain points during the movement process, but it also serves as a prime mover or as a kind of ‘basis’ during the whole release process.

Consequently, the reactivity and explosiveness of the lower extremities can be developed, or at least be used, rather less in the ‘standing delivery’ (cf. BRANDT

1990), than in the 'jump delivery'. For this technique, a high specific flexibility and a highly developed performance ability of the oblique trunk muscles are indispensable.

In Figures 19 and 20 the two release techniques discussed here are juxtaposed with one another.



Figures 19 and 20: **Double support** (above) **and jump delivery in direct comparison**

This comparison shows that, when each variation is executed optimally, only quite slight differences can be discerned. The primary characteristic of the support delivery is a significant running ahead of the hips, with a corresponding trailing of the implement and a considerable twist of the body. The 'slinging movement' resulting from this, together with a preceding development of tension via the right hip, with the front leg serving as a prop, cannot be achieved to the same degree in the jump delivery because of the 'condensed' dynamics of this delivery technique. This applies even if the double support position, prior to the 'jump delivery', has been taken up very early as is shown in Figure 20.

In order to achieve the considerable twist mentioned above, as well as the 'delayed' release, it is, however, essential to utilize the steering function of the head. Therefore, the head must not run ahead of the throw but, during the whole release phase, must be kept at the anatomical 'zero position'. Figure 21 illustrates this prerequisite of a successful support-slinging action (cf. ARBEIT et al. 1987). This figure shows, from above, the slinging process with a corresponding active use of the hips (cf. CARR 1970).

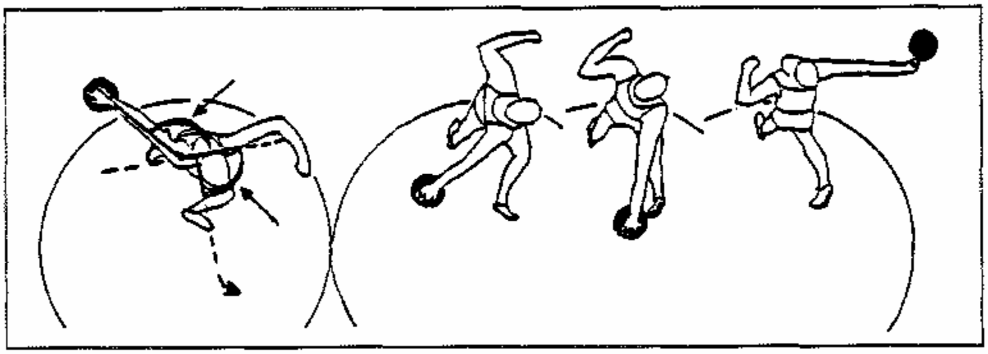


Figure 21: The four phases of the delivery process
In phase 1 (just before the double support position is reached) the torque angles between the throwing arm and shoulder axes and between the shoulder and pelvic axes are indicated. There is a fluent release of the twist until the delivery of the implement, so that in phase 4 (delivery) both axes are parallel.

A comparison of the positions of the head and the shoulder axes in all four phases shows that the demand mentioned above is completely fulfilled.

Another important difference to note is the 'lifted delivery position,' with a vertical alignment of the longitudinal axis of the body, in the case of the jump delivery, as opposed to the slightly backward lean of the trunk in the case of the support delivery. McCOY et al. arrive at the same conclusion in their analysis (1985).

However, today's leading 'support' throwers do not show the 'incomplete leg extension', which NETT, for example, identified as a technique characteristic of Ludwik Danek, Olympic Champion in 1972 (cf. NETT 1970). Although even Imrich Bugar (world champion in 1983) showed a bent left knee during the delivery, there can be no doubt that the front leg can fulfill its double function as a prop and pivoting axis more effectively, if the knee is completely extended (see also the leg action in Figure 18).

Finally, in direct connection with the main criterion of the difference between the three variations, the 'reverse' and subsequent 'recovery' is an intrinsic element of technique, both in the jump delivery and in the delivery with single support. From the point of view of the transmission of force, the support delivery has the advantage, in that here the reverse is normally superfluous. The continuation of the turn after the delivery, which can be seen in many throwers, is also a sign of a 'transmission loss' (cf. VRABEL 1987). Ideally, the kinetic energy produced during the turn and delivery should be completely transmitted to the discus. To what extent this has been achieved can, at least to some extent, be seen from the thrower's behavior after the discus has left his hand.

The main goals of the thrower are the maximization of the release velocity and the optimization of the delivery conditions (cf. WARD 1981). On this basis there is no clear evidence of the superiority of any one variation. Let us assume that, in each case, a maximum acceleration impulse is produced.

During the jump delivery the rotational axis shifts from the left side of the body (left foot / left shoulder head) towards the centre of the body, as the ground contact is lost. This leads to a shortening of the turning radius, at the outer end of which are the throwing hand and discus. The shortening of the radius, however, leads to an increase in the angular velocity. The velocity of the discus, as it moves along its path with increased angular velocity, becomes the release velocity as soon as the implement leaves the thrower's hand; therefore the 'jump delivery' could produce the same velocity as that achieved by the 'support' delivery. In the 'support' delivery the maximum 'turning radius' (from the left shoulder to the discus) remains constant until the release and the angular velocity is kept correspondingly somewhat lower. Therefore the end product, the velocity of the discus along its path, possibly remains the same in each case.

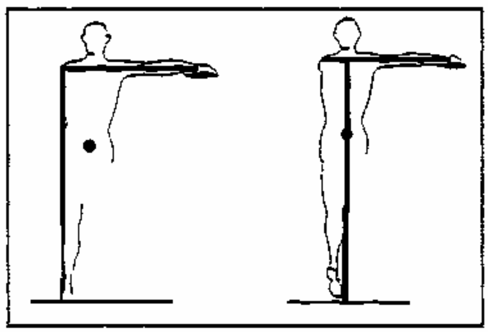


Figure 22: The effect of the jump delivery on the position of the rotational axis and on the radius (according to NETT 1961)

The reflections published by NETT, which suggest that all three variations are of equal value, are, however, based on the assumption of an identical release impulse (cf. NETT 1970). For the time being, the question must remain open as to what extent delivery with support may increase the release impulse, by means of an optimal utilization of the muscle stretch reflex and the comparatively prolonged period during which force can be applied to the implement.

While ARBEIT et al. give a clearly positive answer to this question and mainly support the 'support slinging' option (cf. ARBEIT et al. 1987). BARTLETT is more cautious in his judgment. He says that there are no hints or proofs that the variations are not merely of an individual nature. In his view, it is not yet possible to say that certain technical faults or advantages are definitely typical of any one variation.

7 Summary

The discus 'analysis sheet' is an attempt to integrate the elements of the phase structure discussed above in an ideal-typical way. The selection of model phases, which was indispensable in this context, led to two difficulties. The first of these difficulties was that a decision had to be made on the type of release technique, while the other was the limited availability of really exemplary models, from an identical point of view.

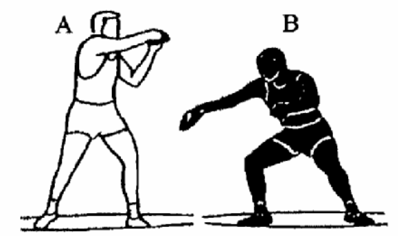
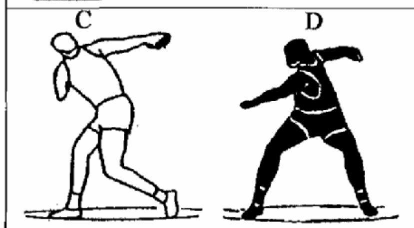
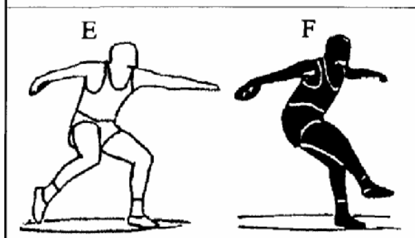
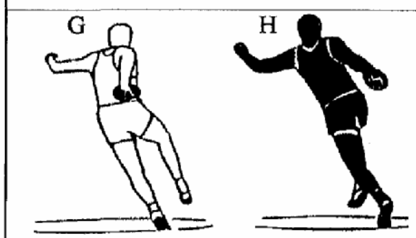
Therefore, compromises had to be made: The conturograms, or outline drawings, mainly depict the type of support delivery with an accentuated slinging action. However, in the ‘release configuration’, this selection deliberately leaves open the question as to whether the thrower still has ground contact or whether he is about to make a jump delivery. The reason for this selection is that the support delivery is a kind of basic teaching model, through which both beginners and advanced athletes pass. Only when the ‘slinging action’ is mastered, can the reverse, or possibly the jump delivery, be introduced.

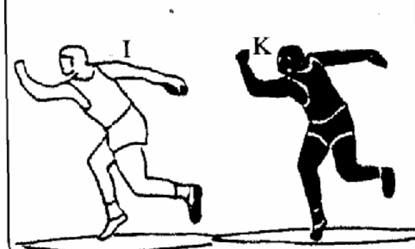
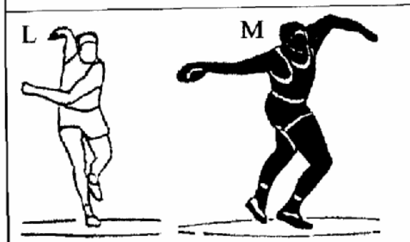
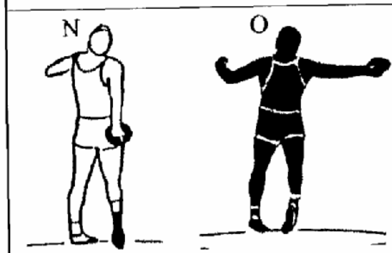
In regard to the drawing from the rear perspective, the main difference between the two delivery variations is that, contrary to the jump delivery, in the ‘standing delivery’ the criterion of phase element ‘N 47’ (front foot: ground contact with the whole sole) is also completely valid in the delivery figuration ‘O’. A vertical extension of the whole body, on the other hand, which naturally includes the front leg, is assumed to be optimal in both variations. Correspondingly, only this criterion (‘0 53’) has been presented. The additional slight backward lean of the trunk, which can be observed in most athletes performing this variation, cannot be seen from the rear perspective and is therefore ignored here. On the other hand, the horizontal alignment of the shoulder and the throwing arm, in order to maximize the length of the radius, do not depend on the respective release variation chosen (see criterion ‘0 52’).

To avoid the ‘left-right-problem’, the designation of extremities has been made in relation to their functions or positions. Thus, in the entry into the turn, the words ‘swinging leg’ and ‘pivot leg’ are used and, in the release, a differentiation is made between the ‘front’ and the ‘back’ leg. Analogous to this, the terms ‘free arm’ and ‘throwing arm’ are used. The abbreviations ‘HP’ and ‘LP’ stand for the respective high and low point of the discus orbit, which is about 8m to 10m long. ‘LL’ means ‘lower leg’.

As far as the phase designations are concerned, once again new terms had to be invented because there are no special terms available. This was necessary because the structuring method (5 phases), which is the basis of this analysis, is further differentiated because of the double picture representation chosen here. This method does not suffer from the lack of information, as is the case with the use of static figures from phase to phase (see Tidow 1981). For example, the ‘single support starting phase’ is presented using four conturograms and, as far as function is concerned, it is divided into a ‘phase of swing development’ and a ‘turn-push-off phase’. For the ‘single support delivery phase’, however, position-related designations have been used: The ‘landing position’ is chronologically followed by the ‘270° position’ and the ‘180° position’. Here, the alignment of the throwing arm and, with it, the acceleration path of the discus up to the delivery, measured in degrees, becomes the criteria of differentiation. As far as the ‘180°

position’ is concerned, the term ‘power position’ could have been used instead of the 180° position. This, however, would require a landing of the front foot. However, as there are relatively great individual variations in timing, particularly in regard to the foot plant, the throwing-arm-related designation in degrees of angle has been preferred.

	Phase	Reference	Criterion	Judgement +	o	–
	Starting position	A 1 Foot position	At the rim of the circle / wide V formation			
	↓	A 2 Pivot leg / foot	Weighted / ground contact with the whole sole			
		A 3 Swinging foot	Lifted heel / ground contact with the ball of the foot			
		A 4 Throwing arm	At the reversal point of the forward swing			
		AB 5 Discus / throwing arm	Swings back with large radius			
		AB 6 Body weight	Shifted to swinging leg			
	Backswing	AB 7 Trunk	Follows throwing arm / slight forward lean			
		AB 8 Legs	Fluent bending			
	Start	C 9 Throwing arm / discus	At the reversal point of the backward swing / first HP			
	↓	C 10 Swinging leg / foot	Weighted / ground contact with the whole sole			
		C 11 Pivot leg / foot	Unweighted / ground contact with the ball of the foot			
		C 12 Body	In twisted position			
		CD 13 Body weight	Shifted to pivot leg in a flowing manner			
		CD 14 Pivot leg / foot	Turning to the inside / on the ball of the foot			
	Bridge position	D 15 Knee	Bent			
		D 16 Throwing arm	'Back' and high			
	Buildup of momentum	DE 17 Free arm	Extended control / at shoulder height			
		DE 18 Pivot leg / foot	Bent / knee leads / actively turning to the inside			
		E 19 Foot of pivot leg	Lifted			
		EF 20 Swinging leg	Active / extending / outward circular movement			
		F 21 Free arm	Control at constant position			
		F 22 Throwing arm	'Back' / follows			
		F 23 Trunk	Constant forward lean			
		FG 24 Knee of swinging leg	Bending = shortening of the radius			
	Rotational push-off	G 25 Throwing arm / discus	At first LP			
		GH 26 Swinging leg	Close passing of the pivot leg			
		H 27 Turning foot / tip	Push-off from the ball of the foot / points toward the centre of the circle			
		H 28 Swinging foot / LL	Low path / vertical position			
		H 29 Trunk	Passive turn			
		HK 30 Discus / throwing arm	Wide swing / constantly held back			

Position	Phase	Reference	Criterion	Judgement +	Judgement o	Judgement –
	Flight	I 31 CG Trajectory	Low / directed toward the centre of the circle			
		IK 32 Trunk	Passive turn / slight forward lean			
		IK 33 Lower extremities	Active turn			
		IK 34 Push-off leg - LL	Horizontal			
	Landing position	IK 35 Landing leg - LL	Vertical			
		K 36 Throwing arm	Horizontal / trailed			
		K 37 Free arm	Bent / closes against turning direction			
		KL 38 Landing leg / landing foot	Locked joints / ground contact with the ball of the foot at the centre of the circle			
	270° position	L 39 Body / body segments	Vertical alignment / forward lean			
		L 40 Free arm	Closes			
		L 41 Glance / head	Contrary to throwing direction			
		L 42 Discus / throwing arm	Second HP / at head height & and pointing towards the centre of the sector			
	180° position	LM 43 Free leg	Active touchdown / foot length lateral displacement			
		LM 44 Free arm	Active opening			
		MNTrunk / support leg	Use of hip / heel: turning to the outside			
		M 46 Throwing arm	Parallel to ground / twist: constant			
	90° position	N 47 Front foot	Ground contact with the whole sole			
		N 48 Rear foot	Turned to point inwards			
		N 49 Hip	'In front' (running ahead)			
		N 50 Discus	Second LP			
	Delivery posture	O 51 Left side of the body	Fixed (left arm blocked)			
		O 52 Throwing arm	Horizontal in line to shoulder axis			
		O 53 Body / legs	Vertical / extended			
	(Discus) flight	54 Flight direction	As related to the wind (direction): optimal			
		55 Angle of attitude & angle of tilt	Optimal / stable / 'cutting'			
Position	HP = High point	LP = Low point	LL = Lower leg			

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