



BIOMECHANICAL REPORT

FOR THE

IAAF World Championships

LONDON 2017

100 m Hurdles Women's

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INTRODUCTION

Billed as one of the most highly anticipated races of the championships, Sally Pearson emerged victorious with a technically flawless display of hurdling, holding off Dawn Harper-Nelson of the USA to win the gold in a time of 12.59 s. Germany's Pamela Dutkiewicz held off the challenge of the Americans Kendra Harrison and Christine Manning to secure the bronze in 12.72 s; her first global championships medal. Although Pearson did not improve upon her impressive semi-final performance (12.53 s), interestingly the performances of Harper-Nelson and Dutkiewicz were almost identical to their semi-final winning times. The race outcome may have been very different had world record holder (12.20 s) and world lead (12.28 s) Harrison produced the same technical prowess of Pearson. Harrison matched Pearson to the first hurdle and held a slight lead by the third hurdle. However, the cumulative effect of hitting the first hurdle and knocking over the following three meant she lost momentum. By hurdle seven she had slipped down the field and was tied for sixth place. This technical issue almost cost her a place in the final itself. In the semi-final she hit the first hurdle hard and as a result was seventh by hurdle four. Despite hitting all but four hurdles, she managed to fight back and take the last non-automatic qualification place by one hundredth of a second. Her compatriot Manning was also in contention for the gold medal, however, her medal prospects faded after the seventh hurdle.

IAAF		World Championships		London		4-13 August 2017		IAAF World Championships LONDON 2017		
RESULTS										
100 Metres Hurdles Women - Final										
RECORDS		RESULT	NAME	COUNTRY	AGE	VENUE	DATE			
World Record		WR	12.20	Kendra HARRISON	USA	24	London (Olympic Stadium)	22 Jul 2016		
Championships Record		CR	12.28	Sally PEARSON	AUS	25	Daegu (DS)	3 Sep 2011		
World Leading		WL	12.28	Kendra HARRISON	USA	25	Székesfehérvár (Sóstói Stadion)	4 Jul 2017		
Area Record		AR	National Record		NR	Personal Best	PB	Season Best	SB	
12 August 2017		20:05	START TIME	21° C	53 %	TEMPERATURE	HUMIDITY	+0.1 m/s	WIND	
PLACE	NAME	COUNTRY	DATE of BIRTH	LANE	RESULT	REACTION	Fn			
1	Sally PEARSON	AUS	19 Sep 86	4	12.59					
2	Dawn HARPER NELSON	USA	13 May 84	6	12.63	SB	0.167			
3	Pamela DUTKIEWICZ	GER	28 Sep 91	5	12.72		0.143			
4	Kendra HARRISON	USA	18 Sep 92	3	12.74	(.736)	0.146			
5	Christina MANNING	USA	29 May 90	7	12.74	(.737)	0.183			
6	Alina TALAY	BLR	14 May 89	8	12.81	SB	0.139			
7	Nadine VISSER	NED	9 Feb 95	2	12.83		0.154			
8	Nia ALI	USA	23 Oct 88	9	13.04		0.149			
Timing and Measurement by SEIKO				AT-100H-W-f--1--.RS1..v1			Issued at 20:08 on Saturday, 12 August 2017			
Official Partners										
TDK		TOYOTA		asics		SEIKO		EUROVISION		
								TBS		

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 5th 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.

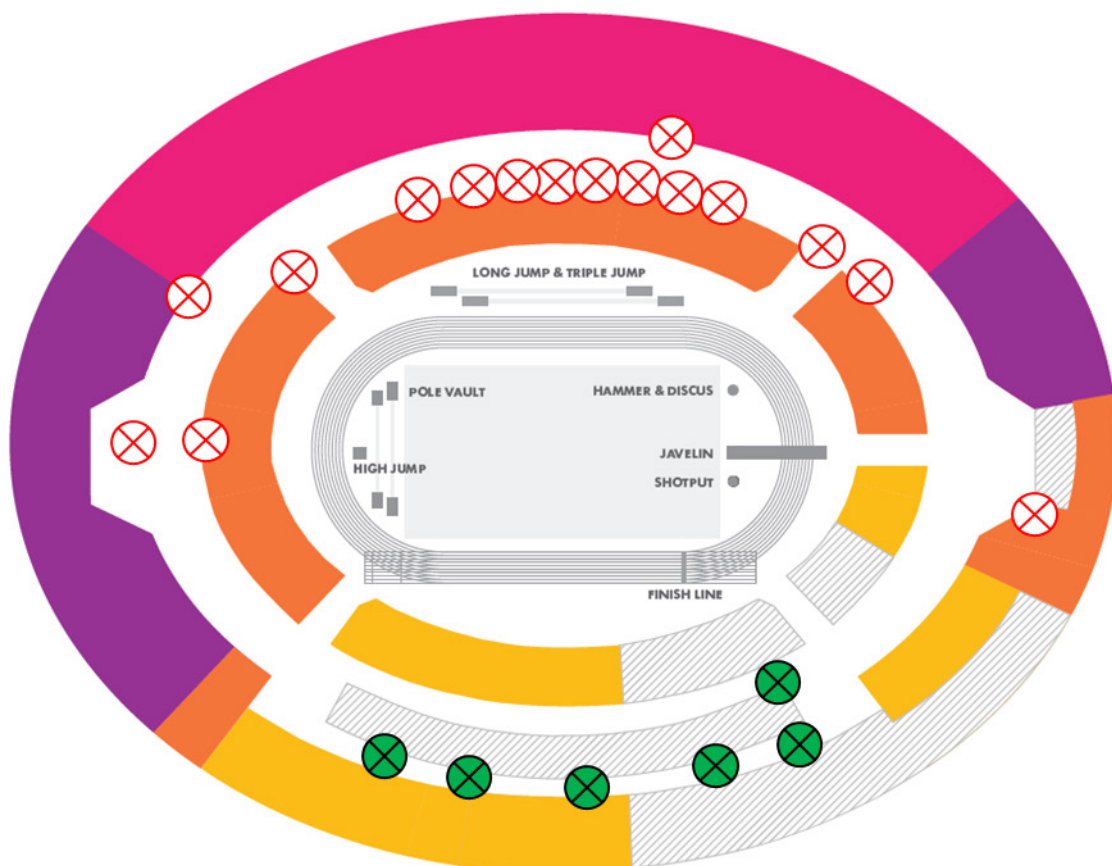


Figure 1. Camera layout within the stadium for the 100 m hurdles indicated by green in-filled circles.

A total of 17 high-speed cameras were employed to record the action during the 100 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 100 m women'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			
	<p>WHITE BORDER ONLY</p> <p>Slight contact made with the hurdle.</p>		<p>WHITE BORDER WITH WHITE LINE</p> <p>Larger contact, but hurdle is not knocked over.</p>
	<p>YELLOW BORDER WITH YELLOW LINE</p> <p>Hurdle is completely knocked over.</p>		<p>WHITE BORDER WITH RED CROSS</p> <p>Athlete fell or stopped due to contact with this hurdle.</p>
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
PEARSON	12.48 s	2	12.28 s	2	12.53 s	1	
HARPER-NELSON	12.66 s	6	12.37 s	3	12.63 s	2	SB
DUTKIEWICZ	12.61 s	5	12.61 s	6	12.71 s	3	
HARRISON	12.28 s	1	12.20 s	1	12.86 s	8	
MANNING	12.58 s	4	12.58 s	5	12.71 s	3	
TALAY	12.88 s	8	12.63 s	7	12.85 s	7	SB
VISSER	12.78 s	7	12.78 s	8	12.83 s	6	
ALI	12.52 s	3	12.48 s	4	12.79 s	5	

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
PEARSON	12.59 s		0.06 s	0.11 s	0.31 s
HARPER-NELSON	12.63 s	SB	0.00 s	-0.03 s	0.26 s
DUTKIEWICZ	12.72 s		0.01 s	0.11 s	0.11 s
HARRISON	12.74 s	.736 s	-0.12 s	0.46 s	0.54 s
MANNING	12.74 s	.737 s	0.03 s	0.16 s	0.16 s
TALAY	12.81 s	SB	-0.04 s	-0.07 s	0.18 s
VISSER	12.83 s		0.00 s	0.05 s	0.05 s
ALI	13.04 s		0.25 s	0.52 s	0.56 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).

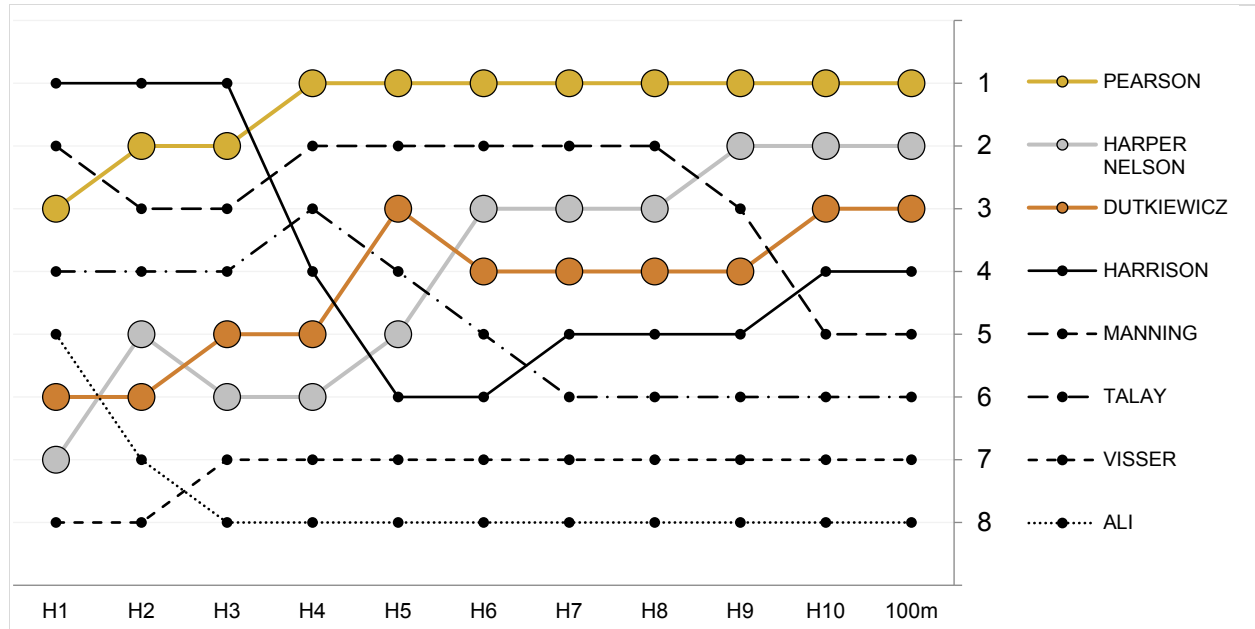


Figure 4. Position of each athlete as they crossed each hurdle and the finish line.

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 (*).

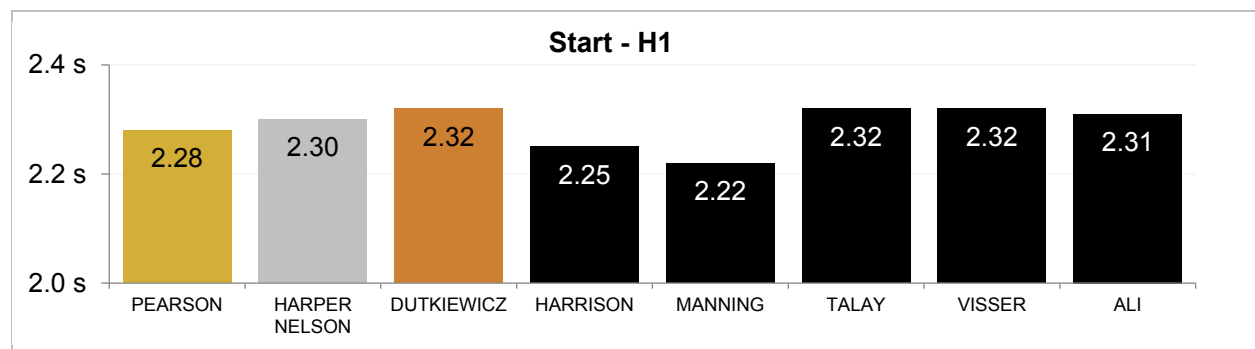


Figure 5. Individual split times between the start and first hurdle (minus the reaction time).

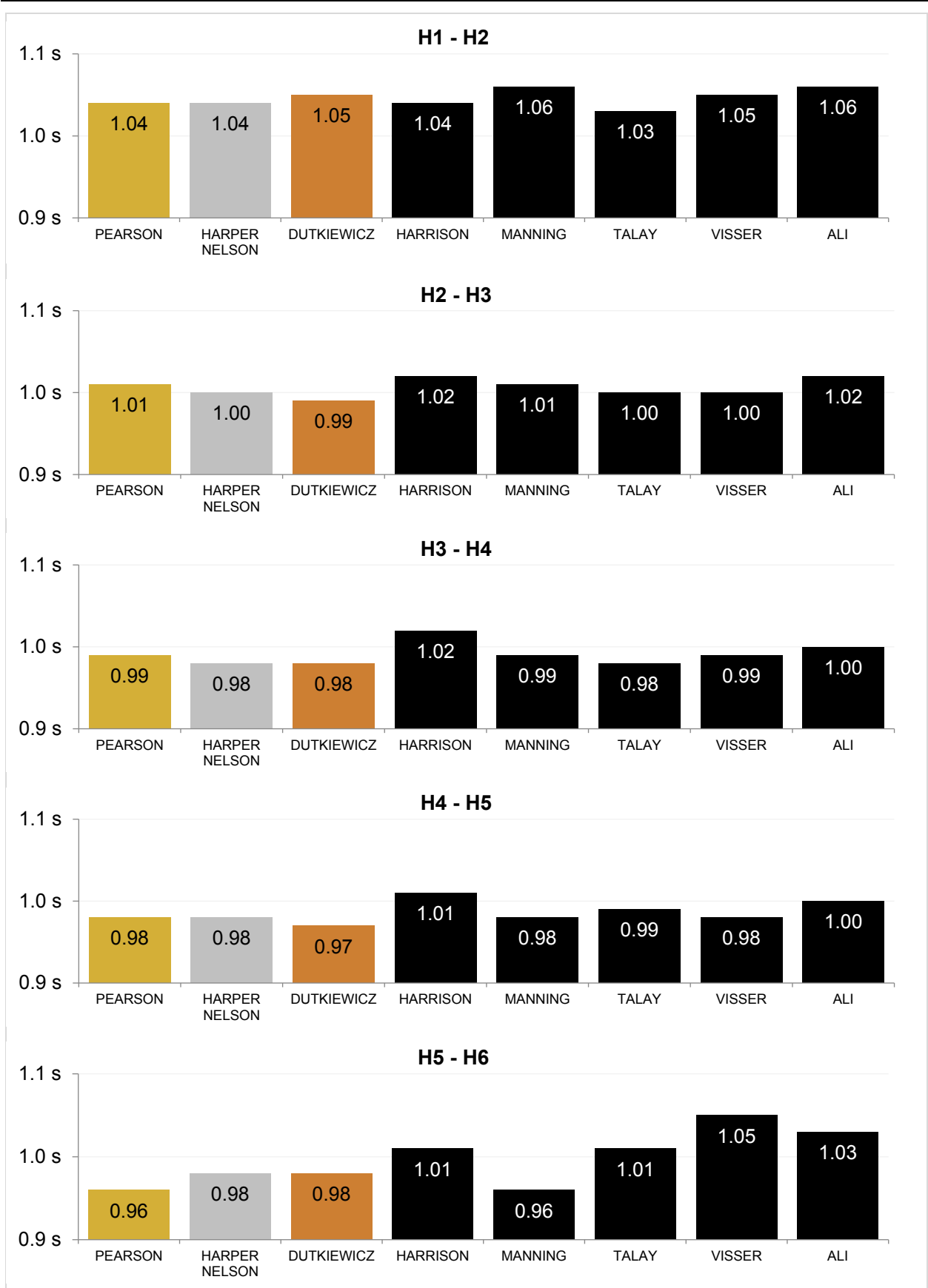


Figure 6. Individual split times between the first six consecutive hurdles.

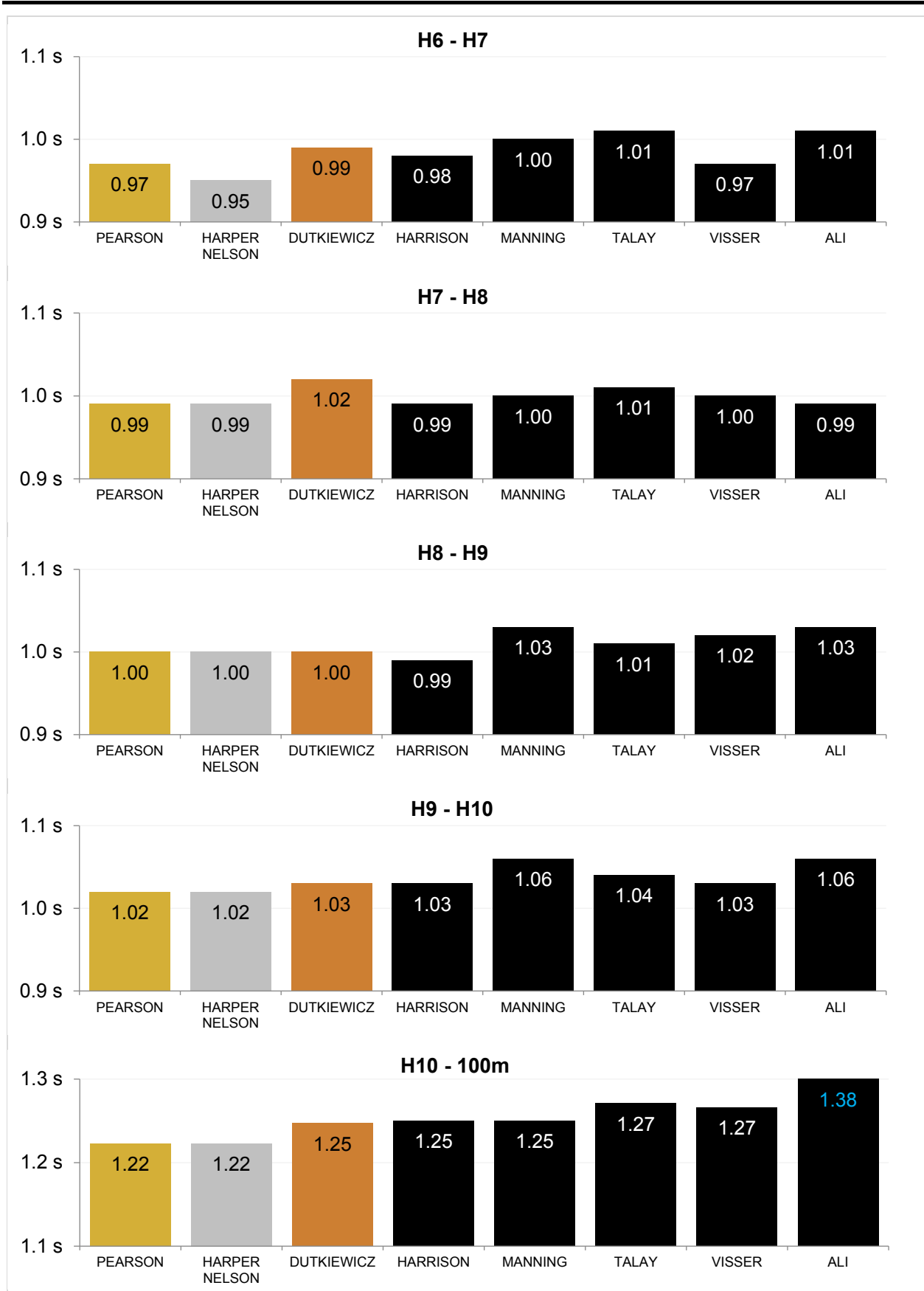


Figure 7. Individual split times between the final four consecutive hurdles and hurdle ten to the finish.

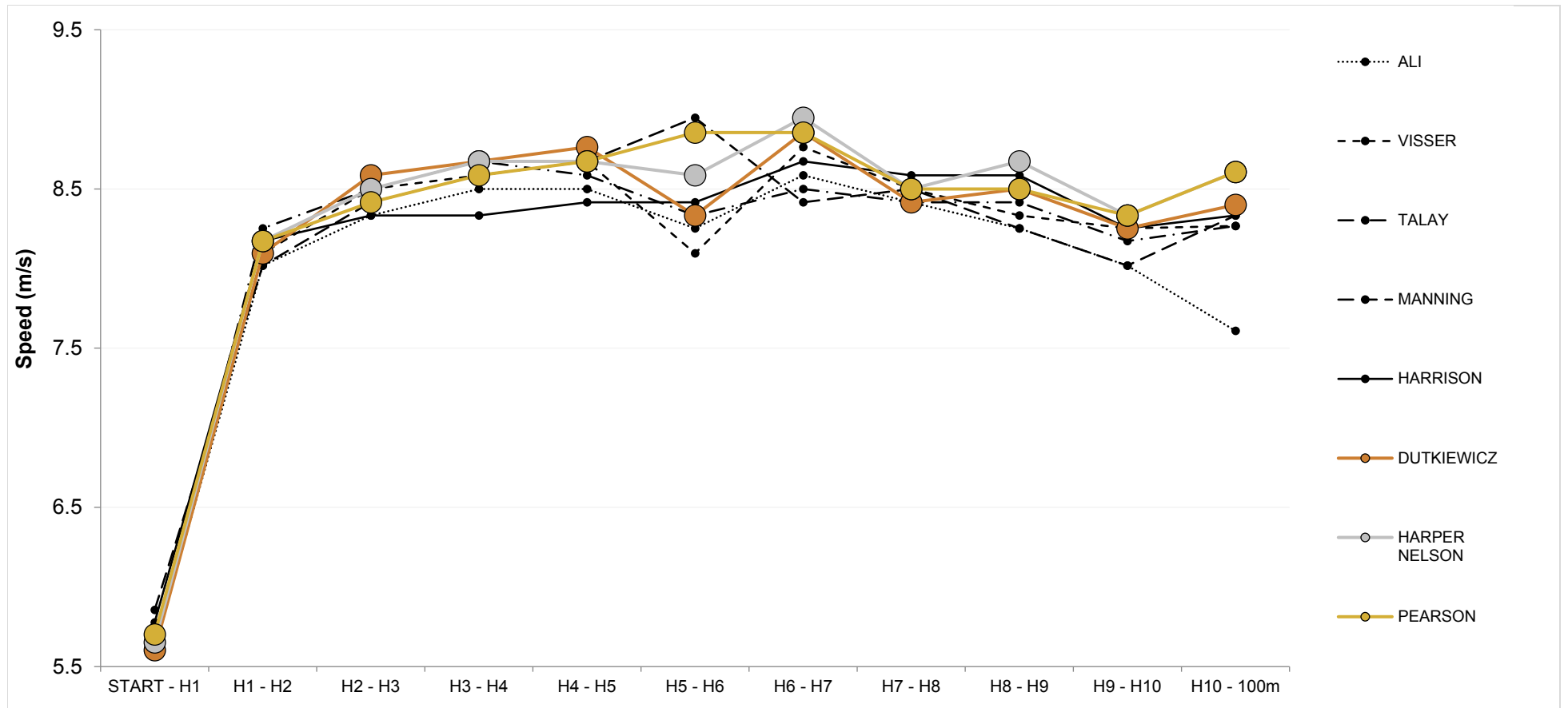


Figure 8. Mean speed for each hurdle split.

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).

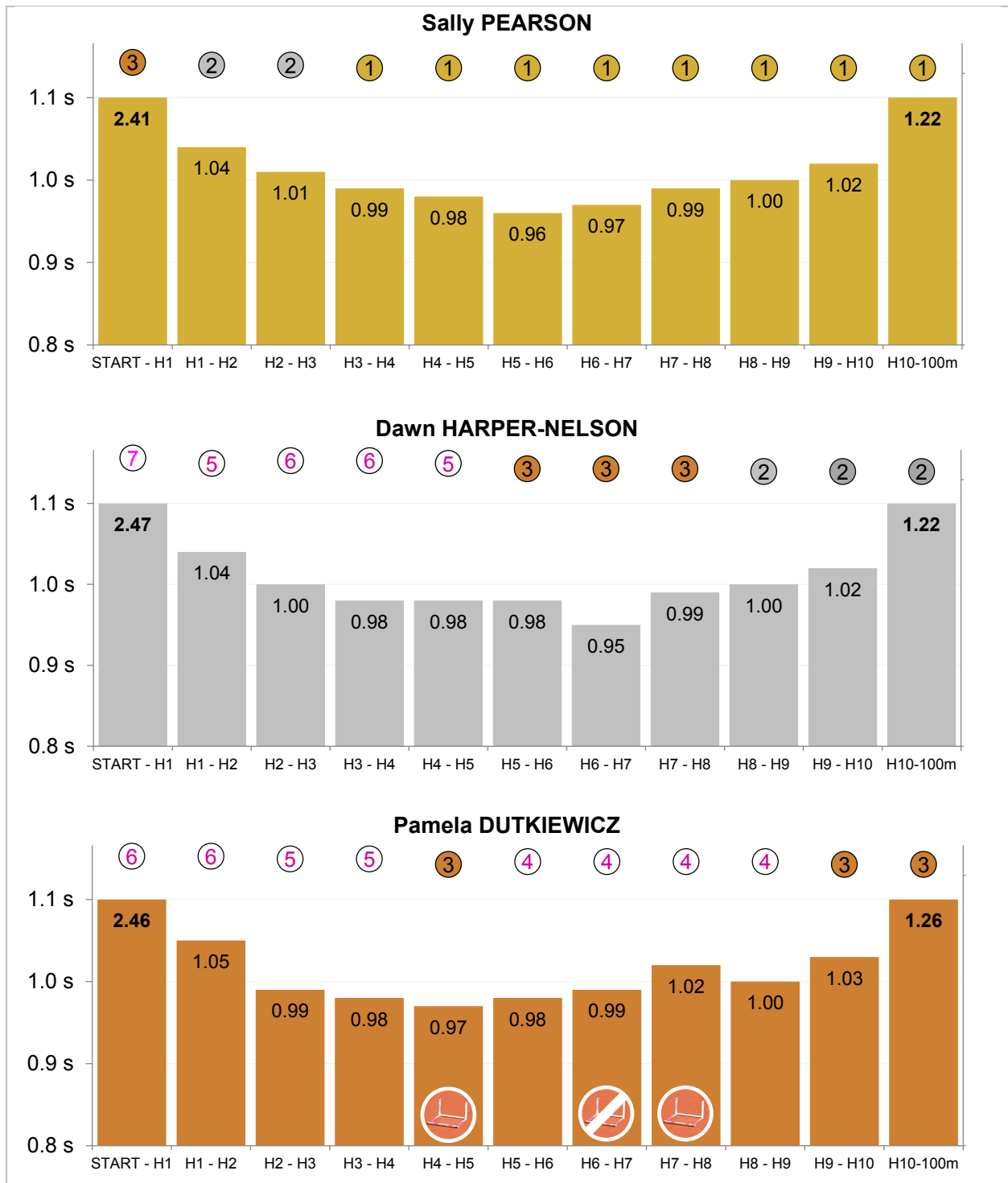


Figure 9. Hurdle profiles for the medallists (Start – H1 includes reaction time).

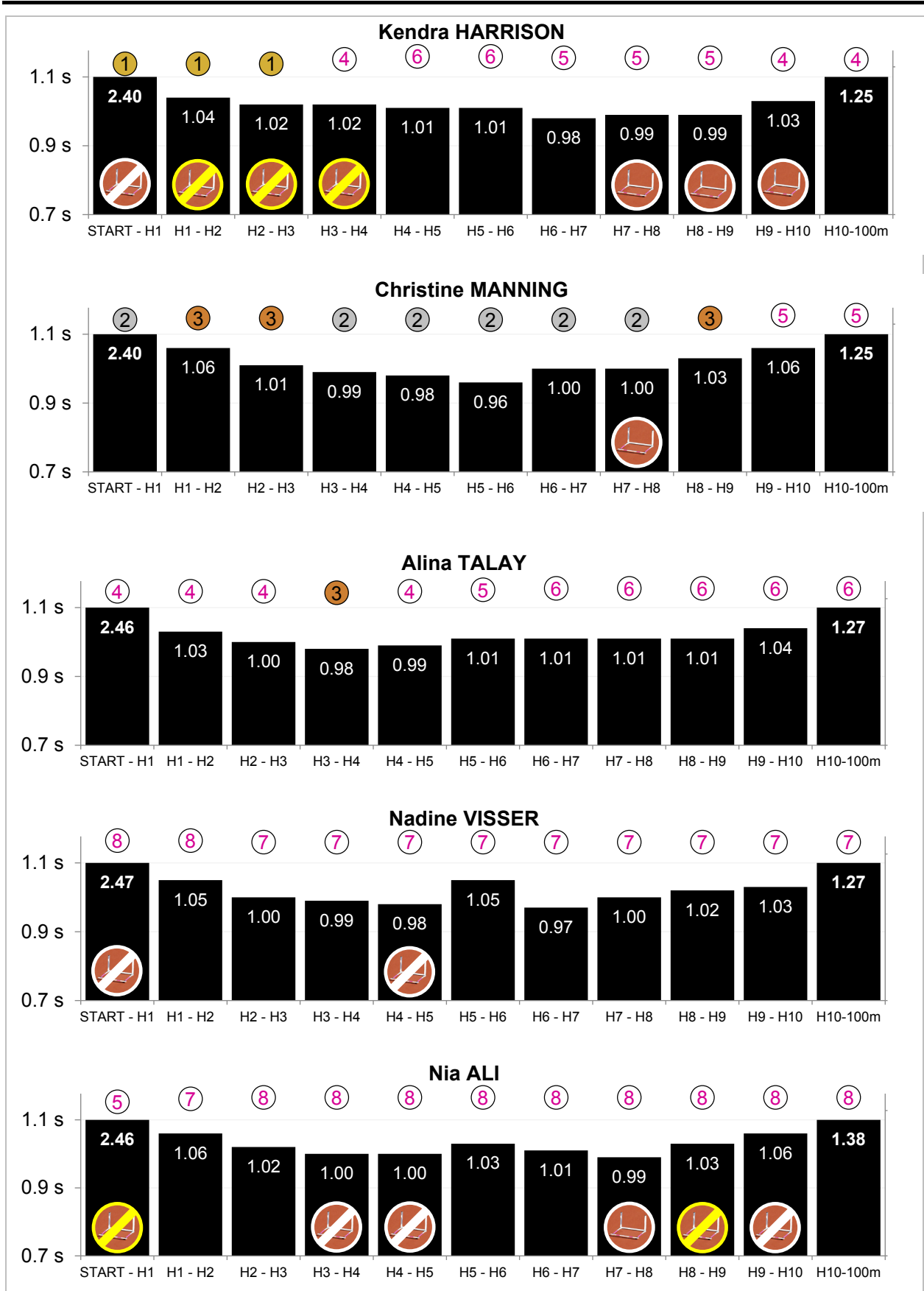


Figure 10. Hurdle profiles for the non-medallists (Start – H1 includes reaction time).

GOLD MEDALLIST: Sally Pearson



	RT	Start - H1	H1 - H2	H2 - H3	H3 - H4	H4 - H5
<i>Final</i>	0.127 s	2.28 s	1.04 s	1.01 s	0.99 s	0.98 s
<i>Rank</i>	1 st	3 rd	4 th	5 th	5 th	2 nd
<i>vs. silver</i>	-0.040	-0.02	0.00	+0.01	+0.01	0.00
<i>vs. bronze</i>	-0.016	-0.04	-0.01	+0.02	+0.01	+0.01
<i>Semi-Final</i>	0.119 s	2.27 s	1.04 s	0.99 s	0.98 s	0.97 s
<i>Rank</i>	3 rd	7 th	2 nd	1 st	1 st	1 st
	H5 - H6	H6 - H7	H7 - H8	H8 - H9	H9 - H10	H10 - Finish
<i>Final</i>	0.96 s	0.97 s	0.99 s	1.00 s	1.02 s	1.22 s
<i>Rank</i>	2 nd	2 nd	2 nd	3 rd	1 st	1 st
<i>vs. silver</i>	-0.02	+0.02	0.00	0.00	0.00	0.00
<i>vs. bronze</i>	-0.02	-0.02	-0.03	0.00	-0.01	-0.03
<i>Semi-Final</i>	0.94 s	0.97 s	0.99 s	1.00 s	1.02 s	1.24 s
<i>Rank</i>	1 st	2 nd	3 rd	2 nd	1 st	1 st

KINEMATIC CHARACTERISTICS

This section describes kinematic and temporal variables for each of the finalists at the fifth 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 5 – Take-off phase

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

	Lead leg	Contact time (s)	Take-off distance (m)	relative
PEARSON	Left	0.107	2.11	1.26
HARPER-NELSON	Left	0.127	2.20	1.31
DUTKIEWICZ #	Right	0.113	2.11	1.24
HARRISON	Left	0.120	2.08	1.27
MANNING	Left	0.127	2.10	1.29
TALAY	Right	0.113	2.23	1.36
VISSER #	Right	0.127	1.95	1.11
ALI #	Right	0.133	2.05	1.20

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

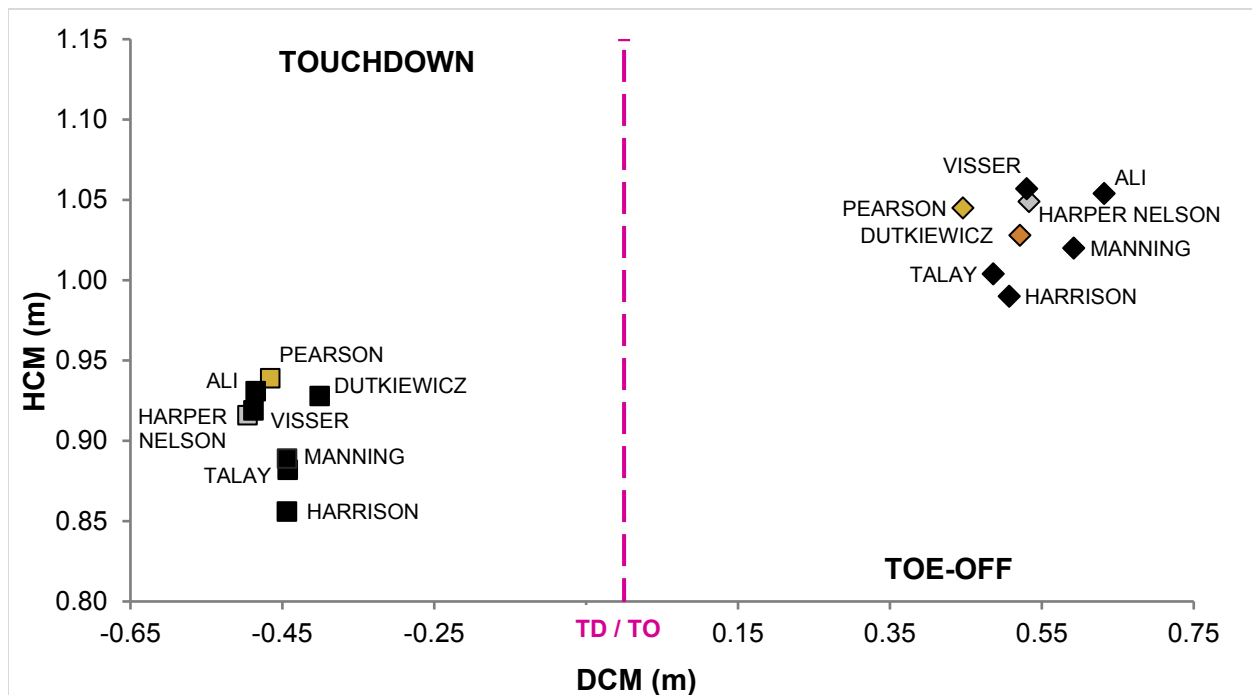


Figure 11. Height of the body's CM (HCM) and horizontal distance to the body's CM (DCM) at touchdown (TD) and toe-off (TO) of the final foot contact before the fifth hurdle.

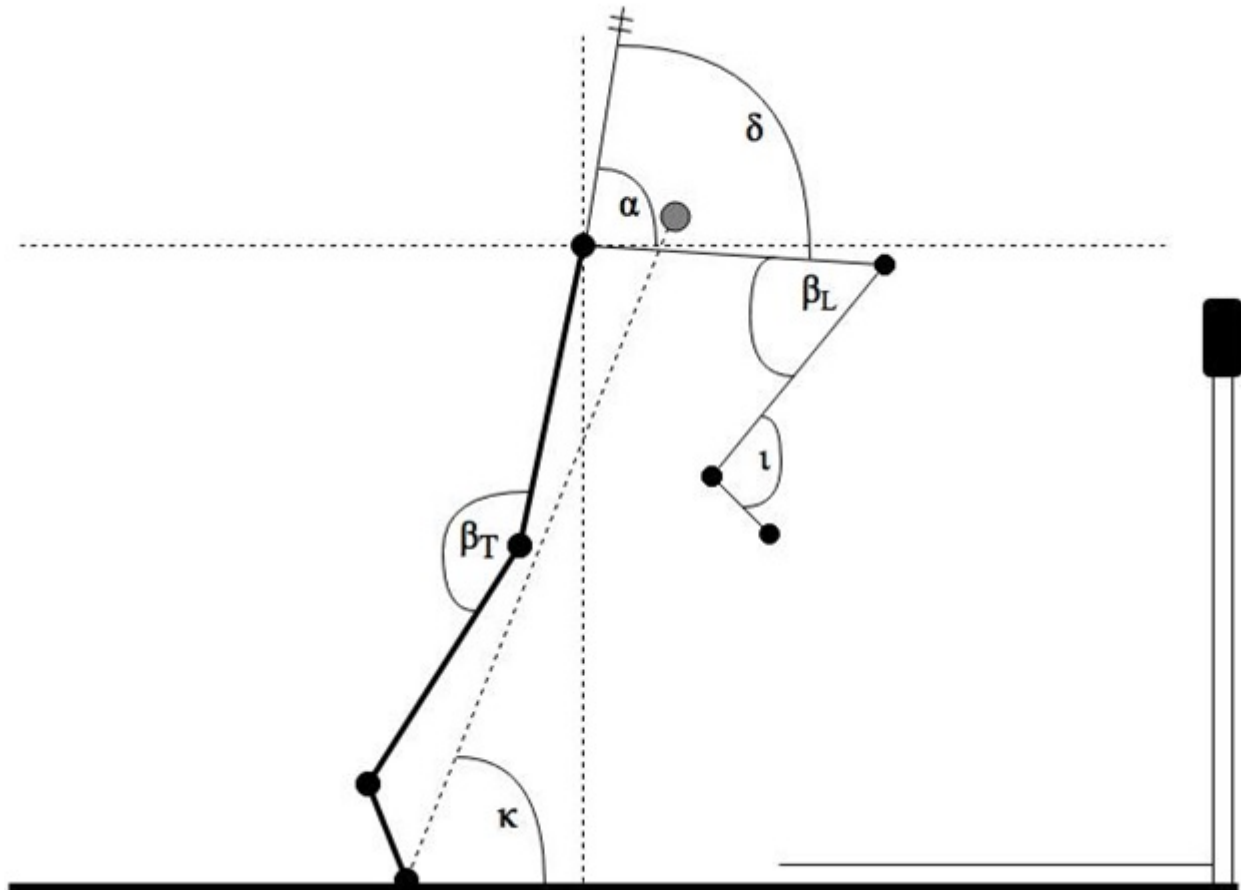


Figure 12. Body schematic denoting joint angles measured at toe-off during the take-off phase.

Table 5. Angular kinematics at toe-off during the take-off phase for each athlete before the fifth 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)
PEARSON	67.7	106.7	162.4	88.7	74.9	66.9
HARPER-NELSON	53.2	96.3	156.6	74.8	71.0	63.1
DUTKIEWICZ #	63.9	115.7	155.5	67.7	67.6	63.1
HARRISON	90.5	104.2	167.8	84.0	71.4	62.9
MANNING	69.7	80.2	159.0	76.5	70.8	59.9
TALAY	60.5	115.0	141.6	80.9	72.8	64.2
VISSER #	65.6	102.3	153.9	74.0	71.1	63.4
ALI #	79.1	107.5	173.8	80.7	73.7	59.1

Note: # athlete contacted the hurdle.

Hurdle 5 – 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 fifth hurdle.

	Hurdle flight time (s)	Hurdle distance (m)	relative
PEARSON	0.300	3.26	1.95
HARPER-NELSON	0.267	3.00	1.78
DUTKIEWICZ #	0.280	3.22	1.90
HARRISON	0.280	3.14	1.92
MANNING	0.273	3.12	1.91
TALAY	0.313	3.33	2.03
VISSER #	0.260	3.03	1.73
ALI #	0.267	3.20	1.88

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

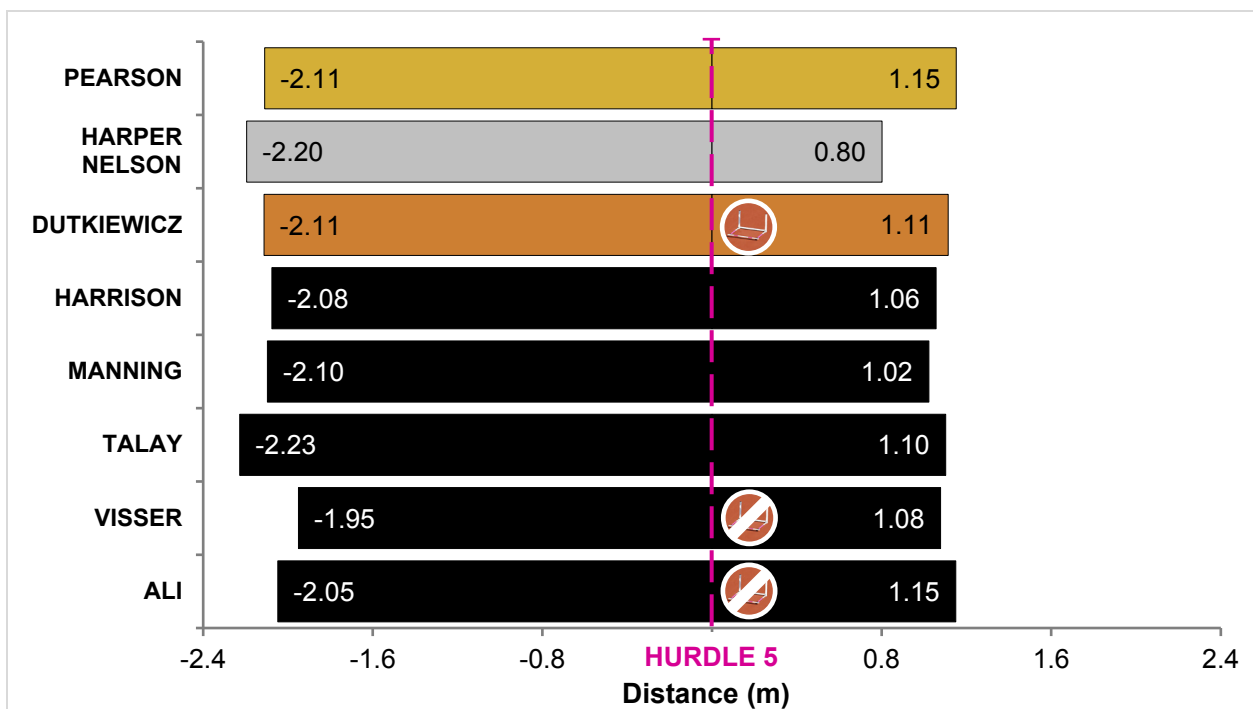


Figure 13. Horizontal distance to the fifth hurdle, between: toe-off during the take-off phase (left of hurdle line) and touchdown during the landing phase (right of hurdle line).

Hurdle 5 – Landing phase: Initial contact and landing step

The following section displays the characteristics of the landing step during the landing phase after the fifth 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 (s)	Flight time (s)	Step length (m)	relative
PEARSON	0.087	0.067	1.70	1.02
HARPER-NELSON	0.093	0.067	1.54	0.92
DUTKIEWICZ #	0.087	0.087	1.70	1.00
HARRISON	0.100	0.073	1.57	0.96
MANNING	0.087	0.067	1.57	0.96
TALAY	0.087	0.060	1.63	0.99
VISSER #	0.093	0.093	1.72	0.98
ALI #	0.113	0.060	1.54	0.91

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

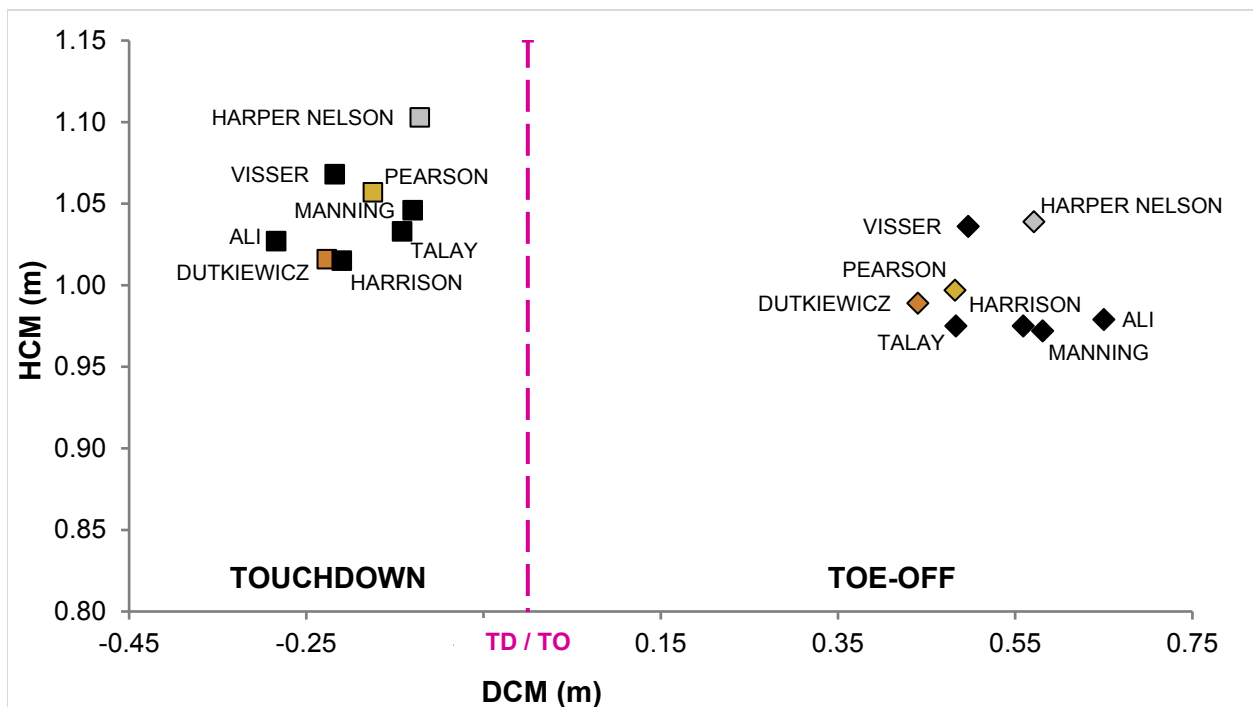


Figure 14. Height of the body's CM and horizontal distance to the body's CM (DCM) at touchdown (TD) and toe-off (TO) of the initial foot contact after the fifth hurdle.

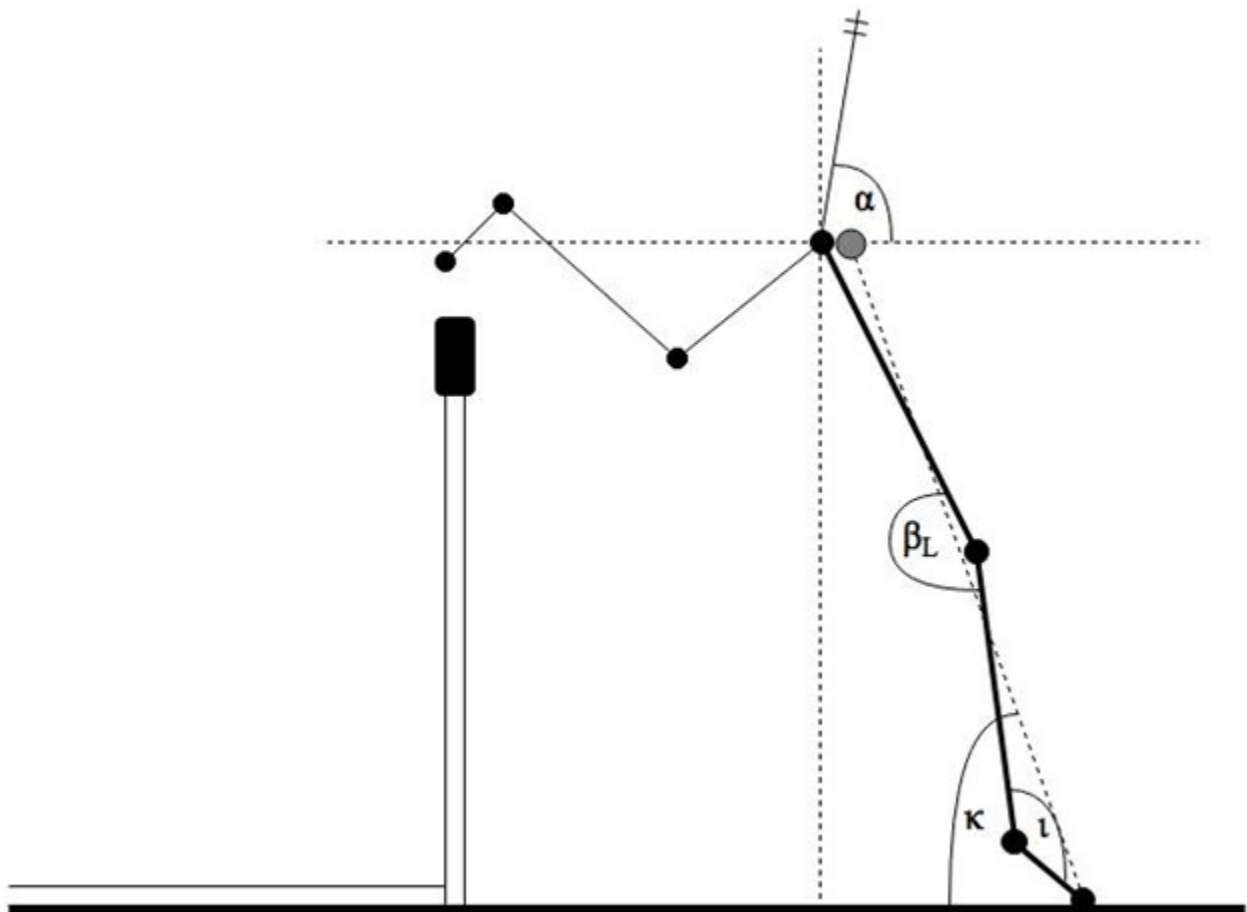


Figure 15. Body schematic denoting joint angles measured at touchdown during the landing phase.

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

	Lead leg knee angle (°) (β_L)	Lead leg ankle angle (°) (l)	Deviation angle (°) (κ)
PEARSON	173.6	140.0	-80.6
HARPER-NELSON	150.6	128.4	-83.7
DUTKIEWICZ #	153.4	122.4	-77.4
HARRISON	151.5	121.1	-78.3
MANNING	154.9	118.4	-82.9
TALAY	146.7	118.2	-82.2
VISSER #	162.9	131.5	-78.5
ALI #	152.5	128.3	-74.5

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.

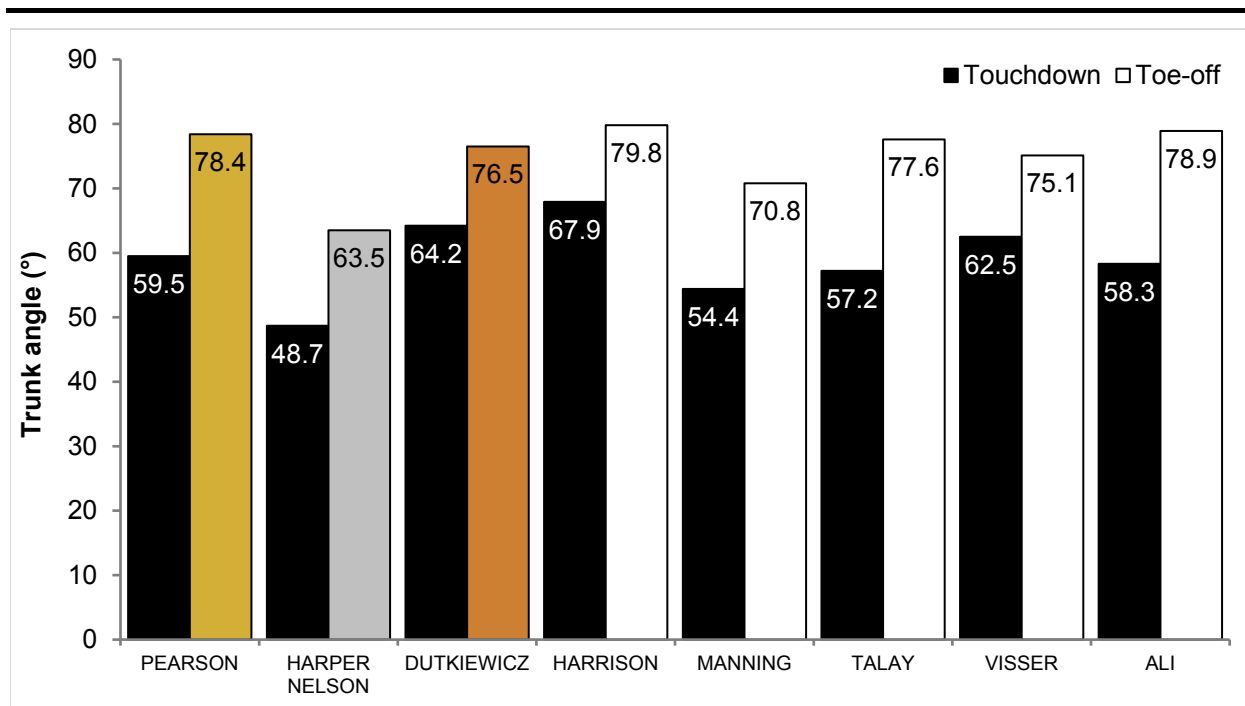


Figure 16. Trunk angles (α) at touchdown (black columns) and toe-off (white or medal colour columns) during the landing step.

Hurdle 5 – Landing phase: Second contact and recovery step

The following section displays the characteristics of the recovery step during the landing phase after the fifth 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
PEARSON	0.113	0.113	1.67	1.00
HARPER-NELSON	0.120	0.107	2.05	1.22
DUTKIEWICZ #	0.107	0.100	1.80	1.06
HARRISON	0.113	0.107	1.90	1.16
MANNING	0.120	0.100	2.01	1.23
TALAY	0.113	0.113	1.71	1.05
VISSER #	0.113	0.107	1.95	1.11
ALI #	0.120	0.100	2.02	1.19

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

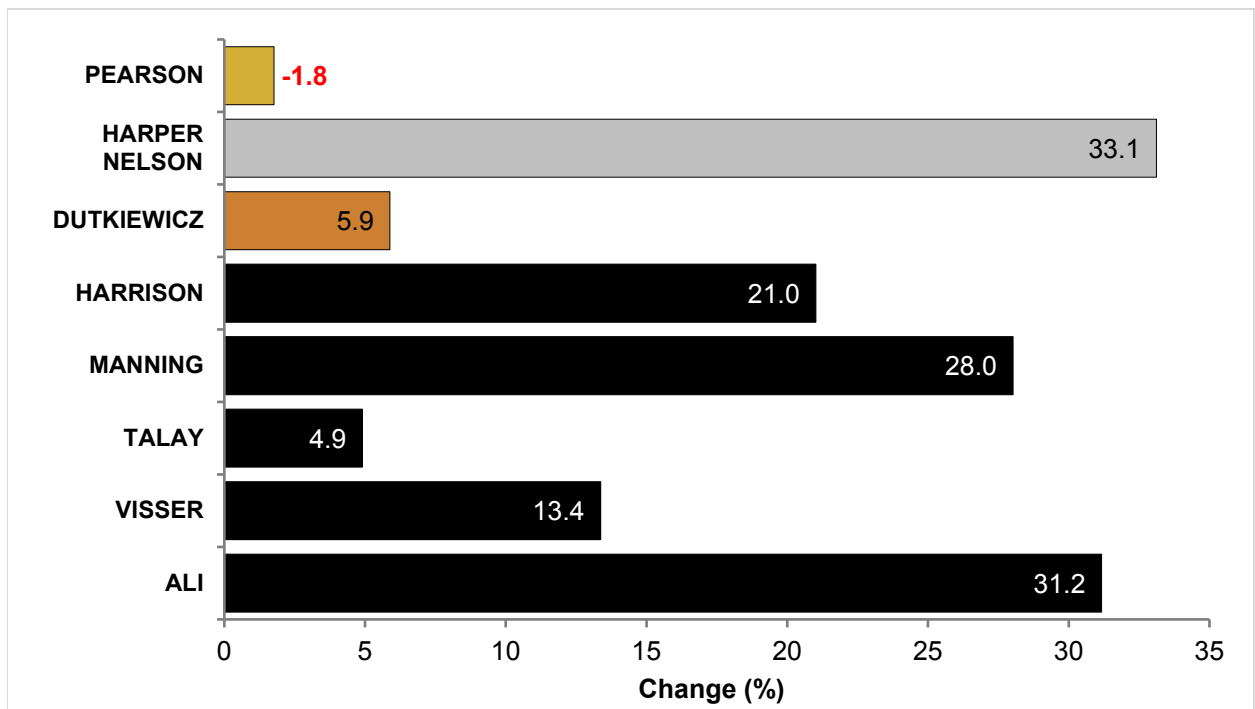


Figure 17. Increase (%) in step length from the landing step to the recovery step after the fifth hurdle.

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.

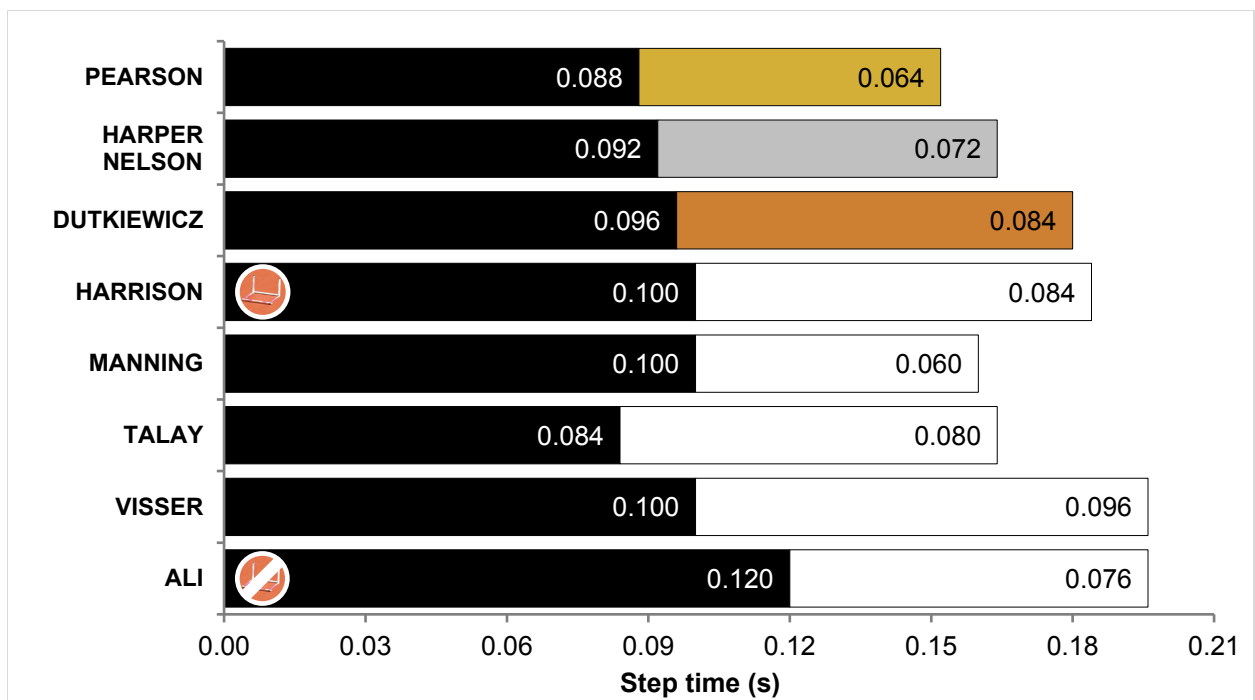


Figure 18. Contact time, flight time and step time immediately after the tenth hurdle.

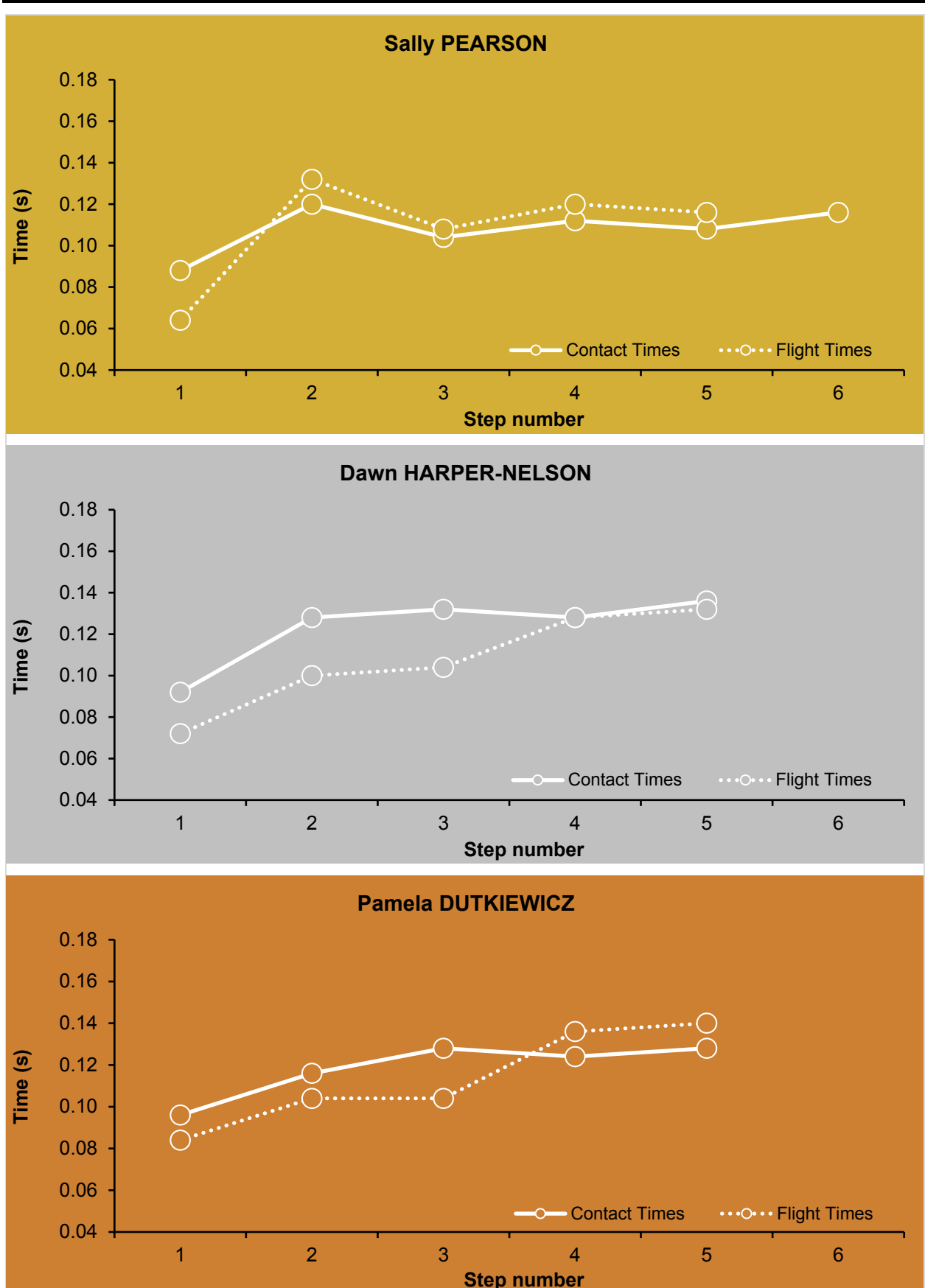


Figure 19. Individual contact and flight times of the medallists after the tenth hurdle.

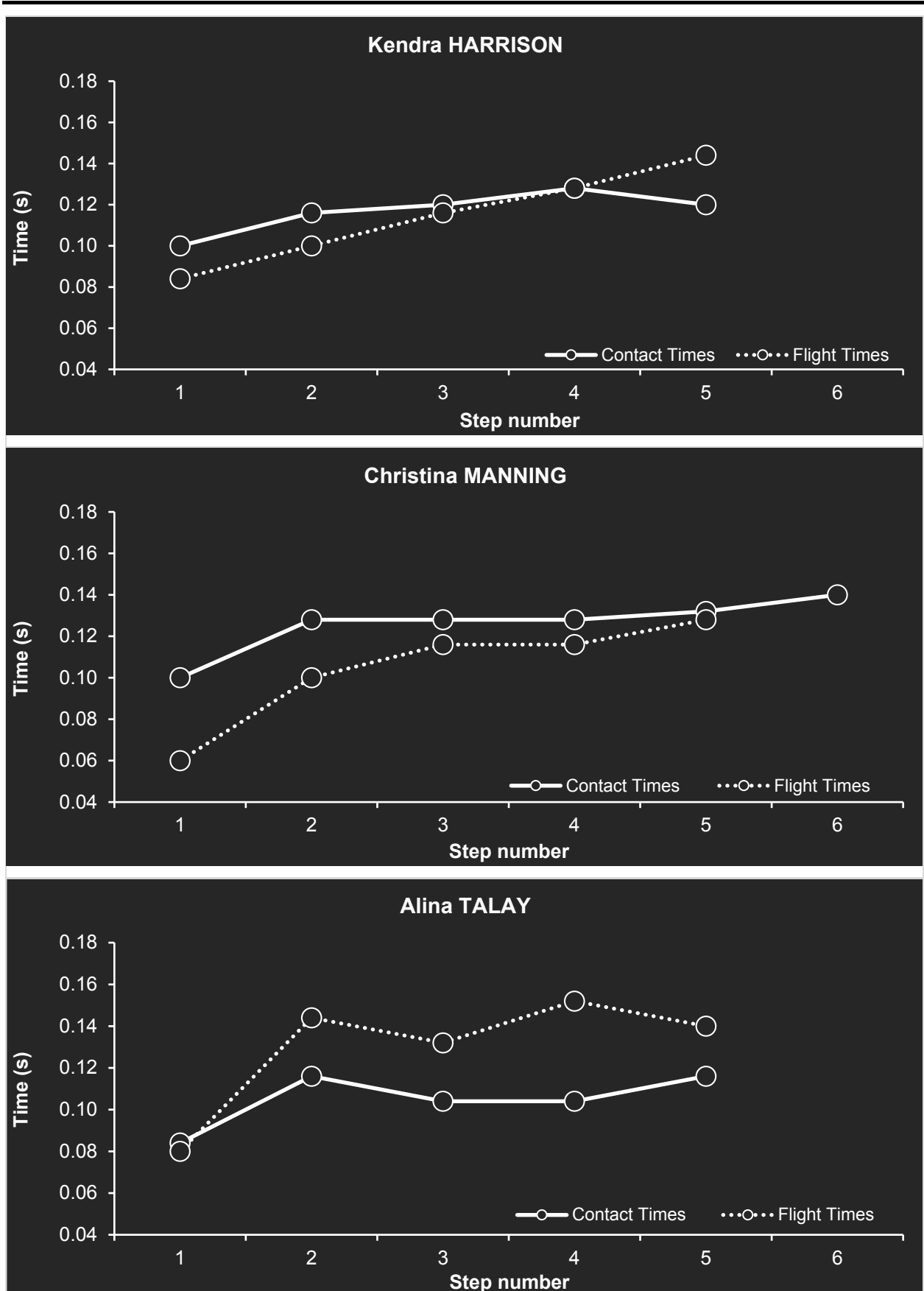


Figure 20. Individual contact times and flight times for: Kendra Harrison, Christina Manning and Alina Talay, after the tenth hurdle.

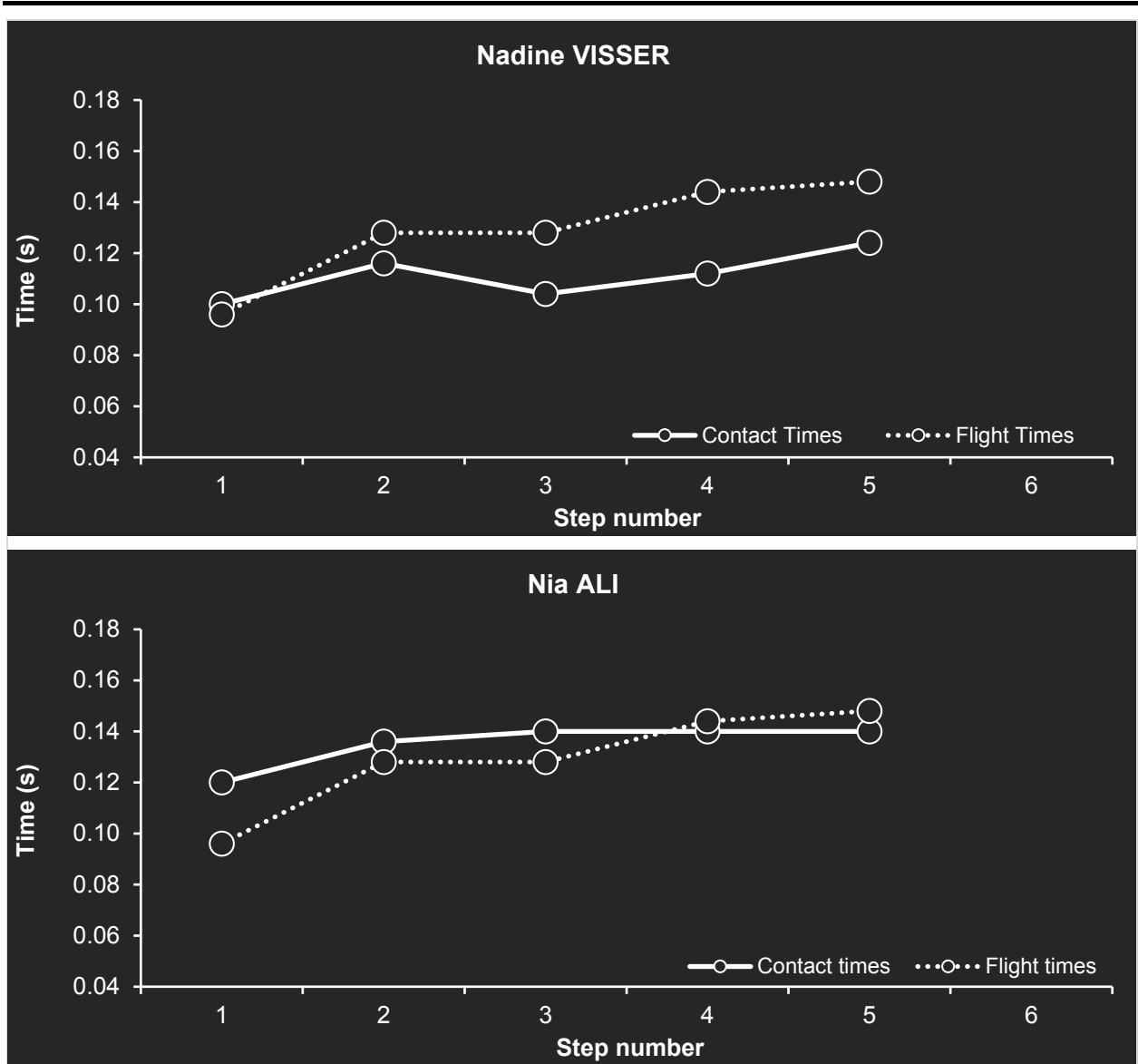


Figure 21. Individual contact times and flight times for: Nadine Visser and Nia Ali, after the tenth hurdle.

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
PEARSON	2	2	12.53 s	Q	0.05 s	0.25 s
ALI	3	4	12.79 s	Q	0.27 s	0.31 s
VISSER	14	17	12.83 s	q	0.05 s	0.05 s
SIMMONDS	8	9	12.93 s		0.30 s	0.30 s
GEORGE	15	11	13.04 s		0.19 s	0.39 s
LOBE	19	23	13.11 s		0.20 s	0.20 s
LINDLEY	18	22	13.18 s		0.28 s	0.28 s
ZAGRE	20	14	13.34 s		0.38 s	0.63 s

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.

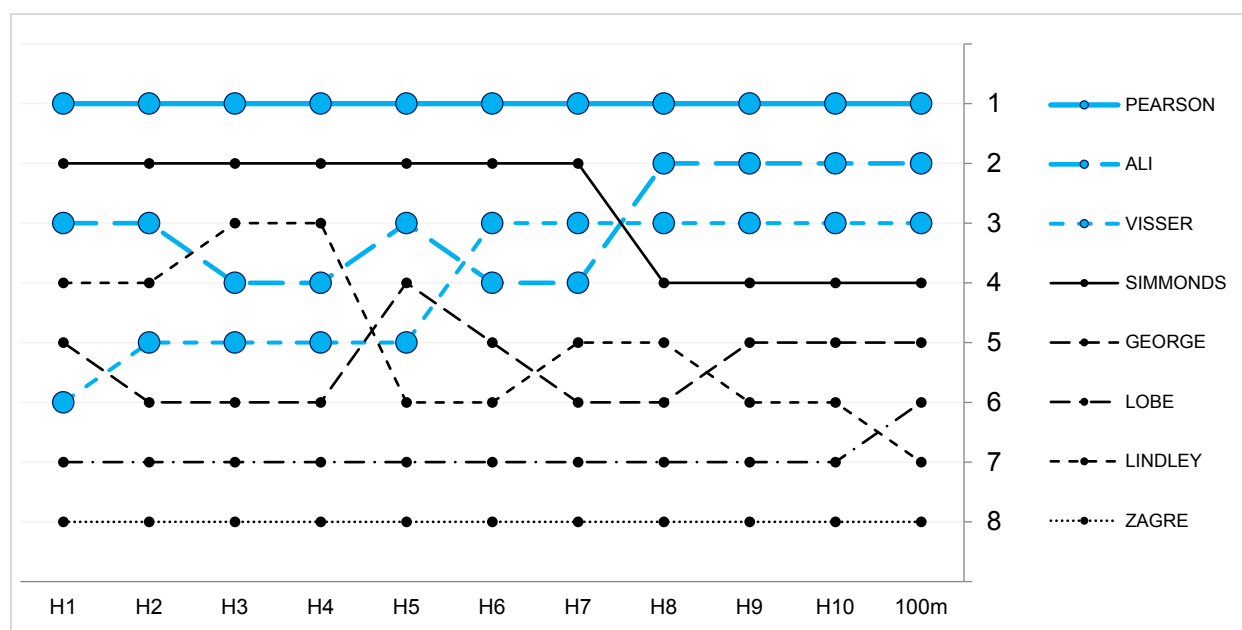


Figure 22. Position of each athlete as they crossed each hurdle and the finish line.

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.

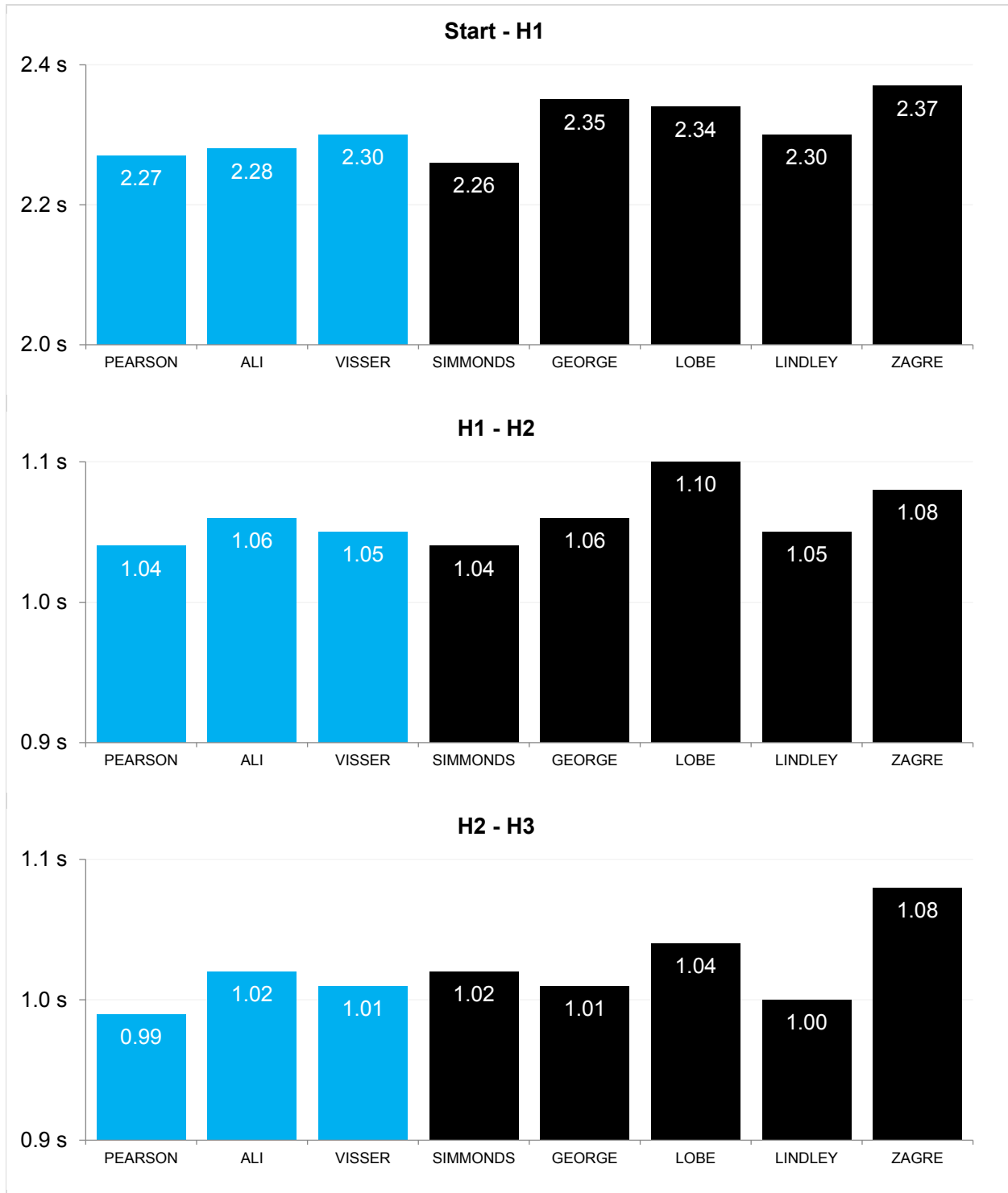


Figure 23. Individual split times between the start and first three consecutive hurdles.

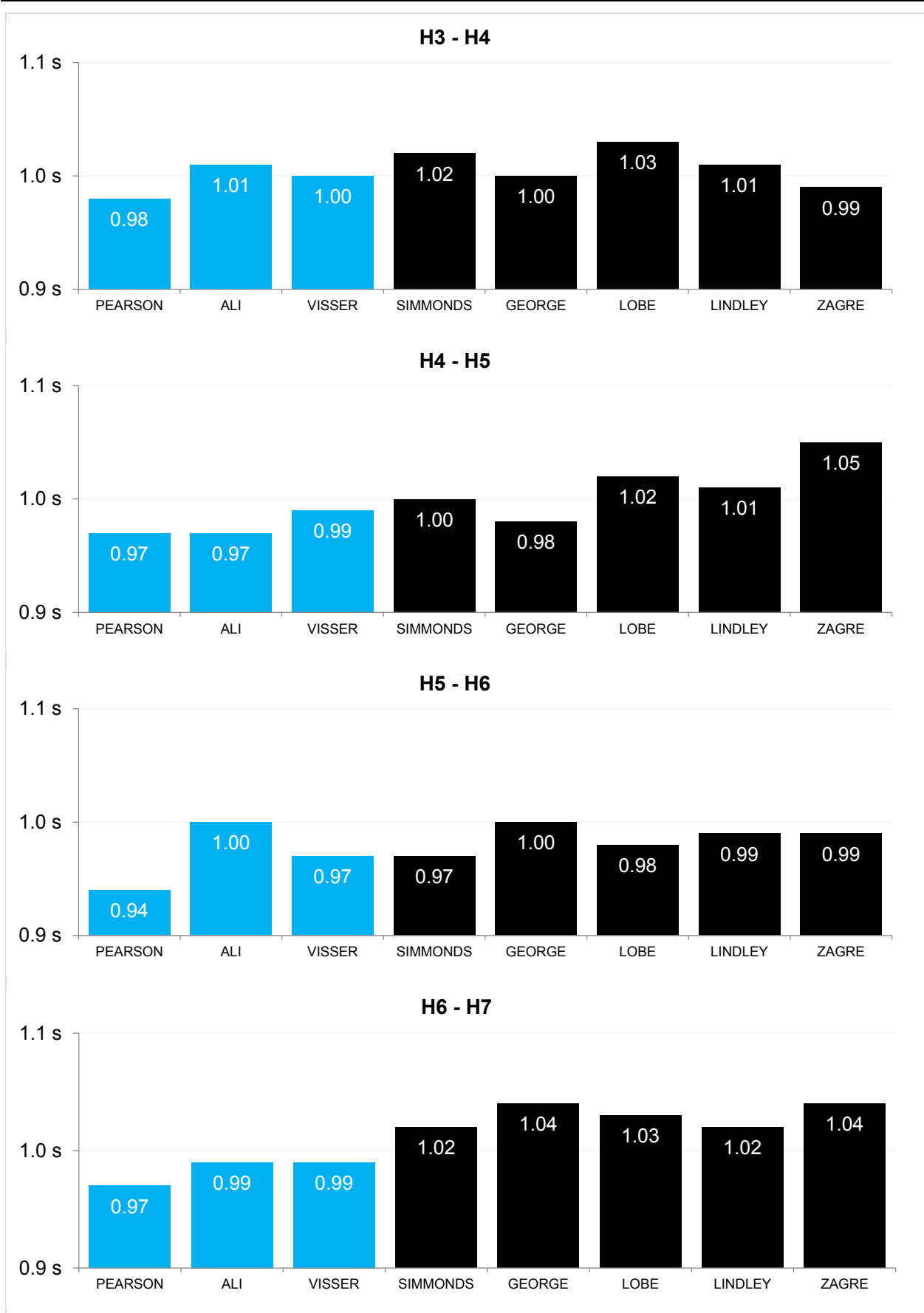


Figure 24. Individual split times for consecutive hurdles between hurdles three and seven.

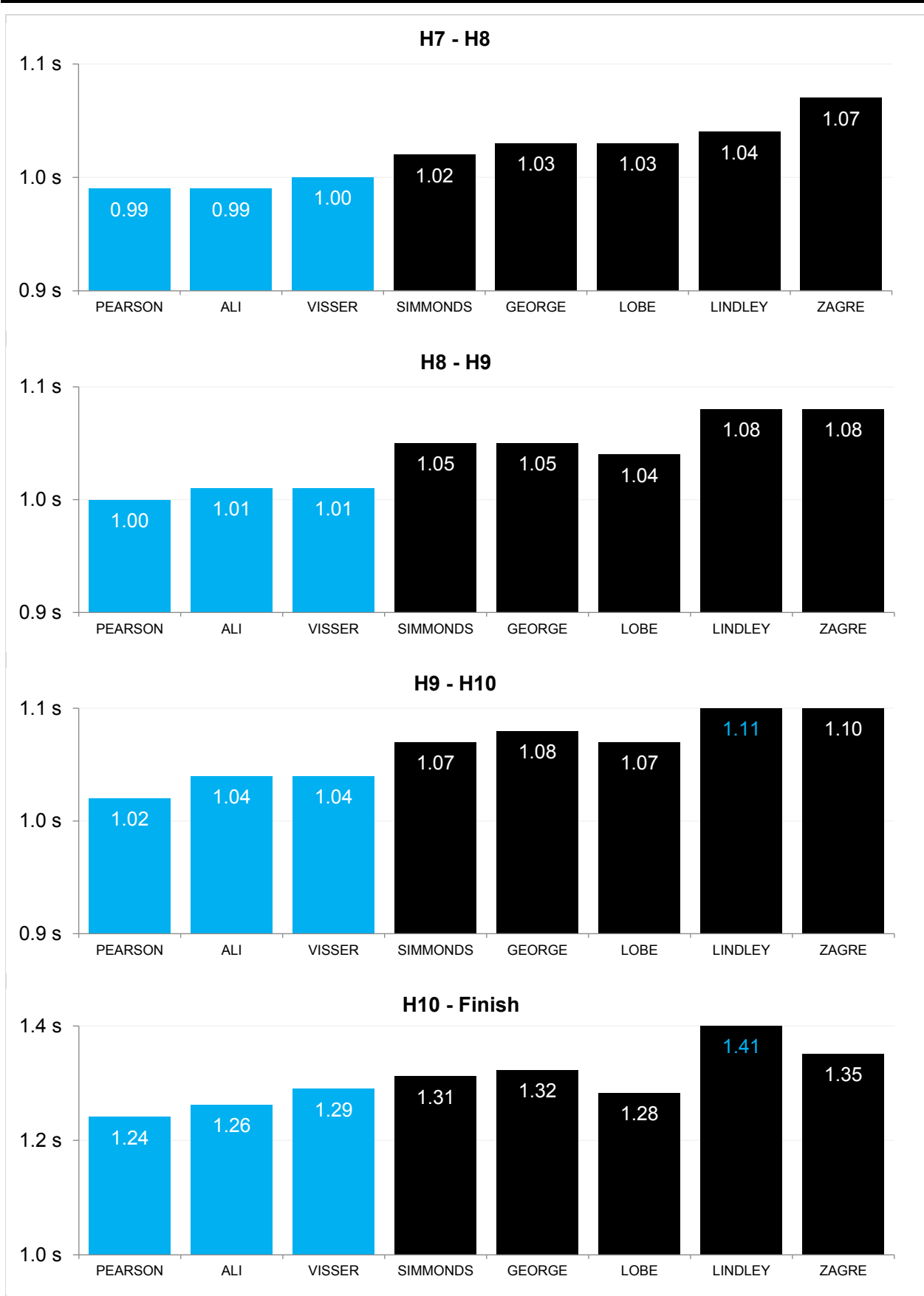


Figure 25. Individual split times between the final three consecutive hurdles and hurdle ten to the finish.

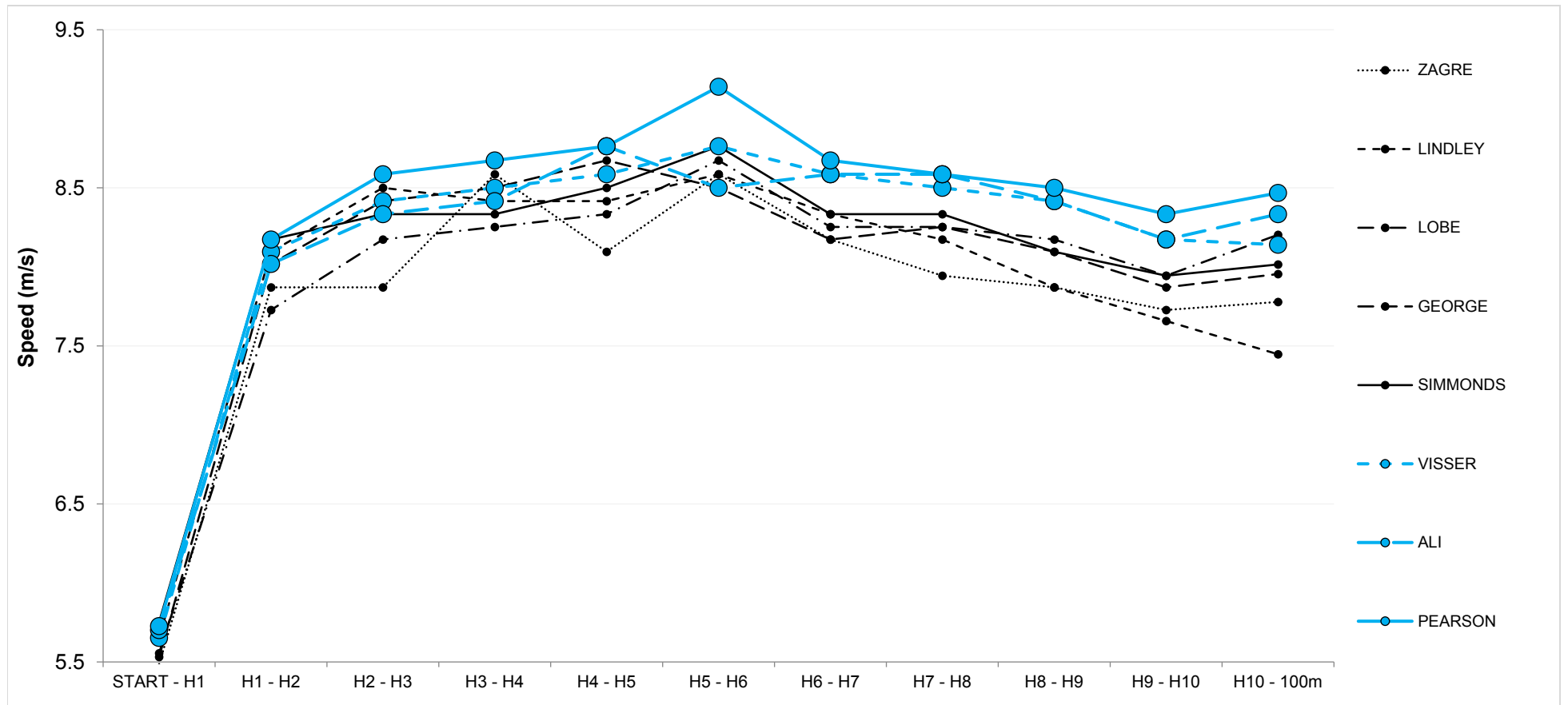


Figure 26. Mean speed for each hurdle split.

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), (Figure 27) followed by the non-qualifiers (Figure 28).

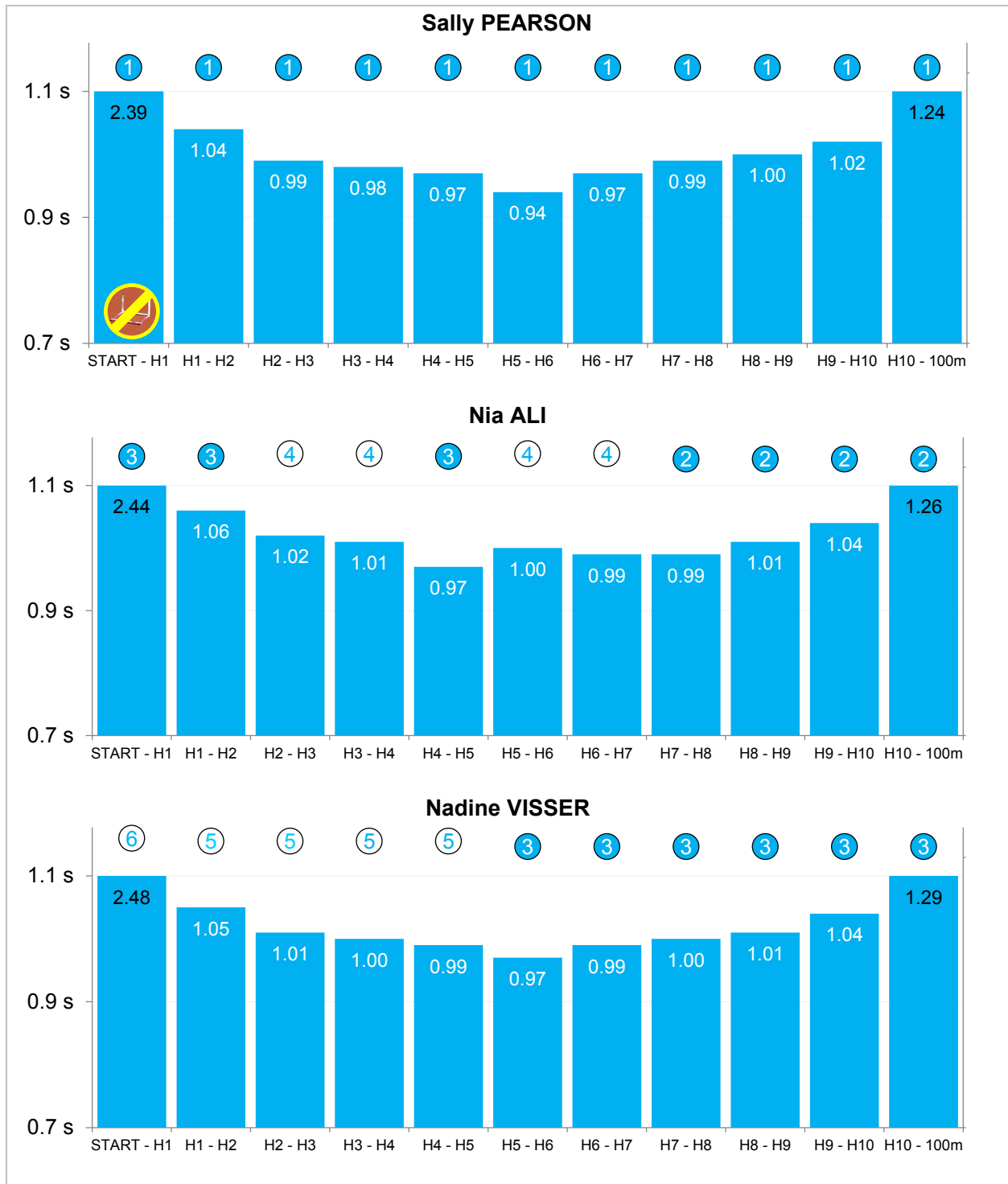


Figure 27. Hurdle profiles for the athletes qualifying for the final.

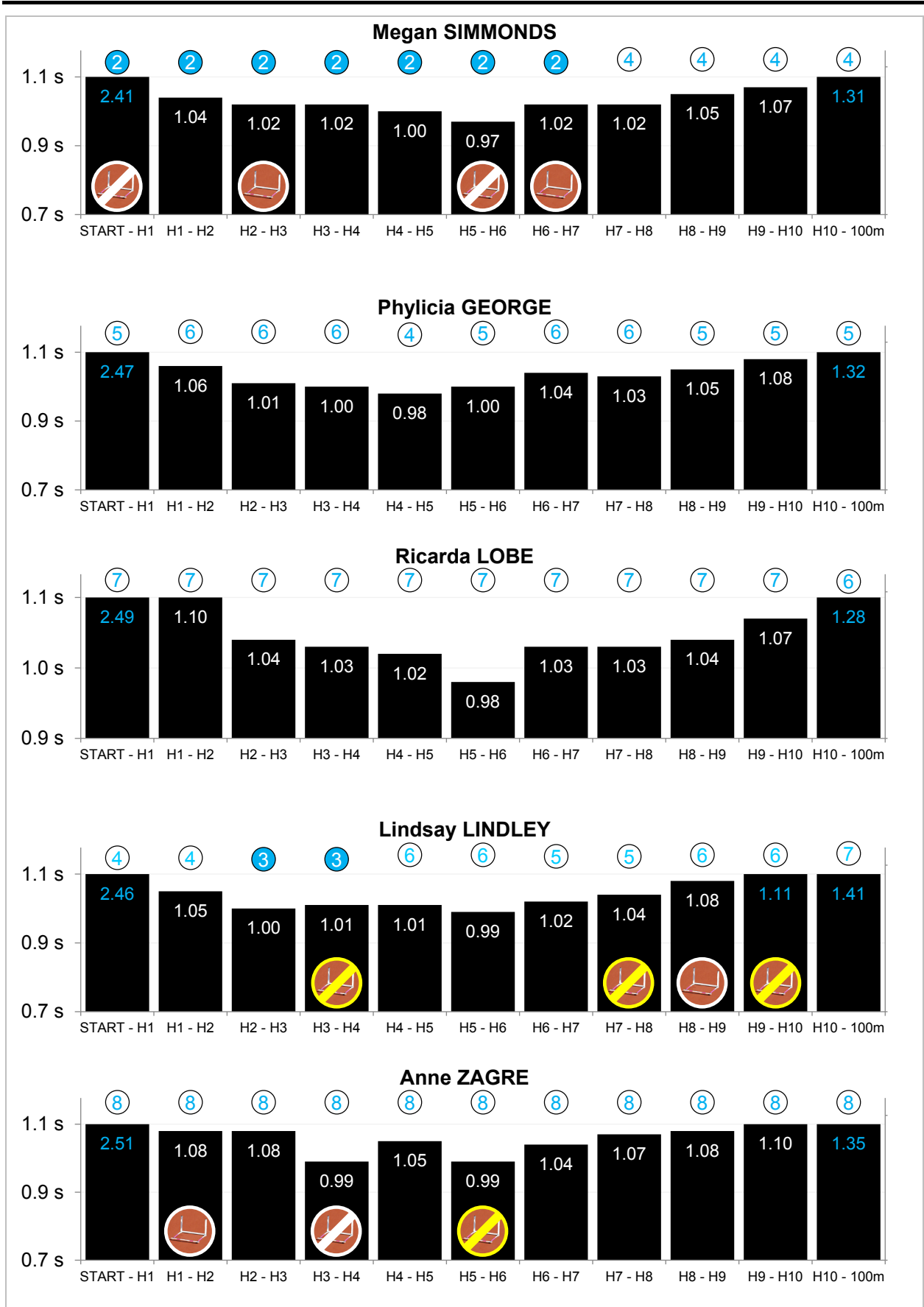


Figure 28. Hurdle profiles for the non-qualifying athletes.

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
MANNING	6	7	12.71 s	Q	0.13 s	0.13 s
TALAY	16	9	12.85 s	Q SB	-0.03 s	0.22 s
THOMPSON	11	13	12.88 s		0.19 s	0.19 s
AMUSAN	5	6	13.04 s		0.47 s	0.47 s
WILLIAMS	4	5	13.14 s		0.58 s	0.58 s
HERMAN	20	19	13.16 s		0.20 s	0.31 s
JENNEKE	23	18	13.25 s		0.26 s	0.43 s
KIMURA	24	24	13.29 s		0.23 s	0.26 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.

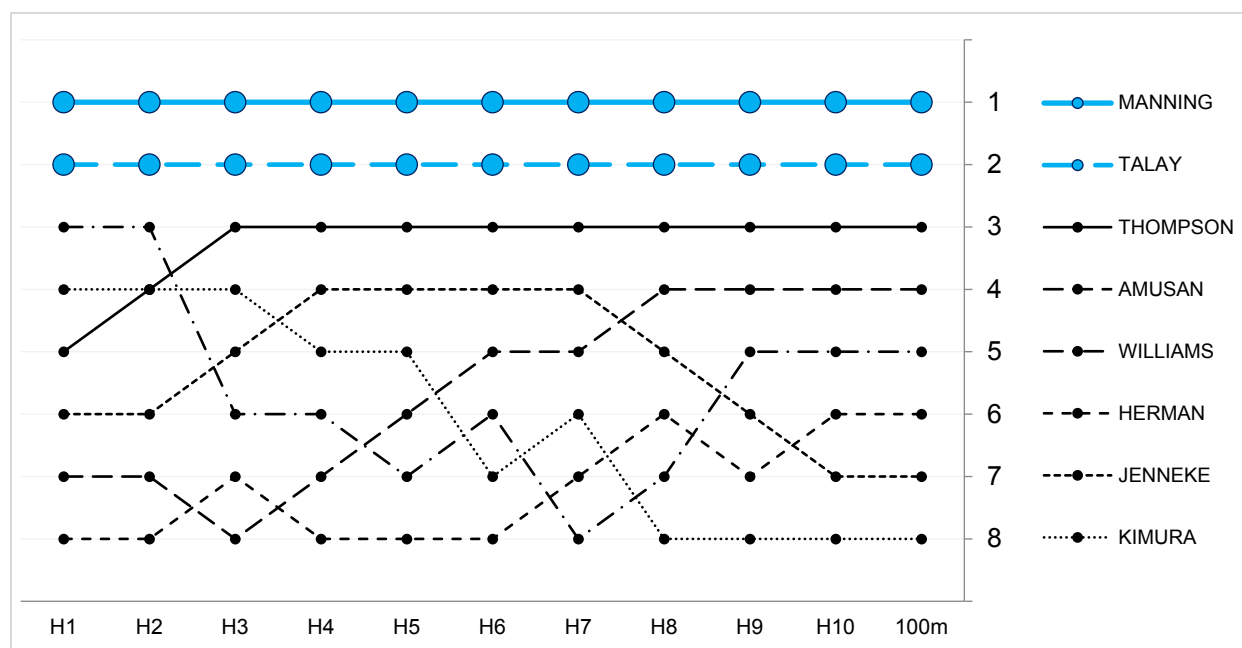


Figure 29. Position of each athlete as they crossed each hurdle and the finish line.

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.

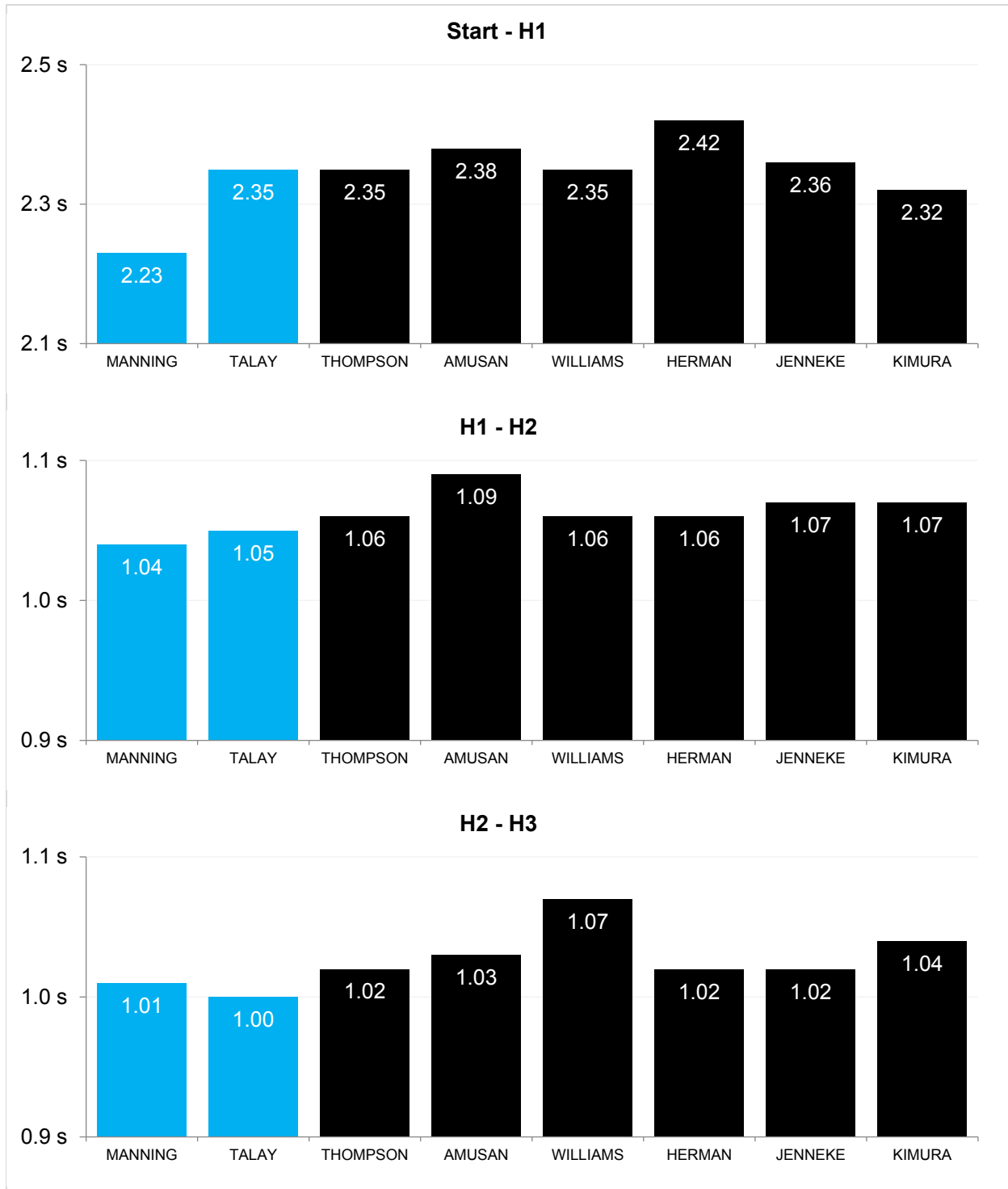


Figure 30. Individual split times between the start and first three consecutive hurdles.

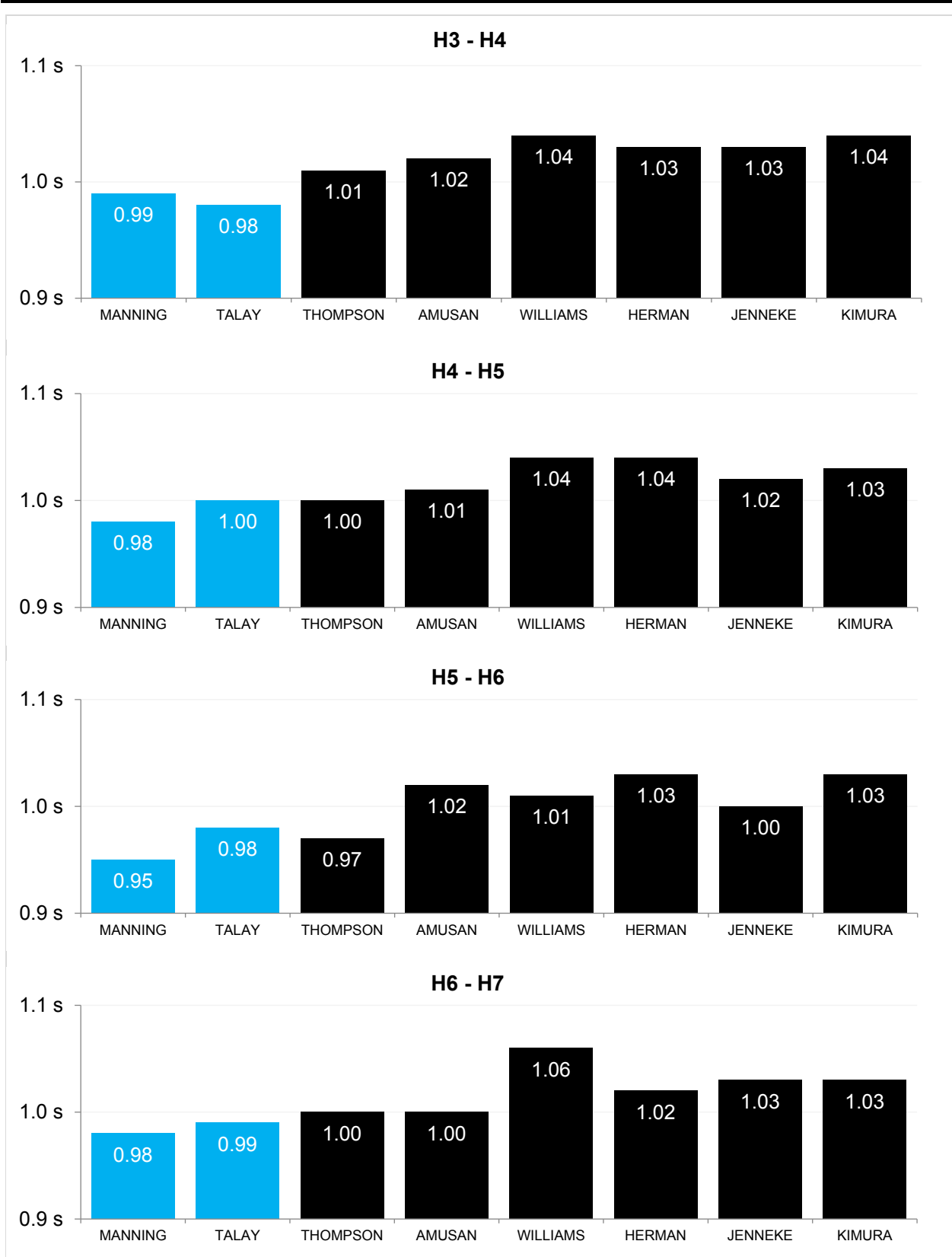


Figure 31. Individual split times for consecutive hurdles between hurdles three and seven.

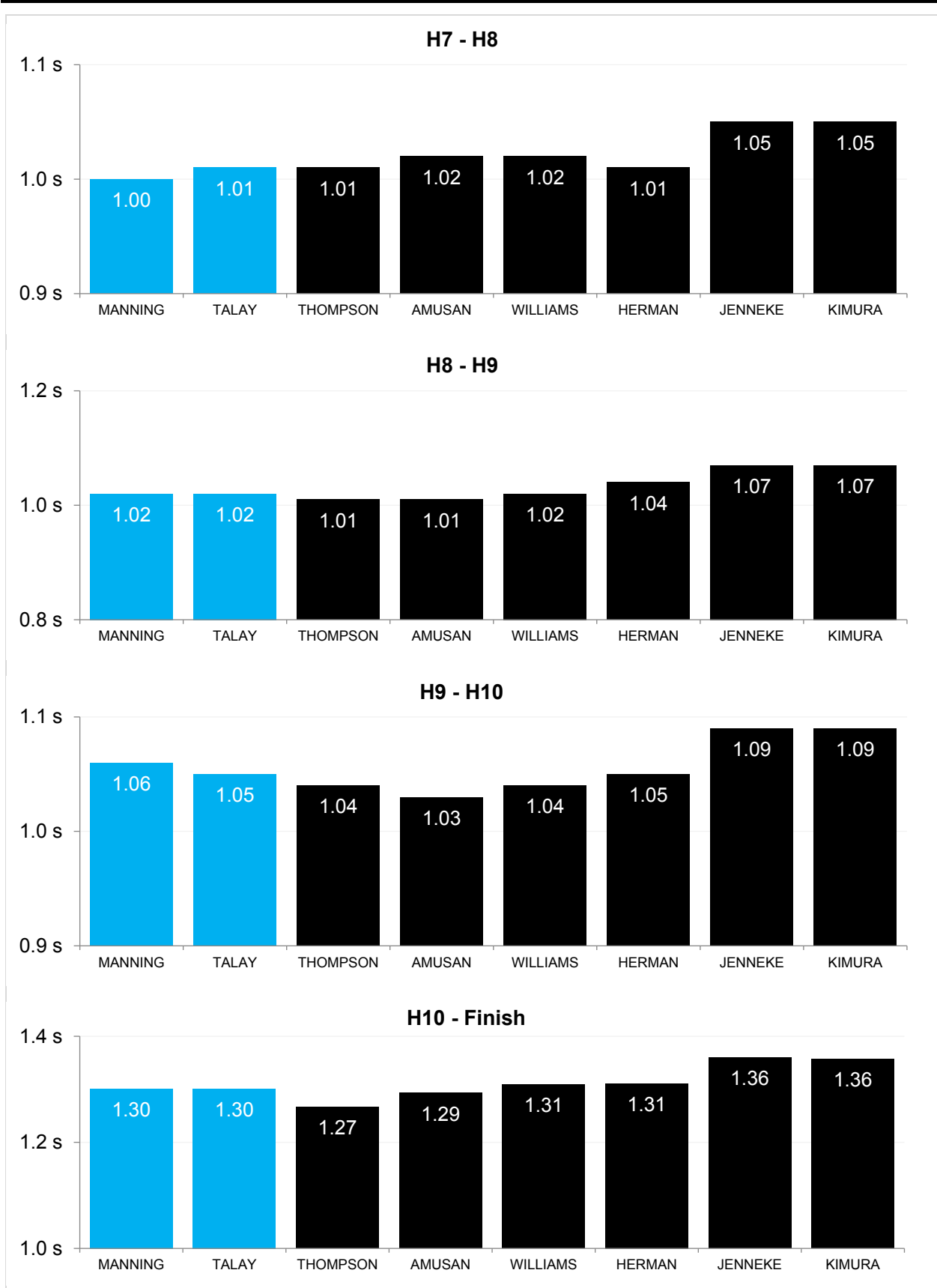


Figure 32. Individual split times between the final three consecutive hurdles and hurdle ten to the finish.

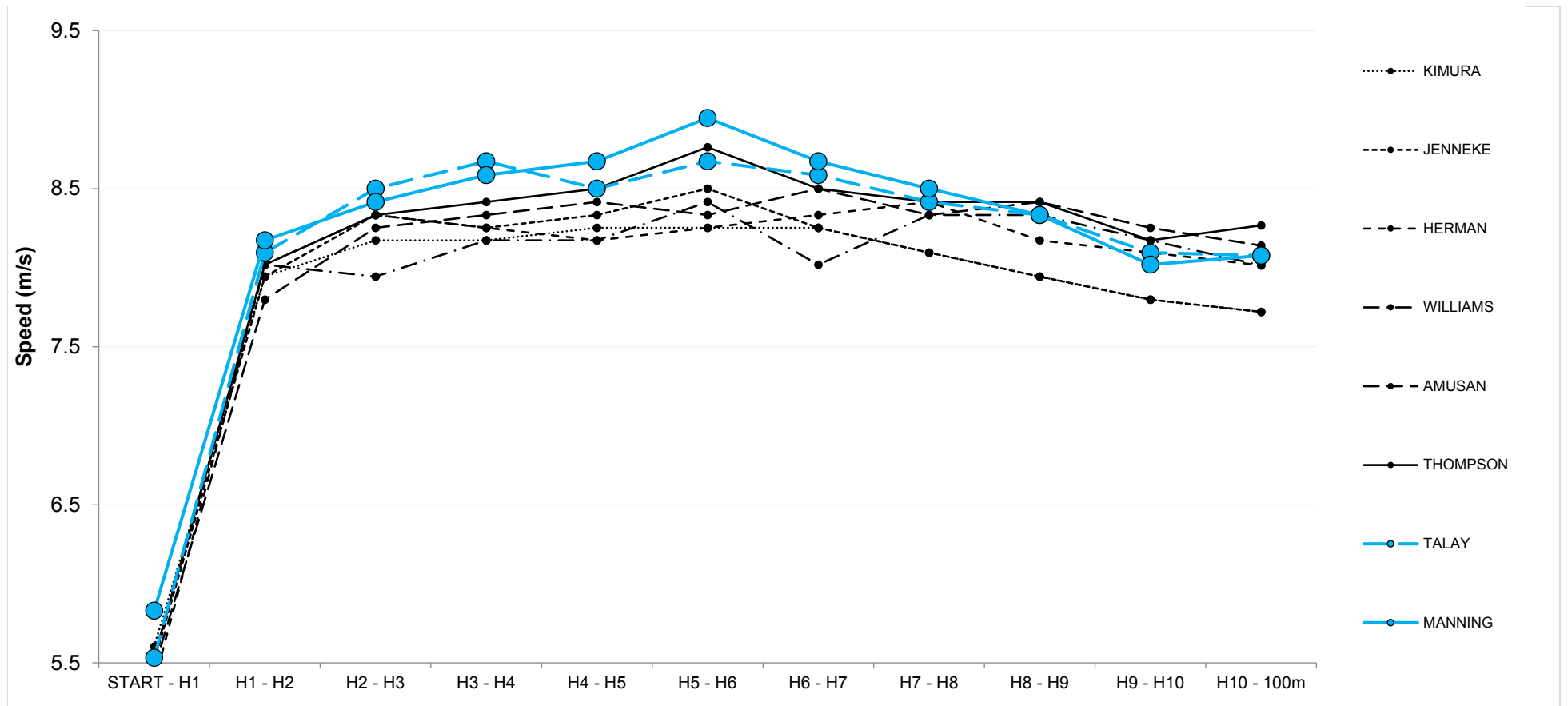


Figure 33. Mean speed for each hurdle split.

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).

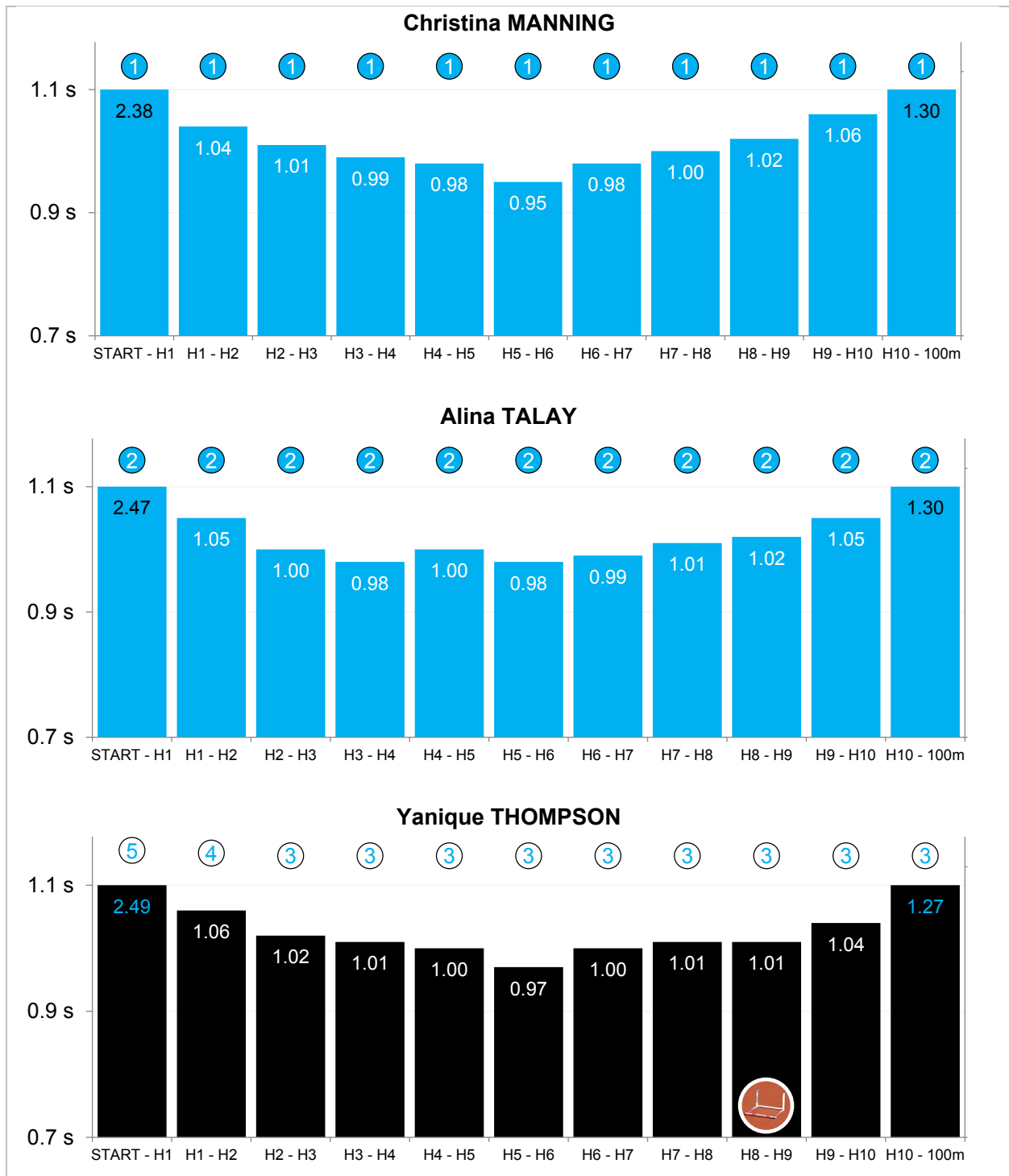


Figure 34. Hurdle profiles for the athletes qualifying for the final, and a non-qualifying athlete.

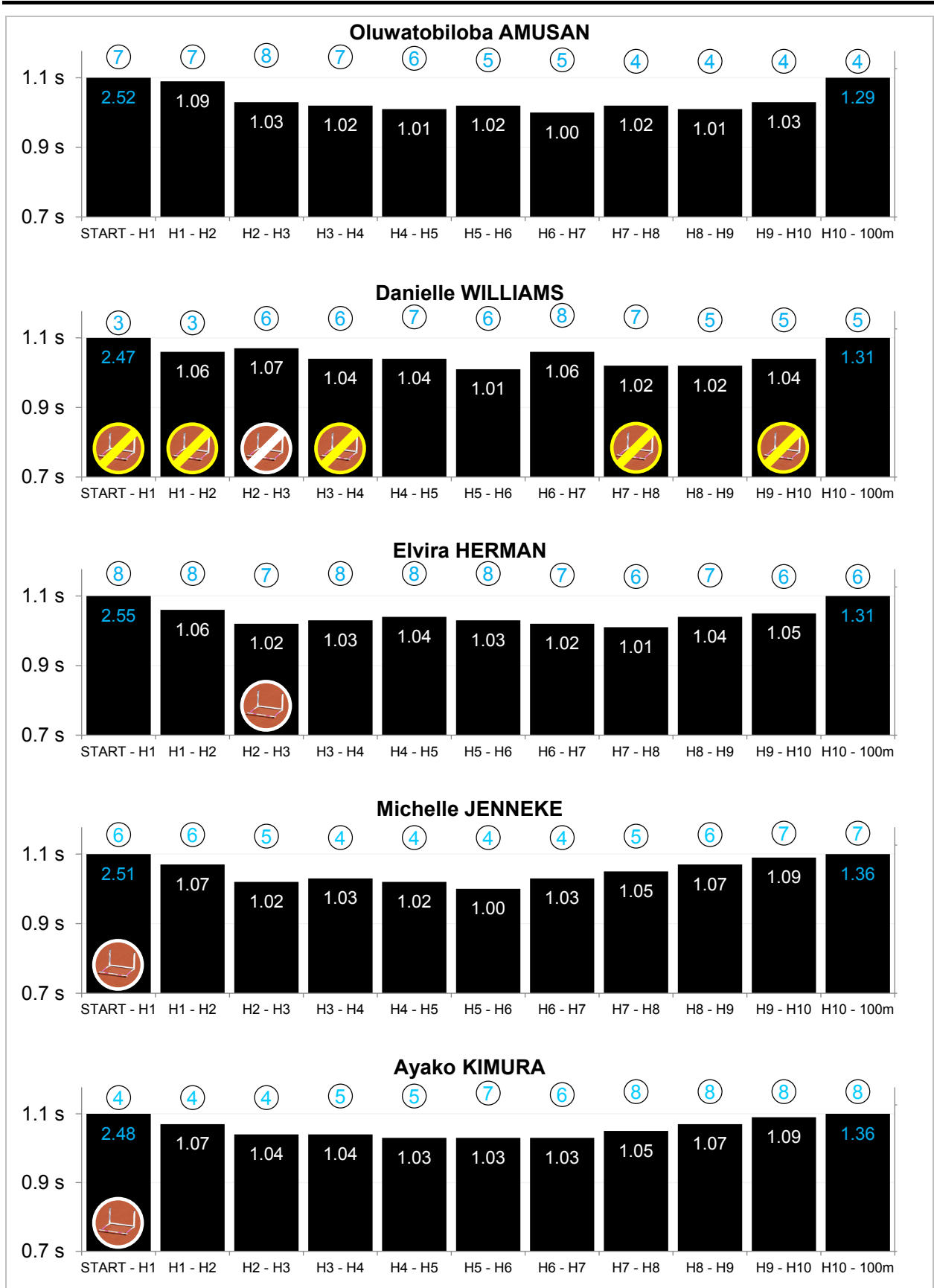


Figure 35. Hurdle profiles for the non-qualifying athletes.

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
HARPER-NELSON	10	3	12.63 s	Q SB	-0.03 s	0.26 s
DUTKIEWICZ	7	8	12.71 s	Q	0.10 s	0.10 s
HARRISON	1	1	12.86 s	q	0.58 s	0.66 s
PEDERSEN	13	16	12.87 s		0.12 s	0.12 s
BURTON	9	11	12.94 s		0.29 s	0.29 s
CHARLTON	12	15	12.95 s		0.21 s	0.21 s
PLOTITSYNA	17	21	13.08 s		0.19 s	0.19 s
BAKKER	22	19	13.29 s		0.32 s	0.44 s

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

Positional analysis

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

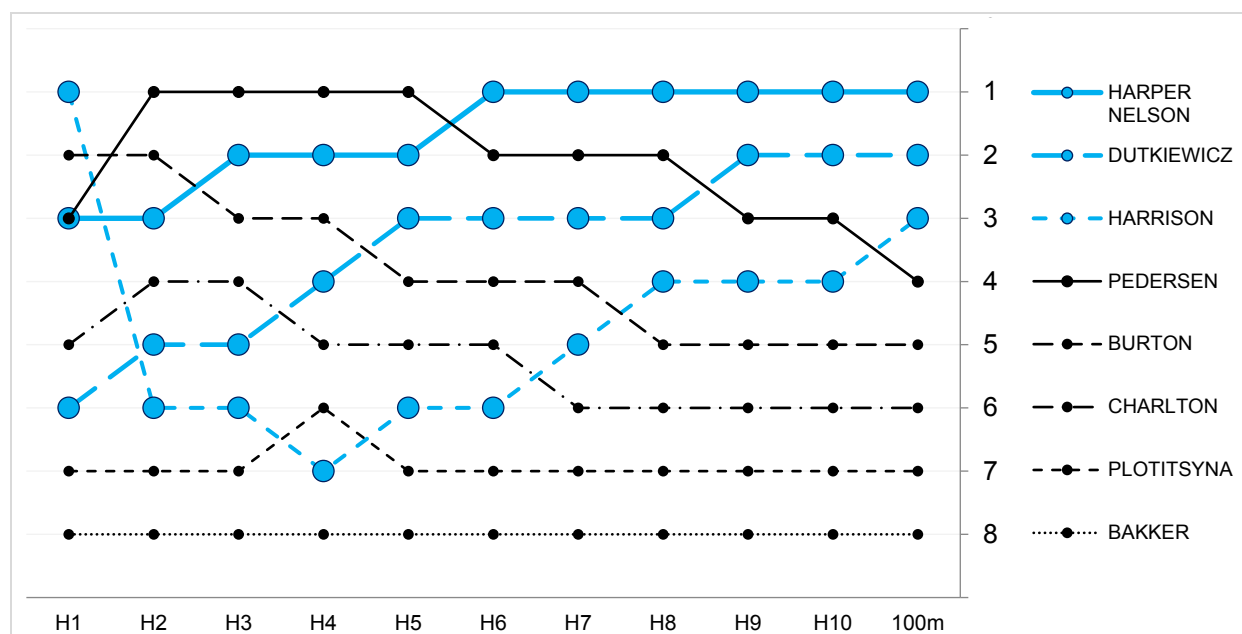


Figure 36. Position of each athlete as they crossed each hurdle.

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.

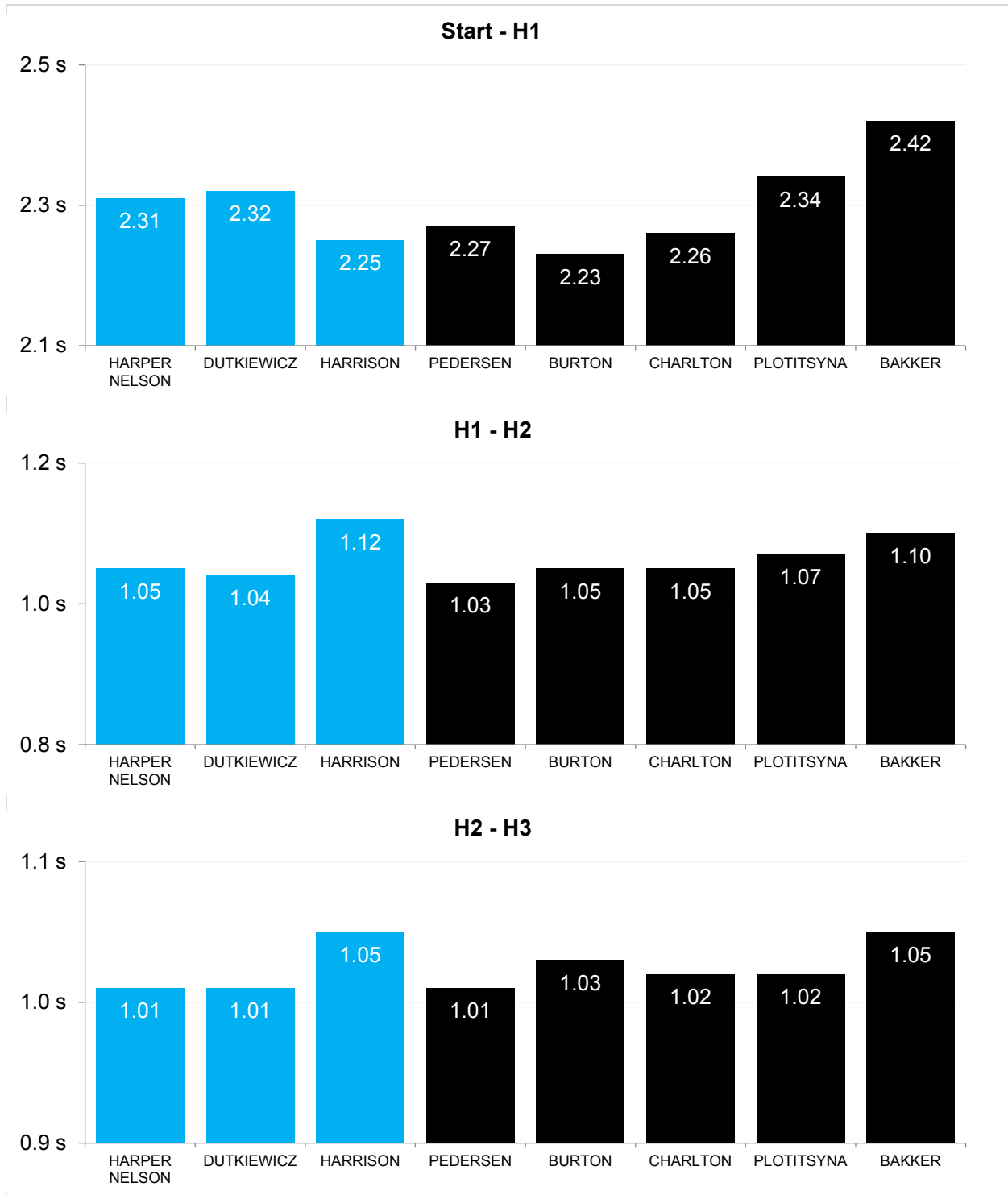


Figure 37. Individual split times between the start and first three consecutive hurdles.

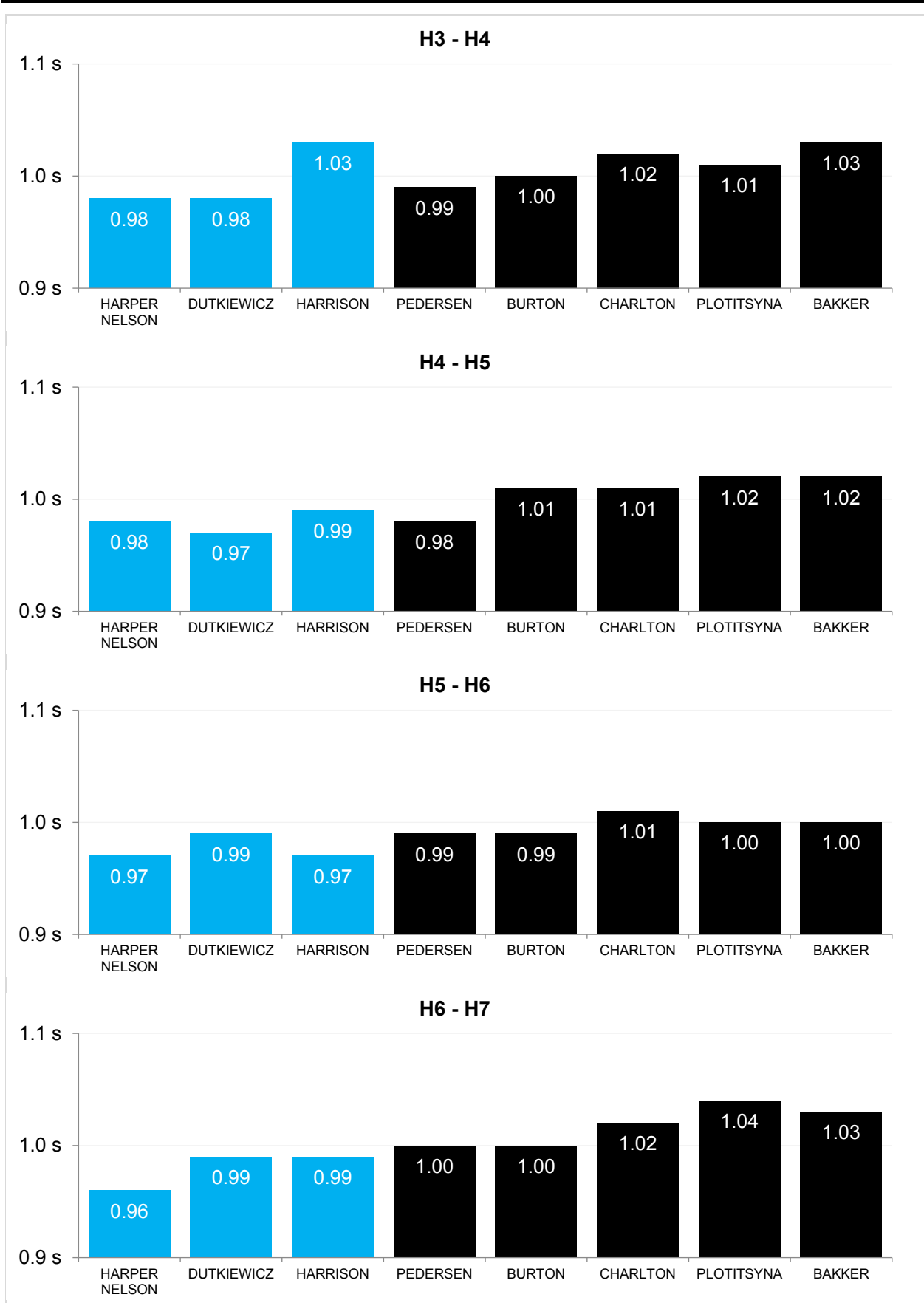


Figure 38. Individual split times for consecutive hurdles between hurdles three and seven.

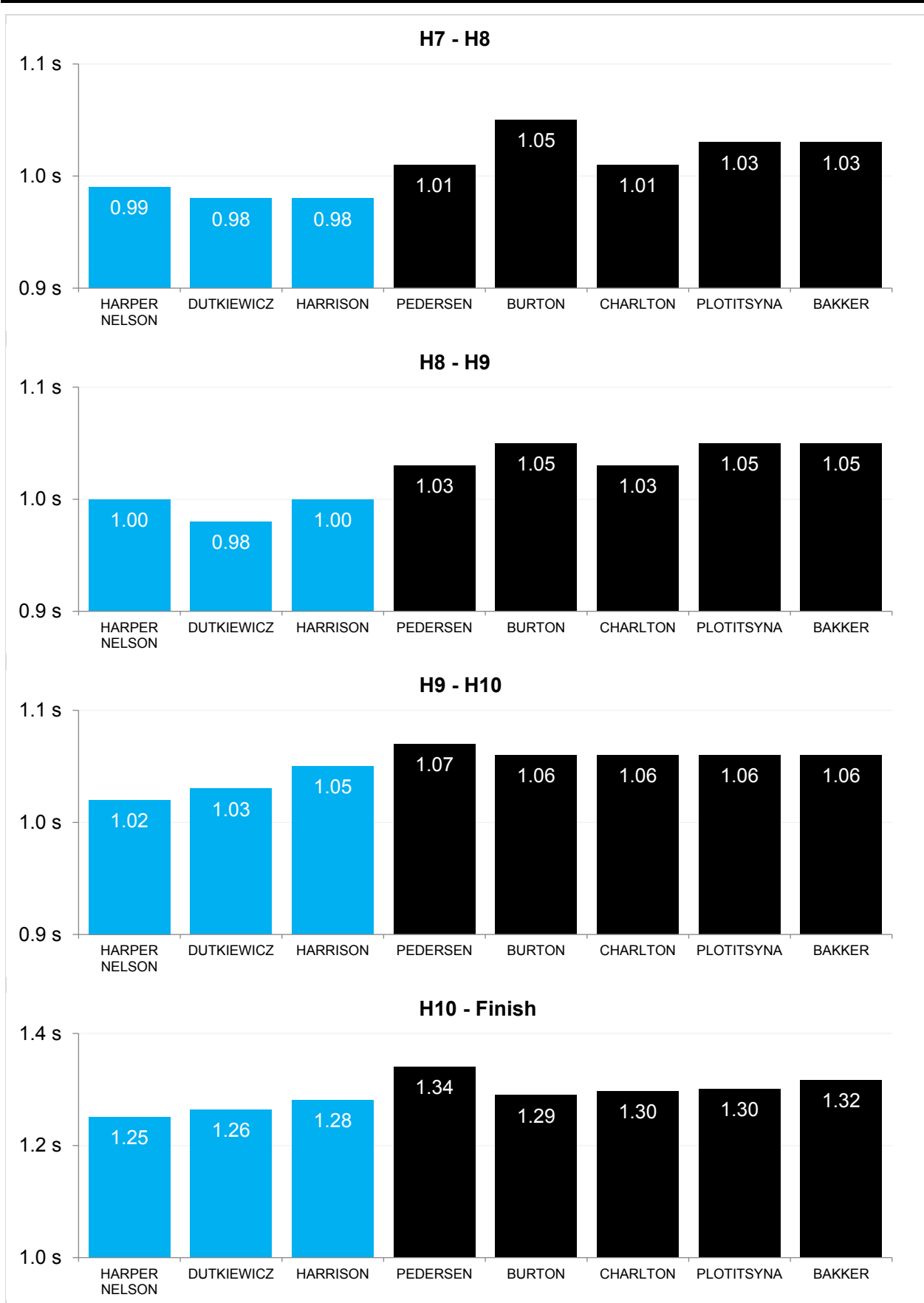


Figure 39. Individual split times between the final three consecutive hurdles and hurdle ten to the finish.

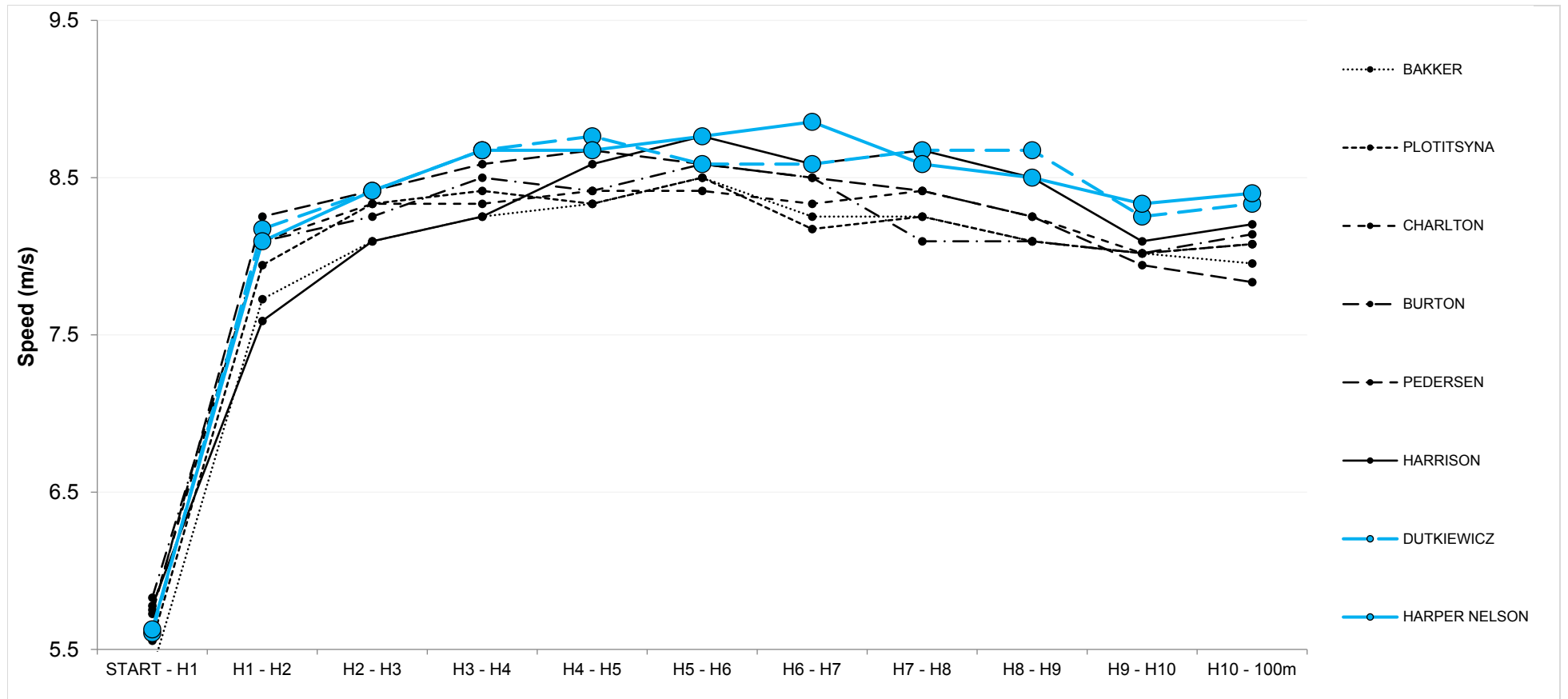


Figure 40. Mean speed for each hurdle split.

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).

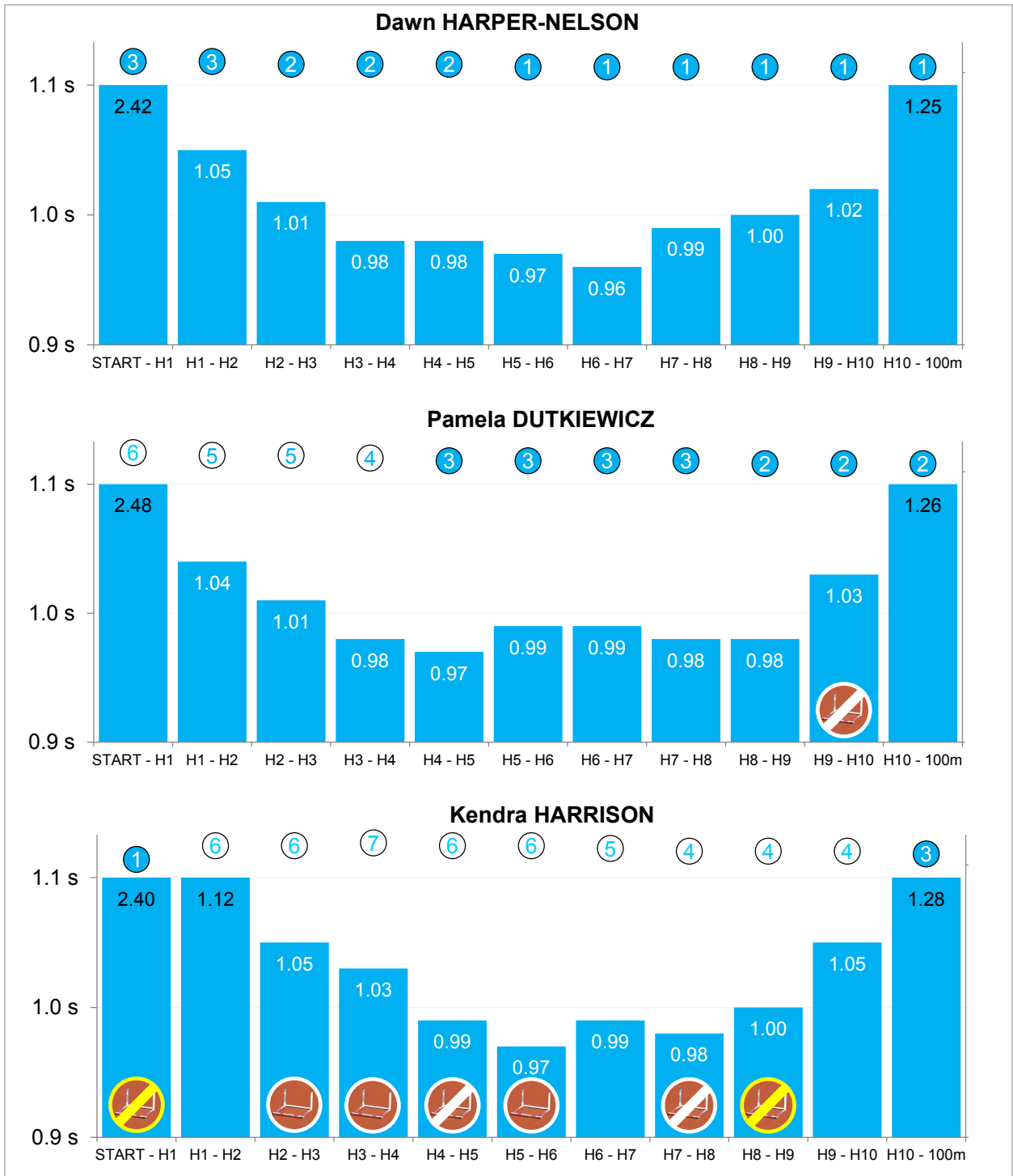


Figure 41. Hurdle profiles for the athletes qualifying for the final.

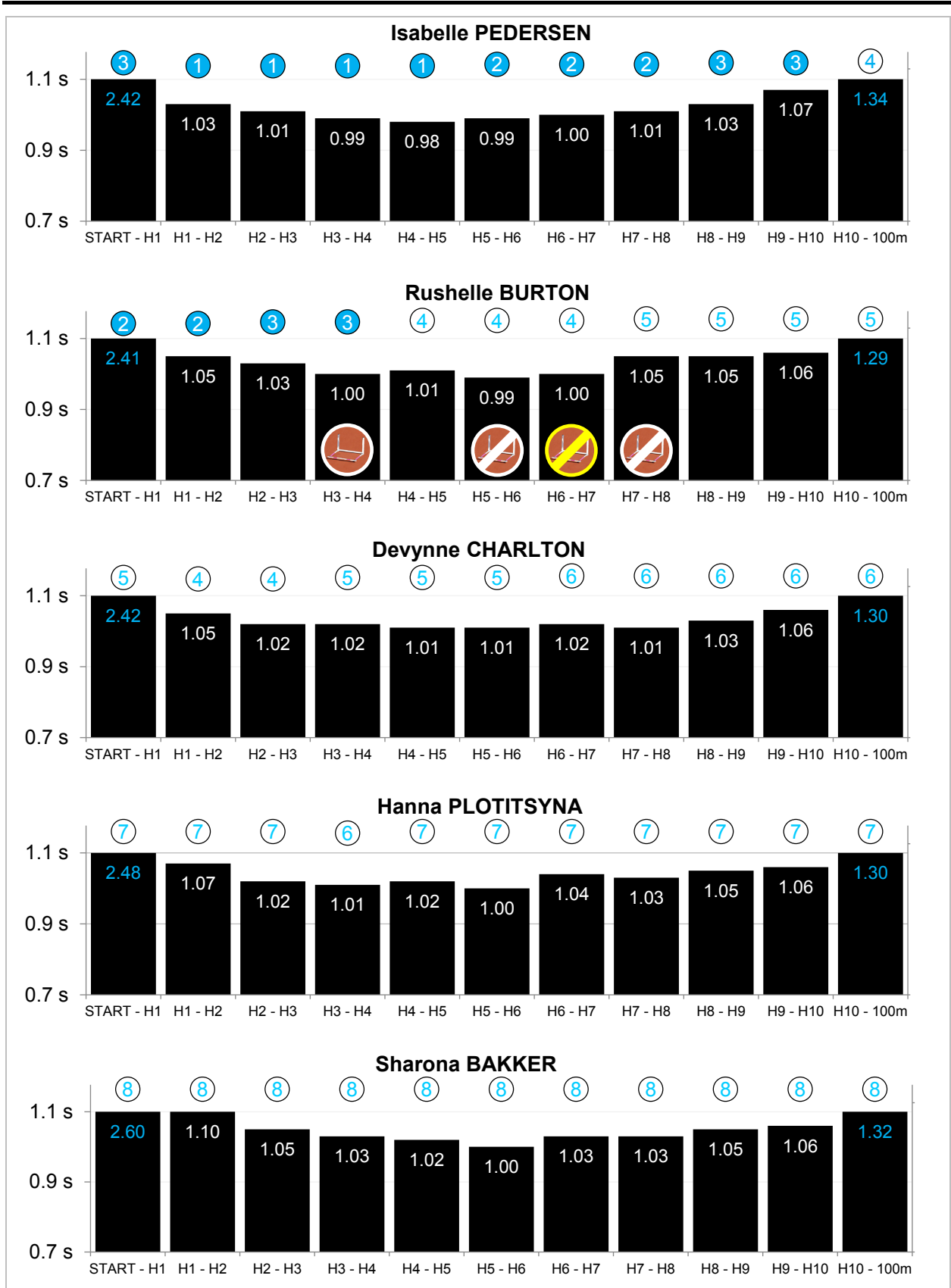


Figure 42. Hurdle profiles for the non-qualifying athletes.

COACH'S COMMENTARY

The women's 100 m hurdles were always going to be full of excitement, given the fact that previous Olympic and world champion Sally Pearson was facing off against Kendra Harrison, who set the world record (12.20 s) in the London Stadium just over 12 months previous. Comparing the athletes' final performance to their respective SB and PB provides a good background of their current form relative to their best. However, it could be argued that SB is slightly more relevant, as this gives an indication of where they are currently at, as their PB could be a number of years ago, as was the case for Sally Pearson.

First, 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 an athlete's race position. 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 following hurdle split time. There is a key connection between making contact with the hurdle and the time of the next split. For instance, the bronze medallist, Pamela Dutkiewicz had a H6-H7 split time of 0.99 s and then hit the seventh hurdle quite significantly, which caused her H7-H8 split time to increase to 1.02 s. Kendra Harrison's split times are quite impressive, given that she contacted several hurdles in the first half of the race. The fact that she managed to get quicker between the hurdles up to H7 shows that she is incredibly quick, and is probably why she is the current WR holder. It is interesting to see that Sally Pearson took until H3-H4 to start running sub-1 s splits. I would have maybe expected her to be running under 1 s splits for longer in the race. This may explain why her final time (12.59 s) was slower than what she is capable of, given she did not hit any hurdles throughout the final.

The body height values provided by athletes are often inaccurate, so the relative values should be interpreted with slight caution, which is worth noting when discussing them in the following sections. The take-off distance relative to body height is interesting, although it depends on how coaches approach this variable. For me, showing values relative to limb length would be ideal, however relative to body height does provide an indication of certain trends. Generally, coaches will aim for their athletes to take-off around 2 m away from the hurdle and land 1 m beyond. Here, Nadine Visser appears to take-off quite close to the hurdle, which could explain why she hit hurdle five. Interestingly, the two athletes that took off closest to the hurdle (relative to body height) both hit hurdle five (Visser and Ali), while Dutkiewicz was third closest (relative) and also made slight contact with the hurdle.

Figure 13 showing the components of hurdle distance is informative and shows that all of the female athletes are generally taking off from over two metres away and touching down over one metre away (e.g. Pearson: take-off = 2.11 m, touchdown = 1.15 m), which highlights the athleticism of these individuals. Talay took off furthest from the hurdle and although she isn't particularly tall, she may have a proportionally long leg length, highlighting the idealness of having data relative to limb length.

The joint angles around take-off, and how they may relate to performance over the hurdle is interesting to see. Eighth place Ali had the most extended knee angle at take-off, which may explain why she had the greatest distance to the centre of mass and the lowest deviation angle. This may all connect to explain why she hit the hurdle and lost 0.03 s in the following split.

The step after touchdown will usually be short as the athlete is wanting to actively get the second foot down to accelerate as quickly as possible. What you should see in the three steps between hurdles is a "short-long-short" approach, where the first and third steps are significantly shorter than the second. This was not the case for Pearson, as her second step was 3 cm (1.8 %) shorter than her first. She is the only athlete in the field to do this, and may not have been the case for her between the other hurdles, but is interesting to consider that the world champion may have this quirk in her technique that does not follow the general trend. Assuming Pearson takes off from hurdle six at the same distance as hurdle five, her sequence between H5 and H6 would be: 1.15 m (touchdown), 1.70 m (step one), 1.67 m (step two), 1.87 m (step three) and 2.11 m (take-off). This would mean that her sequence is almost a "short-short-long". It is difficult to say from these results whether this is a deliberate technique or if it is a one-off for this particular hurdle. The fact that Pearson is lengthening into the hurdle means that she is probably braking more than the other athletes, which may be the case and may explain the zero hurdle contact throughout the race. On the other hand, when you consider what her PB is, you could just say that, despite winning the gold medal, this was an imperfect race for Pearson.

The touchdown angles, particularly the deviation angle, shows how they manage to get their centre of mass over the foot at ground contact. As $\pm 90^\circ$ means that the centre of mass is directly over the foot, Harper-Nelson ($\kappa = -83.7^\circ$) is clearly upright at contact compared to the other two medallists (Pearson: $\kappa = -80.6^\circ$; Dutkiewicz: $\kappa = -77.4^\circ$). Dutkiewicz works really hard to get this deviation angle as high as possible, so she will be disappointed to see -77.4° at touchdown, although this may be explained by the fact that she clipped the hurdle on the way over.

The information around the tenth hurdle shows that, as was the case for hurdle five, the athletes are trying to actively accelerate as quickly as possible into the run-off. This is shown by the short flight times after initial contact. Harrison is one of the best ever runners in the women's hurdles

so despite catching the last hurdle, her contact and flight times may be something to aim towards. Eighth placed Ali had a particularly long contact, which can probably be explained by the fact that she hit H10 quite heavily. The number of contacts from H10 to the line is usually six, but the athlete does typically not know the specific value. Their coach may know how many contacts they do take, but it is not something that is coached as much as the number of contacts before H1. The number of steps an athlete will take after the last hurdle could be determined by the ground contact time and step frequency of the run-off, so will be of importance to coaches when focussing on the sprinting technique during this late stage of the race. I believe directing coaching towards the final run-off is hugely important, and training an athlete to focus on that aggression off of the final hurdle is key.

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.

