IAAF World Championships
LONDON 2017

BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

Discus Throw Men's

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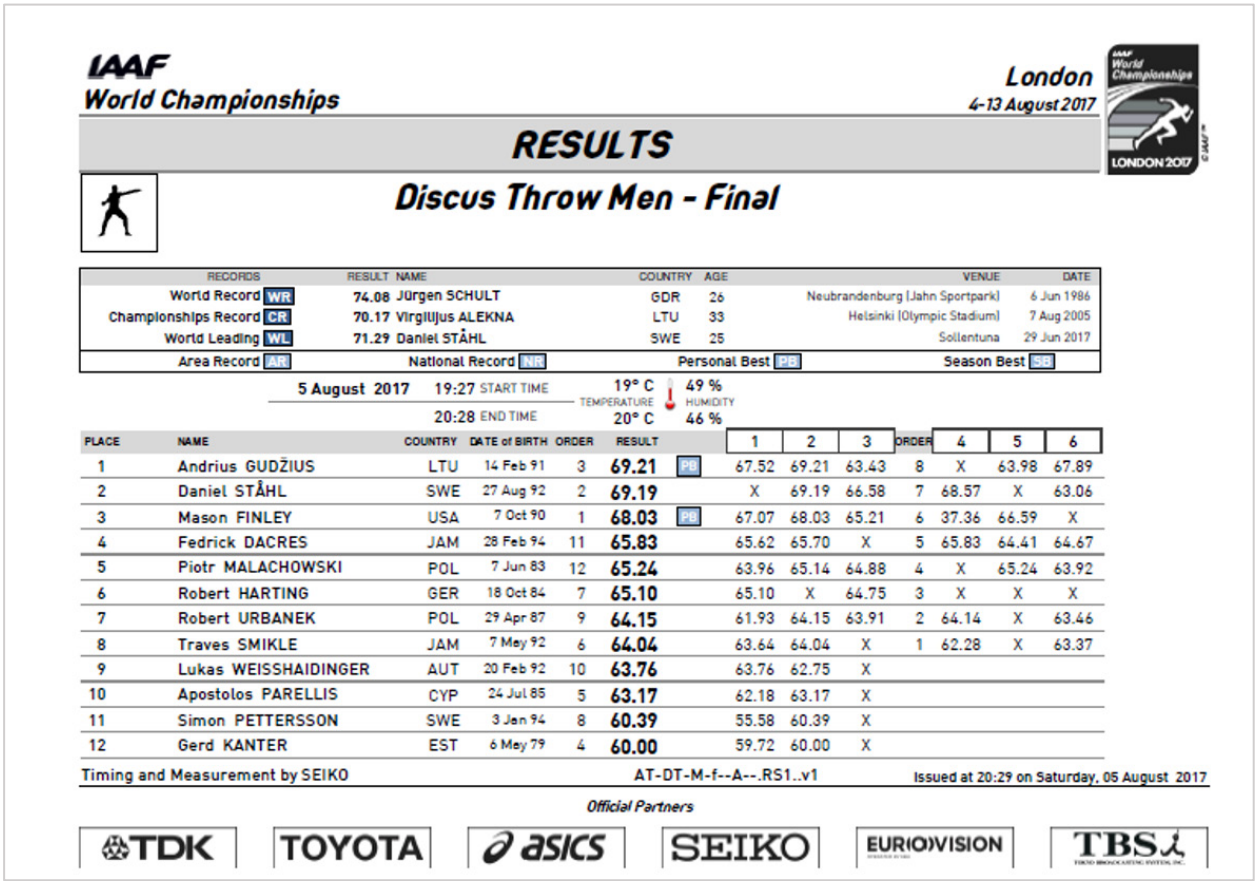
INTRODUCTION

The discus final took place on the night of August 5th in good weather conditions. Coming into the final, Daniel Ståhl from Sweden was the favourite as the world leader in 2017. Despite this, Andrius Gudžius produced the first major upset of the championships after producing a lifetime best throw of 69.21 m in the second round. Ståhl came a very close second producing a 69.19 m effort in the second round, shortly before Gudžius regained the lead by a mere two centimetres. However, Stahl presented a serious challenge throughout the competition, producing throws of 66.68 m and 68.57 m in the third and fourth rounds, respectively. Mason Finley also produced a lifetime best of 68.03 m in the second round to finish in the bronze medal position.



IAAF World Championships — London 4-13 August 2017

RESULTS

Discus Throw Men - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	74.08	Jürgen SCHULT	GDR	26	Neubrandenburg (Jahn Sportpark)	6 Jun 1986
Championships Record CR	70.17	Virgilijus ALEKNA	LTU	33	Helsinki (Olympic Stadium)	7 Aug 2005
World Leading WL	71.29	Daniel STÅHL	SWE	25	Sollentuna	29 Jun 2017

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

5 August 2017 — 19:27 START TIME — 19° C TEMPERATURE — 49 % HUMIDITY

20:28 END TIME — 20° C — 46 %

PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT		1	2	3	ORDER	4	5	6
1	Andrius GUDŽIUS	LTU	14 Feb 91	3	**69.21**	PB	67.52	69.21	63.43	8	X	63.98	67.89
2	Daniel STÅHL	SWE	27 Aug 92	2	**69.19**		X	69.19	66.58	7	68.57	X	63.06
3	Mason FINLEY	USA	7 Oct 90	1	**68.03**	PB	67.07	68.03	65.21	6	37.36	66.59	X
4	Fedrick DACRES	JAM	28 Feb 94	11	**65.83**		65.62	65.70	X	5	65.83	64.41	64.67
5	Piotr MALACHOWSKI	POL	7 Jun 83	12	**65.24**		63.96	65.14	64.88	4	X	65.24	63.92
6	Robert HARTING	GER	18 Oct 84	7	**65.10**		65.10	X	64.75	3	X	X	X
7	Robert URBANEK	POL	29 Apr 87	9	**64.15**		61.93	64.15	63.91	2	64.14	X	63.46
8	Traves SMIKLE	JAM	7 May 92	6	**64.04**		63.64	64.04	X	1	62.28	X	63.37
9	Lukas WEISSHAIDINGER	AUT	20 Feb 92	10	**63.76**		63.76	62.75	X				
10	Apostolos PARELLIS	CYP	24 Jul 85	5	**63.17**		62.18	63.17	X				
11	Simon PETTERSSON	SWE	3 Jan 94	8	**60.39**		55.58	60.39	X				
12	Gerd KANTER	EST	6 May 79	4	**60.00**		59.72	60.00	X				

Timing and Measurement by SEIKO — AT-DT-M-f--A--.RS1..v1 — Issued at 20:29 on Saturday, 05 August 2017

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METHODS

Three vantage locations for camera placements were identified and secured at strategic locations around the stadium. A total of three high-speed cameras were used to record the action during the discus 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 discus throw.

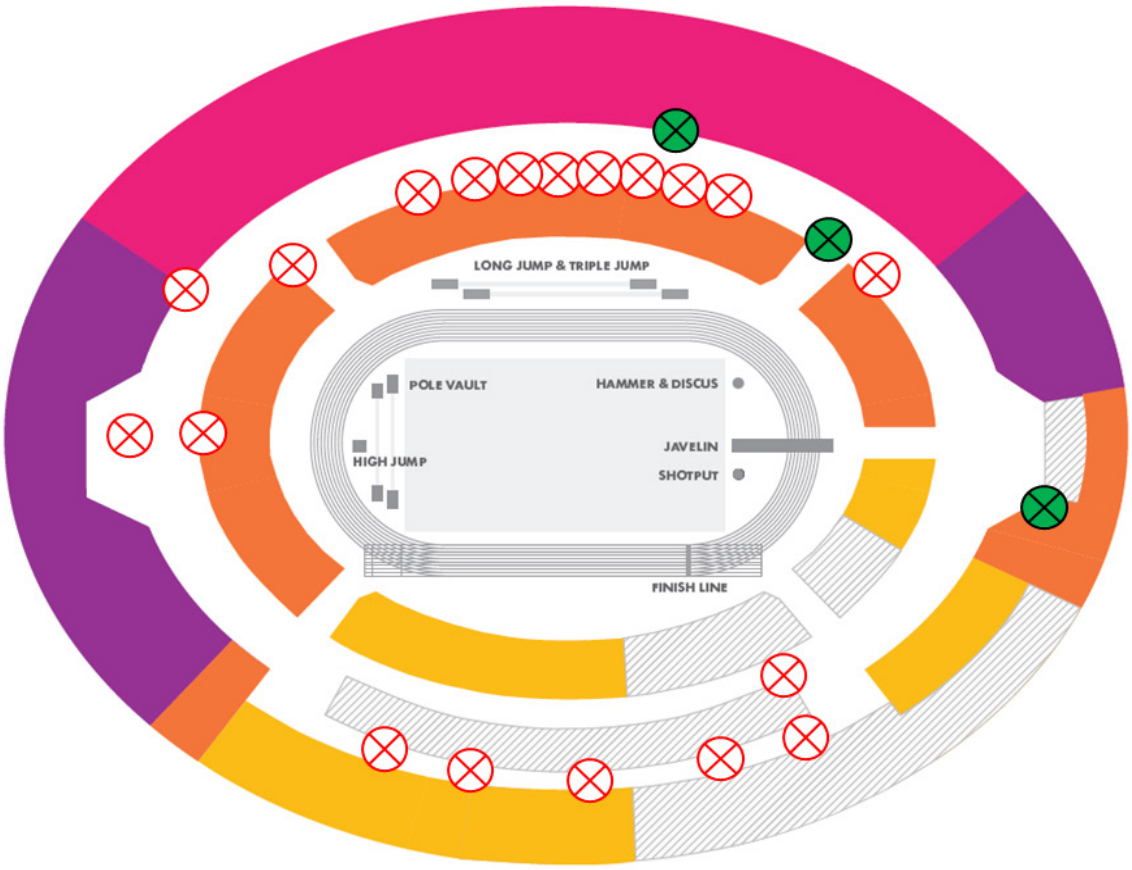


Figure 1. Stadium layout with camera locations for the men's discus throw (shown in green).

After the final competition a calibration procedure was conducted to capture the performance volume. A rigid cuboid calibration frame was positioned around the throwing circle providing an accurate volume within which athletes performed the throwing movement. 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. The discus was digitised

15 frames before the beginning of the preparation phase and 10 frames after release to provide padding during filtering. Discrete and temporal kinematic characteristics were also digitised at key events. All video files were digitised frame by frame, and upon completion the points over frame method was used to make any necessary adjustments, where the discus was tracked at each point through the full motion.

Figure 2. Discus 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. 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. Key events during throw: A = peak backswing position (PBP); B = right foot take-off (RFO); C = left foot take-off (LFO); D = right foot touchdown (RFD); E = left foot touchdown (LFD); and F = release.

Table 1. Definition of each key phase.

Key Phase	Definition
Preparation	From PBP to RFO (right-handed) / From PBP to LFO (left-handed).
Entry	From RFO to LFO (right-handed) / From LFO to RFO (left-handed).
Airborne	From LFO to RFD (right-handed) / From RFO to LFD (left-handed).
Transition	From RFD to LFD (right-handed) / From LFD to RFD (left-handed).
***Delivery / Block / Power**	From LFD to release (right-handed) / From RFD to release (left-handed).

Note: ** For the purpose of this report, this phase will be referred to as the 'Delivery Phase' throughout the methods and results sections.*

Table 2. List of variables.

Variable	Definition
Absolute velocity	The resultant velocity of the discus at each key event from entry. Preparation not included as discus velocity is zero at PBP.
Horizontal release velocity	The horizontal (anteroposterior) component of the discus release velocity at release.
Vertical release velocity	The vertical component of the discus release velocity at release.
Angle of release	The angle between the discus direction of travel and the horizontal at release.
Release height	The vertical distance from the discus centre to the ground at release.
Relative release height	The vertical distance between the shoulder joint of the throwing arm and the discus centre at release.
Aerodynamic quality	The difference between official distance and theoretical distance. ***Note:*** *The theoretical distance only takes into account the following discus parameters: Height of release, absolute velocity at release and angle of release.*
Flight distance	The distance between ground contact points at LFO and RFD (or RFO and LFD for left-handers).
Delivery base of support	The distance between position of RFD and position of LFD.
Throwing arm elevation angle	The angle between the discus, throwing shoulder, and horizontal ground (0° = parallel to the horizontal ground).
Hip-shoulder separation (RFO, LFO, RFD, LFD and release)	The angle between a vector joining the right and left hips and a vector connecting the right and left shoulders.
Shoulder-arm separation (RFO, LFO, RFD, LFD and release)	The angle between a vector joining the right and left shoulder and a vector between the throwing shoulder and the discus.

Trunk tilt (forward-backward) (RFO, LFO, RFD, LFD and release)	The angle between the trunk and the vertical (0° = perpendicular to the horizontal ground).
Duration of key phases	The duration of preparation, entry, airborne, transition and delivery phases.
Style of release	Reverse = either one of no feet in contact with the ground at release. Fixed foot = both feet in contact with the ground at release.

Note: *CM = centre of mass.*

Please note that the results from this report supersede the results contained within the fast report published in August 2017. The results presented here have been derived from data extracted from all cameras involved in the recording and digitised fully to provide a more accurate analysis of performance.

RESULTS

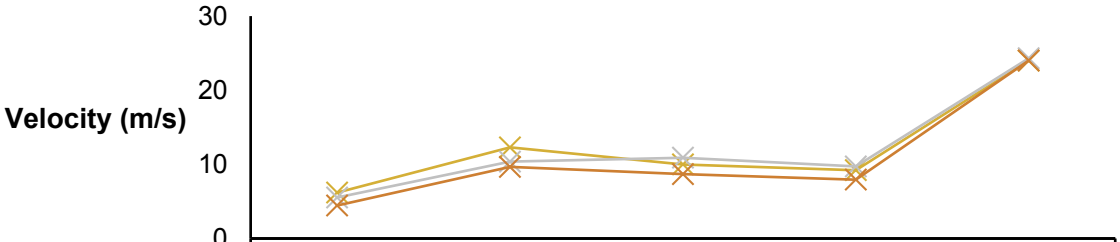
The following section of the report shows key outcome measures of the men's discus final. This includes biomechanical parameters of the implement at release and the motion path of the discus across all key phases.

Table 3. Attempts analysed for each athlete, the distance thrown and the style of released used.

Athlete	Attempt analysed	Distance (m)	% Season's best	% Personal best	Style of release
GUDŽIUS	2	69.21	+0.87	+0.87	Reverse (NS)
STÅHL	2	69.19	−2.95	−2.95	Reverse (LFD)
FINLEY	2	68.03	+3.89	+1.96	Reverse (NS)
DACRES	4	65.83	−4.43	−4.43	Reverse (NS)
MALACHOWSKI	5	65.24	−3.61	−9.19	Reverse (NS)
HARTING	1	65.10	−1.81	−7.87	Fixed foot
URBANEK	2	64.15	−3.87	−4.15	Reverse (NS)
SMIKLE	2	64.04	−1.48	−4.59	Reverse (NS)
WEISSHAIDINGER	1	63.76	−4.15	−5.18	Reverse (LFD)
PARELLIS	2	63.17	−3.01	−3.84	Reverse (NS)
PETTERSSON	2	60.39	−6.92	−6.92	Reverse (RFD)
KANTER	2	60.00	−8.91	−18.23	Reverse (NS)

Note: *Distances also displayed as percentages of previous season and personal best throws. RFD = right foot touchdown at release; LFD = left foot touchdown at release; NS = no support at release.*

Analysis of implement parameters



	Entry	Airborne	Transition	Delivery	Release
GUDŽIUS	6.19	12.29	9.99	9.21	23.99
STÅHL	5.53	10.37	10.90	9.72	24.31
FINLEY	4.45	9.65	8.68	7.94	24.01
DACRES	4.78	9.34	8.08	8.18	23.98
MALACHOWSKI	5.69	9.65	8.21	9.04	24.23
HARTING	4.82	7.02	7.84	9.60	23.68
URBANEK	8.06	8.95	7.35	6.70	23.44
SMIKLE	5.55	8.70	8.27	7.93	23.46
WEISSHAIDINGER	5.89	8.70	8.92	12.04	23.43
PARELLIS	8.07	8.46	7.82	8.45	22.64
PETTERSSON	5.65	10.44	9.65	8.66	22.45
KANTER	2.80	8.93	8.90	8.16	23.24

Figure 4. Absolute velocity of the discus at the beginning of each of the key phases from entry and release. All athletes can be seen in the table, however the three medallists can also be seen on the line graph. All values in the table are presented in metres per second (m/s).

Table 4. Other release parameters.

	Release angle (°)	Release height / relative to shoulder (m)	Aerodynamic quality (%)
GUDŽIUS	36.6	1.66 / 0.15	15.7
STÅHL	37.8	1.66 / 0.12	12.7
FINLEY	36.4	1.74 / 0.12	14.1
DACRES	36.0	1.67 / 0.11	12.0
MALACHOWSKI	35.5	1.52 / 0.06	10.2
HARTING	32.5	1.20 / −0.15	17.7
URBANEK	36.5	1.58 / −0.01	13.3
SMIKLE	32.0	1.33 / −0.09	18.0
WEISSHAIDINGER	34.2	1.48 / 0.01	15.1
PARELLIS	40.9	1.69 / 0.22	15.2
PETTERSSON	37.0	1.29 / −0.16	15.5
KANTER	38.1	1.67 / 0.24	7.5

Note: *A negative relative release height indicates that the height of release was less than the height of the shoulder at the time of release.*

Figure 5 shows the respective contributions of the horizontal and vertical components of discus 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.

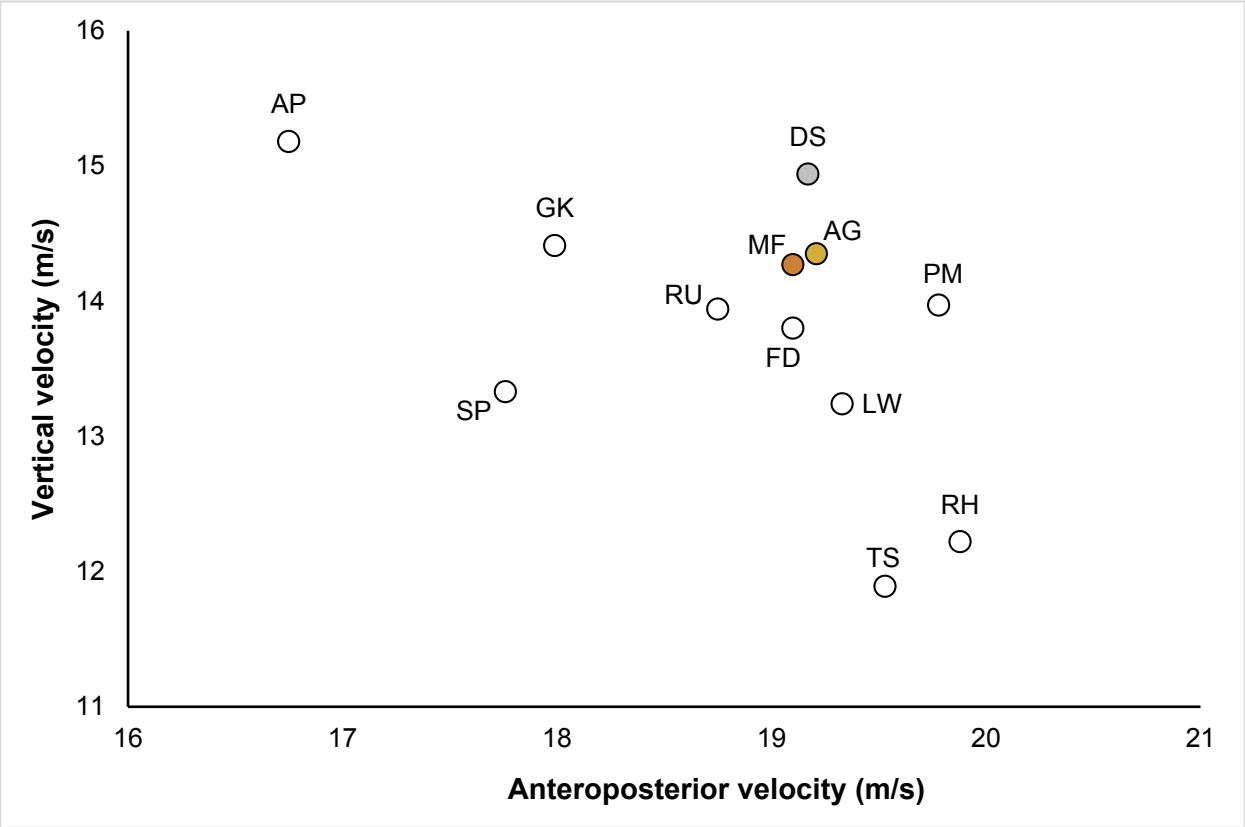


Figure 5. Horizontal (anteroposterior) and vertical components of discus release velocity.

The following six pages contain individual graphs for each athlete, displaying the motion path for the discus through each key phase from a superior view. Phases are displayed according to the key found in Figure 6.1.

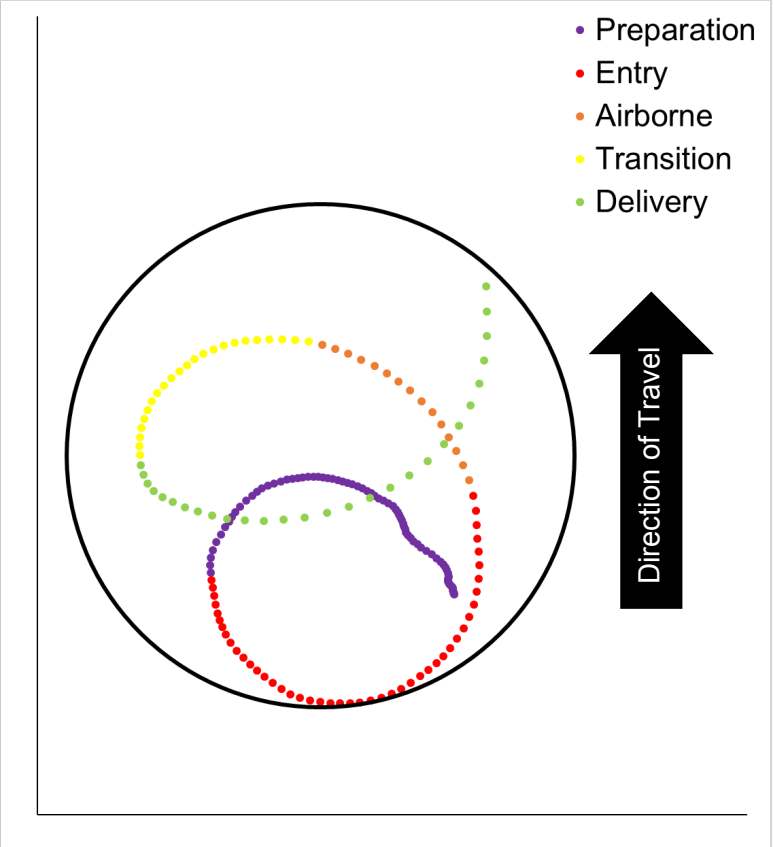


Figure 6.1. Discus motion path for Andrius Gudžius from the beginning of the preparation phase to release. Figure includes colour key for each phase, which is consistent throughout this figure series (Figures 6.1 to 6.12).

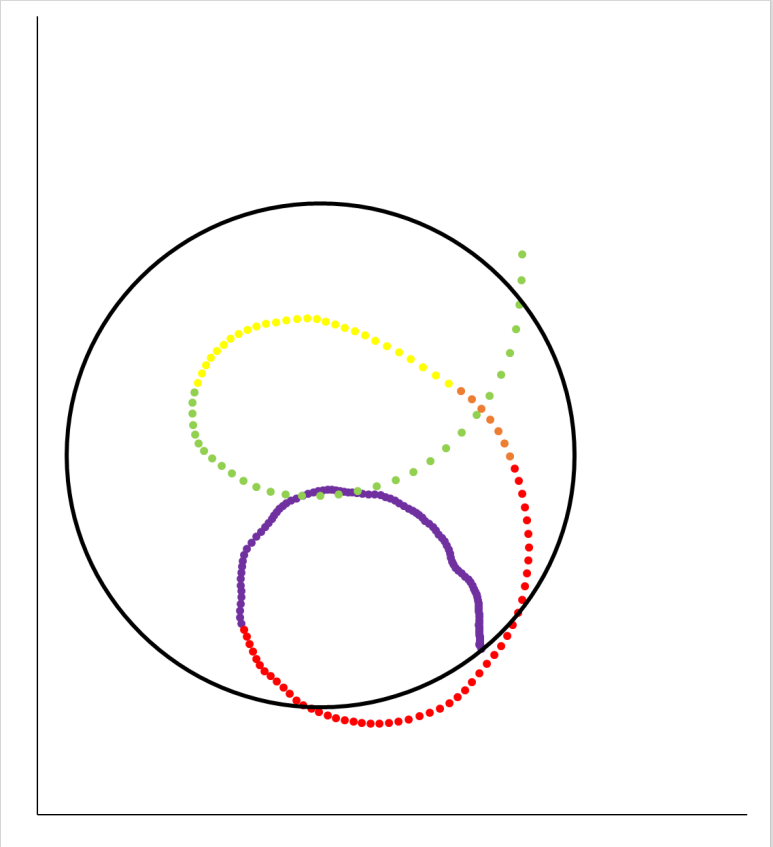


Figure 6.2. Discus motion path for Daniel Ståhl from the beginning of the preparation phase to release.

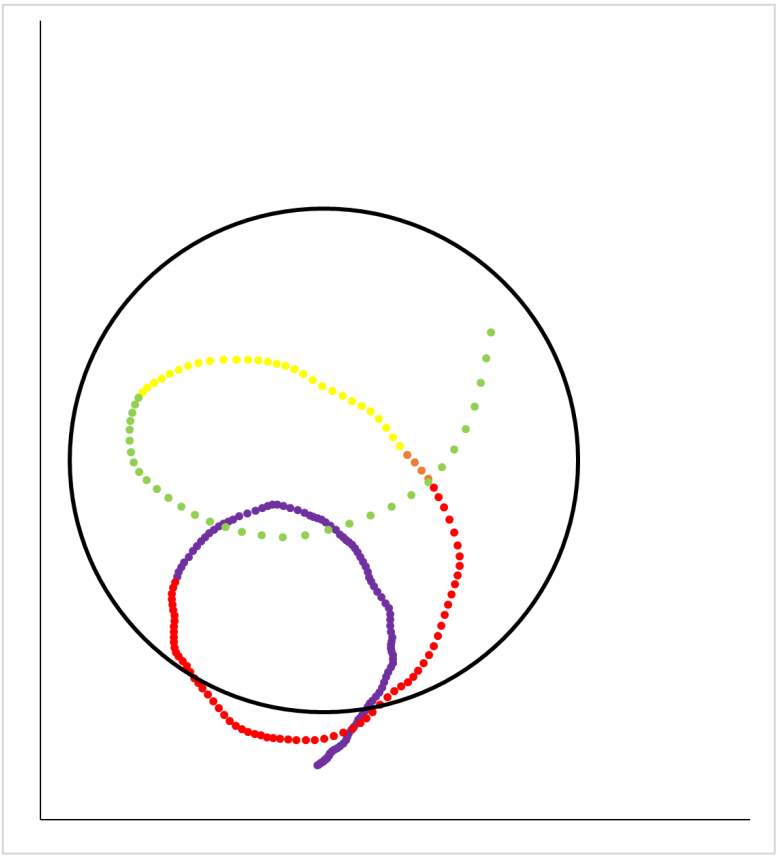


Figure 6.3. Discus motion path for Mason Finley from the beginning of the preparation phase to release.

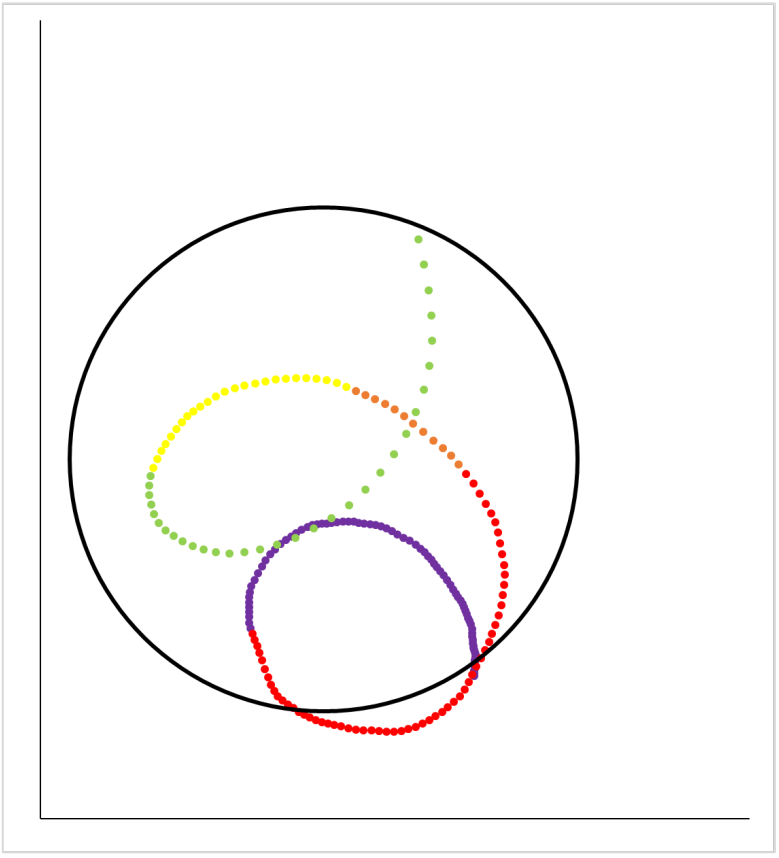


Figure 6.4. Discus motion path for Fedrick Dacres from the beginning of the preparation phase to release.

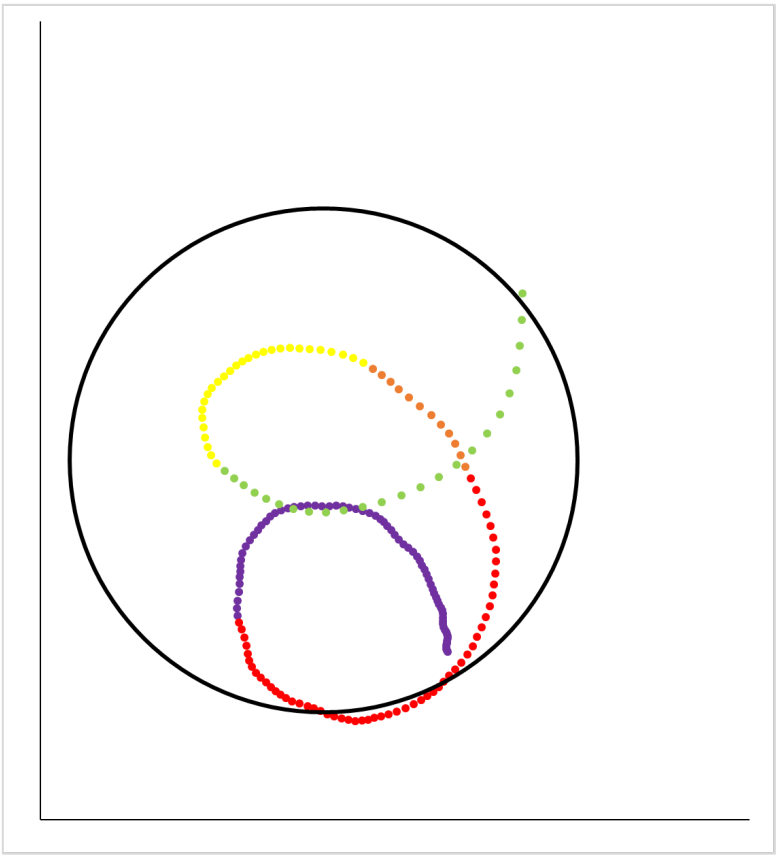


Figure 6.5. Discus motion path for Piotr Malachowski from the beginning of the preparation phase to release.

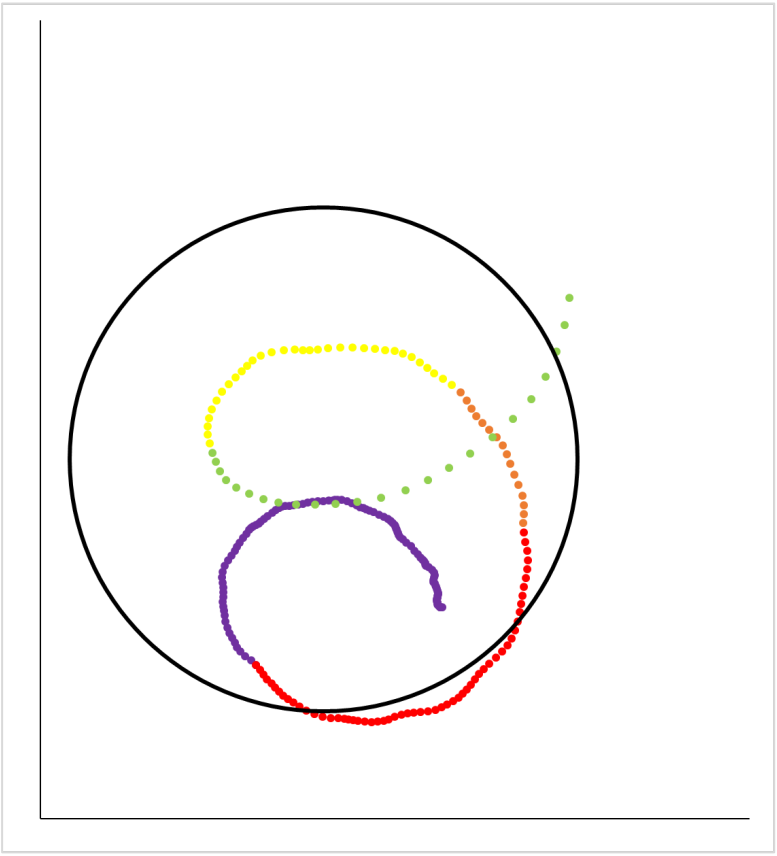


Figure 6.6. Discus motion path for Robert Harting from the beginning of the preparation phase to release.

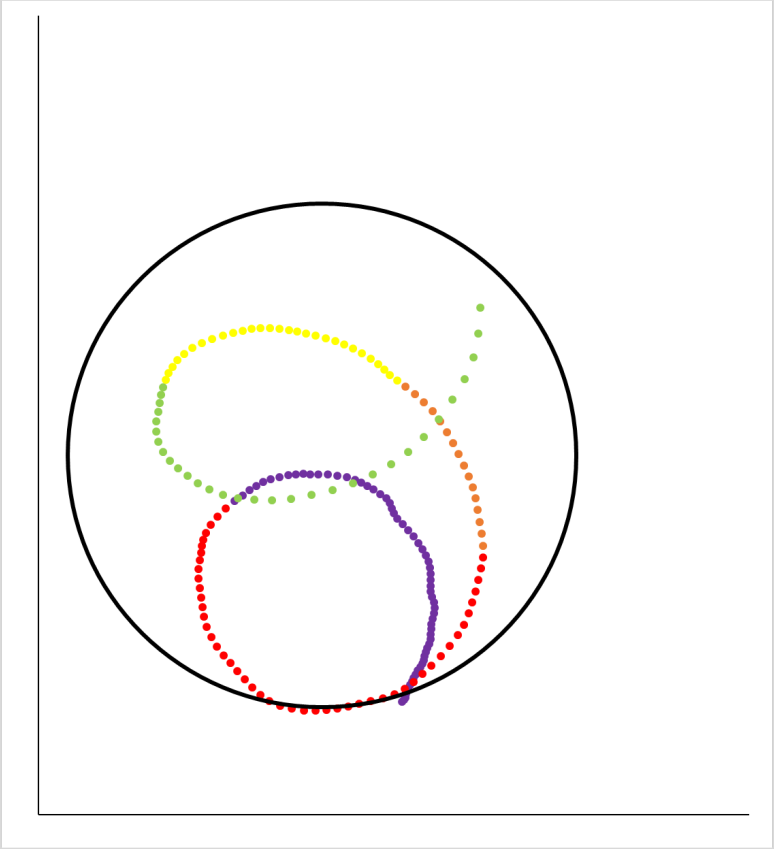


Figure 6.7. Discus motion path for Robert Urbanek from the beginning of the preparation phase to release.

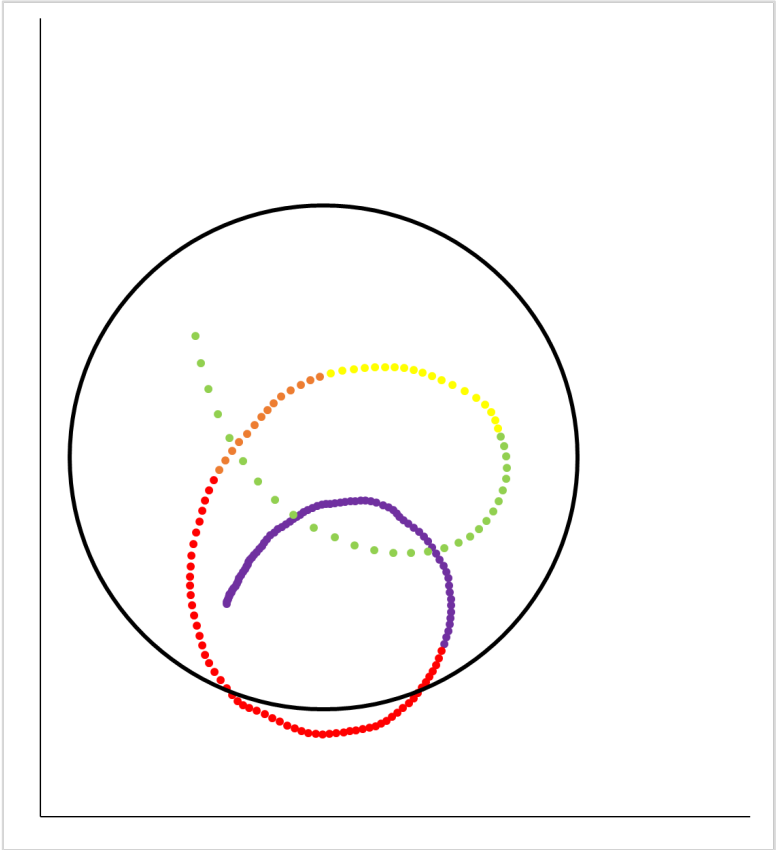


Figure 6.8. Discus motion path for Traves Smikle from the beginning of the preparation phase to release.

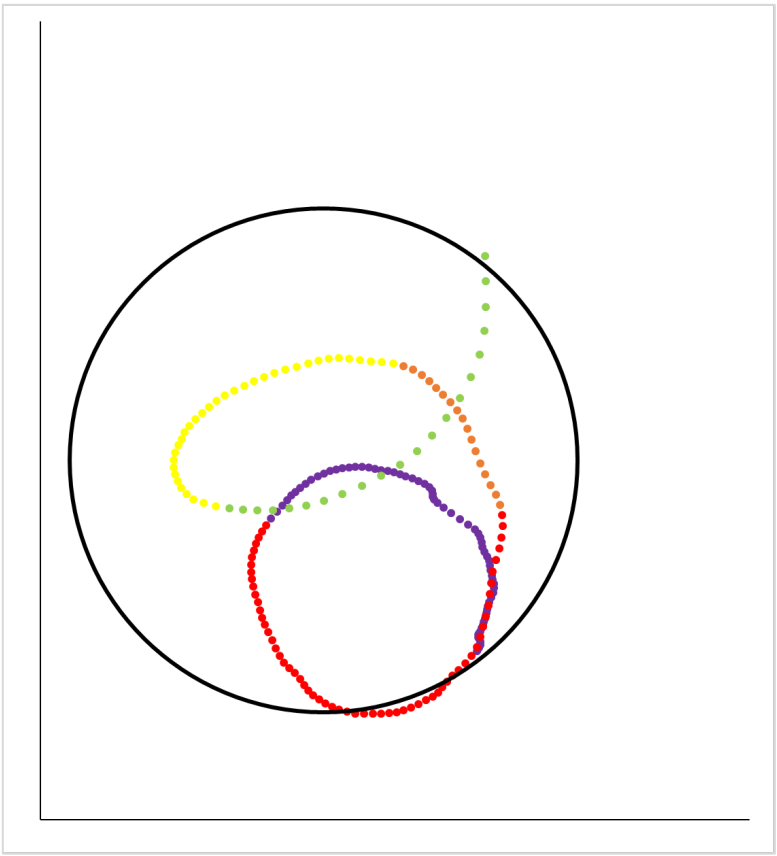


Figure 6.9. Discus motion path for Lukas Weisshaidinger from the beginning of the preparation phase to release.

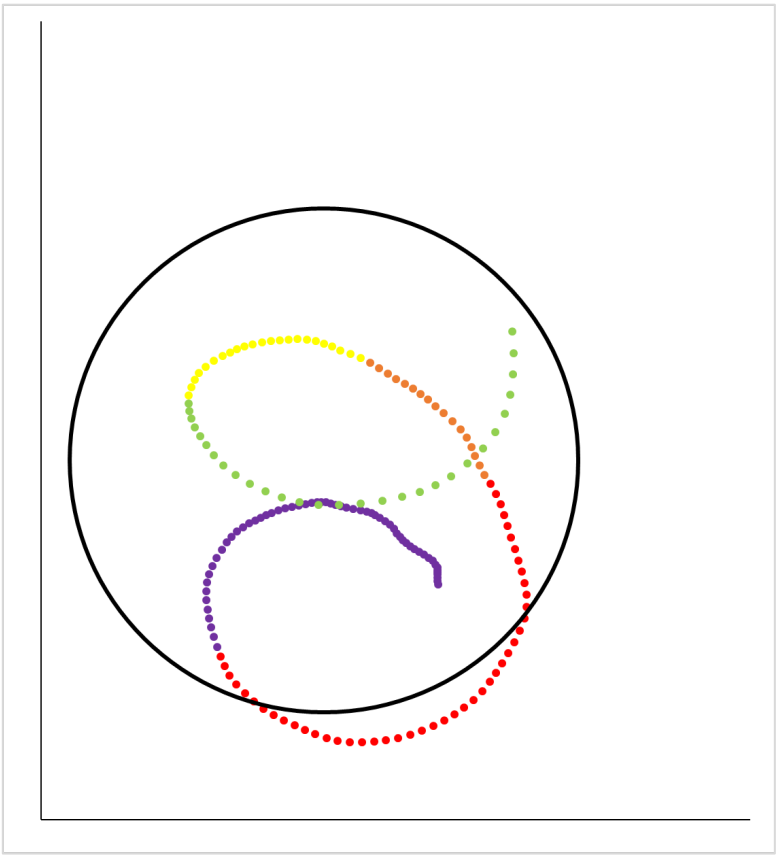


Figure. 6.10. Discus motion path for Apostolos Parellis from the beginning of the preparation phase to release.

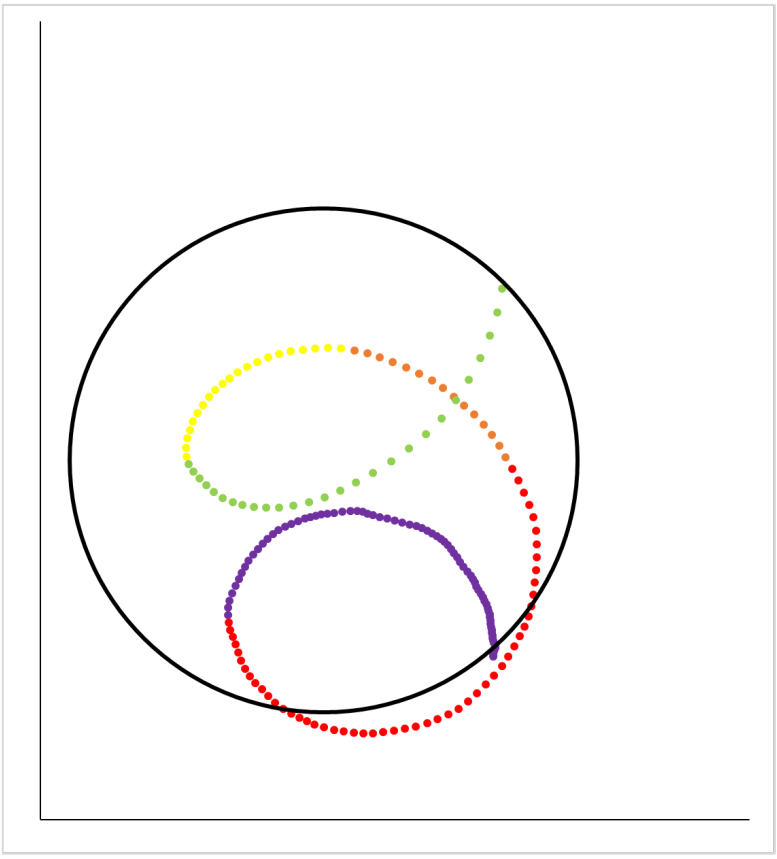


Figure 6.11. Discus motion path for Simon Pettersson from the beginning of the preparation phase to release.

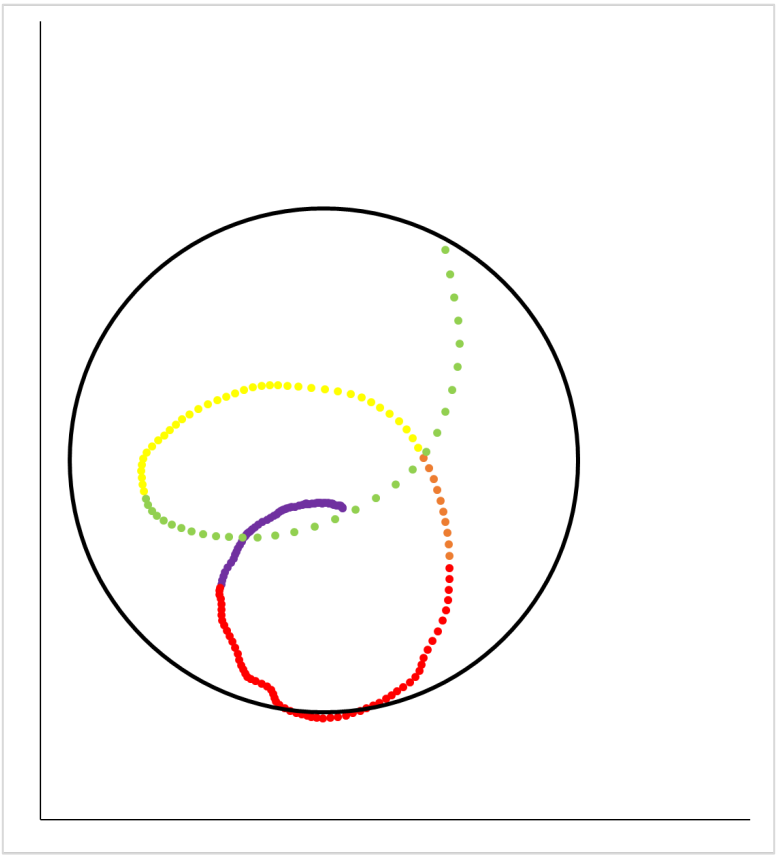


Figure 6.12. Discus motion path for Gerd Kanter from the beginning of the preparation phase to release.

Temporal characteristics of the athletes' movement

Table 5. Absolute duration of each analysed key phase before release.

	Preparation (ms)	Entry (ms)	Airborne (ms)	Transition (ms)	Delivery (ms)
GUDŽIUS	520	293	107	153	180
STÅHL	693	333	47	187	207
FINLEY	673	427	67	193	213
DACRES	560	413	80	167	207
MALACHOWSKI	487	380	80	187	153
HARTING	767	380	113	227	147
URBANEK	433	327	107	193	200
SMIKLE	540	393	93	127	187
WEISSHAIDINGER	487	413	113	133	133
PARELLIS	407	307	113	153	187
PETTERSSON	520	353	100	140	173
KANTER	460	413	67	253	200

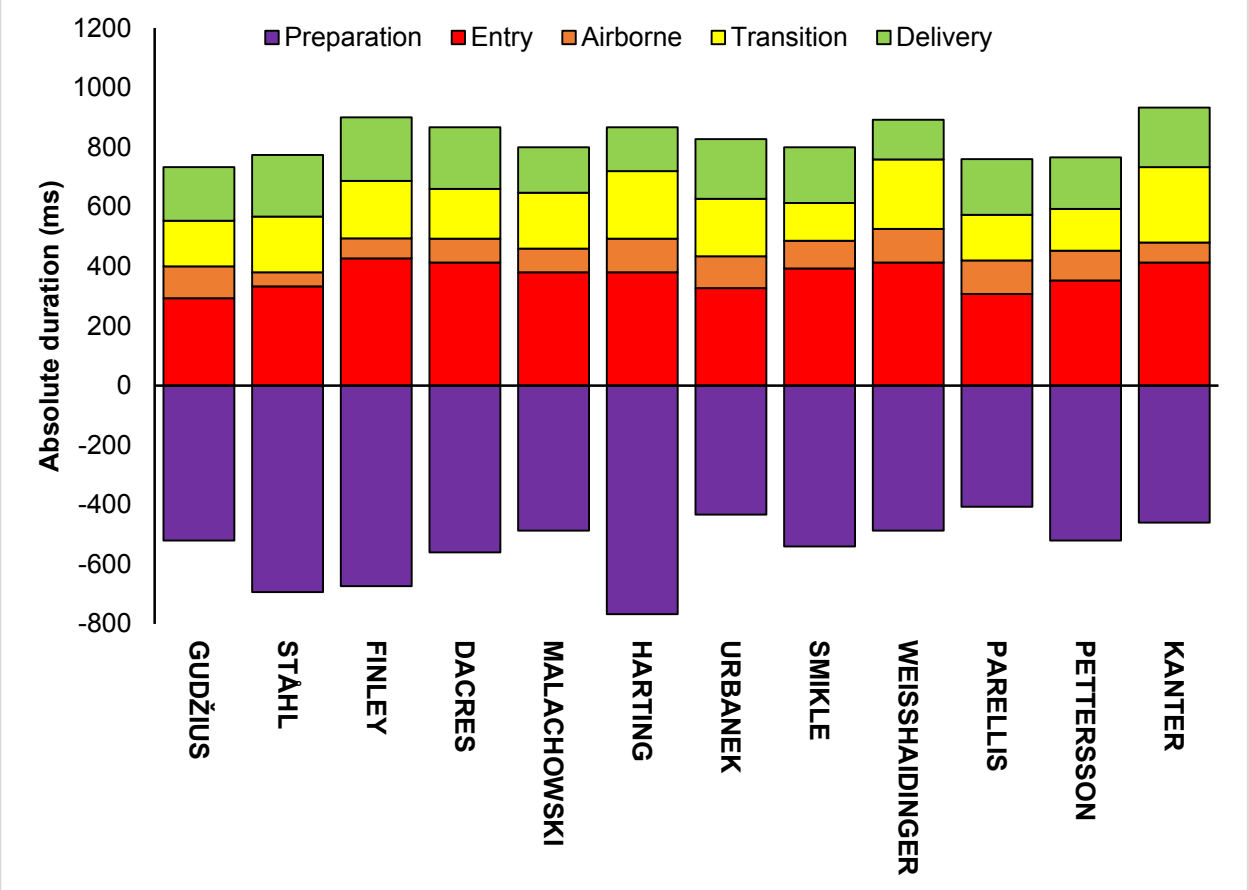


Figure 7. Absolute durations for each key phase before release. Entry phase starts at 0 ms.

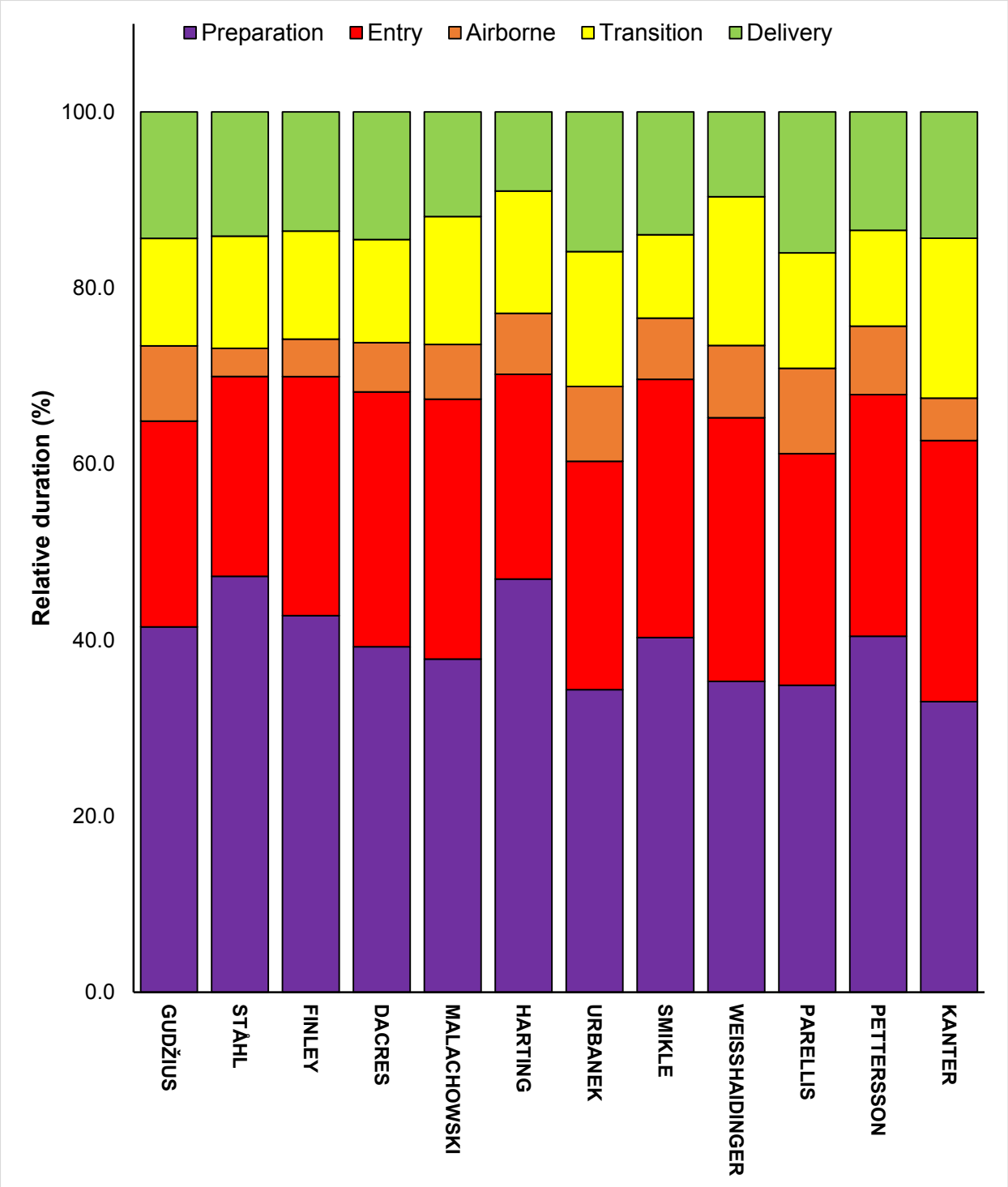


Figure 8. Relative duration of each key phase before release. 0 % indicates the start of the preparation phase and 100 % indicates release of the discus.

Kinematics of the athletes' techniques

The athletes' technique kinematics are shown in this section, both at release and key events across the throwing motion.

Table 6. Hip-shoulder separation angles at key events before and including release.

	RFO (°)	LFO (°)	RFD (°)	LFD (°)	Release (°)
GUDŽIUS	45.6	68.2	48.6	74.6	−11.6
STÅHL	22.6	55.9	38.6	59.5	−39.6
FINLEY	46.8	59.5	45.6	97.0	−20.5
DACRES	33.8	−43.1	29.7	92.3	−45.0
MALACHOWSKI	17.8	45.8	5.1	53.8	16.2
HARTING	19.9	57.5	77.5	64.5	−37.4
URBANEK	50.1	38.5	32.0	82.3	−9.5
SMIKLE	12.0 (LFO)	22.8 (RFO)	36.2 (LFD)	52.9 (RFD)	−3.0
WEISSHAIDINGER	33.1	64.8	40.5	41.8	−42.1
PARELLIS	2.3	64.8	40.9	97.9	−54.4
PETTERSSON	28.9	44.0	32.0	66.1	14.3
KANTER	49.2	12.7	60.6	79.7	−26.3

Note: *Negative separation angles indicate that the shoulder axis is ahead of the hip axis in the angular motion path.*

Table 7. Shoulder-arm separation angles at key events before and including release.

	RFO (°)	LFO (°)	RFD (°)	LFD (°)	Release (°)
GUDŽIUS	38.6	10.3	7.6	6.5	−10.4
STÅHL	12.5	13.0	21.4	54.9	7.6
FINLEY	19.6	15.9	24.1	22.2	−4.0
DACRES	26.5	52.9	18.2	33.0	10.2
MALACHOWSKI	21.2	34.7	45.4	46.3	−13.0
HARTING	28.8	30.8	25.5	29.1	−5.8
URBANEK	35.4	23.9	35.9	44.0	−4.2
SMIKLE	9.7 (LFO)	21.5 (RFO)	26.5 (LFD)	44.4 (RFD)	−40.8
WEISSHAIDINGER	10.0	12.8	20.5	42.7	14.7
PARELLIS	19.4	−6.1	19.7	23.0	−21.1
PETTERSSON	16.9	11.4	23.2	11.2	14.6
KANTER	15.4	31.8	16.1	15.7	7.3

Note: *Negative separation angles indicate that the arm axis is ahead of the shoulder axis in the angular motion path.*

The following three pages contain graphical representations of the hip-shoulder and shoulder-arm separation angles for the three medallists. Hip-shoulder separation angle is illustrated by the arc shaded in red with blue borders and the shoulder-arm separation angle is illustrated by the arc shaded in black with black borders (Figure 9A).

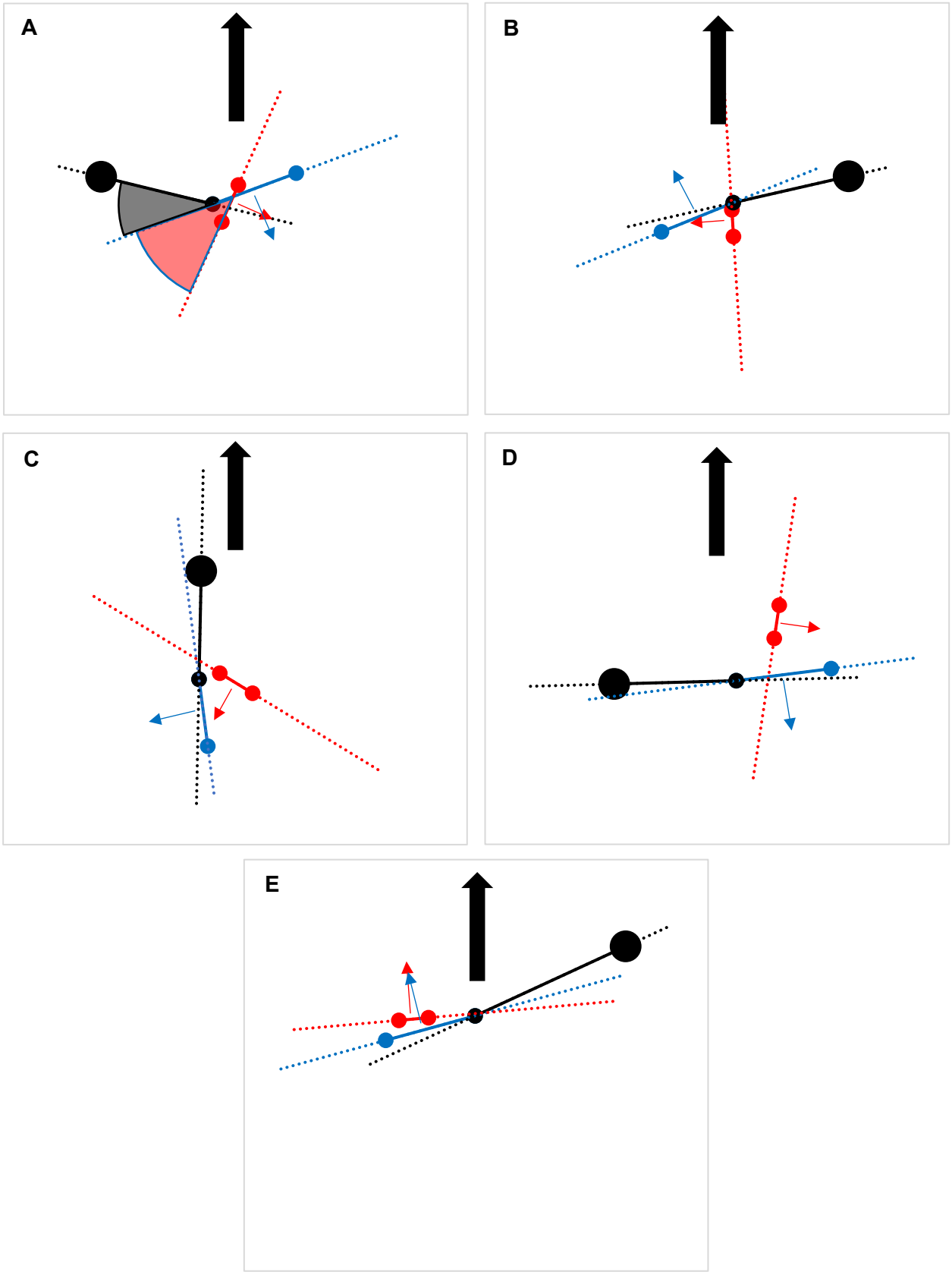


Figure 9. Graphical representation of Andrius Gudžius' hip, shoulder and arm positions at (A) right foot take-off; (B) left foot take-off; (C) right foot touchdown; (D) left foot touchdown; and (E) release. Blue and red arrows represent facing direction of shoulders and hips, respectively. Black arrow indicates throwing direction.

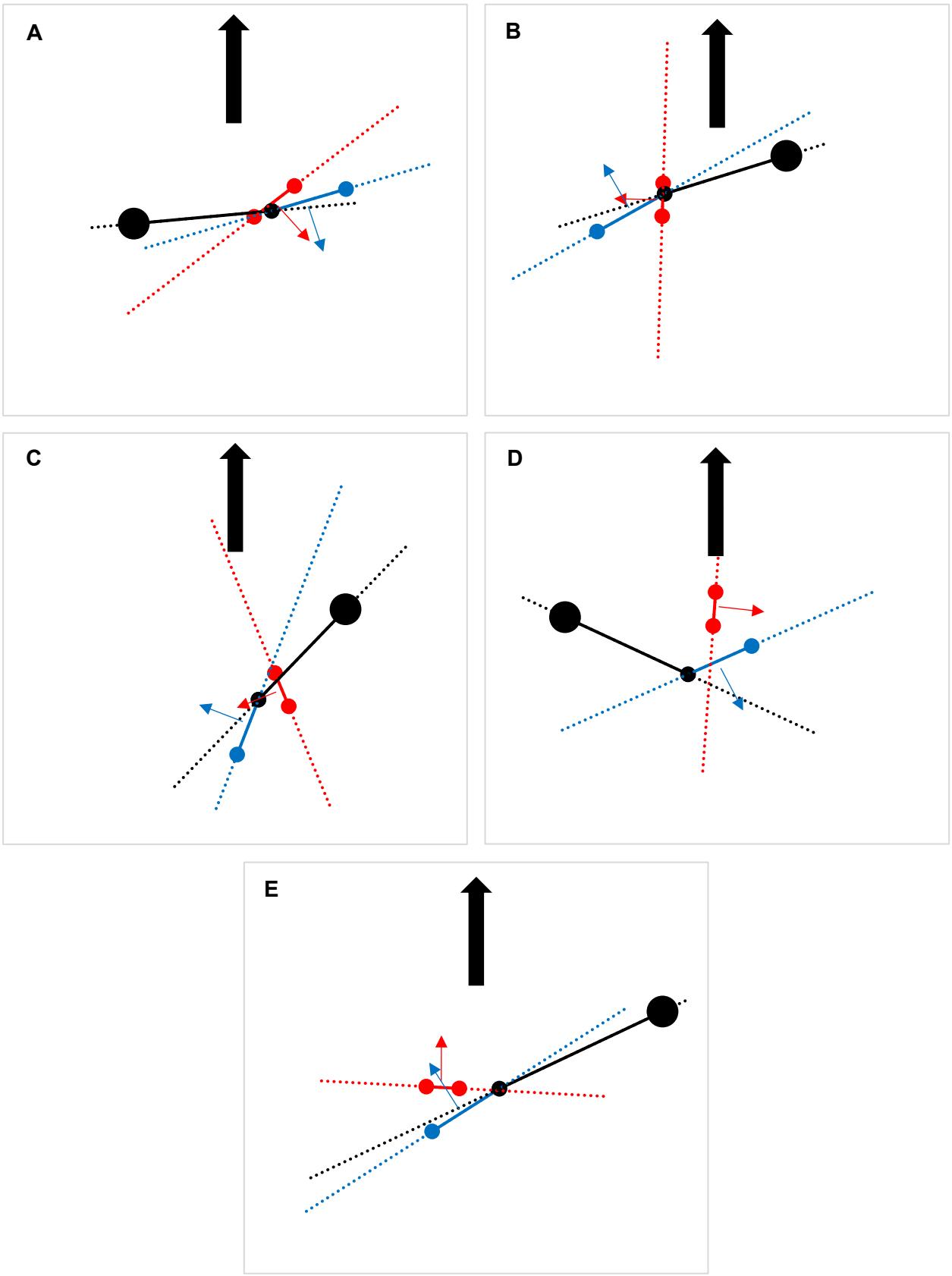


Figure 10. Graphical representation of Daniel Ståhl's hip, shoulder and arm positions at (A) right foot take-off; (B) left foot take-off; (C) right foot touchdown; (D) left foot touchdown; and (E) release. Blue and red arrows represent facing direction of shoulders and hips, respectively. Black arrow indicates throwing direction.

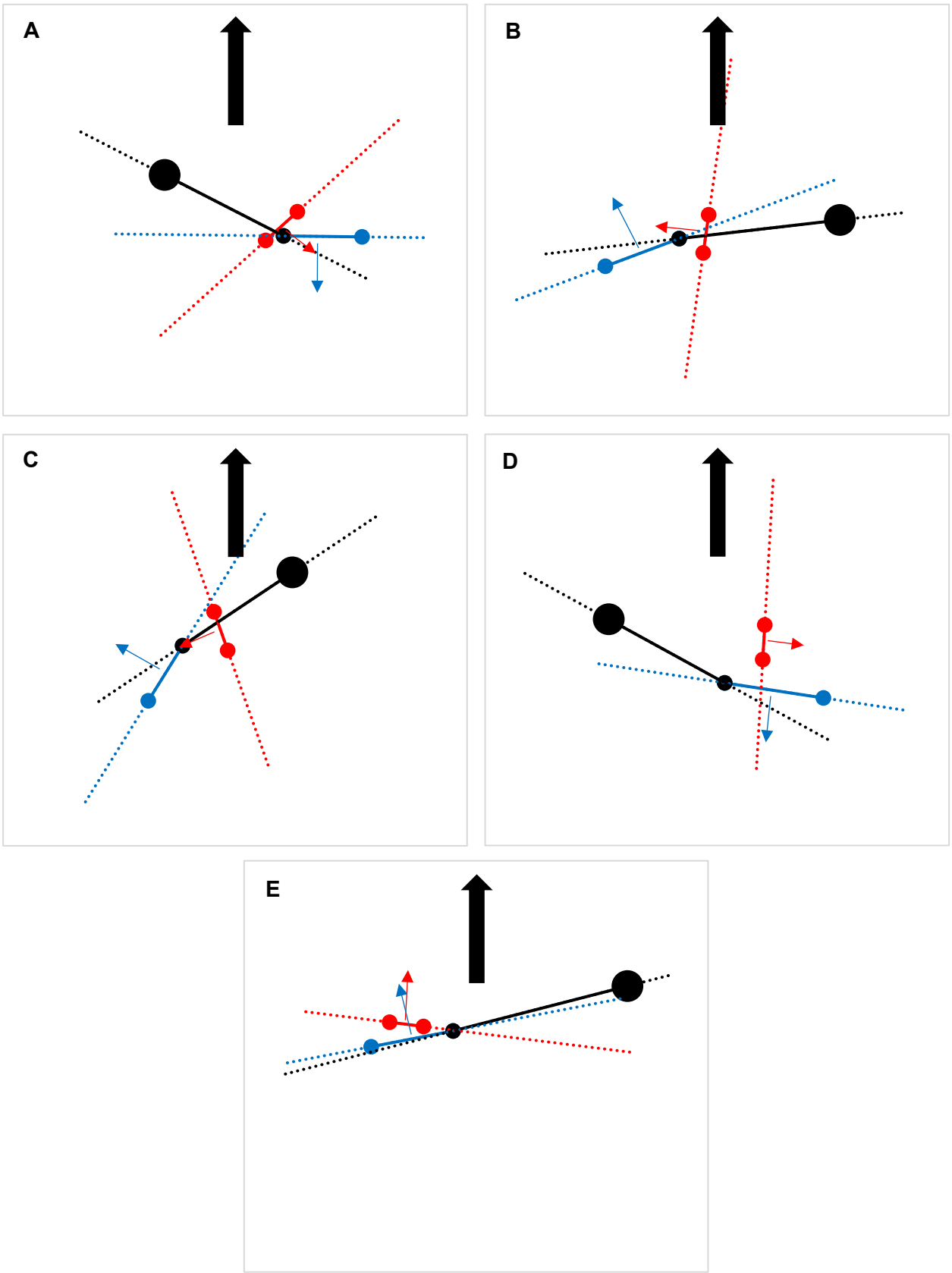


Figure 11. Graphical representation of Mason Finley's hip, shoulder and arm positions at (A) right foot take-off; (B) left foot take-off; (C) right foot touchdown; (D) left foot touchdown; and (E) release. Blue and red arrows represent facing direction of shoulders and hips, respectively. Black arrow indicates throwing direction.

Table 8. Distance covered during the airborne phase and the base of support at the start of the delivery phase for each athlete.

	Flight distance (m)	Delivery base of support (m)
GUDŽIUS	1.11	0.61
STÅHL	1.15	0.73
FINLEY	1.00	0.69
DACRES	1.18	0.73
MALACHOWSKI	1.15	0.61
HARTING	1.33	0.85
URBANEK	1.19	0.67
SMIKLE	1.21	0.53
WEISSHAIDINGER	1.17	0.64
PARELLIS	1.00	0.73
PETTERSSON	1.28	0.72
KANTER	1.25	0.55

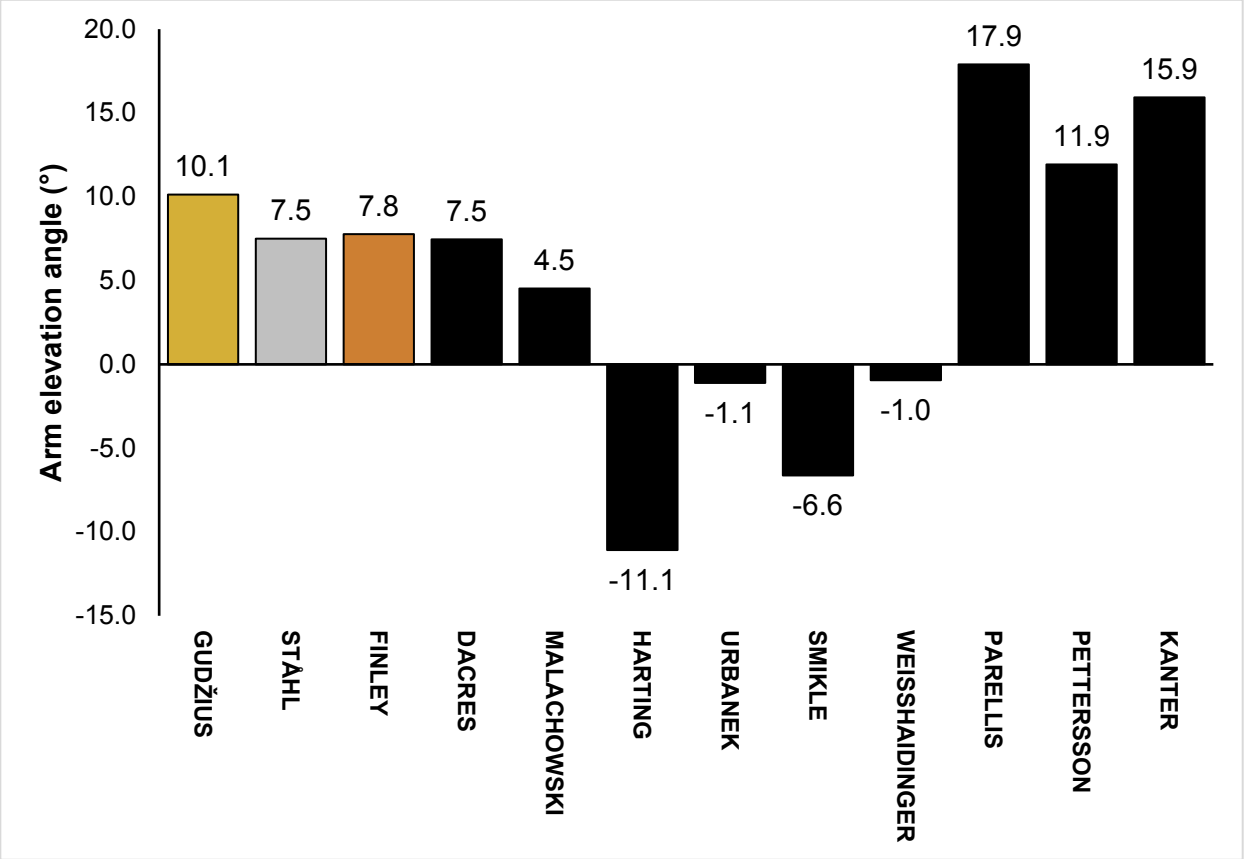


Figure 12. Arm elevation angle for each athlete at release. A positive elevation angle indicates an incline from the shoulder joint to the discus, whereas a negative value indicates a decline.

Table 9. Angles of trunk tilt at key events before and including release.

	RFO (°)	LFO (°)	RFD (°)	LFD (°)	Release (°)
GUDŽIUS	7.6	3.1	14.3	24.3	−4.4
STÅHL	0.8	6.8	19.1	26.9	−11.4
FINLEY	5.7	9.6	23.5	24.6	−6.9
DACRES	4.4	18.6	31.3	22.2	−5.3
MALACHOWSKI	3.9	0.4	27.7	26.3	−12.1
HARTING	8.1	5.3	24.2	35.1	−4.0
URBANEK	0.5	14.3	11.3	28.3	−12.5
SMIKLE	1.9 (LFO)	1.2 (RFO)	23.8 (LFO)	26.9 (RFD)	−4.8
WEISSHAIDINGER	11.2	6.2	28.4	18.1	−6.5
PARELLIS	2.9	4.7	18.1	29.3	−13.2
PETTERSSON	6.4	8.8	25.0	27.9	−7.1
KANTER	3.9	4.8	26.5	29.3	−0.8

Note: *Negative trunk tilt angles indicate a backwards lean, whereas positive values indicate a forward lean.*

COACH'S COMMENTARY

When looking at these results and the data obtained from the resulting biomechanical study we must be aware that we are looking at the best registered throws of each of the finalists. This means that for comparison purposes we are working with an n=1 for each athlete and while this was their best registered throw, this does not necessarily mean that it was the best representation of their technical model or what they were trying to achieve technically. It was noticeable, for example that Robert Harting had only 2 valid throws in the competition, unusual for him, but perhaps indicative of his struggle with a knee injury over the past 2 years.

While the last 5 World Championships Winners were represented in the Final with Malachowski (2015), Harting (2013, 2011, 2009) and Kanter (2007), it should also be noted that these athletes are coming towards the end of their careers and at age 34, 33 and 38 respectively, they were the oldest in the field. In what may be seen as a changing of the guard in Men's Discus, the top 4 finishers, Gudzius, Stahl, Finley and Dacres, were among the youngest in the field at age 26, 25, 26 and 23 respectively. It is perhaps interesting to note also that the medallists were also the biggest athletes in the field at 2.00 m/135 kg, 2.00 m/150 kg and 2.04 m/150 kg respectively compared to an average of 1.96 m/126.8 kg.

The three medallists produced some of the highest absolute release velocities of the competition with their medal winning throws, averaging just over 24 m/s at the point of release (see Figure 4). As expected, a very strong positive correlation of 0.81 was found between the absolute velocity at release and throwing performance. This finding seems to affirm the position that the release velocity is the most important release factor in determining performance. The correlations between other release factors, such as angle of release and height of release, with throwing performance were found to be much lower at −0.09 and .37, respectively.

A strong correlation was also found between horizontal release velocity and throwing performance at 0.54 for the men's discus finalists. In addition, the medal winners had a higher implement velocity (seen in Figure 4) entering the airborne phase relative to the other finalists (at 51.2%, 42.6%, and 40%). The overall average for the all finalists upon entry to the airborne phase is 39.6%. Given these outcomes, it appears the top throwers may have attempted a speed-oriented approach with an aggressive drive across the ring before transitioning to the delivery phase in order to maximize release velocity. This was particularly noticeable with Gudzius and Stahl, Gold and Silver medallists, who despite being some of the biggest and heaviest of the athletes, they displayed great speed across the circle. If you look at the relative time from Entry (Right Foot Off) at the back of the circle to landing in the "power position" (Left (Blocking) Leg

touchdown) at the front, they were noticeably the fastest with a cumulative time of 553 ms for Gudzius and 567 ms for Stahl, compared to an average of 651 ms of the remaining finalists.

In terms of throwing technique, eleven out of the twelve finalists utilised the jump reverse technique at the finish of the throw. Only Harting used a fixed foot delivery. As seen in Figure 4, almost all the male throwers exhibited the classic discus acceleration model where the implement gains close to 40% of its final release velocity in the first double support (DS_1) and first single support phases (SS_1), before losing a small amount of velocity in the transition phase (SS_2) before they enter the power position (DS_2). This was then followed by a large increase in implement velocity (an average of 62.4% of final release speed) in the delivery phase (DS_2) into release.

Only Harting and Weisshaidinger exhibited a slightly different acceleration pattern in which they were able to accelerate the discus through the airborne and transition phases. This in turn saw them produce the lowest percentage of final release velocity developed in the delivery phases at 59% and 48%, respectively. It can be seen in Harting's case that the increase in velocity through all phases is a hallmark of the fixed foot delivery technique. It should also be noted that Harting had a distinctly slower implement speed (29.6% of final release velocity) going into the airborne phase than all the other male competitors, which was designed to set up this type of acceleration pattern.

When comparing Robert Harting, as the only fixed foot release thrower among the male finalists, you can see some interesting data from the report that shows some key differences in this technique. Harting demonstrates the lowest release height of all athletes at 1.20 m (average 1.57 m) and lowest arm elevation angle at release of −11.1° (average 5.3°), from the widest base of 0.85 m, (average 0.67 m) and the greatest trunk tilt angle of 35.1° (average 26.6°) at power position before delivery. This implies that he is trying to get the longest radius of the implement path which can be seen in Figure 6.6, the superior view of the discus motion path, where the wide position of the implement at release can be seen. This can also be seen when comparing the absolute duration of each phase in Table 5, where from entry (Right Foot Off) at the back of the circle, to landing at the power position (Left Foot Down) at the front of the circle, Harting has the longest total duration of 720 ms, compared to the overall average of 636 ms and particularly Gudzius (553 ms) and Stahl (567 ms), but has the quickest delivery phase of 147 ms, compared to the average of 182 ms. This may be seen by some as a "slingshot" delivery, utilising a long preparation through the turn and a "cracking of the whip" at delivery. As seen in Figure 5, Harting displayed the highest horizontal component of velocity of all athletes, but one of the lowest vertical components giving one of the lowest release angles of 32.5°.

Harting matches up very closely with the implement speed at the same portion of the throw as the female discus finalists (29.5%), of which the vast majority also utilised the fixed foot delivery. This suggests it could be a distinguishing factor in the kinematics between the fixed foot delivery and the jump reverse delivery. A second distinguishing kinematic factor between the two technical styles may be the difference in implement acceleration in the transition (SS_2) phase. In this phase the men's finalists, in which 11 out of 12 used a reverse delivery, as a group averaged adding a mere 0.4% of final release velocity to the implement. In contrast, the women's finalists, of which 10 out of 12 used the fixed foot delivery, added 11.6% of the final release velocity in the transition phase.

CONTRIBUTORS

Dr Tim Bennett is a Senior Lecturer in Sport and Exercise Biomechanics. His research interests are in the area of striking sports, particularly soccer kicking analysis. He is also interested in motor control and human movement variability and this can influence sports performance under varying task constraints. Tim is also involved in golf and throwing research projects, which aim to provide a better understanding of human movement and performance.

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Shaun Pickering is the former Head of Heavy Throws for UK Athletics through the London 2012 Olympic Games and is an IAAF Coaching Academy Member. As an athlete, Shaun was a GB International in the Shot Put, Discus and Hammer throw, and competed at the 1996 Atlanta Olympics and was a Commonwealth Games medallist in 1998. Shaun is coach to various international athletes, and has previously coached Rob Womack (Great Britain) to Paralympic bronze medal in the F55 Shot Put at London 2012.