MODEL TECHNIQUE ANALYSIS SHEET FOR THE THROWS PART X: THE JAVELIN THROW

By Günter Tidow

In this very detailed analysis, the javelin throw is divided into three distinct yet smoothly connected phases — the cyclic part of the approach, the acyclic part, and the final delivery.

Referring to the cyclic part of the approach, the author describes the procedure generally adopted by top class throws, as regards posture, the carry of the javelin and the number of strides, and makes appropriate recommendations.

For the acyclic part of the approach, consideration is given to the 'counting' and the rhythm (5 or 7 strides) and the withdrawal of the javelin, with a comparison between the Finnish and Swedish methods. The method and purpose of the intermediate and impulse strides, leading to the 'power' position, are described.

For the purpose of analysis of the delivery, various phases are described — from the 'support contact' to the 'bracing contact', from the bracing contact to the striking position, from the striking position to the release and from the delivery to the recovery. Finally the nature of the 'arm whip' is discussed.

Prof Dr Günter Tidow is the Head of the Department of Movement and Training Science at the Humboldt University in Berlin.

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1. Introduction

This is the tenth of a series dedicated to the analysis of model techniques in athletics. The series was introduced in 1989 by a general article about the significance of the model techniques of athletics events, written by Günter Tidow (Models for teaching techniques and assessing movements in athletics, NSA 4 (1989), 3, pp. 43-45). Tidow also wrote most of the articles on model technique analysis sheets which followed: Part I: The long jump, NSA 4 (1989), 3, pp. 47-62; Part II: The triple jump, NSA 4 (1989), 4, *pp. 63-66 (by Eckhard Hutt); Part Ill: The pole vault, NSA 4 (1989), 4, pp. 43-58; Part IV: The shot put, NSA 5 (1990), 1, pp. 45-59; Part V: The hammer throw, NSA 5 (1990), 1, pp. 61-67 (by Eberhard Gaede); Part VI: The women's 100 meter hurdles, NSA 5 (1990),* 4, *pp. 33-58 (by Johannes Hucklekemkes; Part VII: High hurdles, NSA 6 (1991], 2, pp.*

5 1-66; Part VIII: The flop high jump, NSA 8 (1993], 1, pp. 3 1-44; Part IX: The discus throw, NSA 9 (1994], 3, pp. 47-68. This final part deals with the technique of the javelin throw. (Eds.)

The technique of throwing the javelin can be very roughly divided into the cyclic and the acyclic part of the approach run, including the final throwing action.

2. Cyclic part of the approach run

The main function of the cyclic part of the approach run is to impart an optimal 'basic velocity' to the thrower-javelin system, which can be transformed into the maximal 'final velocity' of the javelin during the acyclic part of the approach run. During the approach the thrower holds the javelin at the cord grip and carries it with a bent arm close to the head in such a way that the tip of the javelin points in the throwing direction (see *Figure 1).* The athlete takes an upright running posture and swings the free arm in a relaxed way opposite to the direction of movement of the right leg (right-hander). However, the throwing arm is kept in an almost stationary position, with the hand kept at about head height.

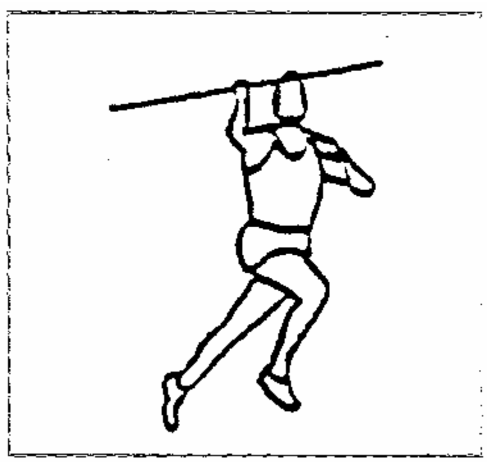


Figure 1: Javelin carry in the cyclic part of the approach

The number of strides is closely related to the approach velocity that the thrower tries to achieve. According to MENZEL, the approach velocity of world-class throwers varies between 5.5m and 7.6m/sec (inter-individual variation) or by about 0.6m/sec (intra-individual variation) (cf. MENZEL, 1990). Only a few strides are necessary to achieve such a velocity.

However, the thrower should demonstrate a smoothly accelerated run-up, which still permits an increase of concentration. In the cyclic part about 10 to 12 strides are usual, followed by 4 to 7 additional strides during the acyclic part. According to the rules, the approach area should have a length of between 30 and 36 meters; this is completely sufficient for such an approach. Unlike the other throwing events, which must be performed in a circle of quite a small diameter

(2.135m to 2.5m), in the javelin throw the available space to accelerate the total system from the start of the movement to the release of the implement is more than adequate. This often (mis) leads beginners and decathletes to violate the 'principle of economy': They choose a much too long cyclic approach run, so that they reach their maximal velocity well in advance of the intermediate checkmark.

2. Acyclic part of the approach run: counting method and rhythms

The start of the withdrawal of the javelin, triggered by the peripheral perception of passing the aforementioned intermediate checkmark, Introduces the acyclic part of the approach run. Depending on the type of withdrawal and the number of approach strides used by the thrower for the withdrawal, there are even or uneven rhythms prior to the delivery. In the four-stride rhythm the javelin is taken back during the flight phase of a 'quasi' impulse stride. This stride is followed by an 'intermediate stride' which is only characterized by locomotion (without any other technical changes). After this comes the 'impulse stride', which initiates the delivery, and finally the thrower performs the 'delivery stride' as the fourth and last stride. If instead of one intermediate stride the athlete favors three strides, the result is the six-stride rhythm.

Uneven rhythms normally exist when the javelin is withdrawn during two strides. Together with the following subunits, 'intermediate stride', 'impulse stride' and 'delivery stride', this creates a five-stride rhythm, or, if two additional strides are taken, a seven stride rhythm.

A special kind of action entails the introduction of the withdrawal of the javelin with a preliminary forward movement of the throwing arm. If for the withdrawal itself two additional strides are added, the intermediate stride of the 'five-stride rhythm' is left out, so that the end of the withdrawal must be linked directly with the impulse stride. If the athlete prefers this sort of preliminary action, it is recommended that he or she should withdraw the javelin immediately after this preliminary movement of the throwing arm, so that he or she does not 'hurry too much' the following transition to the impulse stride (cf. BAUERSFELD / SCHROTER 1986). Besides, this is the only way to avoid the problem of running with unopposed arm and leg movement. Such a measure is necessary because every two-stride withdrawal of the javelin automatically leads to an unopposed arm and leg movement.

4. Variants of the javelin withdrawal

Only the 'Finnish throwing style', which is characterized by a two—stride withdrawal of the javelin, enables the thrower to continue his or her approach run in a smooth way, with opposed leg and arm movement. In this style the hand holding the javelin is first moved in a semi-circle to the front and downward. If a right-hander does this between his or her right and left foot contact at the intermediate checkmark, there is automatically an opposed forward movement of the right arm and the left leg. If the semi-circular movement or the withdrawal of the javelin is completed by the end of the second step (i.e. from left to right), the cross-coordination is guaranteed here also; now the right arm and left leg move backward synchronously. However, it is a disadvantage that the Finnish method of javelin withdrawal forces the athlete, at least to some extent, to loosen the grip. Although, considering the length of the javelin shaft, this is unavoidable for anatomical reasons alone, it is mainly necessary in order to guarantee that after the withdrawal the tip of the javelin is still in its technically correct position. That at least elite athletes have no problem with this ‘change of the grip’ has been proved by throwers like J. Lusis (URS), H. Schreiber, M. Wessing (GER) and J. Zelezny (CZE).

Besides the ‘Finnish’ withdrawal, the ‘Swedish’ method is used all over the world. (According to Jonath et al. these terms were invented by German athletes who got to know the Swedish variant in 1914 and the Finnish variant in 1927; cf. JONATH et al. 1977). In the Swedish withdrawal the javelin is taken back in an almost straight line from the starting position close to the head until the throwing arm is extended and the throwing hand a little higher than the shoulder (see *Figure 2).*

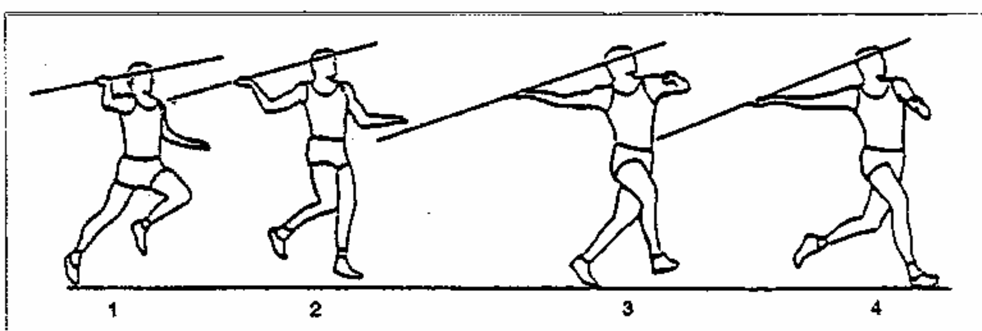


Figure 2: Swedish javelin withdrawal during two strides

It is necessary that the javelin is not taken back in a jerky way but smoothly and close to the athlete’s head. After the final phase of the withdrawal *(picture 4),* the throwing arm is in a horizontal position and is extended and relaxed. The tip of the javelin is close to the athlete’s temple, the feet point straight forwards and the javelin and shoulder axes are in line with the throwing direction.

Unlike this, the ‘Russian’ javelin withdrawal is characterized by a semi-extended throwing arm, with the hand held well above the height of the head. The withdrawal is performed, as it were, from top to back. In this method the thrower does not completely turn the shoulder axis about 90° against the throwing direction, as is typical of both the ‘Finnish’ and the ‘Swedish’ withdrawal. For this reason, the ‘Russian’ method is also called ‘frontal withdrawal’ (cf. JONATH et al., 1977). It was first used mainly by throwers from the USSR just after the end of World War II. Although elite athletes no longer use this method, it is an effective way of introducing the overhead throw, especially as far as the transition from the flexed to the extended throwing arm is concerned.

The influence of the type of withdrawal on the activity and effectiveness of the arm/shoulder muscles has not yet been clarified, especially from the point of view of the stretch of the pectoralis major muscle, whose individual cords are possibly released (i.e. 'de-spun') with a different power output. Corresponding electromyographic investigations have not produced clear findings. It was revealed only that a (spatially) long withdrawal can lead to a prolonged activity of the corresponding muscles (cf. ANOKINA/HOMMEL 1975). Although it is stated that this could be advantageous within the limited time span of the javelin release, there are no reasons given for this assumption.

If the assessment of the different variations of the withdrawal is based on the actual 'goal of the movement', which is the prolongation of the acceleration path of the javelin by turning one's shoulder and extending one's arm, the Finnish and Swedish techniques are almost of equal value. However, non-specialists are recommended to use the Swedish method of javelin withdrawal because this method is characterized by a constant grip. If, when using this method of javelin withdrawal, one thinks of 'running away from the javelin', instead of pulling it back, a smooth transition from the cyclic to the acyclic part of the approach run should be possible.

Very few athletes are able to continue to accelerate during the acyclic part of the approach run, although the need to do so is postulated by many authors. One reason for this is that the withdrawal-induced swinging action of the shoulder axis leads to a torqued position of the upper body. If the athlete lacks concentration, this torqued position causes a rather lateral foot plant and corresponding 'crossover strides' so that the sprinting run which the athlete tries to achieve is no longer possible.

The achievement of a continuous acceleration does not become easier if the athlete is recommended to lean back during the withdrawal by about 30° to 36° and to demonstrate almost parallel shoulder and pelvic axes (cf. BAUERSFELD / SCHROTER 1986, LENZ 1988). Here, demand and recommendation almost exclude one another. Therefore the praise that a thrower shows an exemplary 'parallelism' of the three axes (longitudinal axis of the javelin, shoulder and pelvic axis: cf. HARNES 1990) is confusing, at least to those throwers who really strive to achieve a further acceleration. The parallel position of the shoulder and pelvic axes can be achieved even by beginners without much effort. However, it is much more difficult to maintain a sprint-adequate foot plant with the throwing shoulder taken back and the trunk in a torqued position. The athlete can only succeed in doing so if he or she tries to

- keep the pelvis as frontal to the direction of the approach run -and throw as possible,

- make a pronounced backward lean of the trunk only when it is urgently needed, i.e. during or after the impulse stride.

An evaluation of the velocity course during the last three strides proves that there is no real increase in velocity even if the movement execution is exemplary. However, a reduction in velocity immediately prior to the delivery stride will bring about a proportional disadvantage (cf. MENZEL 1989, HARNES 1990).

5. Intermediate stride(s)

As already mentioned, the thrower performs one to three intermediate strides, depending on the type of withdrawal and number of acyclic strides. These intermediate strides are basically the link between the completion of the withdrawal and the impulse stride, which serves as a direct preparation for the delivery. The intermediate strides should propel the athlete forward, and apart from an anticipatory inclination of the shoulder axis, the javelin and the throwing arm (variant A), there should be no great deviations from the running movement (see *Figure 3).*

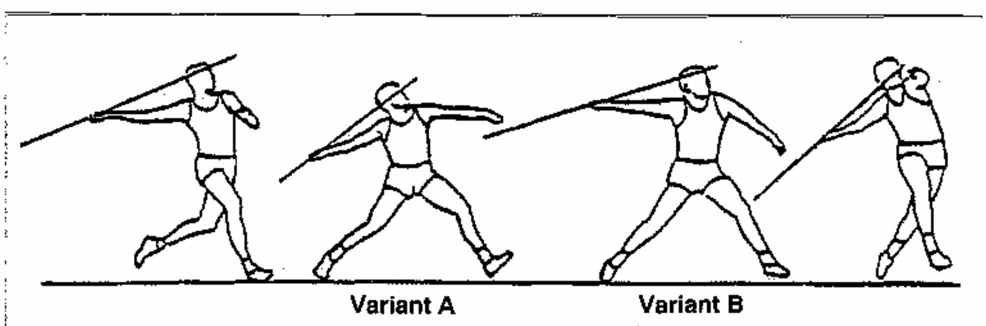


Figure 3: The intermediate step as a link between the completion of the withdrawal and the subsequent impulse stride

If the athlete does not strive for a pronounced lean-back of the trunk during the following power position, the shoulder axis is kept constantly horizontal (variant 'B'; see *Figure 3).*

There is no answer to the question of many intermediate strides should be considered as optimal. In general it can be said that running (and accelerating!) with an extended throwing arm and torqued trunk are certainly difficult. This is also the main reason why the thrower does start (or should not start) the approach run as the throwing arm extended to the rear — i.e. without any withdrawal phase during the approach.

Furthermore, a throwing arm which is kept constantly horizontal and high can, step by step, lose the required looseness in the shoulder muscles. Nevertheless, the final selection of the number of intermediate strides seems mainly to depend on the fact that the thrower 'feels comfortable' with the resulting rhythm.

6. Impulse stride

The last intermediate stride is followed by the penultimate stride of the acyclic part of the approach run. Because of its accentuated, rhythmic execution, this stride is aptly called the 'impulse stride' (see *Figure* 4). With right-handers contact is from left (with an emphasized push-off) to right foot. The function of this stride determines its structure.

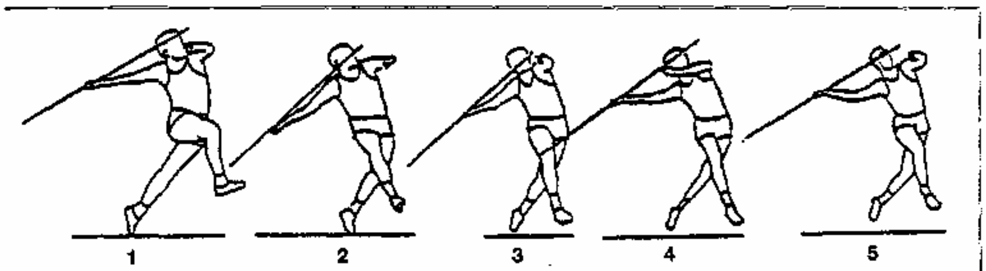


Figure 4: Comparative presentation of the push-off (1; 2) and flight variations during the impulse stride

In general, the impulse stride prepares and introduces the 'power position'. The main characteristic of the power position is a lean-back from the throwing direction. This ensures a long path of acceleration of the javelin and also helps the athlete to achieve the correct alignment of the longitudinal axis of the shoulder and javelin according to the intended angle of release.

Finally, the lean-back, caused by the impulse stride, secures an effective bracing action. This only possible if the upper body is left behind or 'overtaken', due to the very active leg action relative to the points of support (right and then left foot). This causes an 'impulse torque', which is typical of the flight phase of the penultimate stride. A total presentation of this phase, including the immediately following movement behavior during the impulse stride landing, clearly shows the process of 'overtaking' (see *Figure 5).*

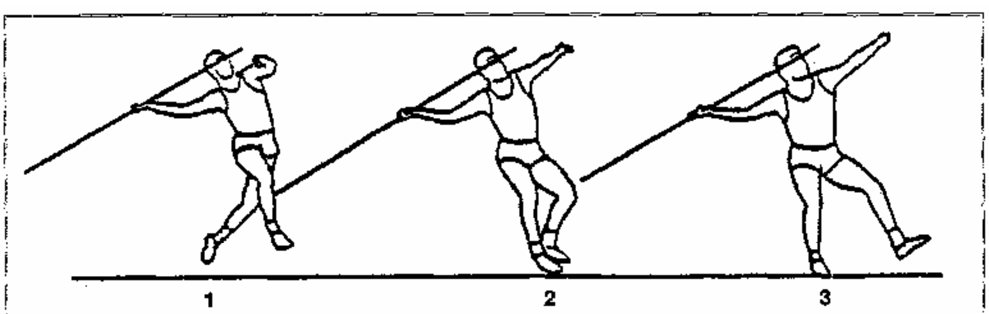


Figure 5: From the impulse stride to the power position in three phases
During the flight phase there is the 'reverse of legs', i.e. the (left) push-off leg passes the lead leg immediately prior to the lead leg's landing (phase 2), to prepare for the following bracing action. The constantly held parallel position of the javelin, the shoulders and the free arm, with a relatively slight lean-back of the trunk (variant I), also deserves attention.

While there are different recommendations concerning the length of the impulse stride (it should be 30% to 60% longer than the following bracing stride), it is generally agreed that it should not be too high. This is sensible, both because too high an impulse stride will cause a reduction of velocity and also because the (right) support leg will be subjected to a quasi decompressing load during the subsequent landing. There will also be a downward movement of the javelin's centre of gravity during this 'support contact'. (This term is introduced to distinguish between the landing of the support leg and the landing of the bracing leg.)

7. From the 'support contact' to the bracing contact'

The thrower can avoid the reduction of velocity and the lowering of the javelin's centre of gravity by adjusting and fixing the angular position of his or her (right) support leg prior to the landing. The result is a slightly sitting position during the 'support contact' (see *Figure* 6), which is caused by a passive amortization of the 'landing pressure' at the knee and hip joint.

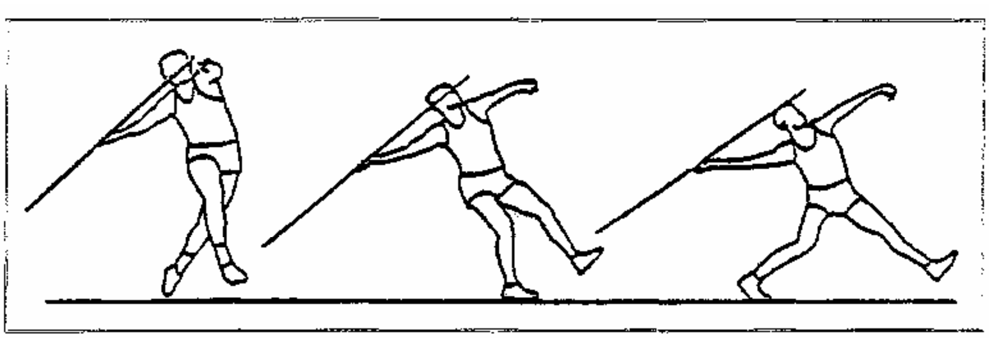


Figure 6: 'Impulse torque', 'support contact' and 'drive-split position' (from left to right)
The pronounced lean-back of the trunk (variant II) and the maintenance of extensive flexion in the knee of the (right) support leg, which rolls forward over the ball of the foot, deserve attention. This brings about the 'drive-split position', here with an exemplary extended throwing arm.

There is a rather significant inter-individual variation of the degree of lean-back (shown at the moment of landing). Although values of 25° to 30° are recommended (cf. ARBEIT et al. 1988, BAUERSFELD / SCHROTER 1986, MENZEL 1986; see variant II a in *Figure* 6), throwers like Tafelmeier or even Zelezny demonstrate significantly smaller 'inclination angles' of the longitudinal axis of the trunk during this phase ('variant I'; see *Figure 6).* Harnes tries to explain this divergence by stating that accentuated lean-back positions cannot be realized at high approach velocities (cf. HARNES 1990).

The accuracy of this hypothesis could be verified by a correlation-statistical calculation of the relationship between the parameters mentioned. As soon as the impulse stride has fulfilled its function and the subsequent landing (in English speaking countries rather aptly called 'soft step') has been performed correctly, the thrower performs a 'bracing step'.

Although this step is regarded as an element of the acyclic part of the approach run, strictly speaking it should be allocated to the direct release preparation because it has no flight phase. Hence, it is also called the ‘delivery stride’ — and similarly the figuration where the system’s centre of gravity passes the point of support is called the ‘power position’. As will be shown later on, the extended left leg and left arm assume a ‘guiding function’ (cf. *Figure 7).*

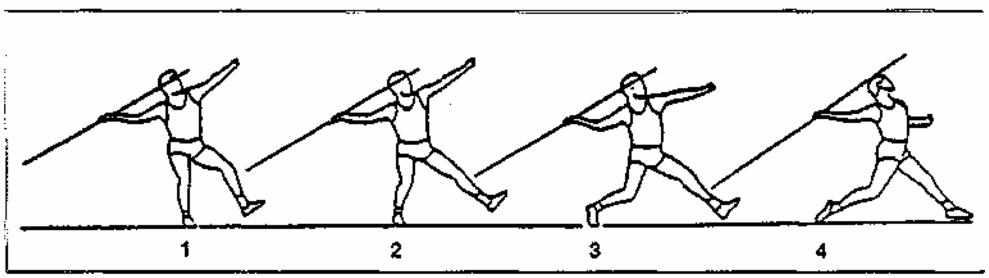


Figure 7: The bracing step in four phases: from the power position to the ground contact of the foot of the bracing leg
The free arm and free leg lead this horizontal movement, which is initiated by the drive of the support leg. Attention should be paid to the alignment of the javelin: The arm is not lowered but is kept parallel to the ground, and the wrist is not bent.

The horizontal translation movement, which is very pronounced during this stride, has two sources: Firstly, the total system possesses a velocity of 6.0m to 7.5m/sec, which has been developed during the approach run and has been reduced only slightly during the ‘soft’ impulse stride landing. It therefore continues according to the principle of conservation of momentum. Secondly, it is at least theoretically possible even to increase this translation by a horizontal push of the foot of the support leg.

However, this leg drive can be achieved only if the athlete has kept the foot and knee of the support leg pointing diagonally forward. Otherwise, i.e. in the case of a sideways position of the support foot, the foot ‘tilts’ over the instep so that the plantar flexors can impart no acceleration. This is because the active and long forward movement of the bracing leg exerts a powerful pulling action at the pelvis. Thus the support leg (with a sideways position of the support foot) is forced to follow the forward movement of the whole system.

The phenomenon of a rather passive right support leg during this phase, which can be observed even in top-level throwers like K. Wolfermann or F. Whitbread, presumably led TERAUD to state that the function of the rear leg during the release is generally overestimated (cf. TERAUD 1990).

It is informative in this context that F. Whitbread, when discussing a photo sequence showing her winning throw at the Rome World Championships, criticizes herself with regard to her right foot by describing it as ‘lazy’ (cf. WorBREAD 1988, p. 94). So, even on the highest level there is a gap between one's concept of the ideal-typical movement behavior and the actual realization of the movement. The question is on whether the resulting 'automatic action of the motor system', which the athlete is obviously not aware of, should not be given a higher priority.

However, it is a fact that many top-level throwers demonstrate this rather passive 'tilt' even in their best throws. It seems, therefore, inappropriate to speak of a fault in this case but rather of a technical variant. Although this 'tilt' is obviously not so efficient for driving the pelvis forward, does not totally exclude an optimal impulse transmission to the javelin during the subsequent delivery phase. At least both Wolfermann and Whitbread often demonstrated exemplary perforances during this phase (see *Figure 8).*

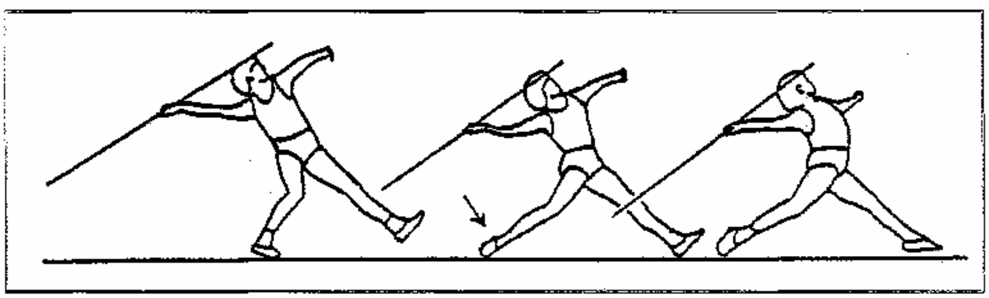


Figure 8: 'Tilt' of the support foot during the delivery stride of F. Whitbread in Rome, 1987

If one goes to extremes, there is no trunk torque at all if the foot toes out completely, because then the pelvic and shoulder axes are parallel to one another in the power position. This makes a 'hip strike' necessary (or possible) and takes more time than when the support foot is pointing exactly in the throwing direction, bringing about a brief transverse position of the pelvic axis in relation to the throwing direction, with a corresponding pre-stretch of the trunk muscles. Thus, the athlete does not strive for an accentuated hip strike here but presses the pelvis immediately into the bow tension phase. This requires a little less time. Therefore, one may surmise that a thrower who uses a fast approach run tries to place the tip of the support foot as nearly as possible in the throwing direction. However, practical observations do not verify this assumption. It seems, therefore, that high release velocities can be achieved both ways. That the thrower should ground the bracing foot during the delivery stride as rapidly as possible and that, consequently, the support leg should show no knee extension for lifting the system but 'work' only in a forward direction, is perhaps an additional explanation for the success of both variants.

During the bracing stride the throwing arm should be still extended in a relaxed way and aligned horizontally. This is important because allowing the throwing arm to drop will make it exceedingly difficult, if not impossible, to achieve the required bow tension of the whole body. The extended posture of the arm is justified by the advice to make the final acceleration path as long as possible.

However, this advice, which can be found in all text books, is also not strictly followed by many elite throwers.

In addition to that, the following considerations speak against the characterization of this deviation from the 'norm' as faulty behavior.

The javelin throw consists of a 'pulling and striking movement' (cf. RIEDER 1968) and it is the resulting release velocity that is crucial for performance. If a thrower with a slightly flexed elbow succeeds in achieving the requisite 'delay of the throw' (cf. BORNER et al. 1990) prior to the striking movement, the main characteristic of which is a throwing arm which is flexed at about 90° and held back up to the striking position, the significance of an initially 'long' arm is considerably reduced. In any case, the extended posture must be given up in favor of a slightly flexed position during the 'bow tension phase' following the bracing contact.

Something completely different is the tendency of many beginners and decathletes to throw only with the arm. Although a prematurely flexed elbow joint is also an indication of this tendency, the difference now is that the 'pull through' continues with no delay of the arm action.

8. From the bracing contact to the striking position

The build-up of the bow tension begins as soon as the thrower plants the foot of the bracing leg and it can be properly developed only it the bracing leg is as straight as possible and is grounded heel first and at a considerable distance in front of the trunk. Since the whole system is moving forward with a velocity of up to 7m/sec when the heel spikes make ground contact, it is obvious that a high mechanical load s placed on the bracing leg. The less the bracing leg yields at the knee joint, the more effective is the braking action. Most authors, therefore, suggest that the angle at the knee joint should never be less than 150 (cf. MENZEL 1990, and others). Theoretically a completely straight bracing leg would be the ideal, since then there would be a complete transference of momentum to the upper and other parts of the body. A few top- level athletes have achieved this extreme to some extent (e.g. Wolfermann). However, the load on the knee joint then becomes so great that there is a possible risk of injury. Consequently, it is recommended that the bracing leg should be completely (or almost completely) extended prior to the moment of ground contact and that then it be allowed to bend slightly 'with control' and again straighten completely during the phase 'from striking position to delivery' (see *Figure 9).*

To meet this demand at a relatively high approach velocity, very powerful leg extension muscles are essential.

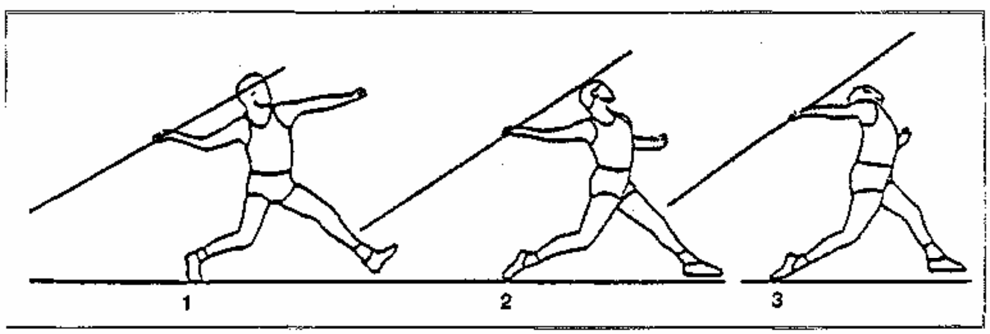


Figure 9: Build-up of tension in three phases
Directly prior to the bracing contact, a side-ways pull-back of the left (free) arm initiates the swinging motion of the right side of the body (see phases 1 and 2). As the throwing arm is still deliberately held back, the right hip swings forward until the pelvis reaches a frontal position ahead of the throwing shoulder (phase 2). Next, still with the arm action delayed, the shoulder axis rotates forward. The 'bow tension phase' has now been reached (phase 3).

The result of an effectively braced front leg is to transfer the approach momentum to other parts of the body. As the throwing arm and the javelin are still kept well back in a relaxed and deliberate way, and as there is no acceleration impulse available from the rear support leg, which performs a 'gliding contact' after the landing of the bracing step, the right hip and, immediately thereafter, the throwing shoulder swing forward against the abutment of the bracing leg. However, this asynchrony can only be observed if the gliding contact is performed with a vertical position of the longitudinal axis of the foot. If the thrower performs a sideways gliding contact both hip and shoulder will swing through together 'as one'. In both cases this rotation movement is introduced and supported by the active, sideways/downwards pull-back of the free arm. During the 'drive-split position' this arm is first held parallel to the longitudinal axis of the javelin. As soon as the thrower arrives at the bow tension position, the shoulder and pelvic axes now both face the throwing direction, with the free arm flexed and 'fixed' to the trunk.

When one considers the tension bow, running from the toe of the support foot (in the gliding contact) through the hip, spinal column, and throwing shoulder right up to the throwing hand it is obvious that great flexibility is required especially in the shoulder area (see Figure I0). Even elite throwers cannot completely fulfill the demand for this degree of flexibility. Consequently, limitations and modifications can be seen in many throwers.

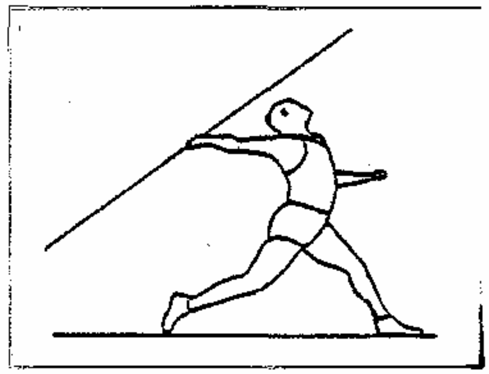


Figure 10: Ideal execution of the bow tension phase

However, this observation in no way denies the advantages to be derived from a 'perfect' bow (from the point of view of functional anatomy. On the contrary, the potential energy 'hidden' in the bow can be well illustrated by a steel leaf spring which is fixed to the ground, bent back and twisted by 90° (see *Figure 11).*

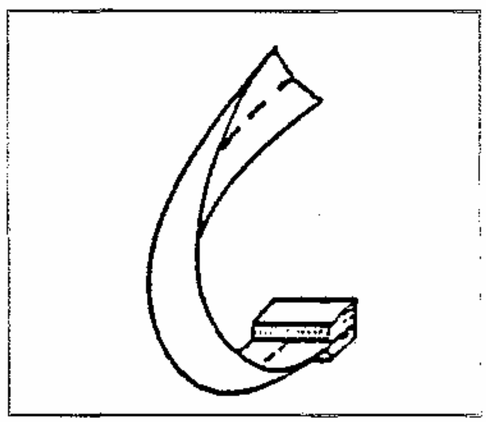


Figure 11: An analogy of the bow tension phase in the javelin throw:
A steel leaf spring which is bent back vertically and also twisted horizontally possesses a translatory and rotational discharge component. (Figure modified following Lindner 1967.)

However, the action of the steel leaf spring differs from that of the javelin thrower, in that the release of the drawn spring causes a simultaneous discharge, whereas the thrower should strive for a successive discharge from the relevant muscles.

It is very important that the thrower gets 'under the javelin' and that the elbow joint of the throwing arm, slightly flexed, is at shoulder height and tending to move upwards. This is because the 'discharge' of the bow must 'hit' the javelin in order to impart its final acceleration. This is only possible, if the javelin is positioned vertically above the tension bow. In this way, the 'unbending' in the throwing direction can act on the centre of gravity of the javelin. This is illustrated in *Figure 12.* The view from the rear has been chosen because it makes possible an assessment of the relative position of the javelin to the thrower in a vertical plane, and one can then observe to what extent the thrower has succeeded in really getting 'under' the javelin. If the thrower does indeed get under the javelin properly, his or her upper body will deviate to the side, in order to facilitate a release over the bracing leg. This has a functional-anatomical reason. The shoulder joint does not allow an exactly vertical forward movement of the previously retroverted arm. In addition this 'freedom of the throwing side' (cf. LINDNER 1967) makes possible a combined rotational action of the diagonally positioned shoulder axis and the throwing arm (which is a prolongation of the shoulder axis; see phase 4 of Figure 12).

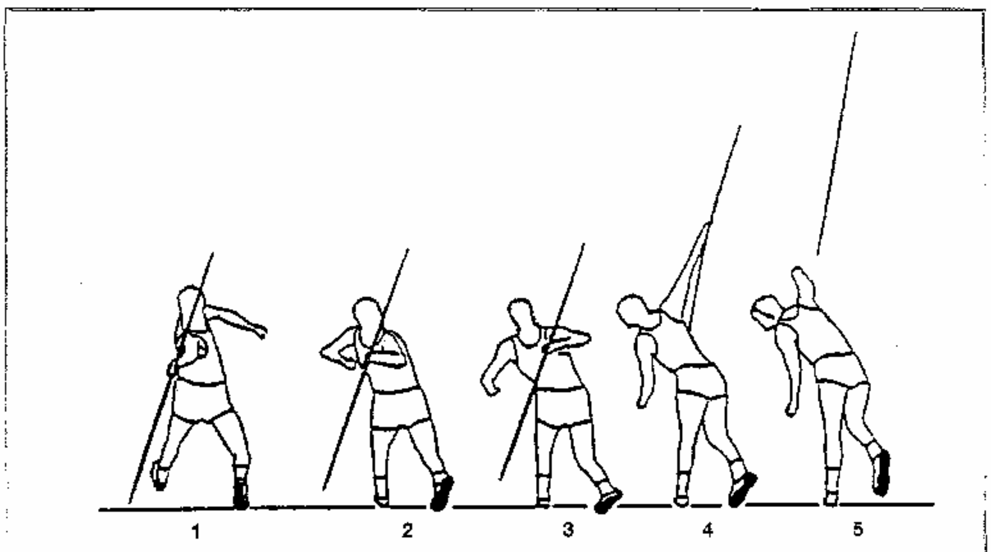


Figure 12: The 'getting under the javelin' from a rear view
In phases 1 to 3 the movement behaviour of the elbow joint of the throwing arm becomes obvious: The arm, which is still extended in phase 1, is (slightly) flexed in phase 2 and passes the shoulder in phase 3 with the elbow joint leading the movement. This diagonally upward movement is induced by the diagonally downward, sideways and backward pull of the free arm and leads to the 'freedom of the throwing side' (phase 4).

The second aspect, that of the slightly flexed elbow joint at shoulder height and lifting, has the following rationale: In order to be able to impart a final strike to the javelin, the throwing arm must be flexed almost at right angles. This is effected through a pulling action during the movement phases from the 'bracing contact' to the 'striking position'. To gain the full benefit from the opening up of its hinge joint, the elbow must 'lead' the movement before the 'strike' and it must not be pulled through below shoulder height. Therefore, for the correct execution of the strike, the elbow must point forward-upwards and be above the level of the shoulder.

As the movement phase from the plant of the bracing leg to the release of the javelin takes only 150 milliseconds, the representation of just a part of this phase in the form of a figure is, of course, difficult. In addition, the fastest movement process in athletics, with release velocities of up to *31m/s,* prevents a detailed identification through direct observation. Therefore, the following figures of the ‘striking position’ are only partly representative and cannot be observed directly *(Figure 13).*

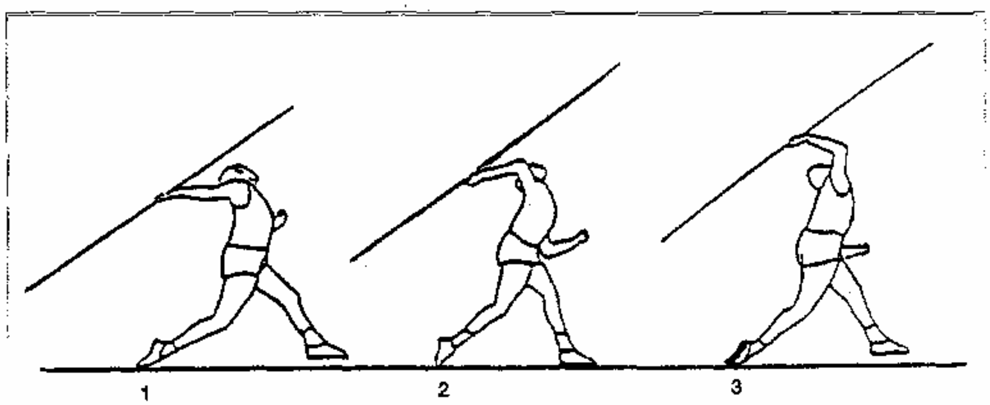


Figure 13: From the bow tension to the striking position
Although here the same thrower (K. Tafelmeier) served as the model, phase 2 was taken from an earlier attempt. It is important that the tip of the elbow ‘leads’ the movement and is lifted to about head height before the joint is extended for the final strike (see phase 3).

It seems to be important to point out that, even in the striking position, the pelvis shows negative acceleration: The hip joint at the side of the throwing arm, which was hyper-extended, is now flexed. The gliding contact of the foot is maintained in order not to release the tension of the upper body too soon and to perform the final striking action during the two-legged support.

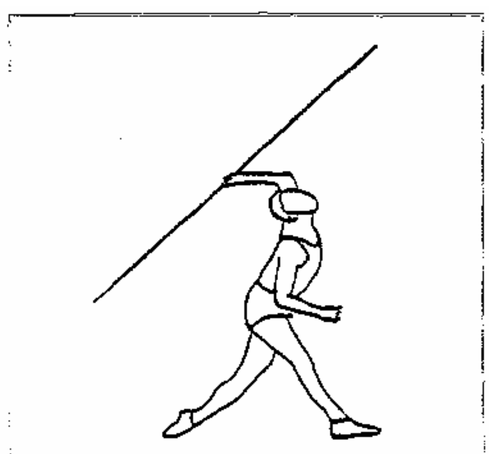


Figure 14: The striking position viewed from the side of the bracing leg
This leg shows excellent extension, the support leg is making gliding contact, and the arms are flexed at almost identical angles. (Here a left-handed thrower is shown.)

If one looks at the 'striking position' from the side of the bracing leg, the fixation of the left arm becomes obvious *(Figure 14).* Due to the aforementioned 'freedom of the throwing arm side', the elbow joint of the free arm is held close to the hip joint during this phase.

Many throwers show a similar flexion of bow elbows briefly during this phase (e.g. 13, 2). Using high speed photography, the actual start of the striking movement can be derived indirectly from observation of the (secondary) oscillation of javelin, caused by the high positive acceleration of the lower arm, which is first directed upward upwards.

9. From the striking position to the release

In elite throwers the final action of the lower arm and hand takes about 15 milliseconds. With the 'pulling and striking movement' completed such an extremely short time and at such a velocity, it is not really possible to differentiate the movement phases of the action of the lower arm and hand by means of normal video film. Only speeds of about 200 frames/sec, which are essential for photo-sequence analysis, make recording of intervals of 5 milliseconds duration possible. But even in this case, the exact time the hand action and its exact movement behavior can be identified only to a very limited extent and certain figurations are repeatedly missing.

It is, therefore, not surprising that no textbook or instructional photo sequence shows this movement phase in detail. Following the principle that things which cannot be observed cannot be judged, the movement phase under discussion can be represented as a model only with reservations. In Figure 15 an attempt has been made at completing the release process by integrating shots from different trials of one and the same athlete.

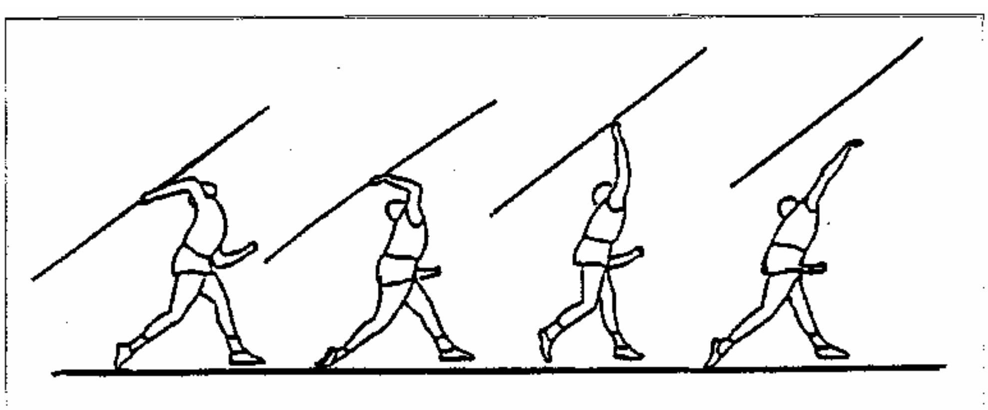


Figure 15: From the striking position to the release

The javelin leaves the throwing hand roughly when the hand is vertically above or slightly in front of the toe of the bracing foot. Since release height clearly plays a secondary role to velocity and angle of release (only RICH et al. - 1986 - state that release height is an important factor'), the thrower maintains whole sole contact of the bracing foot and the gliding contact of the support foot. The 'springing out' of the javelin must be regarded as a serious fault because a slinging movement is only possible if there is a 'point of fixation'. The long acting (imparting of force) on the javelin, the significance of which has always been pointed out (cf. RIEDER/WOLFERMANN 1974; HARNES 1973; SCHENK 1973), can be judged best only after the javelin has left the thrower's hand. That is why it is not the release of the javelin from the throwing hand but the following phase that has been chosen as the 'release figuration'. Here, the thrower shows a definite bend at the hip. The reason for this is that the bracing leg is still fulfilling its abutment function - in almost all throwers the bracing leg is now extended or even hyperextended - and the throwing arm, with its long 'follow-through', together with the 'relaxation' (i.e. release of tension) of the trunk, drives the upper body forward beyond the bracing leg.

It is not clear when the wrist action should start. However, it is undisputable that this action gives the javelin an important final impulse (cf. RIEDER 1968). It is possible that the grip, which varies from athlete to athlete, also has an influence on the timing of this final impulse. Thus, the claw grip presumably enables the athlete to act longer on the javelin, although it prevents the athlete from giving the javelin a rotation about its longitudinal axis. The 'middle finger and thumb grip' probably assist this rotation best while the 'thumb and first finger grip' presumably leads to the least 'slip' at the grip. Further research is needed to clarify this latter aspect, especially since Terauds claims that there is a connection between slip at the grip and injury prevention. According to Terauds a greater degree of slip might have a 'protective' effect on the elbow joint (cf. TERAUDS 1990). It is confusing that this interpretation completely ignores strength transmission losses.

10. From the delivery to the follow-through step

To achieve an optimal transmission of force, it would actually be desirable that the thrower transferred his or her momentum completely to the javelin. Correspondingly, the presentation of javelin technique could end with the analysis of the 'delivery'. In practice, however, no specialist succeeds in terminating the movement with the delivery. On the contrary, a safety distance must be maintained, to avoid stepping onto or over the throwing arc. This distance depends on the 'surplus approach velocity' and is on the average 2 to 3 meters. In other words, although the amount of kinetic energy acting in the throwing direction differs, depending on the approach velocity, efficiency in the use of the bracing leg and the exactness of 'hitting' the javelin, there is enough energy left to necessitate a decelerating 'stepping over' of the bracing leg, as well as a following 'reverse' on to the support leg, in order to avoid a foul throw. Figure 16 is a representation of this movement process.

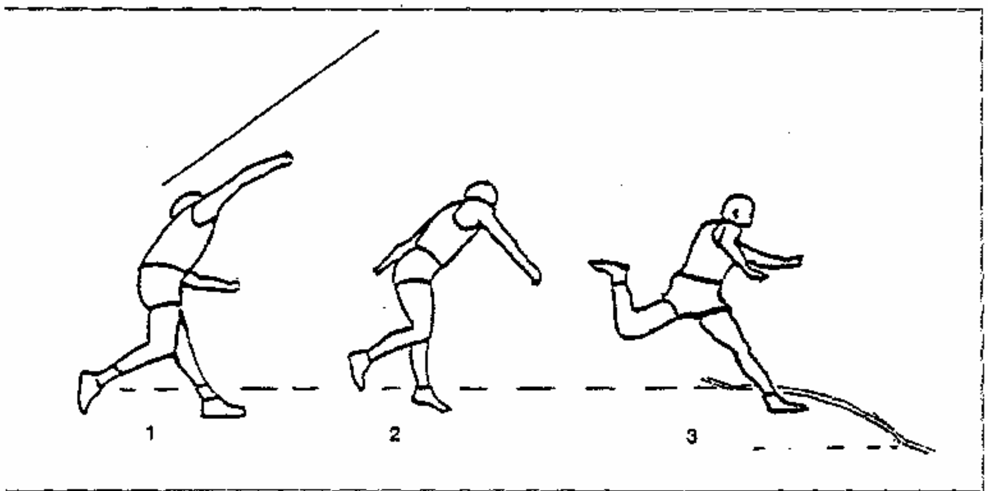


Figure 16: From the release of the javelin (1) to the 'stepping over' (2) and 'follow-through step' (3)
The figure shows that, after 'stepping over', the support leg assumes the function of a bracing leg in order to avoid fouling. The amount of energy still remaining determines whether the stepping over action is followed by a flight phase before the front leg lands near the throwing arc and checks the movement.

11. The 'nature of the whip'

Another aspect of javelin technique, namely the functional course of the impulse transmission, will be discussed now, since it can be dealt with only indirectly in the detailed analysis summary which follows. MATWEJOW tries to draw a parallel between the action of a whip and the acceleration process in the javelin throw (cf. MATWEJEW 1971, p. 1497). Although the author does not show in detail how to use a whip, the very fact that the tip of the whip produces a crack only if the handle is swept down very quickly and then checked abruptly, or even pulled back sharply, shows that the comparison is valid.

With this in mind, it becomes obvious that the javelin throw is by no means just an 'arm throw' but rather a 'whole body action' (cf. SHANNON et al. 1981). First, the approach run serves to impart a certain basic velocity to the whole system. There then follows an active, successively positive and then negative acceleration process, which is initiated by the bracing contact. Here, the acceleration and deceleration at the joints take an upward course, as it were, from 'bottom to top'. As, during this process, the mass to be moved is increasingly reduced, the result must be a considerable increase in velocity of the distal end of the (open) kinetic chain - the throwing hand and the javelin. Consequently, MATWEJEW (1971, p. 1497) remarks that "such a 'whip-like' movement execution with a successive wave of accelerations and velocities from the proximal to the distal links is the heart of an effective throwing ability."

Early attempts to illustrate this process by analyzing the partial velocities of the body, using a high speed camera, were made, for example, by LINDNER (cf. Lindner 1967), ARBEIT et al. (1 988), and BORNER (1990) also emphasize the importance of the successive deceleration and the aforementioned 'delay of the throw' for the efficiency of an over-arm throw. Figure 17 illustrates process by showing the acceleration and velocity parameters of the hips, shoulders, elbow and finally the throwing hand and javelin, measured from the moment of the bracing contact to the final delivery of the javelin from the hand. The clear succession of the accelerating and decelerating phases of the body segments seems to be remarkable. In this process the hip of the throwing arm side is the first segment to reach its maximum velocity and is then quickly decelerated. Subsequently the throwing shoulder and, a little later, the elbow of the throwing arm, show steeper curves. Finally the accumulated velocity is transferred to the throwing hand and consequently to the javelin.

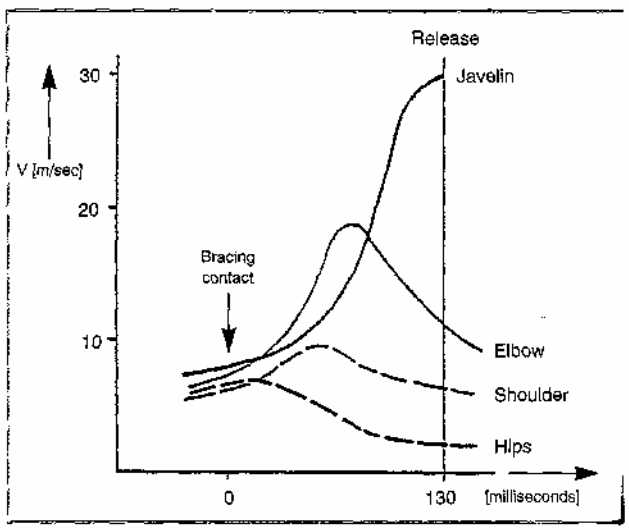


Figure 17: Impulse transmission in the javelin throw (modified according to ARBEIT et al., 1988; for detailed information see text)

According to BORNER (1990) the force-time curve with a peak like the point of a needle is the typical characteristic of a technically perfect throw. Such a curve shows that the throwing arm must 'wait for' the upwards directed acceleration impulses and once again become as long as possible, in order to achieve the most effective final strike of the lower arm (see Figures l7 and 18).

Figure 19 gives a visual impression of the process of the successively increasing phases of acceleration and delay of certain body segments during the release of the javelin. To this end, seven closely interacting phases have been chosen. These phases represent the period of about 150 milliseconds which specialists need to perform the release.

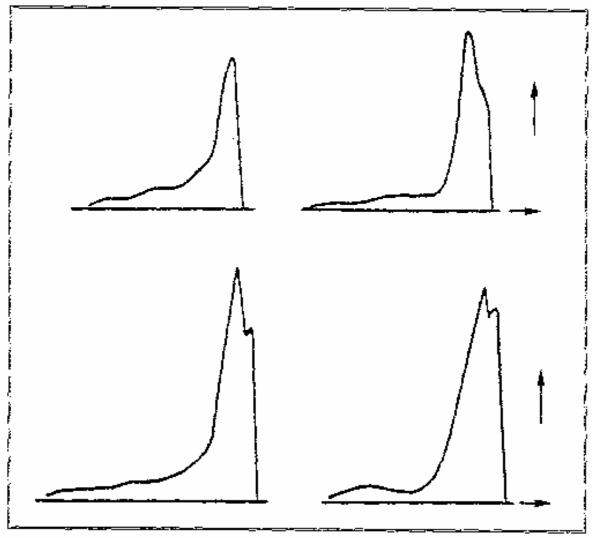


Figure 18: Course characteristics of the javelin acceleration in four world-class athletes

The shape of these curves is due primarily to the 'delay of the throwing arm' which prepares the 'strike'. (According to ARBEIT et al. 1988)

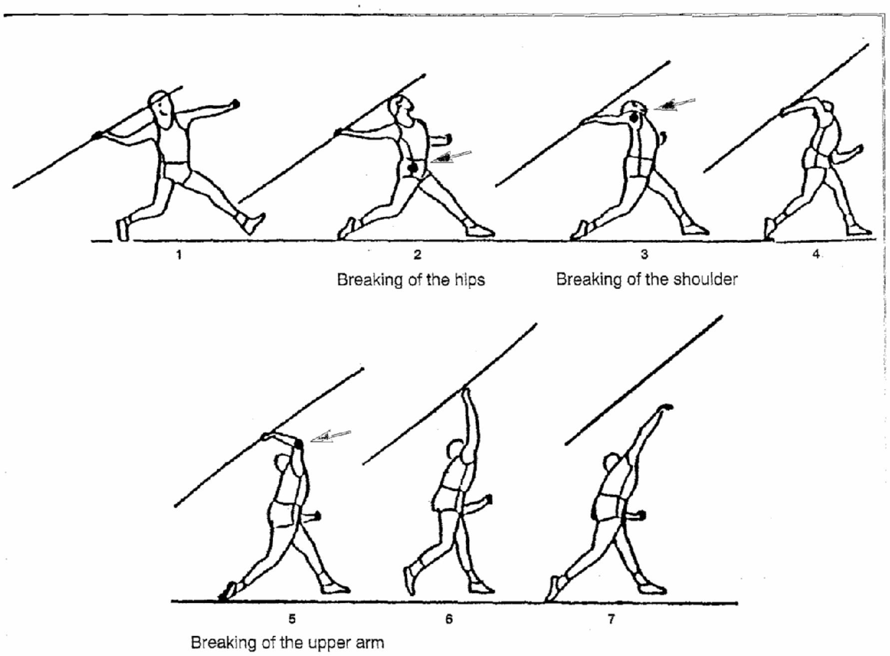


Figure 19: Delivery process in seven phases (P1 to P7)

P1, 2 and 3 cover the movement path of the right hip, and it can be seen that it has already reached its frontal position in P2. Here, therefore, after the active forward twist of the pelvis, the deceleration process of the throwing arm side starts. One phase later, the upper body follows a similar positive and then negative acceleration process, with the rotation of the throwing shoulder following the hip motion. A comparison with the immediately following phases shows that there is no additional rotation of the shoulder axis. Finally, if one traces the movement of the elbow of the throwing arm from P1 on, it can be seen that it follows a diagonally upward path, which ends in phase 5. The final stroke of the end of the whip starts here (notice the deviation of the longitudinal axis of the javelin). This gives the lower arm its final acceleration. In this way the momentum of the whole body can be optimally transferred to the javelin (see P5 to P6/7). The exact 'firing' time of the prime movers in the area of the wrist joint cannot be determined exactly because of lack of information. However, the Figure suggests a corresponding action during phases P5 to P6, which is completed immediately before P7.

12. Summary

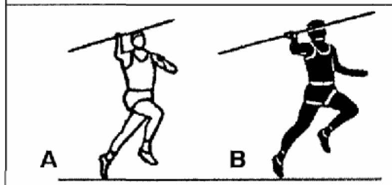
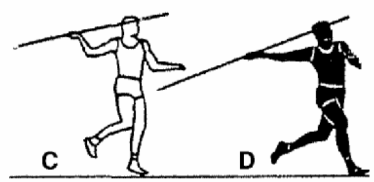
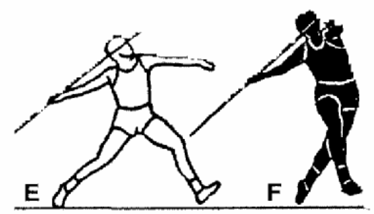
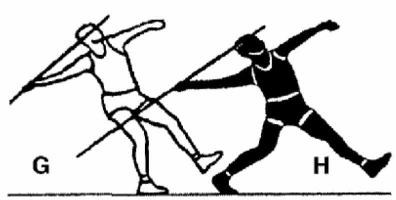
The following javelin sheet analysis an attempt to integrate the elements of the phase structure discussed above in an ideal-typical way. The analysis sheet also includes descriptions and drawings of the respective phases. To emphasize the process of the javelin throwing movement, the technique is divided into different movement phases. In each case, the start of these phases s represented by a (white) conturogram while the end is represented by a black figure.

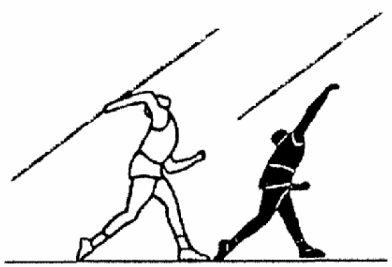
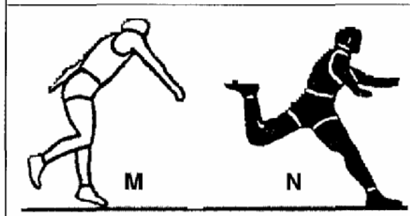
Only the ‘bow tension phase’ is represented in a ‘singular’ way in order to emphasize the central significance of this figuration for the impulse transmission aimed at.

The technique shown is that of the 5-stride rhythm, with the ‘Swedish’ withdrawal of the javelin during two strides and only one intermediate step. The slight tilt of the shoulder axis seen in phase E, and, slightly increased, in phase G (E), implies a moderate approach velocity. From the parallel positions of the longitudinal axis of the javelin during phases ‘H’ to ‘L’ it can be deduced that the thrower is trying to achieve a final acceleration path of the javelin with as few deviations as possible. Thus, as early as at the ‘drive-split position’, the javelin is aligned at the optimal release angle, which should be identical with the angle of attitude (in this model: about 36 degrees).

The last three criteria relate to the flight behavior of the javelin. Here, information is available as to the relation between the magnitude of impulse transmission and the direction of the approach run and release.

Research findings by Kerssenbrock show the importance of this aspect. Even in speed throwers, a comparison of (1) direction of the approach run, (2) the foot placements, or (3) the alignment of the javelin during the delivery stride with (4) the flight direction of the javelin’s centre of gravity shows considerable deviation from ‘straight line’ throwing (cf. Kerssenbrock 1967, p. 1320).

Position	Phase	Reference	Criterion	Assessment +	o	–
 A B	(cyclic) Approach	A 1 Organization	Acceleration run			
		A 2 Javelin carry	Shaft at head height / tip points in throwing direction			
		A 3 Throwing arm / head	Bent / correct grip / near head			
	Start of withdrawal	B 4 Support foot	Contact with check mark			
		BD 5 Shaft of the javelin	Gliding backward at height of temple			
		BD 6 Upper body	Rotates against throwing direction			
 C D	Withdrawal of the javelin	CD 7 Foot plant	Running-adequate			
		CD 8 Trunk	Kept upright			
		CD 9 Javelin movement	Smooth / fluent backward glide			
		D 10 Throwing arm	Extended / parallel to the ground			
		D 11 Throwing hand	Turned inward / at the level of the lower arm			
		D 12 Tip of the javelin	At the height of the temple / close to hand			
	Finish	D 13 Shoulder axis	Points in throwing direction			
 E F	Intermediate stride	DE 14 Shoulder axis	Slightly diagonal position			
		E 15 Throwing arm / javelin	Constant position as related to shoulder line			
		EF 16 Foot plant	Active and emphasis on landing			
		EF 17 Shoulder axis	Increasingly diagonal position			
		EF 18 Throwing arm / javelin	Sychronous with shoulder movement			
		F 19 Push-off	Accentuated / flat			
	Impulse torque	F 20 Swinging leg	Active forward swing / knee leads			
		FG 21 Push-off leg	Fast passing of the support leg			
 G H	Support contact	G 22 Tip of support foot	Points (diagonally) in throwing direction			
		G 23 Knee of support leg	"Soft" landing			
		G 24 Throwing arm / javelin	"Long" / constantly diagonal / close to head			
		GH 25 Support leg / knee	Rolling over ball of the foot / constant angle			
		H 26 Throwing arm	Still extended / lifted parallel to the ground			
	Drive split position	H 27 Javelin alignment	Longitudinal axis points into throwing direction			
		H 28 Tip of javelin	At height of head / close to head			
		H 29 Bracing leg	Heel leads / extended and pre-tensed			
		H 30 Free arm	In line with shoulder axis / parallel to javelin			

Position	Phase	Reference	Criterion	Assessment		
				+	o	–
 I	Bow tension	HI 31 Free arm	Diagonal sideways pull-back			
		HI 32 Throwing arm side	Explosive rotation movement to throwing direction			
		I 33 Javelin alignment	Constantly orientated to attitude angle			
		I 34 Free arm	Flexed and fixed close to trunk			
		I 35 Throwing arm	Slightly flexed / at shoulder height / at the back			
		I 36 Support foot	Gliding contact			
		I 37 Bracing leg / foot	Minimal yielding / contact with the whole sole			
		I 38 Breast / pelvis	Frontal			
		IK 39 Throwing arm elbow joint	Rising			
 K L	Striking position	K 40 Throwing arm	Elbow joint is led over shoulder			
		K 41 Lower body	"Bent hip" (negative acceleration)			
		K 42 Bracing leg	Abutment function with constant angle			
		KL 43 Support foot	In gliding contact			
		KL 44 Bracing leg	Extending			
		KL 45 Throwing arm / hand	Long follow-through / active			
		KL 46 Javelin movement	Longitudinal axis constant alignment			
	Release position	KL 47 Trunk	Marked hip flexion			
		L 48 Bracing leg	Completely extended			
		L 49 Free arm	Elbow joint at the side of the hip joint			
	Levering over	LM 50 Bracing foot	Ground contact with ball of the foot / leg working as a lever			
		MN51 Support leg	Overtakes bracing leg actively			
	Recovery	N 52 Support leg	Takes over checking and bracing function			
	Javelin flight	53	Direction of longitudinal axis identical with that of approach			
		54	Optimal (for distance and wind) = release angle			
		55	Release-induced: only rotation about longitudinal axis			

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