



## BIOMECHANICAL REPORT

FOR THE

**IAAF™**

WORLD INDOOR CHAMPIONSHIPS 2018

### Shot Put Women

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## INTRODUCTION

The highly anticipated women's shot put took place on the evening of Friday 2<sup>nd</sup> March. Coming into the final, Danniell Thomas-Dodd from Jamaica was the favourite as she was the only athlete to throw over 19 m in the build-up to the 2018 Championships. Thomas-Dodd took an early lead, which Lijiao Gong the world outdoor champion from China bettered in the second round. However, Anita Márton from Hungary dominated the competition from the third round, whereby she produced a world leading throw measured at 19.48 m, which she subsequently improved with the last throw of the competition at 19.62 m. Thomas-Dodd secured the silver medal in the third round with her best throw of the evening measured at 19.22 m. Gong who was somewhat off her outdoor form secured the bronze medal with her second throw measured at 18.98 m, although it was not until the final round whereby she bettered it to 19.08 m.

IAAF		World Indoor Championships			Birmingham (GBR)		1-4 March 2018					
RESULTS												
Shot Put Women - Final												
RECORDS		RESULT NAME			COUNTRY		AGE		VENUE		DATE	
World Indoor Record		22.50 Helena FIBINGEROVÁ			TCH		28		Jablonec nad Nisou		19 Feb 1977	
Championship Record		20.67 Valerie ADAMS			NZL		30		Sopot (Ergo Arena)		8 Mar 2014	
World Leading		19.62 Anita MÁRTON			HUN		29		Birmingham		2 Mar 2018	
Area Indoor Record		National Indoor Record			Personal Best		Season Best					
2 March 2018		20:09 START TIME										
		21:31 END TIME										
PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT	1	2	3	ORDER	4	5	6
1	Anita MÁRTON	HUN	15 Jan 89	13	<b>19.62</b> WL	18.29	18.30	19.48	8	X	18.96	19.62
2	Danniell THOMAS-DODD	JAM	11 Nov 92	14	<b>19.22</b> NIR	18.92	18.95	19.22	7	X	18.86	19.07
3	Lijiao GONG	CHN	24 Jan 89	15	<b>19.08</b> SB	X	18.98	X	6	18.83	18.81	19.08
4	Yang GAO	CHN	1 Mar 93	2	<b>18.77</b> PB	18.45	18.77	18.41	5	18.70	18.20	18.51
5	Paulina GUBA	POL	14 May 91	12	<b>18.54</b>	18.53	X	18.16	4	18.31	18.54	
6	Aliona DUBITSKAYA	BLR	25 Jan 90	9	<b>18.21</b> SB	X	X	18.21	3	X	X	
7	Yaniuvis LÓPEZ	CUB	1 Feb 86	7	<b>18.19</b> PB	17.81	18.05	X	1	18.04	18.19	
8	Jeneva STEVENS	USA	28 Oct 89	4	<b>18.18</b>	15.90	18.18	18.00	2	17.64	X	
9	Cleopatra BOREL	TTO	10 Mar 79	11	<b>17.80</b>	17.33	17.80	17.49				
10	Brittany CREW	CAN	6 Mar 94	10	<b>17.61</b>	X	17.61	16.13				
11	Yuliya LEANTSIUK	BLR	31 Jan 84	6	<b>17.44</b>	X	17.44	17.15				
12	Daniella HILL	USA	16 May 91	8	<b>17.26</b>	17.22	17.26	X				
13	Fanny ROOS	SWE	2 Jan 95	5	<b>17.23</b>	17.19	17.23	X				
14	Dimitriana SURDU	MDA	12 Apr 94	1	<b>17.22</b>	17.15	17.22	X				
15	Radoslava MAVRODIEVA	BUL	13 Mar 87	3	<b>16.33</b>	16.33	X	X				
Timing and Measurement by SEIKO					AT-SP-W-f--A--RS1..v1			Issued at 21:34 on Friday, 02 March 2018				
Official Partners												
												

## METHODS

Four vantage locations for camera placements were identified and secured at strategic locations around the arena. A total of four high-speed cameras were used to record the action during the shot put final. Four Sony PXW-FS5 cameras operating at 200 Hz (shutter speed: 1/1250; ISO: 2000-4000 depending on the light; FHD: 1920x1080 px) were positioned at the four locations to provide three-dimensional (3D) footage for the analysis of all key phases of the shot put throw.

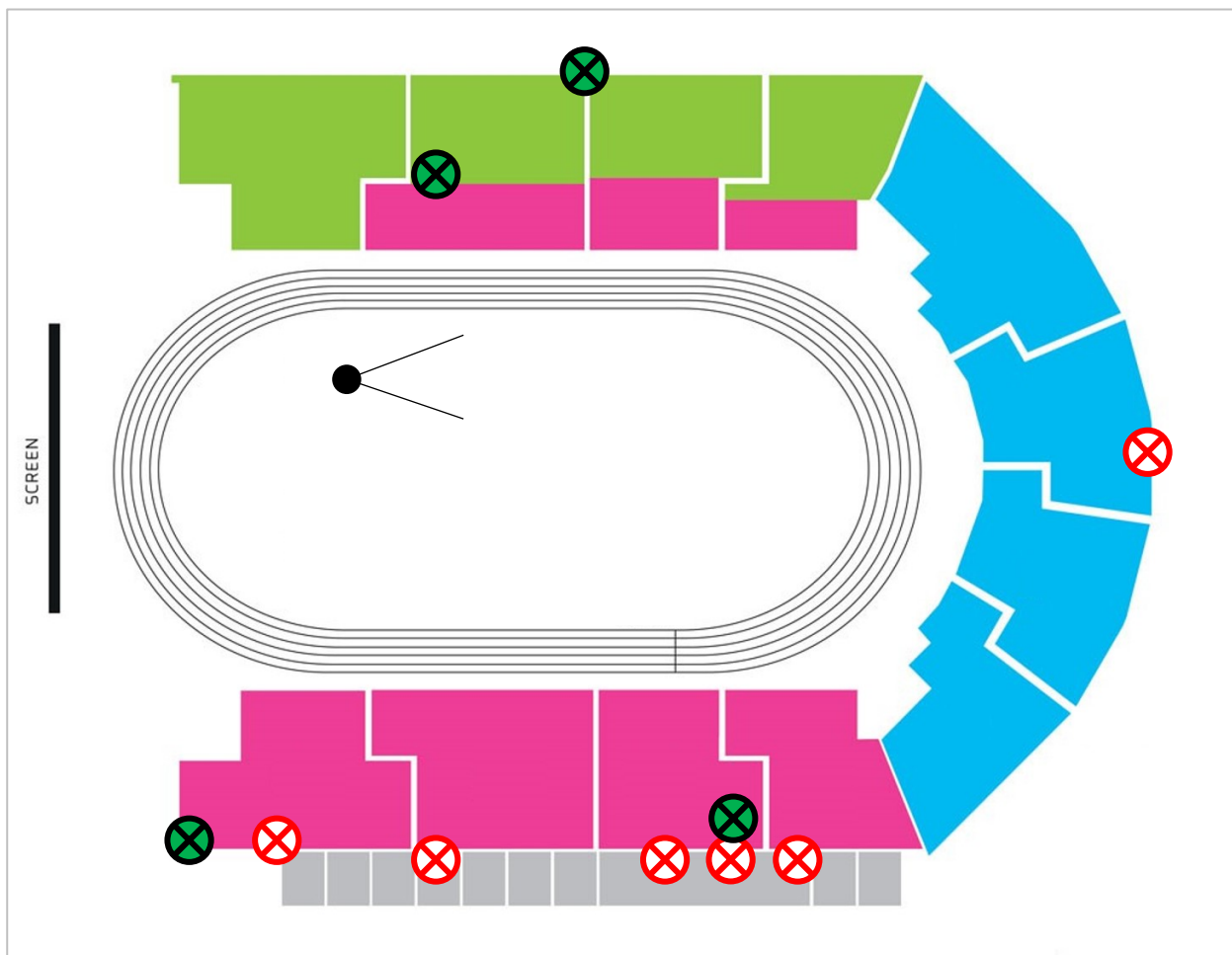


Figure 1. Camera layout for the women's shot put indicated by green-filled circles.

Before and after the 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.



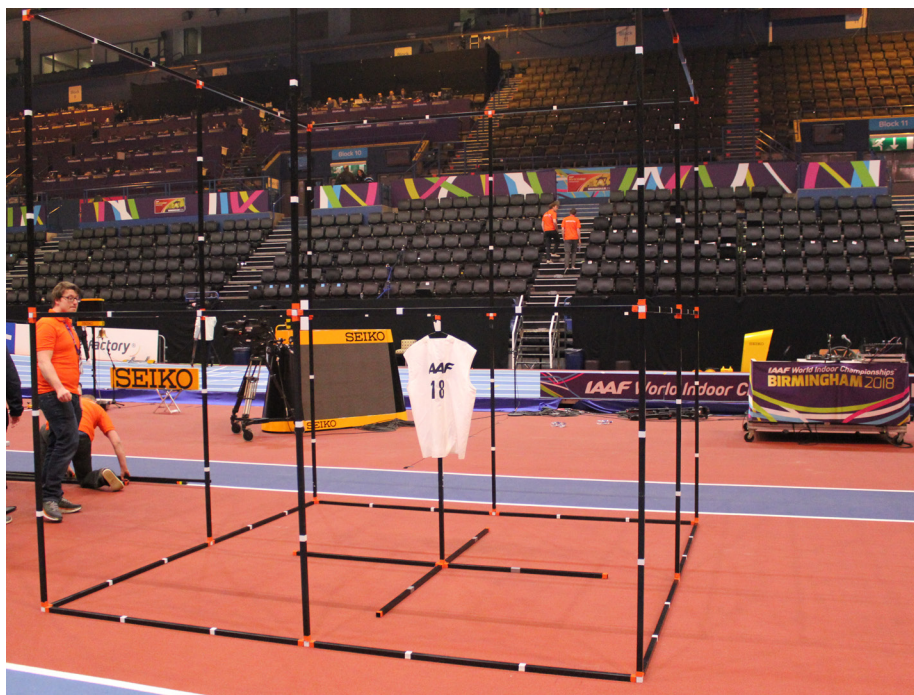


Figure 2. The calibration frame was constructed and recorded before and after the competition.

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 critical instants to synchronise the two-dimensional coordinates from each camera involved in the recording. The shot was digitised 15 frames before the movement was initiated within the start position 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 points over frame method was used to make any necessary adjustments, where the shot was tracked at each point through the full motion. 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. Release parameters were used to mathematically calculate the projectile's range, which was subsequently compared to the officially published distance. The minor but expected differences between the calculated range and the measured distance confirmed the high level of accuracy of the data analysis process. Where available, athletes' heights and weights were obtained from 'Athletics 2017' (edited by Peter Matthews and published by the Association of Track and Field Statisticians), and online sources.

Table 1. Definition of variables.

Variable	Definition
<b>Release velocity</b>	The resultant velocity of the shot at release.
<b>Angle of release</b>	The angle between the shot direction of travel and the horizontal at release.
<b>Height of release</b>	The vertical distance from the shot centre to the ground at release.
<b>Reach over stop board</b>	The horizontal distance of shot to the stop board at release.
<b>Path length of the shot</b>	The shot's cumulative distance travelled across the circle.
<b>Height of shot</b>	The vertical position of the shot at key phases of the movement.
<b>Velocity of shot</b>	The resultant velocity of the shot at key phases of the movement.
<b>Length of glide or flight phase</b>	The anteroposterior distance travelled across the circle in the glide phase or flight phase.
<b>Foot distance in power position</b>	The anteroposterior distance between the two feet in the power position.
<b>Duration of key phases</b>	The total time taken to perform each key phase.
<b>Forward-backward trunk lean at release (<math>\alpha</math>)</b>	The forward-backward trunk lean signifies the angle to the vertical (see Figure 4). Therefore, $0^\circ$ identifies the trunk to be positioned vertically, whereas a positive angle identifies that the trunk is leaning towards the front of the circle (e.g., forward trunk lean). In contrast, a negative angle represents the trunk is leaning towards the back of the circle (e.g., backwards trunk lean).
<b>Left-right trunk lean at release (<math>\beta</math>)</b>	The left-right trunk lean signifies the angle to the vertical (see Figure 4). Therefore, $0^\circ$ identifies the trunk to be positioned vertically, whereas a positive angle identifies that the trunk is leaning towards the right of the circle (e.g., right trunk lean) as viewed from behind. In contrast, a negative angle represents the trunk is leaning towards the left of the circle (e.g., left trunk lean) as viewed from behind.
<b>Shoulder-hip separation angle (<math>\gamma</math>)</b>	The angle between the line of the shoulders and the line of the hips (see Figure 4), where a negative separation angle indicates that the shoulder axis is ahead of the hip axis in the angular motion path.

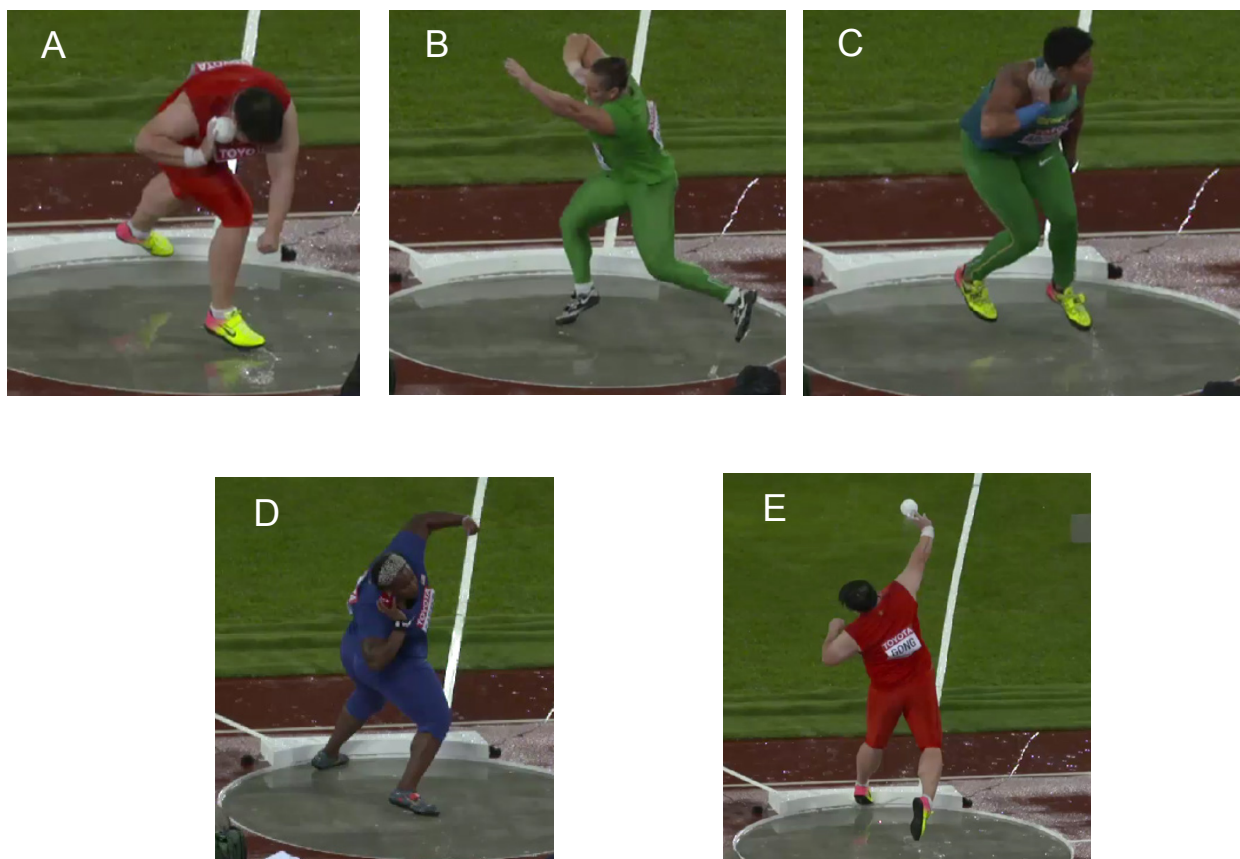


Figure 3. Visual representation of the phases for the three different techniques implemented, the power position and release. A) glide, B) rotational, C) switch glide, D) the power position and E) release.

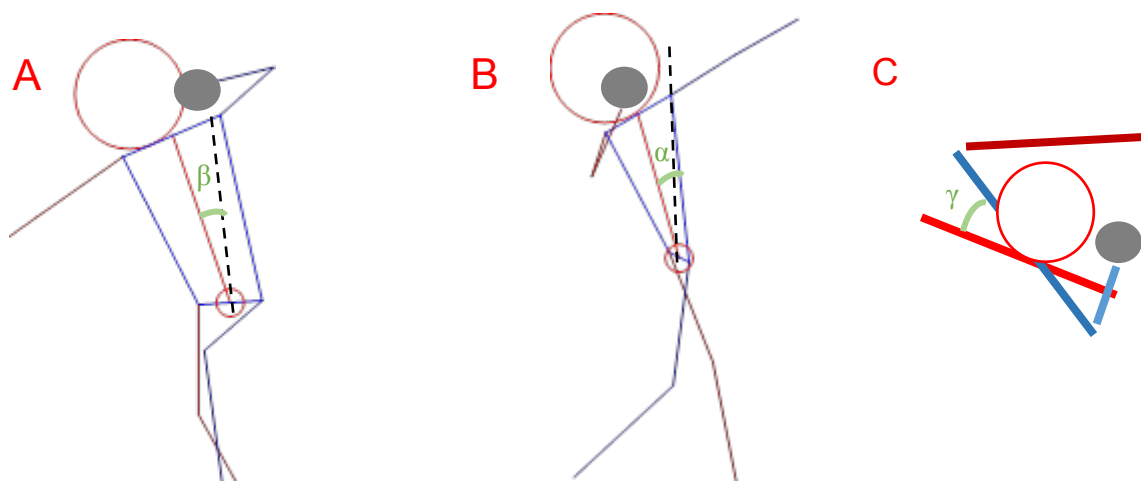


Figure 4. Visual representation of A) left trunk lean ( $\beta$ ), B) forward-backward trunk lean ( $\alpha$ ) and C) shoulder-hip separation angle ( $\gamma$ ).

## RESULTS

### Performance

Table 2 details the fifteen athletes' season's (SB) and indoor personal best (PB) throw before the World Championships, as well as a comparison with their performance. Notably, four of the athletes threw indoor personal bests these included Márton's world leading mark and Thomas-Dodd's National Indoor Record.

Table 2. The measured distances for the season's best (SB), indoor personal best (PB), performance during final (FP) and change scores between these variables for the fifteen finalists.

Athlete	SB (m)	PB (m)	FP (m)	SB vs. FP (m)	PB vs. FP (m)
MÁRTON	18.87	19.33	19.62	0.75	0.29
THOMAS-DODD	19.05	19.05	19.22	0.17	0.17
GONG	-	19.93	19.08	-	-0.85
GAO	18.54	18.54	18.77	0.23	0.23
GUBA	18.77	18.77	18.54	-0.23	-0.23
DUBITSKAYA	-	18.34	18.21	-	-0.13
LÓPEZ	17.90	17.90	18.19	0.29	0.29
STEVENS	18.55	19.10	18.18	-0.37	-0.92
BOREL	18.60	19.48	17.80	-0.80	-1.68
CREW	18.20	18.20	17.61	-0.59	-0.59
LEANTSIUK	17.48	19.00	17.44	-0.04	-1.56
HILL	18.10	18.87	17.26	-0.84	-1.61
ROOS	17.88	18.13	17.23	-0.65	-0.90
SURDU	17.83	17.83	17.22	-0.61	-0.61
MAVRODIEVA	17.85	18.36	16.33	-1.52	-2.03

## Anthropometric data and implemented technique

Table 3 details that seven of the athletes utilised the glide technique and seven utilised the rotational technique. The remaining athlete, Mavrodieva, utilised a switch glide technique, whereby she switched her legs during the airborne phase of the glide (see Figure 3).

Table 3. The anthropometric data and implemented technique for the fifteen competitors.

Athlete	Height (m)	Body mass (kg)	Technique
MÁRTON	1.72	90	Rotational
THOMAS-DODD	1.66	89	Rotational
GONG	1.75	110	Glide
GAO	1.78	110	Glide
GUBA	1.80	90	Glide
DUBITSKAYA	1.80	76	Glide
LÓPEZ	1.80	71	Glide
STEVENS	1.78	102	Rotational
BOREL	1.72	91	Glide
CREW	1.78	111	Rotational
LEANTSIUK	1.85	80	Glide
HILL	1.83	-	Rotational
ROOS	1.73	-	Rotational
SURDU	1.74	83	Rotational
MAVRODIEVA	1.78	86	Switch-Glide

## Release parameters

Table 4 and Figures 5 and 6 detail the release parameters of the best throws for the fifteen athletes, although because of technical challenges when recording López's best throw the data presented within this report is based on her second-best throw of the final (round 2). The gold medallist Márton utilised the rotational technique, whereby she produced the highest release velocity (13.33 m/s) in comparison with the other finalists. Interestingly, Thomas-Dodd and Gong produced the second (13.15 m/s) and third (13.11 m/s) highest release velocities respectively. The three medallists produced a similar angle of release (Medallists' mean:  $35.8 \pm 0.3^\circ$ ), height of release (Medallists' mean:  $1.97 \pm 0.4$  m) and reach over the stop board (Medallists' mean:  $0.07 \pm 0.03$  m). In general, the athletes who utilised the rotational technique leant slightly backwards (rotational mean:  $-7 \pm 2^\circ$ ) and towards the left (rotational mean:  $-2 \pm 8^\circ$ ) at release. In contrast,

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the athletes who utilised the glide technique on the whole leant slightly forward (glide mean:  $3 \pm 8^\circ$ ) and towards the left (glide mean:  $-13 \pm 6^\circ$ ).

Table 4. The release parameters of the best throws for the fifteen finalists.

Athlete	Analysed throw	Result (m)	Release velocity (m/s)	Angle of release (°)	Release height (m)	Release height relative to body height (%)	Reach over stop board (m)	FB trunk lean at release (°)	LR trunk lean at release (°)
MÁRTON	6	19.62	13.33	36.0	2.01	116.6	0.07	-5	3
THOMAS-DODD	3	19.22	13.15	35.4	1.93	116.1	0.11	-8	-11
GONG	6	19.08	13.11	36.0	1.96	111.8	0.03	1	-19
GAO	2	18.77	12.86	38.6	2.08	116.9	0.00	-8	-4
GUBA	5	18.54	12.85	35.0	2.11	117.3	0.15	2	-20
DUBITSKAYA	3	18.21	12.63	36.7	1.98	109.7	0.23	4	-11
LÓPEZ	2*	18.05	12.53	42.2	2.16	120.1	-0.06	8	-18
STEVENS	2	18.18	12.63	37.4	2.10	118.1	0.02	-6	-9
BOREL	2	17.80	12.74	33.5	1.95	113.3	0.15	16	-16
CREW	2	17.61	12.65	34.9	1.87	105.2	0.08	-8	8
LEANTSIUK	2	17.44	12.38	36.8	2.02	109.3	0.04	-5	-5
HILL	2	17.26	12.43	35.2	2.09	114.3	-0.01	-7	-8
ROOS	2	17.23	12.58	31.2	1.91	110.5	0.27	-12	6
SURDU	2	17.22	12.31	40.5	1.94	111.7	0.04	-5	-6
MAVRODIEVA	1	16.33	12.63	27.1	1.88	105.6	0.20	5	-12

Key: FB = forward-backward, LR = left-right lean and \* = second best throw.

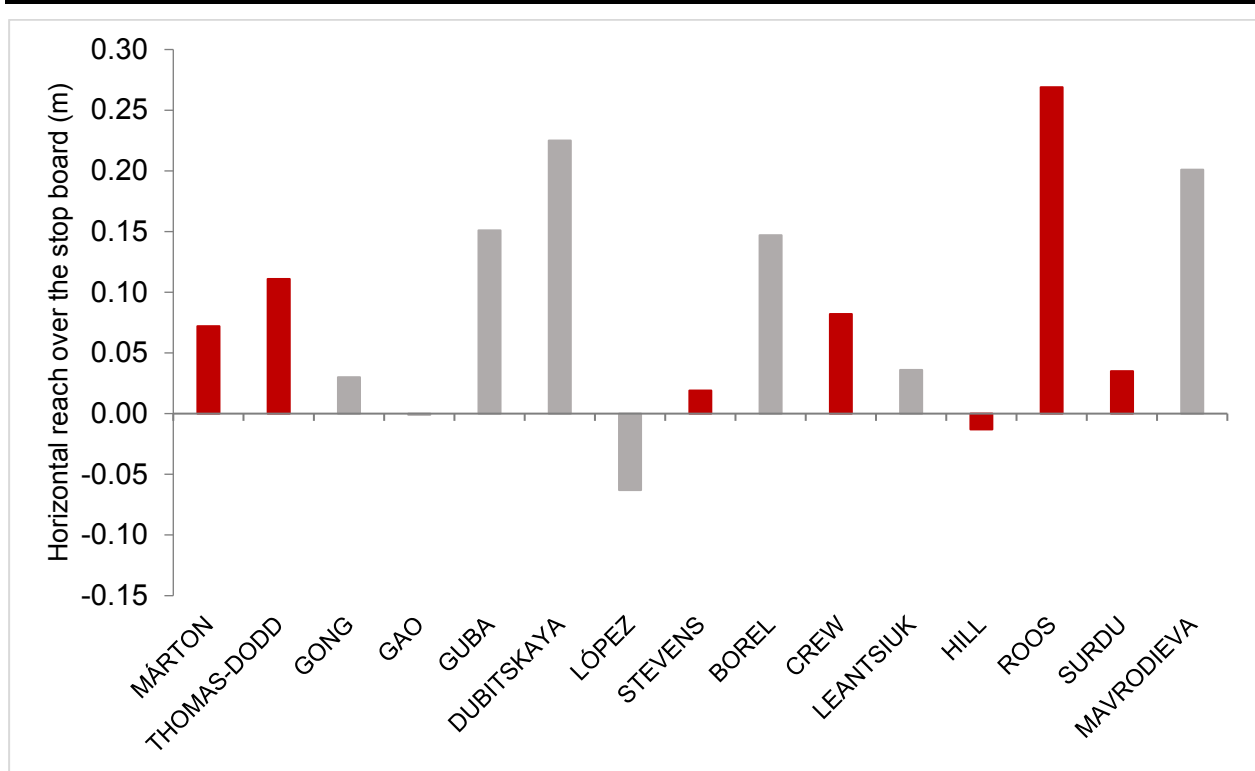


Figure 5. The reach over stop board for the fifteen athletes. The red bars signify the athletes who utilised the rotational technique and the grey bars signify the athletes who utilised the glide/switch glide technique.

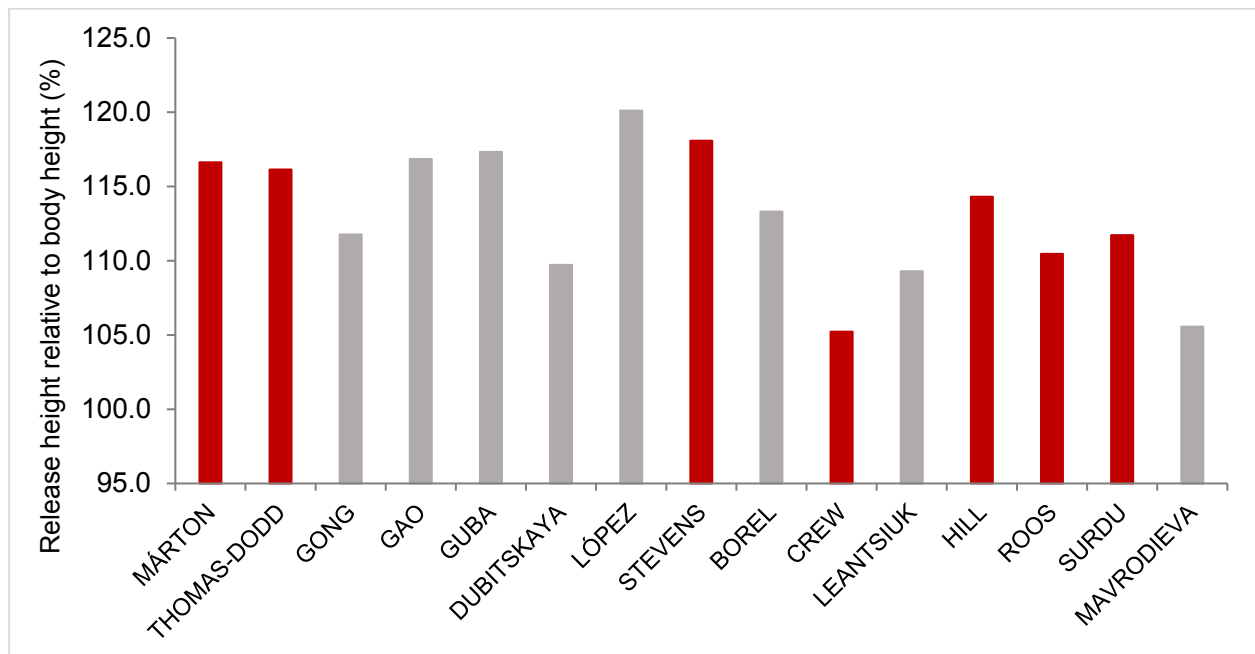


Figure 6. The height of release expressed as a percentage of body height for the fifteen athletes. The red bars signify the athletes who utilised the rotational technique and the grey bars signify the athletes who utilised the glide technique.



## Velocity of the shot



Figure 7. Visual description for each of the key phases in the rotational technique: A) right leg push-off, B) left leg push-off, C) right leg touchdown, D) brace leg touchdown and E) release.

Figure 7 provides a visual description of each key phase in the rotational technique. Table 5 and Figure 8 detail the resultant velocity of the shot at key phases for the athletes that utilised the rotational technique. Notably, Márton entered the power position with a slightly higher shot velocity (1.55 m/s) in comparison with Thomas-Dodd (1.43 m/s). Moreover, Márton developed the highest shot velocity within the power position (11.78 m/s) in comparison with the other athletes who utilised the rotational technique. Interestingly, all of the athletes that utilised the rotational technique delivered the shot without being in contact with the ground. Márton and Crew delivered the shot utilising a sequence whereby the brace leg took off before the right leg, whereas the other five athletes delivered the shot utilising a sequence of right leg take-off and then brace leg take-off.

Table 5. The velocity of the shot at the key phases for the seven rotational athletes.

Athlete	Right leg push-off (m/s)	Left leg push-off (m/s)	Right leg touchdown (m/s)	Brace leg touchdown (m/s)	Right leg take-off (m/s)	Brace leg take-off (m/s)	Release (m/s)
<b>MÁRTON</b>	1.47	1.22	1.15	1.55	12.89	10.09	13.33
<b>THOMAS-DODD</b>	1.90	0.80	1.46	1.43	9.25	11.38	13.15
<b>STEVENS</b>	1.17	1.12	1.39	1.21	10.38	11.14	12.63
<b>CREW</b>	1.68	1.65	0.98	3.05	11.24	10.83	12.65
<b>HILL</b>	3.01	1.04	0.89	1.48	7.31	10.08	12.43
<b>ROOS</b>	1.33	2.16	1.73	2.14	10.08	11.53	12.58
<b>SURDU</b>	3.03	1.21	1.23	1.91	10.11	10.96	12.31

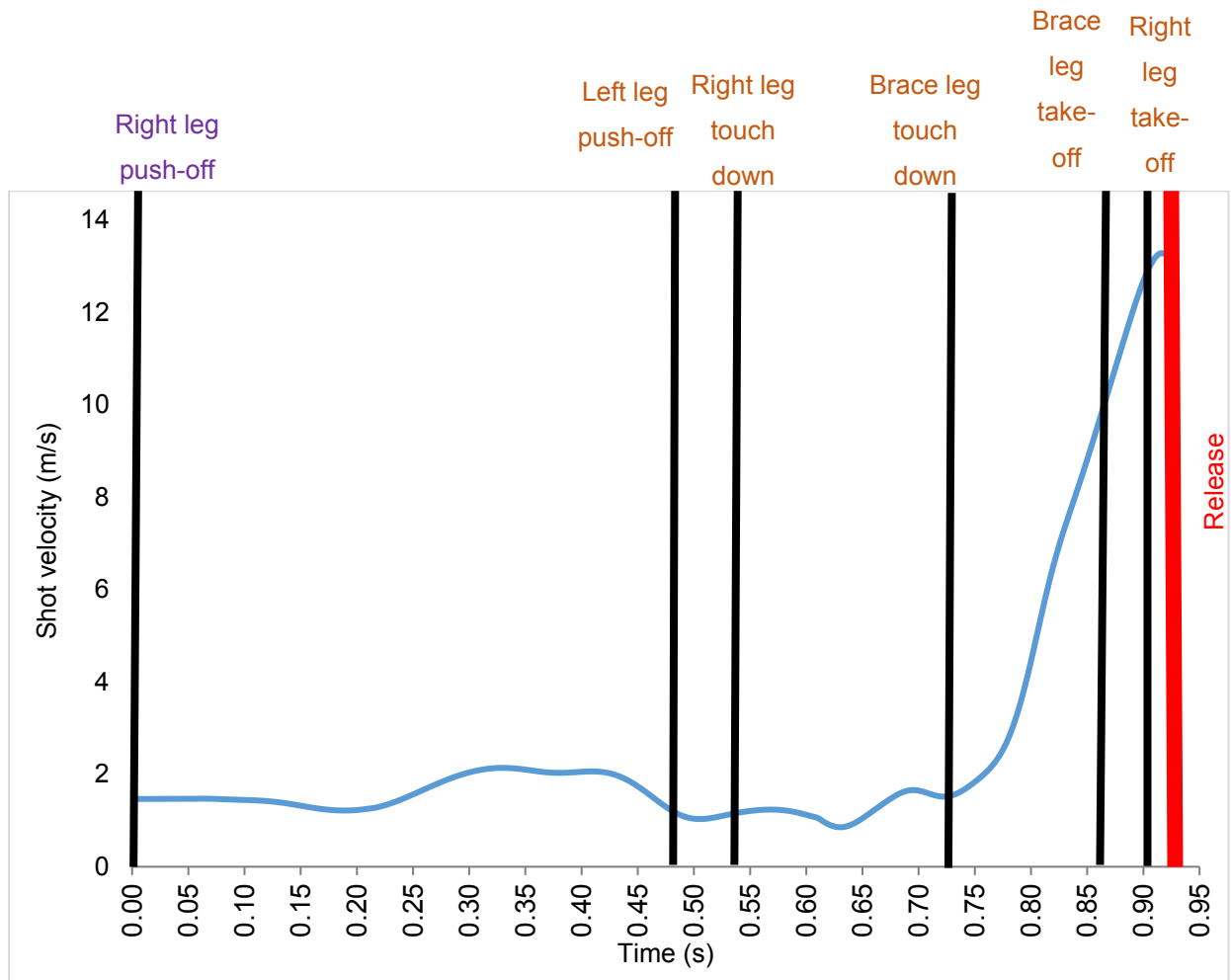


Figure 8. Márton's velocity profile of the shot from right leg push-off to release.

Figure 9 provides a visual description of each key phase in the glide technique. The switch-glide technique, utilised by Mavrodieva, differs in that it starts with a left-footed push-off. Table 6 details the velocity of the shot at key phases for the athletes who utilised the glide technique.

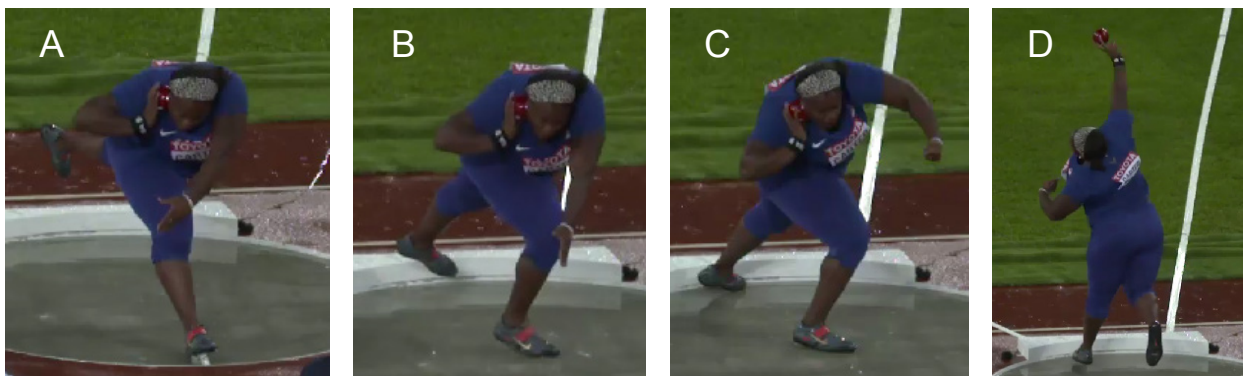


Figure 9. Visual description for each of the key phases in the glide technique: A) right leg push-off, B) right leg touchdown, C) brace leg touchdown and D) release.

Table 6. The velocity of the shot at the key phases for the switch glide and seven glide athletes.

Athlete	Right leg push-off (m/s)	Right leg touchdown (m/s)	Brace leg touchdown (m/s)	Rear leg take-off (m/s)	Brace leg take-off (m/s)	Release (m/s)
<b>GONG</b>	2.79	2.13	3.54	6.69	11.97	13.11
<b>GAO</b>	2.84	2.34	2.21	10.05	10.05	12.86
<b>GUBA</b>	2.90	2.30	2.97	8.99	11.56	12.85
<b>DUBITSKAYA</b>	3.30	2.38	2.51	9.20	11.56	12.63
<b>LÓPEZ</b>	3.51	2.44	2.17	9.70	10.77	12.53
<b>BOREL</b>	2.44	1.76	2.89	9.13	11.52	12.74
<b>LEANTSIUK</b>	2.49	2.22	3.48	9.45	9.45	12.38
<b>MAVRODIEVA</b>	3.49	2.69	2.89	9.79	11.43	13.64

Table 6 and Figure 10 detail the velocity of the shot at key phases for the athletes that utilised the glide technique. On the whole, the glide athletes entered the power position with higher shot velocities when compared with the rotational athletes (mean glide:  $2.5 \pm 1.2$  vs. mean rotational:  $1.8 \pm 0.6$  m/s). In contrast, the rotational athletes produced superior increases in the shot's velocity (mean rotational:  $10.9 \pm 0.8$  m/s) within the power position in comparison with the glide athletes (mean glide:  $9.9 \pm 0.6$  m/s). The net result from these two different strategies provided similar release velocities (mean glide:  $12.7 \pm 0.2$  vs. mean rotational:  $12.7 \pm 0.4$  m/s). Interestingly, all of the athletes that utilised the glide technique delivered the shot without being in contact with the ground. The majority of these athletes delivered the shot utilising the same sequence, whereby the right leg took off before the brace leg. Notably, Gao and Leantsiuk demonstrated a simultaneous take-off of both brace leg and rear leg.

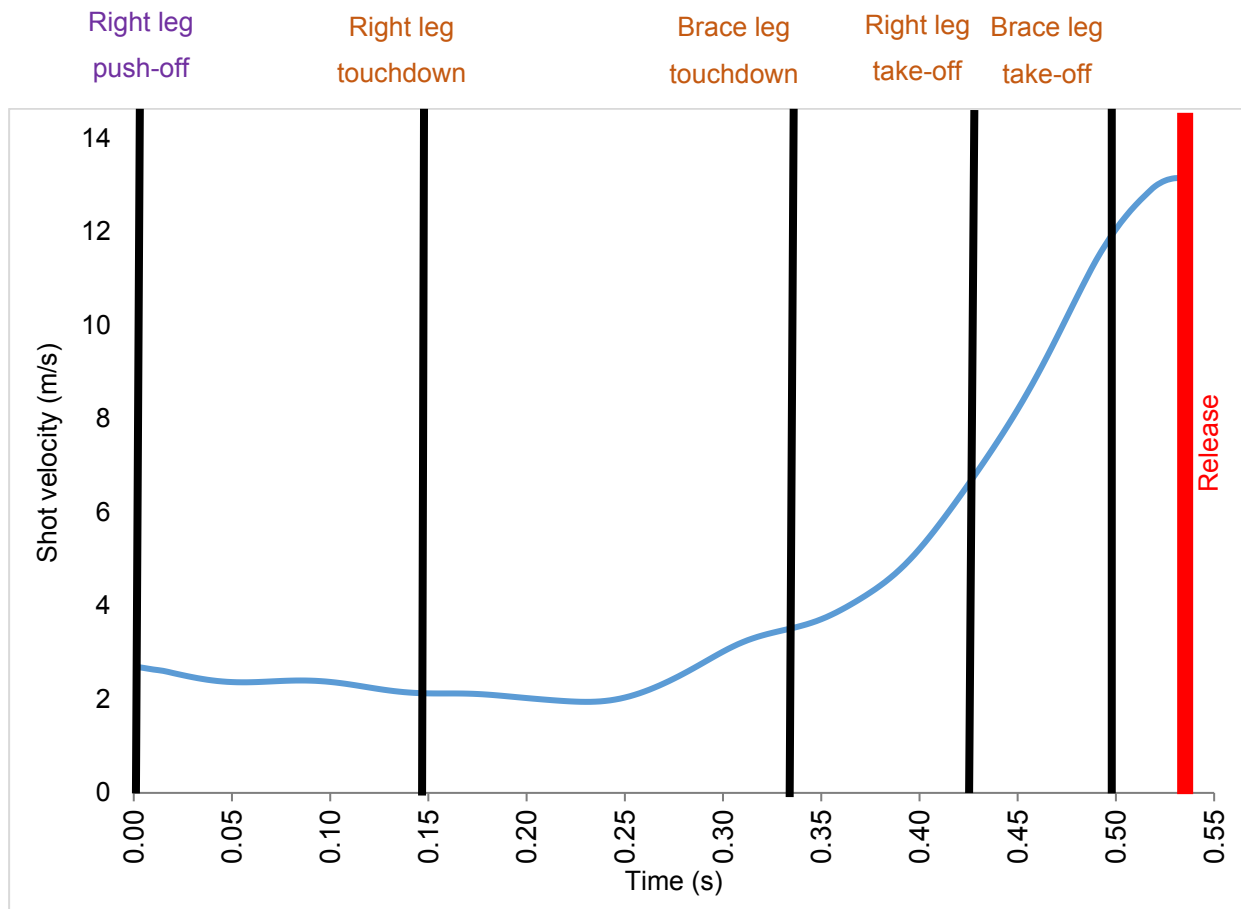


Figure 10. Gong's velocity profile of the shot from right leg push-off to release.

### Path of the shot during the key phases

The following page contains Figure 11, which shows the individual motion path (from a superior view) for the athletes who utilised the rotational technique. Following Figure 11, Table 7 shows the path length of the shot through each key phase of the rotational technique, which represents the shot's cumulative distance travelled across the circle.

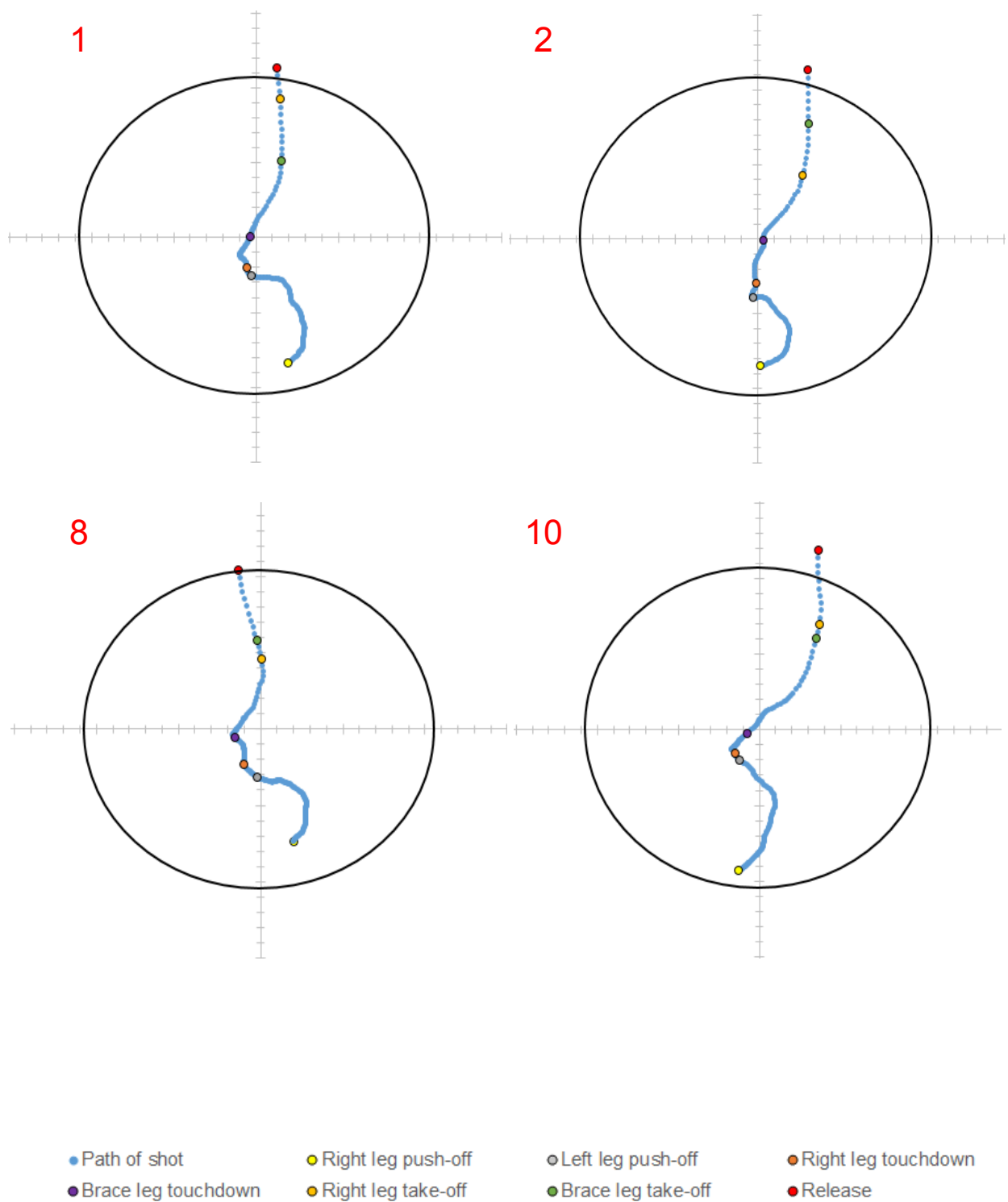


Figure 11. A visual representation from a superior view of the path of the shot from right leg push-off to release. Key: 1) Márton, 2) Thomas-Dodd, 8) Stevens, 10) Crew, 12) Hill, 13) Roos, 14) Surdu.

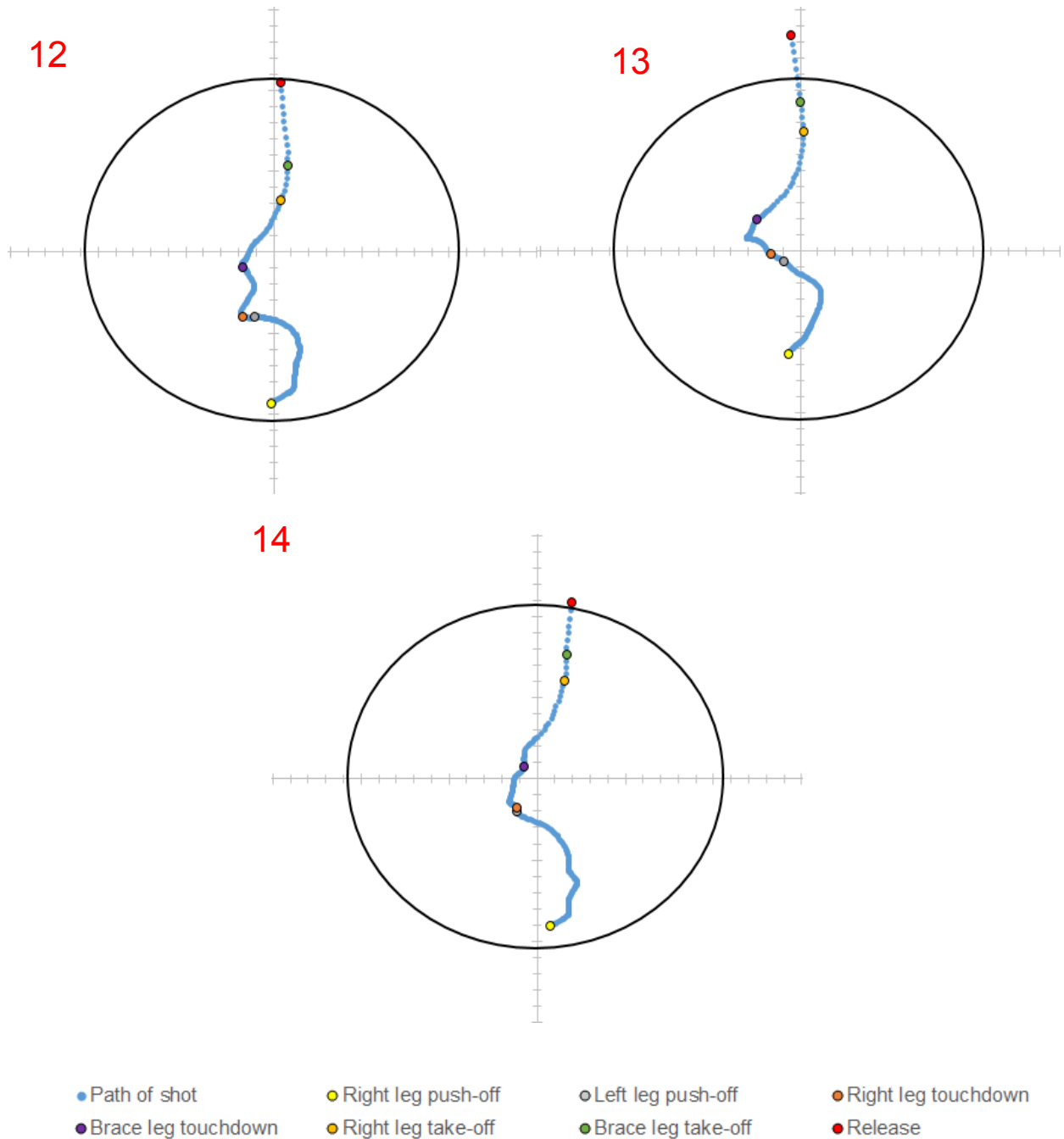


Figure 11 continued. A visual representation from a superior view of the path of the shot from right leg push-off to release. Key: 1) Márton, 2) Thomas-Dodd, 8) Stevens, 10) Crew, 12) Hill, 13) Roos, 14) Surdu.

Table 7. The total path length of the shot depicting the key phases for the seven rotational athletes.

Athlete	Right leg push-off to left leg push-off (m)	Left leg push-off to right leg touchdown (m)	Right leg touchdown to left leg touchdown (m)	Left leg touchdown to release (m)	Total path (m)
<b>MÁRTON</b>	0.80	0.08	0.26	1.44	2.58
<b>THOMAS-DODD</b>	0.70	0.12	0.31	1.47	2.60
<b>STEVENS</b>	0.67	0.11	0.24	1.49	2.51
<b>CREW</b>	0.95	0.06	0.23	1.47	2.71
<b>HILL</b>	0.82	0.07	0.39	1.45	2.73
<b>ROOS</b>	0.78	0.09	0.37	1.42	2.66
<b>SURDU</b>	0.96	0.03	0.32	1.35	2.66

The following page contains Figure 12, which shows the individual motion path (from a superior view) for the athletes who utilised the glide technique. Following Figure 12, Table 8 shows the path length of the shot through each key phase of the glide technique, which represents the shot's cumulative distance travelled across the circle.

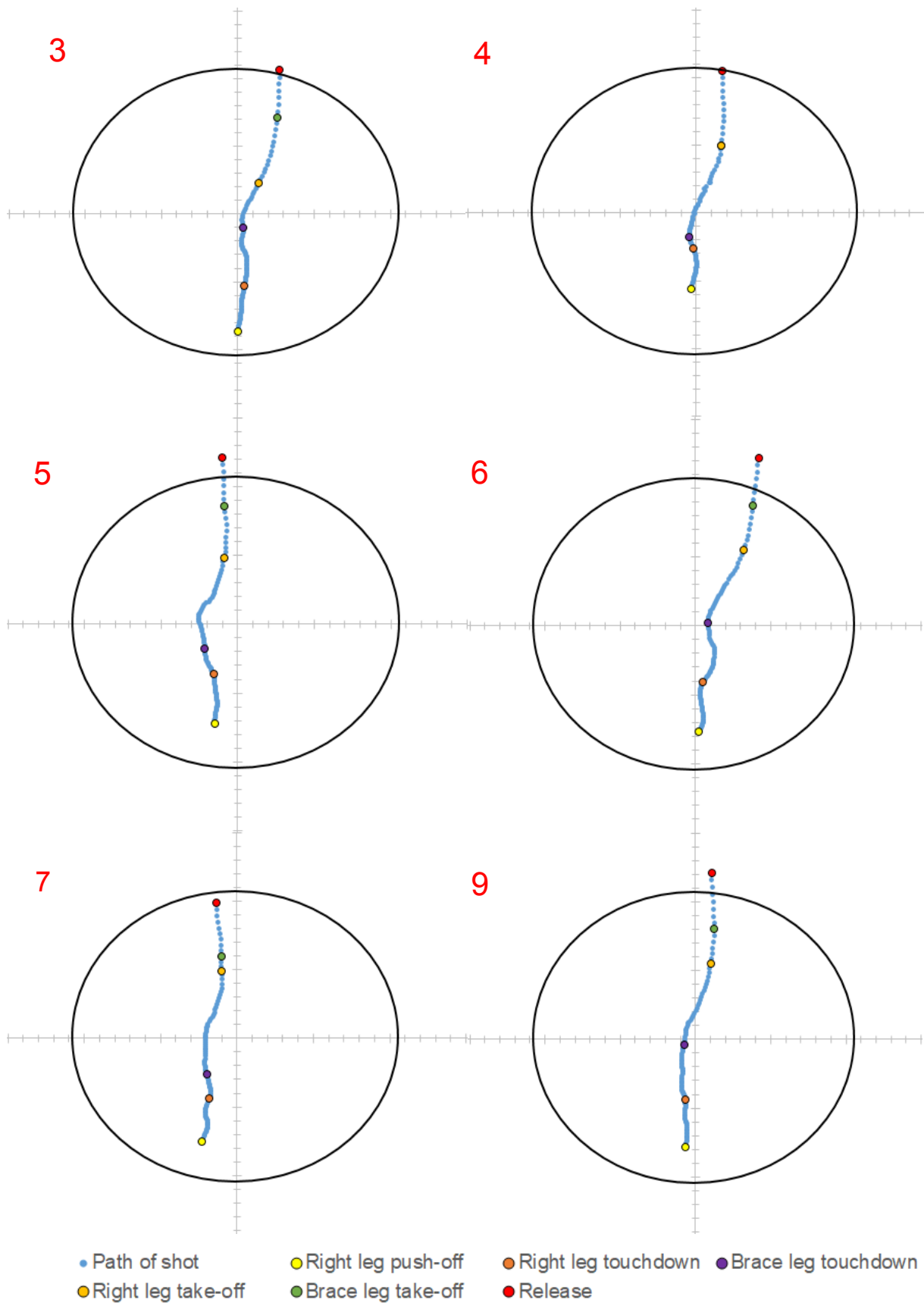


Figure 12. A visual representation from a superior view of the path of the shot from right leg push-off to release. Key: 3) Gong, 4) Gao, 5) Guba, 6) Dubitskaya, 7) López, 9) Borel, 11) Leantsiuk, 15) Mavrodieva.



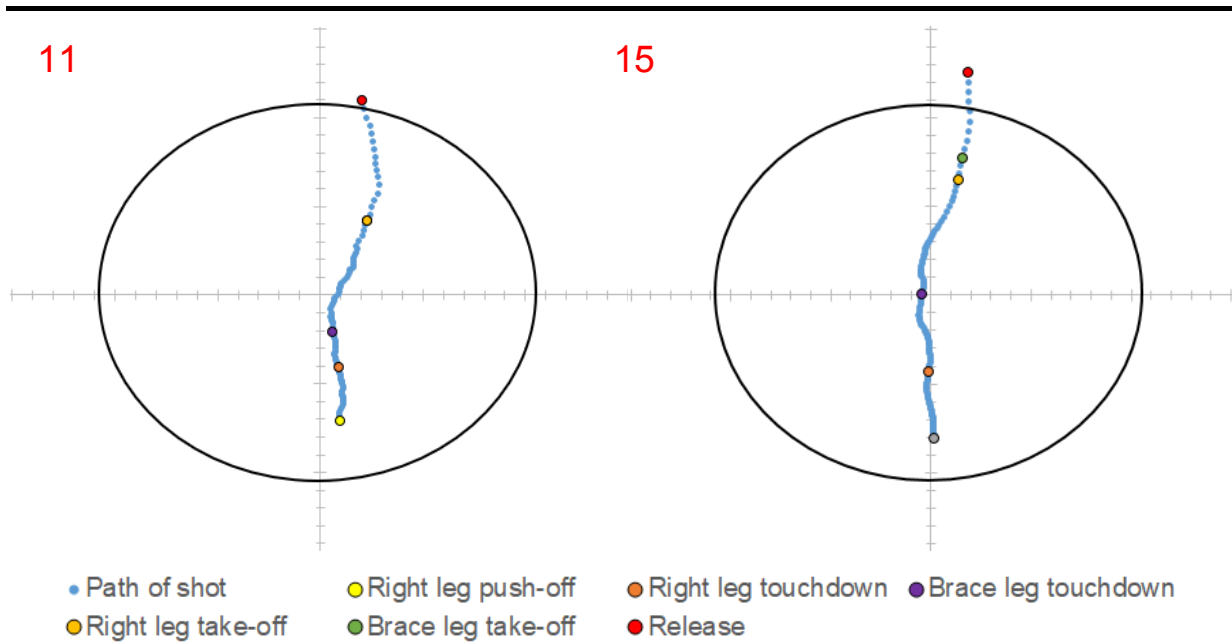


Figure 12 continued. A visual representation from a superior view of the path of the shot from right leg push-off to release. Key: 3) Gong, 4) Gao, 5) Guba, 6) Dubitskaya, 7) López, 9) Borel, 11) Leantsiuk, 15) Mavrodieva.

Table 8. The path length of the shot depicting the key phases for the switch glide and seven glide athletes.

Athlete	Right leg push-off to right leg touchdown (m)	Right leg touchdown to brace leg touchdown (m)	Brace leg touchdown to release (m)	Total path (m)
<b>GONG</b>	0.35	0.46	1.51	2.32
<b>GAO</b>	0.31	0.09	1.66	2.06
<b>GUBA</b>	0.38	0.20	1.78	2.36
<b>DUBITSKAYA</b>	0.40	0.46	1.56	2.42
<b>LÓPEZ</b>	0.36	0.18	1.70	2.24
<b>BOREL</b>	0.37	0.44	1.60	2.41
<b>LEANTSIUK</b>	0.32	0.21	1.73	2.26
<b>MAVRODIEVA</b>	0.41	0.45	1.55	2.41

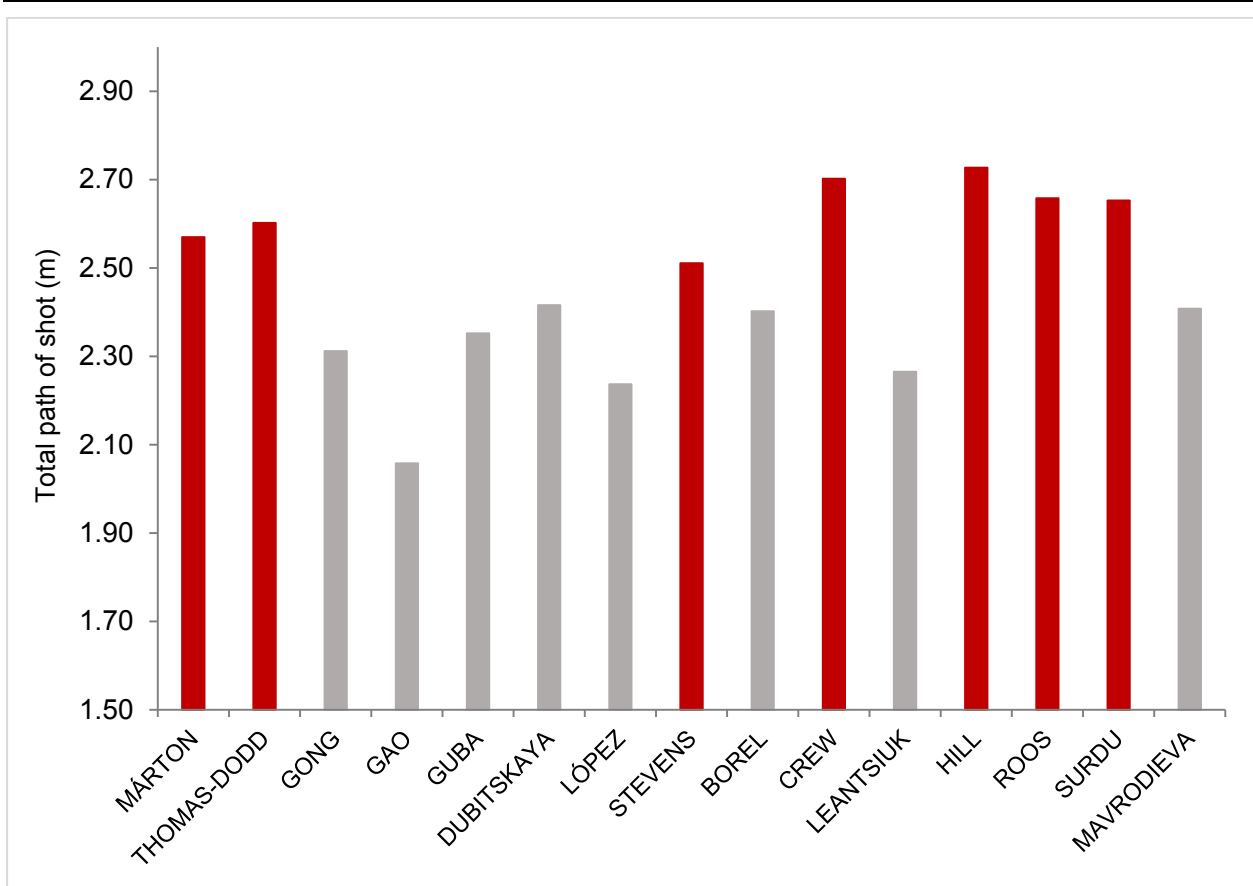


Figure 13. The total path length of shot for the fifteen athletes. The red bars signify the athletes who utilised the rotational technique and the grey bars signify the athletes who utilised the glide technique.

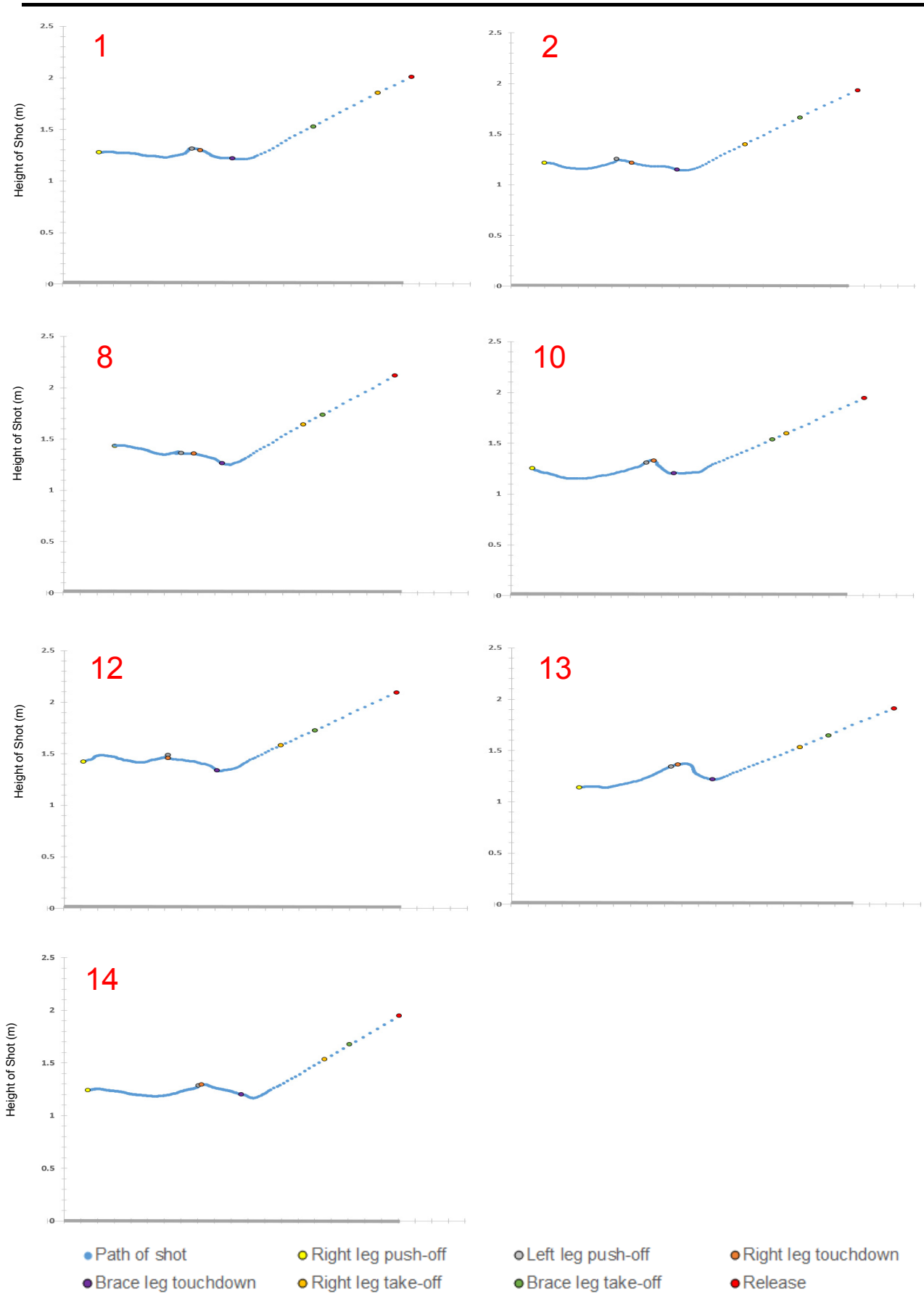


Figure 14. A visual representation from a side on view of the path of the shot from right leg push-off to release. Key: 1) Márton, 2) Thomas-Dodd, 8) Stevens, 10) Crew, 12) Hill, 13) Roos, 14) Surdu.

Table 9. The height of the shot at key phases for the seven rotational athletes.

Athlete	Right leg push-off (m)	Left leg push-off (m)	Right leg touchdown (m)	Brace leg touchdown (m)	Release (m)
<b>MÁRTON</b>	1.28	1.31	1.30	1.22	2.01
<b>THOMAS-DODD</b>	1.22	1.25	1.22	1.15	1.93
<b>STEVENS</b>	1.30	1.37	1.36	1.28	2.10
<b>CREW</b>	1.25	1.31	1.33	1.20	1.87
<b>HILL</b>	1.42	1.48	1.46	1.34	2.09
<b>ROOS</b>	1.14	1.34	1.36	1.22	1.91
<b>SURDU</b>	1.24	1.28	1.29	1.20	1.94

Table 10. The height of the shot at key phases for the switch glide and seven glide athletes.

Athlete	Right leg push-off (m)	Right leg touchdown (m)	Brace leg touchdown (m)	Release (m)
<b>GONG</b>	0.92	0.96	1.06	1.96
<b>GAO</b>	0.96	1.02	1.04	2.08
<b>GUBA</b>	0.99	1.10	1.11	2.11
<b>DUBITSKAYA</b>	0.98	1.10	1.09	1.98
<b>LÓPEZ</b>	0.96	1.09	1.10	2.16
<b>BOREL</b>	1.01	1.06	1.00	1.95
<b>LEANTSIUK</b>	0.96	1.00	0.98	2.02
<b>MAVRDIEVA</b>	1.11	1.09	1.08	1.88

Figure 14 and Table 9 detail the height of the shot for the athletes who utilised the rotational technique. Figure 16 and Table 10 detail the height of the shot for the athletes that utilised the glide technique. Notably, López gained the most height (1.20 m) across the circle, which was identified from the right leg push-off to release.

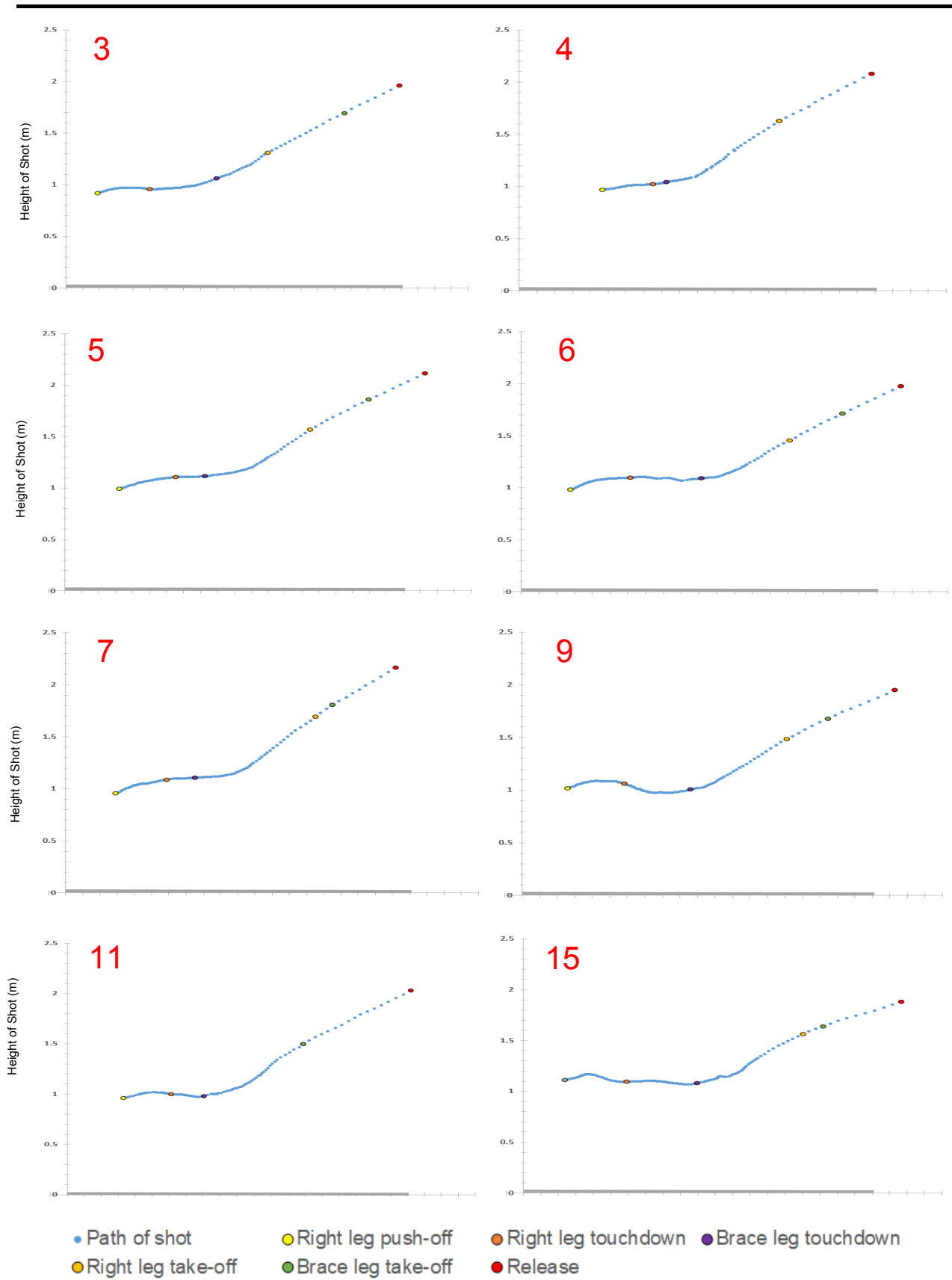


Figure 15. A visual representation from a side on view of the path of the shot from right leg push-off to release. Key: 3) Gong, 4) Gao, 5) Guba, 6) Dubitskaya, 7) López, 9) Borel, 11) Leantsiuk, 15) Mavrodieva.

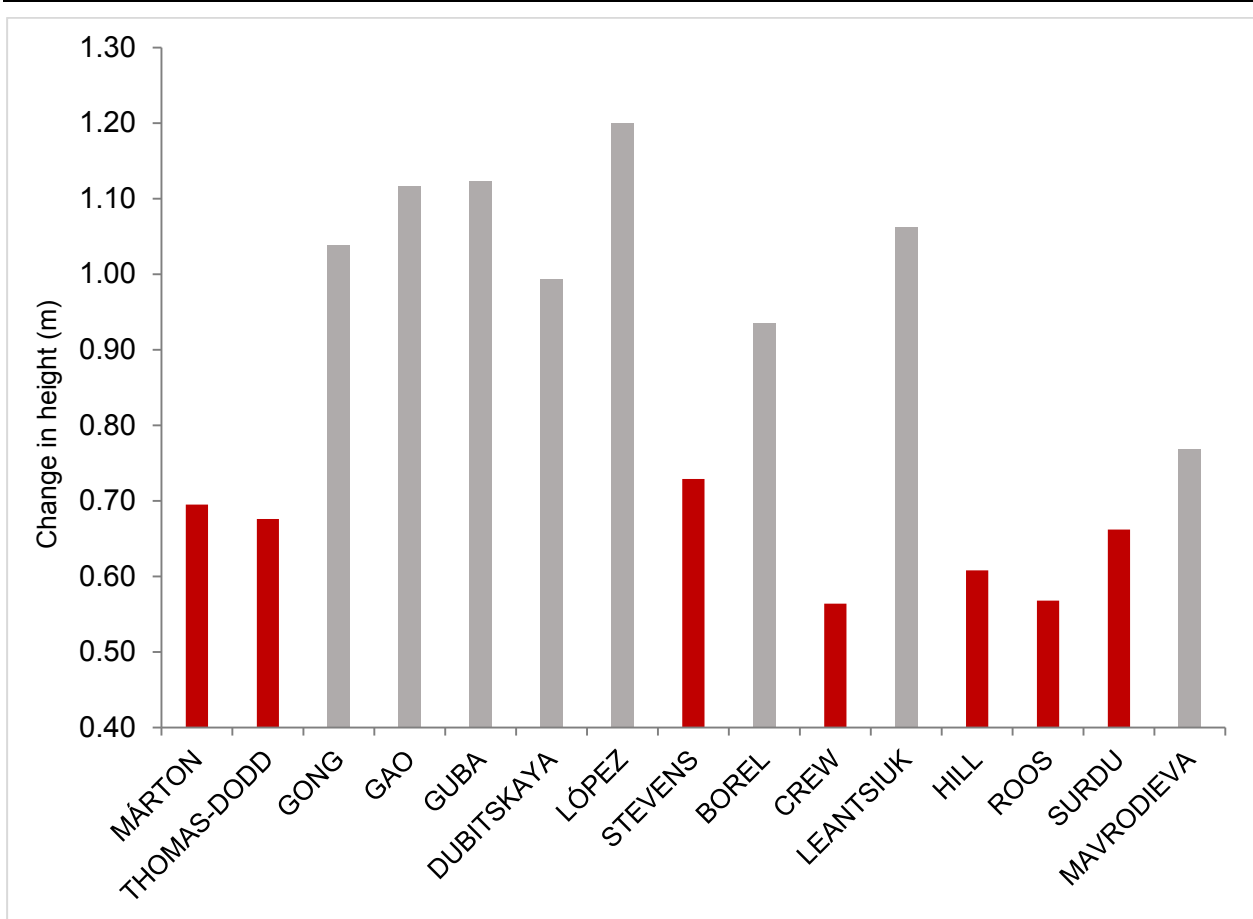


Figure 16. The height gained from push-off to release for the fifteen athletes. The red bars signify the athletes who utilised the rotational technique and the grey bars signify the athletes who utilised the glide and switch glide technique.

## Duration of key phases

Table 11 and Figure 17 detail the duration between the key phases for the athletes that utilised the rotational techniques.

Table 11. The duration of the key phases for the seven rotational athletes.

Athlete	Right leg push-off to left leg push-off (s)	Left leg push-off to right leg touchdown (s)	Right leg touchdown to brace leg touchdown (s)	Brace leg touchdown to release (s)
<b>MÁRTON</b>	0.475	0.060	0.195	0.200
<b>THOMAS-DODD</b>	0.385	0.115	0.170	0.195
<b>STEVENS</b>	0.370	0.085	0.150	0.245
<b>CREW</b>	0.490	0.045	0.160	0.250
<b>HILL</b>	0.565	0.050	0.210	0.270
<b>ROOS</b>	0.445	0.045	0.245	0.185
<b>SURDU</b>	0.490	0.020	0.225	0.215

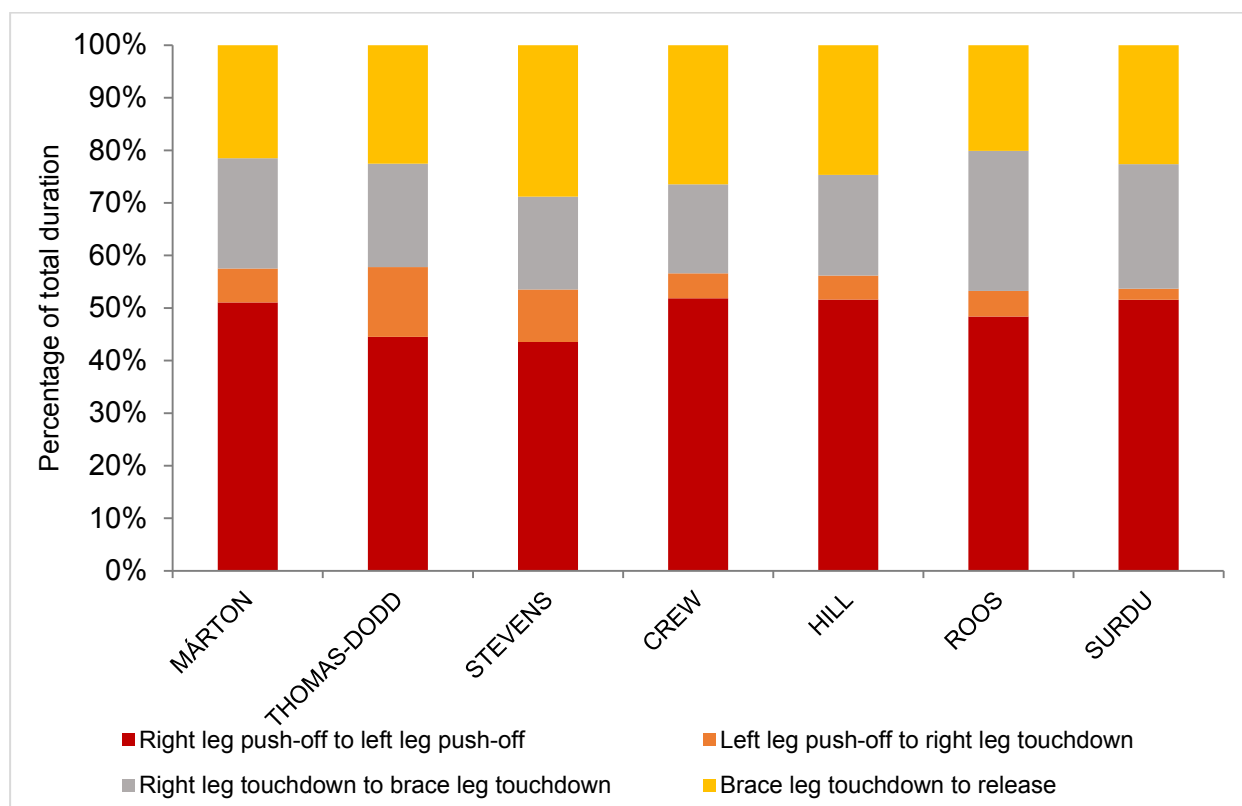


Figure 17. The time taken to perform each of the key phases, expressed as a percentage of the total duration for the seven rotational athletes.

Table 12 and Figure 18 detail the duration between the key phases for the athletes that utilised the glide technique.

Table 12. The duration of the key phases for the switch glide and seven glide athletes.

Athlete	Right leg push-off to right leg touchdown (s)	Right leg touchdown to brace leg touchdown (s)	Brace leg touchdown to release (s)
<b>GONG</b>	0.145	0.190	0.200
<b>GAO</b>	0.125	0.040	0.260
<b>GUBA</b>	0.150	0.080	0.275
<b>DUBITSKAYA</b>	0.165	0.165	0.220
<b>LÓPEZ</b>	0.140	0.080	0.280
<b>BOREL</b>	0.155	0.185	0.225
<b>LEANTSIUK</b>	0.140	0.095	0.290
<b>MAVRODIEVA</b>	0.190	0.190	0.260

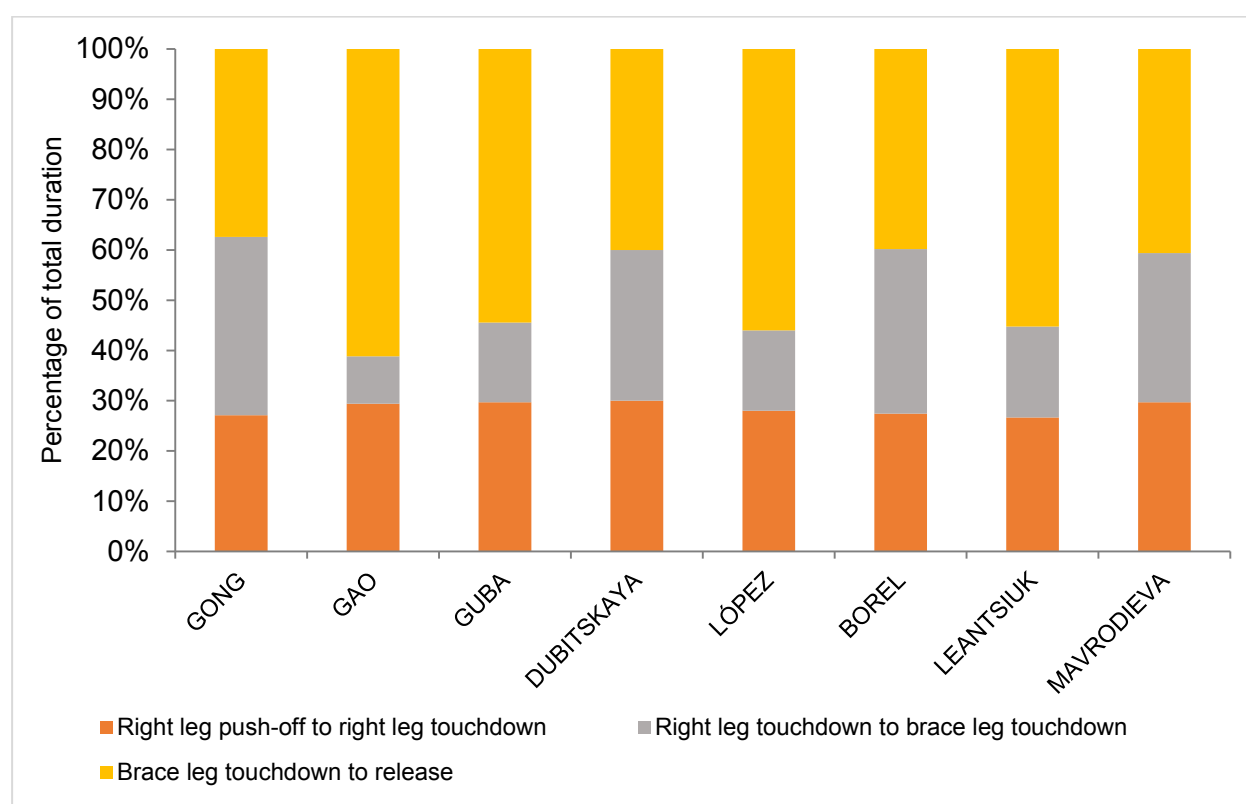


Figure 18. The time taken to perform each of the key phases, which is expressed as a percentage of the total duration for the switch glide and glide athletes.



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**Distance travelled across the circle**

Table 13. The distance travelled in the glide / flight phase and power position for the fifteen athletes.

<b>Athlete</b>	<b>Distance of glide / flight phase (m)</b>	<b>Distance in power position (m)</b>	<b>Total distance in glide / flight phase (%)</b>	<b>Total distance in power position (%)</b>
<b>MÁRTON</b>	0.90	0.72	56	44
<b>THOMAS-DODD</b>	0.88	0.87	50	50
<b>GONG</b>	0.76	1.32	37	63
<b>GAO</b>	0.83	0.92	47	53
<b>GUBA</b>	0.84	1.16	42	58
<b>DUBITSKAYA</b>	1.00	1.10	48	52
<b>LÓPEZ</b>	0.94	1.00	48	52
<b>STEVENS</b>	0.59	0.72	45	55
<b>BOREL</b>	0.76	1.32	37	63
<b>CREW</b>	1.04	0.72	59	41
<b>LEANTSIUK</b>	0.74	1.11	40	60
<b>HILL</b>	0.78	0.79	50	50
<b>ROOS</b>	0.85	0.79	52	48
<b>SURDU</b>	1.05	0.76	58	42
<b>MAVRODIEVA</b>	1.17	0.93	56	44

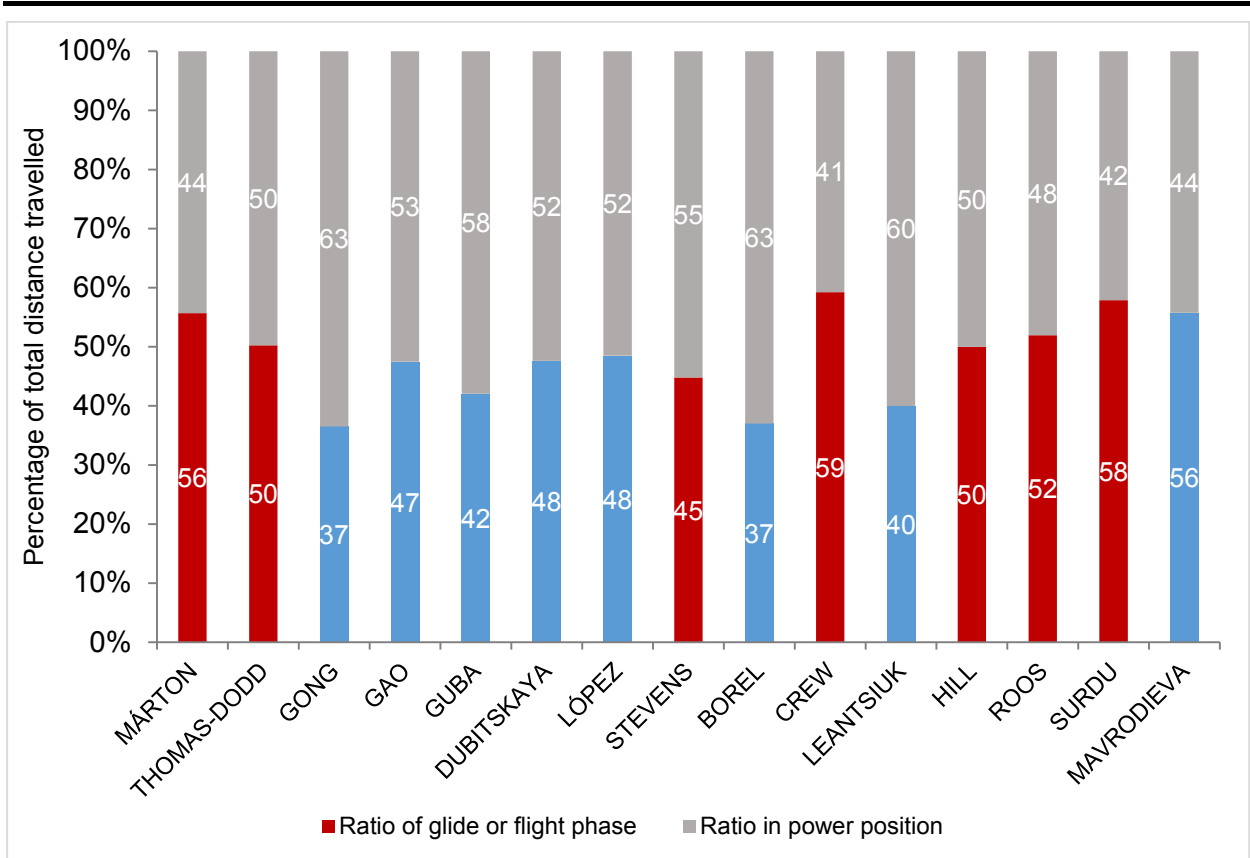


Figure 19. The percentage of total distance travelled in the glide / flight phase and power position for the fifteen athletes. The red bars signify the athletes who utilised the rotational technique and the blue bars signify the athletes who utilised the glide technique.

## Shoulder-hip separation angle

Tables 14 and 15, as well as Figure 20 detail the shoulder-hip separation angle, which represents the angle between the line of the shoulders and the line of the hips. Hence, a negative separation angle indicates that the shoulder axis is ahead of the hip axis in the angular motion path and likewise, a positive separation angle indicates that the hip axis is ahead of the shoulder axis in the angular motion path. All of the finalists released the shot with a negative value and as such the line of their shoulders crossed in front of the line of their hips. Interestingly, Márton and Thomas-Dodd produced some of the smallest changes in shoulder-hip separation angle within the power position with 50° and 57°, respectively. Similarly, Gao produced a relatively small change in shoulder-hip separation angle (55°) within the power position, whereas Gong produced a large change (75°) in the aforementioned variable.

Table 14. The shoulder-hip separation angle at the key phases for the seven rotational athletes.

Athlete	Right leg push-off (°)	Left leg push-off (°)	Right leg touchdown (°)	Brace leg touchdown (°)	Release (°)
MÁRTON	8	6	25	35	-15
THOMAS-DODD	2	2	27	46	-11
STEVENS	4	1	38	61	-1
CREW	17	13	12	41	-28
HILL	9	4	10	82	-16
ROOS	10	3	2	30	-15
SURDU	10	23	11	58	-5

Table 15. The shoulder-hip separation angle at the key phases for the switch glide and seven glide athletes.

Athlete	Right leg push-off (°)	Right leg touchdown (°)	Brace leg touchdown (°)	Release (°)
GONG	24	48	42	-33
GAO	27	36	29	-26
GUBA	26	59	52	-29
DUBITSKAYA	28	58	46	-25
LÓPEZ	32	21	42	-18
BOREL	50	80	3	-44
LEANTSIUK	52	39	44	-19
MAVRODIEVA	-28	7	29	-28

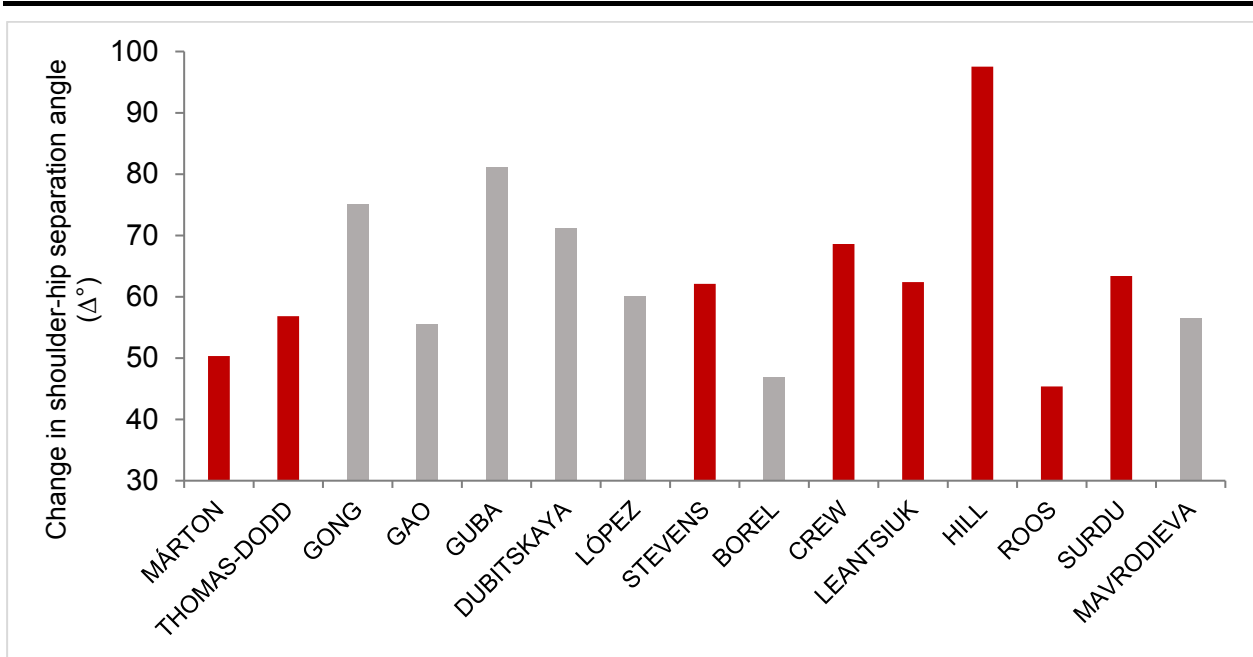


Figure 20. The change in shoulder-hip separation angle between brace leg touchdown and release for the fourteen of the fifteen athletes. The red bars signify the athletes who utilised the rotational technique and the grey bars signify the athletes who utilised the glide technique.

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## COACH'S COMMENTARY

The women's shot put competition at the IAAF World Indoor Championships Birmingham 2018 was run as a straight final, and this report contained data from the best attempt of each of an invited field of 15 athletes. This provided additional data points to the report from the IAAF World Championships London 2017, where only 12 athletes that qualified for the final were studied. This also offered good opportunity to compare some of the data points of the same athlete between the two championships and look for any significant differences or changes between the two competitions.

The most significant outcome was that it marked the first global championship in women's shot put, where a rotational thrower took the title, with Anita Márton of Hungary reaching a major milestone. We have seen the emergence of the rotational technique among the men in recent years, to such an extent that across the 16 participants at these World Indoor Championships, and the 12 finalists from the 2017 London World Championships, there was one solitary glider in David Storl within the upper echelons of global shot put. Also significant in these championships was that of the 15 athletes, there were 7 gliders, 7 rotational throwers and one athlete that used the switch-glide technique, marking the first time that there had been equal number of gliders and spinners, and again demonstrating the emergence and development of the rotational technique among female throwers.

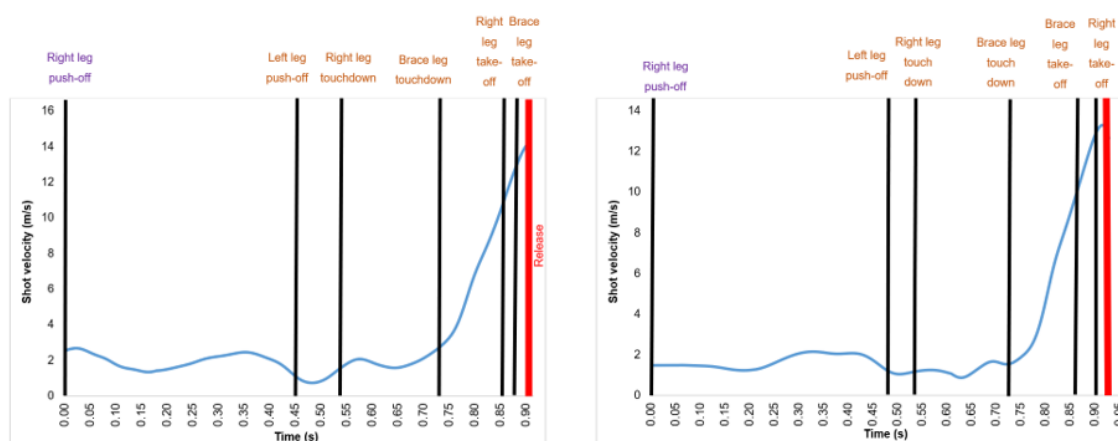
On first viewing, comparing the results and parameters of throwers that competed in both London and in Birmingham, there is a great deal of consistency shown by the female throwers across the two competitions. Unlike the men's results where there were some major changes in the results and the various data points there was much less variance among the seven female athletes that competed in both competitions. Only really the  $-0.86$  m difference in the final distance achieved by Lijiao Gong in finishing third in Birmingham (19.08 m) compared to her London result (19.94 m) where she was crowned World Champion stands out. However, the individual parameters showed smaller differences.

If we are to look a little deeper into the two throws of Gong, we may be able to find some possible explanations for this major drop in distance. The loss of 86 cm in the overall distance (a loss of 4.5%) between the two competitions does not seem to come down to any one single factor, but rather some small incremental changes to a number of parameters throughout the throw. There was a slight drop (0.1%) in release velocity (13.11 m/s compared to 13.24 m/s), but there was a decrease of  $1^\circ$  away from the optimum release angle ( $36.0^\circ$  compared to  $37.0^\circ$  in London), which certainly would have been a factor. This was combined with a drop of 12 cm in the release height from 2.08 m down to 1.96 m, and a reduction of 6 cm in the reach over the stop-board (0.09 m

down to 0.03 m) which can be explained by a reduction in the forward lean at release (8.0° in London compared to 0.9°). Many small factors!

Anita Márton was the beneficiary of this drop in performance by the outdoor world champion, and she took advantage setting two personal bests and world leading marks in the 3<sup>rd</sup> round (19.48 m) and an impressive 19.62 m in the final round. The faster wooden surfaces used for indoor competitions seem to particularly benefit the faster, more rhythmical rotational throwers, of whom Anita Márton is the probably the most efficient female spinner that we have seen in recent years. Not the biggest thrower at 1.72 m and 90 kg, she is very fast in the circle with good acceleration through the whole throw rather than a just a big finish, and perhaps more closely resembles the rotational technique that we are seeing from some of the smaller, faster, male throwers such as Tom Walsh and Tomáš Stanek who both medalled at these championships.

Comparing the velocity profile of Tom Walsh and Anita Márton, we see some similarities in terms of timing and therefore rhythm of the throw.



Shot velocity profiles of Tom Walsh (left) and Anita Márton (right).

While the vertical axis of release velocity is of course not as high in Márton's throw as that of Tom Walsh, you can see some remarkable similarities in terms of the timing of the different key phases of the throw. Beginning with the right leg push-off out of the back, which marks the zero point on the horizontal time axis the left leg push-off occurs slightly later for Márton (0.48 s) compared to Walsh (0.45 s), then the right leg touchdown occurs around the same time (0.54 s), as does the brace leg touchdown (0.73 s). They both employ an active "jump" into the delivery but there is a difference in the order of the take off from the ground, as Walsh first removes his right leg at around 0.86 s into the throw, while Márton first releases the brace leg at around the same time.

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Walsh finally releases the brace leg soon after the right leg at around 0.88 s, while Márton then releases her right leg just after this at 0.90 s. In both athletes, the final release occurs at about 0.92 s.

It would be very interesting to look further into similar timings for the other throwers in future studies, to determine more time and rhythm related factors in the techniques used. This may allow coaches to look at what techniques perhaps suit what size and strength characteristics of the individual thrower and help decide what approach to use with a particular athlete. In these studies, we only see the velocity profile of the leading rotational and the leading glide thrower in each competition, but it would be more useful to compare different athletes utilising the same technique and look at stylistic variations.

If we look to compare the two leading rotational athletes in this competition, namely Márton and Danniell Thomas-Dodd of Jamaica, who finished in gold and silver medal positions, we may see a difference of approach within the rotational technique. Both athletes achieved new personal bests in this competition, so they were certainly on form. Márton took the victory with 19.62 m against Dodd's 19.22 m, but perhaps we can look to compare some of their other key parameters.

If we try to look for any significant factors in their parameters, you can see that there are fine margins between the two athletes across most of these parameters. Of course, we know that the speed of release, height of release and angle of release are the key factors in determining distance thrown, so we would expect these differences based upon the outcome, but some of the other factors may give some insight into how these determining factors were impacted upon in the technical model.

Comparison of key parameters for Anita Márton and Danniell Thomas-Dodd.

	Márton	Thomas-Dodd	Difference
Measured distance (m)	19.62	19.22	0.40*
Release velocity (m/s)	13.33	13.15	0.18*
Angle of release (°)	36.0	35.4	0.6
Release height (m)	2.01	1.93	0.08*
Reach over stop-board (m)	0.07	0.11	-0.04
FB trunk lean at release (°)	-5	-8	3
LR trunk lean at release (°)	3	-11	14*
Total path length of shot (m)	2.58	2.60	0.02
Duration right leg push-off to left leg push-off (s)	0.475	0.385	0.090*
Duration left leg push-off to right leg touchdown (s)	0.060	0.115	-0.055*
Duration right leg touchdown to left leg touchdown (s)	0.195	0.170	0.025
Duration left leg touchdown to release (s)	0.200	0.195	0.005
Distance in flight phase (m)	0.90	0.88	0.02
Distance in power position (m)	0.72	0.87	0.15*
Shoulder-hip separation angle right leg push-off (°)	8	2	6
Shoulder-hip separation angle left leg push-off (°)	6	2	4
Shoulder-hip separation angle right leg touchdown (°)	25	27	2
Shoulder-hip separation angle left leg touchdown (°)	35	46	11*
Shoulder-hip separation angle release (°)	-15	-11	4
Δ Shoulder-hip separation angle left leg touchdown-release (°)	50	57	7

Key: \* = key difference, Δ = change.

We have highlighted some key differences between the two athletes and may suggest that the positive left-to-right trunk lean at release of Márton indicates a more stable attacking delivery, where the connection between the drive leg and arm is more efficient, rather than “pulling” the left side away at release. In addition, the significantly longer duration from the right foot off at the start of the rotation to the left foot off indicates a better balance position in the turn to maintain the movement. This is then followed by a relatively short flight time by Márton, where her right foot comes down quickly in the centre of the circle and utilise a longer work of the right foot against the ground before the delivery.



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Márton also displays a slightly narrower base in the power position, which is typical of many speed/power based rotational throwers with an effective active reverse “jump” delivery, which when timed correctly allows the athlete to continue to add velocity to the shot even once the feet have left the ground. Finally, a smaller shoulder-hip separation angle when reaching the power position i.e., when the brace leg touches down at the front of the circle. This allows more speed to be carried into the delivery, without losing speed by emphasising a “wrap” in the middle, which effectively slows down the implement, requiring more force to put back the speed to the implement at delivery. This is something we see very effectively in Tom Walsh, who carries more speed through the middle of the throw and more effectively into the delivery.

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## CONTRIBUTORS

Aaron Thomas is a Senior Learning Support Officer in Biomechanics, with technical expertise in biomechanical data collection and analysis and over ten years' experience providing sports science research and consultancy services to elite and developing athletes. Aaron is also a successful athletics coach having coached athletes to World, European and Commonwealth Championships. He has consulted in coach development for England Athletics as an Area Coach Mentor and received the British Milers Club Coach of the Year Award, 2015.



Dr Alex Dinsdale is a Senior Lecturer in Sport and Exercise Biomechanics specialising in the teaching of Strength and Conditioning. He is also the current course leader for the MSc in Strength and Conditioning. His main research interests are centred on acute preparation strategies, methods of resistance training, the transference of training and long term training strategies. Alongside his academic role, Alex has been a successful strength and conditioning coach for well over a decade, whereby he has worked with numerous sports at all levels of performance.



Dr Athanassios Bissas is the Head of the Biomechanics Department in the Carnegie School of Sport at Leeds Beckett University. His research includes a range of topics but his main expertise is in the areas of biomechanics of sprint running, neuromuscular adaptations to resistance training, and measurement and evaluation of strength and power. Dr Bissas has supervised a vast range of research projects whilst having a number of successful completions at PhD level. Together with his team he has produced over 100 research outputs and he is actively involved in research projects with institutions across Europe.



Don Babbitt is an Associate Head Track & Field Coach at the University of Georgia (USA), where he has coached since 1996. Additionally, Don has been CECS Editor for the throwing event for the IAAF since 2010. Don has coached three World champions and one Olympic champion amongst over 50 athletes who have appeared in the World Championships or Olympic Games across the four throwing disciplines. Don has also conducted clinics across six continents and published over 60 articles or book chapters in seven different languages.



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.

