ROTATIONAL SHOT PUT TECHNIQUE: BIOMECHANIC FINDINGS AND RECOMMENDATIONS FOR TRAINING

By: Klaus E. Bartonietz

The put of the iron shot, coming to us from the boredom of British gunboats more than 100 years ago, underwent a new variation in the last decades. This technique was born by a play instinct of creative hammer and discus throwers. The fathers and "male midwives" of this technique in the 40s and 50s, F. Tootell, O. Chandler, B. Ward, J. McGrath (USA), J. Malek (Czechoslovakia), V. Alekseev (Russia) - the list of names will not be complete - we won't forget. This study is dedicated to them and many other unknown pioneers.

More than four decades have passed since the first puts using the rotational technique by Chandler took place, who reached 17.08m / 56' ¼" (at that time the world record of his compatriot Fuchs was 17.95m / 58' 10 ½"). The following years brought some well known performances of Baryshnikov, Oldfield, Laut and Barnes. Not so well known to the public was the 22.11m put (72' 6 ¼") by the former East German RoIf Oesterreich in 1976. It would have been a world record but through different "internal" reasons it was not recognized. Dave Laut had apparently said that he got the needed impulses for his own turn from movement studies of Oesterreich.

Highlights of the rotational technique were set in Germany also by girls. In 1983 the 14-year-old Ilke Wyludda reached with the rotational technique a record throw of 15.18m (49' 9 ½"). In the same year Constanze Simm put 18.41m (60' 4 ½", at the Europeon Juniors Championships, 1st place). The German indoor season in 1992 was opened by Astrid Kumbernuss throwing with the rotational technique 20.03m (65' 8 ¼"). In Spring she was seriously injured—and out of the run for Barcelona. In Stuttgart she used the glide technique.

Regardless of different German athlete's throws near to the 65 mark during the last years the rotational technique in Germany stayed in the shadow. In Europe this year the best shot putter from Italy (Dal Soglio), Poland (Krieger), Cechy (Barti), Sweden (Larsson), Ireland (Quirke), Hungary (Koczian) and former Yugoslavia (Peric) are rotationists. They have pumped more life into this event during this year.

This study might shorten the stony way of trials and errors in the development of the athletes, using the rotational technique.

Basic Patterns of the Rotational Technique

Opposite to the glide, which has clear criteria for an effective work of the body parts, the rotational technique is more complicated in giving instructions to athletes. In practice we find a great deal of difference between the individual performances of athletes. That is because of a great deal of differences in individual movement experiences, in interaction with the personal structure of abilities. We must also take into consideration that the knowledge of the coach and the internal movement picture of the athlete can be an element of uncertainly.

The assumptions in the available literature and the results of a few experimental studies leave a lot to speculate about in the rotational technique. It is therefore important and necessary to look at the specific features of the movement pattern of this technique.

Turn On, Body Weight Shift, Take-Off and Support-less Phase

1. Beginning: End of the back turn of the upper body

2. End: Planting the right foot about in the middle of the circle

3. Main goal: Pre-acceleration of the entire system thrower-implement producing an optimal velocity and momentum.

These preparatory movements (turn on, weight shift, take-off) are carried out with great variability of the body positions. Most athletes use a low starting position with bent knees about 90-120 degrees (upper part of the body over the thighs, e.g. , Oldfleld, Laut, Doering, Toth, Barnes). This variant offers some advantages such as:

- A smooth and controlled starting movement with a wide amplitude;

- A continuous increasing lift of the center of gravity (shot and athlete); and therefore;

- A flat movement path during the support-less phase without dropping the upper body onto the right foot.

The coach must keep in mind that at the same time a greater shearing load can be produced in the left knee joint, going into the turn with a relatively low center of gravity.

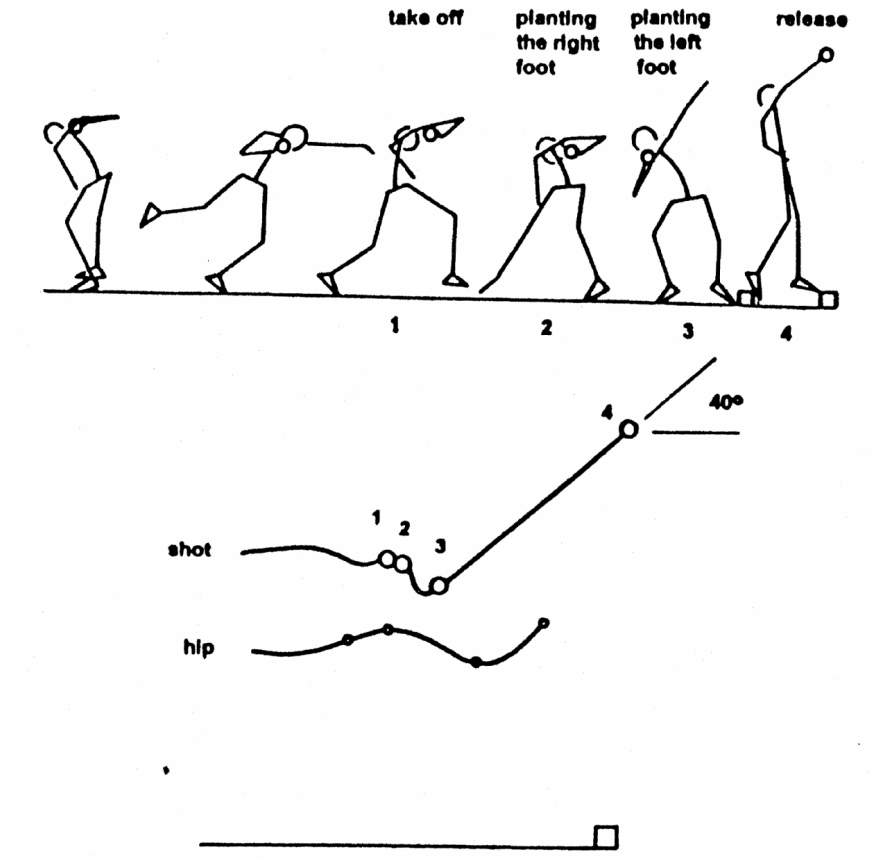
The upright starting position with relative extended knees (130 degrees or more) and a partly leaned forward upper body (e.g. , especially in the past such as Solotuchin/USSR, Qesterreich, Simm/Germany, Barnes in 1988 and recently Krieger/Poland, Peric/former Yugoslavia) gives the possibility to use a reactive movement after planting the feet and going down at the beginning of the delivery. It can have a positive influence on an explosive leg extension. To lower short-timed down with the shot in the middle of the circle is also possible using a low starting position. Oldfield lowered his body after planting the right foot up to a knee angle of the right leg about 90 degrees, then explosively extending the legs. It is worthy also to note that an upright starling position allows outstanding performances. (An upright start is mostly necessary if the bulge of the stomach does not allow a lower position.) Figure 1 illustrates selected body positions and the shot path, using the not so common upright starling position. Figure 4 shows the path of the shot using a lower entry.

By pushing the body with the right leg over the left one, the twist between the hip and shoulder axis is now growing up to 20 degrees at the moment of the take off of the right legs. The hip axis is moving forward of the shoulder axis producing a muscular pre-tension at the right hip area. This is necessary for the following kicking action of the right leg. As a result of the kick of the right leg, the ankle reaches a velocity of 8.8m/s (3D-video analysis with the Peak Performance system). Turning on the ball of the left foot the 'twist' decreases to almost zero. The accelerating push from the extension of the left leg and the efforts towards holding back the left side allows increase of the angular difference between the hip and shoulder axis (Figure 2). With it, it is helpful that the direction of the left leg's forces produces a momentum (the athlete turns during the support-less phase around a vertical axis).

During the beginning of the turn and the body weight shift from the right over the left leg (pre-acceleration of the body) the velocity of the shot can reach nearly 4m/s (about 13 ft/s, Figure 3). The same level was reached by the Jr. Darren Crawford per data from Stepanek 1987; however, by an analyzed invalid throw about 16.50m/54' (release parameters: 12.1 m/s, 35 degrees, 2.1 m). It is more significant than by the glide. The data of the throw illustrated in Figure 2 at the same time shows a shot velocity of only 2.5m/s.

Baryshnikov's shot had at that time a maximum velocity of 2.9m/s and at the take-off of 1 m/s (about 10 ft/s. 3D analysis, 15.96m respectively 52' 4 ¼" with the 10kg shot – it's about 22 pounds! - data from Palm, 1990). By a not so exact 2D analysis of a competition throw the shot had a maximum of about 4m/s (data from Kressenbrock, 1975 and Bosen, 1984, the latter quoted by Pyka/Otrando, 1990). Baryshnikov is an example of the variability of this technique concentrated in one person: moving from the right to the left leg with an extreme lean forward of the upper body and knee angles about 90 degree in 1972 and later on - with growing performance - moving with related upright upper body and knee angles about 130 degrees.

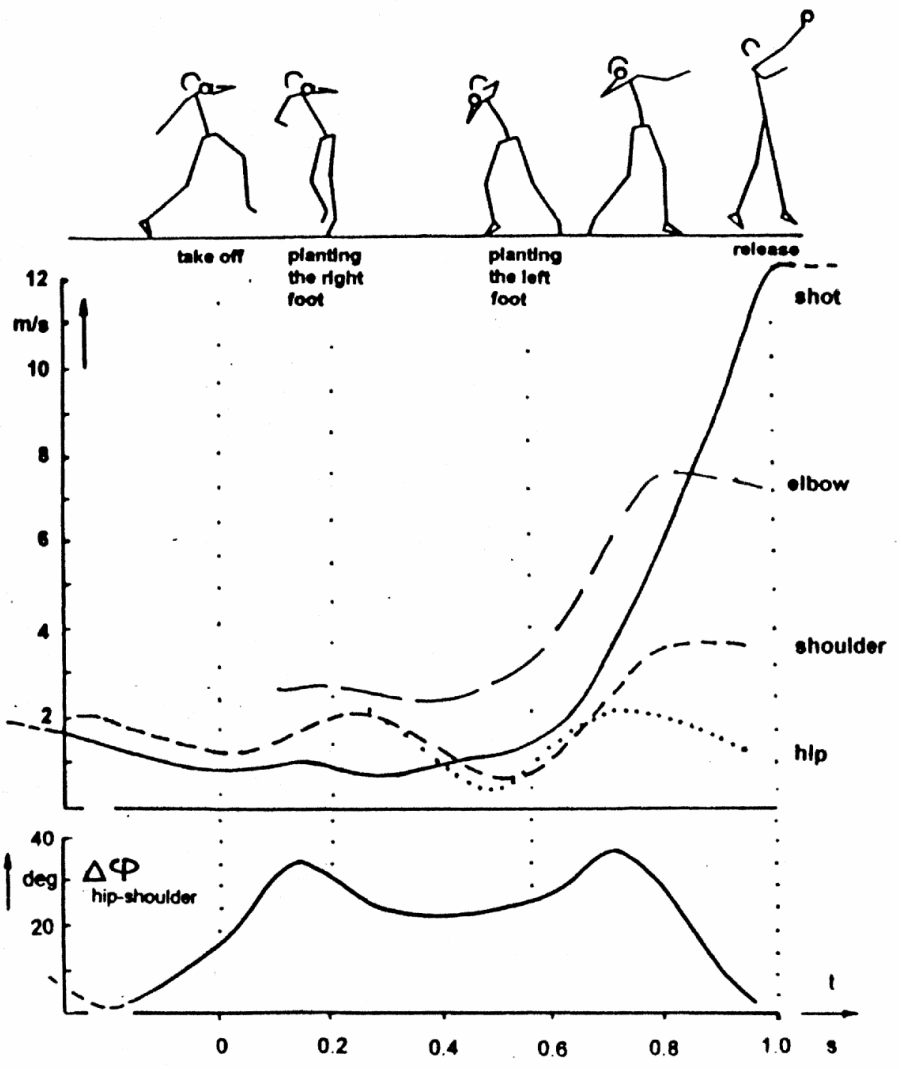
Fig. 1: Selected body positions and the path of the shot and the hip throw of the junior Oleg SOLOTUCHIN 18.88m/61' 11" (1983)



The flat direction of the take-off from the left must be supported decisively by a well-timed and well-dispensed kicking action of the right leg. Otherwise the take off must be a distinct jumping movement with a too-steep ascent and also a so steep fall of the right foot. The necessary torque for the turn on the right ball after planting must come from the leg kick (right) and the push off (left). Without initial torque the thrower can't turn on the right ball without rest after planting, the heel puts down, the left foot plants too late and the hips can't come through. Most athletes go into the turn on the left ball with a knee angle about 100-120 degrees. It is the most comfortable angular area to keep the upper body stable during the one-legged phase and gives the possibility for on effective push-off.

At the moment of take off the velocity of the center of gravity reaches a maximum and the trajectory of the center of gravity is determined for the support-less phase. The athlete must strive for a flat and short timed movement path. A simple changing by a step from the left leg to the right one reduces the dynamics of the turning movement. Step turn drill variations are supportive and comfortable, not only for beginners.

Fig. 2: Time related changes of the velocity of the main joints, of the shot and the angular difference between hip and shoulder axis by a throw of Astrid KUMBERNUSS 18.20m/59' 8 1/4" (in training, January 1992)



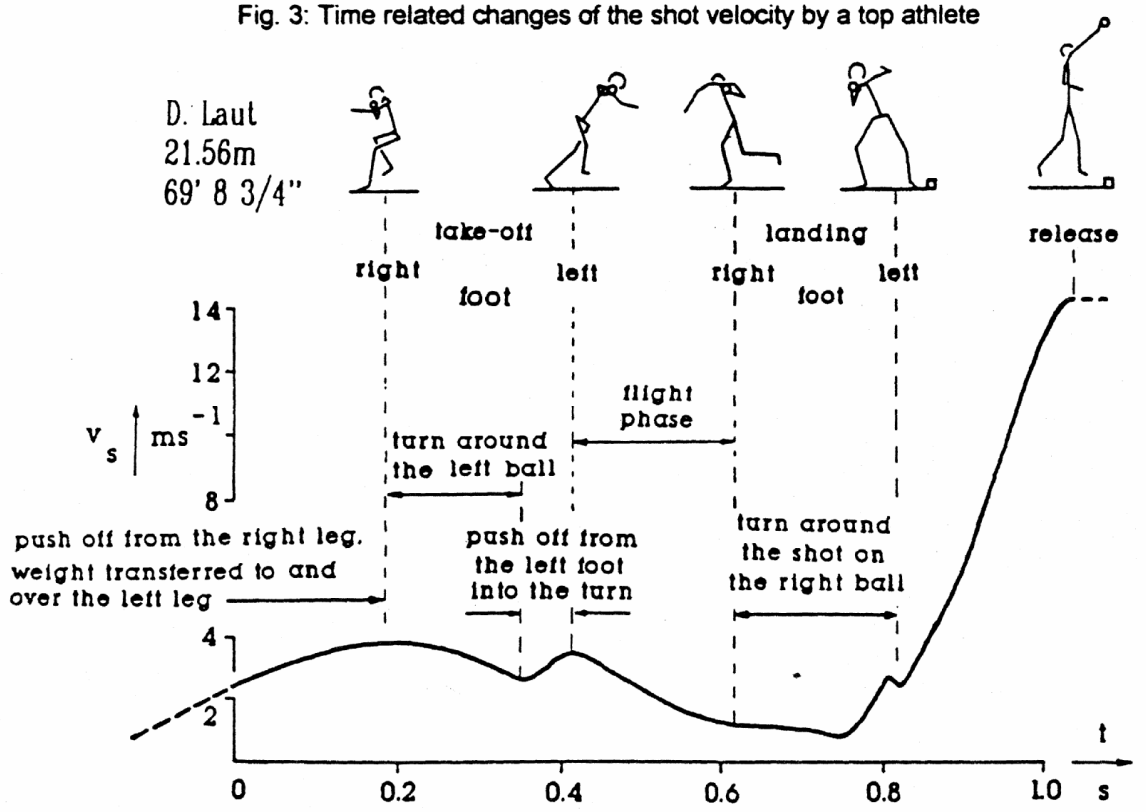
Delivery

Main goal: transform a maximum of kinetic energy (velocity) to the shot by an optimal movement direction inside the circle.

The delivery starts during the planting of the right foot in the middle of the circle and ends with the release of the implement. As in the glide, the athlete must at first get over on amortization phase (the center of gram is located behind the support - therefore the velocity of the center of gravity decreases).

A long med amortization brings a related great decrease of velocity and a late planting of the left foot. It can be prevented by an active leg planting process: turning without rest on the ball and without marked bracing against the movement direction. For that, the athlete must bring along the necessary torque and in addition put the right leg under the body and bring the left arm closer (effect of pirouette: decreasing the moment of inertia by an increase of the angular velocity for the turn on the ball and a fast planting of the left foot). Stopping the lower limbs, the hip-shoulder twist decreases as a result of the inertia of the upper limb movement. The beginning of the body straightening creates a stable situation of the hip and shoulder axis (see Figure 2). During this period the shot velocity increases only slightly because a pre-tension in the upper body is produced (see Figures 2 and 3).

Fig. 3: Time related changes of the shot velocity by a top athlete



Landing with an optimally turned right foot guarantees a great amplitude for the shoulder movement (8-1 0 oc1ockposition as for example, in the past Oldfield, Laut, now Doering, Barnes). A more turned (see the video print 7 o' clock-position) isn't effective — because it decreases the trunk path and therefore the possibilities for the acceleration.

Laut's 22.02m/72' 2 ¾" throw differs at the external picture from a 21m/69' throw just in the landing position of the right foot: about 9 o' clock by the 72' and about 7 o'clock by the 69' throw (both throws in 1982). An 8 to 10 o' clock-planting is effective on the condition that the necessary initial torque for the turn on the ball.

The implement can move in a loop (for example, related wide loop Baryshnikov, cramped loop Barnes, Doering, Dal Soglio) or the athlete can turn around the shot (Laut, Crawford).

A loop reduced by the one hand decreases the shot velocity, but by the other hand increases the acting centripetal force component. Here is a square influence of the linear velocity on the centripetal force:

$$F_{cp} = m\ v^2/r$$

Where:

- F_{cp} = centripetal force component, N
- m = shot mass, kg
- v = velocity of the shot, m/s
- r - radius of the shot movement, m

An estimation for average values of the centripetal force component shows the following (real data shows Figure 4):

wide loop (*r=0.21m*)	cramped loop (*r=0.07m*)
7.26kg x 32m/s /0.21m	*7.26kg x 1m/s / 0.07m*
$F_{cp} = 311N$	$F_{cp} = 104N$

As a result of great centripetal forces a wide loop often brings problems with the stability and with the throwing direction (the shot is landing out of the right boundary), also because the thrower's body acts as a great centripetal force component. The demand of Grigalka 1980 to reduce the decrease of shot velocity moving the shot on a wide loop (as in the past Baryshnikov) is also with this to reject from the paint of biomechanics (Bartonietz 1983). The practice certifies this finding to this day.

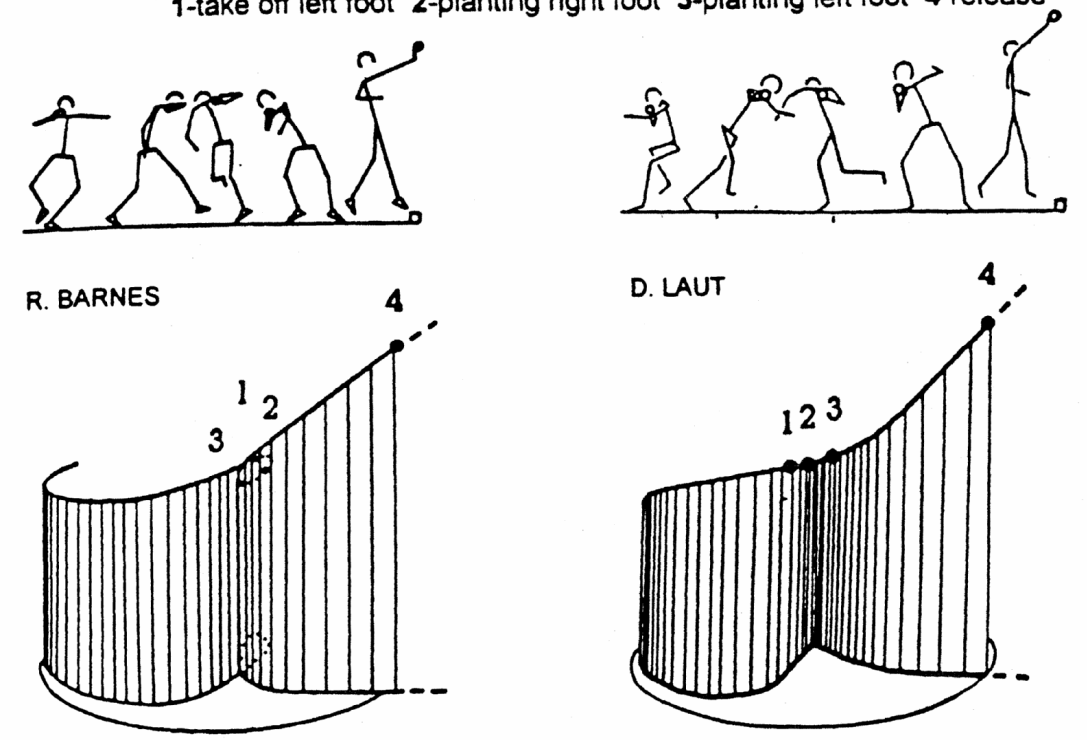
And that's just by the way: effective learning with the light shot based amongst other effects also of a reduction of the centripetal force component respectably about 25 percent for female and about 14 percent for male athletes (by the well known shot masses and comparable velocities of the turn).

The glide technique is characterized by a marked short-long rhythm based on the stride length after the glide and during the delivery (Table 2, especially the athletes from the East). It improves good conditions for the driving action of the right leg and especially for the bracing function of the left leg. On the contrary, the common rotational technique shows the tendency to a long-short rhythm with harder conditions for the leg work during the delivery.

It results also in the level and in the direction of the ground reaction forces. The example in Figure 5 belongs to an athlete who was changing the glide for the

rotational technique. She reached with the glide 20.92m (68 7 ½"), after one year training with the turn indoors by 20.19m (66' 2 ½") and outdoors 19.82m (62' 3 ¾"). These data show a higher level of the vertical component of the ground reaction forces, a steeper direction of the ground reaction forces. For discussion, note that Gregor 1990 reported for the glide a higher level of the ground reaction forces.

Fig. 4: Path of the shot with (left) and without a loop (right)
1-take off left foot 2-planting right foot 3-planting left foot 4-release



The data from film and video analysis of top rotationists shows that the angular difference between shoulder and hip axis (the twist after planting the right foot) isn't greater than by the glide (suggested by Scheerer 1975 and Sivas 1990, the last author reported from Zaciorskij 1990—however, both authors by not high skilled shot putters). For example, Timmermann (22.62m / 74' 2 ¼" and Gunthor (22.23m I 72' 11") reached angular differences of 75 and 90 degrees (Gunthor's values show a hyper-mobility of the lumbar region. His problems with the spine in 1989/90 were well known). These values and values from other gliders (Andrei, Stulce, Buder, Lisovskajya, Neimke, Storp) are over the level by throws of rotationists (Oldfield, Laut, Barnes, Doering, Dal Soglio and 50-60 degrees, see also Figure 2).

But a significant advantage turns out by the angular path for the shoulder and hip movement during the delivery: gliders reached no more than about 180 degrees, rotationists by contrast about 270 degrees. Taking into account the necessary time for the trunk movement, Table 3 shows the reached angular velocities by the glide and by the rotational technique.

Of course, one parameter alone isn't sufficient to judge the efficiency of different movements. But it gives a hint in what direction we must search for the causes for ineffective movement parts.

Table 1: Minimum of the shot velocity during the delivery (without source - own unpublished data)

Athlete	Shot kg	Range m/ft-in	Minimum Velocity m/s	Author
Baryshnikov	10	15.96/52-4 1/4	0.6	Palm 1990
Baryshnikov	7.26	20.54/67-4 1/2	1.4	Kressenbrock 1975
Laut	7.25	21.56/69-8 3/4	0.9	Bartonietz 1983
Laut	7.25	20.60/67-6 3/4	0.6	Stepanek 1990
Crawford	7.26	x	0.65	Stepanek 1990
Schmidt	7.26	18.43/60-5 1/2	1.2	
Schmidt	6.26	19.48/63-10 3/4	1.2	
Kumbernuss	4.00	18.20/59-8 1/4	0.8	

Under the precondition that the turner hasn't clearly more time for the delivery (see Figures 5 and 6, also Table 4) a greater increase of the shoulder velocity produced a greater pre-tension in the upper body also. The pre-tension needs the reaction forces in the legs and the lower parts of the body (Newton: actio et reactio — each action produced a reaction by the same amount, but opposite direction). After planting the left leg the hip-shoulder twist repeatedly increases as the result of the driving right leg. At the maximum twist starts the final extension of the throwing arm. The twists maximum ties up with the torqued body position. The range of the twisting movement isn't so important because the differences between the axis changed about 15 degrees - it seems the result of the elastic coupling of the moving limbs.

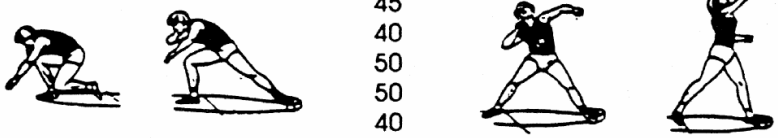
These results supported the supposition of Koltai 1974, Geese 1982, lhring 1982, Vanegas 1987, Palm 1990 and others, that the rotational technique can create better conditions for the muscle work than the current glide can. But it isn't a must: without the necessary leg work the athlete can't create the conditions for an effective acceleration of the implement.

Turning around the shot after planting the right foot on the right body side (hip and shoulder) can decelerate as a result of different processes (overlapping of the rotation and translation, friction between right ball and ground). The powerful acceleration of the trunk (and with it the shot) starts directly before planting the left foot (Figures 2 and 3). The right hip and shoulder are going on simultaneously - in other words, the right side comes completely through. This coordination shows a parallel to the coordination of throwing the discus by top athletes: a combined acceleration of the right hip and shoulder reaching the maximum velocity at the same time as the necessary base for a powerful arm sling shot (Bartonietz 1987). By the more linear acting glide we observe at all

times a reaching of the velocity peaks in succession (the trunk acceleration decelerates the hip area, the following arm extension decelerates the shoulder area).

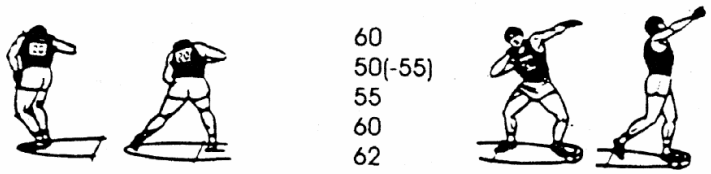
Table 2: Length of the strides after the starting movements and during the delivery (%)

Glide Technique



Athlete	Percentage	
B. Oldfield	45	55
U. Timmermann	40	60
J. Brenner	50	50
M. Stulce	50	50
W. Gunthor	40	60
J. Reinhard	40	60
Average	44	56
I. Briesenick	40	60
N. Lissovskaja	40	60
Z. Huang	42	58
C. Price-Smith	50	50
R. Pagel	50	50
Average	44	56

Rotational Technique



B. Oldfield	60	40
A. Baryshnikov	50(-55)	50(-45)
D. Laut	55	45
R. Barnes (1993)	60	40
K. Toth	62	38
J. Doering	67	33
Dal Soglio	58	42
H. Krieger	57	43
K. Larsson	60	40
Average	59	41

The conclusion of Palm (1990), that the activity of the right leg is the decisive element in the acceleration of rotationists is to specify: during the delivery an effective acceleration of the center of gravity can come from the right leg only in an indispensable interaction with the work of the left. The function of the legs during the delivery is to manage the straightening the body with a heave-up push to give the base for the powerful trunk turn. These actions create the push to give the base for the powerful trunk turn. These actions create the first part of the final shot acceleration and with it must produce as much as possible internal muscular pre-tension in the chest and shoulder area for the final arm extension.

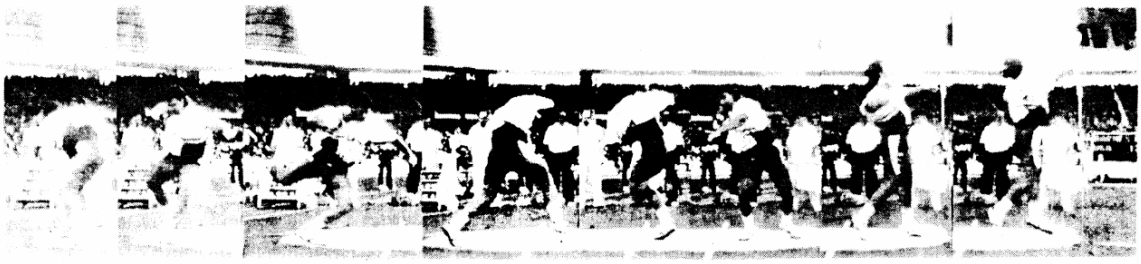
The effect of the leg work is also directed to change the moment of inertia of the entire system turning around a vertical axis. The moment of inertia characterized the distribution of the masses around the rotational axis. After planting the right

foot the momentum of inertia of the thrower with the shot reaches about 2.4kgm^2 (pivot: right ball, Picture 7 of the video print). During the planting process of the left foot this parameter decreases substantially (1.2kgm2, pivot: between the feet, Picture 10 of the video print). This conducts an increase of the angular velocity of the turning throwers center of gravity and also by the upper limbs with the implement. A part of rotational energy is loosing by the friction, otherwise the halving of the momentum of inertia would bring a doubling of the angular velocity.

It is important to note that on the one hand a related narrow position of the feet helps to decrease the momentum of inertia. On the other hand a related wide position gives better possibilities for the bracing work of the left leg. Therefore, the athlete must strive to optimize the stride length during the delivery. The always shorter stride length by the rotationists (see Table 2) seems to be the result of the athletes' optimization. To get the necessary body position and to give the impetus from the right—it's at first a problem of coordination.

The power demands for the right leg are sometimes smaller than for the left leg (by the glide about 3 times). To brake and heave up with the left is a harder job. On the assumption that Baryshnikov's throw with the 10kg shot, analyzed by Palm (1990), is characterized by a different movement pattern in relation to the throw with the competition implement (especially in the direction of the leg work of the aim-technique) it is questionable to qualify the right leg work as the 'decisive element' (Palm). The work of the right leg has a trigger-off function. Palms demand that the athlete should maximally accelerate the entire system thrower-shot during the delivery in the direction of the put can drive the athlete in a wrong direction: A maximal acceleration from the right leg results in a bending of the left knee. It was typical for Baryshnikov and it is a general effect of throws with heavy implements—if the athlete does not make an accent on the stable left leg. Baryshnikov has not used all his potentials of this technique. It is supported also by statements of Vanegas (questions to Vanegas, 1987) and Ionescu, (1992).

The athlete must strive for an optimal angle of release about 42 degrees. A lower angle of release of 35 degrees decreases the result by one foot (Tutevic, 1969). As a result of the powerful leg extension and body straightening, the rotationists are losing the contact with the ground at the beginning of the arm extension. We can often observe after release a jumping height of about 10 inches based on a vertical component of the center of gravity's velocity about 2.2m/s. It is more than by the glide. But the influence of the distance is a small one because there is a direct relation: some inches higher release—the same benefit in the distance. The athlete must try to hold the training throws within the circle because it is the competition rules. Overstepping of the board often results in an increase of distance because the body moves with a greater basic velocity. This effect is also observed in the other throwing events. But such a behavior produces an adaptation to another technique (especially of the leg work) as is allowed by the competition.



Selected body positions by the 21.80m / 71' 6" throw of Randolph BARNES at the WC in Stuttgart in 1993
video: BARTONIETZ/FELDER, DLV- Research-Project

Bernd KNEISSLER 19.84m / 65' 1" video: BARTONIETZ

Randolph E. Barnes gave a short and precise summary:

- When everything is done right
  The hips come completely through,
  The right foot is turned all the way through,
  You're practically in the reverse stage
  Before the shot is even gone.
  When you're in that kind of torqued-up position,
  It is all in the fingers.
  Everything is happening so fast.
  (T. & F.N 42 (1989) 3, p. 11)

Recommendations for Athletes and Coaches

1. Take into consideration that skills and abilities are two aspects of training and competition movements.

    - They are existing only in unity.

- Not any technique without abilities and no abilities without technique.

- In all spheres of training is a learning of movements. The neuromuscular system must learn what is useful for the competition movement.

- Use as a matter of principle a growing specificity of training loads during the year and during several training years (regarding volume and intensity of the training loads, selection of exercises and of movement execution).

2. You need a position orientation for your training of technique.

    - Do not go on about the faults. Search for the causes for faults noticed by observing the external movement pattern.

    - Use guidelines to see and imitation drills to feel the necessary movement execution.

    - Perfect your knowledge about the rotational technique. It is a fact: Who knows more can see and feel more.

    - Biomechanical knowledge helps you to understand the nature of the rotational technique and to find effective training exercises.

3. Derive the structure of your training uncompromising from the demands of the competition exercise's structure. Therefore try to get, by the strength training exercises, a great affinity to parts of the competition movement.

    - Use the bench press, not as in the inclined, but lying on the spine and working vertically, so you have a greater pre-tension in the pectoral and shoulder muscles at the beginning of the extension.

    - See in this element the realization of specific strength demands.

    - Focus the attention in all squats to the final extension of the ankles.

    - Discs under the heels have no place for young healthy athletes. They give more load to the knee extensors and reduce the working amplitude for the ankles.

    - The turn on the ball and the extension of the legs need reactive power abilities of the leg muscles, developed by special exercises with plyometric character including sprints.

4. Develop your technique by making an effort on The starting parts of The competition movement. Faults during the delivery have their source mostly at the start. Therefore:

    - Shift the body weight accurately over the left leg and hold back the right side for the kicking movement of the right leg.

    - Close the left side going into the turn (look at the watches on the left arm, held in front of the face).

    - Losing contact with the ground, the left leg does not become totally extended (if it extended the turn on finished with a pronounced jump).

5. Be careful with your spine.

    - The rotation of the trunk needs a distinct muscle corsage, especially the stomach muscles, including the muscles of the back and sides of the spine.

    - Use for the general strengthening periods before starting the special throwing training.

6. An effective leg work is the base of each throw.

    - Without heave up pushes from the right and left leg there is no powerful turn of the upper body.

    - The stride length must be optimized for a fast turn of the upper body around the left side.

    - Try to be a puma, not a blind bear (a modified remark of Oldfield, quoted by Dmitriev, 1981).

7. Reduce the number of classical throws from the stand step by step near zero.

    - They cannot produce the needed interplay of body movements, it is another technique.

    - With such movement by special warm ups you do not get in the right mode.

8. Heavy implements are useful to develop the leg, trunk and arm power.

- Throws with additional weights (i.e. vest, belt) can be used to set higher power demands for the explosive leg work,

- A good level of technique is the use of heavy implements and additional weights.

9. Realize an angle of release about 40-42 degrees.

    - You must search the source for a too flat a throw in the leg work (accent the push of the right leg, bending of the left knee, accent the upper body drive).

10. Hold the training throws in the circle.

    - That makes demands especially for the left leg.

    - Overstepping the board creates undesirable deviations and adaptations to an undesirable movement pattern.

Athlete	Result m / ft-in	Average value of the angular velocity of the shoulder axis (interval planting the right foot--maximum body tension[2]) deg/s
Rotational Technique		
J. Doering	20.96 / 68-9	750
D. Laut	21.56 / 70-8 1/2	790
R. Barnes	20.12 / 68-11 3/4	830
R. Barnes	21.80 / 71-6	900
D. Peric	19.57 / 64-2 1/4	765
Dal Soglio	19.79 / 64-11	845
A. Kumbernuss	18.20 / 59-8 1/4	670 (training throw)
(By competition 20.03m /65-8 1/4)		
		Average 775
Glide Technique		
M. Stulce	21.49 / 70-5 3/4	410
V. Lycho	20.94 / 68-8 1/4	560
U. Timmermann	20.38 / 66-10 1/4	540
W. Gunthoer	20.91 / 68-7	500
W. Gunthoer	22.23 / 72-11	470[3]
A. Kumbernuss	18.77 / 61-6 3/4	500
		Average 497

[2]"Maximum of body tension" was called the moment directly before the beginning of the elbow extension.
[3]Based on data of Susanka/Stepanek 1987

Fig. 5: Time-related ground reaction forces during the delivery by one athlete changing the technique (data from BARTONIETZ 1983, 1987)