SHOT PUT

1.- THROWS OVERVIEW.

Jesus Duran (2002) made a classification of the throwing events based on the weight of the implement (light or heavy) and depending on the throwing form (Rotation or Translation):

	Implement	Form	Initial position
SHOT-PUT	Heavy	Translation (also Rotation)	Backwards
DISCUS	Light	Rotation	Backwards
JAVELIN	Light	Traslation	Forward
HAMMER	Heavy	Rotation	Backwards

Table 1.- Classification of the throwing events (Duran, 2002).

Implement	Girls/Women Youth/Junior/Senior	Boys Youth	Men Junior	Men Senior
Shot	4.000kg	5.000kg	6.000kg	7.260kg
Discus	1.000kg	1.500kg	1.750kg	2.000kg
Hammer	4.000kg	5.000kg	6.000kg	7.260kg
Javelin	600g	700g	800g	800g

Table2.- Implements used by each age group (IAAF, 2009).

In all throwing events, the release velocity of the implements is zero and, throughout the throwing, the athlete should provide it the largest increase in the amount of movement possible by maximizing the impulse trajectory, in order to give the implement the fastest final velocity possible. A proper technique, optimal levels of flexibility and throwing specific strength, are required.

Anyhow, the ultimate goal of the throwing will be to project the implement as far as possible, fulfilling the regulation standards.

1.2.- FACTORS THAT AFFECT THE THROWING RANGE

In throwing events, the theoretical distance achieved is calculated using the formula for a parabolic shot range (D):

$$D = h_o + \frac{V_o^2 \cdot sen(2\alpha_o)}{g}$$

In this formula “h_o” is the output height, “V_o” is the release velocity of the implement, “sen_i ($2\alpha_o$)” is for the release angle of the implement α_o, and “g” is the gravity acceleration (9,8 m/s)².

The fact that the release velocity (V_o) is squared, makes it the most important fact of a throw. We can appreciate it in Table 3. Choosing a random release height, with a constant angle and release velocity, if we increase the velocity, the increase in the length of the throw will be higher than if we increase the angle. The faster release velocity of the implement, the more the importance of the “velocity” factor against the angle.

In the case of the release height, as shown in Table 3, the difference will only become significant when the release velocity and angle are very small. That is why, even though the ideal morphological characteristics of a thrower involve a large size and height, it is only to increase the length of the levers that generate the force of the throw, rather than to increase the release height of the implement.

	RELEASE VELOCITY (m/s)													
	α_o	19	20	21	22	23	24	25	26	27	28	29	30	33
h_o = 1,90 m.	15	11,43	12,46	13,55	14,68	15,87	17,11	18,41	19,75	21,15	22,61	24,11	25,67	30,66
	20	14,50	15,86	17,29	18,79	20,36	22,00	23,71	25,49	27,34	29,26	31,25	33,31	39,91
	25	17,47	19,15	20,92	22,77	24,71	26,74	28,85	31,05	33,34	35,71	38,17	40,71	48,86
	30	20,32	22,31	24,40	26,59	28,89	31,29	33,79	36,39	39,09	41,90	44,81	47,82	57,46
	33	21,96	24,13	26,41	28,80	31,30	33,91	36,63	39,47	42,41	45,47	48,64	51,92	62,42
	35	23,03	25,31	27,71	30,23	32,86	35,61	38,48	41,47	44,57	47,79	51,12	54,58	65,64
	40	25,58	28,14	30,83	33,65	36,60	39,68	42,89	46,24	49,72	53,32	57,06	60,93	73,33
	45	27,95	30,76	33,72	36,82	40,07	43,46	47,00	50,68	54,50	58,47	62,58	66,84	80,48
	50	30,12	33,17	36,37	39,73	43,25	46,92	50,75	54,74	58,88	63,18	67,64	72,25	87,02
h_o = 2,00 m.	15	11,53	12,56	13,65	14,78	15,97	17,21	18,51	19,85	21,25	22,71	24,21	25,67	30,76
	20	14,60	15,96	17,39	18,89	20,46	22,10	23,81	25,59	27,44	29,36	31,35	33,31	40,01
	25	17,57	19,25	21,02	22,87	24,81	26,84	28,95	31,15	33,44	35,81	38,27	40,71	48,96
	30	20,42	22,41	24,50	26,69	28,99	31,39	33,89	36,49	39,19	42,00	44,91	47,82	57,56
	35	23,13	25,41	27,81	30,33	32,96	35,71	38,58	41,57	44,67	47,89	51,22	54,58	65,74
	40	25,68	28,24	30,93	33,75	36,70	39,78	42,99	46,34	49,82	53,42	57,16	60,93	73,43
	45	28,05	30,86	33,82	36,92	40,17	43,56	47,10	50,78	54,60	58,57	62,68	66,84	80,58
	50	30,22	33,27	36,47	39,83	43,35	47,02	50,85	54,84	58,98	63,28	67,74	72,25	87,12
h_o = 2,10 m.	15	11,63	12,66	13,75	14,88	16,07	17,31	18,61	19,95	21,35	22,81	24,31	25,67	30,86
	20	14,70	16,06	17,49	18,99	20,56	22,20	23,91	25,69	27,54	29,46	31,45	33,31	40,11
	25	17,67	19,35	21,12	22,97	24,91	26,94	29,05	31,25	33,54	35,91	38,37	40,71	49,06
	30	20,52	22,51	24,60	26,79	29,09	31,49	33,99	36,59	39,29	42,10	45,01	47,82	57,66
	35	23,23	25,51	27,91	30,43	33,06	35,81	38,68	41,67	44,77	47,99	51,32	54,58	65,84
	40	25,78	28,34	31,03	33,85	36,80	39,88	43,09	46,44	49,92	53,52	57,26	60,93	73,53
	45	28,15	30,96	33,92	37,02	40,27	43,66	47,20	50,88	54,70	58,67	62,78	66,84	80,68
	50	30,32	33,37	36,57	39,93	43,45	47,12	50,95	54,94	59,08	63,38	67,84	72,25	87,22

Table 3.- Theoretical range examples (in metres) of a parabolic shot depending on the variables.

Comentario [m1]: Comprobar las formulas?!

The average figures of the variables in the throwing events really depend on the biomechanical study, on the conditions under which the throws where done (training of competition, weather conditions, etcetera) and on the level of the throwers that where sampled. However, we will consider, as reference the following:

THROW	V_O (*)	α_o
SHOT PUT	13-14	37 - 38º
DISCUS	24-26	33 - 39º
JAVELIN	≈ 28	27 – 36º
HAMMER	28-31	38 - 44º

Table 4. Reference parameters for the throwing events. (*) m/sec (Duran, 2002).

Particularly the optimal angle of release has been studied deeply, coming to the conclusion that is between 37 – 38º. It depends on the individuals and numerous factors such as the height, the energy the athlete can transmit to the implement, or the force the athlete can exert to shot, but the studies of Lenz and Rappl (2010) aside of V_o or H_o state 37 to 38º as the optimal angle.

Another important factor is the aerodynamics of the implement. Two of the implements, discus and javelin, has good aerodynamic conditions, and the manufacturing firms work to improve them inside the standards established by regulations; on the other hand, the shot and the hammer, due to their shape and weight, do not have good aerodynamic conditions.

It is important as well the technique and fitness level of the throwers, which is the main feature the coach should work on.

2.- SHOT PUT.

2.1.- INTRODUCTION.

The shot is a ball, usually made of metal, with a variable weight depending on the age group of the athletes. In Table 5 we can see some of the dimensions of the Shot Put ball for some of the older categories competitions. Instead of being "throwed", the shot is "put" from the neck with one hand. The Shot Put circle has 2,135 metres ± 5 mm in diameter, with a white stop board approximately 10 centimetres high at the front of the circle. The legal sector of the throwing area is 34'92º wide and is bounded by white lines 5 cm wide.

The distance thrown is measured from the inside of the circumference of the circle to the nearest mark made in the ground by the falling shot.

	MIN. WEIGHT	COMPETITION WEIGHT	DIAMETER
SENIOR MEN	7,260 Kg	7,265 – 7,285 Kg	110 – 130 mm
UNDER 17 and SENIOR WOMEN	4 Kg	4,005 – 4,025 Kg	95 – 110 mm
UNDER 17 MEN	5 Kg	5,005 – 5,025 Kg	100 – 120 mm

Table 5.- Weights and measures of the Shots for the different categories.

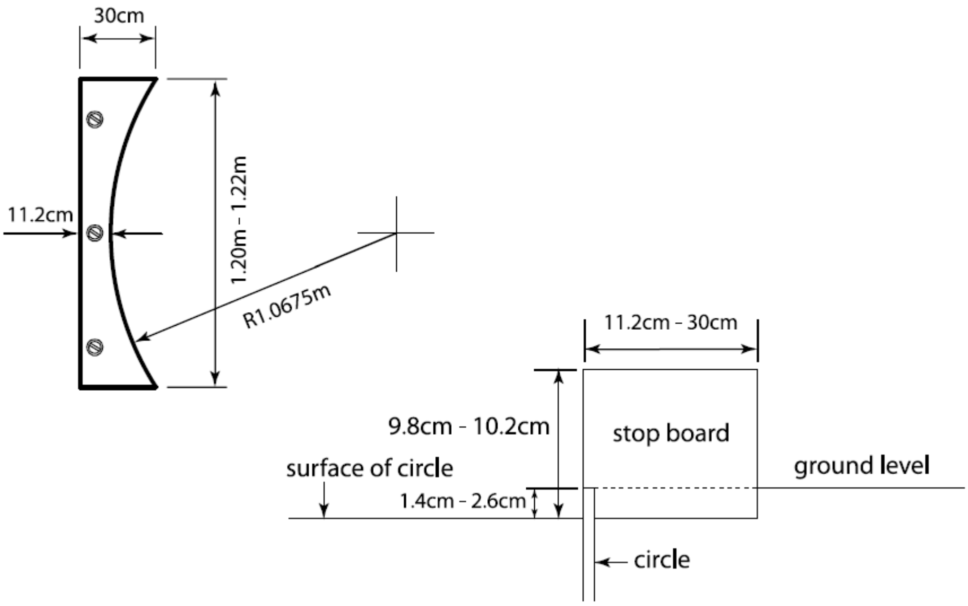


Figure 1.- Shot Put stop board, top and side view (IAAF, 2011).

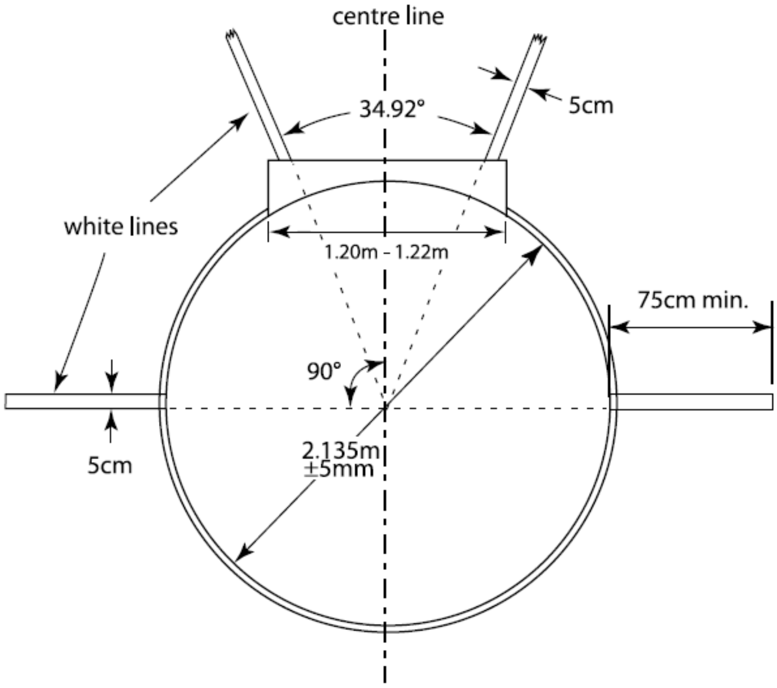


Figure 2.- Layout of Shot Put circle (IAAF, 2011).

Two putting styles are in current general use by shot put competitors: the glide and the spin. The origin of the glide dates to 1951, when Parry O'Brien of the United States invented a technique that involved the putter facing backwards, rotating 180 degrees across the circle, and then tossing the shot. In 1972 the spin was created in the USSR. The spin involves rotating like a discus thrower and using rotational momentum for power.

Currently, most top male shot putters use the spin. However the glide remains popular, especially at the amateur level and among women, since the technique leads to greater consistency compared to the rotational technique. In this course we will only see the glide technique since the spin will be covered in subsequent years.

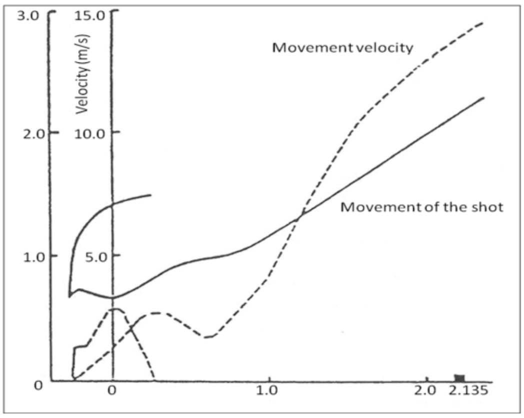
2.2.- BIOMECHANICAL FACTORS AFFECTING THE SHOT PUT.

In this section we specify the biomechanical factors affecting the Shot Put. The most important ones are:

2.2.1.- RELEASE VELOCITY (Vo).

The goal of every thrower is to achieve the maximum release speed of the implement. As we saw earlier, the elite athletes usually achieve more than 13 metres per second both men and women. To get it the shot putter should perform the longest putting trajectory, in order to have more time to increase the acceleration of the shot.

In the glide technique, the inertia is broken starting backwards and standing in one foot. This velocity is only the 15 to 20% of the final velocity, but it is really important since it is related with the subsequent movements. If we try to increase the release velocity too much, the subsequent movements will be anticipated, and we will not be able to adopt effectively the final position.



The rest of the increase in velocity should be done while standing in both feet (85–80%) base on an explosive leg action. It is important that the thrower feels the leg's action on the ground and that the force's sequencing is done connectedly.

In Figure 3, we can appreciate how the put always start without any velocity, but this is not the real start of the throw. We will discuss later more about this technical gesture.

Figure 3.- Movement and velocity of the shot while putting.

2.2.2.- RELEASE HEIGHT (ho).

The release height is the second most important factor while shot putting. It is directly related with the thrower height, but also with the throwing technique. Julio Bravo (2000) stated that the difference between the release height of the throw and the height of the thrower is of around 11% for men and 9% for women.

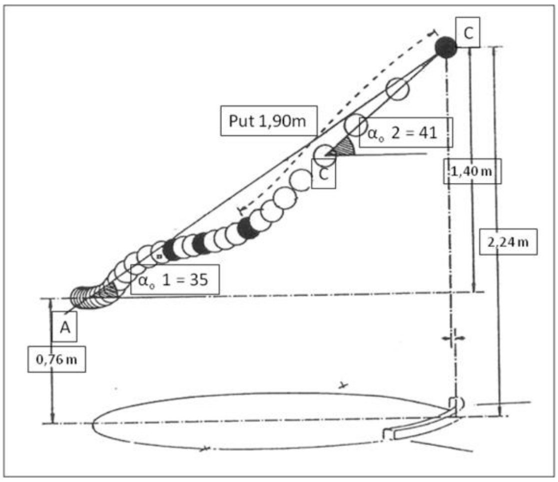
2.2.3.- RELEASE ANGLE (α_o).

It is the least important parameter affecting the Shot Put, as long as it is within a proper range. The optimum angle of a shot, from a ballistic point of view, is of 45º; however this does not work for a real competition, where there are values close to 40º, and for the elite athletes, who throw at 39º.

The optimum release angle depends on the release height and velocity. If the height is kept constant, the fastest the velocity the closest the angle will be to the 45º (theoretical optimum angle for a ballistic shot). This can be seen in the formula:

$$\cos\alpha \ opt = \frac{g * h_o}{V_o^2 + g * h_o}$$

The angle resulting of the velocity at each time of the throw should really close to the trajectory of the shot, and the shot trajectory should be as closed as possible to a straight line; however, due to the throwing techniques, this is impossible.



In Figure 4, we can appreciate the real trajectory of the shot, and the angle and final heights of a throw by Komar. The continuous straight line represents the ideal trajectory of the shot, which would have an angle of 35º. The angle of release was, as shown, 41º, slightly larger than normal due to the trajectory of the second half of the throw.

Figure 4.- Biomechanical analysis framework of Komar's throw in Munich 1976 (adapted from Bravo 2000).

In Table 6 we can appreciate the biomechanical analysis of men's shot put qualification in the Daegu 2011 world championships.

Rank	NAME	analyzed attempt	Results WCh(m)	release velocity (m/s)	release angle (deg.)	release height (m)	Inclination Angle (deg.)	
							Forearm	Upperarm
1.	David STORL(GER)	2	21.50	12.35	42.3	2.27	35.4	29.3
2.	Dylan ARMSTRONG(CAN)	2	21.05	12.53	32.7	2.05	34.2	34.2
3.	Reese HOFFA(USA)	1	20.96	13.74	31.1	2.03	35.0	42.9

Table 6.- Biomechanical analysis of men's shot put qualification, Daegu 2011 (IAAF 2011)

2.3.- ANTHROPOMETRIC CHARACTERISTICS OF THE SHOT PUTTER.

Fito an old INEF Athletics' professor always said that the shot putter should have a big size, mass and height.

Table 7 shows the results by Vorniak (on Bravo 2000), Russian throwers' coach, who proposes the ideal thrower's age, height and weight to obtain their best results. It also refers to the mean values of the top 30 shot putters of all times until 1992.

	Men (Vozniak)	Women (Vozniak)	Men (Top 30)	Women (Top 30)
HEIGHT (Meters)	198 ± 3	180 ± 2	192	178
WEIGHT (Kg)	122 ± 3	92 ± 3	118	80
AGE (Years)	26 ± 2	25 ± 2	26	26

Table 7.- Shot putter's anthropometric parameters.

These anthropometric characteristics must come linked to excellent physical conditions such as strength, power and speed.

2.4.- GLIDE TECHNIQUE.

Parry O'Brien was the first thrower to use this technique (starting backwards) in the 1950s. Before, the ideal putting technique was with a lateral movement. At the end of the book "Atletismo 3. Lanzamientos" (Bravo et al., 2000) an interesting evolution of the putting and throwing techniques throughout history can be found

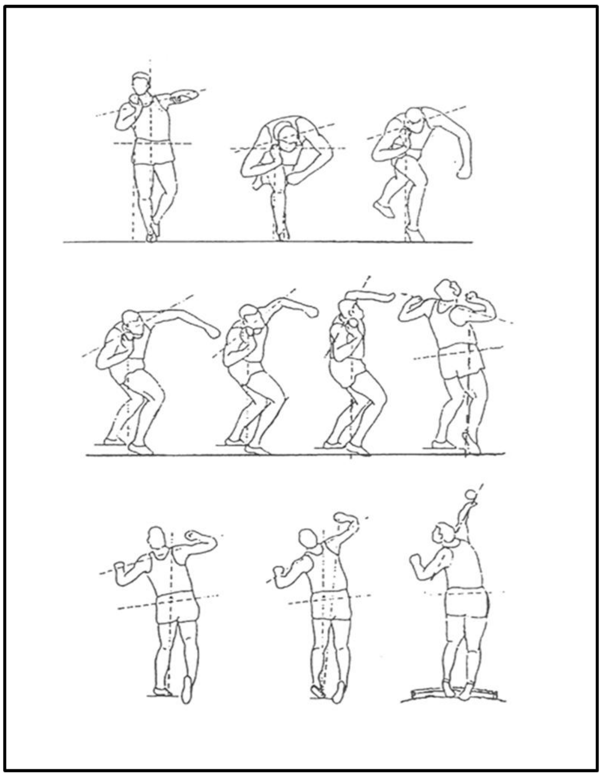
Shot Put is usually divided in 4 phases:

- Starting position and shot grip.
- Glide (Swinging → Grouping → Displacement).
- Delivery.
- Recovery.

Henceforth, these phases will be described for a **right hand thrower**.

2.4.1.- STARTING POSITION AND SHOT GRIP.

The thrower stands backwards to the throwing direction, with the full body weight resting on the right foot. This foot is parallel to the diameter of the circle, with the sole fully supported and the toes in contact with the inner edge of the perimeter of the circle. The left leg is slightly flexed, with the toes and metatarsals supported on the inner part of the circle, 30 cm behind and 10 cm apart from the right foot.



In this phase the hip and shoulder lines are perpendicular to the direction of the throw. In Figure 5, you can see the position of the body axes during the throw.

The right shoulder is lower than the left one (about 10-12 cm) to support the weight of the ball.

The left arm should be flexed and moved a little forward, with the elbow raised above the shoulder.

The head will be in a normal position, although the weight is resting on the neck. With an eye on the direction of the throw (opposite) and focusing on a point 2 or 3 metres in front of the thrower.

Figure 5.- Representation of the throwing technique with emphasis on body axes.

The thrower should be relaxed and concentrated in the subsequent movement while holding this position.

The shot is held in the palm of the hand, mainly in the base of the metacarpals and the three middle fingers. The thumb and the little finger work more balancing rather than impulsing the shot. The elbow must be away from the side but always under the shot.

The rules require that the shot rests in the neck and the jaw.

2.4.2.- GLIDE.

This is a fundamental phase for the performance of the throw, even though the difference between a standing put and another one done with the glide technique is usually only 2 metres less.

The linkage between the different phases of the glide must be fluid, with no pauses that can affect the velocity of the implement.

The amplitude of this movement phases depend on the different athletes, and is described in detail in the book “Atletismo 3: Lanzamientos” (Bravo, 2000).

A) TRUNK’S SWING.

The body is flexed forward slightly raising the left leg bent, to compensate the forward imbalance. With this gesture the throwers try to start the put from the farther point possible to the delivery of the shot, increasing the trajectory of the throw. In Figure 6, this phase would correspond to the interval between points 1 and 2.

The left arm goes down relaxed while lifting the right heel to support all the weight on the forefoot.

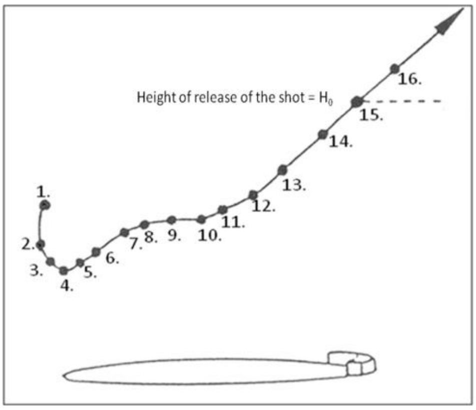


Figure 6.- Shot trajectory.

The thrower should stare at the same point (2-3 metres away) to make easier maintaining the balance.

B) GROUPING.

The body is grouped with an active flexion of the right leg, while the left leg is flexed passively and carried forward (knee slightly toward the chest)

The hip is flexed to reach the trunk on the right tight, this action happens because of a relaxation of the lumbar muscles. The trunk gets close to the horizontal (some throwers even reach it).

At this point, the CG of the "implement and thrower" is at the lowest point of its trajectory, and would correspond to point 4 in Figure 6. In a moment of this phase, the velocity of the shot becomes "0", not stopping again until the end of the throw.

C) DISPLACEMENT.

After the grouping phase throwers should avoid stops, stand in balance, and the stiffness of the right leg. The right foot hits the ground explosively, with a fast extension of the right knee, producing a backward displacement of about 80 to 100 cms. The hip is moved backwards and the left leg extends towards the throw. This displacement should be done as flat as possible, WITHOUT JUMPING.

The thrower continues staring at the same point than before to avoid an early rotation of the hip and the trunk; therefore, shoulders should continue perpendicular to the throw's direction.

The existing suspension phase should be as short as possible. After the suspension the right foot moves closer to the center of the circle, and the left foot contacts the inner edge of the stop board. The supports should be done with this order and with a rhythmic patter: fast but without haste. The leg's separation varies from 135 cms to 170.

It should be performed without any breaking that interrupts the continuity of the throw. Once the double support is done, the rotation of the body starts, with the back and left rotation of the left hip.

After the suspension phase, the right foot is landed with an active rotation between the "12 and 9 hours of a watch", considering 12 hours the direction of the throw (it can also be between the 11 and 10, as shown on frame 6 of Figure 7), with a sole support and without supporting the heel. The left foot rests with the internal part on the ground, and the external touching the inner edge of the stop board. The left toe points slightly towards the throw direction and with a lateral displacement of 10 to 15 cms with respect to the right foot. This lateral displacement will allow the subsequent movement of the hip and the throw itself.

After displacement, the position should be (see frame 7 of Figure 7):

- Shoulders perpendicular to the direction of the throw.
- Left arm in front of the body.
- Shot in front of the right ankle.
- Body weigh supported on the right leg.
- Right knee bent.
- Left knee slightly flexed and supported projecting a line with the trunk position

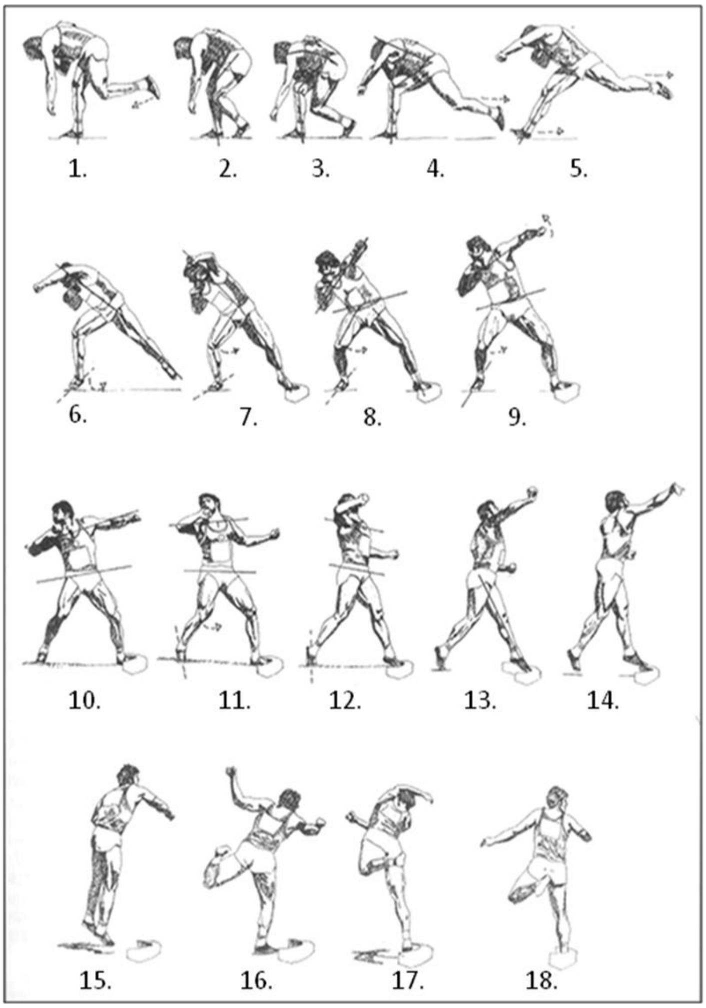


Figure 7.- Frames of the Shot Put by Udo Beyer, by Fernando Pascua.

2.4.3.- DELIVERY

This phase produces most of the final acceleration of the throw.

The action starts with a rotation and impulse of the right foot in the direction of the throw, so that the leg and hip move up and towards the throw.

The right hip starts a gradual rotation forward and to the left of about 170º to 200º while delivering (see Figure 8) .

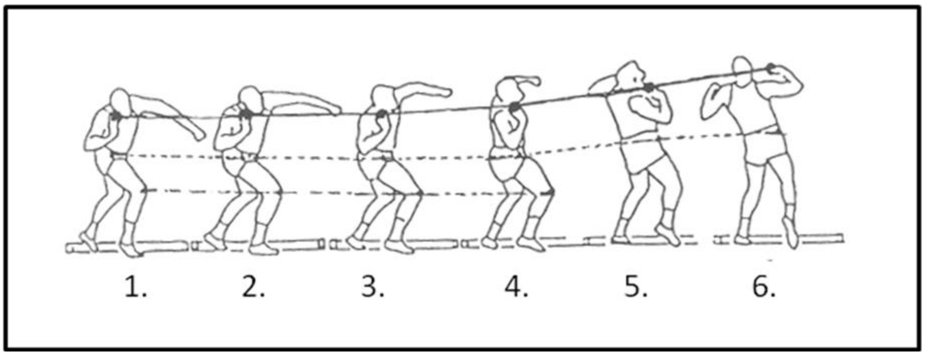


Figure 8.- Rotation of the hip and shoulders while delivering.

The left shoulder and elbow are separated out and back so that:

- It allows passing the weight forward.
- Extend the pectorals for a further action later.
- Eyes looking up and forward. Exactly when the eyes reach the throw's direction the thrower should end up the opening of the left elbow and shoulder.

The left foot and leg (and even the hip) will henceforth act as an axis of rotation of the right side of the body.

Later an extension of the right shoulder and elbow of the thrower is done, trying to speed up the shot without changing its direction.

Double support must exist throughout the final phase of the throw. Only at the end some elite throwers throw jumping, when the arm has been completely extended.

The left leg should be active at the end of the throw, to support the body weight and let the right side of the body rotate on it. (BLOCKING ACTION OF THE LEFT SIDE OF THE BODY).

At the end of the throw, the left leg does is unloaded and the right foot loses contact with the ground.

Finally an extension of the wrist and fingers is done, combined with a slight external rotation of the wrist.

The left side should stay still in order to avoid the backward movement (Action-Reaction Law). If the left shoulder would continue rotating the turning radius would be reduced, impacting negatively on the throw's length.

Main points to improve the delivery:

- Expand as much as possible the trajectory where the forces are done.
- Add as many forces as possible (translation, rotation and elevation).
- Perform solid supports.
- Act first with the strongest muscle groups and then with the weakest.
- Stretch the muscles before doing a concentric action (for example, lumbar muscles group before contracting in the subsequent phases)

2.4.4.- RECOVERY.

The recovery does not affect the length of the shot, but it does affect the validity of it! It helps to cancel the forward movement that unbalances the body at the end of the throw. To perform the recovery, the right leg is moved forward and the left arm and left are projected backwards. In this way we change the support foot while the trunk is flexed to the left side.

Remember that to make a valid throw the thrower should leave the marked circle balanced and through its rear half.

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