



BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

110 m Hurdles Men's

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INTRODUCTION


Olympic champion Omar McLeod withstood the pressure to open the Jamaican gold medal account at the World Championships with victory in a time of 13.04 s. Coming into the event with an impressive world lead (12.90 s) and off the back of an assured semi-final performance (13.10 s), McLeod held off the challenge of defending champion Sergey Shubenkov. Shubenkov had a huge challenge just to make the final after being drawn in the ninth lane in his semi-final and despite being drawn in lane 2 away from the action in the final, he secured silver in 13.14 s one tenth behind McLeod. It was a highly technical performance from Shubenkov as he did not disturb any of his ten hurdles. Hungary's Balazs Baji claimed Hungary's first ever track medal, to capture the bronze. The only other athlete to clear all ten hurdles without disturbing them was 2012 Olympic champion and world record holder Aries Merritt; who, less than two years after undergoing kidney transplant surgery, finished fifth in a time of 13.31 s. The men's final could have been a more closely contested affair if Garfield Darien of France had produced a stronger technical performance. He hit all of the first four hurdles, knocking three completely over. Despite still being in medal contention by the hurdle seven, he knocked over the final three hurdles and was overtaken by Baji on the run-in to the line.

IAAF
World Championships

London
4-13 August 2017



RESULTS



110 Metres Hurdles Men - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	12.80	Aries MERRITT	USA	27	Bruxelles (Boudewijnstadion)	7 Sep 2012
Championships Record CR	12.91	Colin JACKSON	GBR	26	Stuttgart (Gottlieb-Deimler Stadion)	20 Aug 1993
World Leading WL	12.90	Omar MCLEOD	JAM	23	Kingston (NS), JAM	24 Jun 2017
Area Record AR		National Record NR		Personal Best PB		Season Best SB

7 August 2017 21:31 START TIME

19° C TEMPERATURE

73 % HUMIDITY

0.0m/s WIND


PLACE	NAME	COUNTRY	DATE OF BIRTH	LANE	RESULT	REACTION	Fr
1	Omar MCLEOD	JAM	25 Apr 94	4	13.04	0.123	
2	Sergey SHUBENKOV	ANA	4 Oct 90	2	13.14	0.132	
3	Balázs BAJI	HUN	9 Jun 89	5	13.28	0.122	
4	Garfield DARIEN	FRA	22 Dec 87	6	13.30	0.115	
5	Aries MERRITT	USA	24 Jul 85	9	13.31	0.163	
6	Shane BRATHWAITE	BAR	8 Feb 90	7	13.32	0.169	
7	Orlando ORTEGA	ESP	29 Jul 91	3	13.37 (.361)	0.140	
8	Hansle PARCHMENT	JAM	17 Jun 90	8	13.37 (.365)	0.145	


Timing and Measurement by SEIKO


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METHODS

Six vantage locations for camera placement were identified and secured. Each location had the capacity to accommodate up to five cameras placed on tripods in parallel. Five locations were situated on the broadcasting balcony along the home straight (from the starting line to the 90 m line) whilst the sixth location was located within the IAAF VIP outdoor area overlooking the finish line from a semi-frontal angle (Figure 1). Two calibration procedures were conducted before and after each competition. First, a rigid cuboid calibration frame was positioned on the running track around the 6th hurdle multiple times over discrete predefined areas along and across the track to ensure an accurate definition of a volume within which athletes were achieving high speeds (Figure 2). This approach produced a large number of non-coplanar control points per individual calibrated volume and facilitated the construction of bi-lane specific global coordinate systems. Second, an additional volume spanning all 9 lanes was defined for the final metres of the race (from the 10th hurdle to the finish line) through a calibration process similar to the middle section.

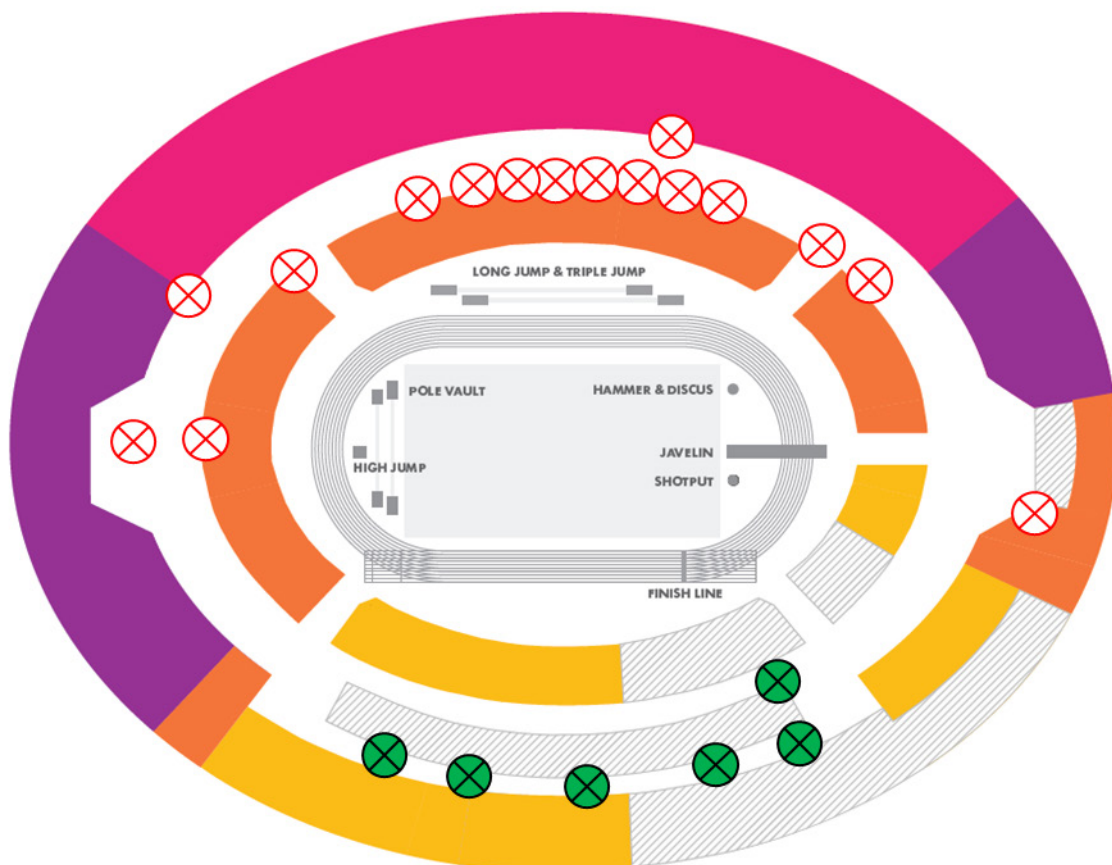


Figure 1. Camera layout within the stadium for the 110 m hurdles indicated by green in-filled circles.

A total of 17 high-speed cameras were employed to record the action during the 110 m hurdles semi-finals and finals. Five Sony RX10 M3 cameras operating at 100 Hz (shutter speed: 1/1250; ISO: 1600; FHD: 1920x1080 px) were positioned strategically along the home straight with their optical axes perpendicular to the running direction to capture motion in the sagittal plane and provide footage for the analysis of the hurdle split times. Four Sony PXW-FS7 cameras operating at 150 Hz (shutter speed: 1/1250; ISO: 1600; FHD: 1920x1080 px) were used to capture the motion of athletes as they were moving through the calibrated middle section. Each of the four Sony PXW-FS7 cameras was paired with an additional Sony RX10 M3 camera operating at 100 Hz as a precaution against the unlikely event of data capture loss. Finally, two Fastec TS3 operating at 250 Hz (shutter speed: 1/1000; ISO: 1600; SXGA: 1280x1024 px) and two Sony RX10 M3 (100 Hz) cameras operating as two separate pairs were employed to record motion in the final section of the race.



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

The video files were imported into SIMI Motion (SIMI Motion version 9.2.2, Simi Reality Motion Systems GmbH, Germany) and were manually digitised by a single experienced operator to obtain kinematic data. An event synchronisation technique (synchronisation of four critical instants) was applied through SIMI Motion to synchronise the two-dimensional coordinates from

each camera involved in the recording. Because of greater variability of performance across athletes during the calibrated middle section compared to the flat sprints, the digitising process centred upon critical events (e.g. touchdown and toe-off) rather than an analysis of the full sequence throughout the calibration volume. Each file was first digitised frame by frame and upon completion adjustments were made as necessary using the points over frame method. The Direct Linear Transformation (DLT) algorithm was used to reconstruct the three-dimensional (3D) coordinates from individual camera's x and y image coordinates. Reliability of the digitising process was estimated by repeated digitising of a hurdle clearance with an intervening period of 48 hours. The results showed minimal systematic and random errors and therefore confirmed the high reliability of the digitising process.







Figure 3. Action from the 110 m men's hurdles final.

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. Split times between consecutive hurdles, as well as to the first hurdle and from the final hurdle to the finish line, and kinematic characteristics were processed through SIMI Motion by using the 100, 250 and 150 Hz footage, respectively. Where available, athletes' heights were obtained from 'Athletics 2017' (edited by Peter Matthews and published by the Association of Track and Field Statisticians), and online sources.

Table 1. Variables selected to describe the performance of the athletes.

Variable	Definition
TAKE-OFF PHASE	
Contact time	The time the foot is in contact with the ground.
Take-off distance	Horizontal distance from point of ground contact (foot tip) to the centre of the hurdle at take-off.
DCM TD	The horizontal distance between the ground contact point at touchdown (TD) and the centre of mass (CM).
HCM TD	The vertical distance between the ground contact point at TD and the CM.
DCM TO	The horizontal distance between the ground contact point at toe-off (TO) and the CM.
HCM TO	The vertical distance between the ground contact point at TO and the CM.
HURDLE CLEARANCE PHASE	
Hurdle flight time	Flight time over hurdle.
Hurdle distance	Distance between last point of ground contact before flight and the first point of TD after flight.
LANDING PHASE (INITIAL AND SECOND CONTACTS)	
Contact time	The time the lead foot is in contact with the ground.
Landing distance	Horizontal distance from point of ground contact to the centre of the hurdle at TD.
DCM TD	The horizontal distance between the ground contact point at TD and the CM.
HCM TD	The vertical distance between the ground contact point at TD and the CM.
DCM TO	The horizontal distance between the ground contact point at TO and the CM.
HCM TO	The vertical distance between the ground contact point at TO and the CM.
Step length	The distance covered from TO of one foot to TO of the other foot.
Flight time	The time from TO of one foot to TD of the other foot.
Step time	Contact time + flight time.

SPLIT TIMES & POSITION			
Split times	Duration between each hurdle and between the start line and the first hurdle and between the final hurdle and the finish line.		
Race position	Determined by the chest position of each athlete during the clearance phase vertically above the hurdle.		
HURDLE PROFILING			
	WHITE BORDER ONLY Slight contact made with the hurdle.		WHITE BORDER WITH WHITE LINE Larger contact, but hurdle is not knocked over.
	YELLOW BORDER WITH YELLOW LINE Hurdle is completely knocked over.		WHITE BORDER WITH RED CROSS Athlete fell or stopped due to contact with this hurdle.
No symbol	Clean hurdle clearance.		
ANGULAR KINEMATICS			
Trunk angle (α)	Trunk angle relative to the horizontal at the point of TO of take-off phase and TD and TO of the landing phase (considered to be 90° in the upright position).		
Lead leg knee angle (β_L)	Thigh-shank angle of the leading leg at the point of TO of take-off phase and TD of the landing phase (considered to be 180° in the anatomical standing position).		
Trail leg knee angle (β_T)	Thigh-shank angle of the leg in contact with the ground at TO of the take-off phase (considered to be 180° in the anatomical standing position).		
Trunk-thigh angle (δ)	Angle between the trunk and the thigh of the leading leg at TO of the take-off phase (considered to be 180° in the anatomical standing position).		
Deviation angle (κ)	Angle between ground contact point and CM relative to the horizontal (considered to be 90° in the upright position).		
Lead leg ankle angle (ι)	Shank-foot angle of the leading leg at the point of TO of take-off phase and TD of the landing phase (considered to be 90° in the anatomical standing position).		

Note: Please see Figures 12 and 15 for a visual representation denoted by the symbols above.

Note: CM = centre of mass.

RESULTS – Final

PERFORMANCE PROFILING

Performance data

The tables below display the season's (SB) and personal best (PB) times of each athlete competing in the final before the World Championships, and their performance during the semi-finals (Table 2). These values are then compared to their performance in the final itself (Table 3).

Table 2. Individual season's (SB) and personal bests (PB), and performance during the semi-final (SF).

Athlete	SB	rank	PB	rank	SF	rank	notes
MCLEOD	12.90 s	1	12.90 s	2	13.10 s	1	
SHUBENKOV	13.01 s	2	12.98 s	5	13.22 s	3	
BAJI	13.15 s	5	13.15 s	7	13.23 s	5	
DARIEN	13.09 s	3	13.09 s	6	13.17 s	2	
MERRITT	13.09 s	3	12.80 s	1	13.25 s	6	
BRATHWAITE	13.27 s	8	13.21 s	8	13.26 s	7	SB
ORTEGA	13.15 s	5	12.94 s	3	13.22 s	4	
PARCHMENT	13.19 s	7	12.94 s	3	13.26 s	8	

Key: SB = season's best, PB = personal best, SF = semi-final.

Table 3. Comparison of athletes' performance during the final compared to PB, SB and semi-finals (SF).

Athlete	FINAL	notes	vs. SF	vs. SB	vs. PB
MCLEOD	13.04 s		-0.06 s	0.14 s	0.14 s
SHUBENKOV	13.14 s		-0.08 s	0.13 s	0.16 s
BAJI	13.28 s		0.05 s	0.13 s	0.13 s
DARIEN	13.30 s		0.13 s	0.21 s	0.21 s
MERRITT	13.31 s		0.06 s	0.22 s	0.51 s
BRATHWAITE	13.32 s		0.06 s	0.05 s	0.11 s
ORTEGA	13.37 s	.361 s*	0.14 s	0.21 s	0.42 s
PARCHMENT	13.37 s	.365 s	0.10 s	0.18 s	0.43 s

Key: SB = season's best, PB = personal best, SF = semi-final.

Positional analysis

Figure 4 shows the relative position of each athlete at each hurdle throughout the race. This shows each finalist's race position at each hurdle, based on cumulative split time data. Note that positional analysis (Figure 4) is based on time to three decimal places. This should be considered when comparing race position with cumulative split times (Figures 5-7).

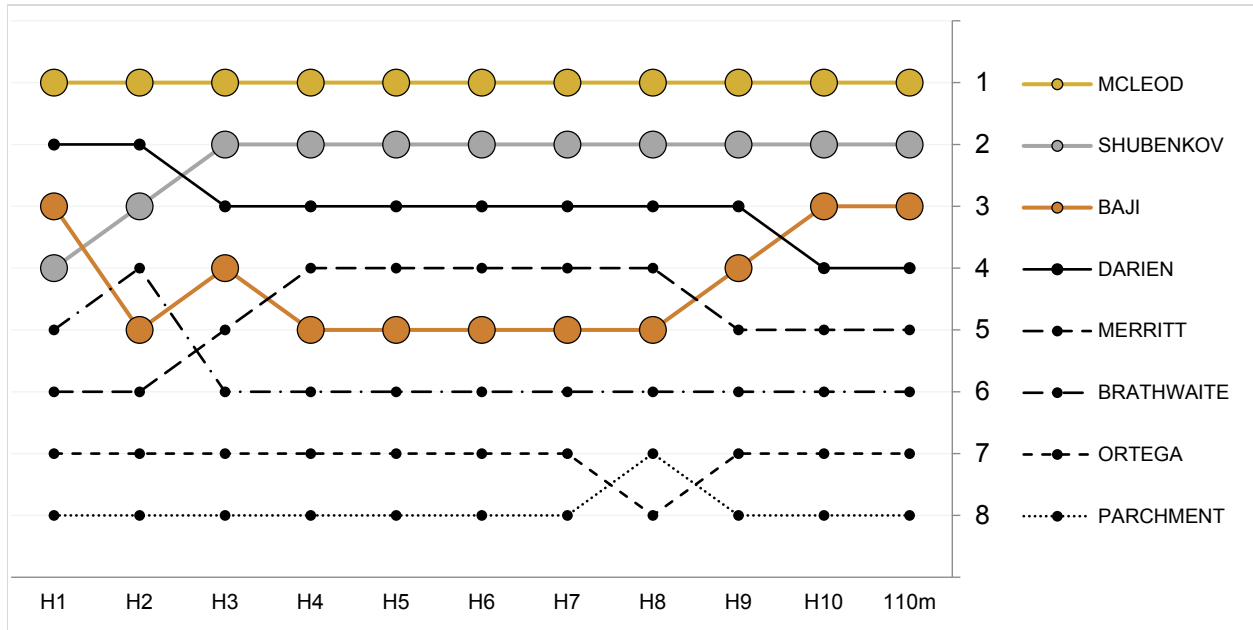


Figure 4. Position of each athlete as they crossed each hurdle and the finish line.

Split times at each hurdle

The following graphs display consecutive splits between: the start and hurdle one (Figure 5; Note: this is minus the reaction time), hurdles one to six (Figure 6), hurdles six to ten and from hurdle ten to the finish line (Figure 7). The mean speed between these consecutive hurdle splits is presented in Figure 8. Please note that split times have been rounded mathematically to two decimal places throughout this report. However, the official result is always rounded up in accordance with the IAAF Competition Rules – this causes some instances where our total race times differ by 0.01 seconds. Any instances of this are highlighted in the notes section of the performance tables by an asterisk (*).

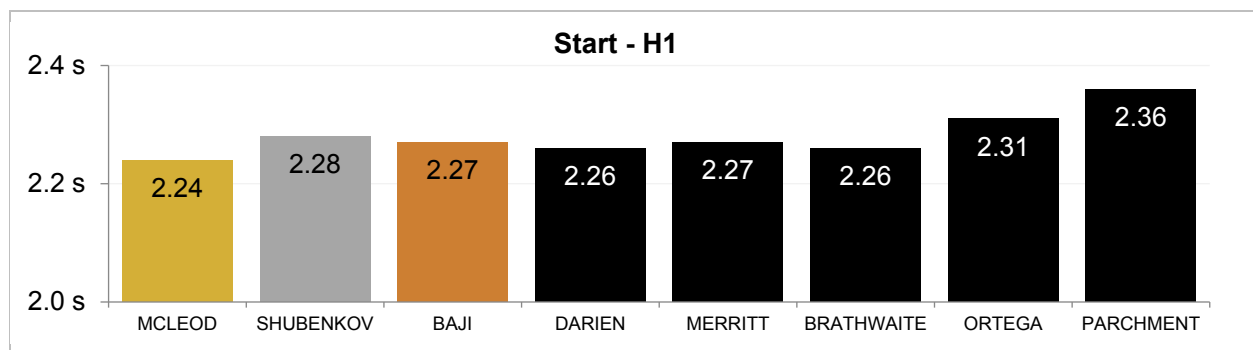


Figure 5. Individual split times between the start and first hurdle (minus the reaction time).

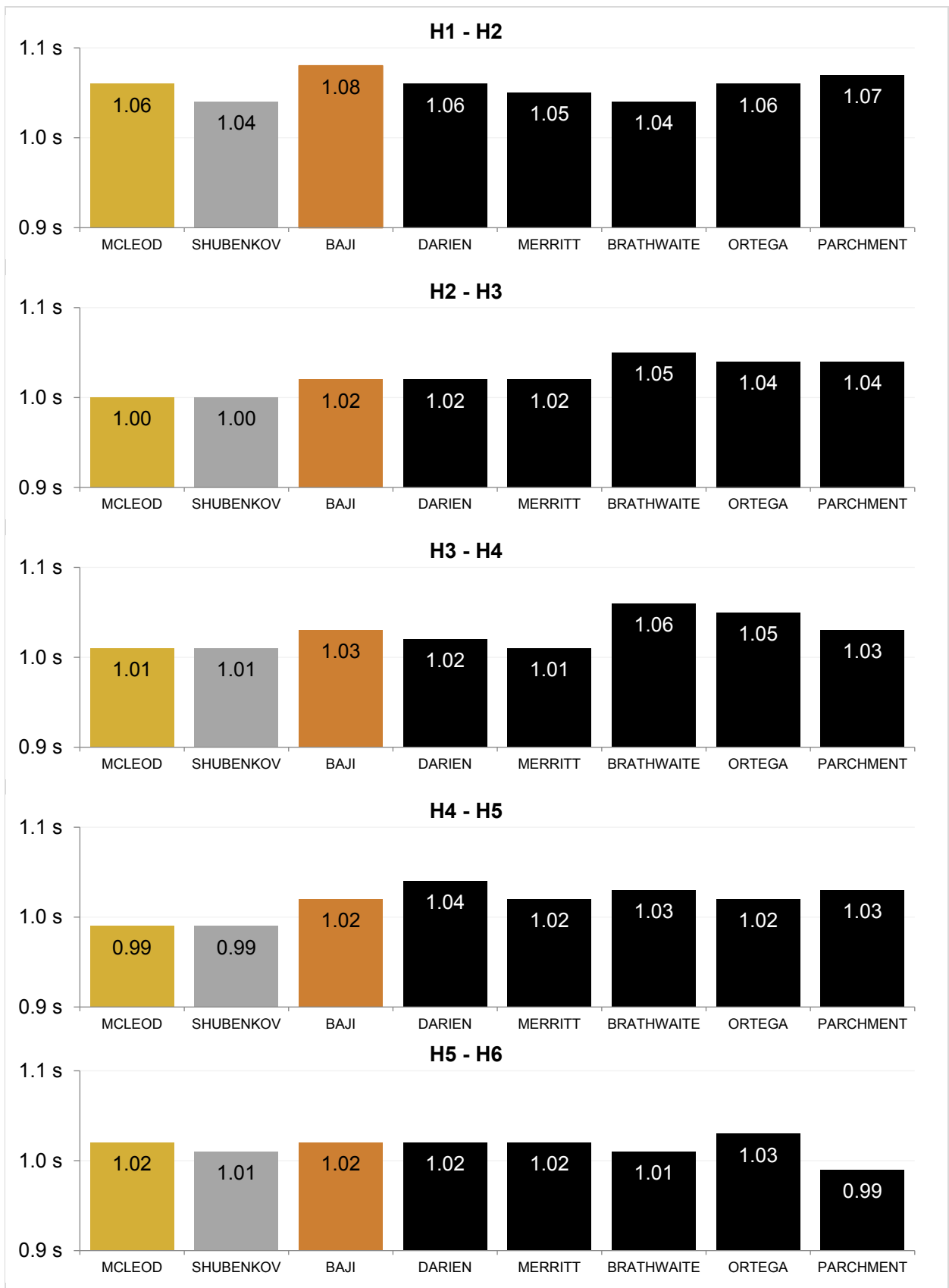


Figure 6. Individual split times between the first six consecutive hurdles.

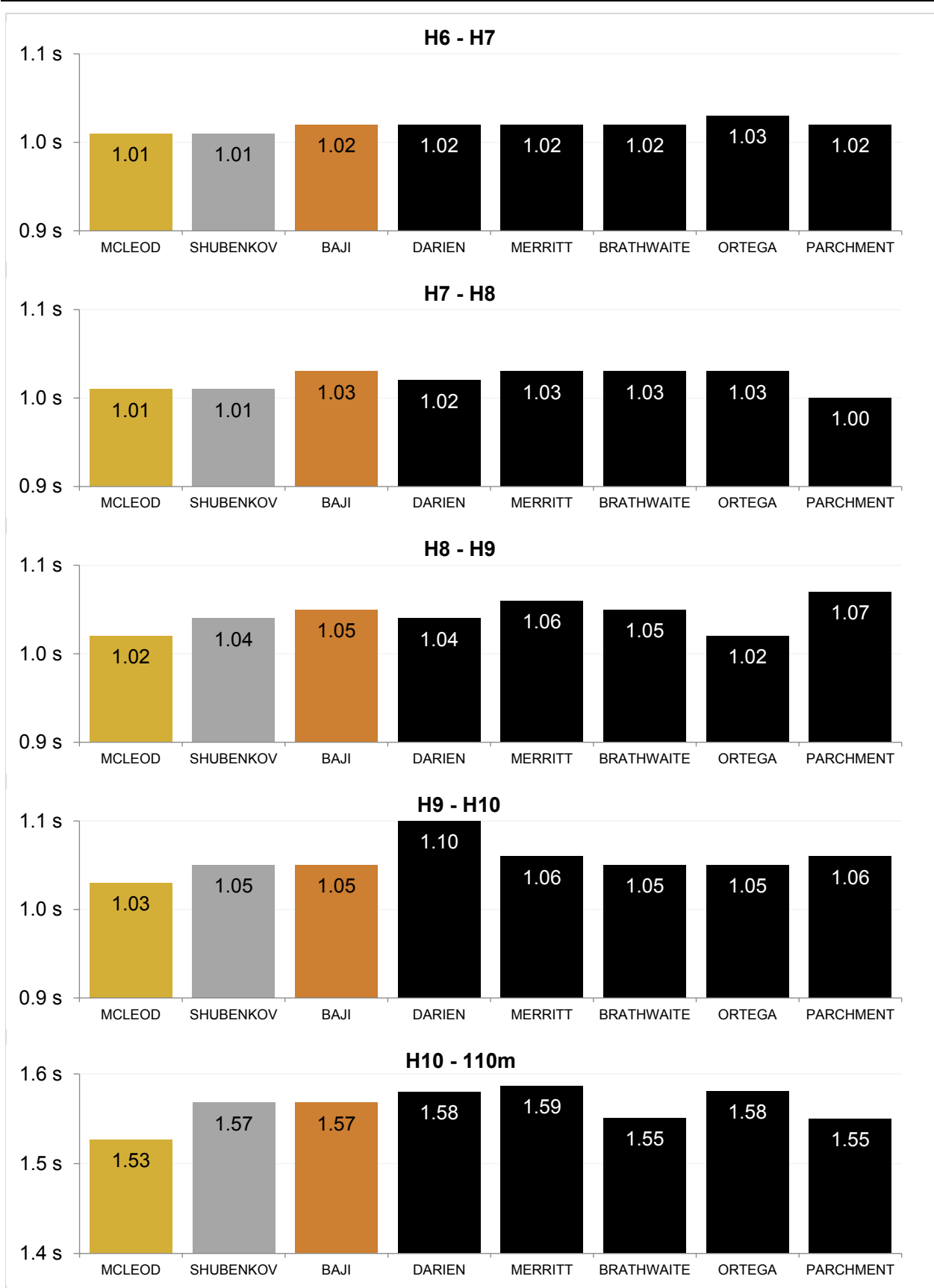


Figure 7. Individual split times between the final four consecutive hurdles and hurdle ten to the finish.

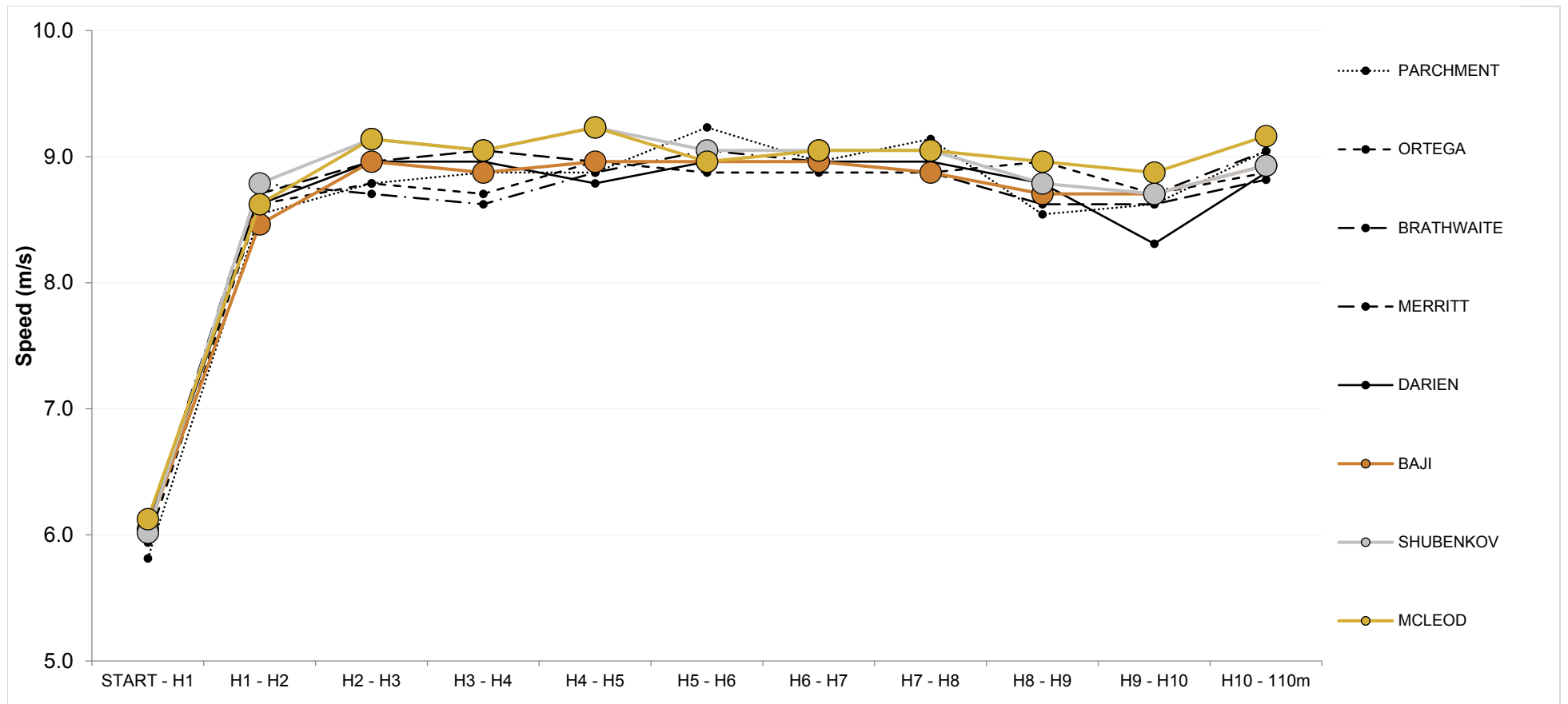


Figure 8. Mean speed for each hurdle split.

Hurdle profiles for each athlete

The following graphs display the individual split times between hurdles as well as to the first and from the last hurdle. Also included is the position at each hurdle and the type of clearance (see Table 1; page 9), for the medallists (Figure 9) followed by the non-medallists (Figure 10).

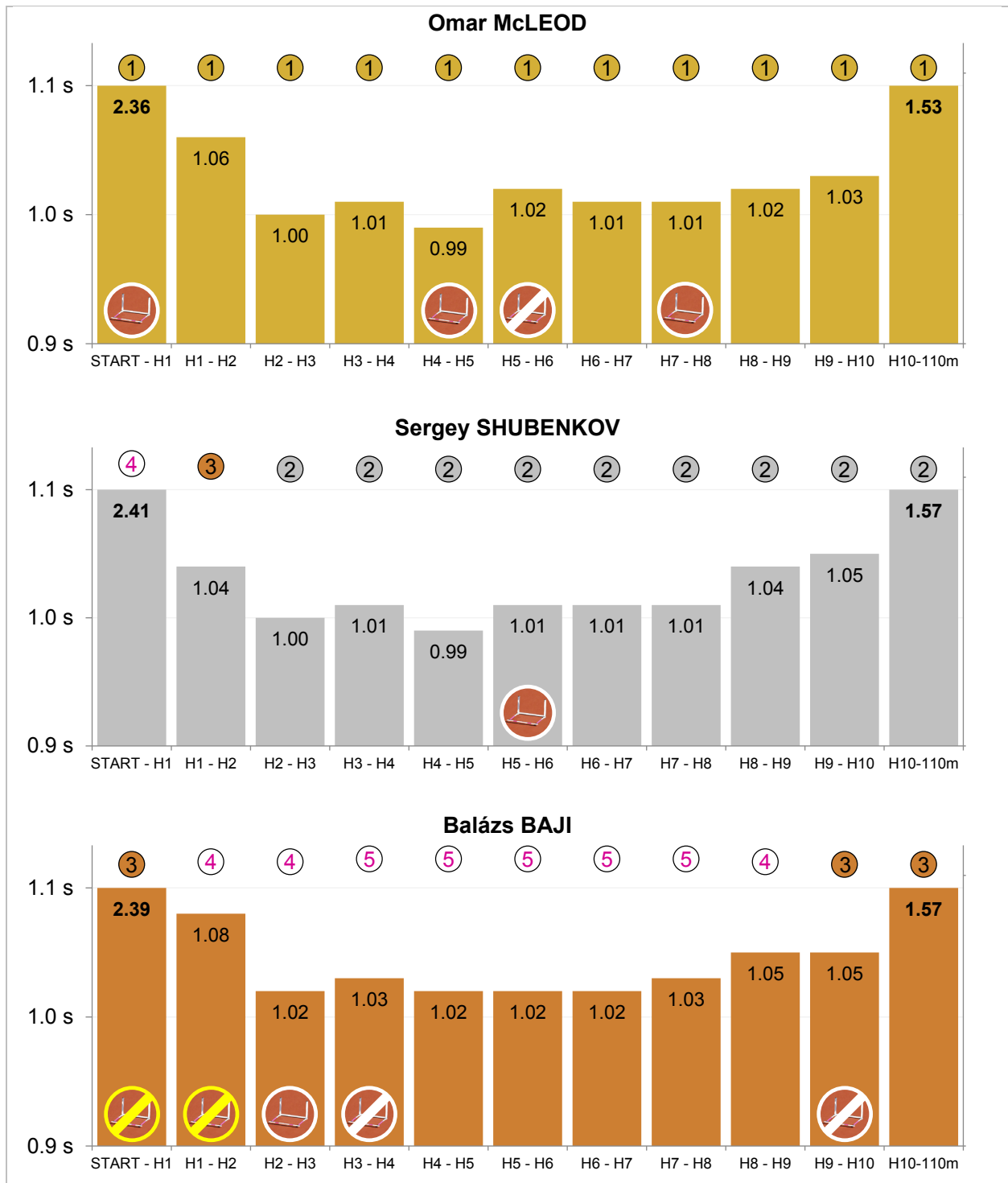


Figure 9. Hurdle profiles for the medallists (Start – H1 includes reaction time).

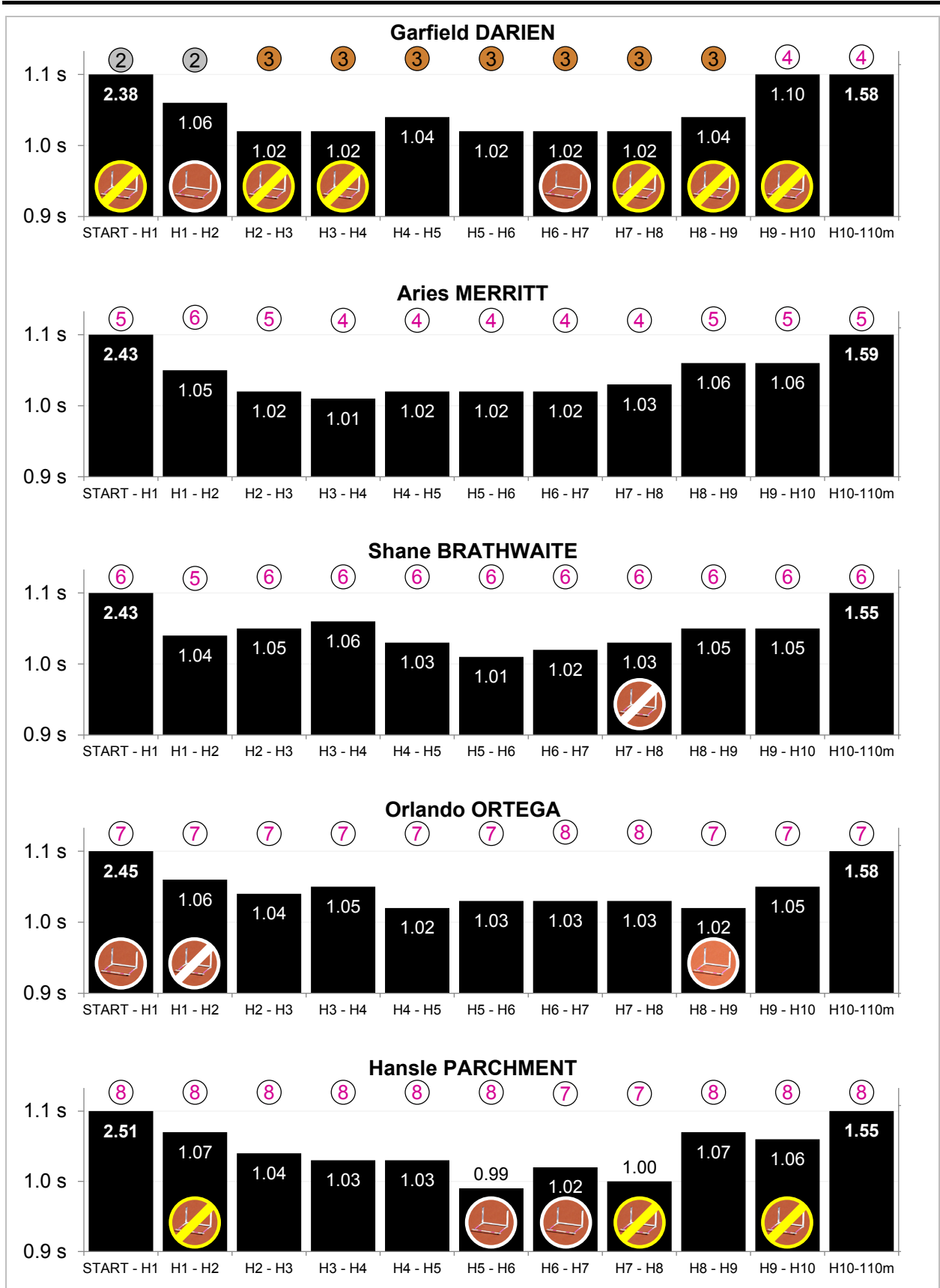


Figure 10. Hurdle profiles for the non-medallists (Start – H1 includes reaction time).

GOLD MEDALLIST: Omar McLeod



	RT	Start - H1	H1 - H2	H2 - H3	H3 - H4	H4 - H5
<i>Final</i>	0.123 s	2.24 s	1.06 s	1.00 s	1.01 s	0.99 s
<i>Rank</i>	3 rd	1 st	4 th	1 st	1 st	1 st
<i>vs. silver</i>	-0.009 s	-0.04 s	+0.02 s	0.00 s	0.00 s	0.00 s
<i>vs. bronze</i>	0.001 s	-0.03 s	-0.02 s	-0.02 s	-0.02 s	-0.03 s
<i>Semi-Final</i>	0.135 s	2.23 s	1.06 s	1.02 s	1.01 s	1.02 s
<i>Rank</i>	6 th	7 th	9 th	5 th	2 nd	4 th
	H5 - H6	H6 - H7	H7 - H8	H8 - H9	H9 - H10	H10 - Finish
<i>Final</i>	1.02 s	1.01 s	1.01 s	1.02 s	1.03 s	1.53 s
<i>Rank</i>	4 th	1 st	2 nd	1 st	1 st	1 st
<i>vs. silver</i>	+0.01 s	0.00 s	0.00 s	-0.02 s	-0.02 s	-0.04 s
<i>vs. bronze</i>	0.00 s	-0.01 s	-0.02 s	-0.03 s	-0.02 s	-0.04 s
<i>Semi-Final</i>	0.99 s	1.00 s	1.02 s	1.04 s	1.04 s	1.53 s
<i>Rank</i>	2 nd	2 nd	1 st	4 th	1 st	5 th

KINEMATIC CHARACTERISTICS

This section describes kinematic and temporal variables for each of the finalists at the sixth and the tenth hurdle, respectively. Data are presented for the key events (i.e., the take-off and landing phases), as well as characteristics relating to the hurdle clearance phase. All variables have previously been described in Table 1.

Hurdle 6 – Take-off phase

Table 4. Take-off characteristics of each athlete before the sixth hurdle.

	Lead leg	Contact time (s)	Take-off distance (m)	relative
MCLEOD #	Right	0.127	2.15	1.19
SHUBENKOV #	Right	0.127	2.10	1.11
BAJI	Right	0.113	2.21	1.15
DARIEN	Left	0.140	2.28	1.22
MERRITT	Left	0.127	2.51	1.36
BRATHWAITE	Left	0.133	2.11	1.16
ORTEGA	Left	0.120	2.24	1.21
PARCHMENT #	Left	0.133	2.30	1.17

Note: relative = relative take-off distance based on athlete's height. # athlete contacted the hurdle.

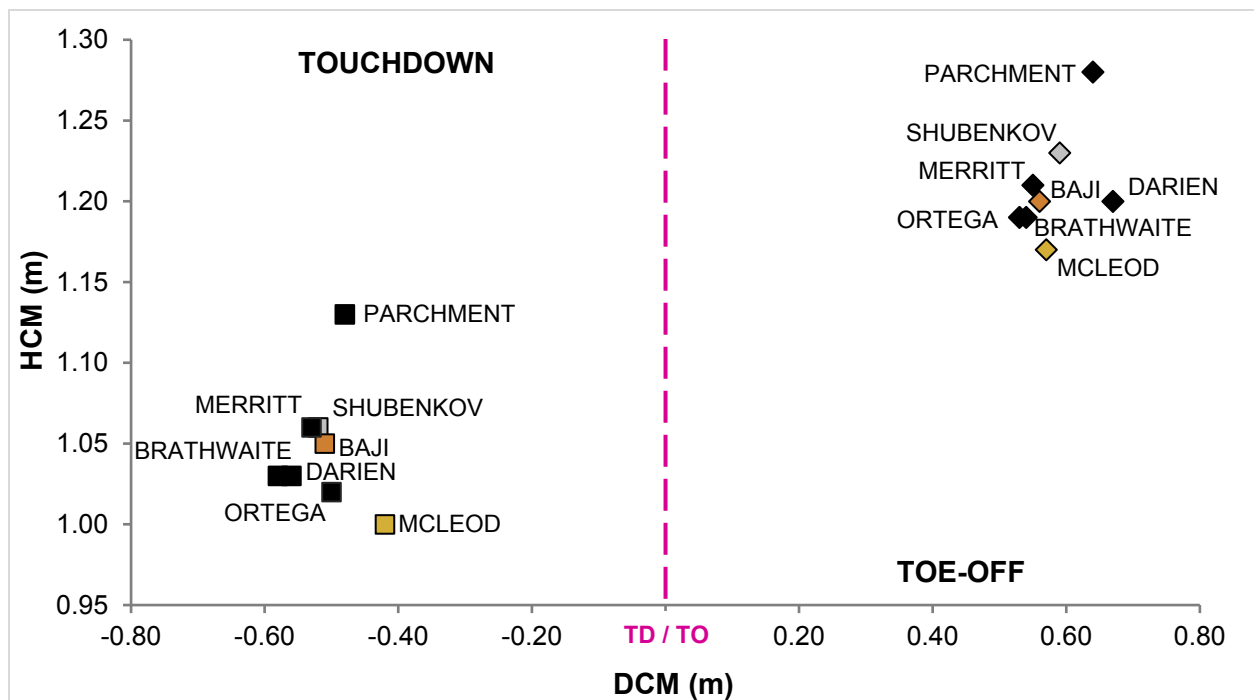


Figure 11. Height of the body's CM (HCM) and horizontal distance to the body's CM (DCM) at touchdown (TD) and toe-off (TO) of the final foot contact before the sixth hurdle.

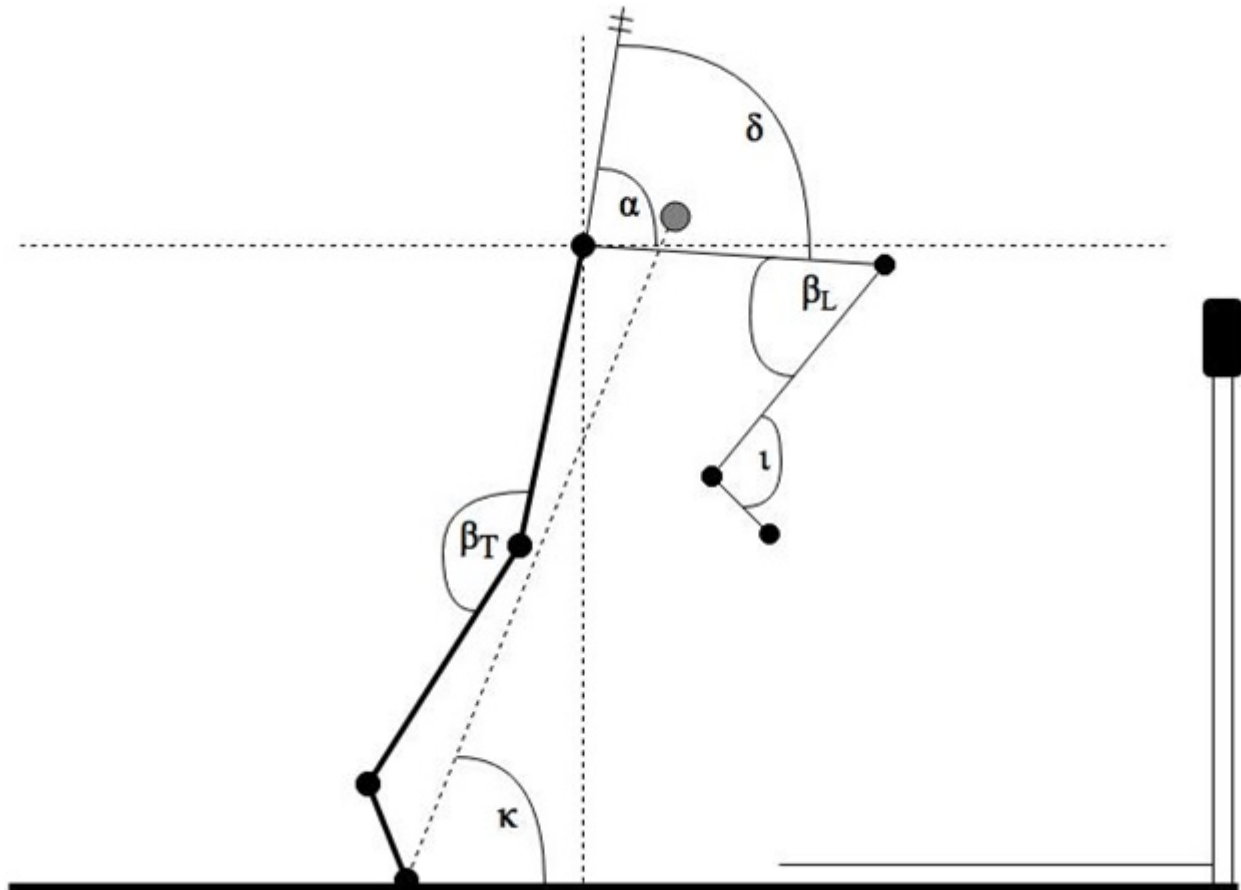


Figure 12. Body schematic denoting joint angles measured at toe-off during the take-off phase.

Table 5. Angular kinematics at toe-off during the take-off phase for each athlete before the sixth hurdle.

	Lead leg knee angle (°) (β_L)	Lead leg ankle angle (°) (ι)	Trail leg knee angle (°) (β_T)	Trunk- thigh angle (°) (δ)	Trunk angle (°) (α)	Deviation angle (°) (κ)
MCLEOD #	77.2	119.7	153.9	70.5	75.7	64.0
SHUBENKOV #	74.7	115.7	159.0	53.9	64.1	64.4
BAJI	76.0	121.0	167.7	68.9	71.8	65.0
DARIEN	77.1	114.6	158.9	65.1	72.4	60.8
MERRITT	73.9	108.6	155.7	57.1	63.8	65.6
BRATHWAITE	69.8	94.4	159.1	82.8	76.2	65.6
ORTEGA	70.9	100.6	163.7	80.4	76.6	66.0
PARCHMENT #	75.7	98.2	166.1	66.1	82.2	63.4

Note: # athlete contacted the hurdle.

Hurdle 6 – Hurdle clearance phase

Table 6. Hurdle flight times and the absolute and relative (i.e., based on each athlete's height) horizontal distance covered (i.e., hurdle distance) during the hurdle clearance phase at the sixth hurdle.

	Hurdle flight time (s)	Hurdle distance (m)	relative
MCLEOD #	0.333	3.88	2.16
SHUBENKOV #	0.320	3.83	2.02
BAJI	0.347	4.00	2.08
DARIEN	0.313	3.67	1.96
MERRITT	0.347	3.85	2.08
BRATHWAITE	0.327	3.66	2.01
ORTEGA	0.353	3.87	2.09
PARCHMENT #	0.307	3.64	1.86

Note: relative = relative hurdle distance based on athlete's height; # athlete contacted the hurdle..

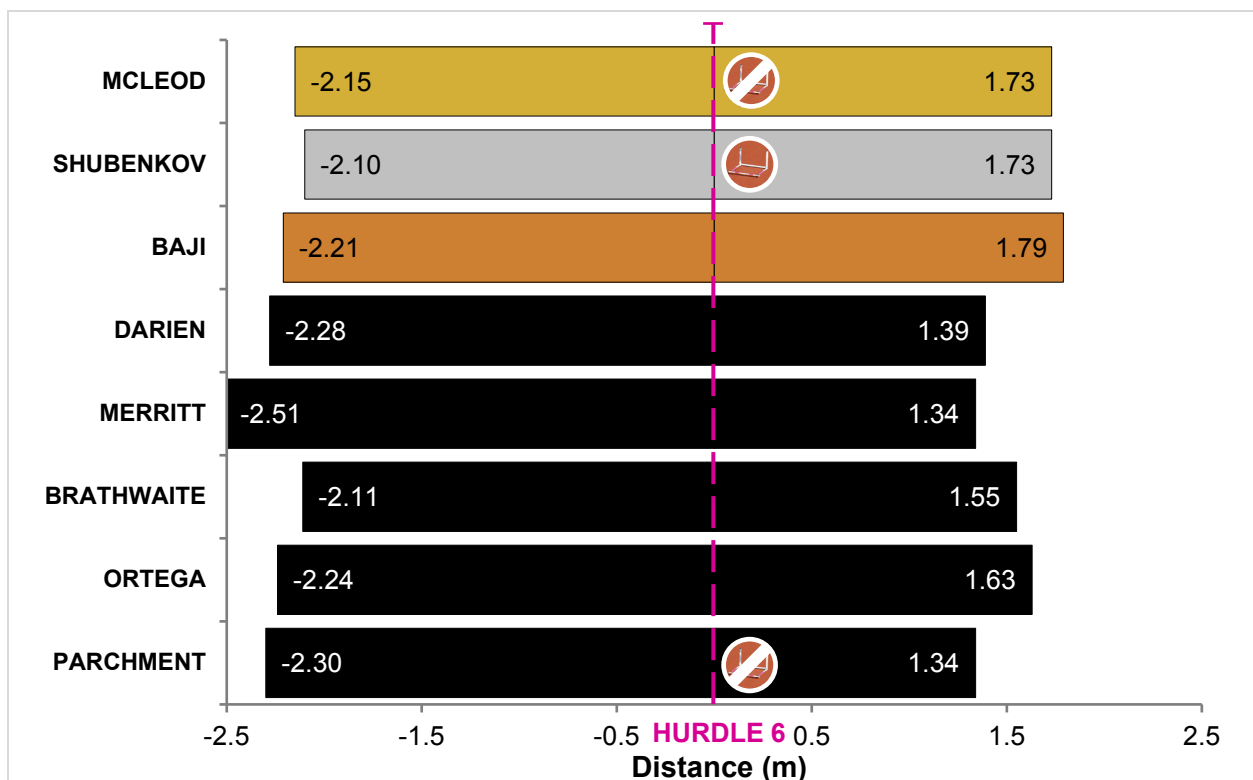


Figure 13. Horizontal distance to the sixth hurdle, between: toe-off during the take-off phase (left of hurdle line) and touchdown during the landing phase (right of hurdle line).

Hurdle 6 – Landing phase: Initial contact and landing step

The following section displays the characteristics of the landing step during the landing phase after the sixth hurdle. The step has been defined from touchdown of the initial contact to touchdown of the second contact between hurdles.

Table 7. Contact time, flight time and step length of the landing step for each finalist.

	Contact time (m)	Flight time (s)	Step length (m)	relative
MCLEOD #	0.093	0.053	1.37	0.76
SHUBENKOV #	0.087	0.053	1.42	0.75
BAJI	0.100	0.033	1.36	0.71
DARIEN	0.087	0.053	1.47	0.79
MERRITT	0.087	0.047	1.45	0.78
BRATHWAITE	0.100	0.040	1.35	0.74
ORTEGA	0.087	0.040	1.35	0.73
PARCHMENT #	0.093	0.047	1.42	0.72

Note: relative = relative step length based on athlete's height; # athlete contacted the hurdle.

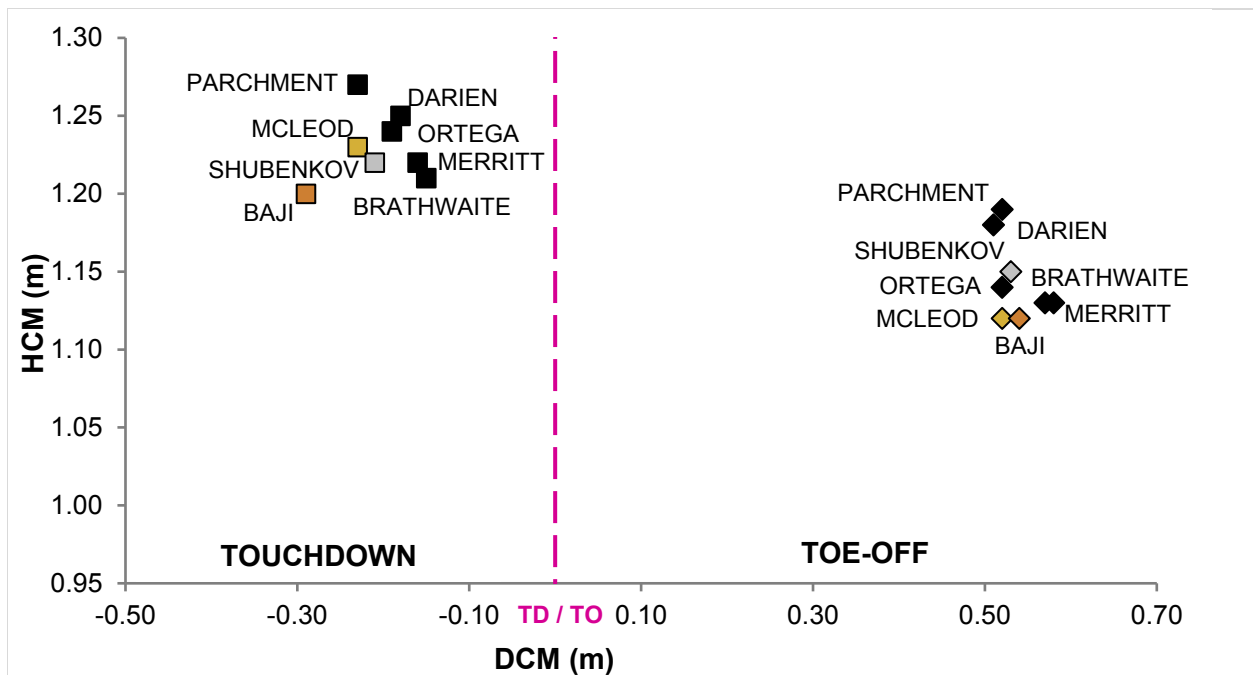


Figure 14. Height of the body's CM and horizontal distance to the body's CM (DCM) at touchdown (TD) and toe-off (TO) of the initial foot contact after the sixth hurdle.

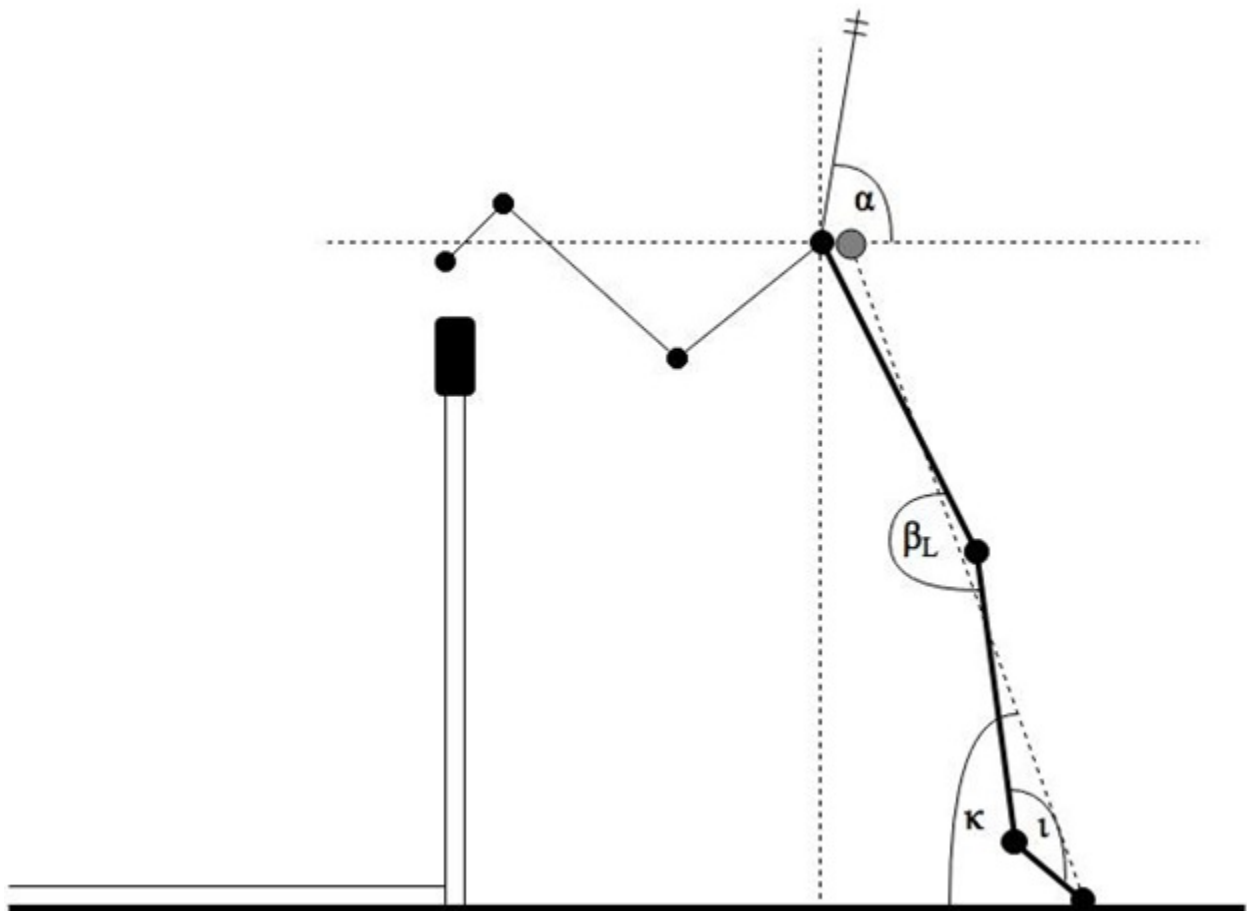


Figure 15. Body schematic denoting joint angles measured at touchdown during the landing phase.

Table 8. Joint angles at touchdown after the sixth hurdle for all finalists.

	Lead leg knee angle (°) (β_L)	Lead leg ankle angle (°) (ι)	Deviation angle (°) (κ)
MCLEOD #	177.6	140.5	-79.4
SHUBENKOV #	175.4	144.3	-80.2
BAJI	169.3	134.4	-76.4
DARIEN	165.2	132.9	-81.8
MERRITT	173.3	132.5	-82.5
BRATHWAITE	150.0	122.2	-82.9
ORTEGA	161.4	126.7	-81.3
PARCHMENT #	157.5	109.9	-79.7

Note: The lead leg is the leg in contact with the ground. A negative deviation angle indicates that the CM is behind the point of ground contact.

athlete contacted the hurdle.

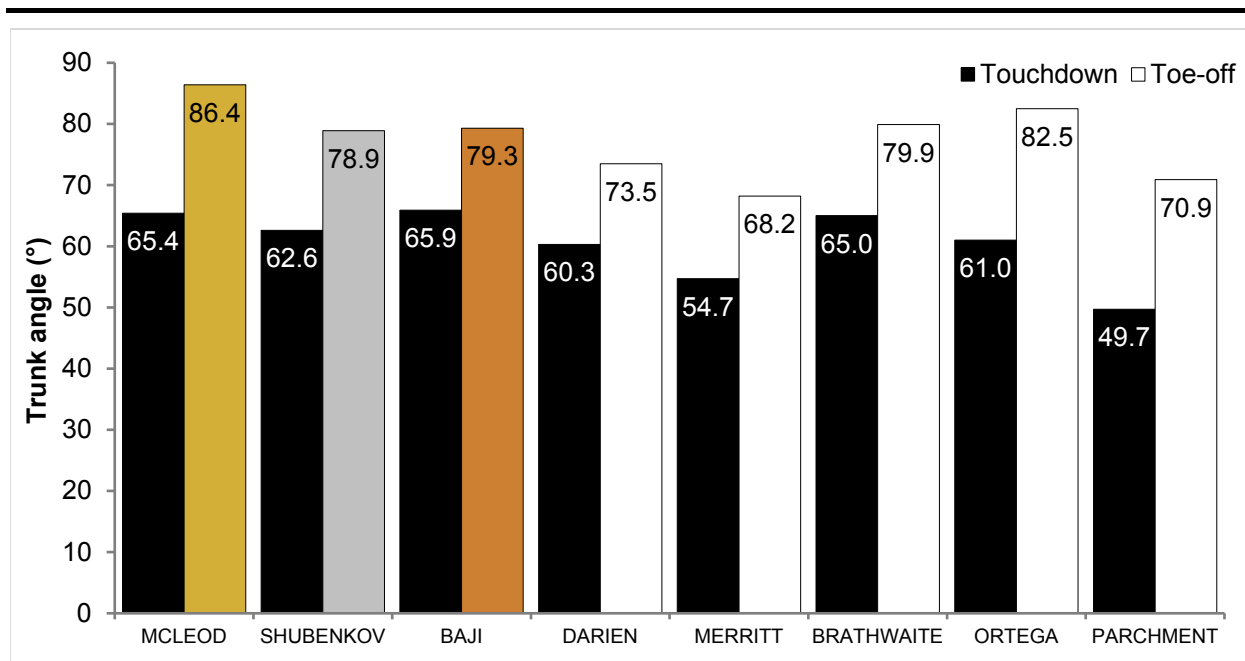


Figure 16. Trunk angles (α) at touchdown (black columns) and toe-off (white or medal colour columns) during the landing step.

Hurdle 6 – Landing phase: Second contact and recovery step

The following section displays the characteristics of the recovery step during the landing phase after the sixth hurdle. The step has been defined from touchdown of the second contact to touchdown of the third contact between hurdles.

Table 9. Contact time, flight time and step length for each finalist.

	Contact time (s)	Flight time (s)	Step length (m)	relative
MCLEOD #	0.113	0.100	1.91	1.06
SHUBENKOV #	0.120	0.100	2.04	1.07
BAJI	0.120	0.100	1.89	0.98
DARIEN	0.127	0.093	2.01	1.07
MERRITT	0.113	0.120	2.07	1.12
BRATHWAITE	0.107	0.133	2.14	1.18
ORTEGA	0.120	0.120	2.06	1.11
PARCHMENT #	0.127	0.113	2.20	1.12

Note: relative = relative step length based on athlete's height.

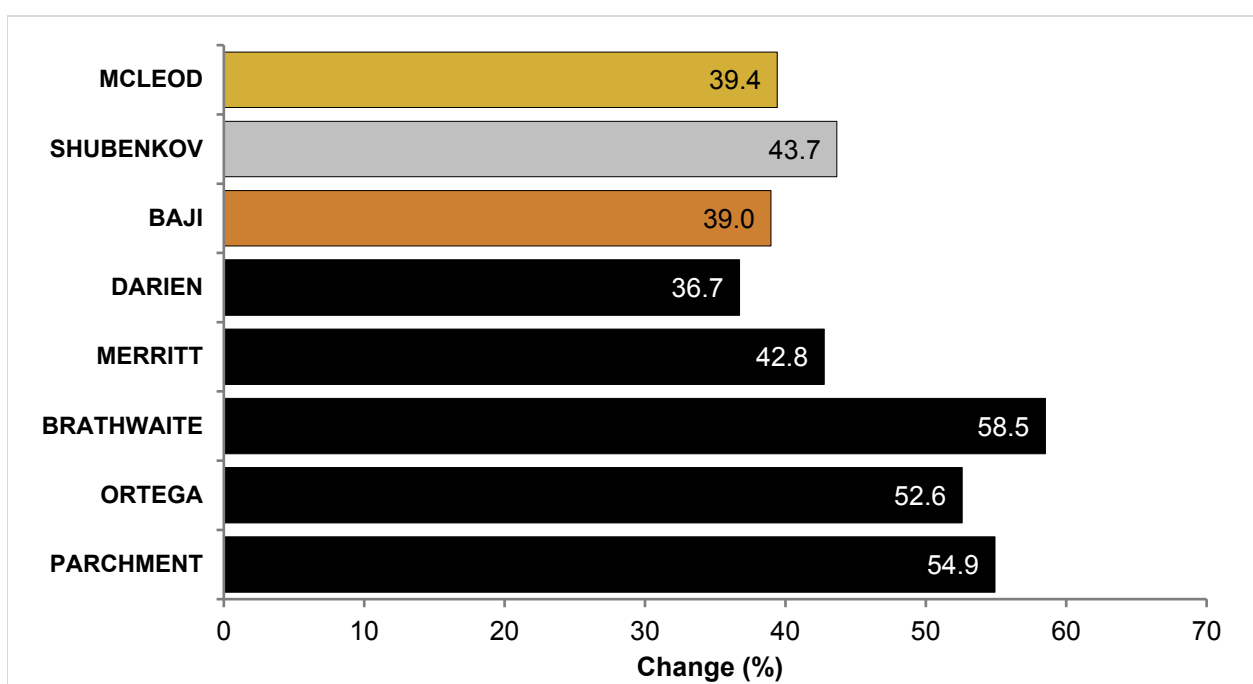


Figure 17. Increase (%) in step length from the landing step to the recovery step after the sixth hurdle.

Hurdle 10 – Landing phase and run-in to finish

The following section of results shows the temporal characteristics of the initial and subsequent steps after the tenth hurdle to the finish for each of the finalists. Figure 18 focusses on the first step only, whilst Figures 19-21 display contact and flight times for each completed step from hurdle 10 to the finish line.

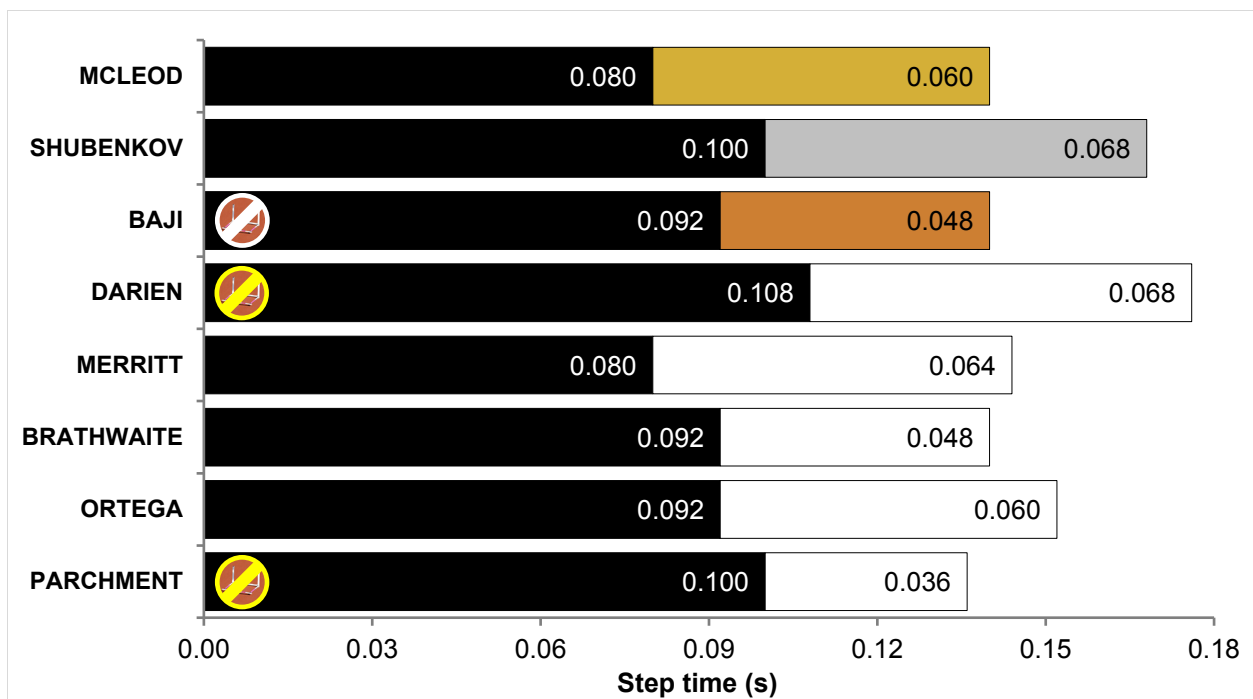


Figure 18. Contact time, flight time and step time immediately after the tenth hurdle.

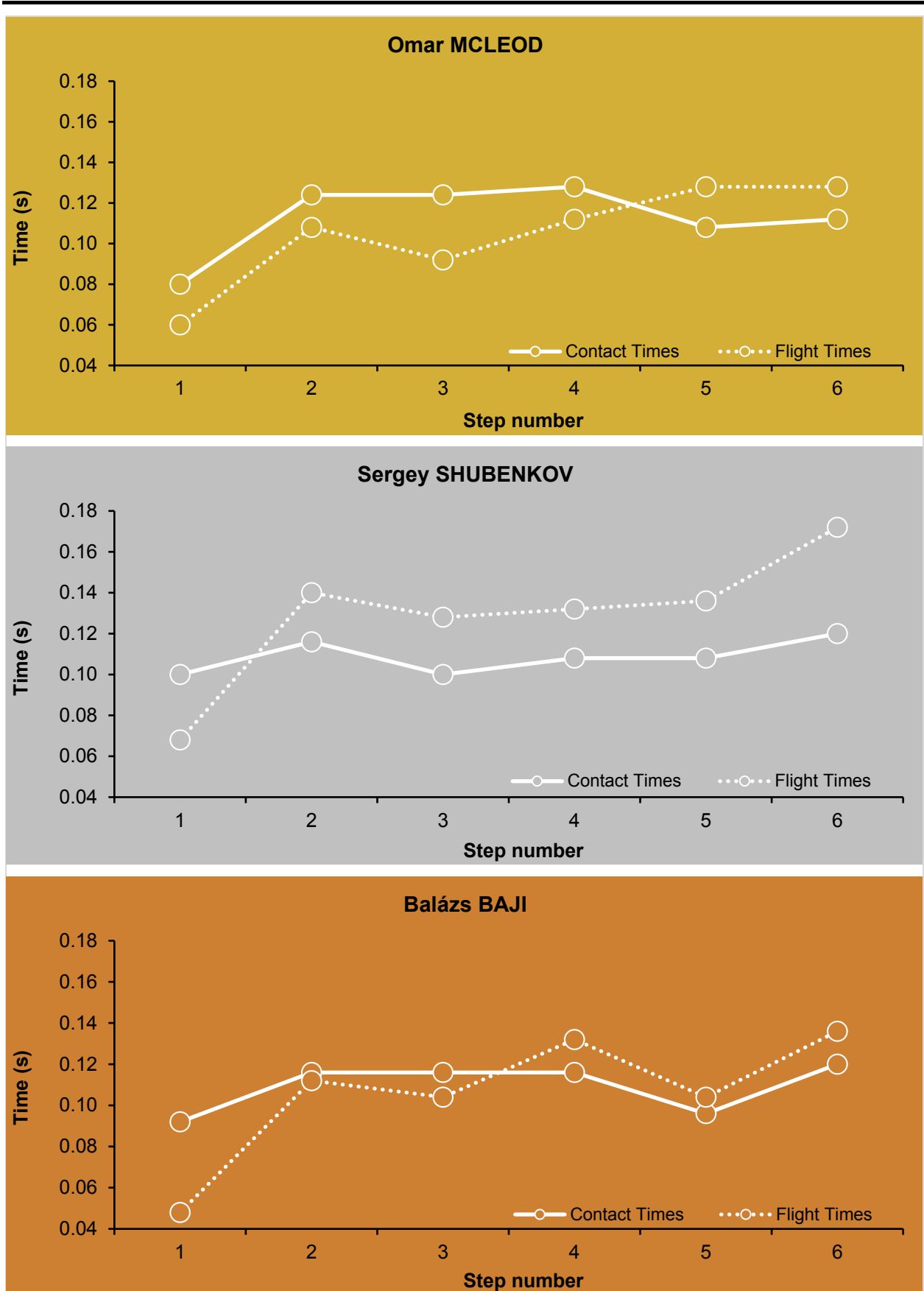


Figure 19. Individual contact and flight times of the medallists after the tenth hurdle.

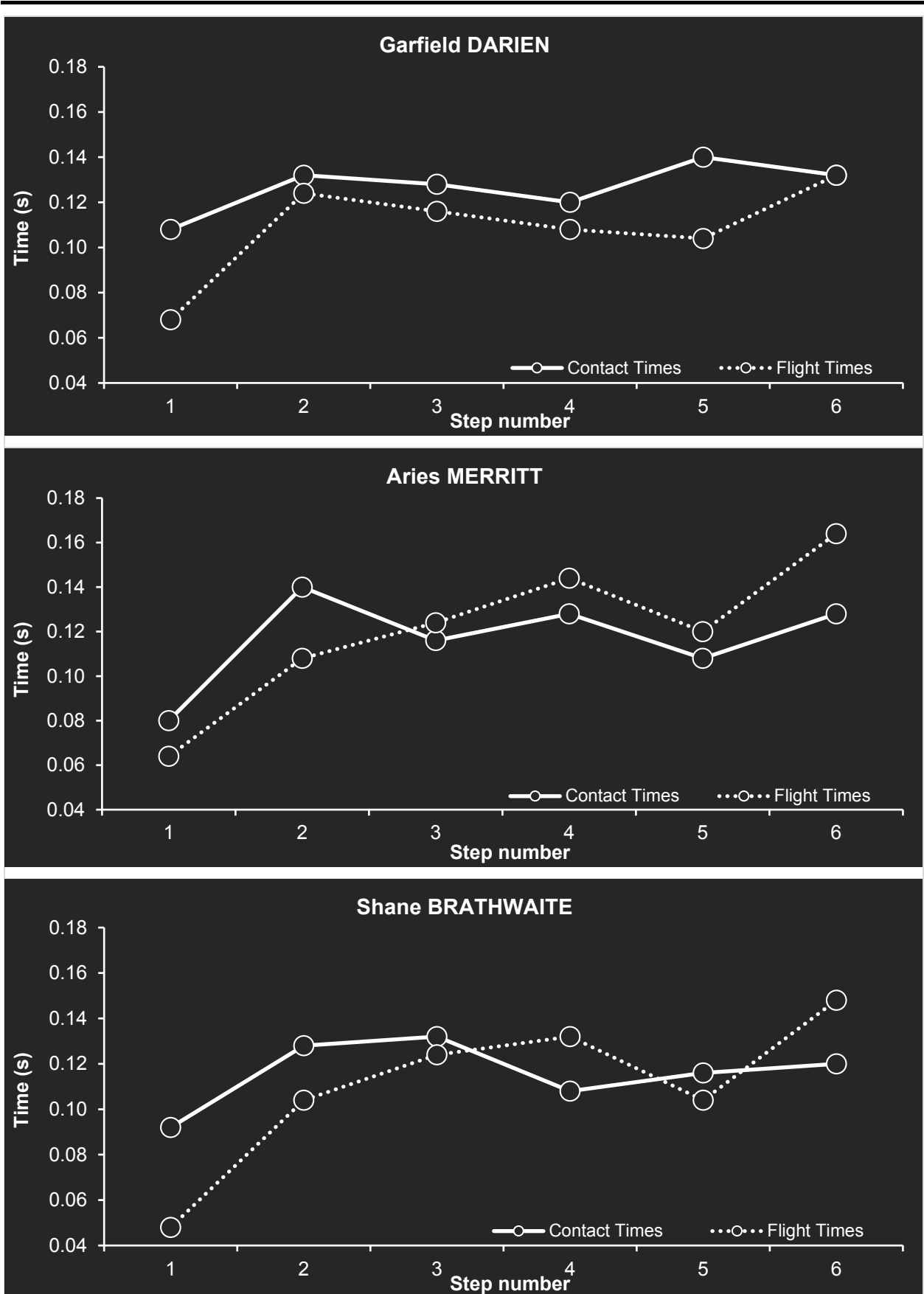


Figure 20. Individual contact times and flight times for: Garfield Darien, Aries Merritt and Shane Braithwaite, after the tenth hurdle.

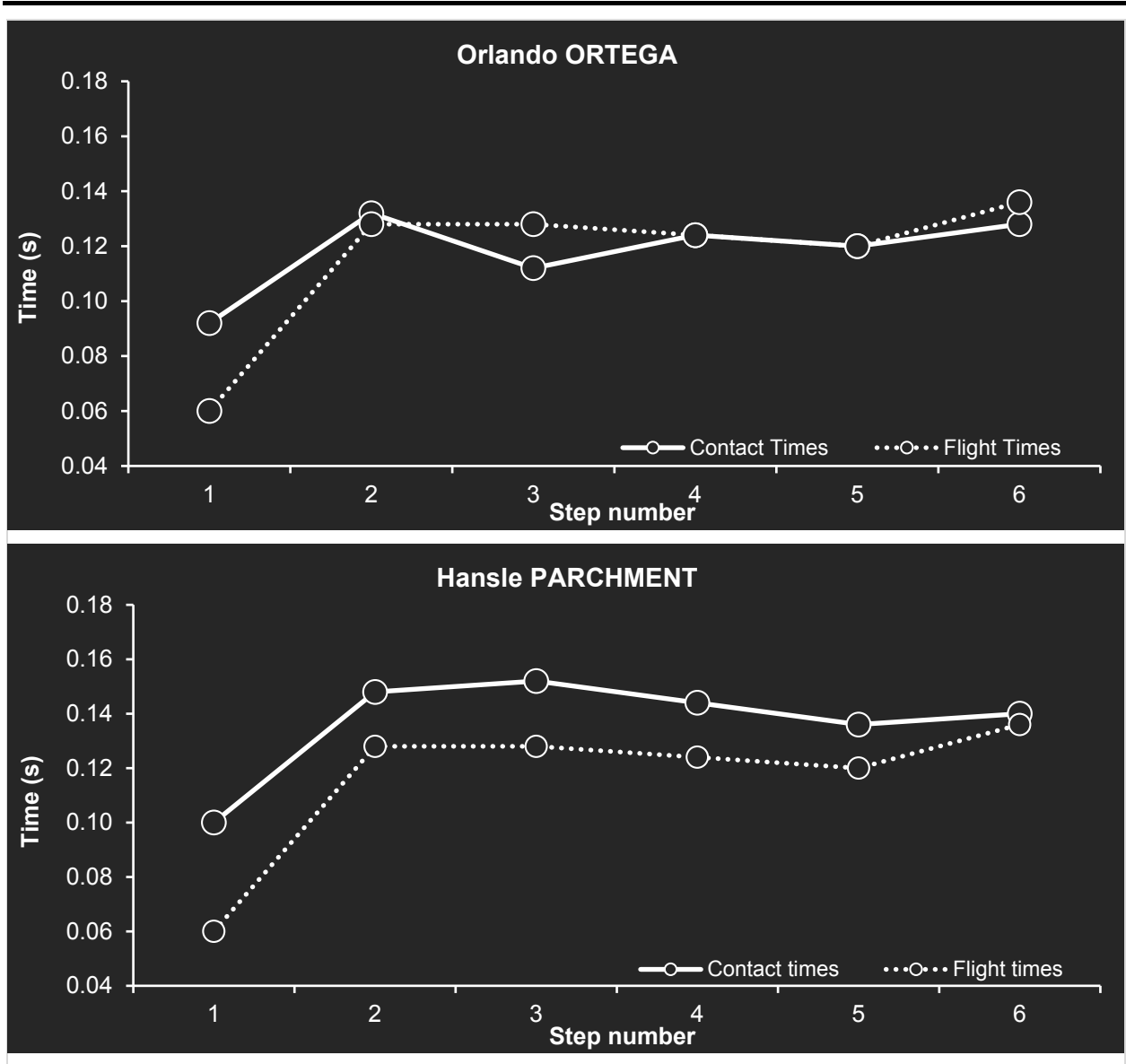


Figure 21. Individual contact times and flight times for: Orlando Ortega and Hansle Parchment, after the tenth hurdle.

RESULTS – Semi-Final 1

Performance data

Table 10 below displays the ranking of each athlete before the World Championships based on their season's (SB) and personal best (PB) times, and a comparison to their semi-final time. The athletes qualifying for the final are highlighted in blue.

Table 10. Athletes' ranking based on SB and PB, and comparison to their semi-final performance.

Athlete	SB rank	PB rank	SEMI-FINAL	notes	vs. SB	vs. PB
MCLEOD	1	2	13.10 s	Q	0.20 s	0.20 s
DARIEN	3	7	13.17 s	Q	0.08 s	0.08 s
SHUBENKOV	2	5	13.22 s	q	0.21 s	0.24 s
ORTEGA	8	3	13.22 s	q	0.07 s	0.28 s
TRAJKOVIC	12	15	13.32 s		0.07 s	0.07 s
HARRIS	10	8	13.40 s		0.22 s	0.29 s
MASUNO	19	22	13.79 s		0.38 s	0.38 s
AL-YOUHA	24	24	-	DNF	-	-

Key: Q = automatic qualifier, q = secondary qualifier, SB = season's best, PB = personal best, DNF = did not finish.

Positional analysis

Figure 22 shows the relative position of each athlete at each hurdle split throughout the race.

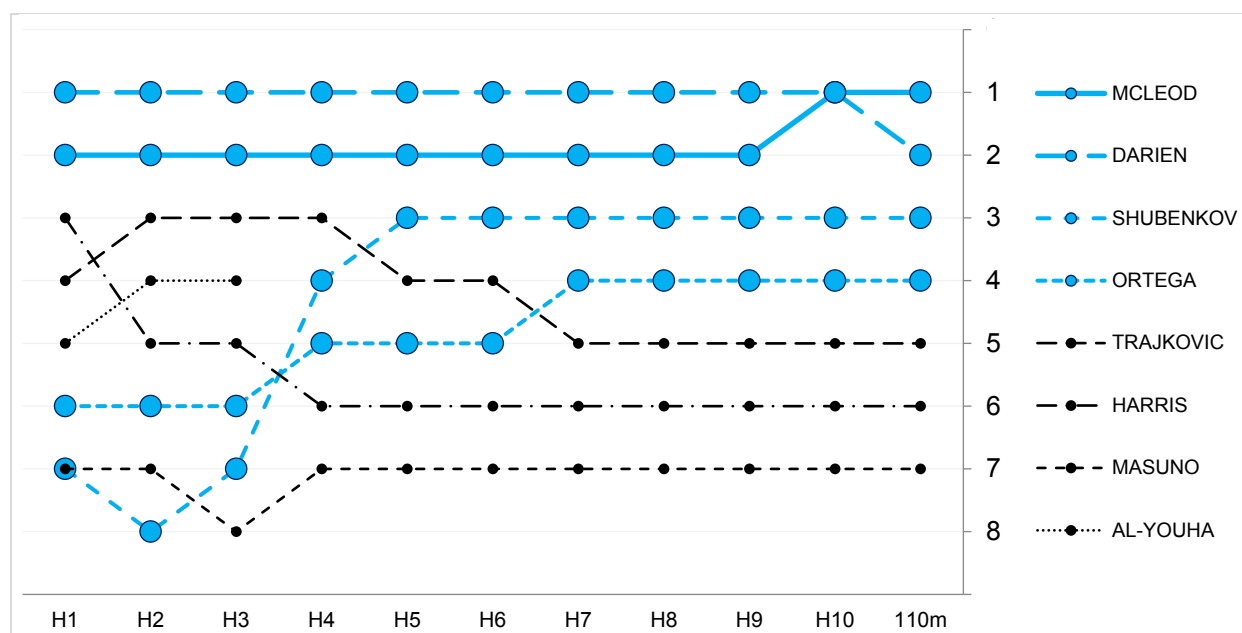


Figure 22. Position of each athlete as they crossed each hurdle and the finish line.

Split times at each hurdle

The following graphs display consecutive splits between: the start and hurdle three (Figure 23; Note: the split between the start and hurdle one is minus the reaction time), hurdles four to seven (Figure 24), hurdles seven to ten and from hurdle ten to the finish line (Figure 25). The mean speed between these consecutive hurdle splits is presented in Figure 26.

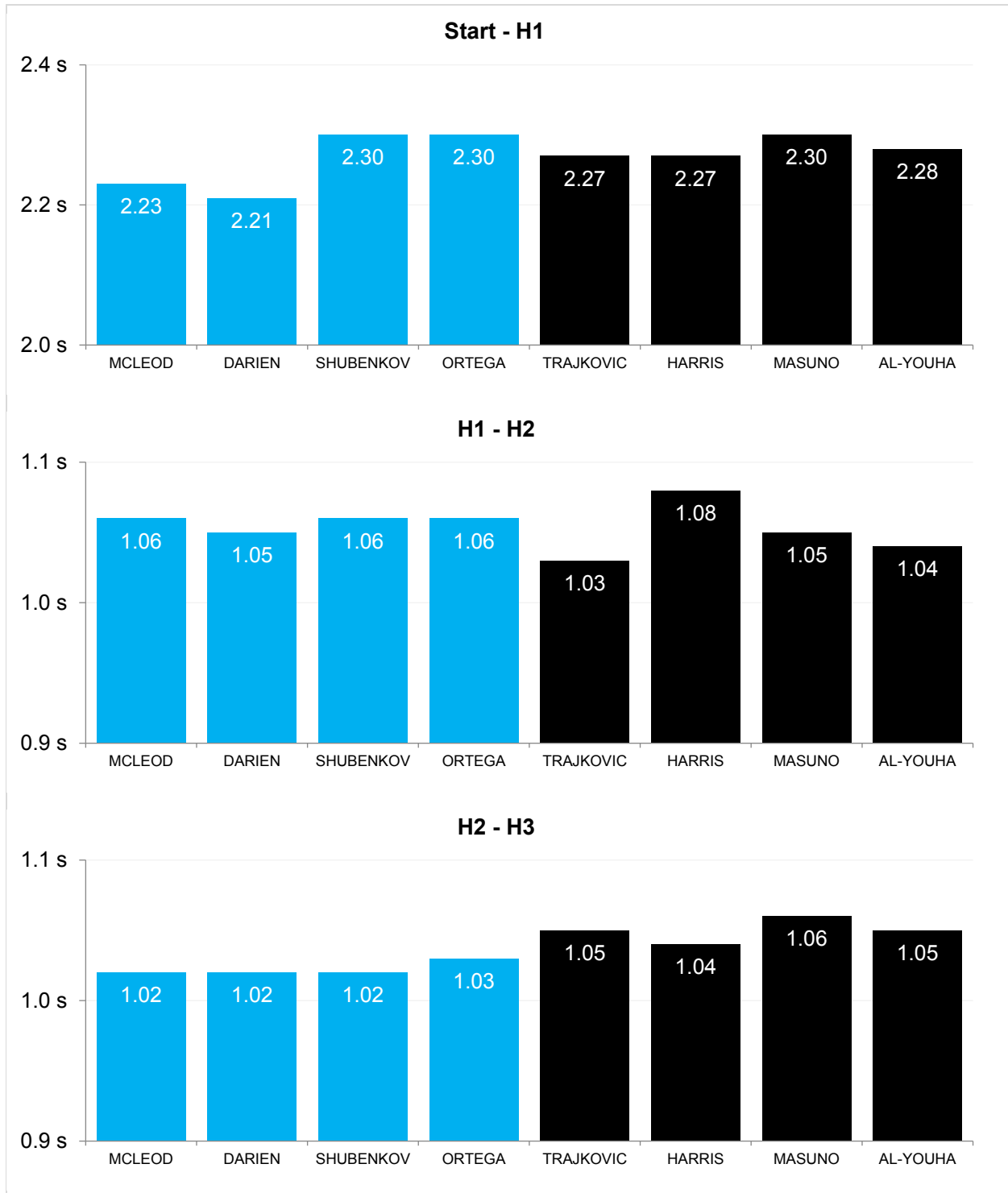


Figure 23. Individual split times between the start and first three consecutive hurdles.

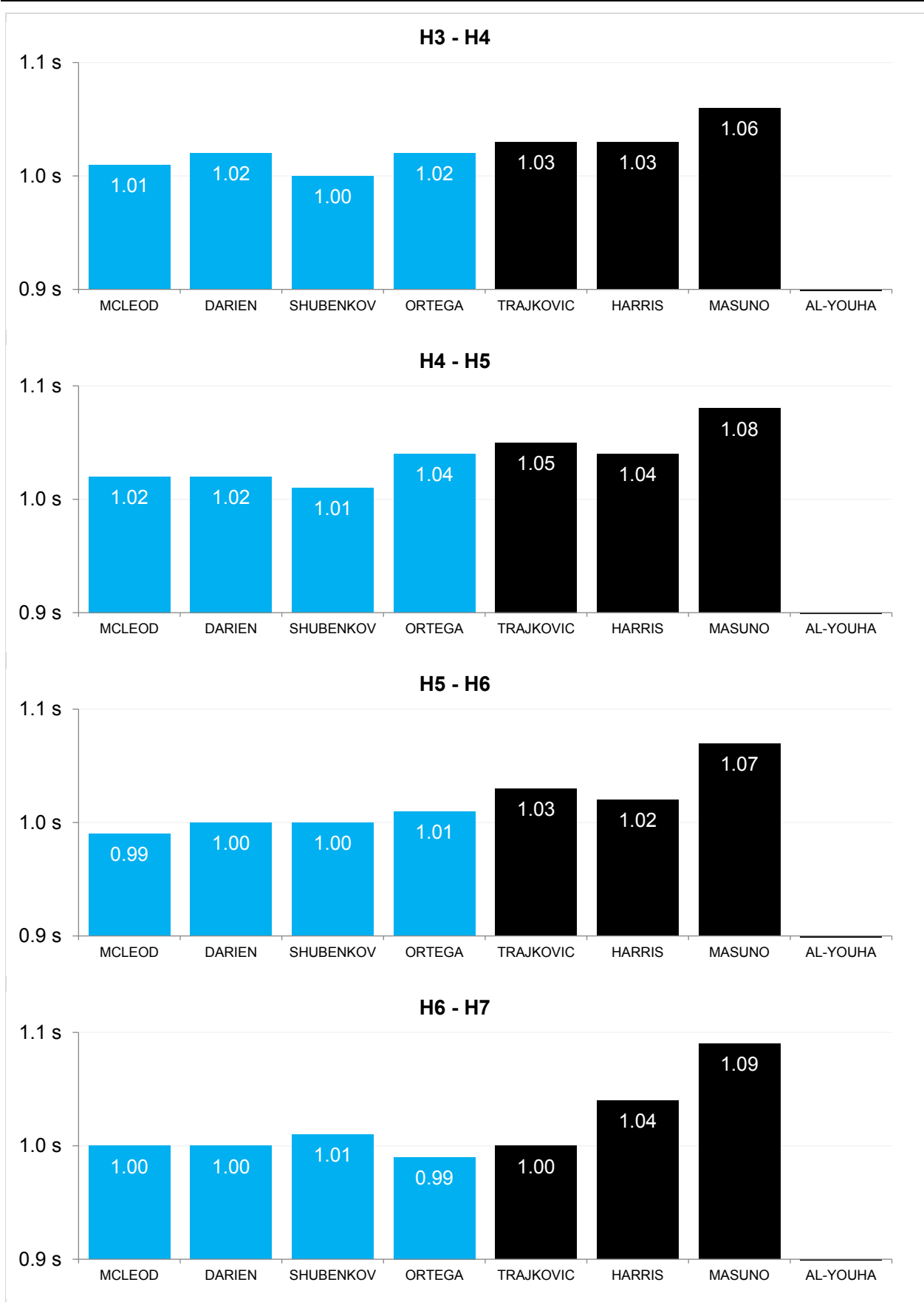


Figure 24. Individual split times for consecutive hurdles between hurdles three and seven.

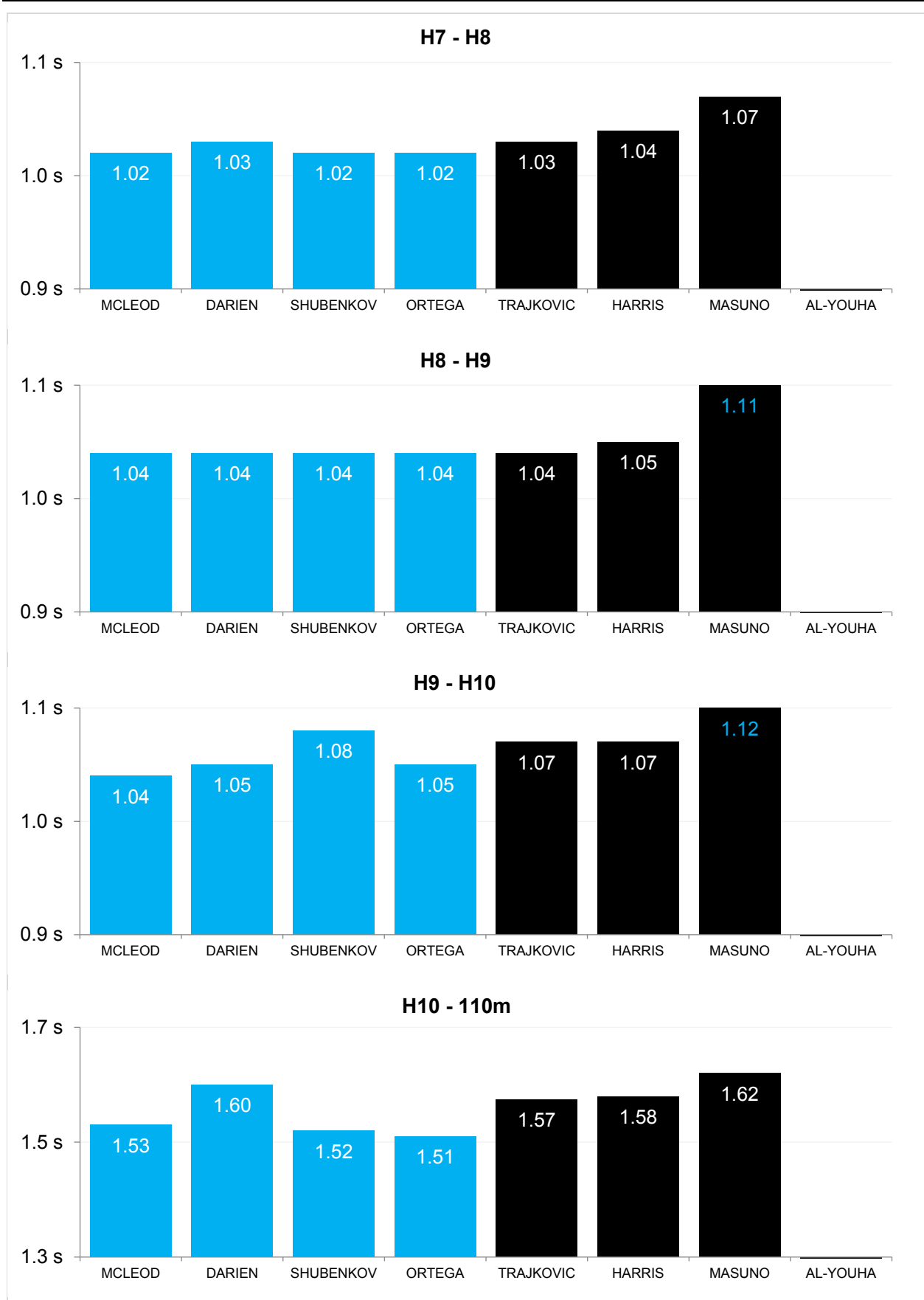


Figure 25. Individual split times between the final three consecutive hurdles and hurdle ten to the finish.

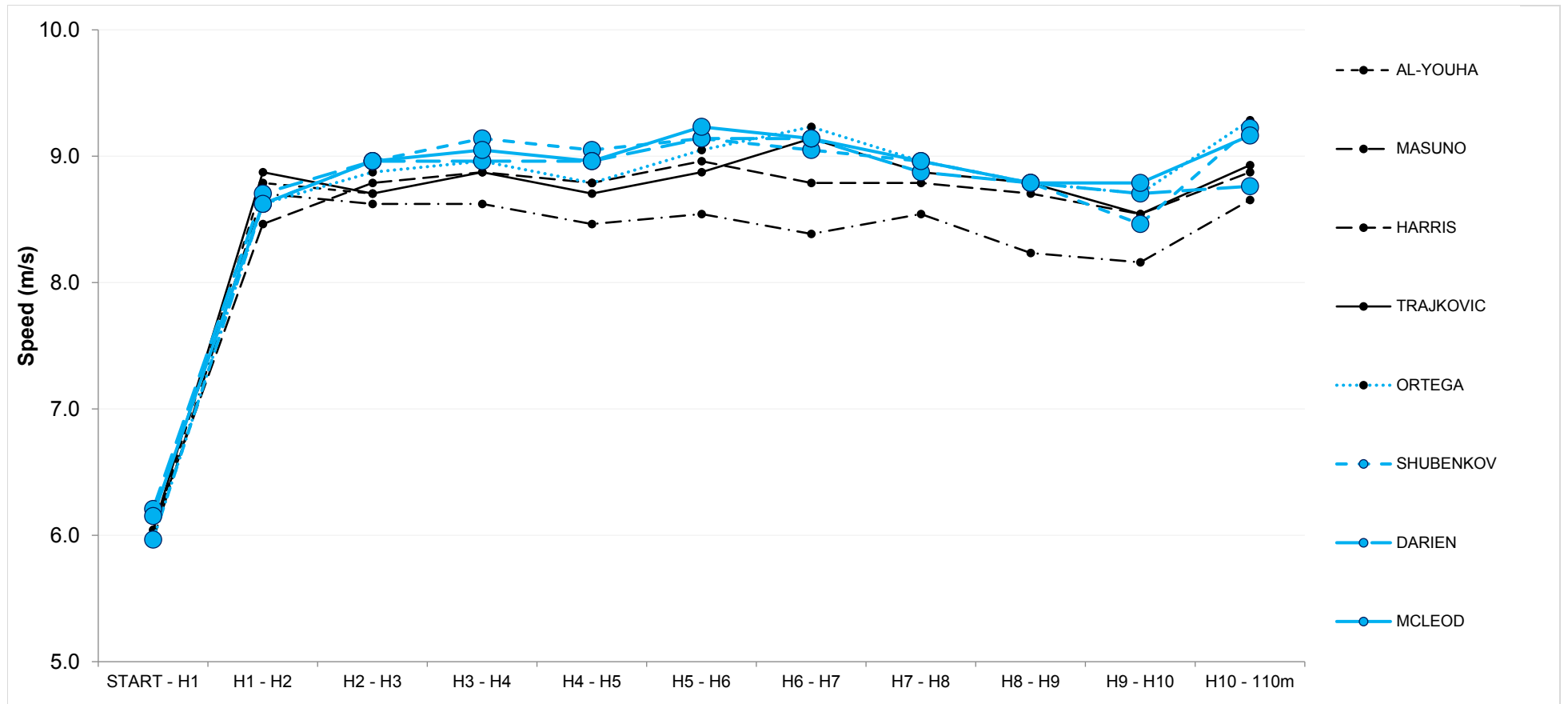


Figure 26. Mean speed for each hurdle split.

Hurdle profiles for each athlete

The following graphs display the individual split times between hurdles as well as to the first and from the last hurdle. Also included is the position at each hurdle and the type of clearance (see Table 1; page 9), for the qualifiers (Figure 27) followed by the non-qualifiers (Figure 28).

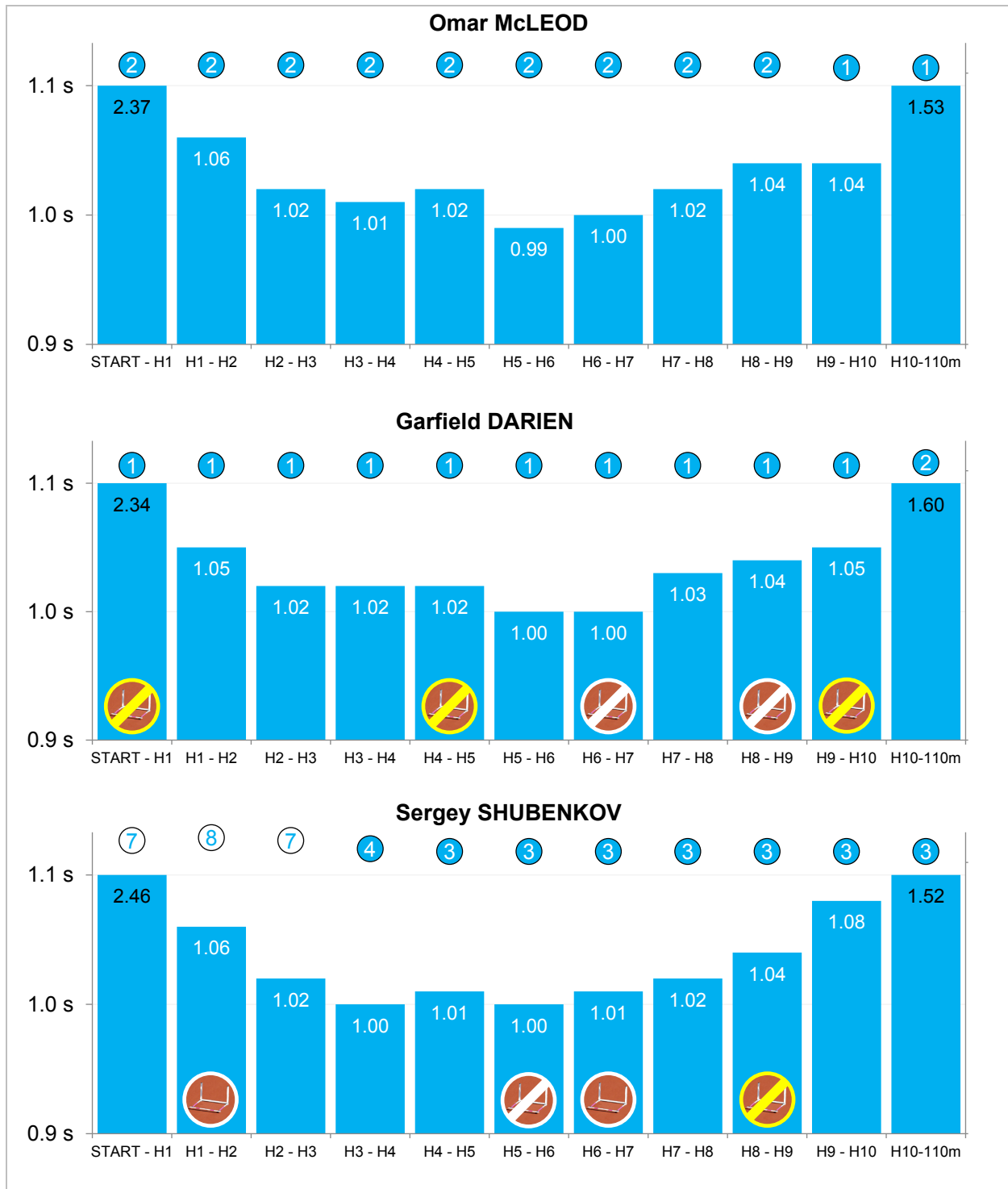


Figure 27. Hurdle profiles for the athletes qualifying for the final.

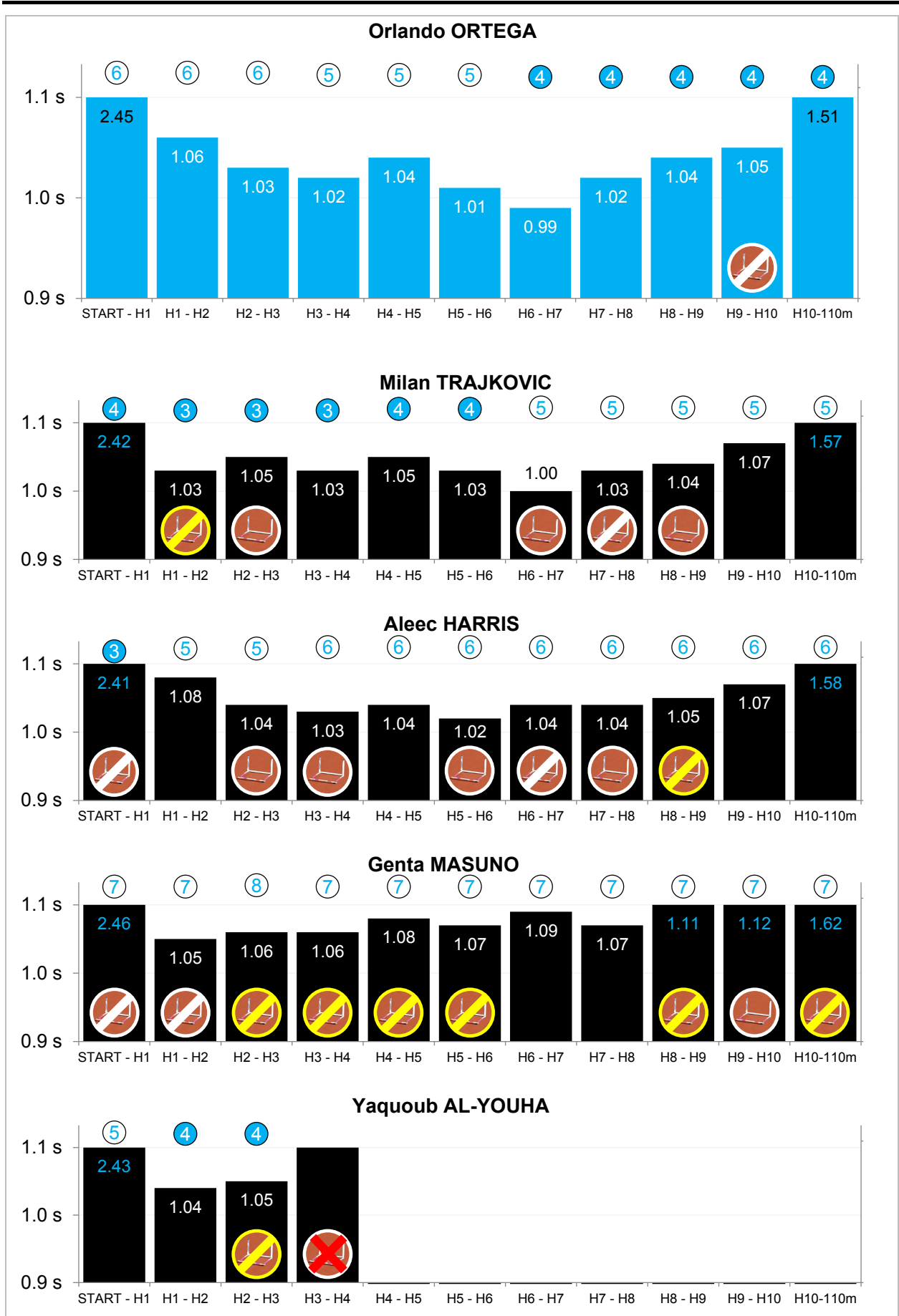


Figure 28. Hurdle profiles for one qualifying athlete, and the non-qualifying athletes.

RESULTS – Semi-Final 2

Performance data

Table 11 below displays the ranking of each athlete before the World Championships based on their season's (SB) and personal best (PB) times, and a comparison to their semi-final time. The athletes qualifying for the final are highlighted in blue.

Table 11. Athletes' ranking based on SB and PB, and comparison to their semi-final performance.

Athlete	SB rank	PB rank	SEMI-FINAL	notes	vs. SB	vs. PB
BRATHWAITE	13	13	13.26 s	Q SB	-0.01 s	0.05 s
PARCHMENT	11	3	13.27 s	Q .262* s	0.07 s	0.32 s
ALLEN	5	6	13.27 s	.265 s	0.17 s	0.24 s
POZZI	7	10	13.28 s		0.14 s	0.14 s
CZYKIER	14	16	13.42 s		0.14 s	0.14 s
IRIBARNE	18	21	13.43 s		0.04 s	0.04 s
CONTRERAS	19	19	13.65 s		0.25 s	0.30 s
BÜHLER	22	18	13.79 s		0.32 s	0.45 s

Key: Q = automatic qualifier, SB = season's best, PB = personal best.

Positional analysis

Figure 29 shows the relative position of each athlete at each hurdle split throughout the race.

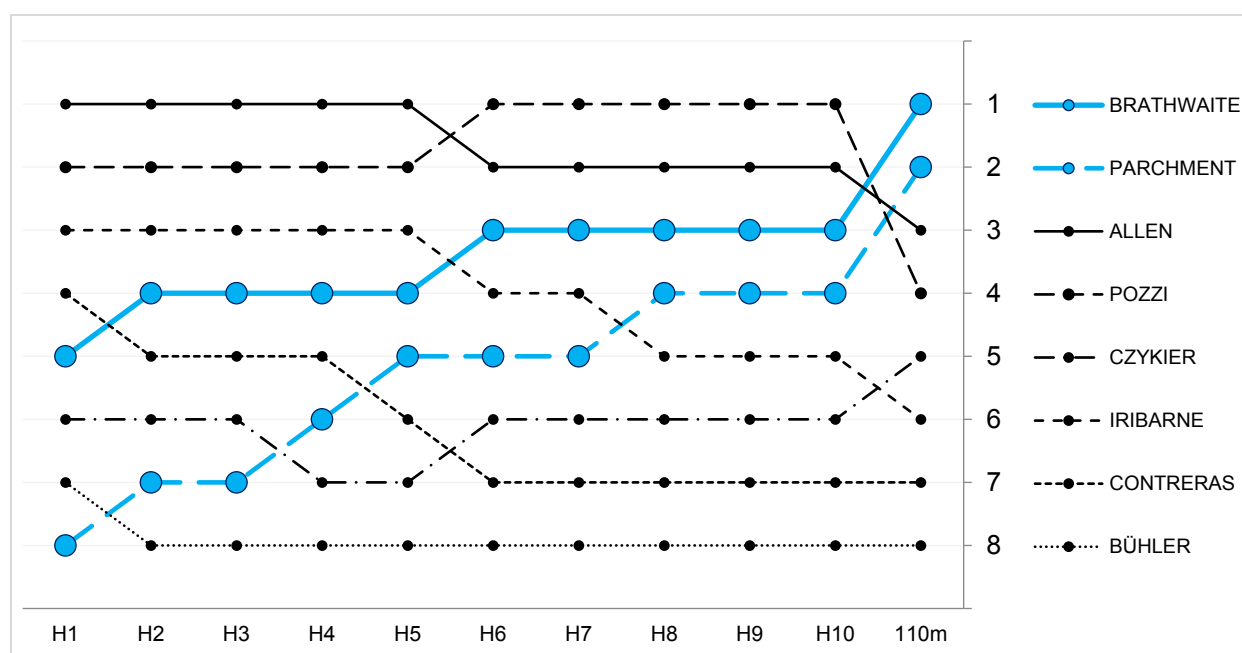


Figure 29. Position of each athlete as they crossed each hurdle and the finish line.

Individual hurdle split times

The following graphs display consecutive splits between: the start and hurdle three (Figure 30; Note: the split between the start and hurdle one is minus the reaction time), hurdles four to seven (Figure 31), hurdles seven to ten and from hurdle ten to the finish line (Figure 32). The mean speed between these consecutive hurdle splits is presented in Figure 33.

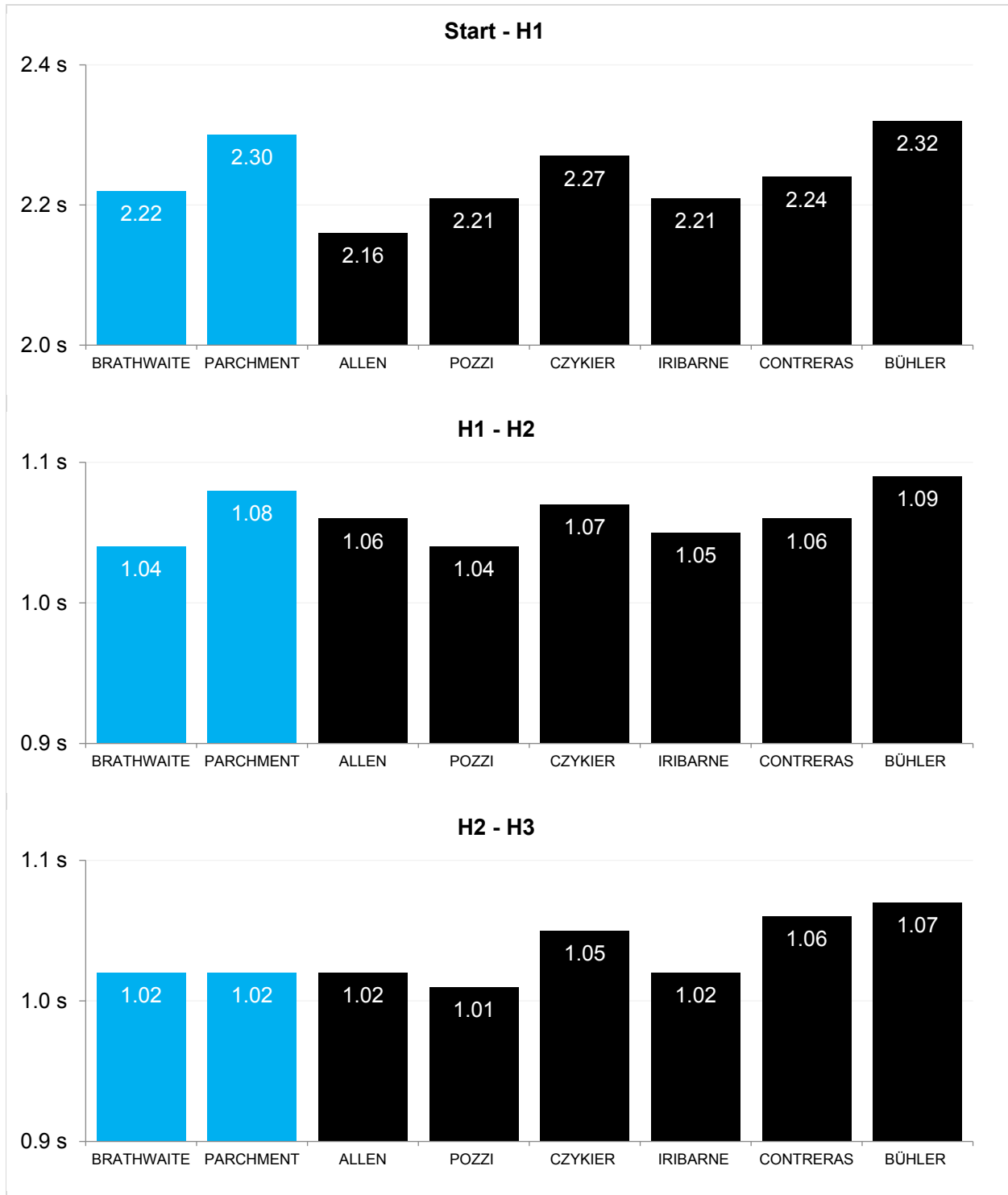


Figure 30. Individual split times between the start and first three consecutive hurdles.

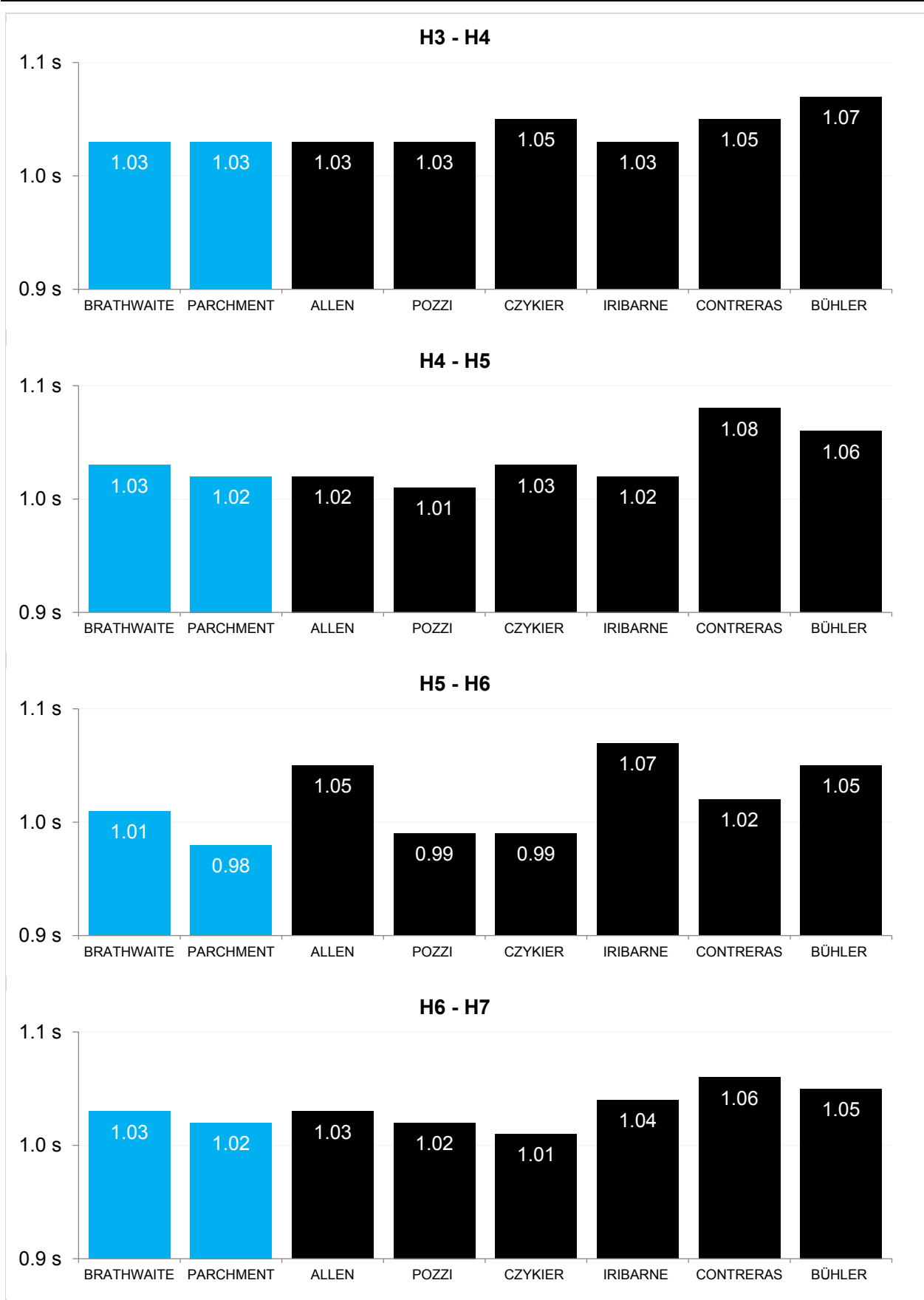


Figure 31. Individual split times for consecutive hurdles between hurdles three and seven.

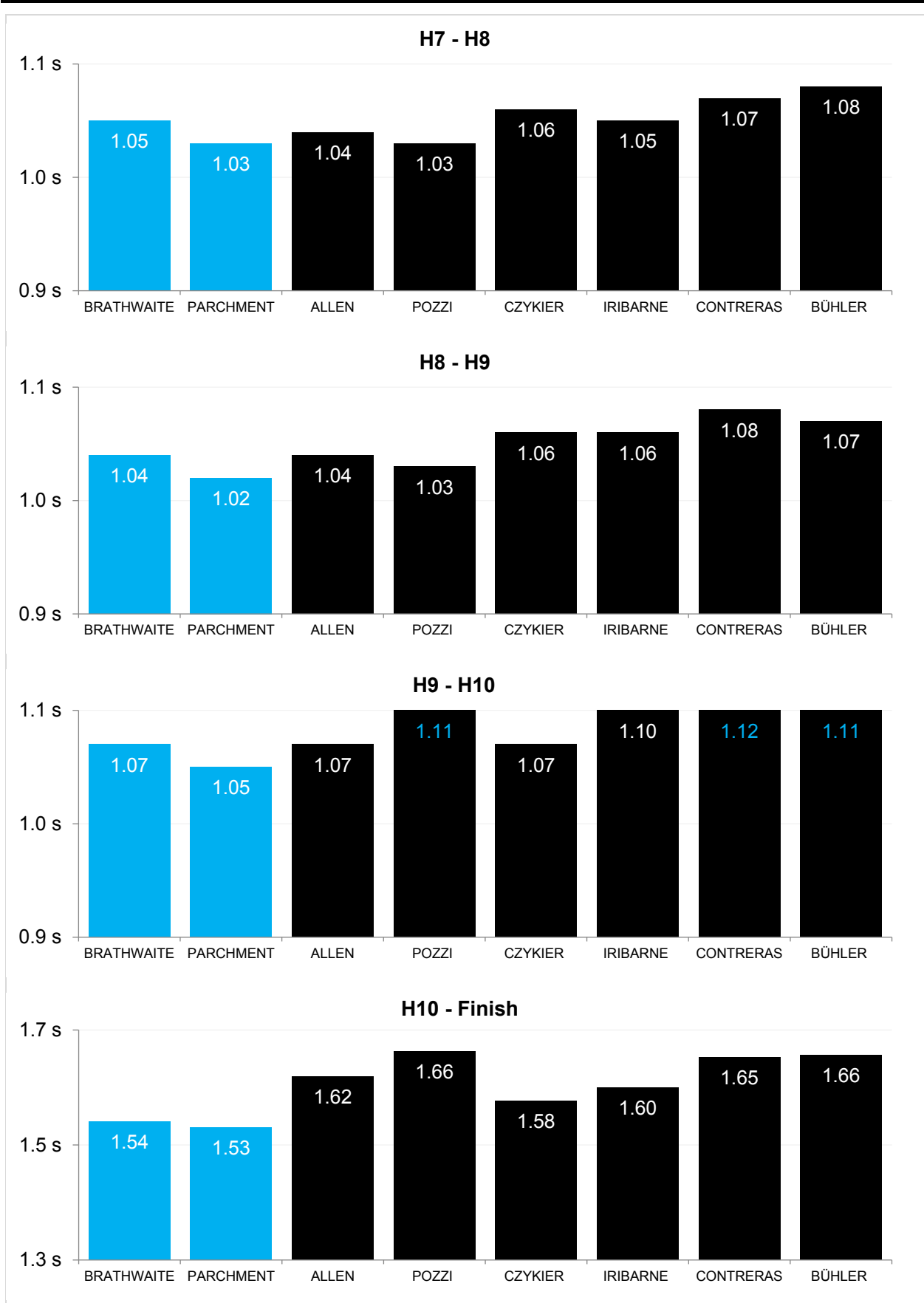


Figure 32. Individual split times between the final three consecutive hurdles and hurdle ten to the finish.

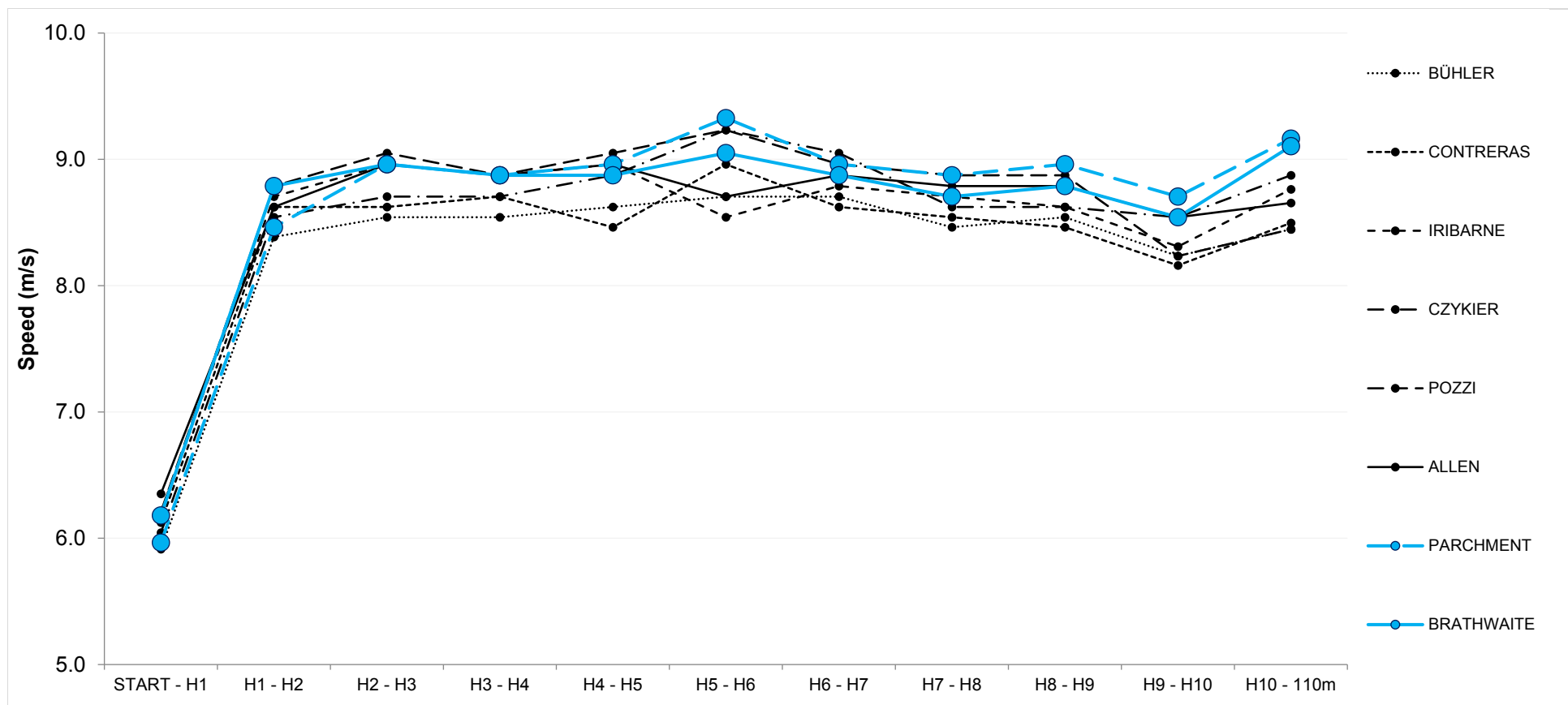


Figure 33. Mean speed for each hurdle split.

Hurdle profiles for each athlete

The following graphs display the individual split times between hurdles as well as to the first and from the last hurdle. Also included is the position at each hurdle and the type of clearance (see Table 1; page 9), for the qualifiers (Figure 34) followed by the non-qualifiers (Figure 35).

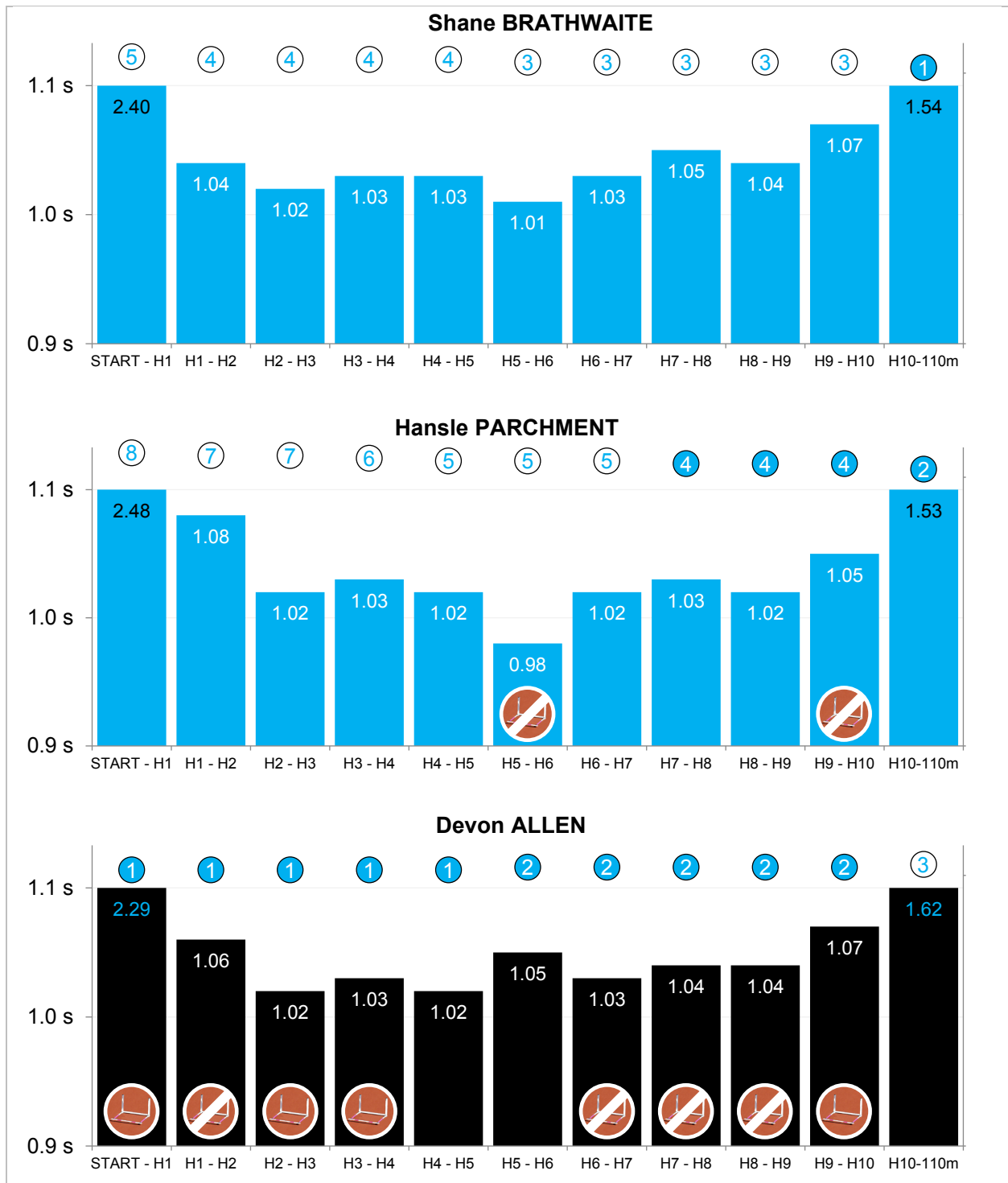


Figure 34. Hurdle profiles for the athletes qualifying for the final, and a non-qualifying athlete.

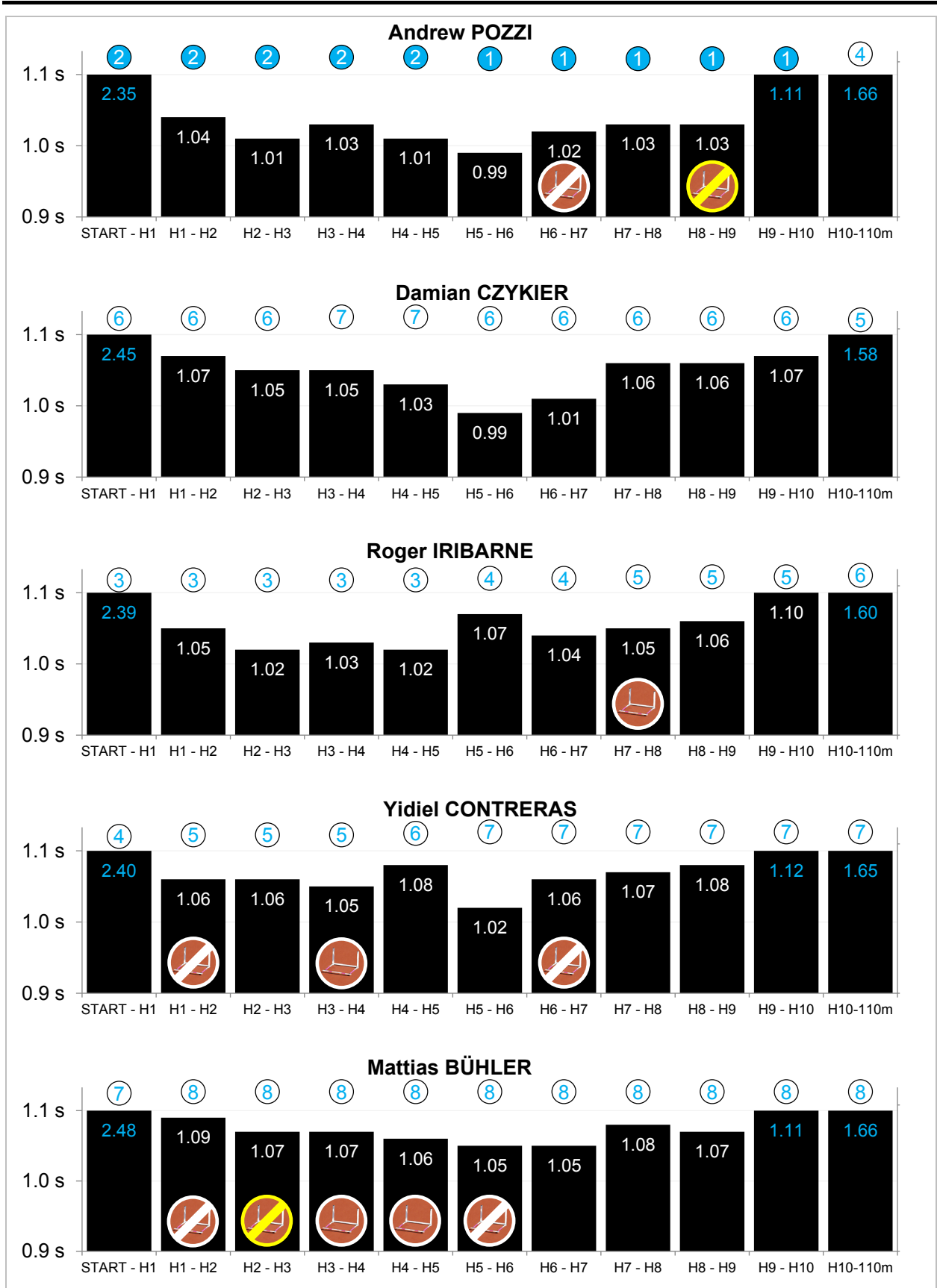


Figure 35. Hurdle profiles for the non-qualifying athletes.

RESULTS – Semi-Final 3

Performance data

Table 12 below displays the ranking of each athlete before the World Championships based on their season's (SB) and personal best (PB) times, and a comparison to their semi-final time. The athletes qualifying for the final are highlighted in blue.

Table 12. Athletes' ranking based on SB and PB, and comparison to their semi-final performance.

Athlete	SB rank	PB rank	SEMI-FINAL	notes	vs. SB	vs. PB
BAJI	8	11	13.23 s	Q	0.08 s	0.08 s
MERRITT	3	1	13.25 s	Q	0.16 s	0.45 s
XIE	15	14	13.36 s		0.05 s	0.13 s
ALKANA	6	8	13.59 s		0.48 s	0.48 s
LOVETT	21	17	13.67 s		0.26 s	0.36 s
SOUZA	23	23	13.70 s		0.23 s	0.24 s
CABRAL	17	19	14.98 s		1.60 s	1.63 s
O'FARRILL	16	12		<i>DNF</i>		

Key: Q = automatic qualifier, SB = season's best, PB = personal best, DNF = did not finish.

Positional analysis

Figure 36 shows the relative position of each athlete at each hurdle split throughout the race.

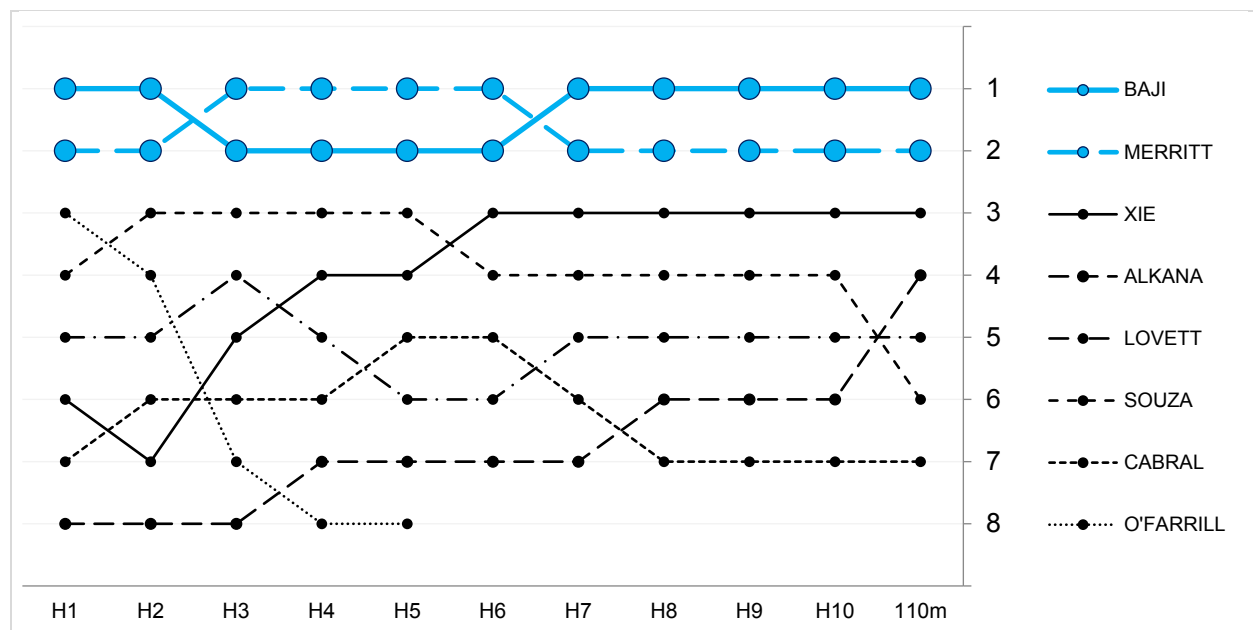


Figure 36. Position of each athlete as they crossed each hurdle.

Individual hurdle split times

The following graphs display consecutive splits between: the start and hurdle three (Figure 37; Note: the split between the start and hurdle one is minus the reaction time), hurdles four to seven (Figure 38), hurdles seven to ten and from hurdle ten to the finish line (Figure 39). The mean speed between these consecutive hurdle splits is presented in Figure 40.

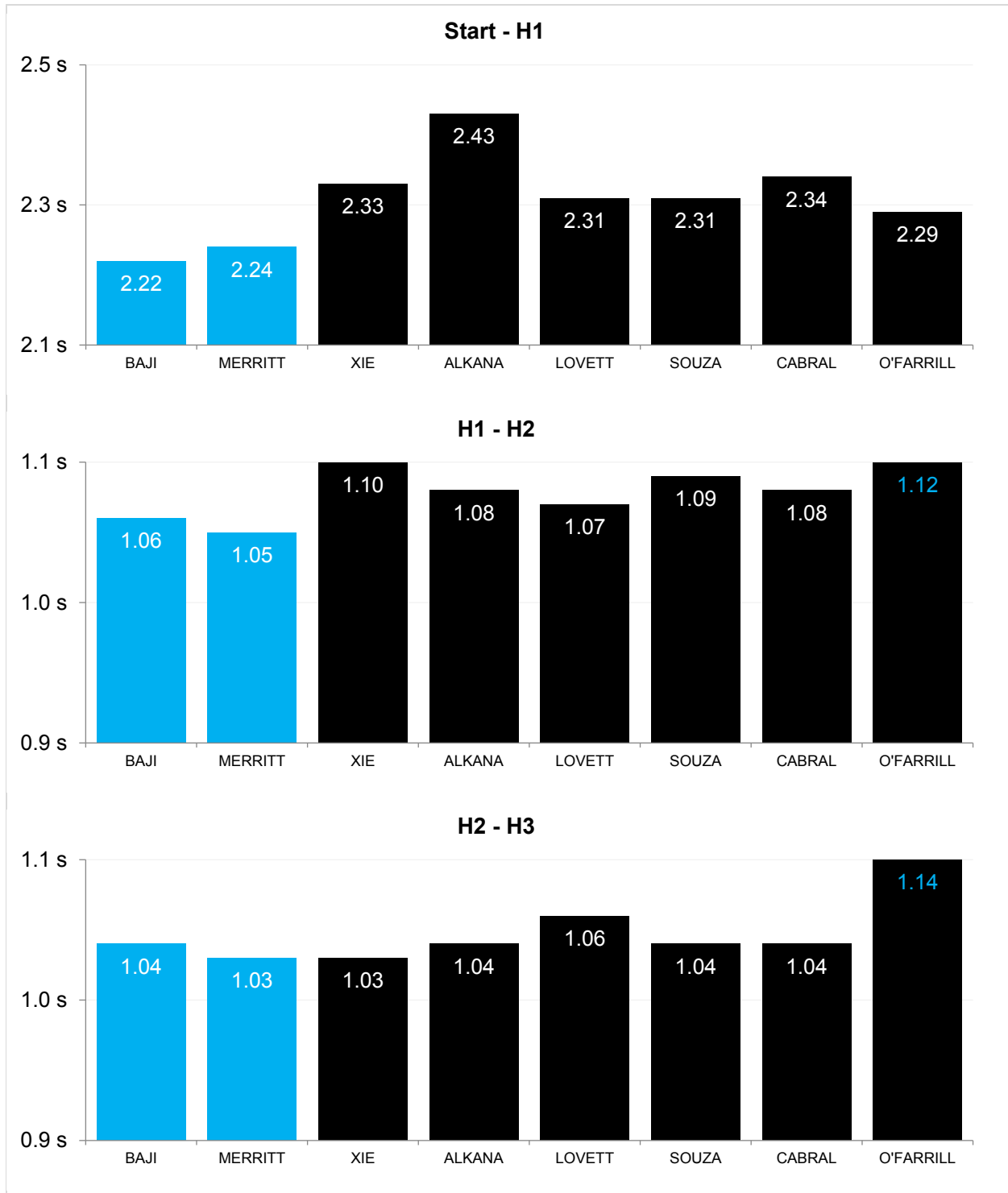


Figure 37. In Individual split times between the start and first three consecutive hurdles.

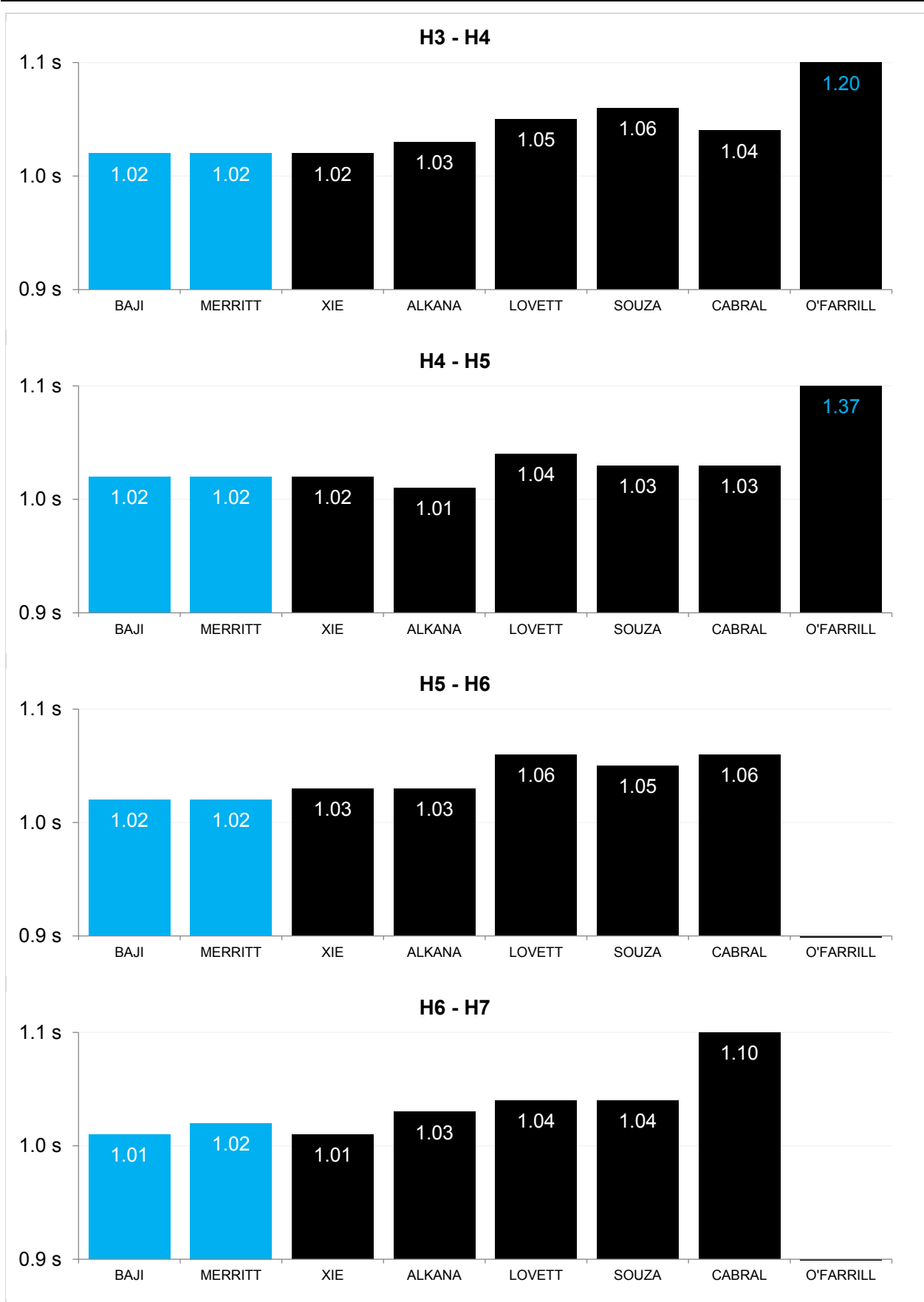


Figure 38. Individual split times for consecutive hurdles between hurdles three and seven.

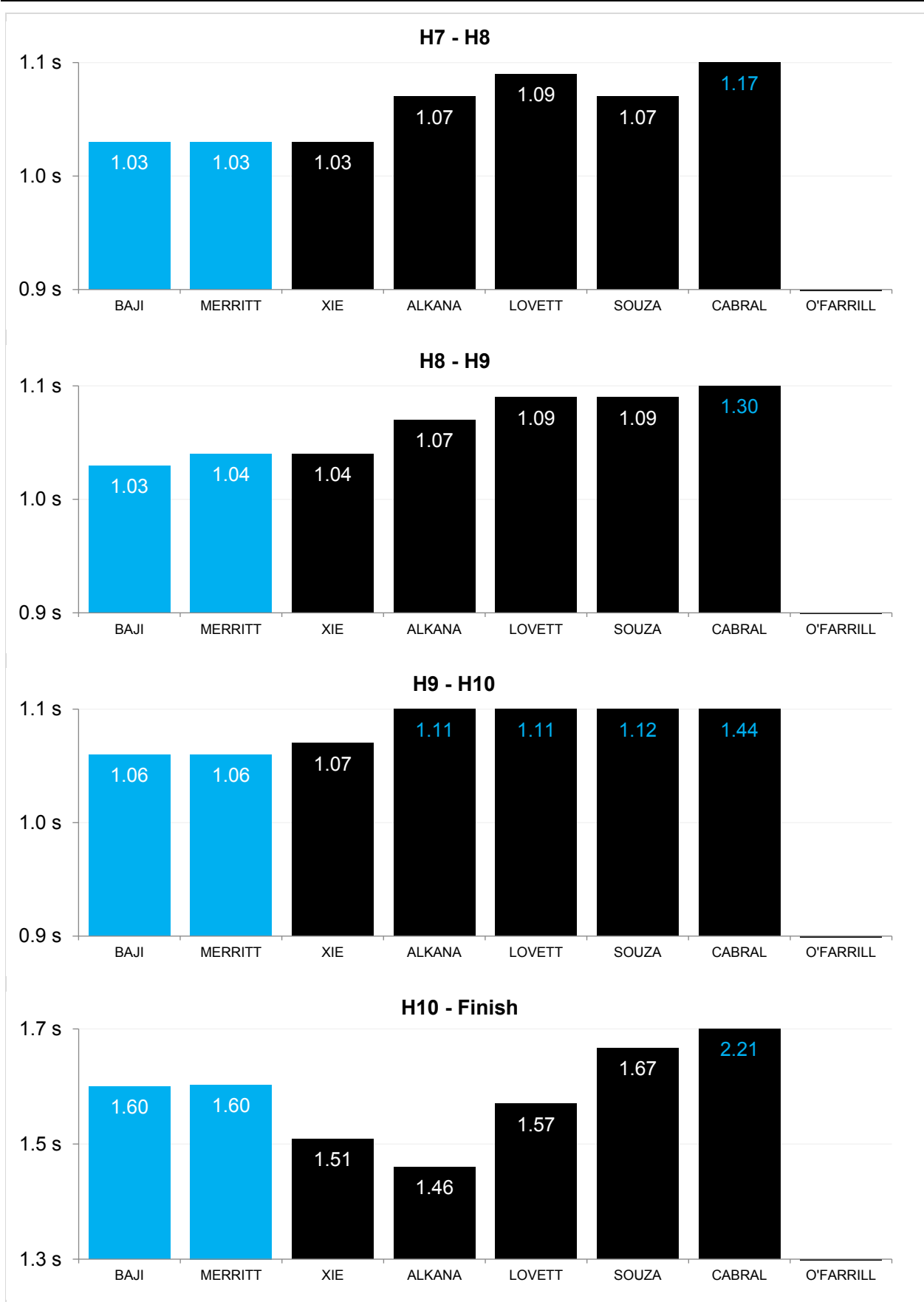


Figure 39. Individual split times between the final three consecutive hurdles and hurdle ten to the finish.

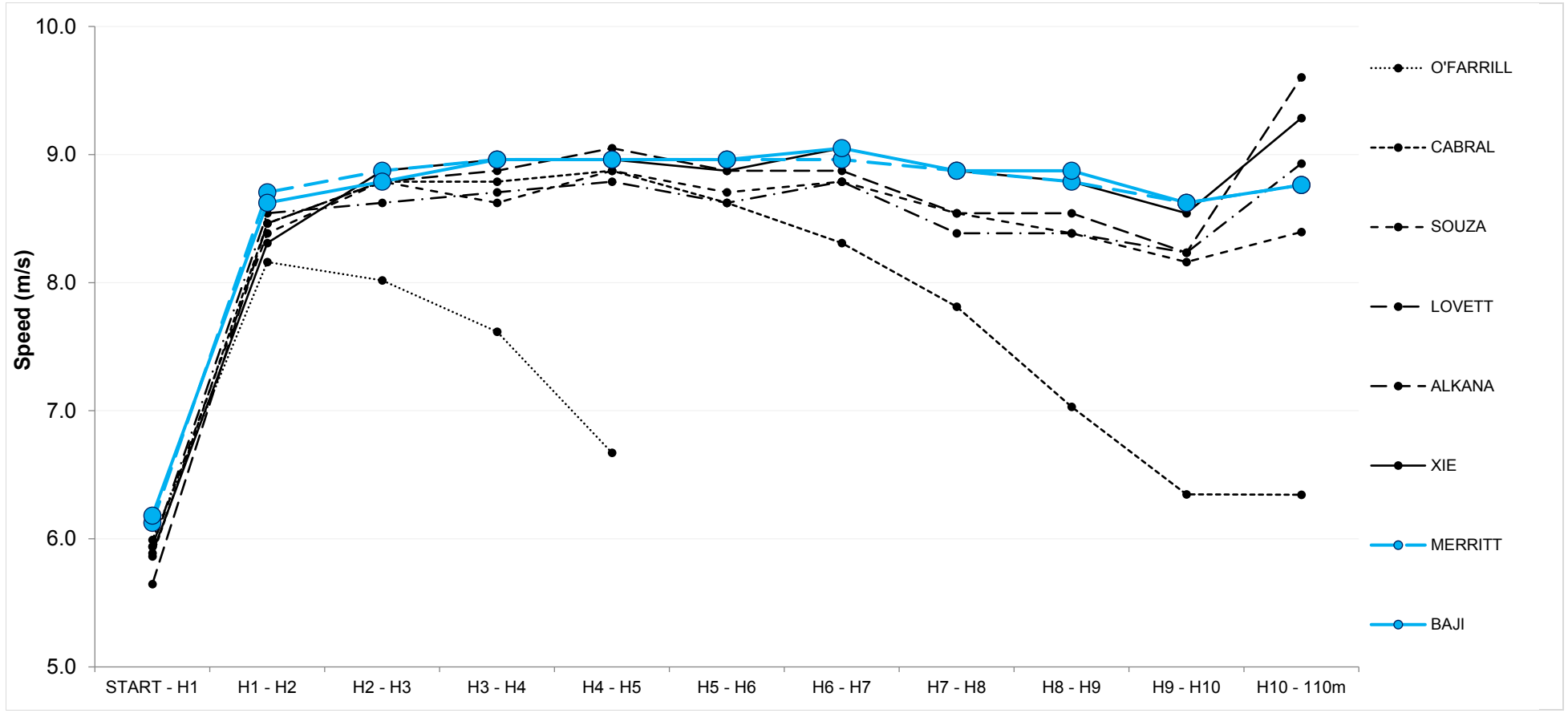


Figure 40. Mean speed for each hurdle split.

Hurdle profiles for each athlete

The following graphs display the individual split times between hurdles as well as to the first and from the last hurdle. Also included is the position at each hurdle and the type of clearance (see Table 1; page 9), for the qualifiers (Figure 41) followed by the non-qualifiers (Figure 42).

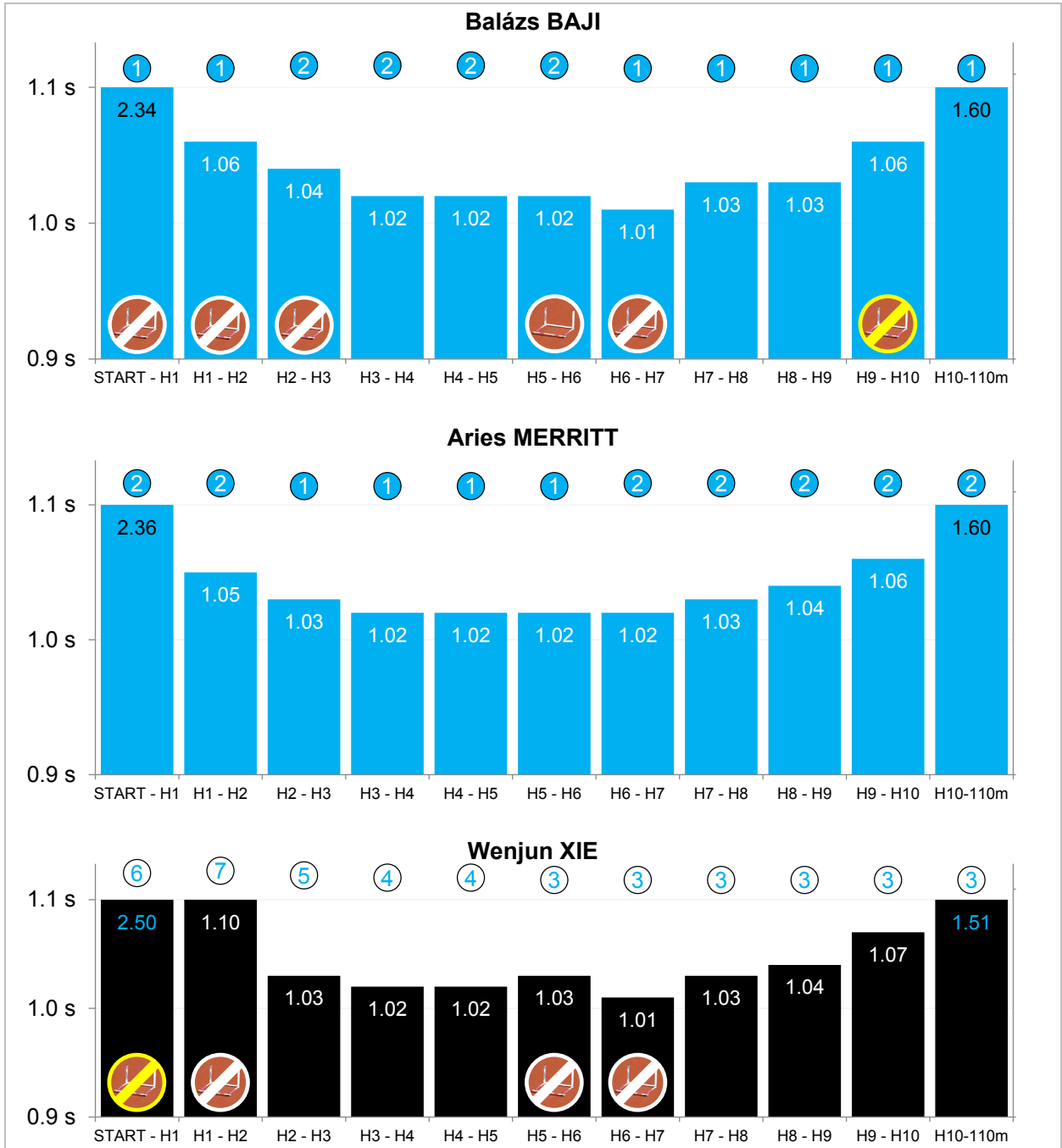


Figure 41. Hurdle profiles for the athletes qualifying for the final, and a non-qualifying athlete.

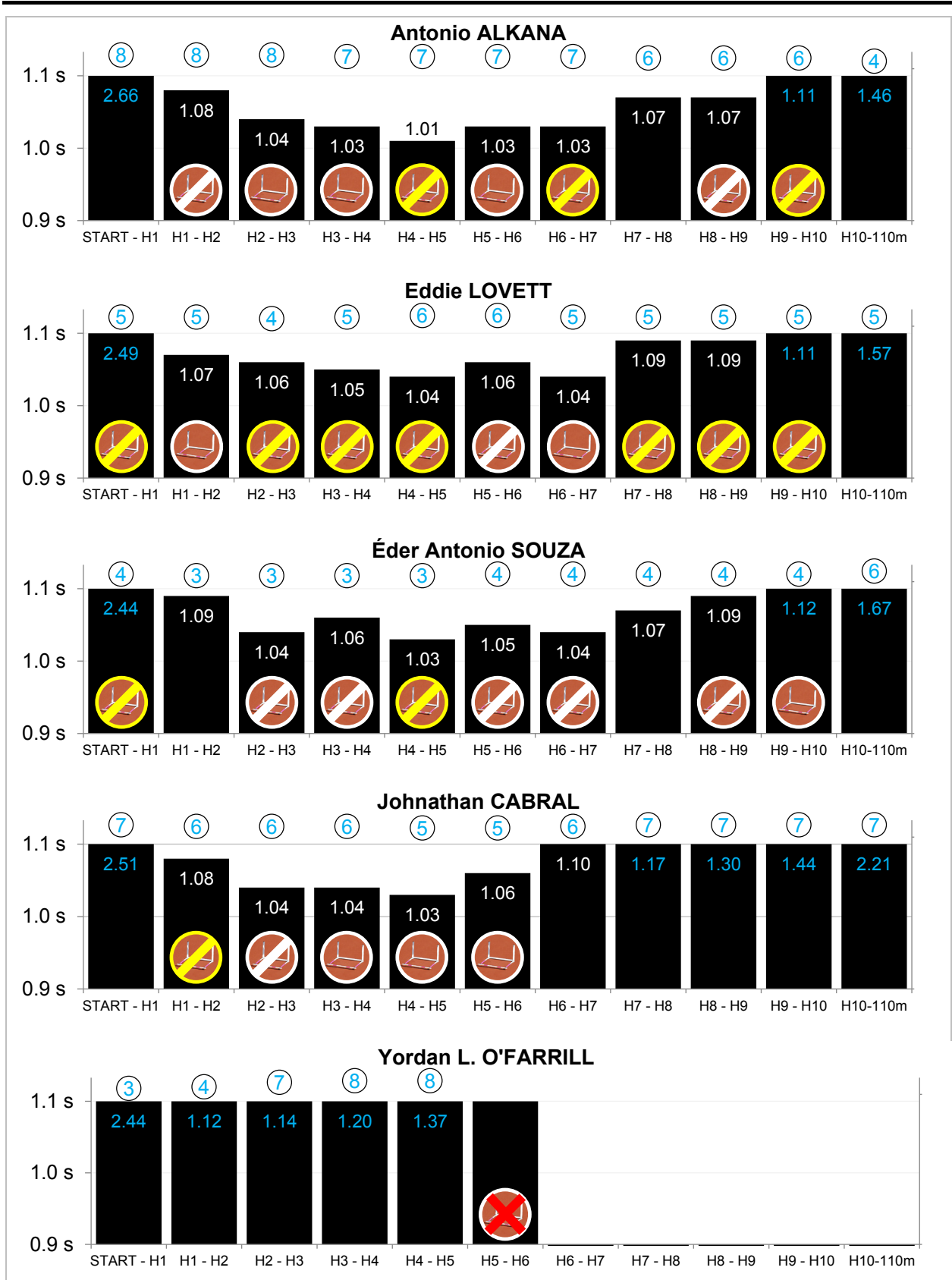


Figure 42. Hurdle profiles for the non-qualifying athletes.

COACH'S COMMENTARY

In the men's hurdles event, the eventual gold medallist Omar McLeod is a special athlete and was the deserved favourite going into the race. First of all, showing the ranking of each athlete in the race gives a good indication of who was strong in the start, middle and end. The nature of all sprint track events means that athletes can change ranking in a race very quickly, especially in the hurdles, where a more or less efficient hurdling technique will have a major impact on your race position. The fact that he was ranked first from start to finish shows how good of an athlete he is.

Presenting the hurdle split times in graph format is different to what you would typically see, and allows you to compare athletes at each hurdle as well as follow an athlete's progression through the race. The fact that that it has been shown when an athlete has hit a hurdle means that you can see how that may have affected the next hurdle split time – there is normally a key connection between making contact with the hurdle and the time of the next split. McLeod did hit hurdle six quite hard, but still managed to improve his split time by 0.01 s between H6-H7. This may show that it did not affect his overall performance. However, the fact that he hit the hurdle may have actually spurred him on and encouraged him to regain his focus, as he will have been aware that silver medallist Shubenkov, who was running a smooth race, was close behind. That being said, the time differences between splits here are minimal, so it is probably more appropriate to say that hitting the hurdle did not influence his overall performance in this case. Actually, it is often coached to slightly brush a hurdle on the way over, as this would, in theory, reduce distance covered in the air and improve hurdling efficiency. Contacting hurdles appears to happen more frequently in the men's race, but seems to have less of an impact on race performance than in the women's event. For instance, 4th placed Garfield Darien made contact with eight out of ten hurdles, knocking six completely over. Despite this, he managed to uphold a medal position until after hurdle nine, where the eventual bronze medallist Baji took over.

McLeod is not the tallest athlete, but did display the highest relative hurdle clearance distance. This may suggest that he has a relatively large leg length, which would be comparable with other former hurdle athletes, such as Colin Jackson. The knee joint angle at touchdown shows that the gold and silver medallists, along with Aries Merritt, were standing up taller upon ground contact after the sixth hurdle. This may show that they are able to withstand the eccentric landing forces more effectively and induce less braking when stepping into the next contact. A coach may take away and implement into their training, both on and off the track. Additionally, it shows that Merritt is still technically very good, but maybe is not back to full speed following his kidney transplant. This ultimately shows the most efficient hurdlers stand up taller, whereas the less efficient hurdlers tend to buckle under the impact. Hitting the hurdle did not appear to affect the

knee angle at touchdown, as both gold and silver medallists made contact with hurdle six, but had two of the most extended knee angles at touchdown. The other athlete to contact the hurdle was 8th placed Parchment, whose knee angle was one of the lowest in the field, but did hit the hurdle quite hard. These values confirm the coaching point of standing up as high as possible upon landing and try to ride over the top of a straight leg into the next contact.

These reports are ultimately showing coaches values and variables that are different to what they have previously seen, which is one of their main strengths. If a coach sees these numbers, they may find it difficult to interpret immediately, but it is something that they can take away and look for in their own athletes, and maybe implement into coaching and training in the future. For instance, if I saw the trunk angle values seen in Figure 16 on one of my athletes, and saw that they are not getting upright enough at toe-off, I would then focus on that in my coaching to help them work harder on getting their body upright as quickly as possible after landing.

The relative step length for the men appears to show a trend. The step length of step one after H6 appears to be consistently around 70-80 % of body height. The small range of values generally continues into step two, where six of the eight finalists show a relative step length between 1.06 and 1.12, with the exception of Baji (0.98 times body height) and Brathwaite (1.18 times body height). Here we potentially see the classical coaching point that is the “short-long-short”, where the first and third steps between the hurdles are shorter than step two. Interestingly, the bottom three finalists showed the greatest percentage increase in step length here, potentially showing a non-optimal hurdling technique, which could have been due to a response to their race position. If we assumed that McLeod took off at H7 from the same distance as H6, then his sequence between H6 and H7 would be as follows: touchdown distance = 1.73 m, step length one = 1.37 m, step length two = 1.91 m, step length three = 1.98 m, take-off distance = 2.15 m. This would indicate that McLeod might have been adopting a “short-long-long” technique, although steps two and three were more comparable than steps one and three.

When looking at the ground contact data after the final hurdle, it is worth noting that all eight finalists completed six steps during the run-in. This is generally considered the norm in both men’s and women’s senior hurdles, so reinforces any coaching strategies that may focus on having six contacts between H10 and the finish line, providing the hurdle clearance over H10 is clean. It is worth noting that McLeod and Merritt both had the shortest contact time after H10 (0.08 s). This could mean that they required less time to stabilise after the hurdle and transitioned quickly into the run-off. This would show high levels of technical skill, reinforcing the fact that these are two of the best technical athletes in world hurdling.

CONTRIBUTORS

Dr Lysander Pollitt is a Senior Lecturer in Sport and Exercise Biomechanics at Leeds Beckett University. His research interests primarily focus on neuromuscular biomechanics, particularly the impact of surface instability on performance. Previously, Lysander has provided applied biomechanical support to British Weight Lifting, including preparation for the 2012 Olympics in London. He was also an integral part of the development and implementation of the talent identification programme, which also aimed to increase awareness and enhance participation within the sport.



Josh Walker, MSc is currently a Senior Research Project Officer within the Carnegie School of Sport at Leeds Beckett University. Josh joined Leeds Beckett in 2013 where he studied at both undergraduate and postgraduate level and has a research interest into the biomechanics of cycling and running, particularly within the areas of muscle-tendon architecture, neuromuscular performance and the effects of different modes of exercise on muscle fascicle behaviour and neuromechanical effectiveness.



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.



Toni Minichiello is a coach for British Athletics. He has worked with a number of elite and senior athletes, most notably Olympic gold medallist and triple world champion Jessica Ennis-Hill, who he coached from the age of 15 years old. In 2012, Toni won the BBC Sports Personality of the Year Coach Award. Toni has also been awarded the accolade of UK Sports Coach of the Year and was inducted into the Fellowship of Elite Coaches in 2014.

