IAAF World Championships
LONDON 2017

BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

Javelin Throw Men's

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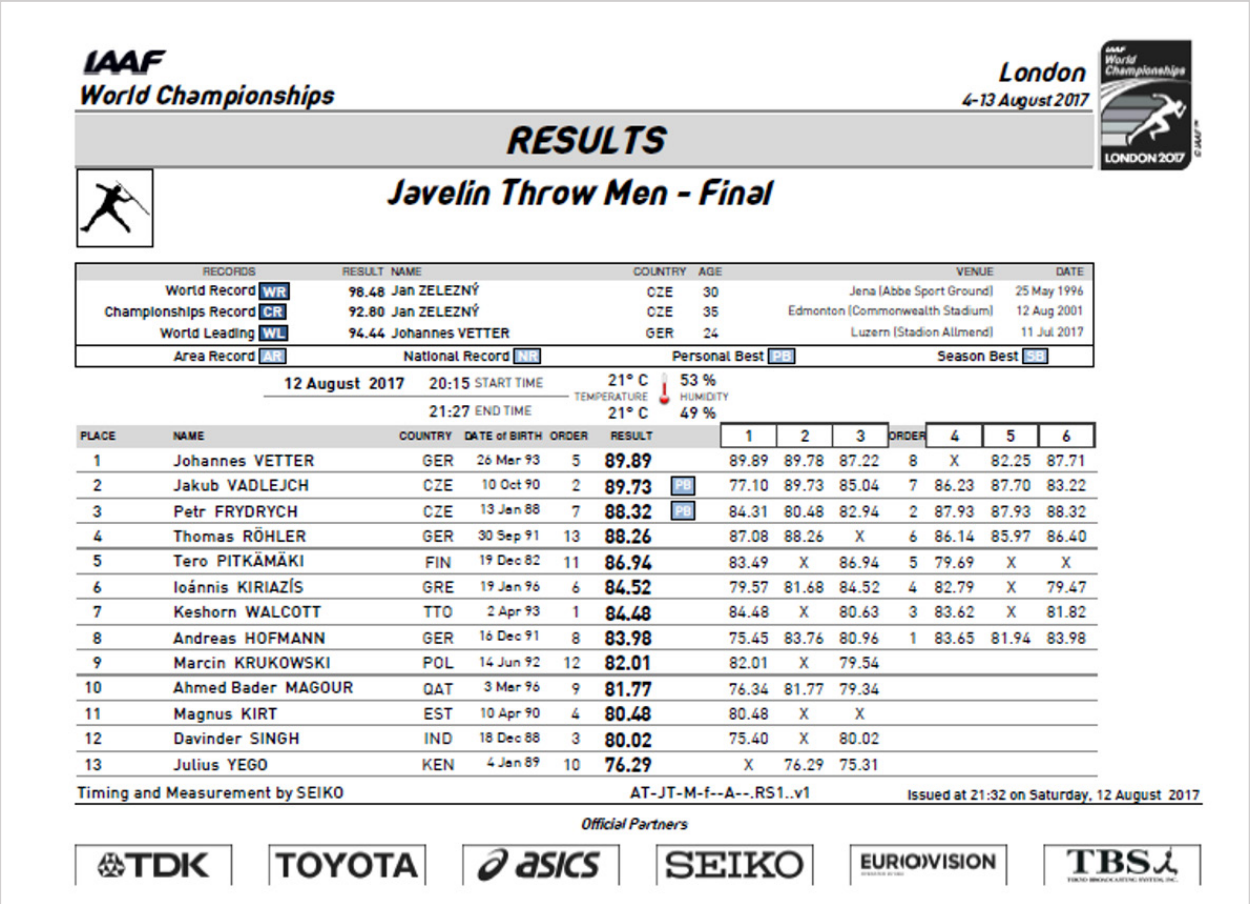
INTRODUCTION

The men's javelin final took place on the evening of August 12th in good weather conditions. Thomas Röhler and Johannes Vetter, both from Germany, were identified as strong candidates for the gold medal after producing world leading throws in 2017 of 93.90 m and 94.44 m, respectively. It was Vetter, however, who delivered the gold medal throw in the first round, recording a distance of 89.89 m. In contrast, Röhler's best attempt of 88.26 m in the second round was not enough to secure bronze medal, with Petr Frydrych of the Czech Republic producing a final throw of 88.32 m (a personal best) to consolidate third place. In a very close and competitive contest it was Jakub Vadlejch from the Czech Republic who produced a personal best throw of 89.73 m to secure the silver medal.



IAAF World Championships — London 4-13 August 2017

RESULTS

Javelin Throw Men - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	98.48	Jan ZELEZNÝ	CZE	30	Jena (Abbe Sport Ground)	25 May 1996
Championships Record CR	92.80	Jan ZELEZNÝ	CZE	35	Edmonton (Commonwealth Stadium)	12 Aug 2001
World Leading WL	94.44	Johannes VETTER	GER	24	Luzern (Stadion Allmend)	11 Jul 2017

Area Record AR | National Record NR | Personal Best PB | Season Best SB

12 August 2017 — 20:15 START TIME — 21° C TEMPERATURE — 53 % HUMIDITY

21:27 END TIME — 21° C — 49 %

PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT		1	2	3	ORDER	4	5	6
1	Johannes VETTER	GER	26 Mar 93	5	**89.89**		89.89	89.78	87.22	8	X	82.25	87.71
2	Jakub VADLEJCH	CZE	10 Oct 90	2	**89.73**	PB	77.10	89.73	85.04	7	86.23	87.70	83.22
3	Petr FRYDRYCH	CZE	13 Jan 88	7	**88.32**	PB	84.31	80.48	82.94	2	87.93	87.93	88.32
4	Thomas RÖHLER	GER	30 Sep 91	13	**88.26**		87.08	88.26	X	6	86.14	85.97	86.40
5	Tero PITKÄMÄKI	FIN	19 Dec 82	11	**86.94**		83.49	X	86.94	5	79.69	X	X
6	Ioánnis KIRIAZÍS	GRE	19 Jan 96	6	**84.52**		79.57	81.68	84.52	4	82.79	X	79.47
7	Keshorn WALCOTT	TTO	2 Apr 93	1	**84.48**		84.48	X	80.63	3	83.62	X	81.82
8	Andreas HOFMANN	GER	16 Dec 91	8	**83.98**		75.45	83.76	80.96	1	83.65	81.94	83.98
9	Marcin KRUKOWSKI	POL	14 Jun 92	12	**82.01**		82.01	X	79.54				
10	Ahmed Bader MAGOUR	QAT	3 Mar 96	9	**81.77**		76.34	81.77	79.34				
11	Magnus KIRT	EST	10 Apr 90	4	**80.48**		80.48	X	X				
12	Davinder SINGH	IND	18 Dec 88	3	**80.02**		75.40	X	80.02				
13	Julius YEGO	KEN	4 Jan 89	10	**76.29**		X	76.29	75.31				

Timing and Measurement by SEIKO — AT-JT-M-f--A--.RS1..v1 — Issued at 21:32 on Saturday, 12 August 2017

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METHODS

Three camera positions were secured at vantage locations around the stadium (Figure 1). A total of three high-speed cameras were used to record the action during the javelin final. Three Sony PXW-FS7 cameras operating at 150 Hz (shutter speed: 1/1250; ISO: 2000-4000 depending on the light; FHD: 1920x1080 px) were positioned at the three locations to provide three-dimensional (3D) footage for the analysis of all key phases of the javelin throw.

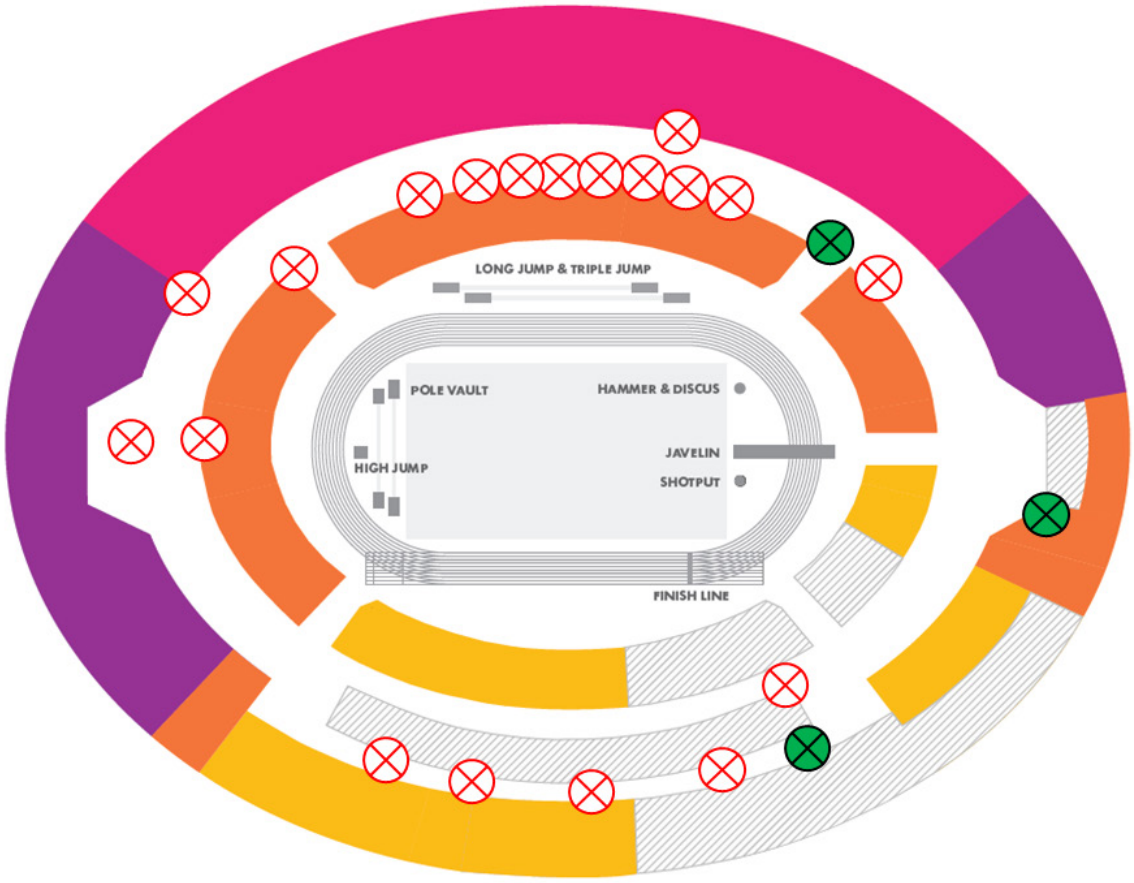

Figure 1. Stadium layout with camera locations for the men's javelin throw (shown in green).

Before and after the final competition a calibration procedure was conducted to capture the performance volume. A rigid cuboid calibration frame was positioned at multiple points on the javelin runway to ensure an accurate capture volume of the athlete's approach and release. This approach produced a large number of non-coplanar control points within the calibrated volume to facilitate the construction of a global coordinate system.

All video files were imported into SIMI Motion (SIMI Motion version 9.2.2, Simi Reality Motion Systems GmbH, Germany) and manually digitised by a single experienced operator to obtain

kinematic data. Each video file was synchronised at four critical instants to synchronise the two-dimensional coordinates from each camera involved in the recording. Both the javelin and body segments were tracked 15 m before the throw line and up to 10 frames after release to provide padding during filtering. All video files were digitised frame-by-frame, and upon completion, the points-over-completion was used to make any necessary adjustments. The javelin and selected body segments were tracked at each point through the full motion.

Figure 2. Javelin calibration frame during construction at the London Stadium.

The Direct Linear Transformation (DLT) algorithm was used to reconstruct the real-world 3D coordinates from individual camera's x and y image coordinates. The reliability of the manual digitising was estimated by repeated digitising of a whole throw with an intervening period of 48 hours. Results showed minimal systematic and random errors and therefore confirmed the high reliability of the digitising process. De Leva's (1996) body segment parameter models were used to obtain data for the whole body centre of mass. A recursive second-order, low-pass Butterworth digital filter (zero phase-lag) was employed to filter the raw coordinate data. The cut-off frequencies were calculated using residual analysis.

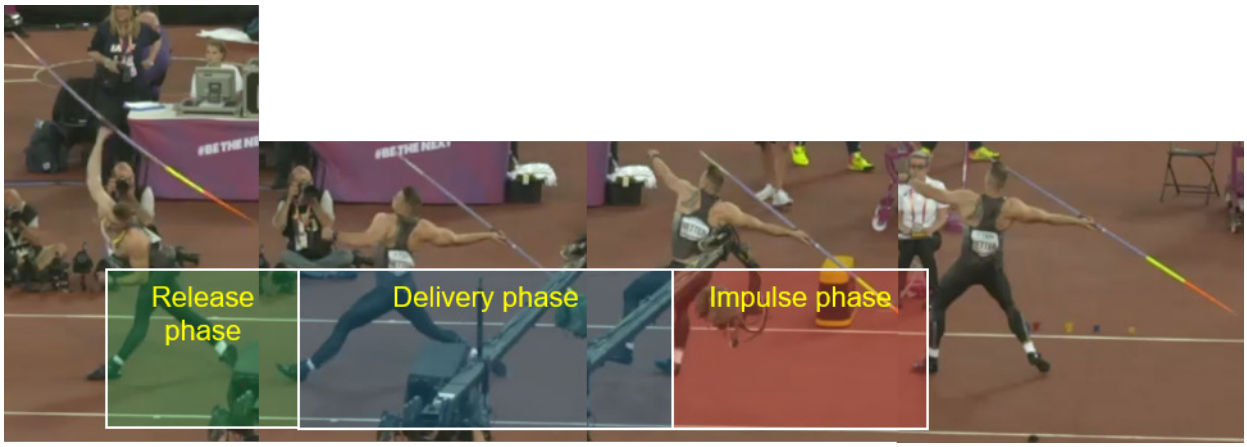

Figure 3. Visual representation of key phases leading up to release.

For the right-handed athletes, the impulse phase was from penultimate left foot touchdown to the final right foot touchdown, whereas for the left-handed athlete (Kirt), the impulse phase was from penultimate right foot touchdown to the final left foot touchdown. The delivery phase was from final right foot touchdown to final left foot touchdown for all athletes apart from Kirt, where his delivery phase was from final left foot touchdown to final right foot touchdown. Therefore, the release phase was from final left foot touchdown to release for all athletes apart from Kirt, where his release phase was from final right foot touchdown to release.

Table 1. List of variables.

Variable	Definition
Release velocity	The resultant velocity of the javelin at the point of release.
Horizontal release velocity	The horizontal (anteroposterior) component of the javelin release velocity.
Vertical release velocity	The vertical component of the javelin release velocity.
Release height	The vertical distance from the javelin's grip to the ground at release.
Release angle	The angle between the javelin direction of travel and the horizontal at release.
Attitude angle	The angle between the javelin's longitudinal axis and the horizontal at release.
Angle of attack	The difference between the angle of release and the angle of attitude at release.
Sideslip angle	The angle between the direction of the velocity vector at release and the javelin's longitudinal axis (looking from behind).

Forearm angle at release	The angle between the forearm and the horizontal at release.
Upper arm angle at release	The angle between the upper arm and the horizontal at release.
Trunk angle at release	The angle between the trunk and the horizontal at release.
Horizontal CM velocity	The anteroposterior velocity of the body CM at release.
Vertical CM velocity	The vertical velocity of the body CM at release.
Absolute CM velocity	The resultant velocity of the body CM at release.
D_{imp} – Distance of impulse step	The penultimate left foot contact to final right foot contact.
D_{del} – Distance of delivery step	The final right foot contact to final left foot contact.
D_{FL} – Distance to the foul line	The horizontal distance from the plant foot to the foul line at release.
Duration of impulse phase	The time between penultimate left foot contact and final right foot contact.
Duration of delivery phase	The time between final right foot contact and final left foot contact.
Duration of release phase	The time between final left foot contact and release.
Approach velocity	The velocity of the head at the start of the impulse phase.
CM-RF	The distance between the whole-body CM and the CM of the right foot at the beginning of the delivery phase.
LF-JC	The distance between the point of left foot contact and the javelin grip at the beginning of the release phase.
TT-LTD	The angle of the trunk relative to the vertical at the beginning of the release phase. A positive angle indicates a forwards lean, whereas a negative angle indicates a backwards lean.
SKF	The angle of the supporting (left) knee joint (thigh-shank angle) at the point of release and considered to be 180° in the anatomical standing position. An angle greater than 180° indicates hyperextension at the knee joint.

Note: *CM = centre of mass.*

RESULTS

The following table shows the official distance of the women's javelin final in comparison to personal and season's best throws.

Table 2. Attempts analysed and official distances for each athlete.

Athlete	Attempt analysed	Official distance (m)	% Season's best	% Personal best
VETTER	1	89.89	−4.82	−4.82
VADLEJCH	2	89.73	+1.94	+1.94
RYDRYCH	6	88.32	+2.44	+0.10
RÖHLER	2	88.26	−6.01	−6.01
PITKÄMÄKI	3	86.94	−1.51	−5.01
KIRIAZÍS	3	84.52	−3.97	−3.97
WALCOTT	1	84.48	−2.46	−6.30
HOFMANN	6	83.98	−5.42	−5.42
KRUKOWSKI	1	82.01	−6.90	−6.90
MAGOUR	2	81.77	−4.06	−4.06
KIRT	1	80.48	−6.48	−7.12
SINGH	3	80.02	−5.38	−5.38
YEGO	2	76.29	−13.28	−17.72

Biomechanics of the javelin release

This section of the report presents the key javelin release parameters across all athletes. The medallists are highlighted in their respective medal colours in the figures shown.

Table 3. Javelin release parameters.

	Release velocity (m/s)	Release angle (°)	Release height (m)
VETTER	28.48	32.5	1.96
VADLEJCH	28.23	35.2	1.94
FRYDRYCH	29.17	28.0	2.14
RÖHLER	28.10	36.9	1.94
PITKÄMÄKI	28.55	35.3	2.02
KIRIAZÍS	28.47	38.2	2.09
WALCOTT	28.16	31.8	2.04
HOFMANN	27.96	35.0	2.21
KRUKOWSKI	27.67	33.7	2.07
MAGOUR	27.54	35.5	1.96
KIRT	27.34	32.7	1.93
SINGH	26.67	35.6	1.89
YEGO	26.81	36.7	1.76

Figure 4 shows the respective contributions of the horizontal and vertical components of javelin release velocity, highlighting the potential trade-off between horizontal and vertical velocities. Initials indicate each athlete and medallists have been highlighted by filled circles with medal colours.

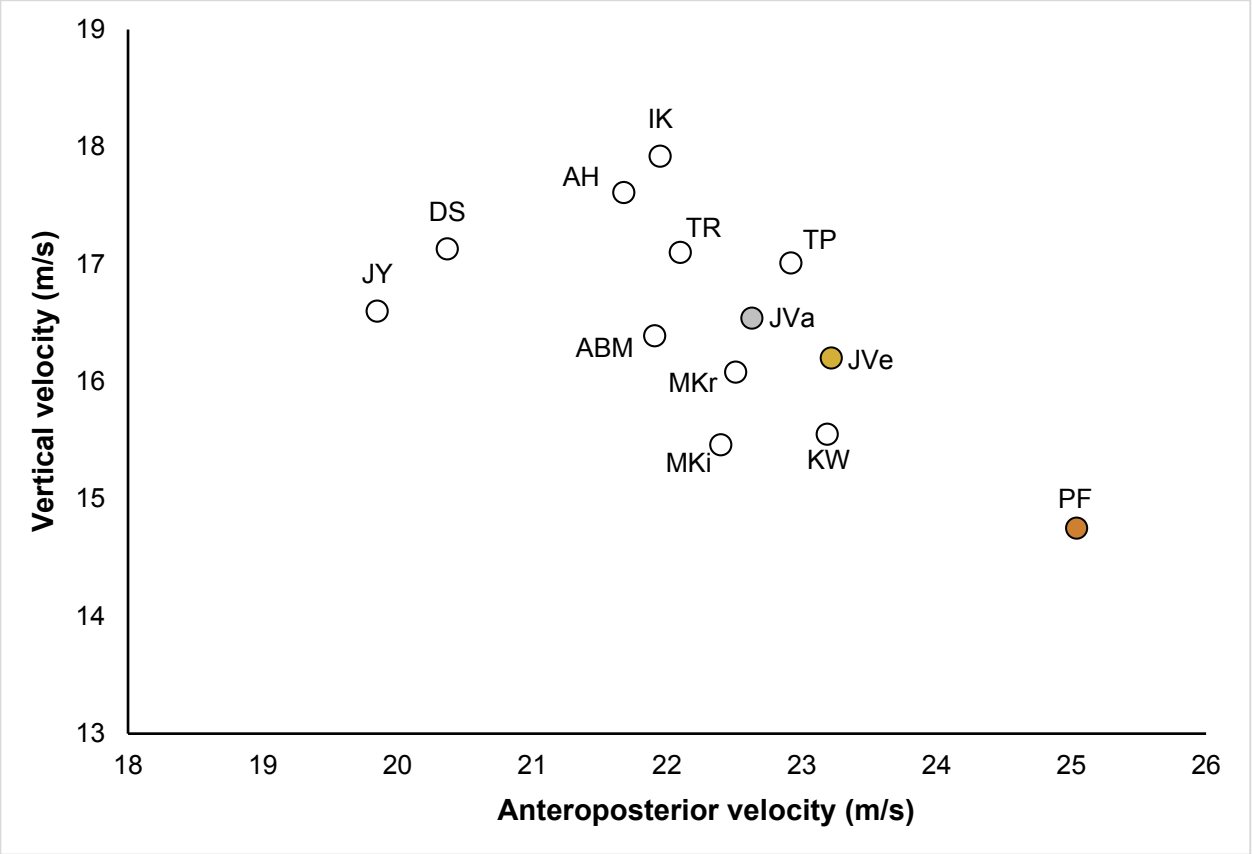

Figure 4. Horizontal (anteroposterior) and vertical components of javelin release velocity.

Table 4. Other javelin release angles.

	Attitude angle (°)	Angle of attack (°)	Sideslip (°)
VETTER	39.7	7.2	13.4
VADLEJCH	41.9	6.8	23.5
FRYDRYCH	27.7	−0.3	16.3
RÖHLER	38.3	1.3	13.0
PITKÄMÄKI	40.2	4.9	8.8
KIRIAZÍS	40.2	2.0	14.3
WALCOTT	41.9	10.1	14.6
HOFMANN	44.6	9.5	18.5
KRUKOWSKI	41.6	7.9	13.3
MAGOUR	36.5	0.9	11.1
KIRT	42.5	9.9	6.4
SINGH	38.2	2.6	15.9
YEGO	41.3	4.7	12.9

Note: *A negative angle of attack indicates an angle of release that was greater than the angle of attitude. For the athletes who were right-handed throwers, a positive sideslip would indicate a sideslip to the right, whereas a positive angle for the left-handed thrower would indicate a sideslip to the left.*

Table 5. Upper body kinematics of each athlete at release. All angles are expressed relative to the horizontal.

	Trunk angle (°)	Upper arm angle (°)	Forearm angle (°)
VETTER	54.4	45.5	60.1
VADLEJCH	68.9	41.8	57.2
FRYDRYCH	55.1	65.1	55.4
RÖHLER	64.4	38.7	56.6
PITKÄMÄKI	47.6	46.8	66.0
KIRIAZÍS	58.1	49.6	58.0
WALCOTT	67.6	34.7	61.4
HOFMANN	61.1	56.0	75.7
KRUKOWSKI	54.8	51.3	69.8
MAGOUR	64.5	52.8	57.0
KIRT	57.1	35.9	58.7
SINGH	61.8	51.0	68.0
YEGO	47.7	51.1	60.7

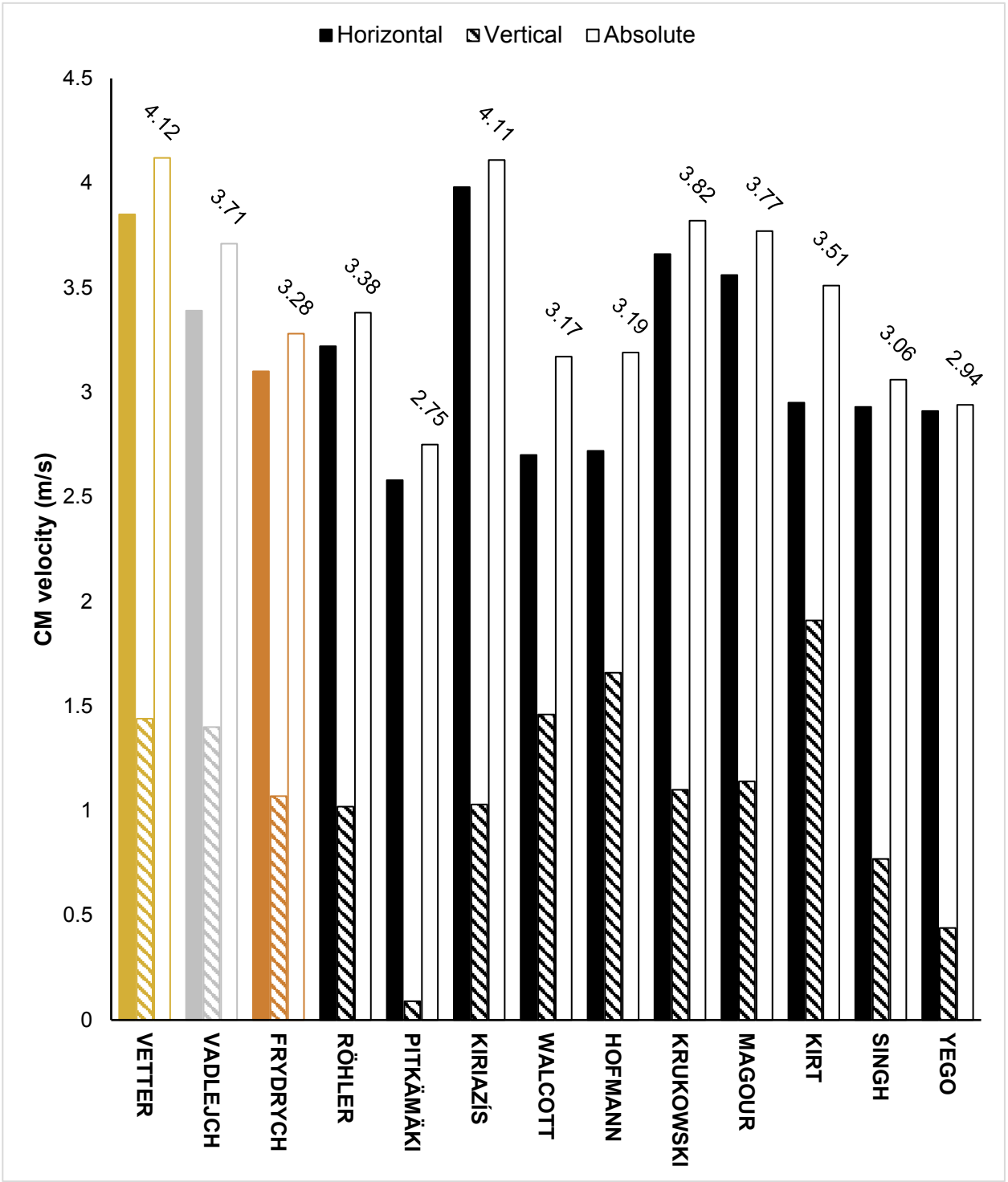

Figure 5. Horizontal, vertical and absolute components of each athlete's centre of mass velocity at the point of javelin release. Absolute (resultant) velocity values are labelled above each white column.

Analysis of the approach phases

This section of the report presents key temporal information on the main phases of the men's javelin throw. The key phases are presented both in terms of absolute (Table 6 and Figure 6) and relative (Figure 7) terms. The athletes' approach characteristics are also show across the final 15 m of the runway, including approach velocity (Figure 8). Several technique variables are also presented as requested by the coaching collaborator (Table 8).

Table 6. Absolute duration of each analysed key phase before release.

	Impulse phase (ms)	Delivery phase (ms)	Release phase (ms)
VETTER	400	220	133
VADLEJCH	280	247	133
FRYDRYCH	287	280	133
RÖHLER	340	253	120
PITKÄMÄKI	360	167	127
KIRIAZÍS	413	173	140
WALCOTT	380	193	120
HOFMANN	427	173	147
KRUKOWSKI	340	187	107
MAGOUR	313	147	127
KIRT	347	213	140
SINGH	447	180	107
YEGO	367	213	140

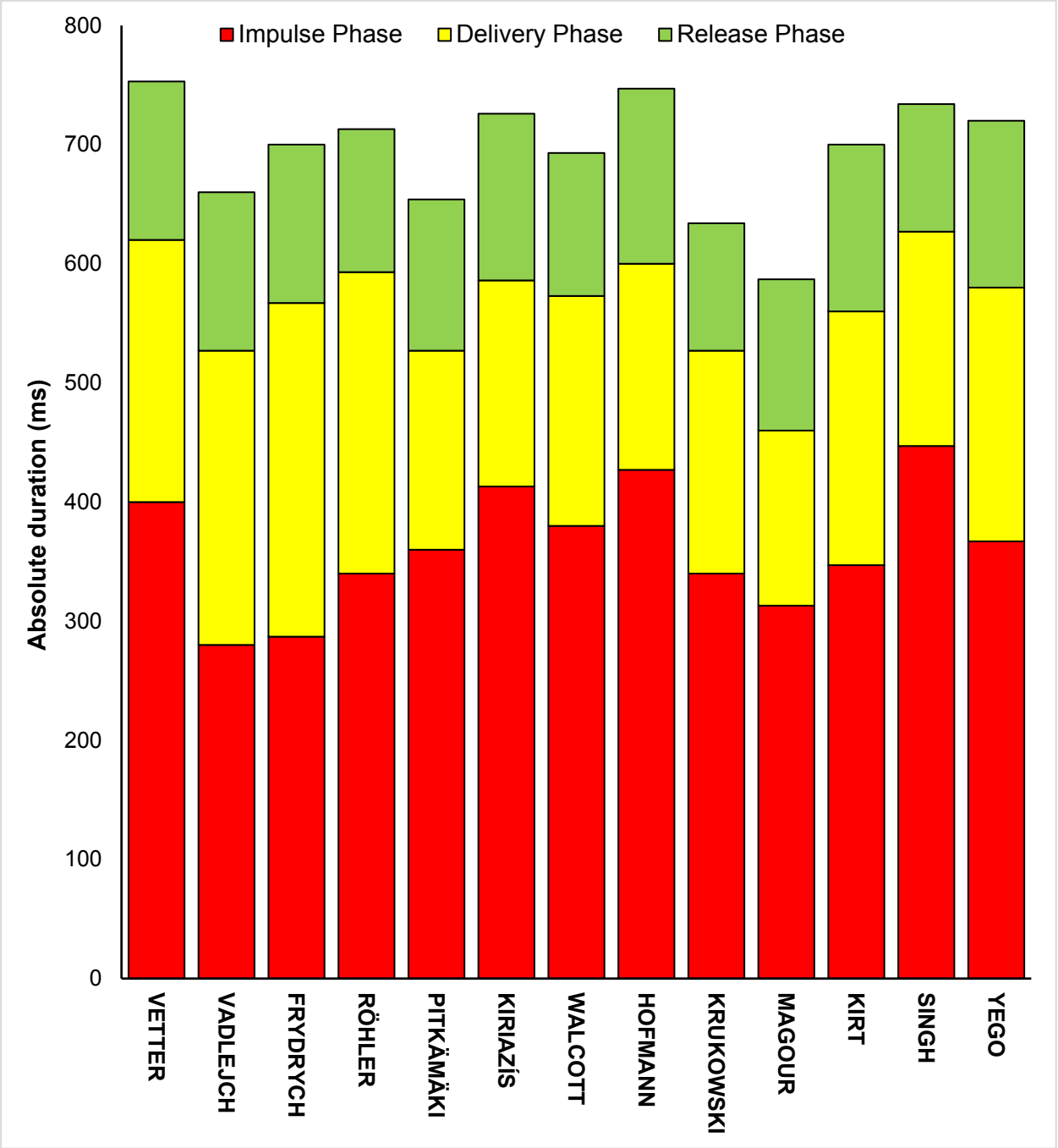

Figure 6. Absolute durations of key phases before release.

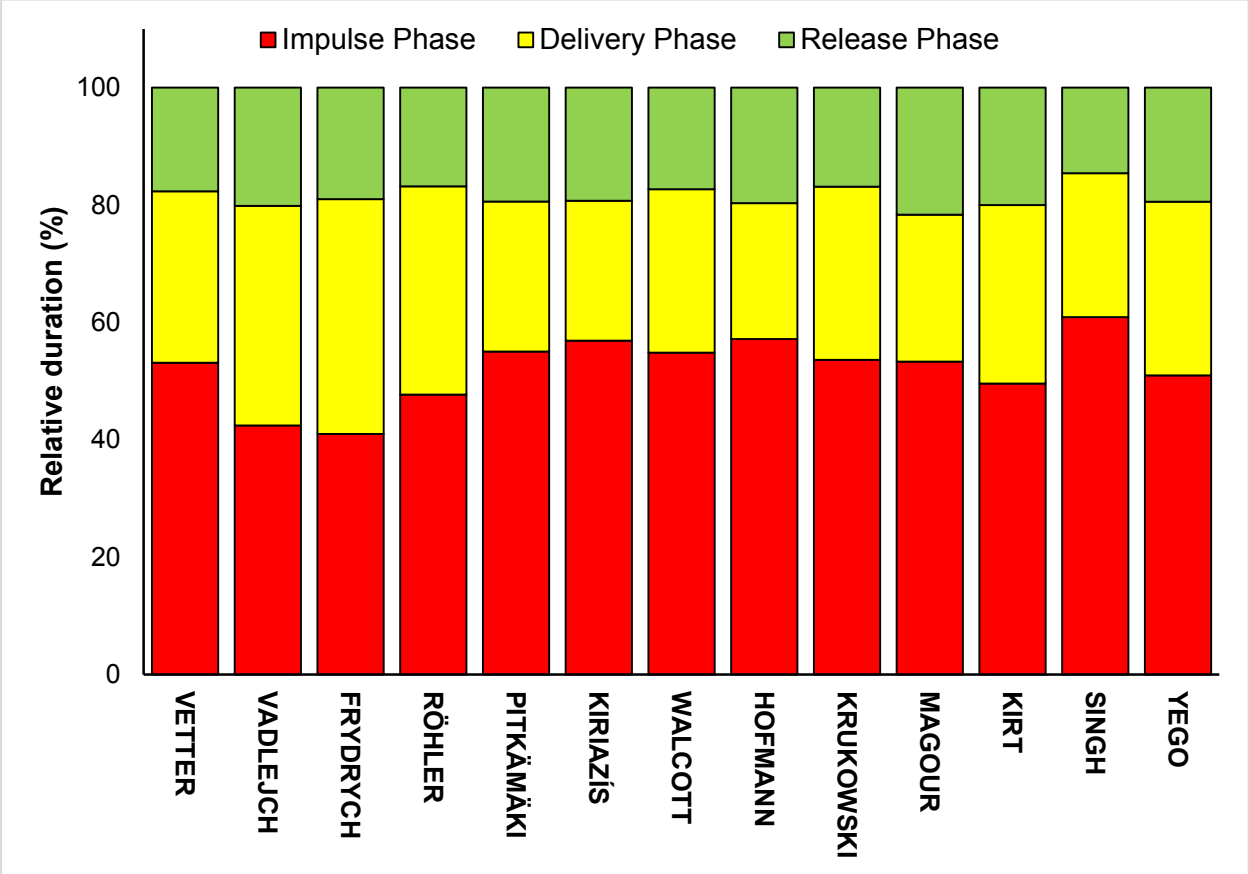

Figure 7. Relative durations of key phases before release. 0 % indicates left foot contact at the start of the impulse phase and 100 % indicates javelin release.

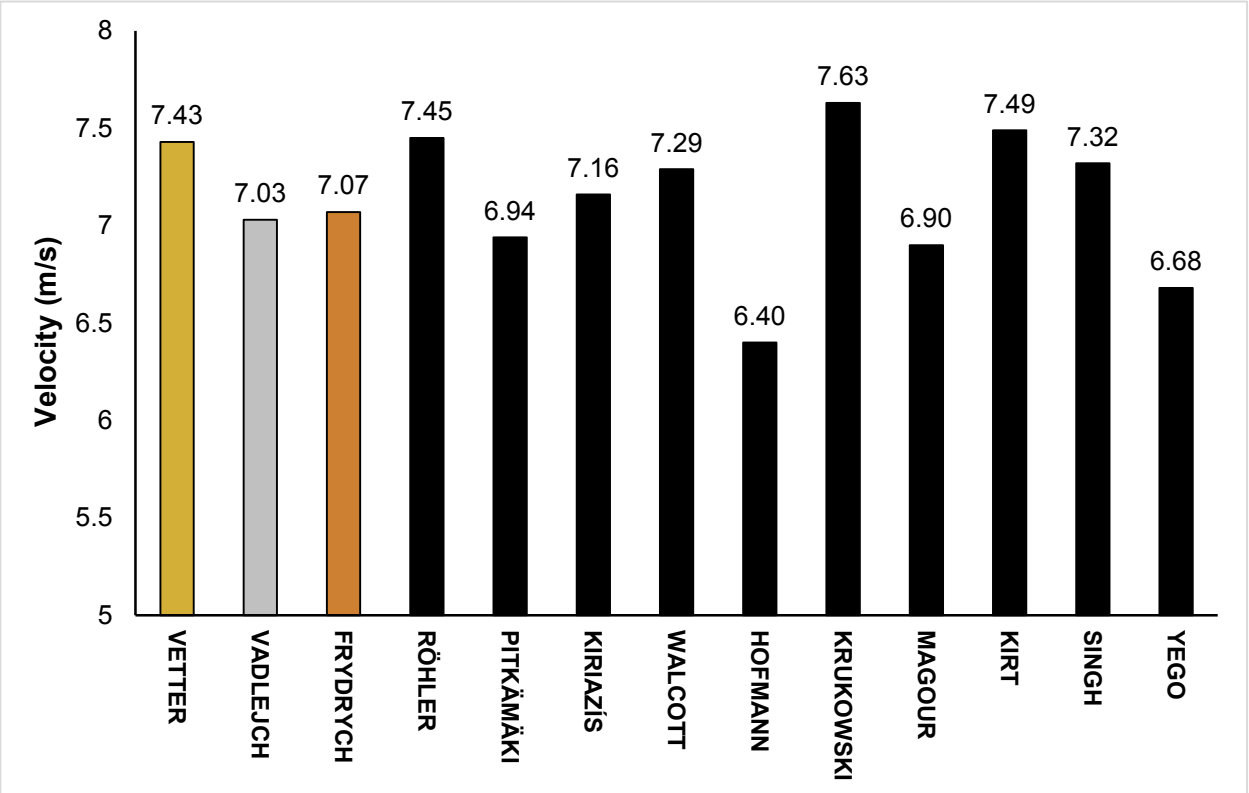

Figure 8. Approach velocity for each athlete at the start of the impulse stride phase.

Figures 9.1 to 9.13 show the motion path of each athlete's head during the final 15 m of approach. The solid black line indicates athlete's relative midline when entering last 15 m and the solid white line represents the foul line.

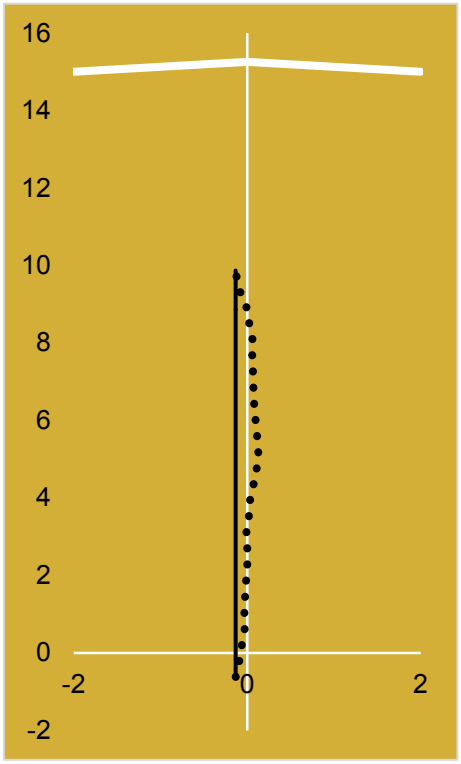

Figure 9.1. Absolute motion path of the head for Johannes Vetter throughout the last 15 m of approach.

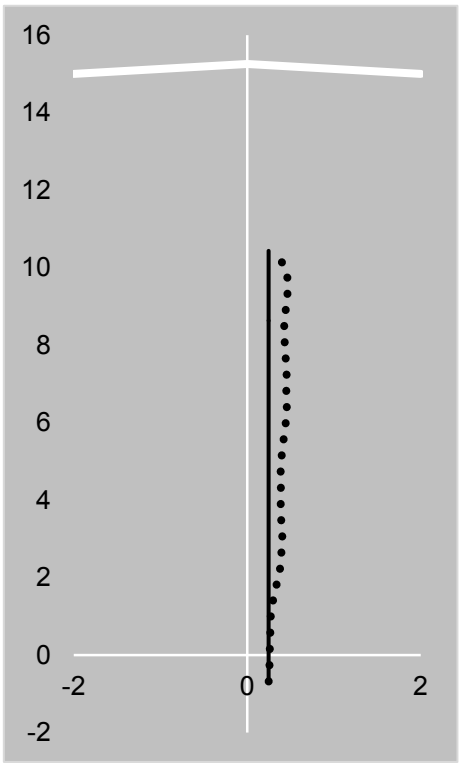

Figure 9.2. Absolute motion path of the head for Jakub Vadlejch throughout the last 15 m of approach.

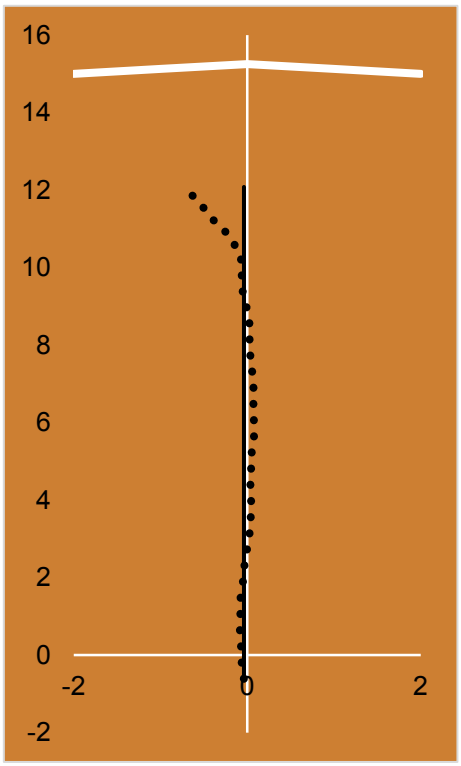

Figure 9.3. Absolute motion path of the head for Petr Frydrych throughout the last 15 m of approach.

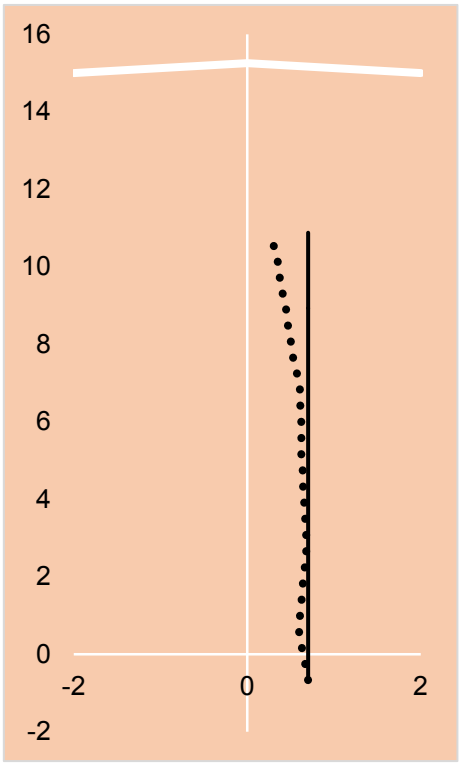

Figure 9.4. Absolute motion path of the head for Thomas Röhler throughout the last 15 m of approach.

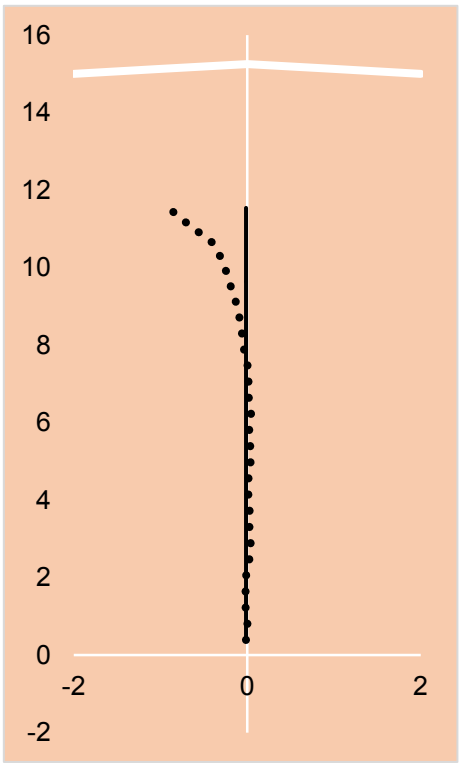

Figure 9.5. Absolute motion path of the head for Tero Pitkämäki throughout the last 15 m of approach.

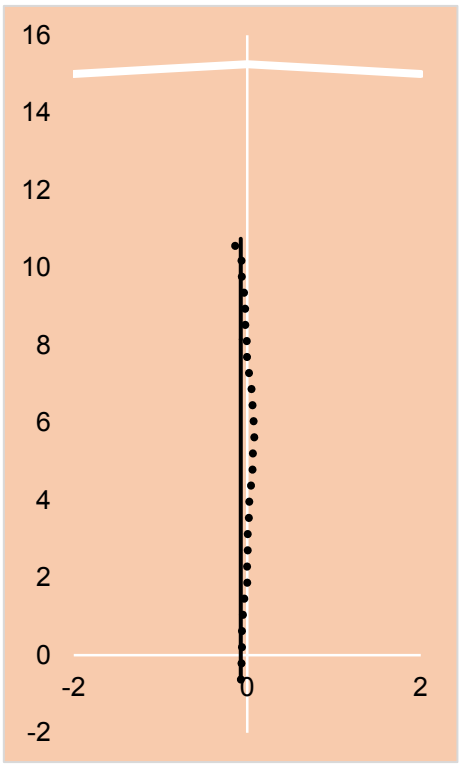

Figure 9.6. Absolute motion path of the head for Ioánnis Kiriazís throughout the last 15 m of approach.

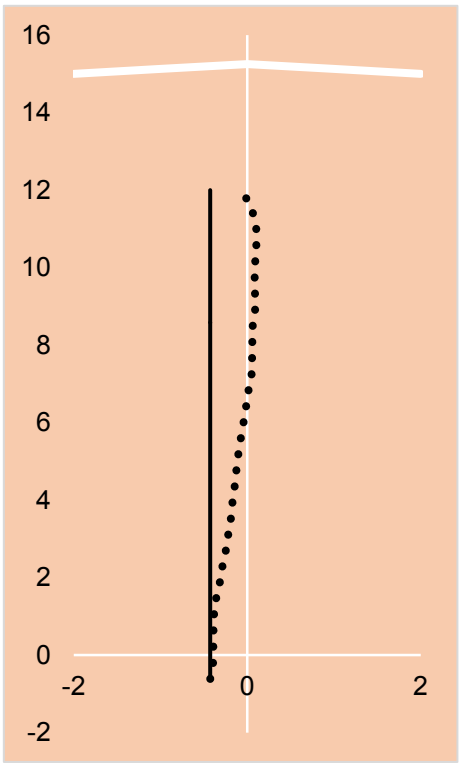

Figure 9.7. Absolute motion path of the head for Keshorn Walcott throughout the last 15 m of approach.

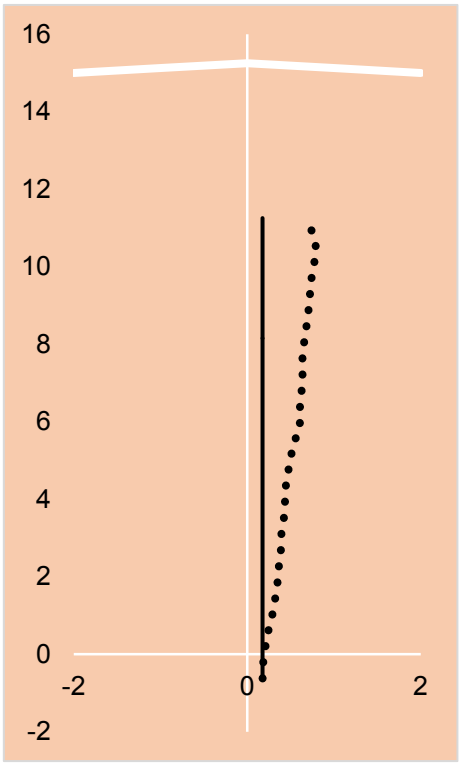

Figure 9.8. Absolute motion path of the head for Andreas Hofmann throughout the last 15 m of approach.

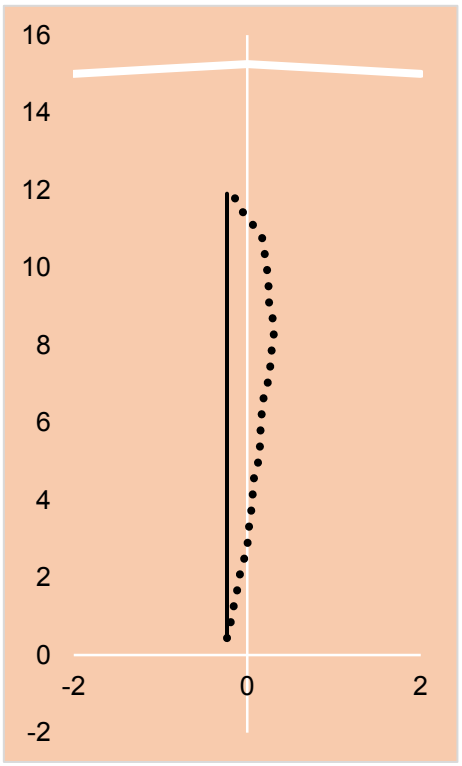

Figure 9.9. Absolute motion path of the head for Marcin Krukowski throughout the last 15 m of approach.

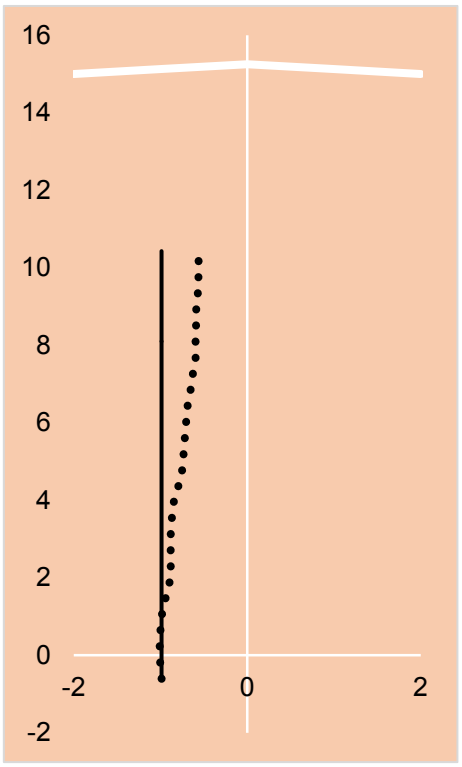

Figure 9.10. Absolute motion path of the head for Ahmed Badir Magour throughout the last 15 m of approach.

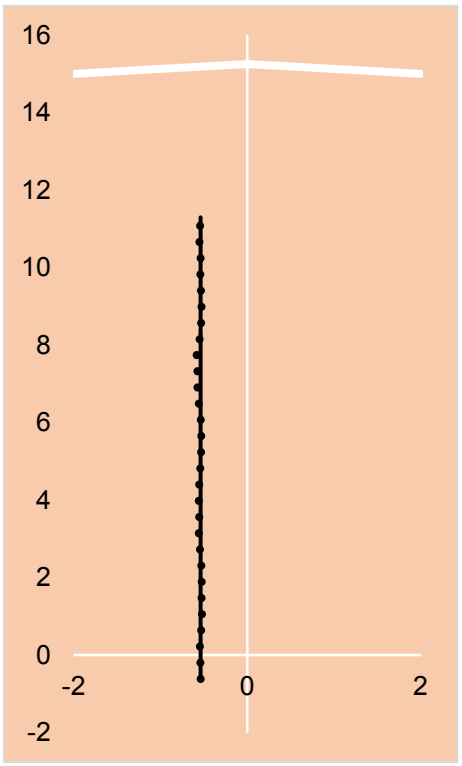

Figure 9.11. Absolute motion path of the head for Magnus Kirt throughout the last 15 m of approach.

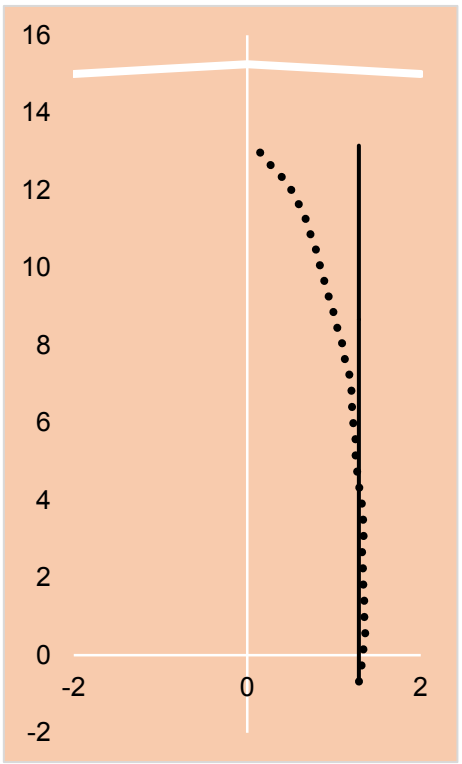

Figure 9.12. Absolute motion path of the head for Davinder Singh throughout the last 15 m of approach.

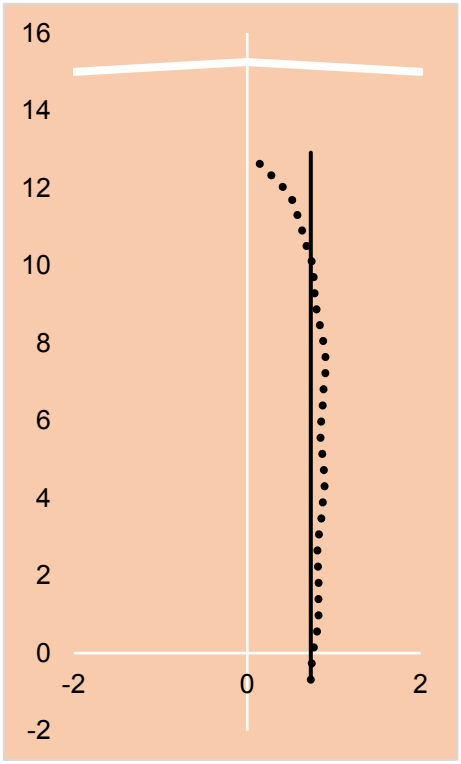

Figure 9.13. Absolute motion path of the head for Julius Yego throughout the last 15 m of approach.

Table 7. Various distance parameters for each athlete during different phases of the approach.

	D_{imp} (m)	D_{del} (m)	D_{FL} (m)
VETTER	2.32	2.26	3.50
VADLEJCH	1.74	2.10	2.78
FRYDRYCH	1.83	2.06	4.02
RÖHLER	2.14	2.17	3.46
PITKÄMÄKI	2.01	1.59	4.38
KIRIAZÍS	2.48	1.67	4.52
WALCOTT	2.30	1.63	2.36
HOFMANN	2.92	1.48	3.87
KRUKOWSKI	2.30	1.68	4.12
MAGOUR	1.62	1.60	3.31
KIRT	2.26	1.77	3.54
SINGH	2.60	1.50	1.54
YEGO	2.14	1.70	2.09

Note: *D_{imp} = distance covered during impulse phase; D_{del} = distance covered during delivery phase; D_{FL} = plant foot distance to the foul line at release.*

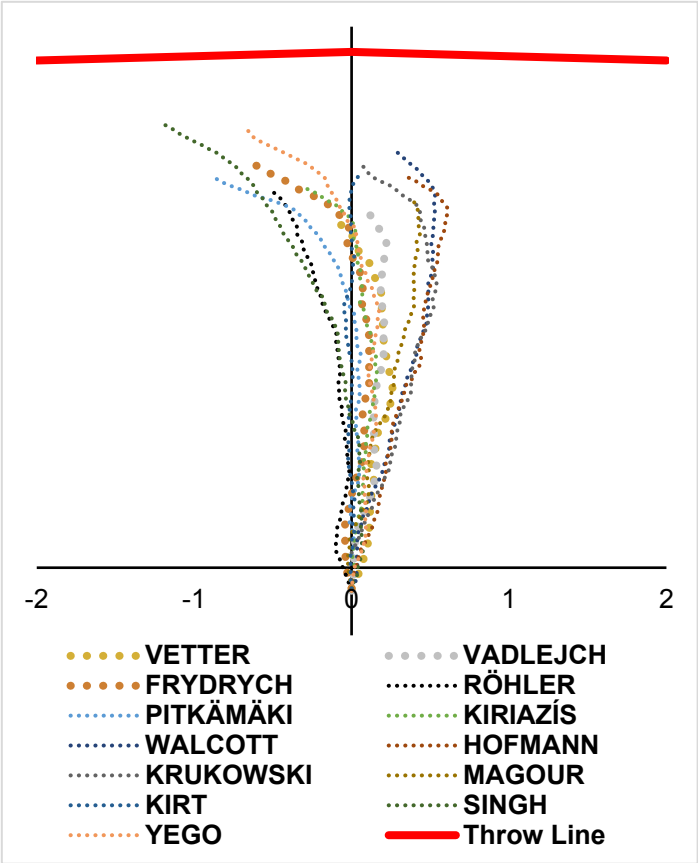

Figure 10. Relative motion path of each athlete's head during the last 15 m of approach.

Table 8. Other key variables requested by the coaching collaborator.

	CM-RF (m)	LF-JC (m)	TT-LTD (°)	SKF (°)
VETTER	−0.11	2.04	−7.2	190.0
VADLEJCH	−0.35	1.80	−15.1	172.7
FRYDRYCH	−0.48	1.92	−13.7	169.7
RÖHLER	−0.41	1.97	−14.2	192.4
PITKÄMÄKI	−0.25	1.94	−18.1	158.0
KIRIAZÍS	−0.15	1.86	−14.7	125.9
WALCOTT	−0.16	1.89	−11.0	170.2
HOFMANN	−0.35	2.01	−15.9	150.0
KRUKOWSKI	−0.29	1.85	−16.4	189.0
MAGOUR	0.01	1.86	−10.9	153.9
KIRT	−0.57	1.94	−14.4	165.8
SINGH	−0.19	1.86	−16.0	134.0
YEGO	−0.28	1.79	−11.9	138.0

Note: *A negative CM-RF values indicates the right (or left for Kirt) foot is ahead of the centre of mass. A negative TT-LTD angle indicates a backwards tilt of the trunk.*

COACH'S COMMENTARY

The biomechanical study looked at many variables of the athletes' furthest throws and it is hoped the data will be very helpful to coaches looking to understand what happened and highlights the different things athletes do to enable them to generate the release velocities necessary to propel the javelin out to world class distances. It is important to note that the data cannot be looked at in isolation as clearly the variables are very much interrelated.

As a javelin coach, I am particularly interested in the speed of the athletes at the point of the impulse step, the length of the impulse step, width of the throwing base, distance of bracing leg from the scratch line, amount of bend in the bracing leg before and at release, and the ability to stop.

Looking at the path of the athlete's head in relation to their relative midline entering the last 15 m of the run-up was interesting as it gives a visual perspective of how the athlete controls their centre of gravity whilst moving from front on to side on and throughout the delivery of the throw. This is a crucial element of the throw as an off-balance athlete will find it much harder to replicate good technique and maintain desirable technical positions than someone who is balanced. Therefore, leaning your head away from the CM will introduce balance / control issues that can be avoided with better posture and awareness.

General observations and comments on the men's final

Thirteen men took part in the final as they all exceeded the automatic qualification standard of 83 m. It turned out to be a very close high quality contest with only 1.63 m covering the first four athletes, the gold medal was won with a throw of 89.89 m and 88.26 m was in 4th place.

Only two athletes in the top eight improved in the last three rounds; significantly Petr Frydrych (last round to snatch the bronze medal) and Andreas Hofmann (last round – but remained 8th).

Release velocity and launch angles

As you would expect there is a very strong correlation (0.85) between distance thrown and release velocity. However, the data shows that gold medal winner Johannes Vetter with 28.48 m/s did not generate the fastest release velocity; Petr Frydrych (bronze) produced the fastest release velocity javelin at 29.17 m/s with Tero Pitkämäki (5th place) delivering the second fastest release velocity at 28.55 m/s. Clearly, other key factors influenced how far their respective javelins flew.

To highlight this Johannes Vetter (28.48 m/s) and Ioannis Kiriazís (28.47 m/s) had almost identical release velocities and yet the resultant distances were 5.37 m apart (89.89 m – 84.52 m). The

loss of distance must be down to the angle of release and its relationship to angle of attitude & sideslip. Both athletes had a similar angle of attitude (Vetter 39.7° and Kiriazís 40.2°) and sideslip (Vetter 13.4° and Kiriazís 14.3°). However, Vetter had a release angle of 32.5° compared to 38.2° for Kiriazís. Vetter therefore had a greater angle of attack, which must have had a positive aerodynamic effect on the flight of the javelin. It is important to note that they threw javelins made by different manufacturers (i.e. Nemeth – Vetter, and Nordic – Kiriazís), which could have different flex characteristics that would obviously influence the final distance. It is also not known if climatic conditions were identical for the throws so these also could have played a part in the distance thrown by each athlete.

Run up velocity, impulse step, delivery stride and bracing leg knee angle (SKF) at release

It is stating the obvious but the ability to execute the throw with good technique at speed will definitely increase distance potential. Looking at speed and the impulse steps of the first four athletes is very interesting, as there appears to be close similarities for the athletes from the same countries i.e. Germany & Czech Republic.

The first four athletes in the final all were moving in excess of 7 m/s at the start of the impulse step. Thomas Röhler was marginally quicker than Johannes Vetter with 7.45 m/s compared to 7.43 m/s. Petr Frydrych and Jakub Vadlejch were slower with 7.07 m/s and 7.03 m/s, respectively. It is interesting that the length of the impulse step (D_{imp}) was over 2 m for the two German throwers (2.32 m for Vetter and 2.14 m for Röhler) whilst the two Czech throwers were well under 2 m with (Vadlejch 1.74 m and Frydrych 1.83 m). It is also important to mention that these four throwers were the only ones out of the 13 finalists to have delivery steps (D_{del}) over 2 m – Vetter 2.26 m, Vadlejch 2.10 m, Frydrych 2.06 m, and Röhler 2.17 m. This appears to be a key variable for long throws.

A good throwing base is only effective if the bracing leg is firm and therefore it has little bend (SKF angle). If the knee bends at release it acts as a shock absorber as energy is dissipated rather than transferred up the kinetic chain through the body into the throwing arm. It is therefore no surprise to me to see that Vetter (190°) and Röhler (192.4°) actually have hyperextended bracing leg angles at release whilst Vadlejch (172.7°) and Frydrych (169.7°) had relatively straight legs at release. Looking at the results 9th place athlete Marcin Krukowski stands out as he has a hyperextended bracing leg angle of 189° but his distance was only 82.01 m, clearly other factors influenced this final distance quite possibly his relatively short throwing stride (D_{del} 1.68 m) this meant he simply did not have the time during the throwing phase to generate the release velocities of the top four who all had throwing strides in excess of 2 m.

An effective blocking front leg enables the athlete to stop efficiently as the energy is transferred up through the body and into the javelin. Of the top four athletes, three of them stop in what might be considered a conventional way by staying on their feet. It is gold medallist Johannes Vetter who has perfected the technique of blocking hard going over the left leg and diving to the ground. Of the 13 finalists, three others employed the dive recovery: Tero Pitkämäki (5th), Magnus Kirt (11th), and Julius Yego 13th.

A brief look at the top eight finalists

Johannes Vetter (Gold - 89.89 m) - Fast and rangy on the run-up travelling at 7.43 m/s at the start of the impulse phase. He had a high throwing hand relative to the throwing shoulder. The javelin is lined up with the intended direction of throw and there is good point control at eye level. Johannes' impulse run-off point was more than 8 m from the scratch line. He has the second largest impulse step at 2.32 m and the largest delivery step of 2.26 m. His bracing left foot is planted 3.50 m from scratch line and he blocks very well with a knee angle of 190° accelerating the javelin to 28.48 m/s at release. He has a dive recovery that sees him flying through the air and landing on his hands. He does have approximately 0.50 m spare indicating this throw was actually over 90 m.

Jakub Vadlejch – (Silver - 89.73 m) - He moves well on the run-up reaching 7.03 m/s at the start of the impulse step. He has noticeably more javelin wrap after withdrawal that causes him to hit across the javelin giving him by far and away the biggest sideslip angle of 23.45°. His final run-off point is approximately 6.80 m from the scratch line, he has a short impulse step (D_{imp}) of 1.74 m and a delivery step (D_{del}) of 2.10 m which means he plants his bracing foot only 2.78 m from the scratch line (D_{FL}), as a result he only just manages to stop after a very good block, excellent hip strike and sequenced throw.

Petr Frydrych – (Bronze - 88.32 m) - His last 3 throws were very good 4th and 5th round 87.93 m then 88.32 m in the last round. He stands out from the other throwers as he carried the javelin very flat along his arm with the point almost under his chin after withdrawal. He was the only athlete to have an angle of release less than 30° and a negative angle of attack. His release angle was 28.0° and he had an attitude angle of 27.7°, giving him an angle of attack of −0.3°. This obviously sent the javelin on a fast (29.17 m/s release velocity) low trajectory. He does wrap the javelin after withdrawal this meant he had a sideslip angle of 16.3° which might have cost him some distance.

Thomas Röhler (4th - 88.26 m) - Has very good speed on the run-up reaching 7.45 m/s at the start of the impulse (the quickest of the finalists). He blocks the throw well (knee angle of 192.4° at release) and generates very good speed at release 28.10 m/s. his javelin alignment is also very

good with a release angle of 36.9° an attitude angle of 38.3°, he has the least amount of sideslip of the top four athletes at 13.0°. His blocking leg is planted 3.46 m from the foul line, he blocks well which helps him to stop very quickly in control with several centimetres to spare. Looking at the path of his head during the last 15 m of the run-up it appears he moves left from his mid line early which may have caused him to slightly miss time the throw. (He threw over 93 m earlier in the year)

Tero Pitkämäki (5th - 86.94 m) - Looks controlled on the run-up, amazingly he plants his left foot 4.38 m from the foul line and has a small delivery stride of only 1.59 m as he drives into his block his knee flexes and straightens after release. This flexion 158° at release possibly causes him to pull down on the javelin and explains the high attitude angle of 40.2°. He still has an effective block and generates the second fastest release velocity of 28.55 m/s. He dives after release and stops approximately 1 m from the scratch line showing this throw actually went approximately 88 m.

Ioannis Kiriazís (6th - 84.52 m) - Showed really good posture into the delivery stride good run-up speed, high hand position and javelin alignment but just at the point of hip strike his bracing leg bends excessively. At release he has a bracing leg knee angle (SKF) of 125.9° which is more than the athletes ahead of him. This limits his ability to create tension and energy transfer up the kinetic chain as it acts as a shock absorber and also causes his centre of gravity to drop which adversely affects the attitude angle and angle of attack because the athlete pulls down on the javelin rather than along its length.

Keshorn Walcott (7th - 84.48 m) - He has a very smooth javelin withdrawal that helps him maintain good speed into the impulse step (7.29 m/s). His hips appear to turn front on as he lands on his right foot at the start of the delivery stride (see direction of his right foot). I feel this meant he couldn't properly strike his hip which as a result shortened his delivery stride (1.63 m) and caused him to pull down on the javelin giving him an attitude angle of 41.9°. With a release angle of 31.79° this meant he had the largest angle of attack of all the finalists which undoubtedly lost him potentially several metres off his final distance.

Andreas Hofmann (8th - 83.98 m) - Is a tall strong looking athlete. He has a pronounced high throwing hand on the run-up and withdraws the javelin smoothly. He was the slowest on the run-up at the start of the impulse step with 6.40m/s. He had a very large impulse step 2.92 m (the biggest in the field) and a relatively small throwing base (delivery stride) of 1.48 m (the smallest of the finalists). His knee is bent at release (150°) which possibly is the cause of him having an attitude angle of 44.6° compared to a release angle of 35.0°. As a consequence, the resultant angle of attack of 9.5° is too big and undoubtedly cost him distance.

Worth a mention

Julius Yego (13th 76.29 m) – Yego was the reigning World Champion having won in Beijing with 92.72 m. He couldn't get anywhere near that distance finishing last in the final.

Points to consider

There are of course many physiological and psychological factors that are unknown or very difficult to quantify that can positively or negatively impact a performance on the day of the competition.

The ability to compete under pressure is what usually separates the medallists from the other athletes in the field as they are usually closely matched physically. It's important to mention that silver and bronze medallists Jacob Vadlejch and Petr Frydrych respectively, both produced lifetime best performances in the men's final and Li Lingwei produced a lifetime best to win the silver medal in the women's event, suggesting they got their preparations for the competition spot on.

Coach's comments and food for thought for coaches of male & female javelin throwers

- The ability to maintain good positions whilst moving quickly is definitely desirable.
- Generating a high release velocity in the javelin at release is still the number one aim of the thrower, closely followed by the need to find the best angles of release, attitude and sideslip that suits their physique, technique and rhythm.
- Understanding how improvements in physical attributes can enable coaches and athletes to make significant technical improvements to increase their personal best and progress the athlete towards their potential.
- Controlling the head position is important to enable balance throughout the different phases of the throw.

Male and female throwers may want to try the diving recovery as this seems to be a way of fully committing to the throw.

CONTRIBUTORS

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