THE THROWING EVENTS AT THE WORLD CHAMPIONSHIPS IN ATHLETICS 1995, GOTEBORG — TECHNIQUE OF THE WORLD'S BEST ATHLETES

Part 3: Javelin throw

By Klaus Bartonietz, Russell J. Best and Anders Borgstrom

Dr. Klaus Bartonietz works as a biomechanics expert at the Olympic Training Centre Rheinland-Pfalz / Saarland, Germany.

Russell J. Best, responsible for the part of flight simulation in this study, works as a biomechanics expert at the Centre for Rehabilitation, Exercise and Sport Science at the Victoria University of Technology, Australia.

Anders Borgstrom works at the Friidrottsgymnasiet Karlstad, Sweden, and is the former head coach of the Swedish athletics team. He was head of the biomechanical crew for the throwing events at the 1995 World Championships in Goteborg.

Co-operators in this project were Mathias Lilleheim (Elite Sport Centre, Oslo, Norway), Anders Henrikson (Eriidrottsgymnasiet, Falun, Sweden) and Jari Keihas (member of the national coaching staff; javelin throwing, Sweden), as well as Calvin Morriss and Neil Fowler (both of Manchester Metropolitan University, Great Britain).

The part on the javelin throw describes in detail the technical characteristics of the medalists, with tables illustrating salient points such as knee angles of the front leg during delivery, release parameters, the duration of the last three strides, and body position at the end of the impulse stride and at the arch position. The general summary of the articles on the throwing events at Goteborg emphasizes the importance of the correction of technical faults, shown even by some of the world's top throwers, and recommends to all throwers serious study of the correct movement patterns and the use of special training exercises and throws with heavy implements, to provide one possibility for the development of event-specific power.

11 Javelin throw technique characteristics — women

Natalya Shikolenko / BLR: 67.56m (1.82m, 80kg, 1.8.1964)

On the whole this athlete threw well, but her technique was far from ideal, especially in regard to the throwing arm, the front leg and the arch position, Figure 10).

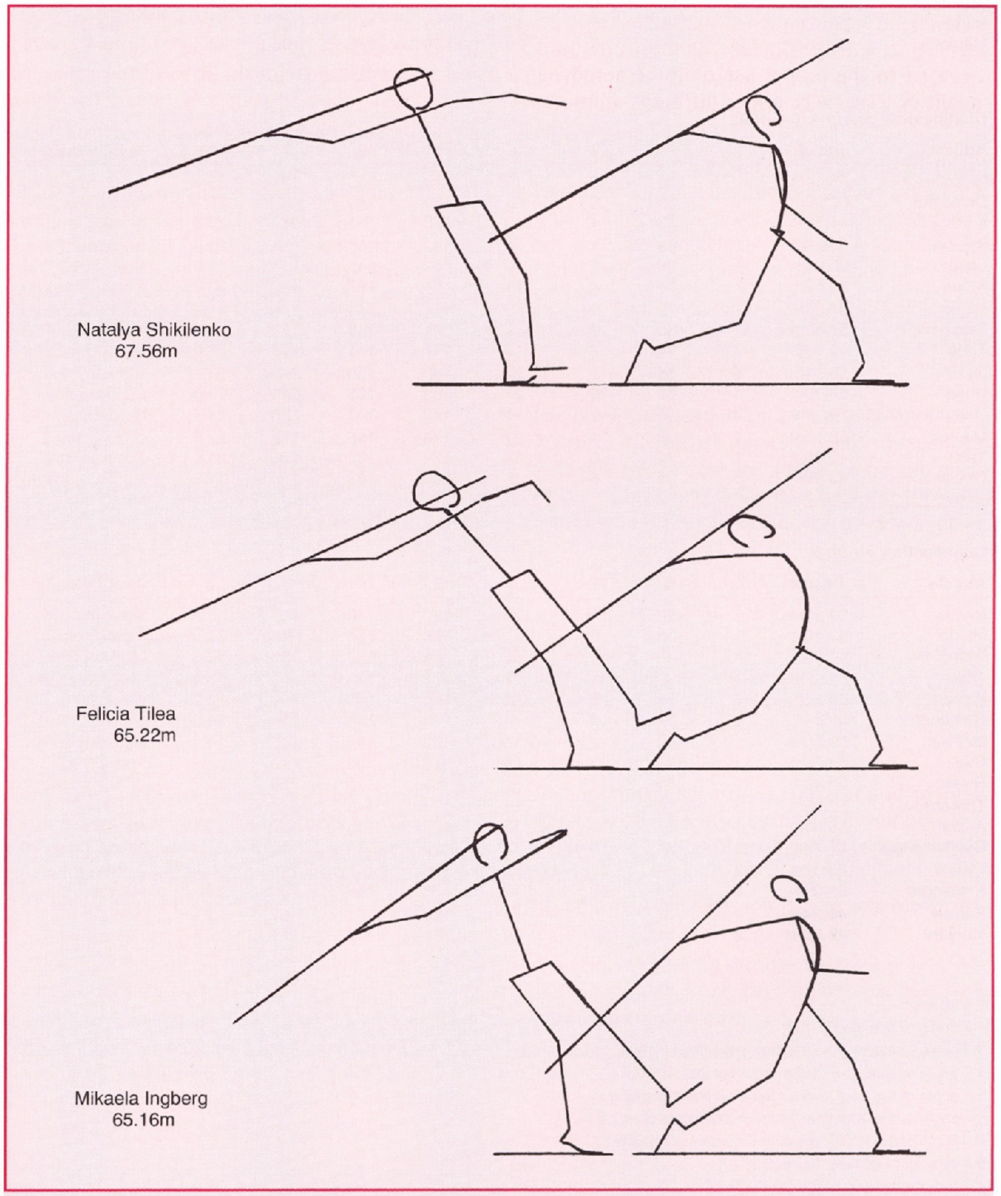


Figure 10: Body positions at the end of the impulse stride (plant of the right foot) and at the arch-position

- The impulse stride is 30% longer than the bracing stride (distance between the ball of the left foot and the toe of the right foot immediately after the plant of the left foot).

- The javelin and shoulder axis are parallel at the moment of planting the right foot.

- An active right leg before the plant of the left leg (as the left heel lands the right hip is moved forward).

- The throwing arm bends too early and too much after the plant of the right foot (up to 90° at the moment of planting the left leg).

- The front leg plants with a bent knee and it is not fully extended at release (see Table 12).

- The throwing action of the arm is not delayed (no distinct arch position, Figure 10).

- Forearm sling not pronounced (minimum angle between javelin and forearm 50°).

- The javelin used was a Nemeth 75; the angle of release was low, with zero angle of attack in the vertical plane but with a 10° angle of side-slip.

Felicia Tilea / ROM: 65.22 (1.67m, 74kg, 29.9.1967)

- During the rather high impulse stride (long duration of flight, Table 13) there is a pronounced backward lean of the body; as the right leg is planted, the c.g. is too much behind the support (long amortization phase with decreasing body velocity, Figure 10); the very active right leg before the left foot is planted can partially compensate for this latter fault.

- As the right leg is planted, the javelin, shoulder and hip axis are parallel.

- The left knee is bent, but extends during release (complete extension only after release).

- A long, extended throwing arm.

- A maximum arch position with a definite lean back of the upper body; the centre of pretension" is in the middle part of the upper body (it should be in the chest/shoulder area: compare this position with Ingberg's body position, Figure 10).

- Pronounced final forearm extension: minimum angle between javelin and forearm 20°.

- Release data: The negative pitching rate (tilting the top of the javelin downwards) and an angle of sideslip of 16° were limiting the performance (cf. chapter 12).

- optimum angles of release and attack, but the sideslip angle is too great (see Table 12).

Table 12: Javelin women: Angle of the front knee at planting, maximum bending and release as well as release data (fast information, presented the morning after competition)

Final, 8-8-1995

Athlete	Result	1	2	3	4	5	6	7	8	Javelin model
Shikolenko	67.56m	6	28	0	10	162	139	150	26.7	Nemeth 75
Tilea	65.22m	4	35	–1	16	161	150	178	25.1	Nemeth 70
Ingberg	65.16m	4	34	8	11	172	150	180	24.9	Nemeth 75
Rantanen	65.04m	6	30	1	16	167	150	162	25.8	Nordic Diana 80
Stone	63.74m	6	34	4	1	167	154	180	24.9	Nordic Diana 80
Damaske	62.32m	1	35	6	5	180	160	180+	24.9	Nemeth 75
Lopez	60.80m	3	33	2	26	175	150	159	24.4	Nordic Diana 70
Ivakina	59.82m	1	34	4	5	174	156	180	23.8	Nordic Diana 70
Strasek	59.10m	2	37	4	12	170	164	180	23.4	Nordic Diana 70
Jeppesen	58.84m	3	36	5	20	166	136	148	24.1	Nordic Diana 80
Nerius	56.50m	1	28	18	23	158	140	142	24.6	Nordic Diana 80
Manjani	55.56m	2	30	6	29	156	149	180	24.4	Nordic Diana 70

Qualification group A, 6-8-1995

Athlete	Result	1	2	3	4	5	6	7	8	Javelin model
Shikolenko	65.64m	1	36	–5	13	178	150	171	25.4	Nordic Diana 80
Damaske	62.82m	1	33	5	2	180	169	180+	25.1	Nordic Diana 70
Ivakina	61.52m	2	32	4	13	170	151	180	23.6	Nordic Diana 70
Strasek	60.26m	1	36	1	21	162	165	180	23.8	Nemeth 75
Lopez	60.04m	3	36	6	15	167	145	154	24.3	Nemeth 70
Stone	59.52m	2	34	4	13	164	157	180	22.9	Nordic Diana 80
Renk	58.86m	3	33	0	19	164	144	176	24.4	Nordic Diana 80
Zsigmond	57.86m	1	33	0	39	171	148	180	24.9	Nemeth 70
Tang	56.98m	2	26	7	19	171	141	175	23.8	Nordic Diana 80
Isalia	55.84m	1	35	5	23	180	150	180+	24.1	Nemeth 70
Uppa	54.38m	3	32	–10	21	153	125	180	23.9	Pacer Held IV
Ramanauskaite	54.14m	2	33	–1	–5	172	132	136	24.4	Nordic Diana 70
Mayhew	53.10m	1	38	14	27	173	145	178	22.2	OTE Tailwind
Tas	49.20m	1	32	0	18	174	122	126	21.8	Pacer Held IV
Obolashivili	43.98m	2	35	8	3	160	133	150	21.5	Nordic Diana 80

Qualification group B

Athlete	Result	1	2	3	4	5	6	7	8	Javelin model
Nerius	62.62m	2	28	17	29	172	149	167	25.3	Nemeth 70
Manjani	62.40m	1	33	0	11	175	156	180+	24.6	Pacer Held IV
Jeppesen	61.96m	2	36	4	25	165	142	155	24.9	Nemeth 75
Tilea	61.52m	3	39	–8	22	168	123	150	24.4	OTE Headwind
Ingberg	60.72m	3	32	8	19	156	148	160	24.2	Nemeth 75
Rantanen	60.34m	1	32	–6	18	175	134	154	24.8	Nemeth 75
McPaul	59.30m	3	34	–2	13	162	136	155	24.1	Nemeth 75
Eve	58.78m	3	33	13	15	170	156	170	24.2	Nemeth 70
Rivero	58.32m	1	25	19	9	163	115	138	23.7	OTE Headwind
Tomeckova	57.98m	3	36	4	10	174	145	160	23.1	Apollo 85
Auzeil	56.80m	1	37	3	15	180	165	180+	23.6	Nemeth 70
Ovchinnikova	56.74m	1	37	0	13	170	124	159	23.3	Nordic Diana 70
Carroll	55.32m	3	34	11	25	170	145	180	22.4	Apollo 85
Preisinger	54.00m	2	34	10	19	178	148	160	22.2	Nemeth 75
Farrow	49.24m	1	37	0	4	180	145	167	21.6	Nemeth 70
Mudiani	40.92m	2	31	7	29	175	142	167	20.8	Pacer Held II

1 = attempt
2 = angle of release [°], γ (0)
3 = angle of attack [°] (seen from the side), α^k (0)
4 = angle of sideslip [°] (seen from behind), β^k (0)
5 = angle of the front knee at the moment of planting [°]
6 = angle of the front knee at the maximum of bending [°]
7 = angle of the front knee at the moment of release [°]
8 = velocity of release, [m/sec], V^k (0)
+ = hyper extension of the front leg

Table 13: Durations of the last strides

Athlete	Distance [m]	Duration of leg work phases [sec] right – left	contact left	left – right (impulse stride)	right – left	left – release
Shikolenko	67.56	0.10	0.12	0.22	0.18	0.12
Tilea	65.22	0.08	0.10	0.26	0.26	0.12
Ingberg	65.16	0.14	0.10	0.24	0.14	0.12

Mikaela Ingberg / FIN: 65.16m (1.73m, 69kg. 29.7.74)

- A stable upper body during the impulse stride, which is 32% longer than the leg base during delivery.
- As the right foot is planted, the javelin, shoulder and hip axis are almost parallel; an active right leg prior to the plant of the left foot.
- A long, extended throwing arm and a distinctly delayed arm movement during the pre-tension build up process.
- Pronounced forearm sling (minimum angle between javelin and forearm 25°).
- The bend of the left leg reduces the body pretension; the left leg extends during release and is fully extended at release.
- The angle of attack is too great; cause — wrist flexion between planting the right and left foot.
- The athlete used the Nemeth 75 javelin during qualification and final.

The landing of the javelin was very flat (at about 2 meters above the ground it was in an almost horizontal position — hypothetically a result of the too great angle of attack). Under such conditions the validity of the throw is a matter of the judges opinion.

12 Javelin throw technique characteristics — men

Jan Zelezny / TCH: 89.58m (1.86m, 77kg, 16.6.1966)

- A long and active impulse stride with a stable upper body.
- The outstanding element in his throw (the unity of technique and specific leg power) was that the right foot plant is made on the ball of the foot and the position of the body allows a very short amortization phase (Figure 11); the right leg works very actively before the left foot is planted.
- Upper body thrust (range of movement of the upper body during delivery about 60°), cf. his photosequence, pictures 17-19.

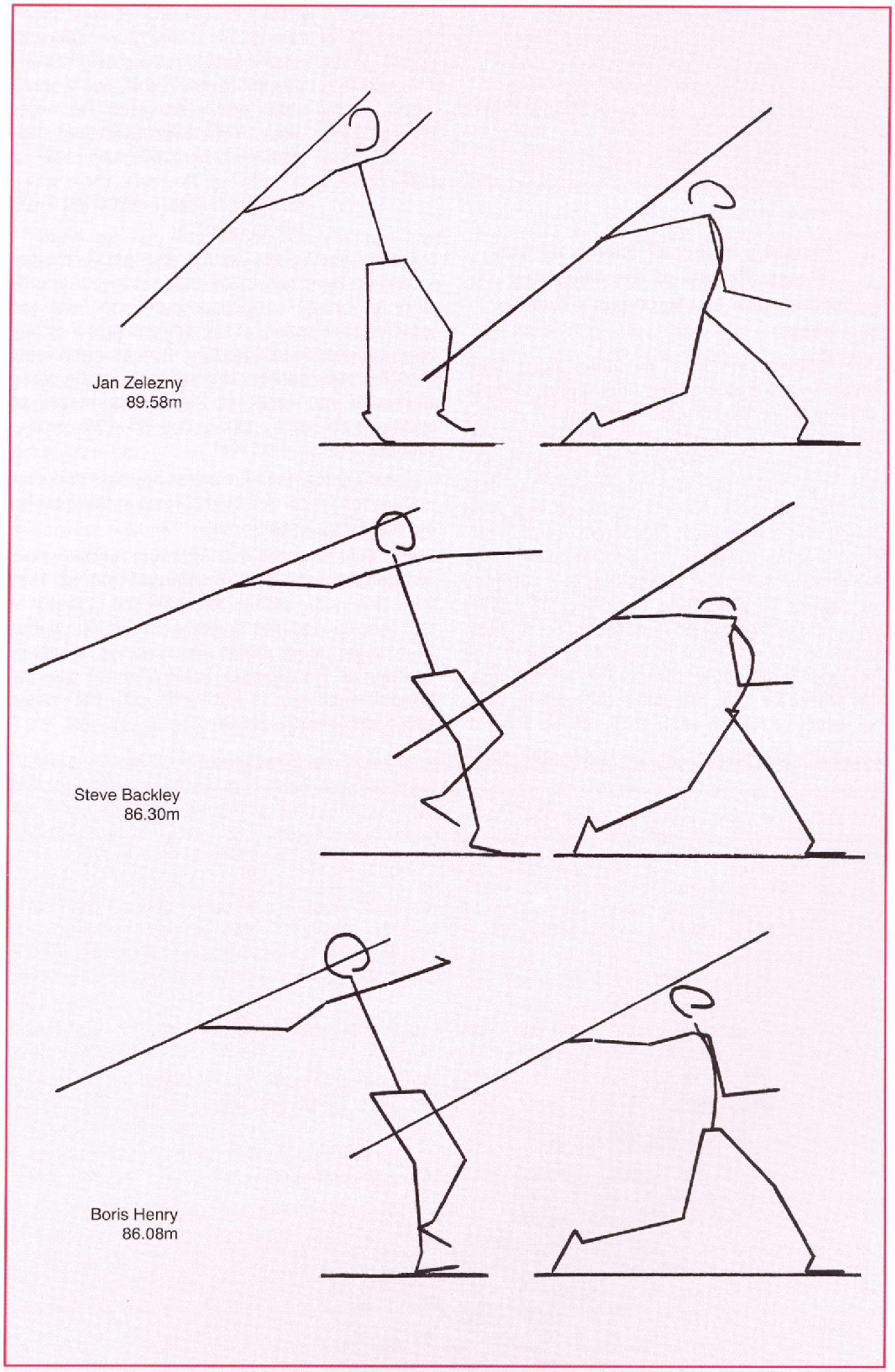


Figure 11: Body positions at the end of the impulse stride (plant of the right foot) and at the arch-position

- Left foot plant is very flat (angle between the axis of the left leg and the horizontal = 45°) effective bracing function.

- Pronounced drag on the top of the toe of the right foot (as a result of the effective direction of the right leg work).

- Left leg is bent at the moment of greatest body pre-tension, but fully extended at the moment of release (hyperextension).

- A marked forearm sling (minimum angle between javelin and forearm 25°).

- A flat angle of release, angle of attack and angle of sideslip at the limit of tolerance.

- No pitching momentum immediately after release.

Steve Backley / GBR: 86.30m (1.96m, 95kg, 12.2.1969)

- The impulse stride is 28% longer than the delivery stride, but the leg work for the impulse stride does not seem to be active enough (as the right foot is planted, the left foot is still behind the right leg, see Figure 11).

- An active right leg before the left foot is planted.

- An extremely long throwing arm (outstanding flexibility of the shoulder joint), a delayed action of the throwing arm and a firm left leg bring about an ideal arch-position (see Figure 11).

- The left leg is planted at an angle of 50° to the horizontal; the left knee is bent at about 20° during the final arm movement and there is no leg extension at release (see data Table 14, leg instability also in a lateral direction).

- A definite upper body thrust; minimum angle between javelin and forearm 35°.

- The angle of release was near optimum, but the pitching rate too great, turning the top of the javelin upward with an angular velocity of 25°/sec. The release velocity of 30.1 m/sec, with a deeply bent front leg, seems to be the result of an outstanding final action of the throwing arm (the same applies to Boris Henry).

Boris Henry / GER: 86.08m (1.93m, 93kg, 14.12.1973)

- Impulse stride only about 16% longer than the delivery stride (see Table 15).

- As the right foot is planted, the left leg is still behind the right one (the result of a relatively passive take-off from the left foot).

Table 14: Javelin men: Angle of the front knee at planting, maximum bending and release as well as release data (fast information, presented at the morning after the competition)

Final, 13-8-1995

Athlete	Result	1	2	3	4	5	6	7	8	Javelin model
Zelezny	89.58	6	33	4	8	177	169	180+	31.5	Nordic Orbit
Backley	86.30	6	34	1	7	173	152	152(!)	30.1	Nordic Champion
Henry	86.08	6	35	–6	15	168	151	154(!)	29.9	Nordic Orbit
Hecht	83.30	1	36	–4	13	168	148	150	29.3	Nordic Champion
Wennlund	82.04	3	31	–4	6	170	165	172	29.1	Nordic Champion
Hill	81.06	3	35	1	12	162	143(!)	149	29.1	Nordic Champion
Rybin	81.00	3	35	–2	11	171	155	174	28.9	Nordic Champion
Linden	80.76	2	32	3	12	170	162	179	28.3	Nordic Orbit
Parviainen	79.58	1	33	4	12	173	142	145	28.8	Nordic Champion
Moruyev	79.14	3	36	0	5	175	133	133(!)	29.2	Nordic Orbit
Räty	78.76	2	35	–7	14	172	160	169	28.9	Nordic Champion
Hakkarainen	78.16	3	37	–10	9	166	149(!)	164	28.3	Nordic Champion

Qualification group A, 11-8-1995

Athlete	Result	1	2	3	4	5	6	7	8	Javelin model
Hill	83.54	2	35	0	19	165	158	164	29.3	Nordic Champion
Linden	80.16	2	37	3	9	169	158	172	28.5	Nordic Orbit
Hecht	79.82	1	41	–7	7	179	148	159	27.8	Nordic Orbit
Hakkarainen	79.66	1	35	–7	9	160	137	155	29.0	Nordic Champion
Sasimovich	78.94	2	35	–5	7	163	145	156	28.4	Nordic Champion
Ovchinnikov	78.28	2	30	2	29	171	152	157	29.0	Nordic Orbit
Bodén	77.62	3	35	0	20	170	162	175	28.0	Nordic Champion
Currey	76.84	1	30	2	–4	170	166	176	29.2	Nordic Champion
Pukstys	76.12	2	34	7	9	167	120	120	27.5	Pacer Held III
Lovegrove	74.98	1	35	6	7	172	150	177	26.5	Nordic Orbit
Petersen	74.22	3	39	3	10	170	140	164	26.5	Nordic Champion
Spies	74.06	3	30	3	0	175	157	160	27.8	Nordic SE 80
Mustapic	73.12	2	35	–3	3	164	140	142	27.4	Nordic Champion
Baumann	72.90	1	32	–1	3	170	158	178	27.4	Nordic SE 80
Zaytsev	71.08	3	42	–5	1	175	150	180	27.1	Nordic Orbit
Fingert	70.94	3	33	–2	26	178	155	177	26.7	Pacer Held III
Mizoguchi	68.66	2	33	3	26	172	160	175	26.5	OTE Tailwind
Mahuse	68.18	2	30	10	7	174	148	154	26.3	Nordic SE 80
Palomo	62.90	2	39	1	5	172	151	167	24.6	Nordic SE 80

Qualification group B

Athlete	Result	1	2	3	4	5	6	7	8	Javelin model
Zelezny	90.12	2	35	3	9	175	170	180+	30.9	Nordic Orbit
Henry	87.60	1	34	–4	6	176	164	180	29.1	Nordic Orbit
Moruyev	85.60	1	35	–2	5	177	122	135	30.5	Nordic Orbit
Backley	83.20	1	31	4	3	174	135	135	29.2	Nordic Champion
Räty	82.42	2	31	–8	4	175	153	173	28.9	Nordic Champion
Rybin	82.14	3	39	–2	14	173	155	180	28.4	Nordic Champion
Parviainen	80.98	2	33	4	7	172	149	162	28.1	Nordic Champion
Wennlund	79.00	3	33	–4	10	171	163	175	28.7	Nordic Champion
Gonzales	76.54	3	30	8	1	166	149	164	27.8	Nordic Champion
Högler	76.40	3	33	4	16	165	158	176	28.7	Nordic Airglider
McHugh	74.58	1	35	4	18	159	133	154	27.7	Nordic Orbit
Einarsson	74.10	1	34	3	12	162	139	151	28.0	Pacer Held III
Parfyonov	73.64	3	32	10	14	171	140	140	28.6	Nordic Airglider
Özsöy	73.50	1	34	–2	18	175	150	162	27.0	Nordic SE 80
Kaminsky	71.92	3	33	8	23	175	164	170	27.7	Nordic Chanpion
Ki-Hoon	70.20	2	40	–8	6	177	156	162	26.5	Nordic Airglider
de la Garza	70.20	3	33	0	5	169	143	151	26.5	Nordic Champion
Sild	X	1	37	8	17	165	142	149	25.8	Nordic Airglider

1 = attempt
2 = angle of release [°], γ (0)
3 = angle of attack [°] (seen from the side), α^k (0)
4 = angle of sideslip [°] (seen from behind), β^k (0)
5 = angle of the front knee at the moment of planting [°]
6 = angle of the front knee at the maximum of bending [°]
7 = angle of the front knee at the moment of release [°]
8 = velocity of release [m/sec], V^k (0)
+ = hyper extension of the front leg
! = extremely ineffective work of the front leg

- A long throwing arm, a short period of body pre-tension, the left leg not firm enough (17° bend at the knee and no leg extension at the release).

- Minimum angle between javelin and lower arm 25°.

- A flexion at the hip during the final arm movement (the result of the ineffective right leg work after the plant).

- No pitching momentum immediately after release.

During the qualifying round, this athlete showed a much better throwing technique with a more active right leg action, a firmer front leg and release angles closer to the optimum values. As a result, he had a longer throw with a lower velocity of release (compare the data in Table 14).

Table 15: Durations of the last strides

Athlete	Distance [m]	Duration of leg work phases [sec] right left	contact left	left-right (impulse stride)	right left	left release
Zelesny	89.58	0.12	0.10	0.24	0.16	0.10
Backley	86.30	0.08	0.12	0.20	0.22	0.12
Henry	86.08	0.12	0.12	0.20	0.20	0.12

13 Toward a higher efficiency of the release: Results of the computer simulation of the javelins flight phase

The following results of computer aided flight simulation are a part of the final report to make available more background information for the interpretation of the realized throwing technique and the measured release data. The software (BEST et al. 1995) uses javelin aerodynamics data (lift, drag, pitching moment measured in a wind tunnel) and the physical characteristics of 7 different javelins. However, the simulation being for two-dimensional flight means that it is currently not capable of simulating the effect of yawing (e.g. angle of sideslip) or spin. The effect of these parameters is discussed in BEST et al. 1995. The simulation programme incorporates an optimization procedure that calculates the specific optimal values of release angle y (0), release angle of attack α^k (0) and release pitch rate q (0) for any given values of release speed, release height (supposing for men 2m, for women 1.8m) and wind speed. The notes made of the wind conditions suggest that there was no headwind or tailwind. However, there was a difficult variable sidewind from left to right.

Interpreting the results, the possible measurement error has to be taken into consideration. An estimated measurement error for the velocity of release of 0.2m/sec results in a difference in distance of about 1 m (e.g. an error value of 0.7m/sec represents about 3m error when translated into simulated throw distance and an error of 1.8m/sec translates into 7.5-10m error in simulated throw distance).

Table 16 describes the measured data and simulation results for selected throws in the qualifying and final competitions.

Table 16: Input data and results of computer simulation of the flight phase

	part A								part B			
	1	2	3	4	5	6	7	8	9	10	11	12
Henry	86.08	88.58	29.9	35	−6	−15	0	89.26	89.30	34	−6.5	1.5
	87.60		29.7	34	−4	−6	0	87.51	87.57	34	−6.5	0.7
Zelezny	89.58	93.48	31.4	33	4	−8	0	95.13	95.88	35.1	−5.3	−2.5
	90.12		30.7	35	3	−9	0	92.86	93.54	34.4	−6.3	−0.1
Backley	86.30	88.70	30.1	34	1	−7	25	84.56	89.66	34.2	−6.5	0.2
Boden	77.62		28.0	35	0	−20	8	78.33	79.61	32.8	−8	4.9
Shikolenko	67.56	70.26	25.9	28	0	−10	17	67.47	69.09	28.9	−7.1	9.6
	65.64		25.4	36	−5	−13	8	69.09	71.71	29.2	−7	9.2
Tilea	61.52	63.52	24.4	39	−8	−22	0	65.76	68.67	29.3	−7	9.5
	65.22		25.1	35	−1	−16	−8	67.52	69.56	29	−6.9	9.2
Rantanen	65.16	67.90	24.9	30	1	−16	0	64.94	69.39	29.1	−7.3	9.8
	60.34		24.5	32	−6	−18	42	54.49	66.16	28.7	−7.1	10.1
Manjani	55.56	58.56	24.4	30	6	29	25	57.16	62.99	28.8	−6.6	10.1
	62.40	64.40	24.5	33	0	−11	8	63.70	65.35	28.7	−7.1	10.1

Part A: measured release data, simulated result

1 = competition result [m]
2 = result including the distance between foul line and the javelin centre of gravity at release [m]
3 = velocity of release [m/sec]
4 = angle of release [°]
5 = angle of attack [°]
6 = angle of sideslip [°]
7 = pitch rate [°/sec]
8 = simulated result

Part B: simulated results, based on measured release velocity and with optimum release angle, angle of attack and pitch rate at release

9 = simulated result, including the distance between foul line and the javelin centre of gravity at release [m]
10 = optimum angle of release [°]
11 = optimum angle of attack [°]
12 = optimum pitch rate [°/sec]

It should be noted that optimum release values are not the same for all throwers. Indeed, they vary, depending on the release speed capacity of the thrower and the make of javelin. The variations in optimum values are, however, relatively continuous. For example, Table 17 shows how the optimal pitch rate (q (0)) varies with the release speed in the men's event.

Table 17: Relationship between release velocity (v^k (0), m/sec) and release pitch rate (q (0), °/sec)

Athlete	v^k (0)	q (0)
Boden	28.0	4.9
Henry	29.9	1.5
Backley	30.1	0.2
Zelezny	30.7	−0.1
Zelezny	31.4	−2.5

The relationship between the angle of release, the angle of attack at the moment of release, the pitch rate at the moment of release and the release velocity are all different (also different between men's and women's javelins and different types of javelin). BEST et al. 1995 give a full description of these relationships.

13.1 Release angle (*y* (0))

There was very little variation in the measured release angle data for the men (range 33-35°). The average measured release angle is almost identical to the average optimum release angle (34.3° vs. 34.1°). For the women's results there was considerable variation in the measured release angle (range 28-39°, average 33°). The measured average was also different to the average optimum release angle (28.9°). This discrepancy could be

- owing to errors within the women's simulation programme or
- because women's training methods are similar to men's, despite the considerable differences in the physical and aerodynamic characteristics of men's and women's javelins.

Note that the Gold and Bronze medal throws in the women's event had release angles measured at 28° and 30° respectively.

13.2 Release angle of attack (α^k (0))

There appear to be differences in the measured release angle of attack data for each individual but when the group average is calculated, a value approaching 0° can be seen. The optimum simulated release angle of attack is between -5° and -8° for all athletes (cf. Table 16, part B). Some athletes get close to this but, as Table 16 shows (especially for women), often at the expense of other parameters. Possible reasons for the difference in measured and optimum angles of attack data may be:

- owing to errors within the simulation programme or
- because the negative optimum angle of attack has only recently been suggested by the research literature or
- because training methods tend towards throwing 'directly through the javelin's long axis'.

While this is relatively easier to coach, it may not be optimal. Furthermore, most throwers tend to 'pull down' on the javelin at release which makes the production of a negative angle of attack less likely.

13.3 Release pitch rate (q (0))

Along with BEST et al. 1993, this is one of very few studies to measure this parameter. Simulation results suggest that release pitch rate may be the most important of the three optimizable parameters y (0), α^k (0) and q (0) (e.g. BEST et al. 1995). The large variability in measured pitch rate data in this and previous studies suggest that this may well be the case. This is despite the fact that pitch rate has received little attention in the research and coaching literature, and also in coaching practice. The largest negative pitch rate was -8°/sec while there were four positive pitch rate values measured at greater than 15°/sec (17, 25, 25 and 42°/sec.). This implies a tendency for 'pull down' to be a major component of a large proportion of non-optimal throws. The analyzed throws of Rantanen and

Manjani underline this finding: While there were relatively small differences in V^k (0), y (0), α^k (0) and $ß^k$ (0), the 42°/sec difference in release pitch rate between the throws is the mostly likely reason for the about 5m difference of measured throw distance.

13.4 Release angle of sideslip ($ß^k$ (0))

Along with BEST et al. 1993 and BARTONIETZ/ FELDER 1994 this is one of very few studies to measure this parameter. The javelin simulation literature is limited to two-dimensional flight at present and, hence, the effect of sideslip angles (and spin) cannot be simulated. The results of these studies appear to confirm that a negative angle of sideslip (top of the javelin to the right of the flight direction, looking from behind) is a very common occurrence in javelin throwing. Both angle of attack and angle of sideslip produce drag forces that are, by themselves, detrimental to the javelin's performance in flight. While the angle of attack can be used to produce beneficial lift forces during flight, an angle of sideslip produces side forces that will tend to cause a javelin only to yaw to the left or right. However, the fact that the javelin is also spinning about its long axis complicates the problem. When there is no wind, a right handed javelin thrower will spin the javelin such that a negative angle of sideslip will result in a positive Robins-Magnus lift force (mostly upward directed). However, here are not data available about the relation between the beneficial Robins-Magnus lift force and the detrimental acting drag force induced by that sideslip angle.

Positive Robins-Magnus lift forces are also generated for a right handed thrower when the wind blows from left to right. Detrimental, negative Robins-Magnus forces are generated when the wind blows from the right to the left. The only report of wind conditions at the finals was subjective but that report did indicate the prevalence of a left to right wind at right angles to the throwing direction. This would assist all right handed throwers.

There are other possible explanations for the prevalence of negative sideslip angles for nearly all throwers (see also BEST et al. 1993):

A negative release sideslip angle may be a 'natural" result caused by a thrower's attempt to maximize the release speed which is the most important parameter. The final delivery of the javelin, not dissimilar to a ball throw or tennis serve, includes rapid internal rotation of the upper arm and rapid pronation of the forearm that will tend to cause the javelin to assume a more negative sideslip angle and yawing angular velocity at release. This effect is essentially the sideways equivalent to the 'pull down' element of the technique that occurs in the vertical plane. Yaw rate values have not previously been reported in the literature, but may be another important release parameter.

Theoretically, the important leg work will influence the upper body during the delivery and the other release parameter discussed, and, therefore, influence the direction of the release velocity. The exact nature and overall result of the effect of sideslip angle and yaw rate throughout flight is yet to be determined. There is no doubt that more three-dimensional investigations on this topic are required (both measuring and simulating the throwing movement and the javelin flight).

14 Summary for the javelin throw

- In general the technical standard reached by the medalists in the javelin event was low in comparison with the other throwing events. Most of the finalists showed shortcomings in the work of the right and/or left leg, thus limiting their performance.

- The throwing technique of Jan Zelezny was close to the ideal, while other throwers, although some elements of their technique were excellent, had major faults, for example:

    - Steve Backley — excellent delay of the throwing arm but very unstable front leg;

    - Mikaela Ingberg — excellent arch position but angle of attack far too high;

    - Mirela Manjani (qualification) — delay of the throwing arm, excellent arch position, front leg hyperextended at release, but cross step too high and left side wide open as she planted her front foot.

    - Close to the requirements but still with definite shortcomings during the finals: Damaske, Wennlund, Parviainen.

- The established relationship between the velocity of release and the distance thrown (Figure 12) stresses that the achievement of the optimal direction of the final effort together with the correct alignment of the javelin (in other words: the correct delivery technique) is one of the most important prerequisites for fulfilling the athlete’s potential.

- Because the power demands of the bracing action of the front leg are several times higher than those of the work of the right leg, special training exercises are required to develop this bracing ability: e.g. various single leg exercises, including the whole spectrum from maximum strength exercises (e.g. snatches) to reactive leg exercises (e.g. jumps, sprints); vide special training exercises for javelin throwers: STASJUK 1994.

- Most of the World’s best athletes displayed an active right leg action after the impulse stride (shown by the right hip moving forward before the plant of the left foot, ground contact with the right foot at the moment of release).

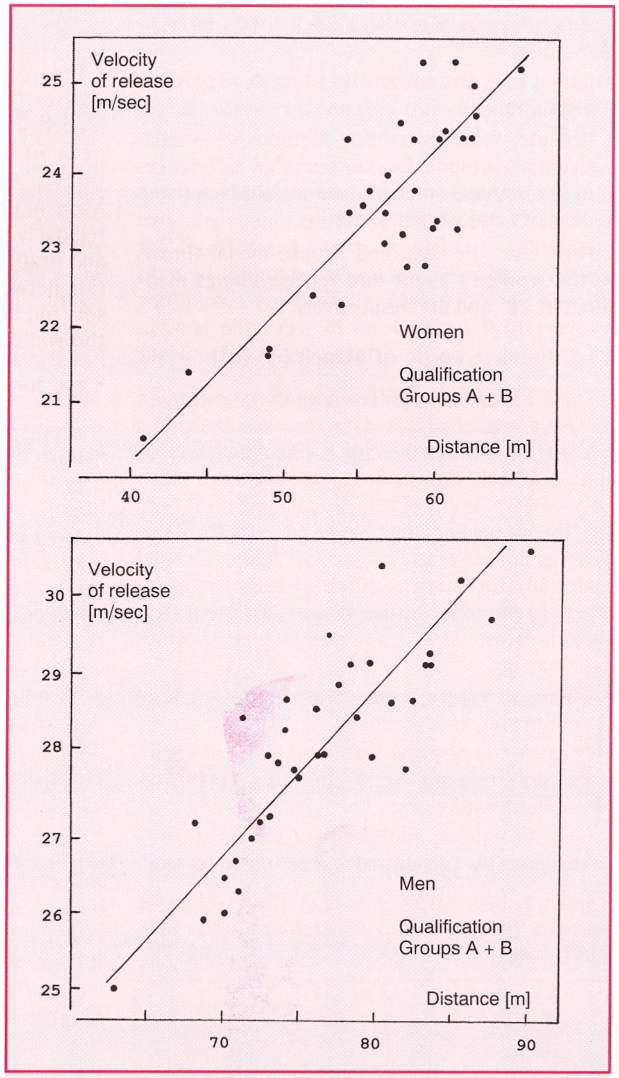
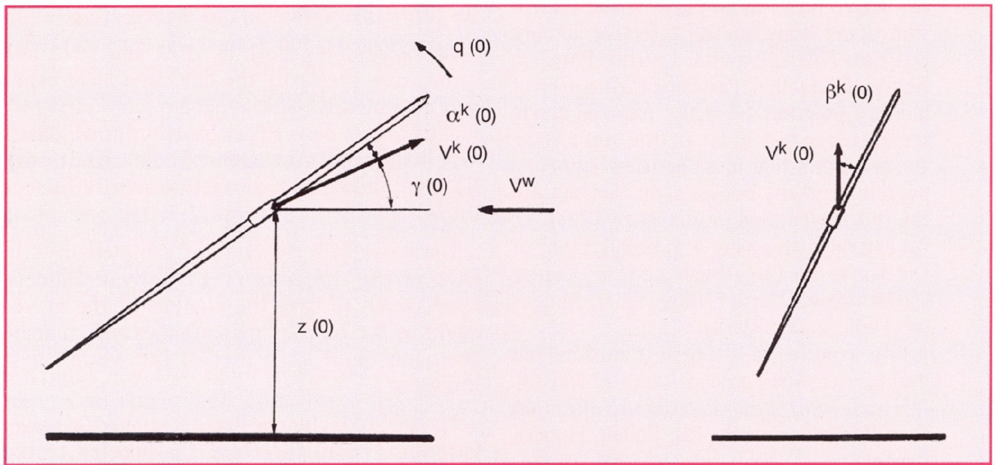


Figure 12: Relationship between velocity of release and distance thrown

- Work on technique should be focused on the following elements (in brackets, athletes with a definite minus in these elements):
  - An accelerated run up.
  - An active and low impulse stride with a firm upper body and an effective landing position (Tilea, Ivakina, Carroll, Backley, Henry, Hill, Linden, Parviainen). The perfect landing position from the impulse stride facilitates a fast plant of the right foot. The impulse stride must be used as a connecting segment between the run-up and the throwing action (SlMON/SIPKA 1994).
  - An extended throwing arm before plant of the front leg (Shikolenko, Stone, Lopez, Ovchinnikova, Carroll, Raty, Spies, Mustapie, Fingert, de a Garza).

- A firm front leg: if it is bent it must extend during release (see data in Tables 12 and 14).
- A release with ground contact of the right foot (McPaul, Carroll, Tas, Bodén, Fingert, Ozsöy).
- The event-specific optimal release parameters (cf. also BEST et al. 1995 and data in Tables 12 and 14), especially the value and the direction of the pitch rate at the moment of release are as important or more important than the release angle of attack. This parameter was not a part of the feedback given to the coaches and athletes at these World Championships and was measured much later to simulate the flight phase. It is to recommend to include into future projects the information on the pitch rate as a part of the feedback for athletes and coaches.



Parameter	Unit of measure	Name	Definition
z (0)	m	release height	height between ground and the javelin's centre of gravity
V^k (0)	m/sec	release velocity	velocity of the javelin's centre of gravity relative to the ground
γ^k (0)	°	release angle	angle between direction of vector of the release velocity and the ground
α^k (0)	°	angle of attack	angle between the javelin's longitudinal axis and the direction of vector of the release velocity at release
β^k (0)	°	angle of sideslip	also: angle of sideattack, angle between the vector direction of the velocity of release and the javelin's longitudinal axis at the moment of release looking from behind)
q (0)	°/sec	release pitch rate	angular velocity of the javelin's tip at the moment of release
V^w	m/sec	wind speed	

Figure 13: Presentation and definitions of release parameters (adapted from BEST et al. 1995)

15 General summary for the throwing events

This study will bring the analysis of the technique of the world's best throwers up to date in preparation for this year's Olympic Games. The conclusions reached respect totally the high performances of these athletes, but show clearly that, in most cases, there is room for improvement.

Often only a few centimeters are decisive for a medal or a better place. Therefore we urge all throwers to take advantage of technical improvement in order to make the most of their potential. Work on the correction of technical faults will surely pay dividends.

On the whole, the world’s best athletes demonstrate a high level of technical skill (shot put: Astrid Kumbernuss, John Godina; discus throw: Elina Zvereva, Olga Chernyavskaya, Jurgen Schult; javelin throw: Mikaela Ingberg, Jan Zelesny; hammer throw: Tibor Gécsek, Balazs Kiss). But there is no doubt that technical faults limit the performances even of world class athletes (hammer throw: Andrey Abduvaliev, Igor Astapkovich; shot put: Aleksandr Bagach; javelin throw: Nataiya Shikolenko, Steve Backley, Boris Henry: discus throw: like Wyludda, Lars Riedel).

Young athletes, born in 1972 and 1973 and earlier, now pressurize the older and more experienced athletes: Mikaela Ingberg (born in 1974!), Joanna Stone, Boris Henry (javelin throw), Balazs Kiss (hammer throw), John Godina (shot put), Natalya Sadova, Vladimir Dubrovshik (discus throw).

The movement analyses of the medalists in each of the throwing events provide models, upon which to base the analysis of the movements of the coaches’ own athletes and compare their technique with that of the world’s best throwers.

Training of technique and event-specific power (strength) must, therefore, be directed to the breakdown of movement faults. Technique and strength cannot be developed separately from each other. Technique training must take place the whole year round. In the course of the year, from development stage to development stage, the number of special exercises (including the throws) must increase in relation to the number of maximum strength training exercises as one of the preconditions to cause the desired training effects.

A leading principle for the training of technique is the acquirement of knowledge about the general and individual movement pattern, because “Who knows more, can see and feel more”.

Knowledge about

- the importance of a minimal variability of the starting movements.
- the function of the active work of the legs.
- the function of a wide stance during delivery.
- the event-specific optimal release parameters.

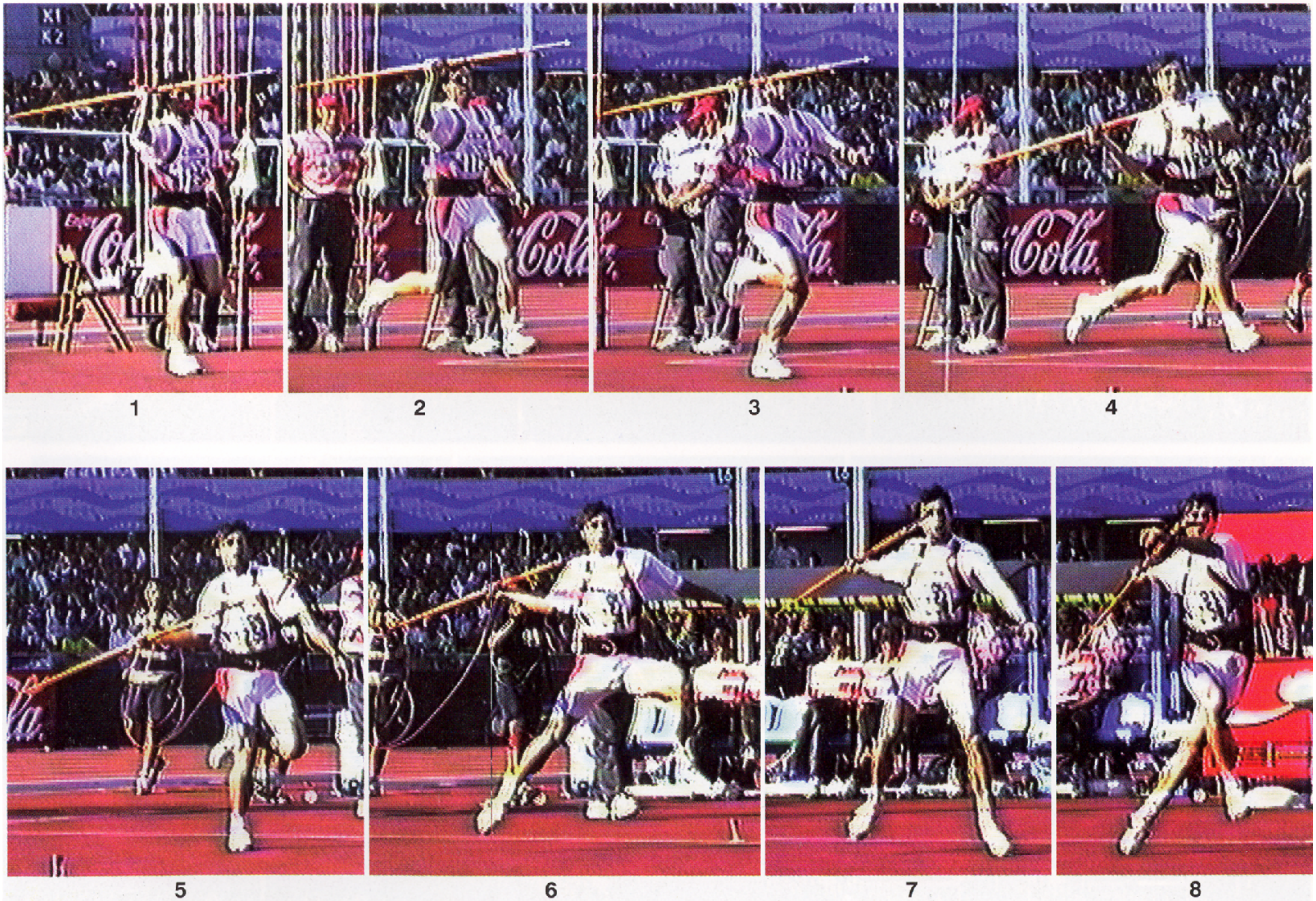
Knowledge about the goal technique and about effective measures for movement correction is a must for coaches (goal setting, positive orientation, comparison between ‘debit and credit’, self-activity of the athlete).

Special strength training exercises and throws with heavy implements provide one possibility for the development of event-specific power. A creative approach by athletes and coaches is necessary (e.g. exercises for the javelin: BARTONIETZ/ HELLMANN 1985, STASJUK, 1994; for the discus: Pensikov/ Denissova 1993; for the shot: Stasjuk 1993, BARTONIETZ 1995; for the hammer: BARTONIETZ 1987, BONDARTCHUK 1995, Losch 1993).

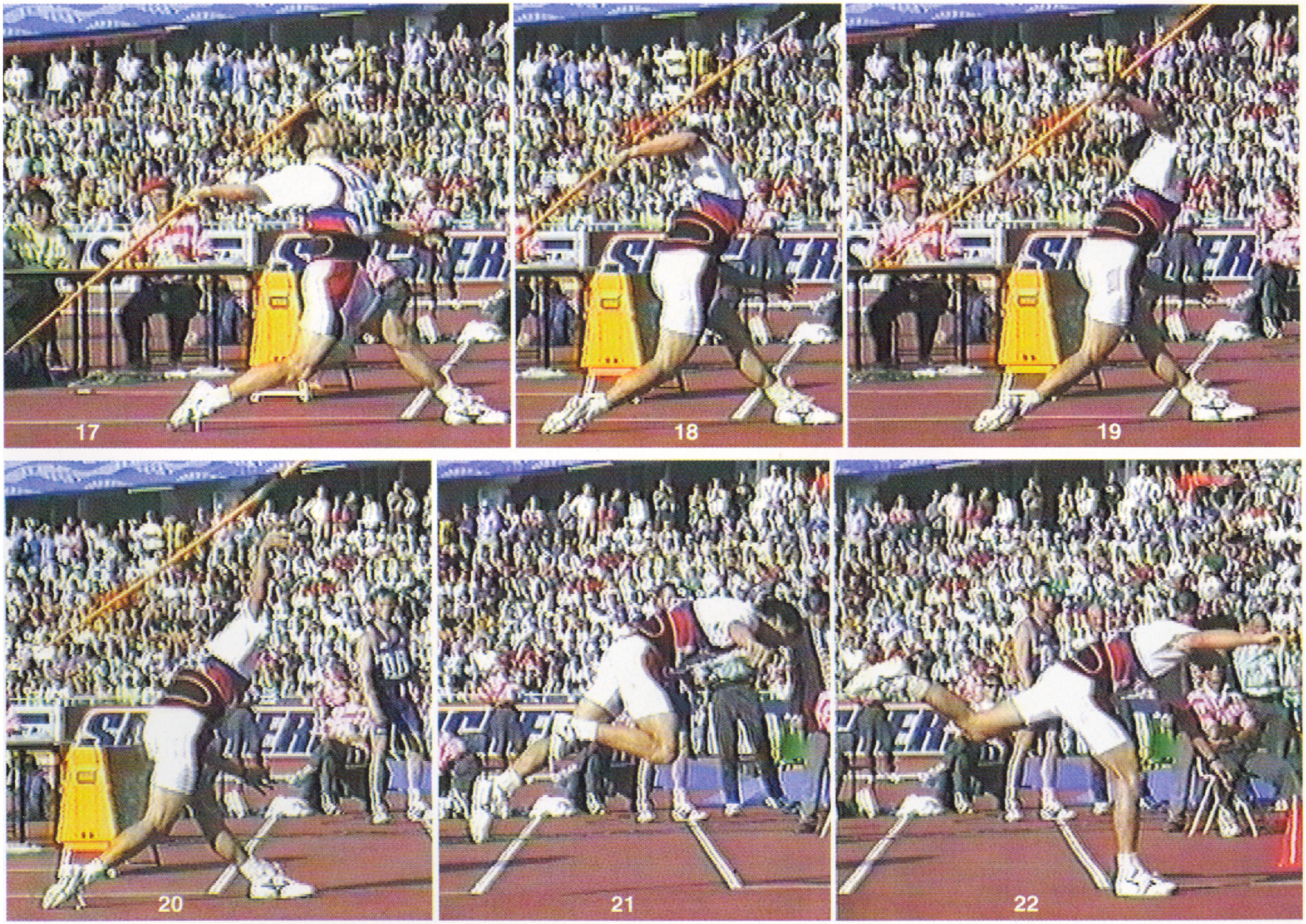
In order to assist those athletes who have no chance of reaching the final, we recommend that the IAAF support a video recording and biomechanical analysis of the qualifying rounds.

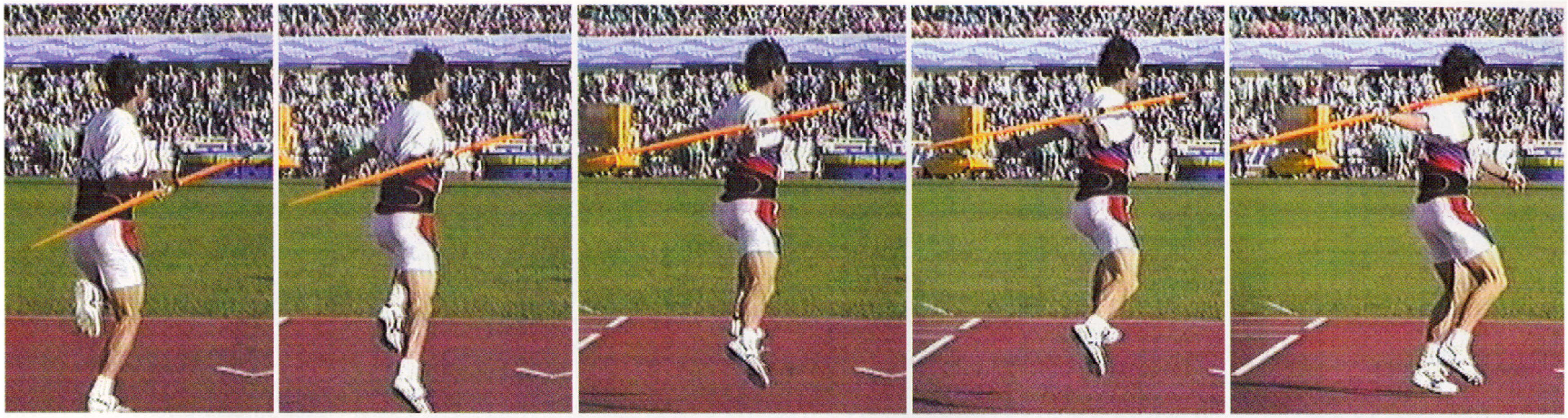
16 Top athletes in action: javelin throw

Two sequences of Jan Zelezny are presented: 89.58m. The sequences are based on the videomaterial taken by the biomechanics team, computerized realization by HOMMELAVS (© 1996).

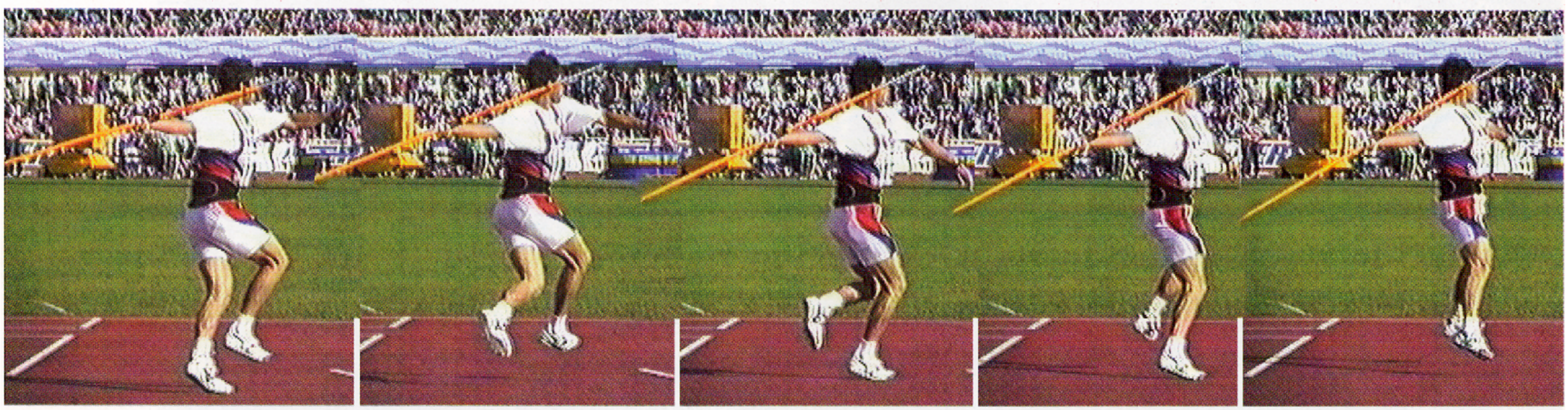

1
2
3
4
5
6
7
8


9
10
11
12
13
14
15
16

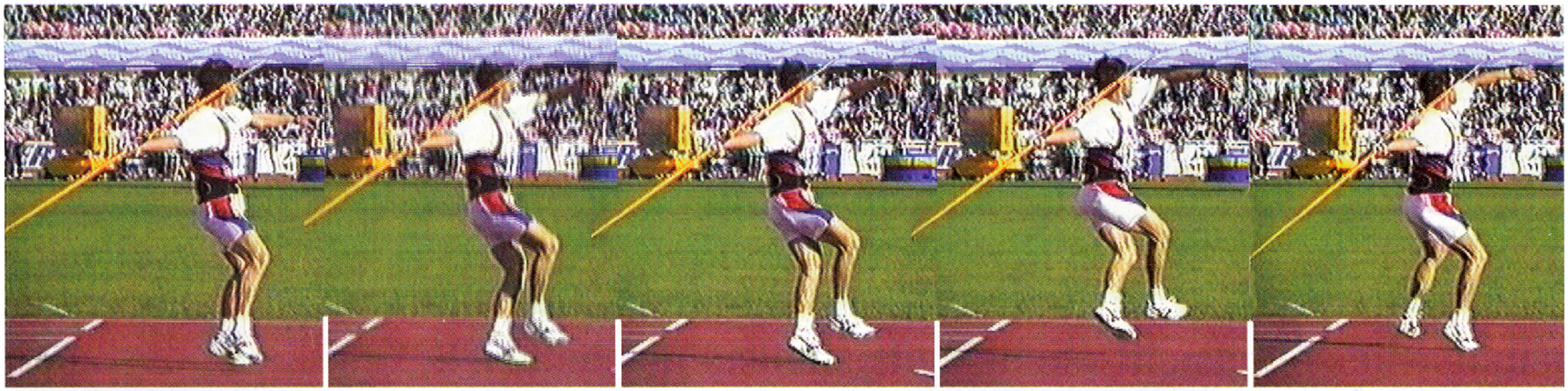

17
18
19
20
21
22



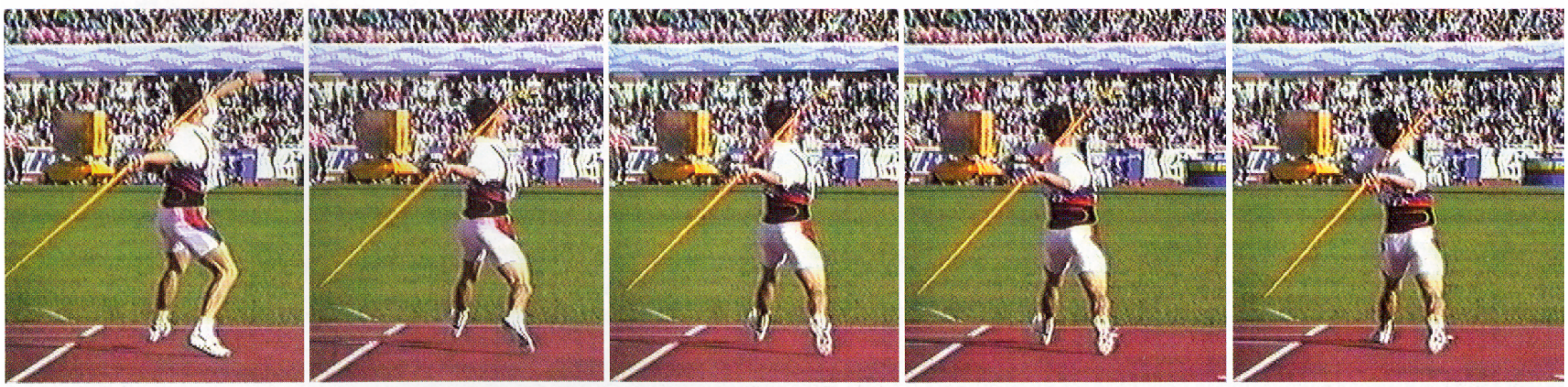
1 2 3 4 5



6 7 8 9 10



11 12 13 14 15



16 17 18 19 20

REFERENCES

BARTLETT, R.M.: The biomechanics of the discus throw: A review. Journal of Sports Sciences, 1992, 10, pp. 467-510

BARTONIETZ, K.: Die aeroclynamischen Eigenschaften von Speer und Diskus besser nutzen! Em Beitrag zur Unterstützung des Technik— trainings. Der Leichtathlet (Berlin) 22(1984)7, pp. 7-10

BARTONIETZ, K. / HELLMANN, K.: Empfehlungen für das Training am KTG Speerwurf mit Soilvorgaben an leistungsbestimmende biomechanische Parameter für spezielle Krafttrainingsubungen am KTG in Ableitung von den Anforderungen der Speerwurf-WettkampfUbung. 1985, Leipzig, Research Institute for Physical Culture and Sport, unpublished research result

BARTONIETZ, K.: Zur sportlichen Technik der Wettkampfubungen und zur Wirkungsrichtung ausgewshlter Trainingsubungen in den Wurf- und StoBdisziplinen der Leichtathletik (The technique of competition exercises and the effect of selected training exercises in the throwing events and shot put). Doctoral thesis FKS Leipzig, 1987, 189 p.

BARTONIETZ, K.: Drehtechnik kontra Angleittechnik — Erfahrungen, Erkenntnisse und Hypothesen zur KugelstoB—Drehtechnik, veranschaulicht an einem 22-ni-Stoll von Randy Barnes. Die Lehre der Leichtathletik, 29(1990)29, pp. 15-18, 29(1990)30, p. 22

BARTONIETZ, K.: Spezielle Analyse der WM 1991 in Tokyo: Wurf/StoB — Zuni Leistungsfaktor Tcchnik in den Wurf- und StoBdisziplinen bei den 3. Leichtathletik-Weltn,eisterschaften und Empfehlungen für das Techniktraining. Die Lehre der Leichtathletik, 31(1992)2, pp. 15-18, 31(1992)3, pp. 15-18

BARTONIETZ, K.: Biomechanical analysis of throws with hammers of various weight and length as basis for an effective training. In: Techniques in Athletics, The 1st International Conference, Cologne, 7-9 June 1990, Conference Proceedings, vol. 2, 542 -551 also in: Modern Athlete and Coach, 32(1994)4, pp. 33-36

BARTONIETZ, K.: Rotational shot put technique: biornechanic findings and recommendations for training. Track ft Field Quarterly Review, 93(1994)3, 18-28

BARTONIETZ, K. / FELDER, H.: WM 1993 — Technikanalyse der weltbcsten Athleten mm Speerwurf. Die Lehre der Leichtathletik 33(1994)26, pp. 15-18, 33(1994)27, pp. 15-18

BARTONIETZ, K.: Training of technique and specific power in throwing events. Modern Athlete and Coach, 32(1994)1, pp. 10-16

BARTONIETZ, K.: Moderne Auffassungen zur Entwicklung von Maxinialkraft—fShigkeiten. Theoretische Ans8tze und praktische Urn— setzung in den Wurfdisziplinen — em Uberblick. Die Lehre der Leichtathletik 34(1995)14, pp. 73-79, 34(1995)15, pp. 81-88, 34(1995)16, pp. 81-96

BEST, RJ.; BARTLETT, R.M.; SAWYER, R.A.: Optimal javelin release. Journal of Applied Biomechanics, 11(1995), pp. 371-394

BEST, R.J.; BARTLETT, R.M.; MORRISS, C.J. A three—dimensional analysis of javelin throwing technique. Journal of Sport Sciences 11(1993), pp. 315-328

BORGSTROM, A. / BARTONIETZ, K.: Biomechanics of the throwing events — an introduction to a simplified way of analyzing with normal video equipment. In: Documentation of the express information given in the throwing events during the 5th IAAF World Championships in Athletics, Goteborg 4-13/8 1995, pp. 10-21 also: Material of the IAAF International Coaching Seminar ‘Going for Gold in Goteborg 1995”, Goteborg 14-16 March 1995

DAPENA, J.: New insights on discus throwing. Track & Field Quarterly Review, 93(1994)3, pp. 37-42

DICKWACH, H. / SCHEIBE, K.: Weltstandsanalyse 1992: Tendcnzcn der Leistungsent— wicklung in den leichtathletischen Sprung— und Wurf—disziplinen. Leistungssport 23(1993)4, pp. 33-40

LOSCH, H.: Training derivations from biomechanical studies in the Hammer throw. The Thrower (1993)October, pp. 4-9

PENSIK0V, V.: Elena Zvereva throws the discus. Legkaja Atletika, (1989)9, pp. 16-17

PENSIKOV, V. / DENISSOVA, E.: Specific exercises for discus throwers. Modern Athlete and Coach, 31(1993)3, pp. 1 7-22

SIMON, J. / SIPKA, I.: Results of analyses of Jan Zelesny’s javelin throw technique and their paedagogic use. Lecture on International EEA Seminar, Nymburk, 10-13 November 1994

STASJUK, A.: Tolkateljam jadra. Specialnye podgotovitelnye i obshepodgotovitelnye uprashnenija (Special and general exercises for shot put preparation). Legkaja Atletika (1993)3, pp. 7-9

STASJUK, A.: General and specific exercises for javelin throwers. Modern Athlete and Coach, 32 (1994) 4, pp. 7-10

TUTEVIC, V.N.: Teorija sportivnych nletanij (Theory of the throws in athletics). Moscow 1969

UEYA, K.: The men’s throwing events. New Studies in Athletics 7 (1992) 1, pp. 57-65