IAAF World Championships
LONDON 2017

BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

200 m Women's

Dr Lysander Pollitt, Josh Walker, Dr Catherine Tucker
and Dr Athanassios Bissas
Carnegie School of Sport

Stéphane Merlino
IAAF Project Leader

LEEDS BECKETT UNIVERSITY

IAAF

Event Directors
Dr Lysander Pollitt
Dr Athanassios Bissas

Project Director
Dr Athanassios Bissas

Project Coordinator
Louise Sutton

Senior Technical Support
Liam Gallagher
Aaron Thomas
Liam Thomas

Senior Research Officer
Josh Walker

Report Editor
Dr Catherine Tucker

Analysis Support
Dr Lysander Pollitt

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Calibration
Dr Brian Hanley

Data Management
Nils Jongerius

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Joshua Rowe
Ruth O'Faolain
Lewis Lawton
Joe Sails

Data Analysts
Dr Lysander Pollitt
Dr Giorgios Paradisis (National and Kapodistrian University of Athens)
Josh Walker
Dr Athanassios Bissas
Parag Parelkar
Pierre-Jean Vazel
Dr Catherine Tucker

Project Team
Dr Tim Bennett
Helen Gravestock
Mark Cooke
Dr Alex Dinsdale
Dr Gareth Nicholson

Masalela Gaesenngwe
Emily Gregg
Mike Hopkinson

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Callum Guest
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James Webber
Lara Wilson

Coaching Commentary
Ralph Mouchbahani

Historical Analysis and Coaching Commentary
Pierre-Jean Vazel

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INTRODUCTION

Dafne Schippers added to her bronze medal from the 100 m by defending her 200 m world title on the evening of Friday 11th August; despite being only sixth on the 2017 world list (22.10 s). While a season's best time of 22.05 s secured the gold, she was made to work by the Ivorian Marie-Josée Ta Lou. After both made excellent starts, Schippers led by the slightest of margins at the bend. Despite a strong finish, Ta Lou, once again narrowly missed out on the gold medal. And despite being just 0.04 s away from two World Championship gold medals, her mark of 22.08 s set a new national record. In the battle for the bronze medal, Great Britain's Dina Asher-Smith headed the remainder of the field into the home straight. In spite of the tremendous roar from the home crowd, she couldn't hold off the challenge of Shaunae Miller-Uibo, who claimed bronze in 22.15 s. While this may have been somewhat of a consolation for Miller-Uibo, after disappointment in the 400 m, for Asher-Smith, finishing fourth in a season's best of 22.22 s, the joint third fastest time of her career, was remarkable considering she broke a bone in her foot in February and only began her season in late June.

IAAF World Championships — London 4-13 August 2017

RESULTS

200 Metres Women - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	21.34	Florence GRIFFITH-JOYNER	USA	29	Seoul (Olympic Stadium)	29 Sep 1988
Championships Record CR	21.63	Dafne SCHIPPERS	NED	23	Beijing (National Stadium)	28 Aug 2015
World Leading WL	21.77	Tori BOWIE	USA	27	Eugene (Hayward Field), OR	27 May 2017

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

11 August 2017 21:50 START TIME 19° C TEMPERATURE 68 % HUMIDITY +0.8 m/s WIND

PLACE	NAME	COUNTRY	DATE of BIRTH	LANE	RESULT		REACTION	Fn
1	Dafne SCHIPPERS	NED	15 Jun 92	6	22.05	SB	0.165	
2	Marie-Josée TA LOU	CIV	18 Nov 88	4	22.08	NR	0.199	
3	Shaunae MILLER-UIBO	BAH	15 Apr 94	5	22.15		0.147	
4	Dina ASHER-SMITH	GBR	4 Dec 95	8	22.22	SB	0.169	
5	Deajah STEVENS	USA	19 May 95	7	22.44		0.178	
6	Kimberlyn DUNCAN	USA	2 Aug 91	9	22.59		0.198	
7	Crystal EMMANUEL	CAN	27 Nov 91	2	22.60		0.158	
8	Tynia GAITHER	BAH	16 Mar 93	3	23.07		0.162	

Timing and Measurement by SEIKO AT-200-W-f--1--.RS1..v1 Issued at 21:52 on Friday, 11 August 2017

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METHODS

Eight vantage locations for camera placement were identified and secured. Six of these were dedicated to the home straight and the additional two were strategically positioned around the start line (Figure 1). Each of the home straight locations 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 100 m line to the 190 m line) whilst the sixth location was located within the IAAF VIP outdoor area overlooking the finish line from a semi-frontal angle. Two separate calibration procedures were conducted before and after each competition. First, a series of nine interlinked training hurdles were positioned every 10 m along the home straight ensuring that the crossbar of each hurdle, covered with black and white tape, was aligned with the track's transverse line (Figure 2). These hurdles were also positioned across all nine lanes on the track markings for the 100 m interval. Second, a rigid cuboid calibration frame was positioned on the running track between the 147-metre mark and the 155.5-metre mark (from the starting line) 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 running speeds (Figure 3). 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.

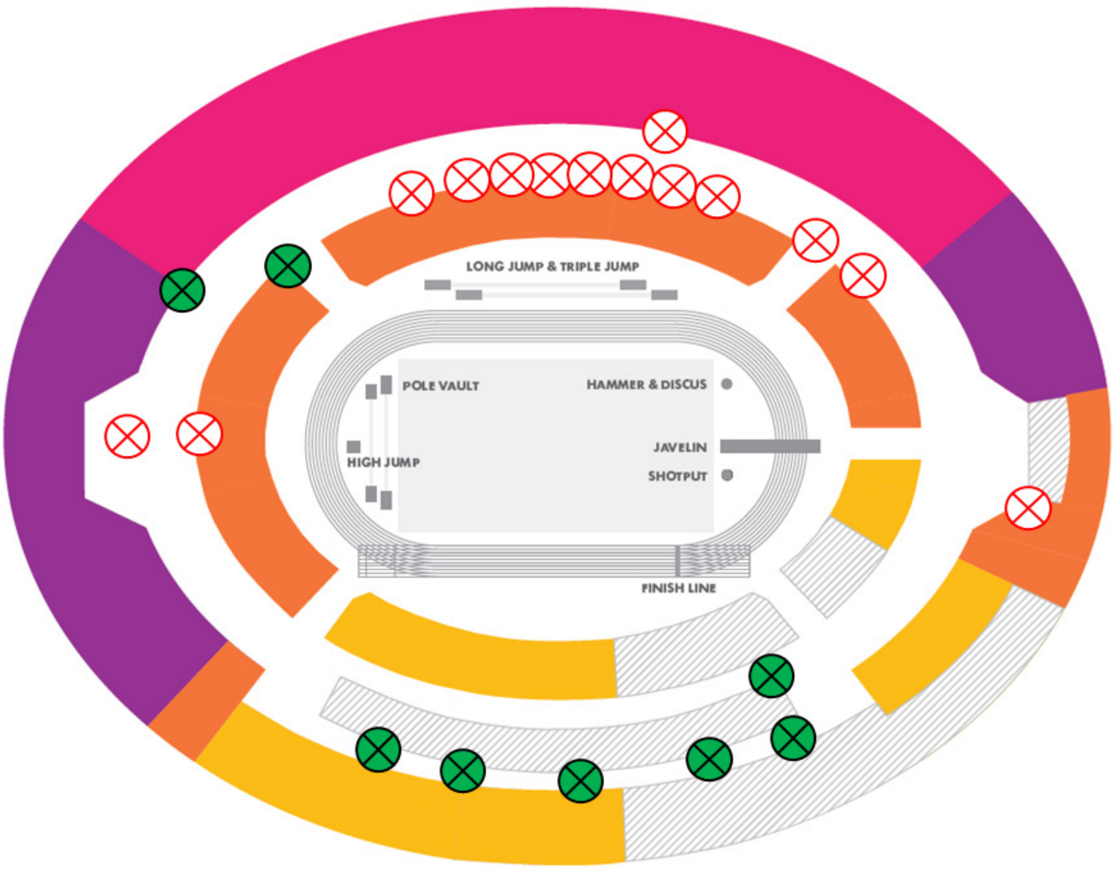

Figure 1. Camera layout within the stadium for the women's 200 m indicated by green in-filled circles.

A total of 18 cameras were employed to record the action during the 200 m 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 in order to capture motion in the sagittal plane and provide footage for the analysis of the split times. Five 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 five 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. To provide additional footage for the analysis of the initial 100 m, three Canon EOS 700D cameras operating at 60 Hz (shutter speed: 1/1250; ISO: 1600; SHD: 1280x720 px) were used.

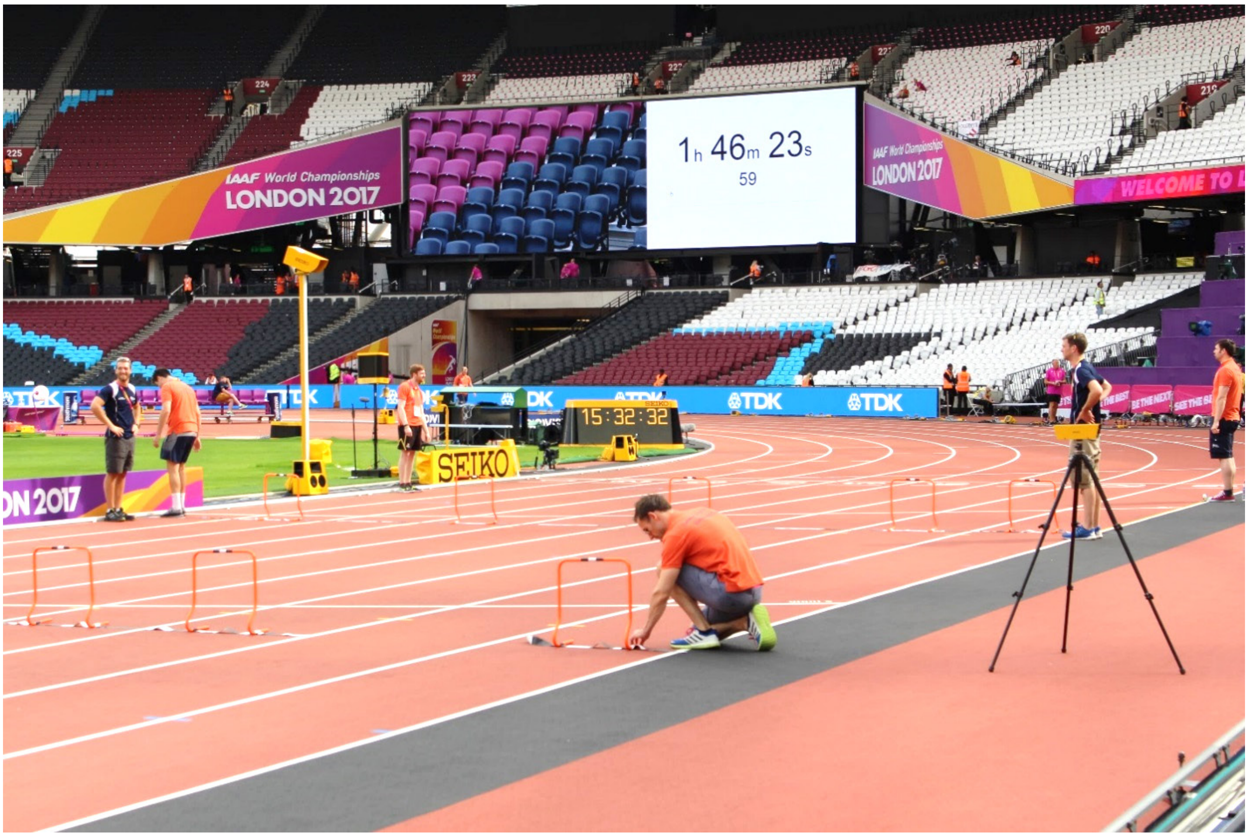

Figure 2. Set-up of the hurdle calibration system used to determine split intervals.

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 middle calibration volume, compared to the shorter sprints, the digitising process for most of the body segments 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 one sprint running stride 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. The calibration frame was constructed and filmed before and after the competition.

De Leva's (1996) body segment parameter models were used to obtain data for the whole body centre of mass and for key body segments of interest. 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 and kinematic characteristics were processed through SIMI Motion by using the 60, 100 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.

Figure 4. Action from the 200 m women's final.

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

Variable	**Definition**
Positional analysis	Position of each athlete at each 100 m interval during the race. Also, throughout the home straight, the position at each 10 m interval (final), and each 20 m interval (semi-finals).
Individual split times	Split time for each athlete based on the positional analysis above.
Mean speed	Mean speed for each athlete based on the individual split times.
Completed steps	Total recorded steps (e.g., right foot to left foot) during each 100 m interval.
Mean step length (split data)	Mean absolute length of each step during the initial 10 m and 100 m interval. And, the relative value, based on an athlete's height, of each step during these intervals (body height = 1.00).
Step length	The distance covered from toe-off on one foot to toe-off on the other foot.
Relative step length	Step length as a proportion of the athlete's height (body height = 1.00).
Step rate	The number of steps per second (Hz).

Contact time	The time the foot is in contact with the ground.
Flight time	The time from toe-off (TO) of one foot to touchdown (TD) of the other foot.
Step time	Contact time + flight time.
Step velocity	Step length divided by step time.
Swing time	The time that the foot is not in contact with the ground during one full stride.
DCM TD	The horizontal distance between the ground contact point (foot tip) at TD and the CM.
DCM TO	The horizontal distance between the ground contact point (foot tip) at TO and the CM.
Foot vertical velocity	The vertical component of the foot CM velocity.
Resultant foot swing velocity	The resultant linear velocity of the foot CM during the swing phase.
Trunk angle (α)	The angle of the trunk relative to the horizontal and considered to be 90° in the upright position.
Knee angle (β)	The angle between the thigh and lower leg and considered to be 180° in the anatomical standing position.
Contact leg hip angle (γ)	The shoulder-hip-knee angle of the contact side.
Swing leg hip angle (δ)	The shoulder-hip-knee angle of the swing side. ***Note:*** *angle taken at toe-off only.*
Contact thigh angle (ε)	The angle between the thigh of the contact leg and the vertical.
Swing thigh angle (ζ)	The angle between the thigh of the swing leg and the vertical.
Thigh separation angle (η)	The angle between the thighs of the contact and swing legs. This has been calculated as the difference between ε and ζ.
Shank angle (θ)	The angle of the lower leg relative to the running surface and considered to be 90° when the shank is perpendicular to the running surface.
Ankle angle (ι)	The angle between the lower leg and the foot and considered to be 90° in the anatomical standing position.

Note: *CM = Centre of mass.*

RESULTS – Final

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*
SCHIPPERS	22.10 s	*3*	21.63 s	*1*	22.49 s	1	
TA LOU	22.16 s	*4*	22.16 s	*5*	22.50 s	3	
MILLER-UIBO	21.91 s	*1*	21.91 s	*2*	22.49 s	1	
ASHER-SMITH	22.73 s	*8*	22.07 s	*3*	22.73 s	5	*SB*
STEVENS	22.09 s	*2*	22.09 s	*4*	22.71 s	4	
DUNCAN	22.54 s	*6*	22.19 s	*6*	22.73 s	5	
EMMANUEL	22.50 s	*5*	22.50 s	*7*	22.85 s	7	*.848 s*
GAITHER	22.71 s	*7*	22.54 s	*8*	22.85 s	8	*.850 s*

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
SCHIPPERS	22.05 s	*SB*	–0.44 s	–0.05 s	0.42 s
TA LOU	22.08 s	*NR*	–0.42 s	–0.08 s	–0.08 s
MILLER-UIBO	22.15 s		–0.34 s	0.24 s	0.24 s
ASHER-SMITH	22.22 s	*SB*	–0.51 s	–0.51 s	0.15 s
STEVENS	22.44 s		–0.27 s	0.35 s	0.35 s
DUNCAN	22.59 s		–0.14 s	0.05 s	0.40 s
EMMANUEL	22.60 s		–0.25 s	0.10 s	0.10 s
GAITHER	23.07 s		0.22 s	0.36 s	0.53 s

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

Positional analysis

The following figure (Figure 5) shows each finalist's race position at each 10 m interval, based on cumulative split time data.

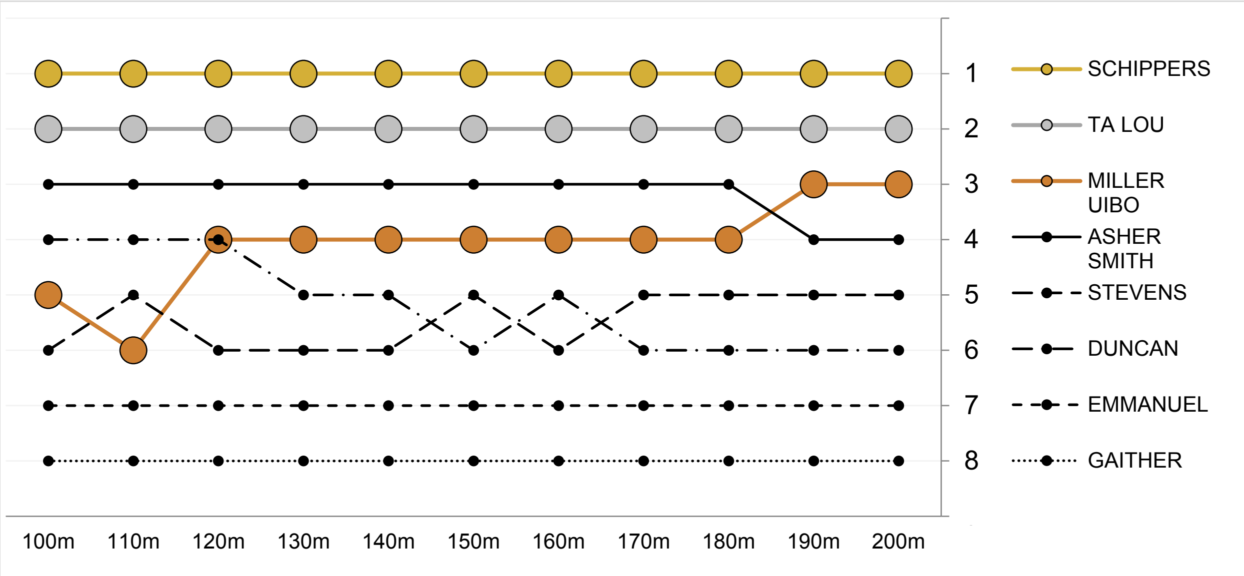

Figure 5. Positions at the beginning of the home straight and at the end of each 10 m split.

Individual split times

The following graphs display the split times of all athletes over each: 100 m split (Figures 6 and 7; note: 0-100 m is displayed without the reaction time) and consecutive 10 m split throughout the home straight (Figure 8). The mean speed over consecutive 10 m splits throughout the home straight is presented in Figure 9. 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 (*).

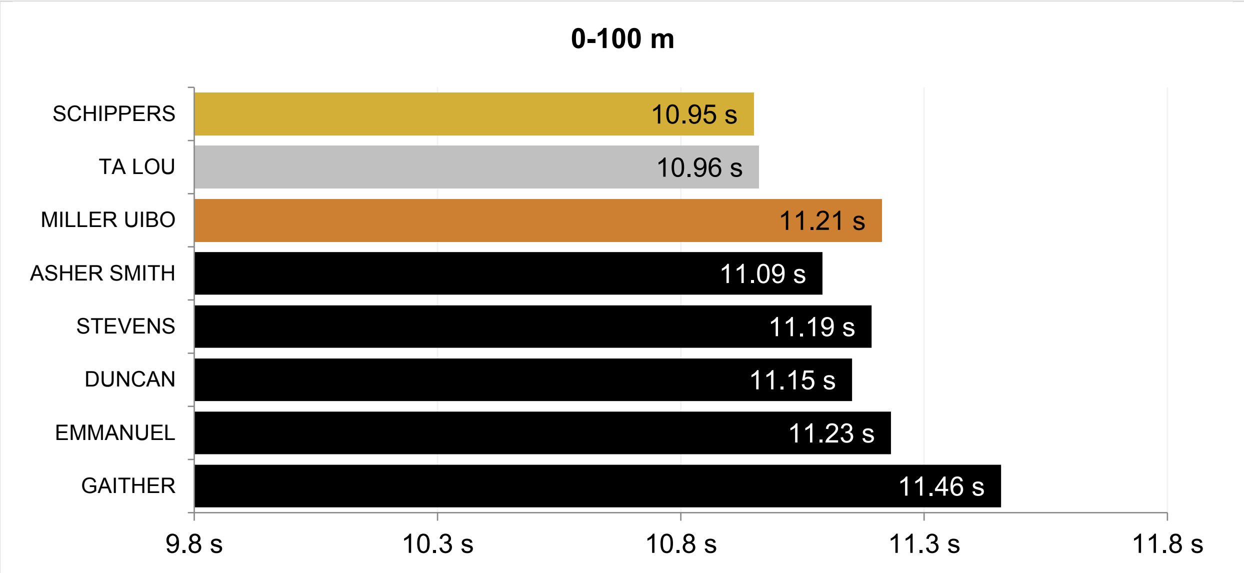

Figure 6. Individual 0-100 m split times (minus reaction time).

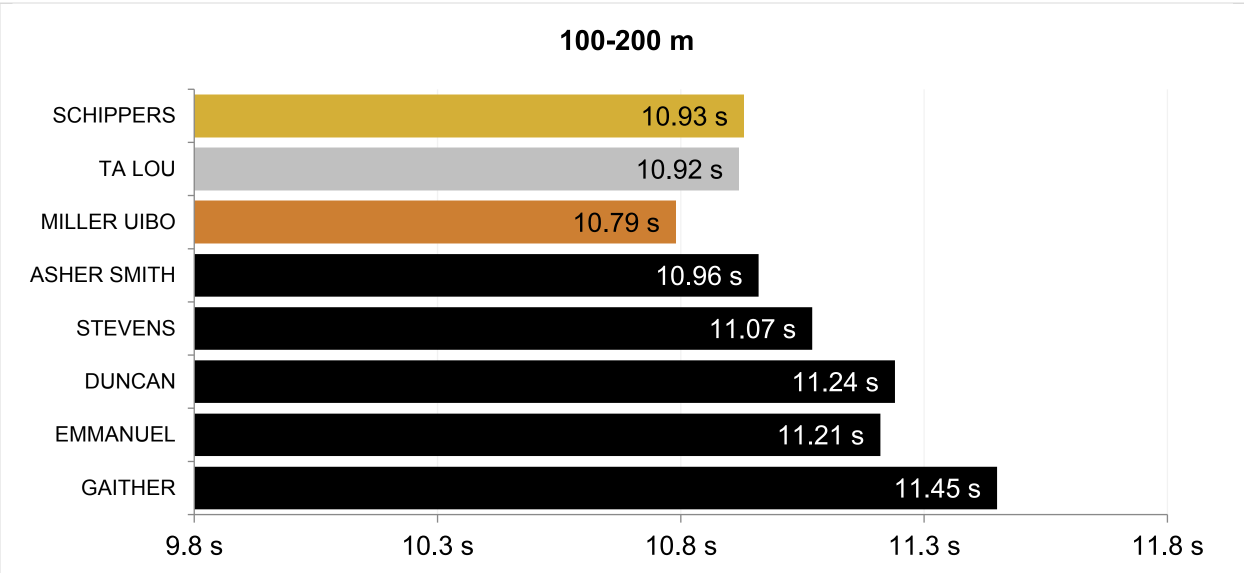

Figure 7. Individual 100-200 m split times.

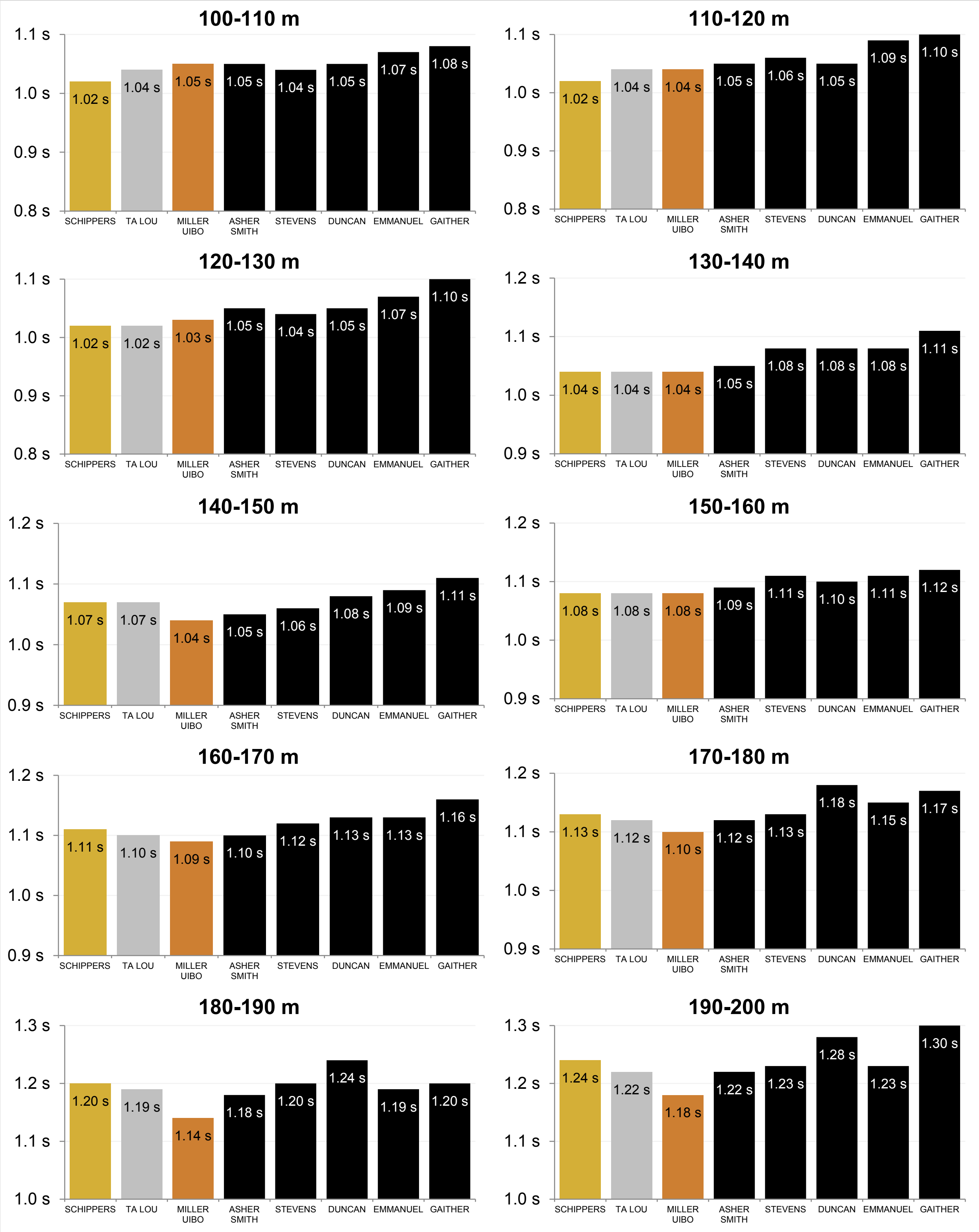

Figure 8. Individual consecutive 10 m split times throughout the home straight.

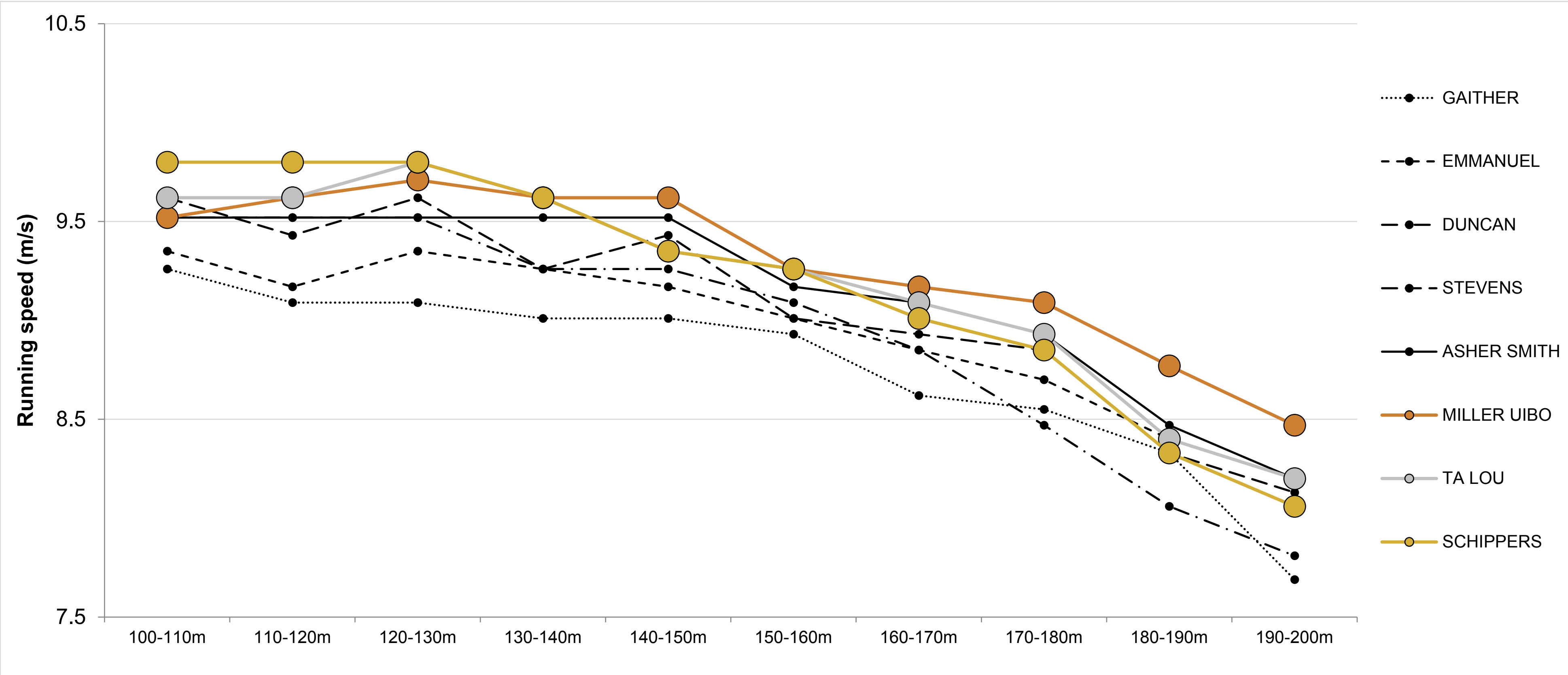

Figure 9. Mean running speed during each 10 m split throughout the home straight.

Completed steps and step length

The following graphs show step information of individual athletes, during the initial 10 m of the race, between 10-100 m and the final 100 m intervals, for the mean step length and relative to each athlete's height (Figure 10). The total completed steps for the race and during each 100 m split for each athlete is presented in Figure 11.

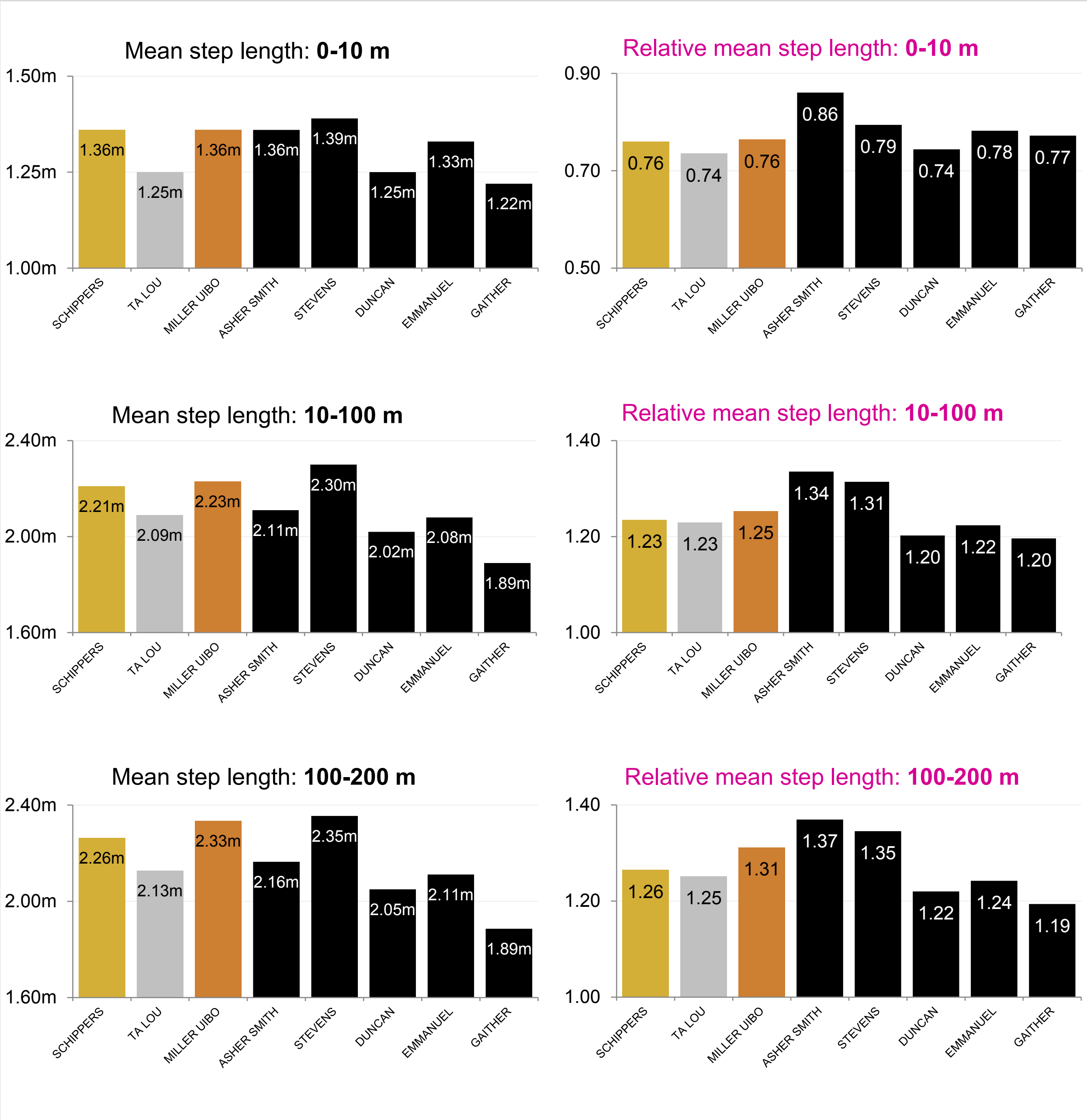

Figure 10. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

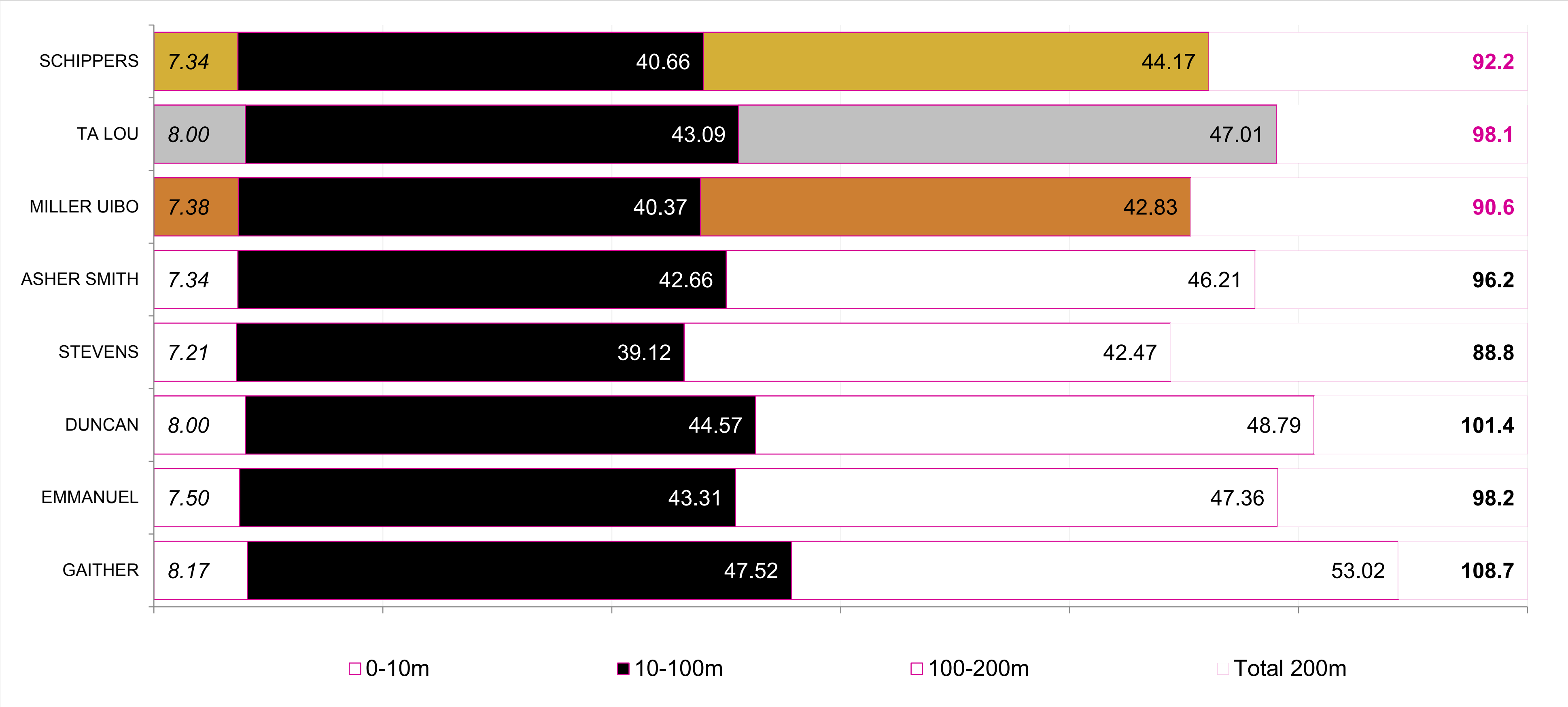

Figure 11. Total number of steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

***Note:** Step based on toe-off to toe-off. Decimals indicate the step was not fully completed within the split interval.*

GOLD MEDALLIST: Dafne Schippers

	RT	0-100 m	100-200 m	RESULT
Final	0.165 s	10.95 s	10.93 s	**22.05 s**
Rank	*4th*	*1st*	*3rd*	***1st***
vs. silver	–0.034 s	–0.01 s	+ 0.01 s	–0.030 s
vs. bronze	+ 0.018 s	–0.26 s	+ 0.14 s	–0.100 s
Semi-Final	0.155 s	11.09 s	11.24 s	**20.49 s**
Rank	*9h*	*2nd*	*5th*	***=1st***

	100-120 m	120-140 m	140-160 m	160-180 m	180-200 m
Final	2.04 s	2.06 s	2.15 s	2.24 s	2.44 s
Rank	*1st*	*=1st*	*3rd*	*=3rd*	*6th*
vs. fastest	0.00 s	0.00 s	+ 0.03 s	+ 0.05 s	+ 0.12 s
vs. silver	–0.04 s	0.00 s	0.00 s	+ 0.02 s	+ 0.03 s
vs. bronze	–0.05 s	–0.01 s	+ 0.03 s	+ 0.05 s	+ 0.12 s
Semi-Final	2.09 s	2.14 s	2.21 s	2.29 s	2.51 s
Rank	*2nd*	*2nd*	*4th*	*5th*	*9th*

Kinematic characteristics

This section presents the results from the digitised data within the calibration zone (i.e., around 150 m) along the home straight. All variables have been described previously (Table 1).

Table 4. Mean step rate, step velocity and step length for each finalist around 150 m.

	Step velocity (m/s)	Step rate (Hz)	Step length (m)	#*relative*
SCHIPPERS	9.42	4.17	2.26	1.26
TA LOU	9.08	4.28	2.12	1.25
MILLER-UIBO	9.27	3.94	2.35	1.32
ASHER-SMITH	9.12	4.28	2.13	1.35
STEVENS	9.20	3.90	2.36	1.35
DUNCAN	9.03	4.41	2.05	1.22
EMMANUEL	8.88	4.17	2.13	1.25
GAITHER	8.76	4.61	1.90	1.20

Note: *Step velocity calculated from step length and step time; # relative step length based on athlete's height.*

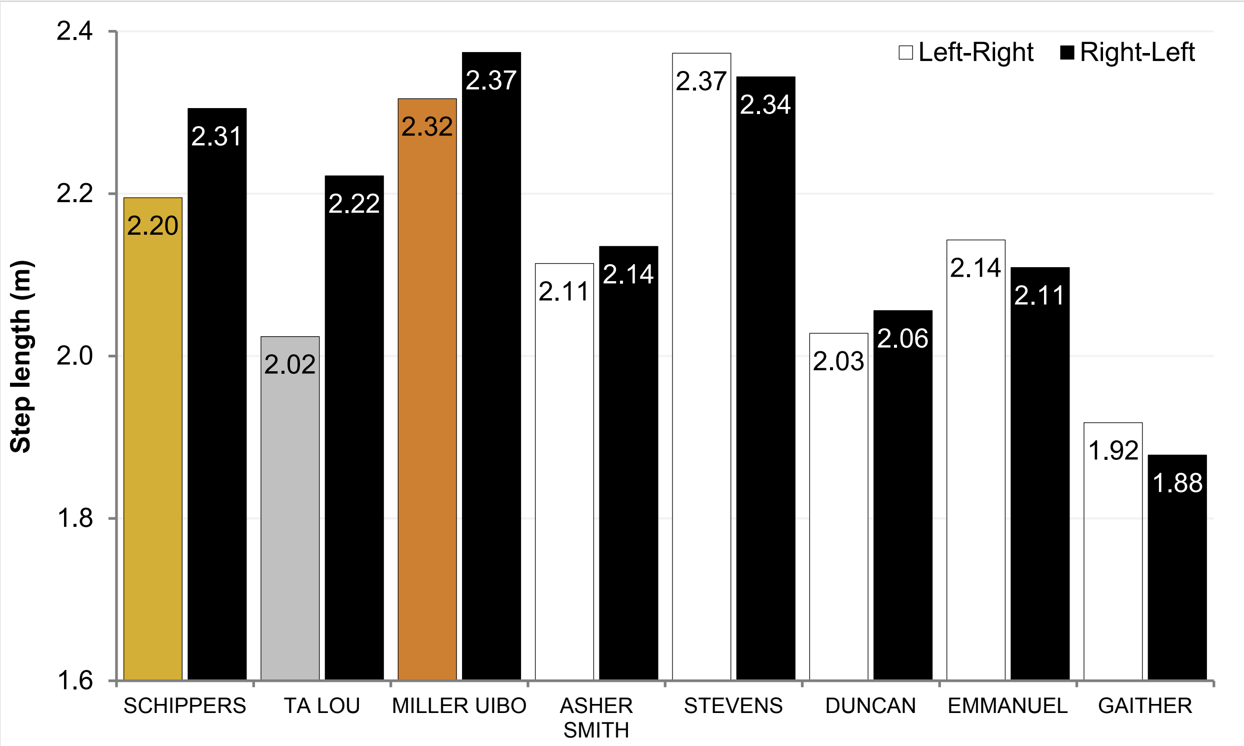

Figure 12. Step lengths for each of the finalists around 150 m.

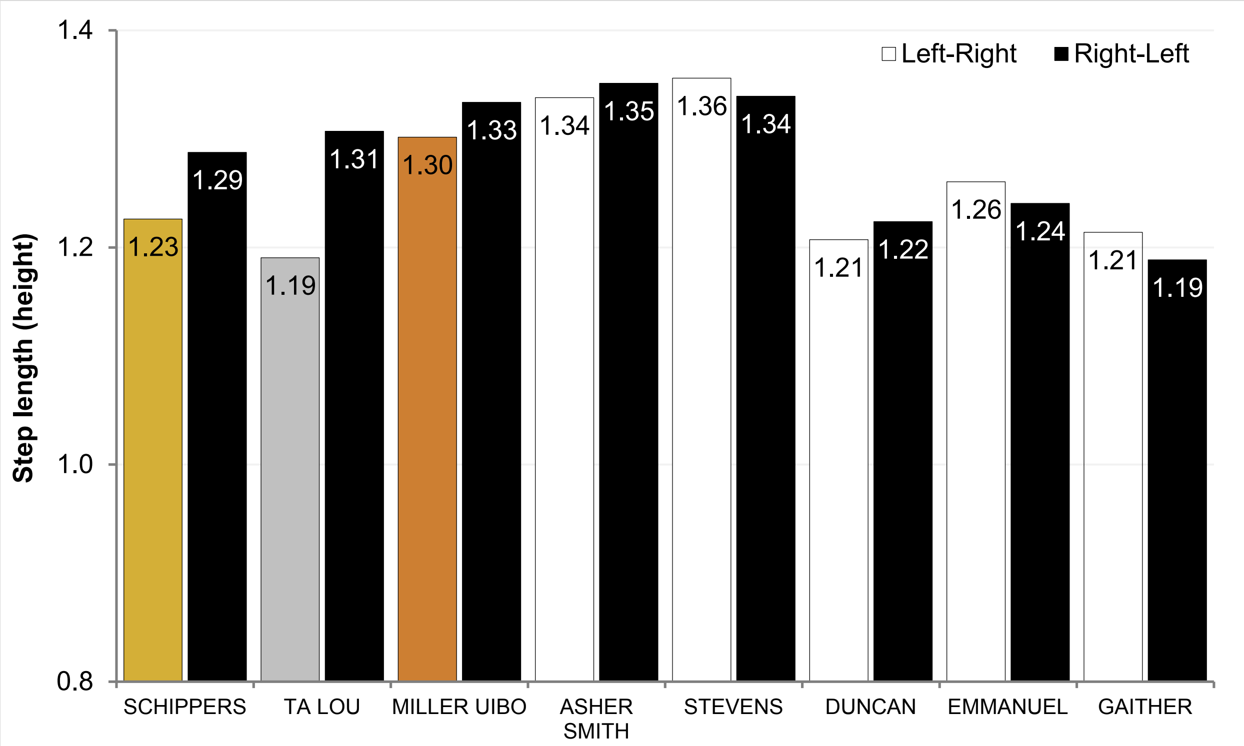

Figure 13. Relative (height) step lengths for each of the finalists around 150 m.

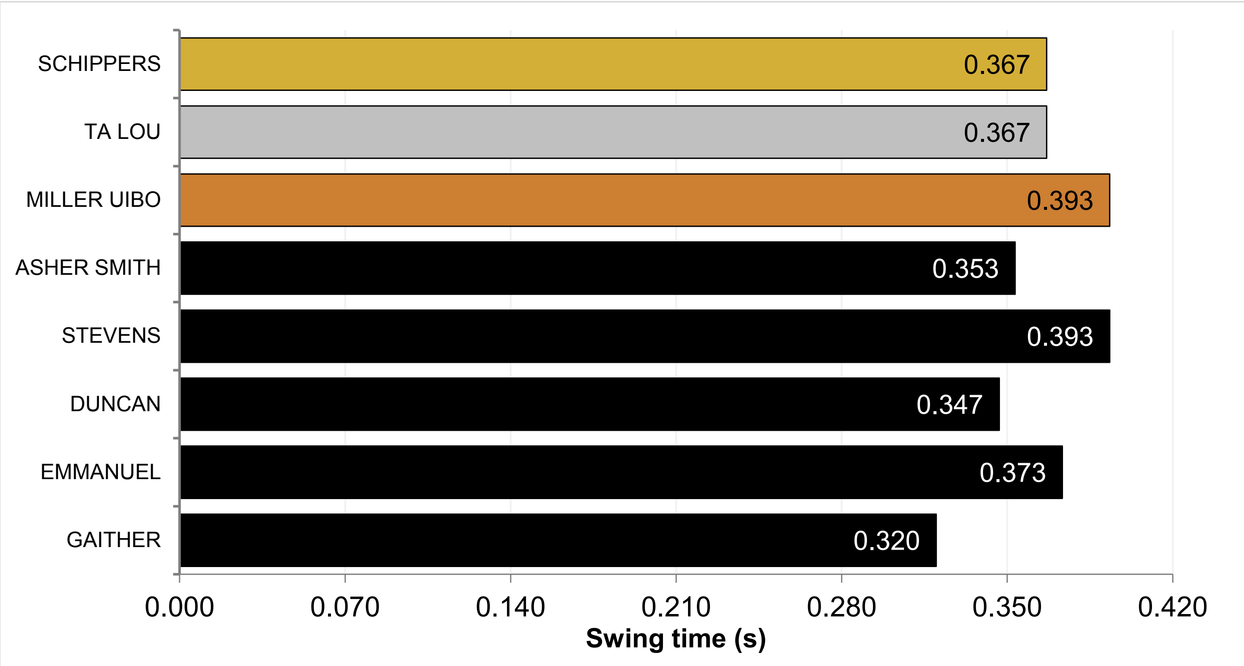

Figure 14. Swing times for each of the finalists around 150 m.

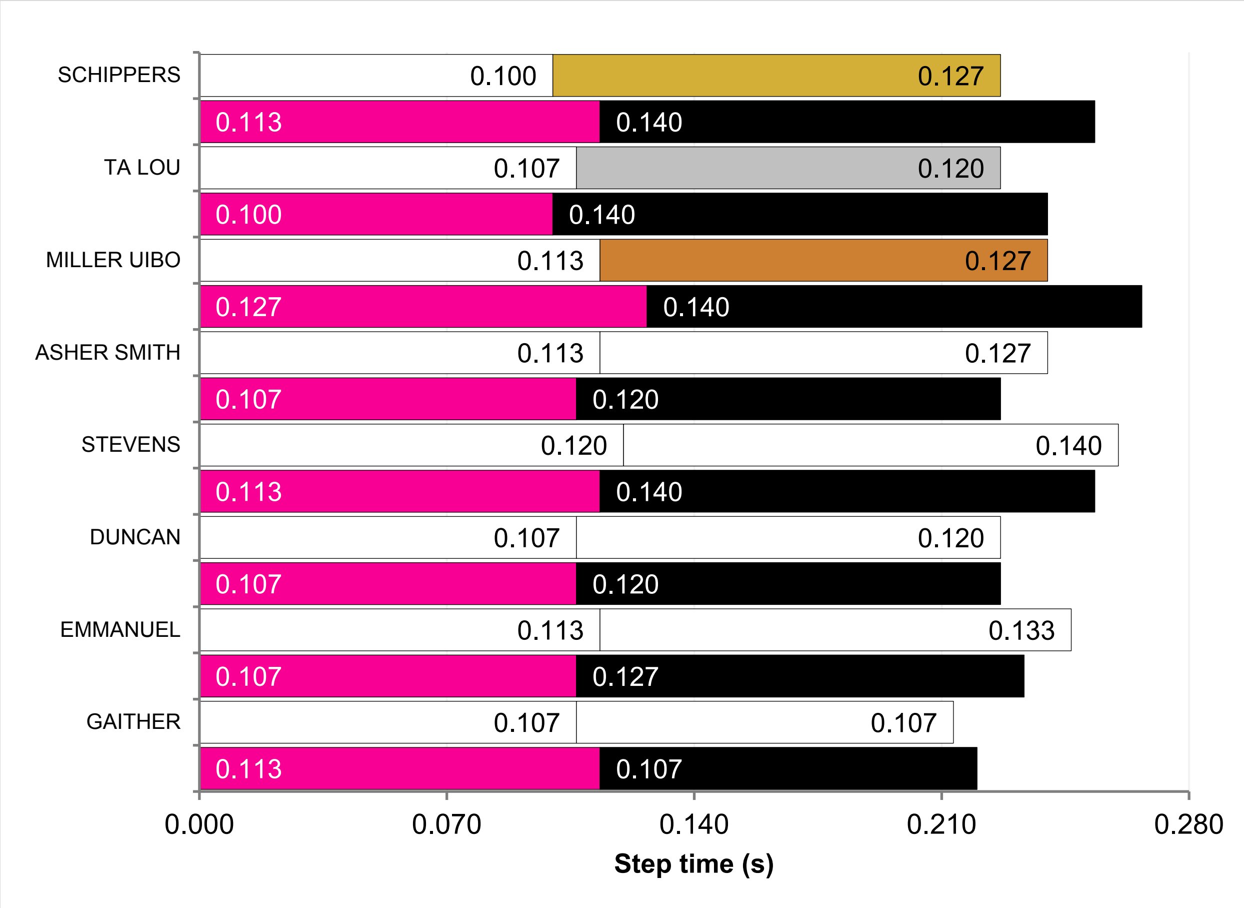

Figure 15. Individual contact and flight times for each of the finalists around 150 m. For each athlete, the top column (black text) represents the left foot contact and left-to-right flight time, and the bottom column (white text) represents the right foot contact (pink shading) and right-to-left flight time (black shading).

Table 5. Horizontal distance to the centre of mass (DCM) at touchdown (TD) and toe-off (TO).

	DCM TD (m / % body height)		DCM TO (m / % body height)	
	Left	Right	Left	Right
SCHIPPERS	0.40 / 22	0.49 / 27	0.48 / 27	0.50 / 28
TA LOU	0.43 / 25	0.40 / 24	0.47 / 27	0.47 / 27
MILLER-UIBO	0.44 / 24	0.53 / 29	0.58 / 33	0.58 / 32
ASHER-SMITH	0.42 / 27	0.39 / 25	0.53 / 34	0.52 / 33
STEVENS	0.47 / 27	0.50 / 28	0.56 / 32	0.52 / 30
DUNCAN	0.41 / 24	0.43 / 26	0.49 / 29	0.44 / 26
EMMANUEL	0.42 / 25	0.37 / 22	0.49 / 29	0.52 / 31
GAITHER	0.42 / 27	0.37 / 23	0.47 / 30	0.50 / 32

Note: *Data displayed as an absolute distance and as a percentage of the athletes' heights. Percentage values have been rounded to the nearest integer.*

The graph below contains time-series data for the resultant velocity of the foot centre of mass, displayed as a percentage of swing time. Here, 0% represents the first frame of toe-off and 100% represents ipsilateral touchdown. The peak vertical and resultant velocities, and the relative time of each, during the swing phase velocity for each of the medallists are presented in Table 6. Silver medallist, Marie-Josée Ta Lou, is not displayed due to obstructed camera views during significant parts of the swing phase.

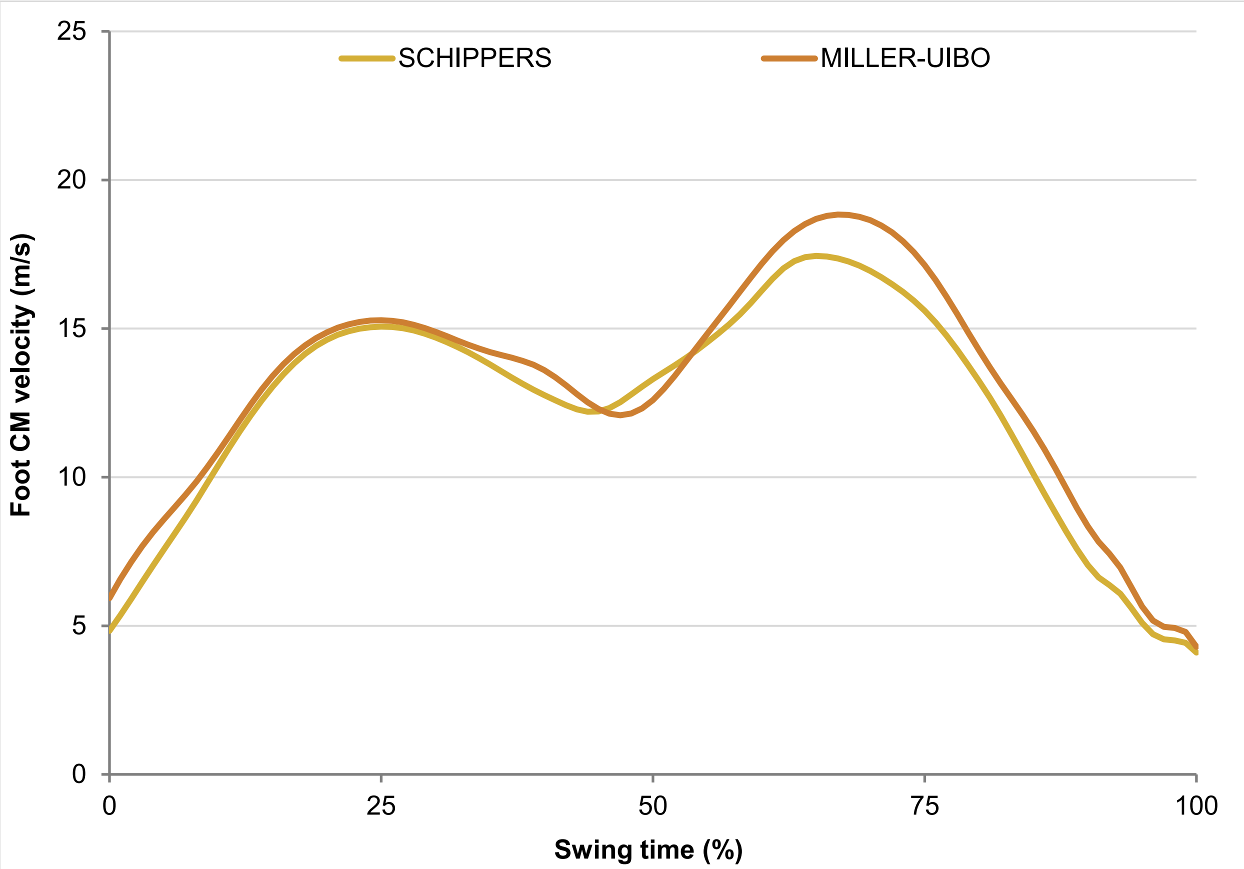

Figure 16. Resultant foot centre of mass (CM) velocity during the swing phase for the medallists, displayed as a percentage of swing time.

Table 6. Peak vertical and resultant foot CM velocity, and the relative time (% phase), that each peak occurred during the swing phase.

	Vertical velocity (m/s)	%	Resultant velocity (m/s)	%
SCHIPPERS	7.13	12	17.45	65
TA LOU	-	-	-	-
MILLER-UIBO	8.33	13	18.84	67

Note: *0% indicates toe-off and 100% indicates the final frame before ipsilateral touchdown.*

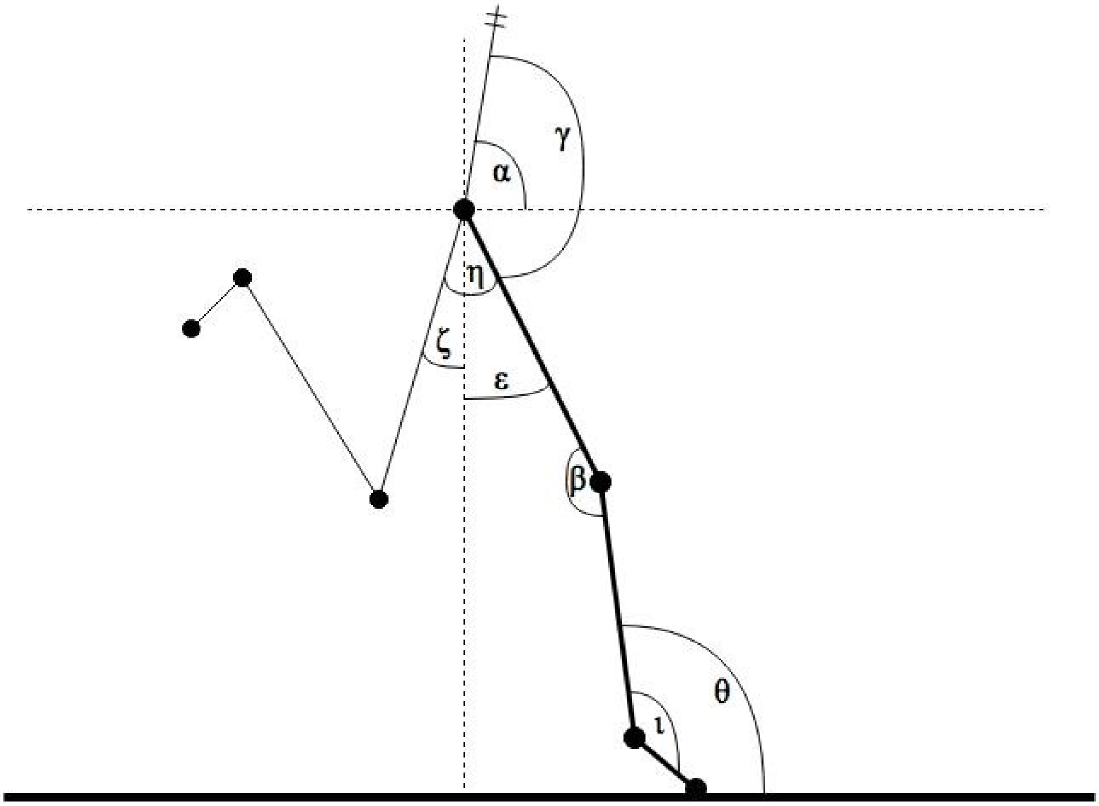

Figure 17. Body schematic denoting joint angles measured at touchdown. This does not represent any athlete's posture but is merely for illustration purposes.

Table 7. Joint angles at touchdown for the three medallists.

	SCHIPPERS		TA LOU		MILLER-UIBO	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	86.3	93.4	85.8	80.1	83.3	85.1
β	168.5	160.4	158.7	153.6	159.4	151.9
γ	156.4	151.4	153.7	150.4	154.7	146.5
ε	22.7	28.5	28.5	29.1	24.0	32.8
ζ	15.6	4.8	–4.5	–1.7	4.0	–8.0
η	–7.1	–23.7	–33.0	–30.8	–20.0	–40.8
θ	102.3	101.1	102.6	96.6	102.7	100.9
ι	123.5	118.7	112.1	123.2	109.7	99.7

Note: *For angles* **ε** *and* **ζ***, a positive value indicates that the thigh segment was in front of the vertical axis. For angle* **η***, a negative value indicates that the swing leg is behind the touchdown leg at the point of contact, whereas a positive value indicates the swing thigh is in front of the contralateral thigh segment. The 2-D schematic should not be used as a model to combine angles as different landmarks have been used for defining certain angles.*

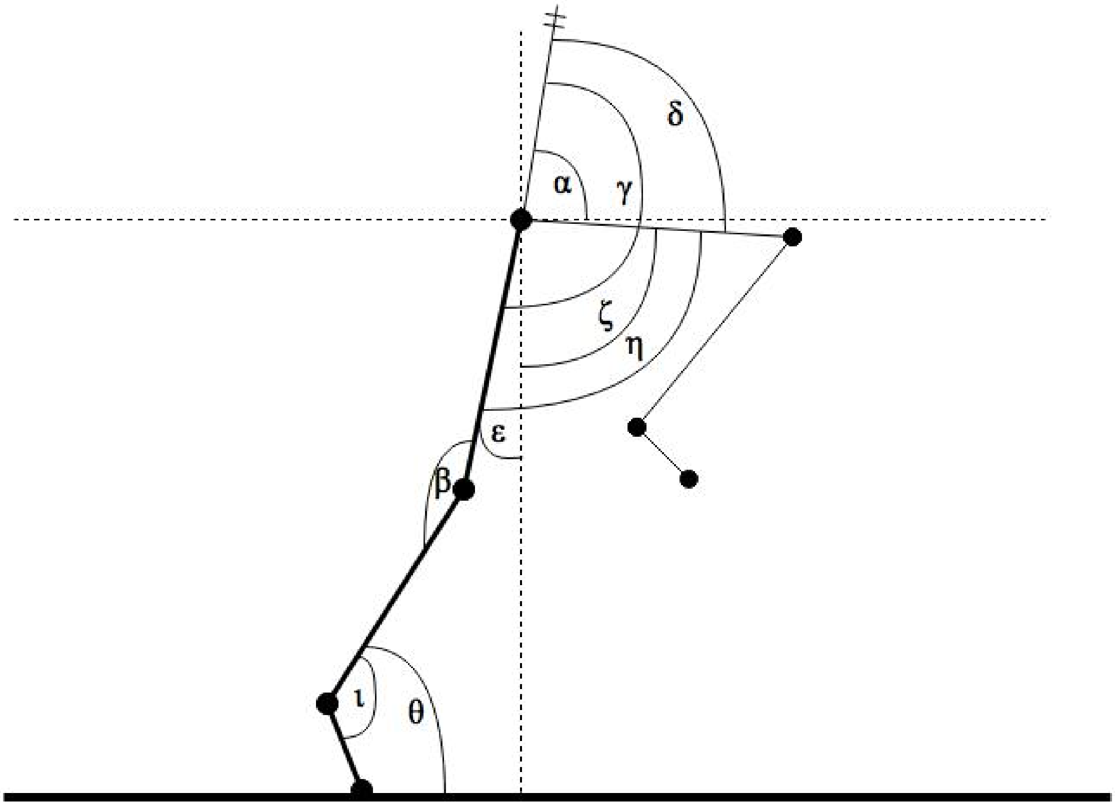

Figure 18. Body schematic denoting joint angles measured at toe-off. This does not represent any athlete's posture but is merely for illustration purposes.

Table 8. Joint angles at toe-off for the three medallists.

	SCHIPPERS		TA LOU		MILLER-UIBO	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	86.4	88.8	89.4	84.4	85.8	88.7
β	164.1	158.7	171.6	156.0	163.9	164.8
γ	210.3	203.3	212.1	203.3	208.0	203.4
δ	118.1	116.4	123.9	123.3	114.7	121.2
ε	–29.4	–24.6	–38.2	–26.9	–30.4	–28.9
ζ	68.3	66.1	62.4	59.7	66.0	63.7
η	97.7	90.7	100.6	86.6	96.4	92.6
θ	44.8	44.1	44.2	41.7	43.7	45.8
ι	131.9	138.2	121.1	118.3	136.9	140.3

Note: *For angles **ε** and ζ, a positive value indicates that the thigh segment was in front of the vertical axis. For angle **η**, a negative value indicates that the swing leg is behind the touchdown leg at the point of contact, whereas a positive value indicates the swing thigh is in front of the contralateral thigh segment. The 2-D schematic should not be used as a model to combine angles as different landmarks have been used for defining certain angles.*

Table 9. Joint angles at touchdown for the remaining five finalists.

	ASHER-SMITH		STEVENS		DUNCAN		EMMANUEL		GAITHER	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	84.4	76.8	83.4	85.8	82.9	82.1	86.7	83.5	86.9	85.2
β	153.4	148.8	160.9	144.8	173.7	162.3	160.2	151.1	157.9	155.2
γ	150.3	135.6	149.4	149.9	154.4	152.7	154.1	143.6	151.8	149.8
ε	31.4	33.4	30.6	35.1	20.8	25.2	28.2	32.8	30.8	28.9
ζ	–2.5	–2.2	0.4	0.7	–0.1	–1.2	3.4	16.7	–6.2	–0.2
η	–33.9	–35.6	–30.2	–34.4	–20.9	–26.4	–24.8	–16.1	–37.0	–29.1
θ	100.5	96.2	101.7	92.6	105.2	97.7	102.4	95.8	101.5	94.3
ι	112.5	110.1	112.1	101.0	131.6	121.3	111.7	114.7	115.5	113.2

Note: *For angles* **ε** *and* **ζ**, *a positive value indicates that the thigh segment was in front of the vertical axis. For angle* **η**, *a negative value indicates that the swing leg is behind the touchdown leg at the point of contact, whereas a positive value indicates the swing thigh is in front of the contralateral thigh segment. The 2-D schematic should not be used as a model to combine angles as different landmarks have been used for defining certain angles.*

Table 10. Joint angles at toe-off for the remaining five finalists.

	ASHER-SMITH		STEVENS		DUNCAN		EMMANUEL		GAITHER	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	81.7	88.2	88.9	84.7	85.1	87.3	87.8	84.7	89.1	86.4
β	160.0	155.6	159.2	159.0	169.1	164.0	166.8	156.2	165.5	162.5
γ	200.3	199.3	203.2	211.0	200.5	203.2	201.3	201.5	204.5	206.3
δ	107.5	124.3	108.3	120.9	124.1	129.5	118.8	116.0	129.0	123.1
ε	–32.5	–26.6	–28.2	–27.7	–29.2	–26.3	–27.8	–42.4	–31.0	–19.6
ζ	69.3	61.9	76.1	65.6	57.0	55.9	64.2	71.5	56.8	63.4
η	101.8	88.5	104.3	93.3	86.2	82.2	92.0	113.9	87.8	83.0
θ	38.5	39.8	40.9	42.2	49.9	47.7	49.0	42.4	44.8	43.4
ι	115.8	121.0	141.8	139.0	141.6	140.3	146.0	132.7	136.5	140.7

Note: *For angles* **ε** *and* **ζ**, *a positive value indicates that the thigh segment was in front of the vertical axis. For angle* **η**, *a negative value indicates that the swing leg is behind the touchdown leg at the point of contact, whereas a positive value indicates the swing thigh is in front of the contralateral thigh segment. The 2-D schematic should not be used as a model to combine angles as different landmarks have been used for defining certain angles.*

RESULTS – Semi-Final 1

Performance data

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

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
SCHIPPERS	*3*	*1*	22.49 s	Q	0.39 s	0.86 s
STEVENS	*2*	*4*	22.71 s	Q	0.62 s	0.62 s
LALOVA-COLLIO	*14*	*8*	22.96 s		0.14 s	0.64 s
HAASE	*12*	*17*	23.03 s		0.27 s	0.27 s
FORBES	*8*	*15*	23.09 s		0.38 s	0.38 s
ATCHO	*18*	*20*	23.12 s		0.22 s	0.22 s
PALFRAMAN	*16*	*19*	23.21 s	*.204 s**	0.36 s	0.36 s
STRACHAN	*16*	*8*	23.21 s	*.207 s*	0.37 s	0.89 s

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

Positional analysis

Figure 19 shows the relative position of each athlete at each 20 m split along the home straight.

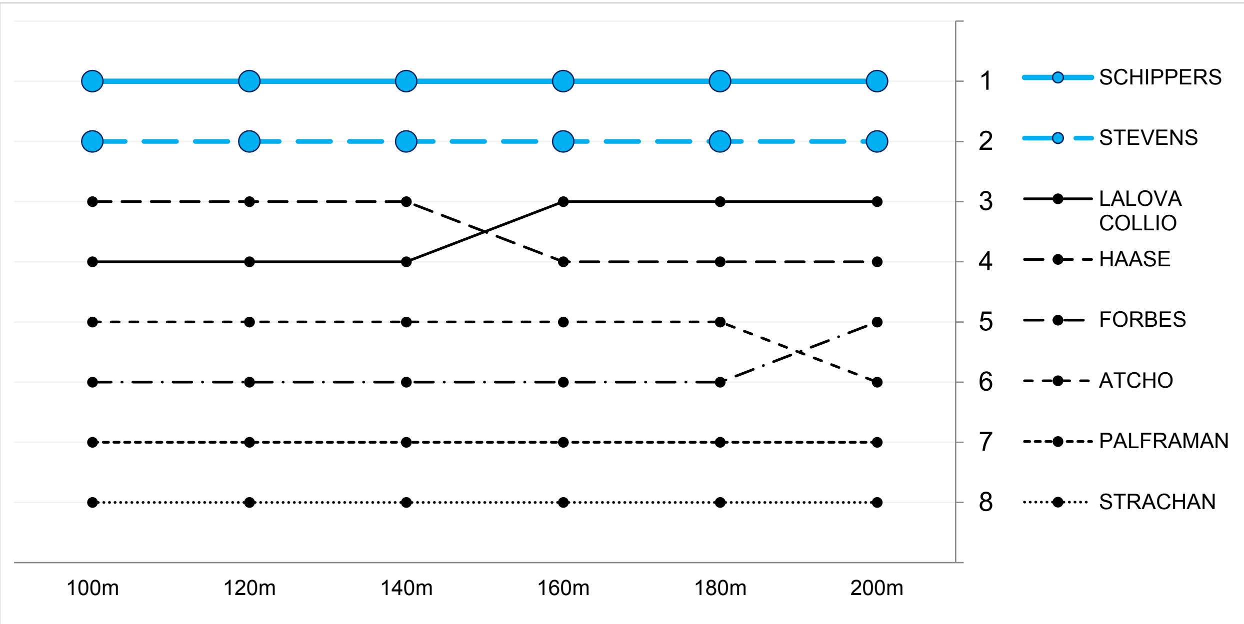

Figure 19. Positions at the beginning of the home straight and at each 20 m split.

Individual split times

The following graphs display the split times of all athletes over each: 100 m split (Figures 20 and 21; note: 0-100 m is displayed without the reaction time), and consecutive 20 m splits during the home straight (Figure 22). The mean speed over progressive 20 m splits throughout the home straight is presented in Figure 23.

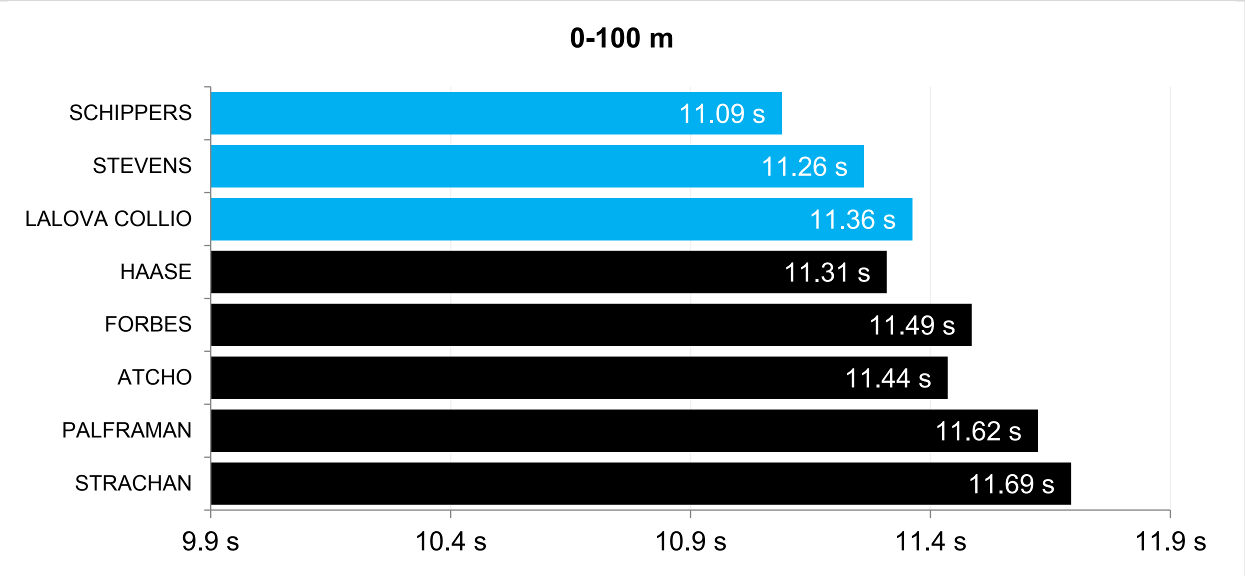

Figure 20. Individual 0-100 m split times (minus reaction time).

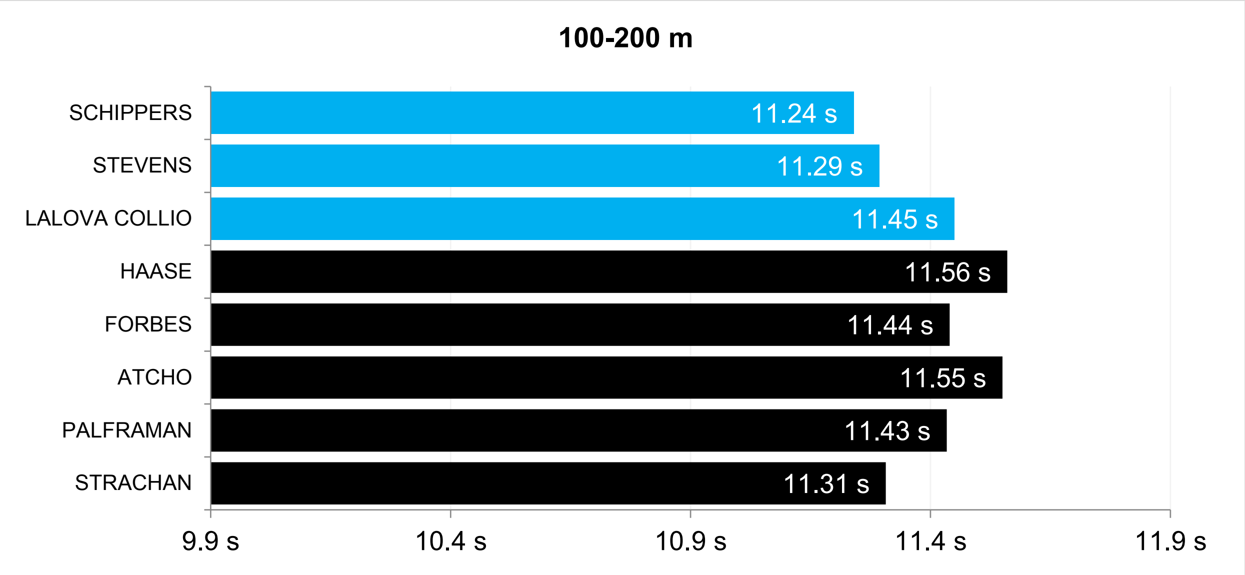

Figure 21. Individual 100-200 m split times.

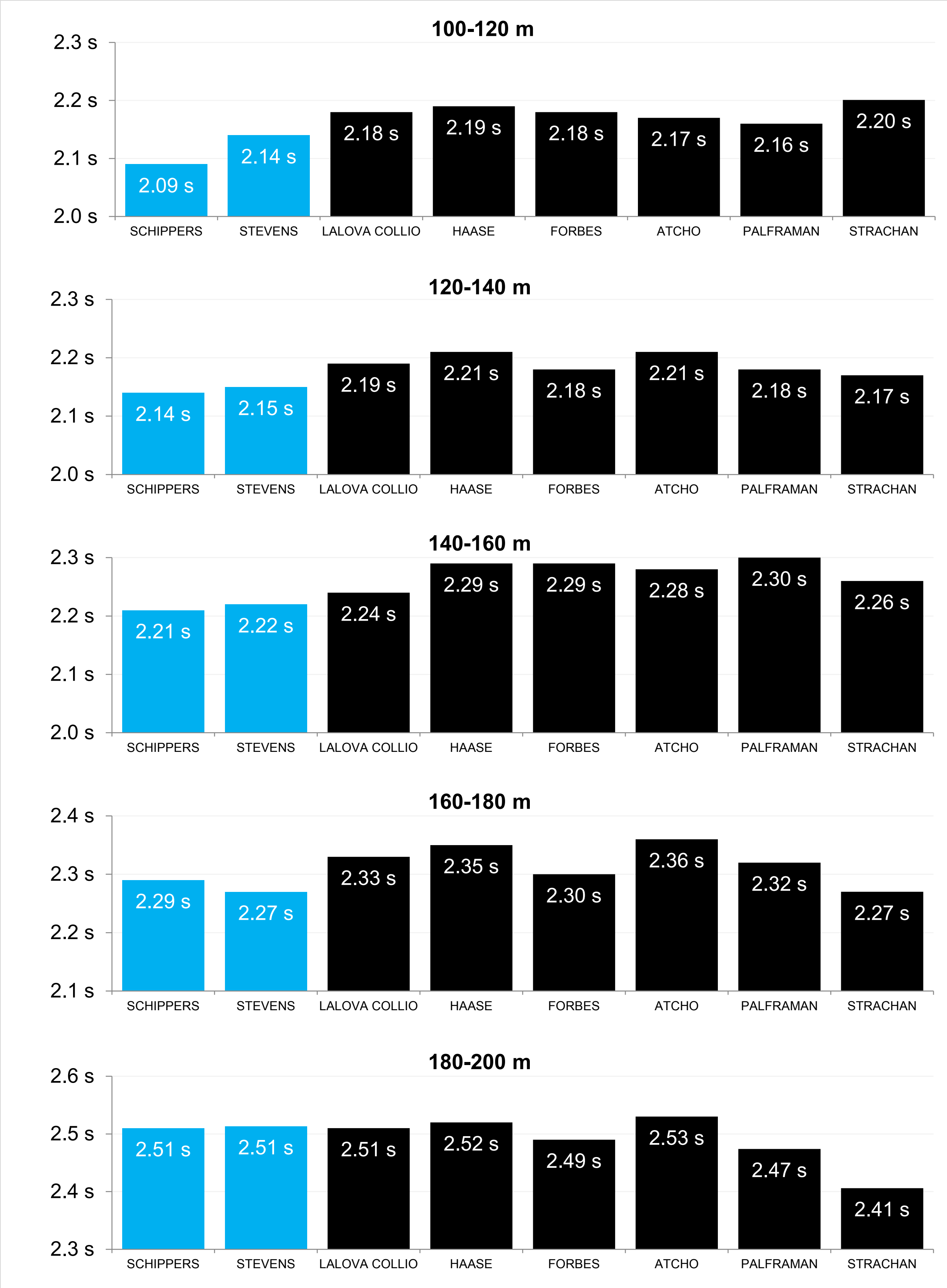

Figure 22. Individual consecutive 20 m split times during the home straight.

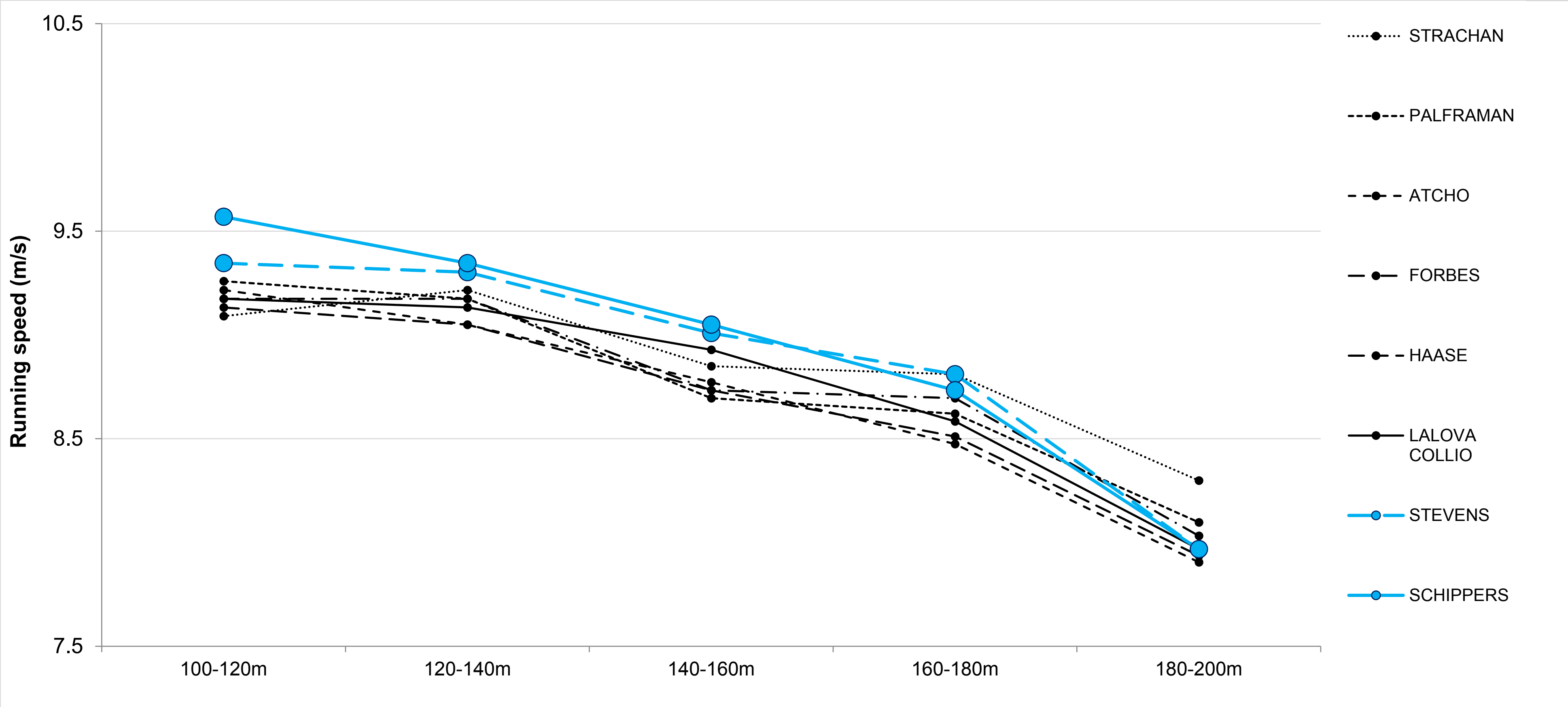

Figure 23. Mean running speed during each 20 m split throughout the home straight.

Completed steps and step length

The following graphs show step information of individual athletes, during the initial 10 m of the race, between 10-100 m and the final 100 m intervals, for the mean step length and relative to each athlete's height (Figure 24). The total completed steps for the race and during each 100 m split for each athlete is presented in Figure 25.

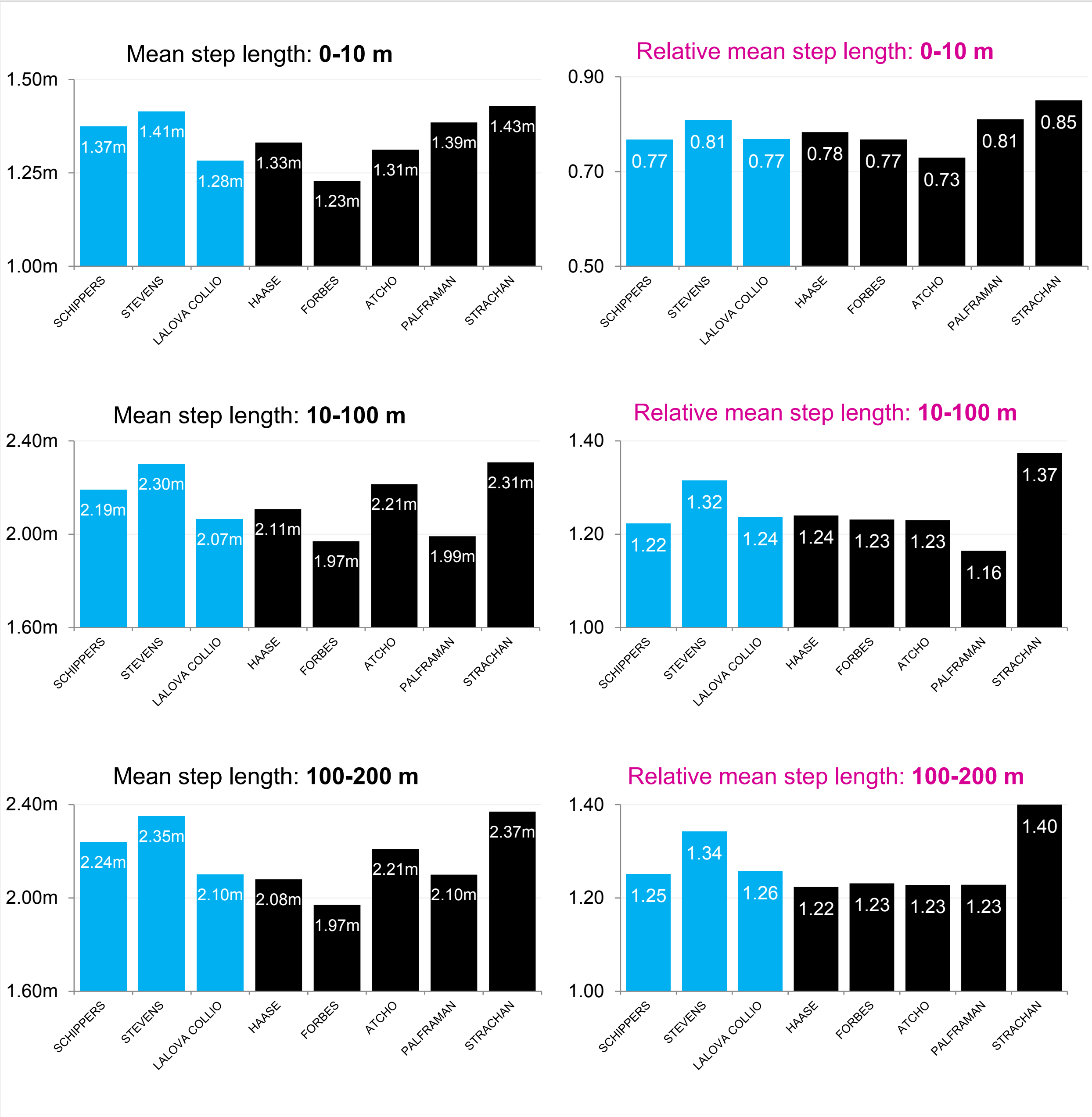

Figure 24. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

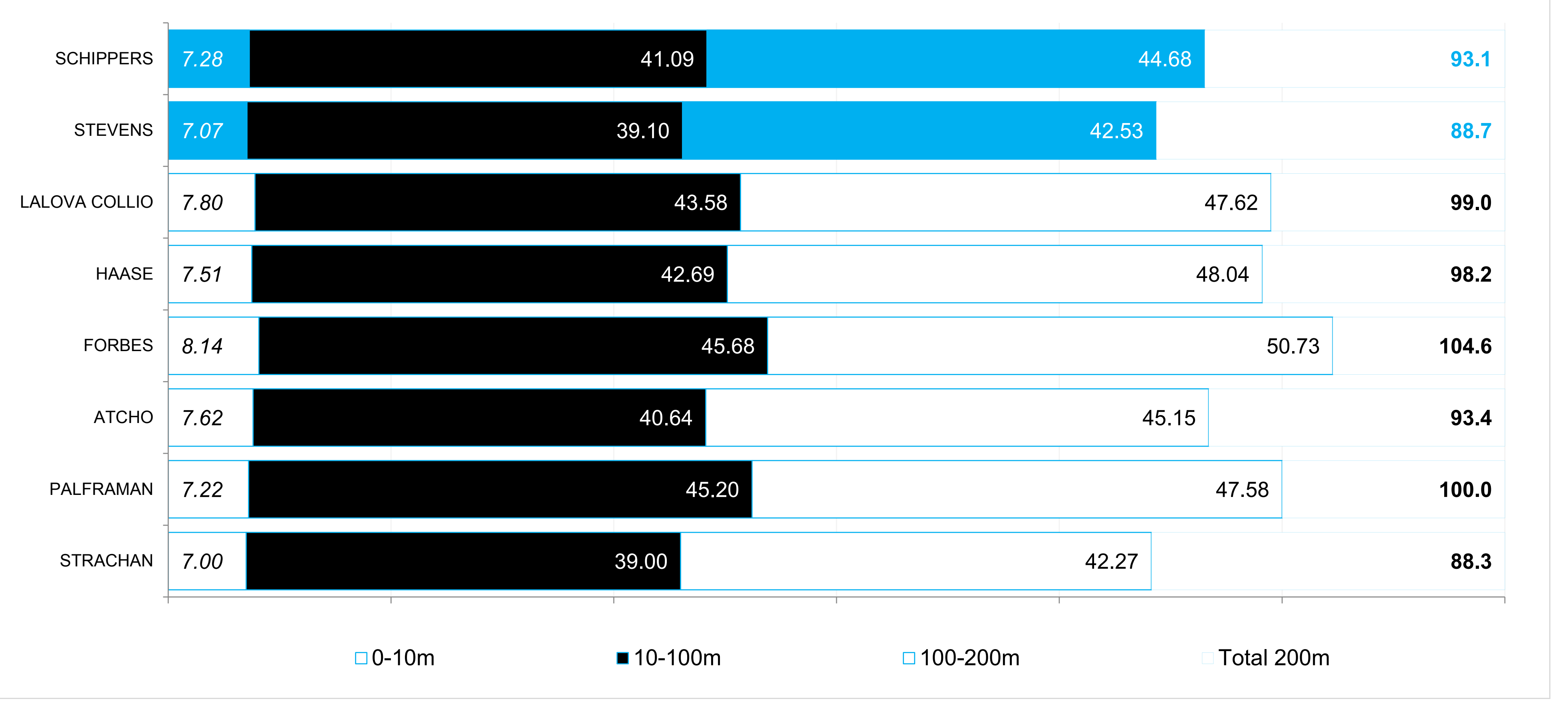

Figure 25. Total completed steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

RESULTS – Semi-Final 2

Performance data

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

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
MILLER-UIBO	*1*	*2*	22.49 s	Q	0.58 s	0.58 s
DUNCAN	*7*	*6*	22.73 s	Q	0.19 s	0.54 s
KAMBUNDJI	*5*	*10*	23.00 s		0.58 s	0.58 s
FACEY	*11*	*7*	23.01 s		0.27 s	0.76 s
ODIONG	*21*	*16*	23.24 s		0.29 s	0.50 s
WILLIAMS	*15*	*14*	23.40 s		0.57 s	0.82 s
HACKETT	*13*	*12*	23.54 s		0.77 s	1.03 s
SANTOS	*21*	*18*	-	*DQ*	-	-

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

Positional analysis

Figure 26 shows the relative position of each athlete at each 20 m split along the home straight.

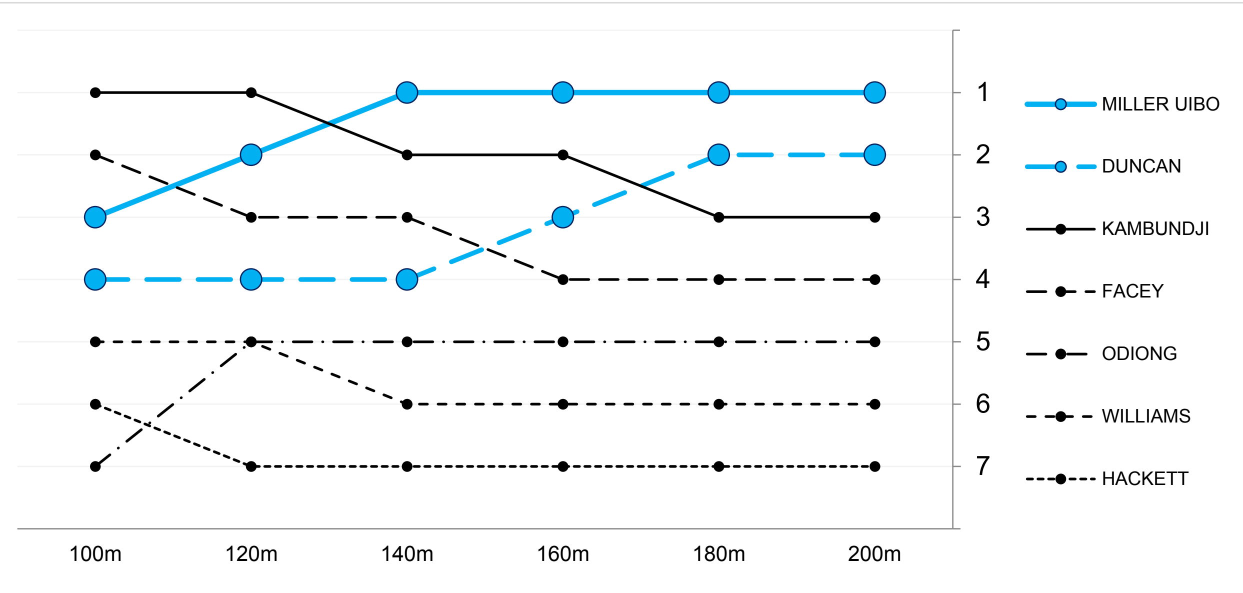

Figure 26. Positions at the beginning of the home straight and each 20 m split.

Individual split times

The following graphs display the split times of all athletes over each: 100 m split (Figures 27 and 28; note: 0-100 m is displayed without the reaction time), and consecutive 20 m splits during the home straight (Figure 29). The mean speed over progressive 20 m splits throughout the home straight is presented in Figure 30.

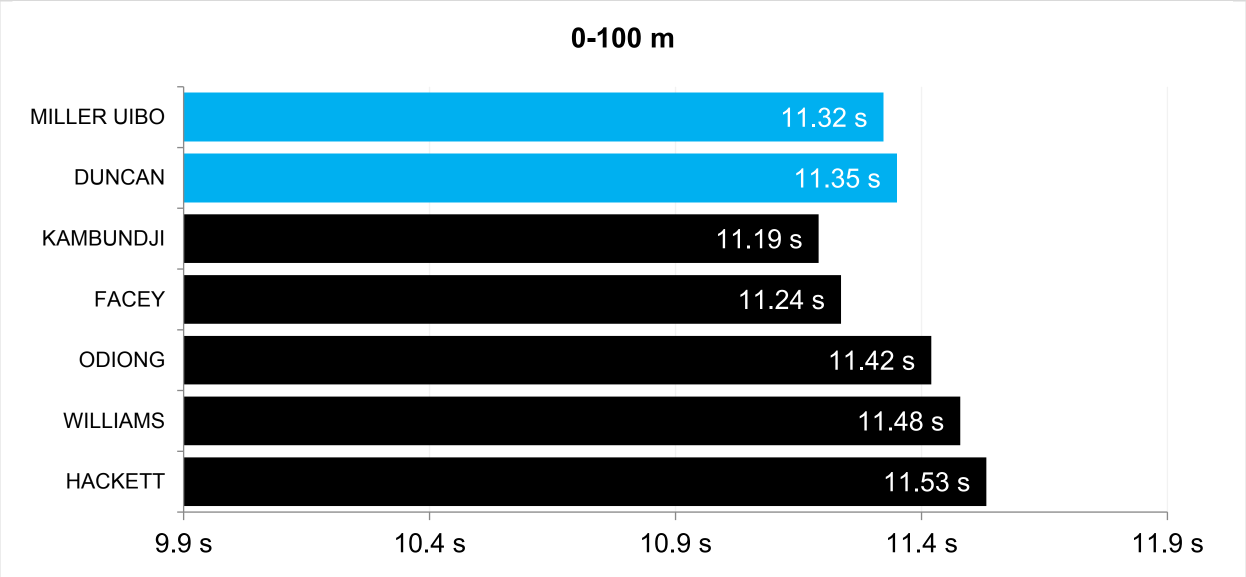

Figure 27. Individual 0-100 m split times (minus reaction time).

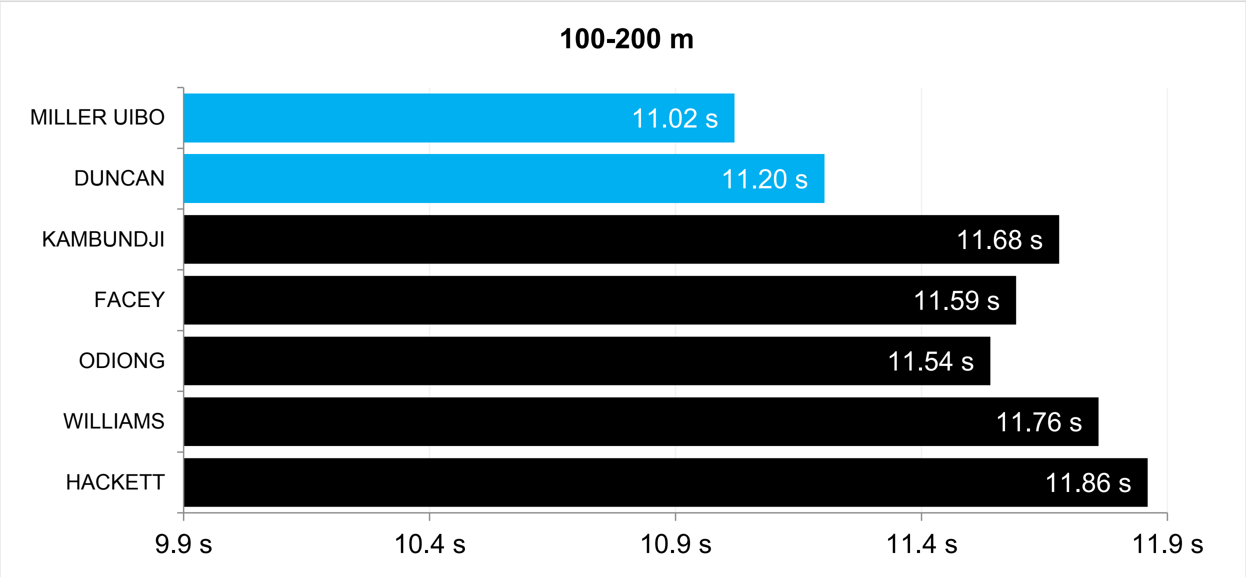

Figure 28. Individual 100-200 m split times.

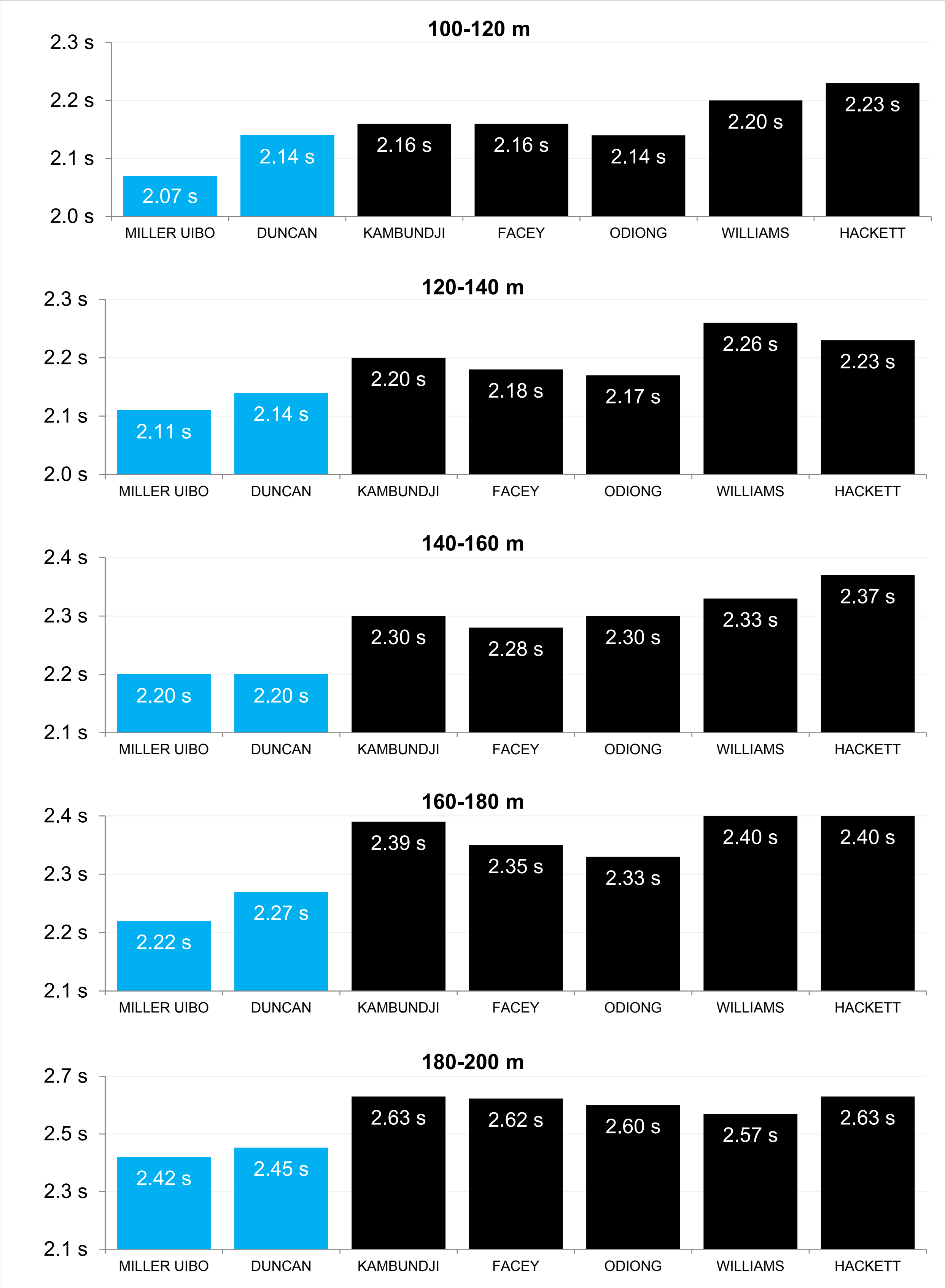

Figure 29. Individual consecutive 20 m split times during the home straight.

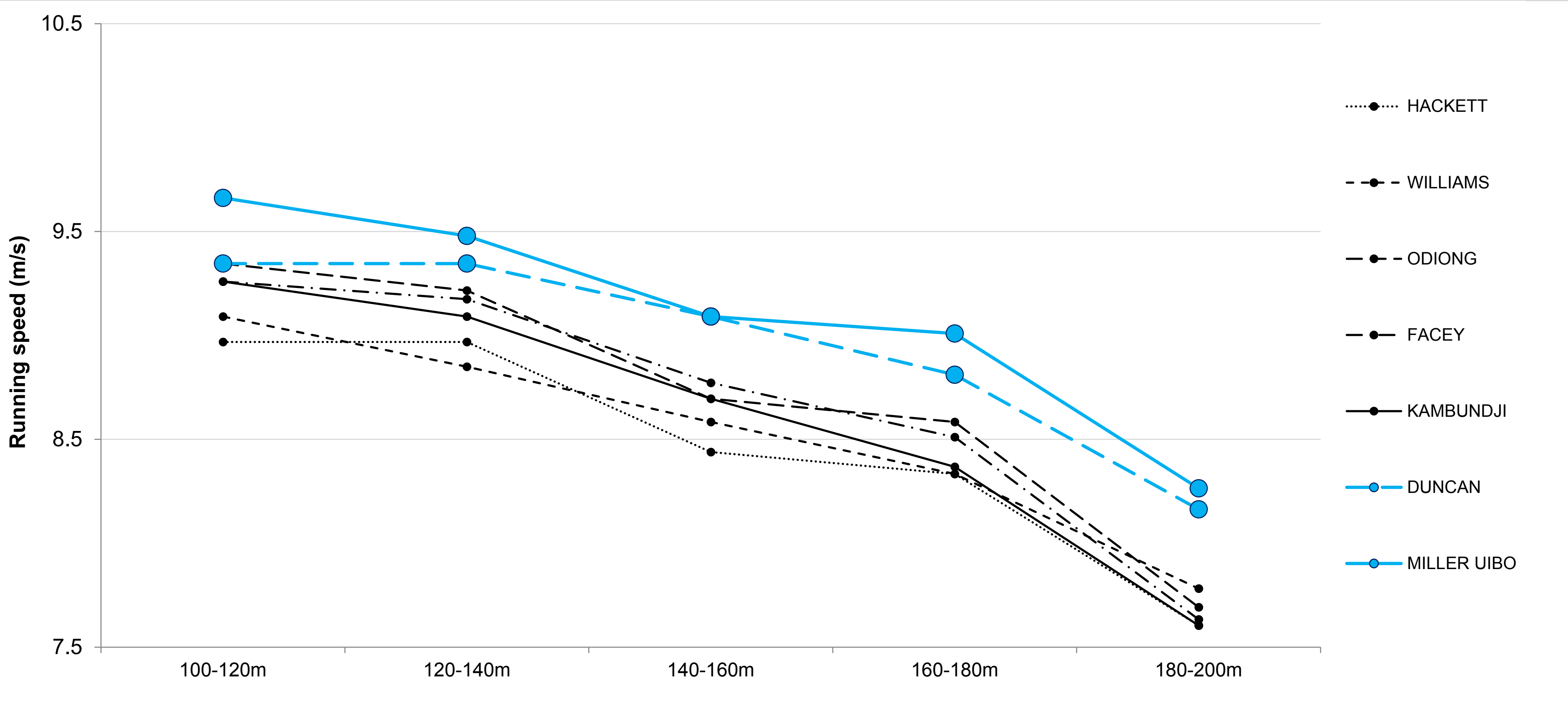

Figure 30. Mean running speed during each 20 m split throughout the home straight.

Completed steps and step length

The following graphs show step information of individual athletes, during the initial 10 m of the race, between 10-100 m and the final 100 m intervals, for the mean step length and relative to each athlete's height (Figure 31). The total completed steps for the race and during each 100 m split for each athlete is presented in Figure 32.

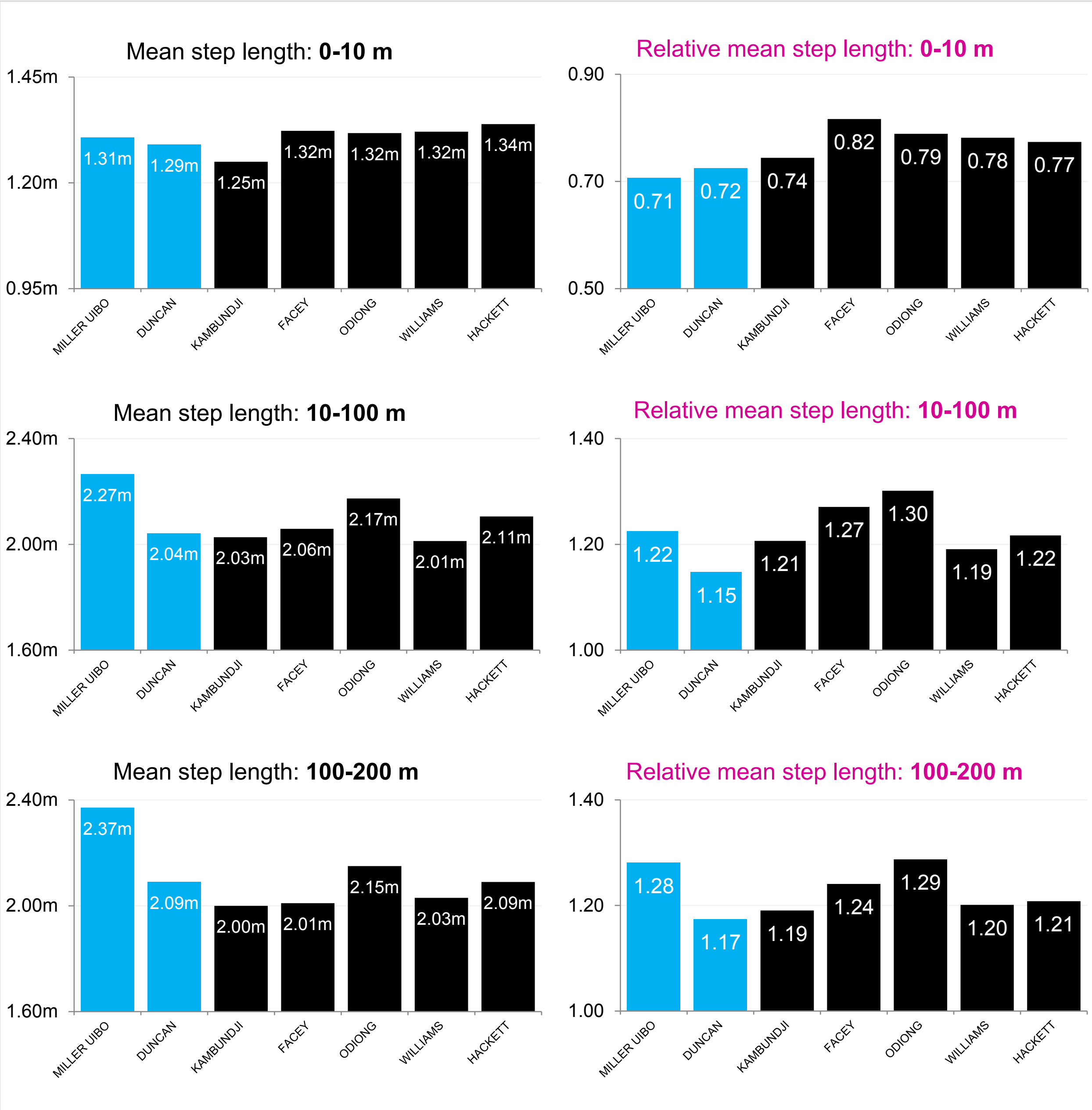

Figure 31. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

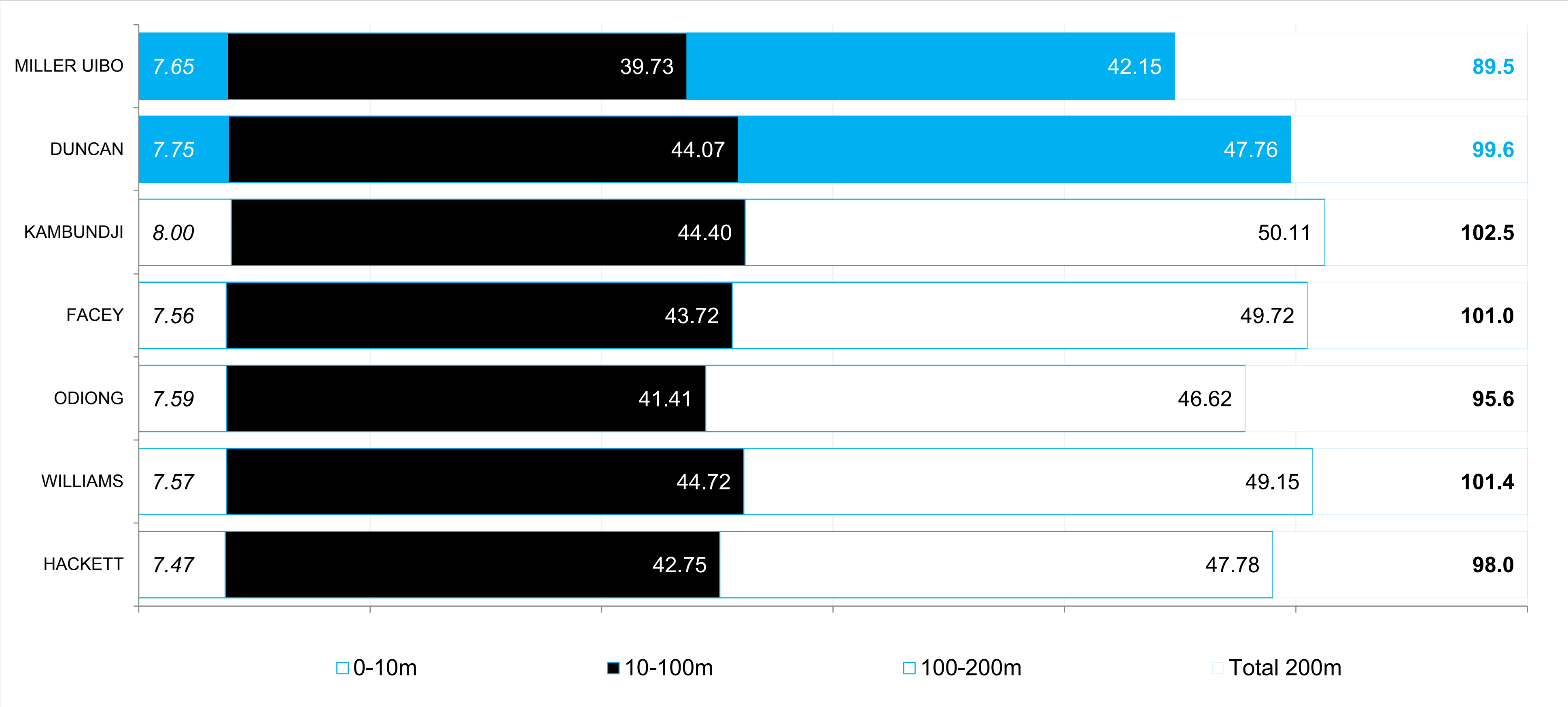

Figure 32. Total completed steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

RESULTS – Semi-Final 3

Performance data

Table 13 below displays the ranking of each athlete before the World Championships across all athletes qualifying for the semi-finals, based on their season's (SB) and personal best (PB) times, and a comparison to their semi-final time.

Table 13. 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
TA LOU	*4*	5	22.50 s	*Q*	0.34 s	0.34 s
ASHER-SMITH	*10*	3	22.73 s	*Q SB*	0.00 s	0.66 s
EMMANUEL	*6*	*11*	22.85 s	*q .848 s*	0.35 s	0.35 s
GAITHER	*8*	*13*	22.85 s	*q .850 s*	0.14 s	0.31 s
BELIMPASAKI	*23*	*23*	23.21 s		0.21 s	0.21 s
ROSA	*19*	*21*	23.31 s		0.38 s	0.38 s
WILLIAMS	*20*	*22*	23.32 s		0.38 s	0.38 s
RAFFAI	*24*	*24*	23.45 s		0.40 s	0.40 s

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

Positional analysis

Figure 33 shows the relative position of each athlete at each 20 m split along the home straight.

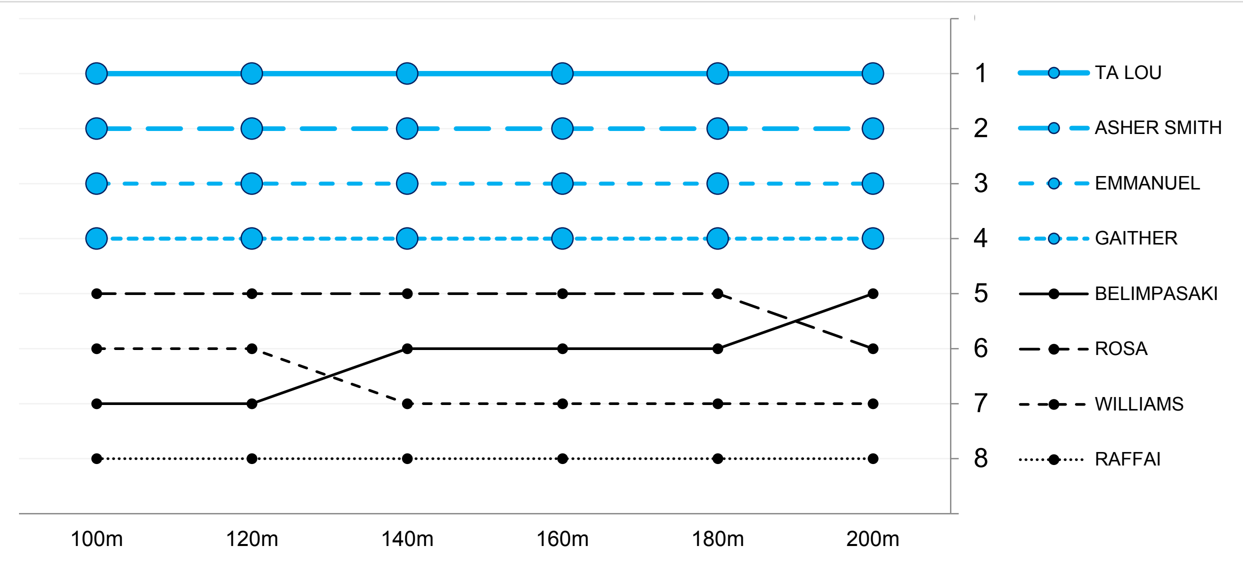

Figure 33. Positions at the beginning of the home straight and each 20 m split.

Individual split times

The following graphs display the split times of all athletes over each: 100 m split (Figures 34 and 35; note: 0-100 m is displayed without the reaction time), and consecutive 20 m splits during the home straight (Figure 36). The mean speed over progressive 20 m splits throughout the home straight is presented in Figure 37.

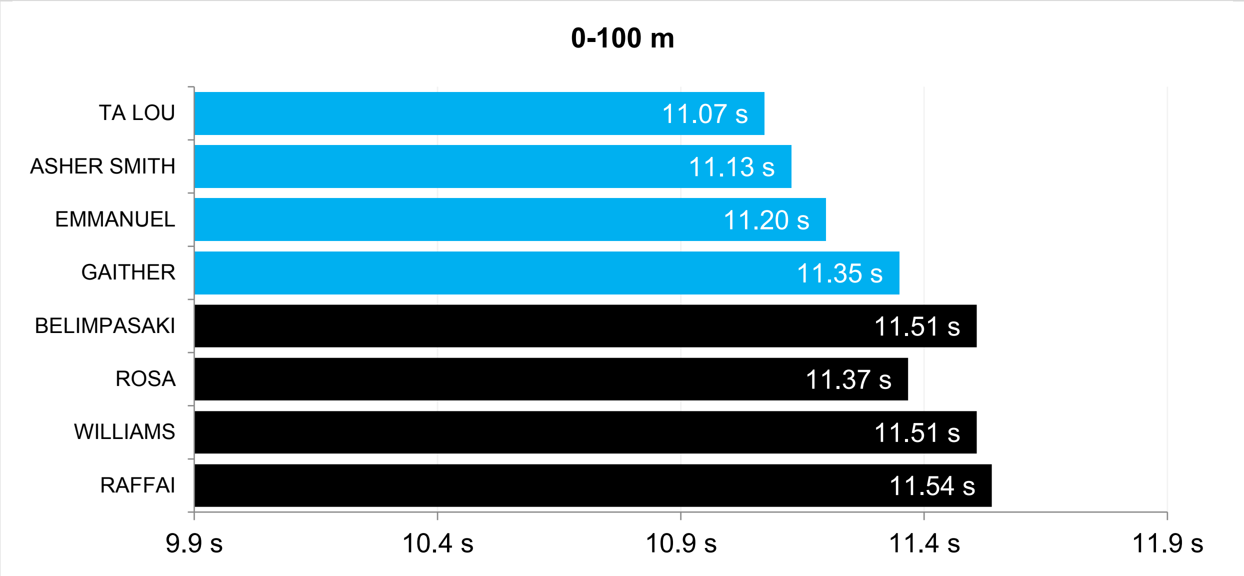

Figure 34. Individual 0-100 m split times (minus reaction time).

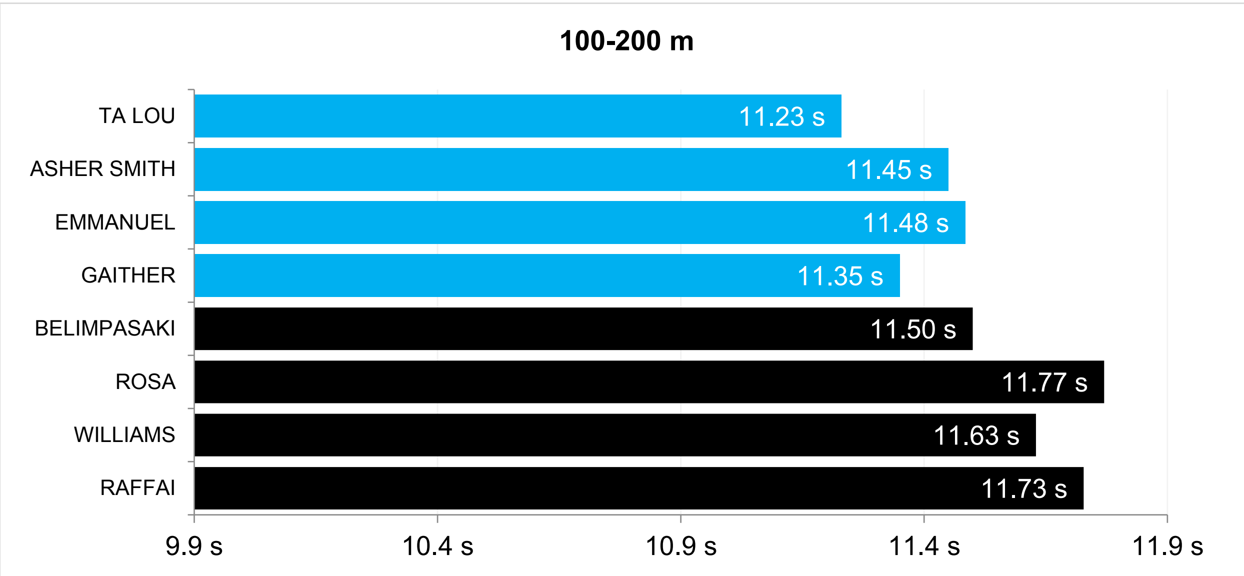

Figure 35. Individual 100-200 m split times.

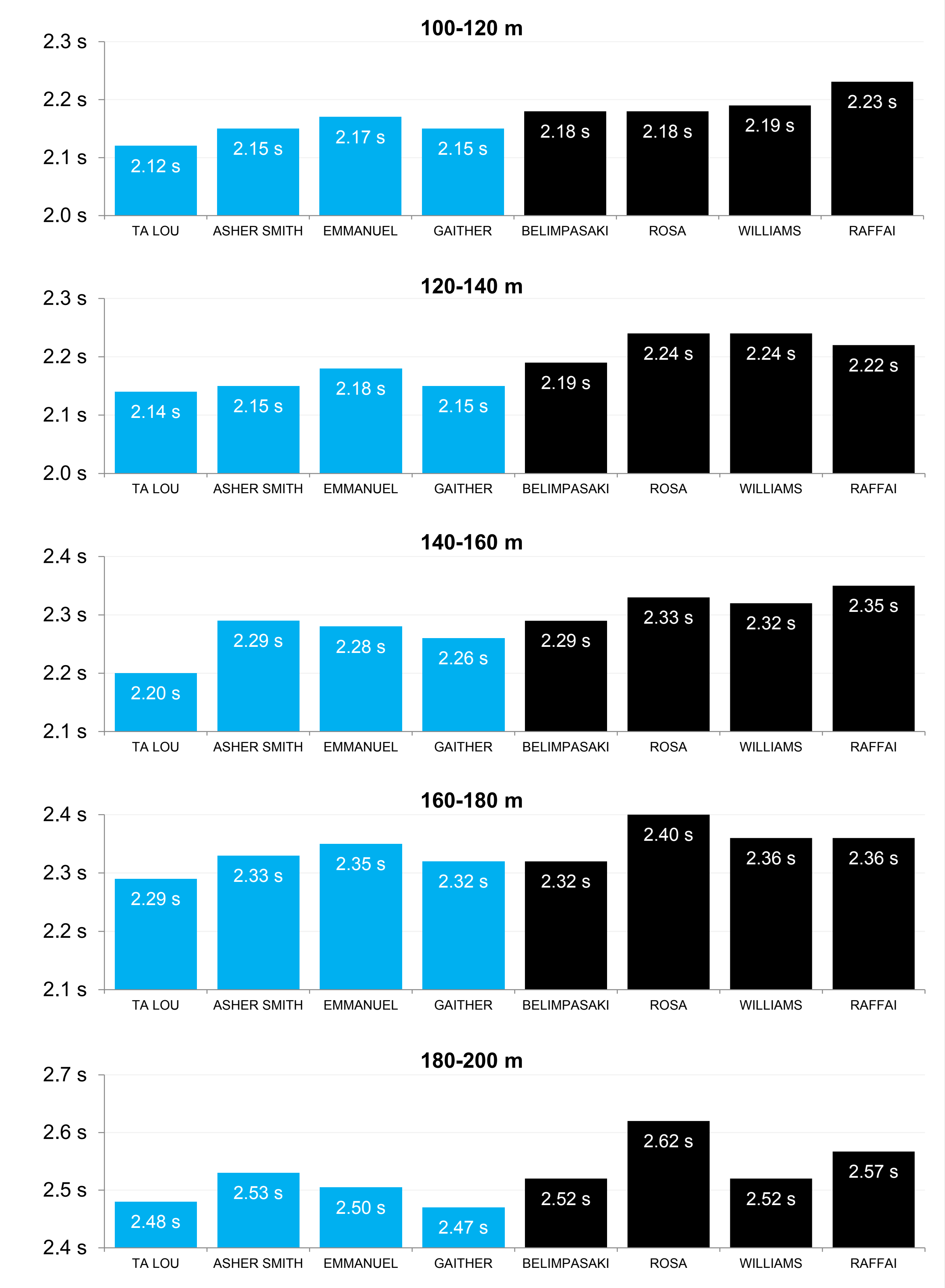

Figure 36. Individual consecutive 20 m split times during the home straight.

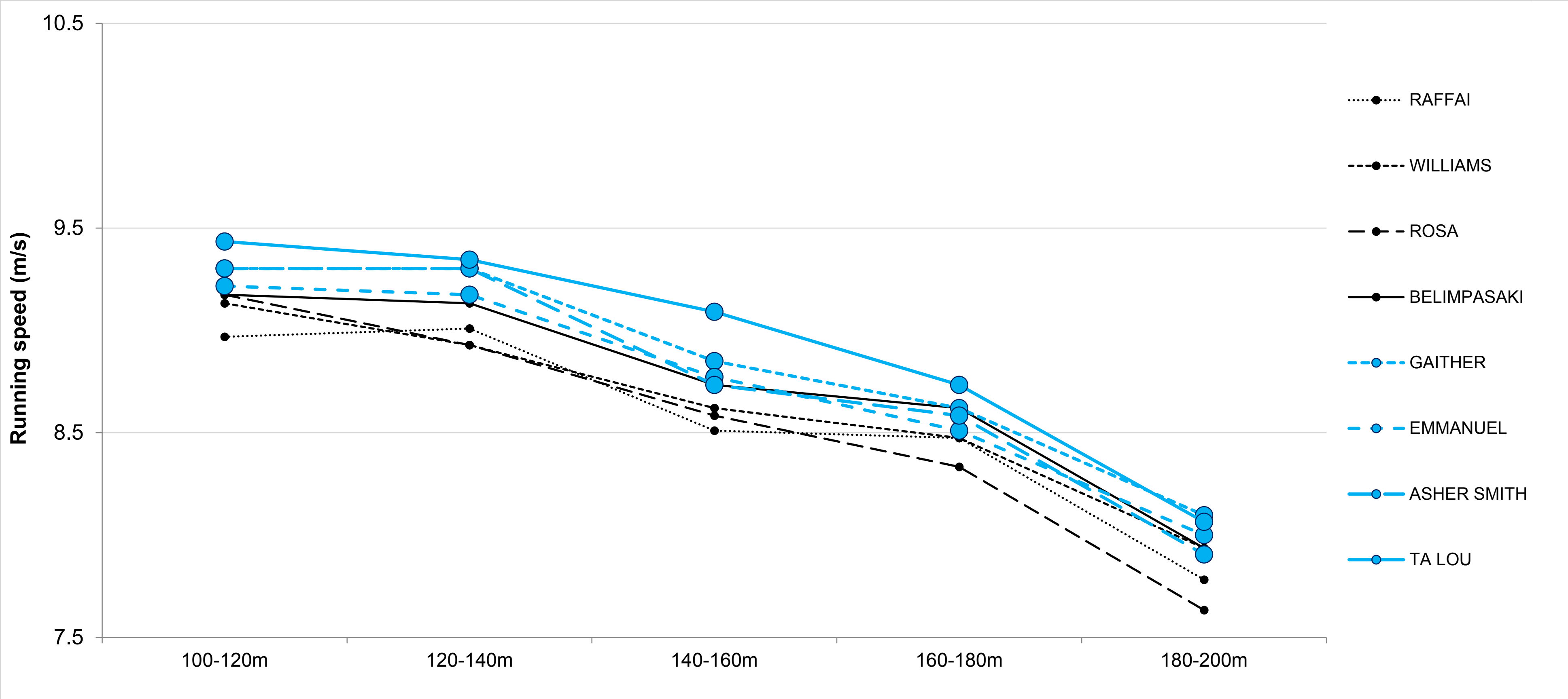

Figure 37. Mean running speed during each 20 m split throughout the home straight.

Completed steps and step length

The following graphs show step information of individual athletes, during the initial 10 m of the race, between 10-100 m and the final 100 m intervals, for the mean step length and relative to each athlete's height (Figure 38). The total completed steps for the race and during each 100 m split for each athlete is presented in Figure 39.

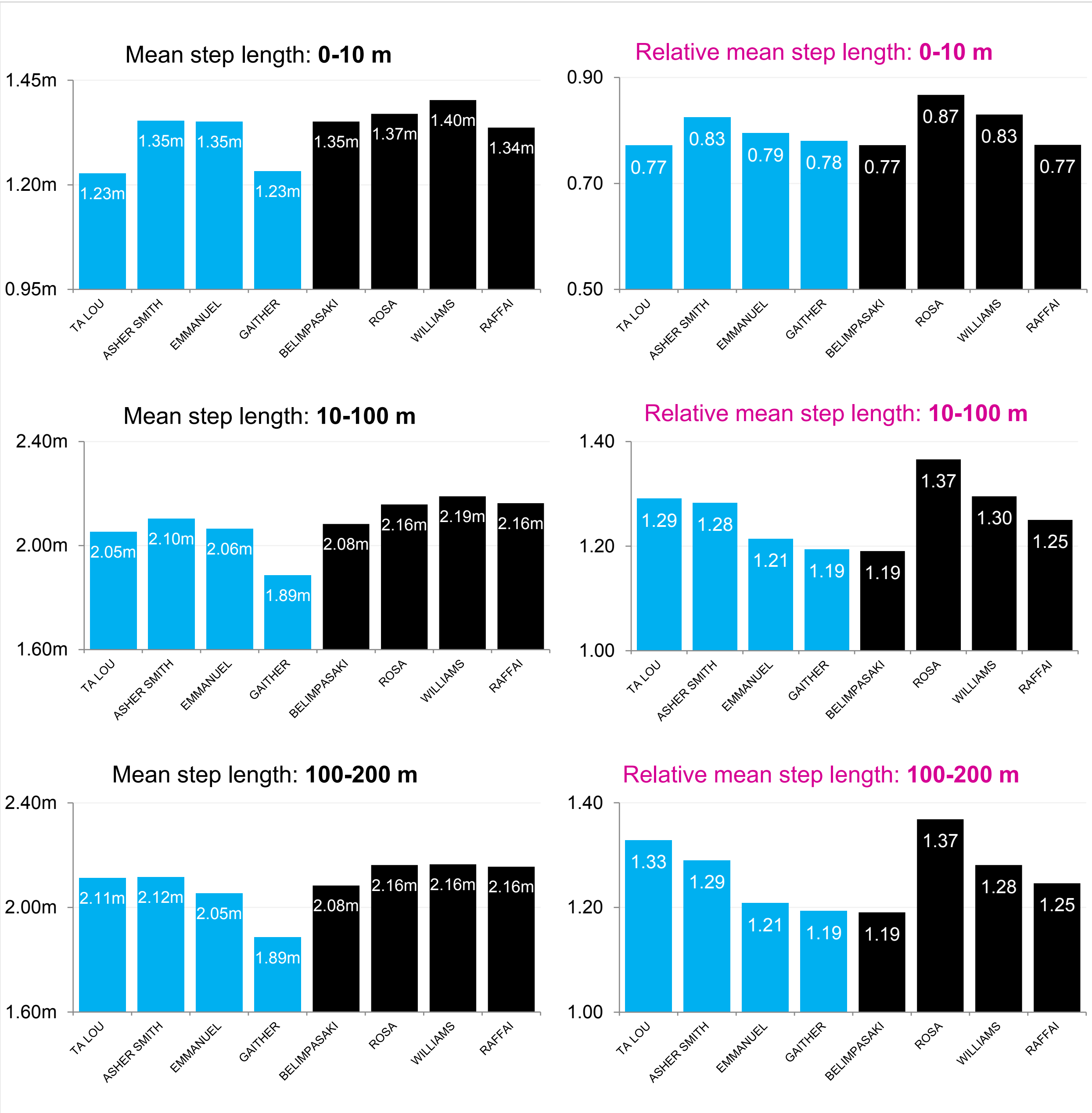

Figure 38. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

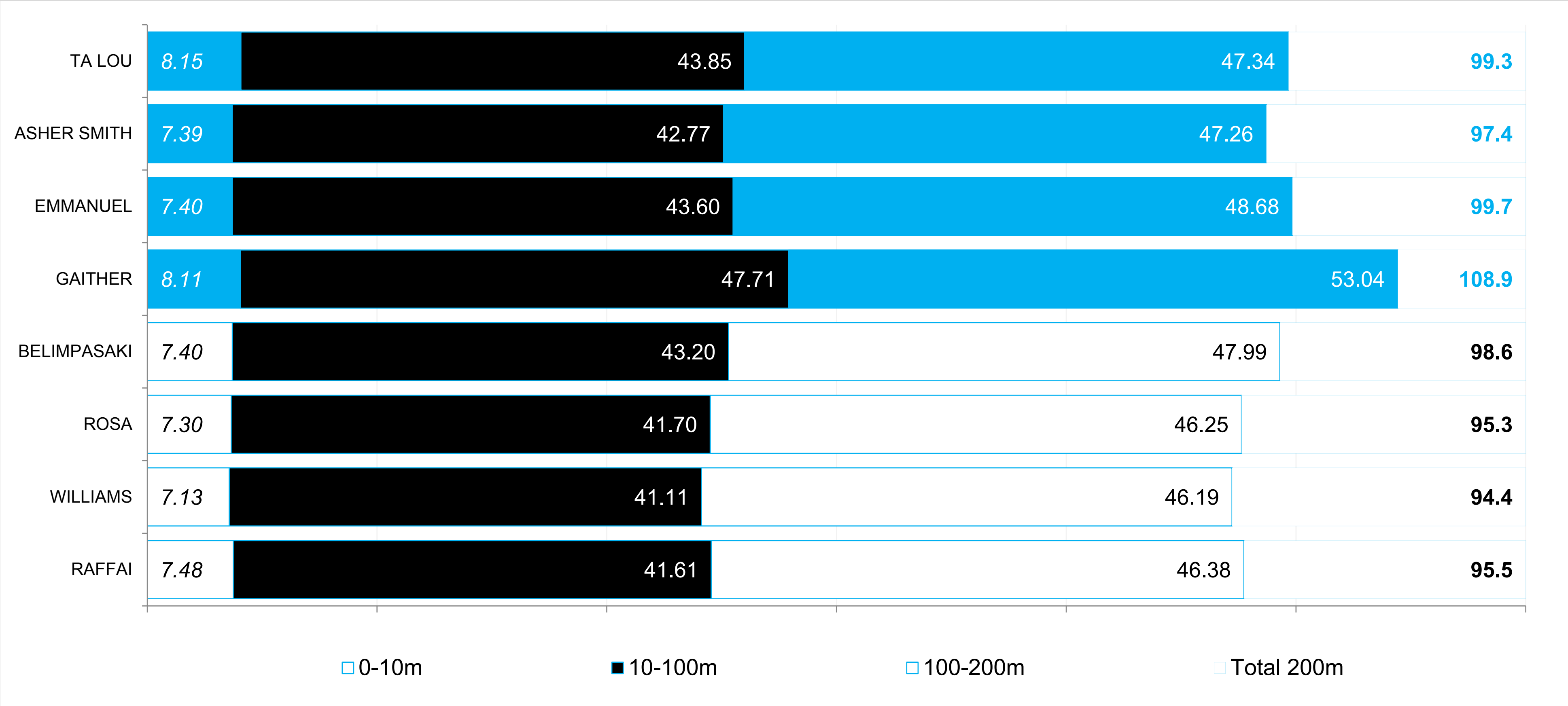

Figure 39. Total completed steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

COACH'S COMMENTARY

Historical analysis and coaching commentary – Pierre-Jean Vazel

The report on the women's 200 m sprint fills a gap in the scientific knowledge regarding this event as it has been sparingly researched so far. The intent of this commentary is to review the historical studies on women's 200 m and link it to the present work. Four of the 200 m finalists took part in the 100 m competition in London earlier that week. It gives the opportunity for comparisons of their respective data for short and long sprints, shedding light on the specific adaptations that occur when sprinters line-up at 200 m.

Reaction times

It has been established since the first extensive studies held in West Germany in the early 1970s that the shorter the sprint distance, the quicker the reaction time (Oberste, 1974). The results of the 200 m finalists who also took part in the 100 m confirmed that trend, as well as the data from the three fastest women ever at 200 m: Florence Griffith-Joyner at 1988 Olympics (Omega, 1988 and Brüggemann, 1990), Jones at 1998 World Cup, Schippers at 2015 World Championships (Takahashi, 2015). This might be due to a non-conscious protective mechanism in order to save nervous output depending on the duration of the effort about to be done.

London (2017)	200 m time (s)	RT (s)	100 m time (s)	RT (s)
Schippers	22.05	0.165	10.96	0.155
Ta Lou	22.08	0.199	10.86	0.180
Stevens	22.44	0.178	11.17	0.155
Emmanuel	22.60	0.158	11.14	0.162
All-time top 3				
Griffith-Joyner (1988)	21.34	0.205	10.62	0.107
Jones (1998)	21.62	0.258	10.65	0.183
Schippers (2015)	21.63	0.149	10.81	0.129

Interestingly, Dafne Schippers' reaction times in London were slower than two years before in the 2015 Beijing World Championships, where she set her personal bests at both 100 and 200 m. It might be an indication that while she managed to retain her world title, she was not in her best shape in London. Nevertheless, reaction times are less important at 200 m than at 100 m, which is illustrated by the world record set with a relatively slow start (0.205 s) by an athlete who reacted exceptionally well during those games, clocking the best reaction times of the field in 6 of the other 7 races she took part in (Omega, 1988).

Running the bend

In standard tracks, the length of the bend portion of the 200 m race is about 116 m, thus the first half of the race is run in the curve. Comparisons between 100 m races in straight lanes and in the curve for the same athletes in the past major championships show differences of around 0.26 s on average, excluding reaction time. The difference between bend and straight running is not solely an indication of a technical efficiency for running the curve, the tactical dimension also comes into play in this event. It is particularly evident in Schippers, who was relatively slow in the bend when she set the European record in 2015 than she was in London. Differences in time between the 100 m run in the bend during the 200 m final and the best result during the 100 m competition for the same athletes in London World Championships (times calculated without reaction times) can be seen in the table below.

London (2017)	Lane	100 m bend (s)	100 m straight (s)	Difference
Schippers	6	10.95	10.81	0.14
Ta Lou	4	10.96	10.68	0.28
Stevens	7	11.19	11.01	0.18
Emmanuel	2	11.23	10.97	0.26
All-time top 3				
Griffith-Joyner (1988)	5	10.91	10.51	0.40
Jones (1998)	9	10.82	10.47	0.35
Schippers (2015)	6	10.98	10.68	0.30

There is no relationship between the final 200 m result and bend running difference, as shown with the current all-time best performances, illustrating the need of a balanced energy distribution along the race, from reaction time to the last metres of the race. It is noteworthy that the only 2017 finalist who set a personal best in London's final, Ta Lou, was the one with the biggest difference between 100 m times in straight lane and in curve (0.28 s), which further underlines the importance of the tactical dimension of the 200 m race from a coaching perspective. Going further into the comparisons between bend and straight running, it is interesting to note that no trend really emerges regarding whether step length or step frequency loss are the most associated with the lower running velocity in the bend, compared to the same parameters measured in 100 m races in straight lane (calculations without reaction times).

London (2017)	Step frequency (Hz) 100 m straight	Step frequency (Hz) 100 m bend	Step length (m) 100 m straight	Step length (m) 100 m bend
Schippers	4.38	4.39	2.11	2.08
Ta Lou	4.65	4.65	2.01	1.96
Stevens	4.11	4.14	2.21	2.16
Emmanuel	4.58	4.52	1.99	1.97
All-time top 3				
Griffith-Joyner (1988)	4.56	4.49	2.09	2.04
Jones (1998)	4.53	4.40	2.11	2.10
Schippers (2015)	4.37	4.28	2.14	2.13

To our knowledge, none of the all-time fastest 200 m runners (sub-22 s) had a significantly longer mean step length during the 100 m in bend than what they displayed in the 100 m race during the same championships. This is not true for the step frequency, which has been found either to be higher or lower in the bend than in the straight, hence lower running velocity should be mostly attributed to step length. However, given the huge variety in adaptations in elite and lower level sprinters, coaches should be warned to not trust general trends before checking the characteristics of a given athlete. Female sprinters' bend running technique has never been analysed at a kinematic or kinetic level, whereas more in-depth comments on this topic are developed in the men's 200 m report.

Speed endurance

Maximum velocity during 200 m races are found in the 50-80 m section of the race, which is not much different from 100 m races. While coming off the bend (at about 116 m), some athletes experience a slight burst of speed, measured in the 110 to 130 m section, sometimes up to the 140 m as reported at 1987 World Championships (Moravec, 1990). It was the case of Ta Lou, Miller-Uibo, Stevens and Emmanuel in the London's final (Figure 9). Split times every 10 m are very rare and this report gives precious information. It confirms the 1987 World Championships report in that the slope of the velocity curves significantly bends after 150 m. This was especially obvious for Schippers, who was the fastest among the finalists for each 10 m section between

100 and 140 m, while in the last 20 m of the race, she was the 2nd or 3rd slowest. Miller-Uibo was the fastest in each section from 140 to 200 m, showing that she has the best speed maintenance abilities, probably because she also is a 400 m specialist, hence might have experienced more work than her opponents over longer distance and velocities between 9.5 and 8.5 m/s.

Into the stride mechanics

100 m and 200 m reports offer comparisons between the mechanics of the two sprinters (Schippers and Ta Lou) who took part in both finals, shedding rare information on alterations of running mechanics while the athlete is still in acceleration, almost reaching maximum velocity as measured at mid-way during 100 m, and in situation of deceleration after 150 m or over 16 s into the 200 m race. With fatigue, the foot lands further in front of the sprinters (Table 5, horizontal distance to the centre of mass at touchdown) which is associated with a longer ground contact. At about 150 m, fatigue doesn’t have much effect yet on step length, a phenomenon which occurs later in the 200 m race for some athletes, or during 400 m races for anyone (cf. women’s 400 m report).

Comparing late acceleration and deceleration mechanics in the same athletes, fatigue causes a lower knee lift, a more erected torso, and larger differences in knee flexion during stance, which resonates with a previous study of Zhanna Pintusevich at 100 m and 200 m during the 1997 World Championships (Kersting, 1997). Another marker is the angle formed between thighs at touchdown, which gets larger with fatigue as discussed in 100 m and 400 m reports. By contrast, world record holder Florence Griffith-Joyner exhibited a relatively small angle during 100 m and 200 m races (Levchenko, 1989; Hommel, 1991). Although this figure is an indication of efficient swing leg action (Tabachnik, 1987), we warn coaches not to force athletes to copy this running form if the athlete doesn’t have the muscular strength already in place. After all, highly successful 200 m sprinters like Bärbel Wöckel (Maslakov, 1982), Marita Koch (Susanka, 1983), Evelyn Ashford (Mansvetov, 1987), Katrin Krabbe and Gwen Torrence (Ito, 1994) or Marie-José Pérec (Krantz, 1996), all Olympic or world champions with personal best under 22 s, had a large angle between thighs at touchdown, but used the inertia of the back leg to swing with less muscular contraction through potential energy.

Focus on the world champion

Dafne Schippers successfully retained her 200 m world title in 22.05 s; she won in 2015 with 21.63 s. The loss in time might be attributed to a reported injury issue during the 2017 season. For her 22.05 s race, she was on the same pace as her 21.63 s for 110 m (12.14 s). In 2015, she probably had a conservative bend, illustrated by the fact that she was slower than the other medallists in the 55-80 m section (10.39 m/s). In the last 20 m of her 21.63 s race, Schippers ran at 8.79 m/s compared to 8.20 m/s in 2017, thus managing to maintain a higher percentage of this top speed through the end of the race, which is the same tactics that Griffith-Joyner used to break the world records. Schippers ran faster in the bend in 2017 due to a higher step frequency, whereas in 2015 she probably had a more conservative effort. In the last half of the race, both length and frequency decreased.

Differences between Schippers' lifetime best and her performance at 2017 World Championships.

Dafne Schippers	0-100 m			100-200 m		
	Time (s)	SL (m)	SF (Hz)	Time (s)	SL (m)	SF (Hz)
2015 (21.63 s)	10.98	2.13	4.28	10.50	2.30	4.14
2017 (22.05 s)	10.95	2.08	4.39	10.93	2.26	4.04

Comparing sub maximum effort in the semi-final and maximum effort in the final during the World Championships further confirms that as she gets faster, Schippers increases both length and frequency.

Differences between sub maximum effort (semi-final) and maximum effort (final).

Dafne Schippers	0-100 m			100-200 m		
	Time (s)	SL (m)	SF (Hz)	Time (s)	SL (m)	SF (Hz)
Semi-final (22.49 s)	11.09	2.07	4.36	11.24	2.24	3.97
Final (22.05 s)	10.95	2.08	4.39	10.93	2.26	4.04

Studies on step length and frequency reliance, as illustrated in the women's 100 m report, are complex. Schippers' career progression is a further example of it, as over 4 years, her improvement in the bend can be attributed to a larger step length, while in the speed endurance phase, both length and frequency of her steps were improved.

Differences between personal best at age 19 and lifetime best at age 23.

Dafne Schippers	0-100 m			100-200 m		
	Time (s)	SL (m)	SF (Hz)	Time (s)	SL (m)	SF (Hz)
2011 (22.69 s)	11.23	2.04	4.35	11.29	2.20	4.02
2015 (21.63 s)	10.98	2.13	4.28	10.50	2.30	4.14

Interpretations in comparing step length and frequency of slower and faster races should take in account whether running speed improvement is observed from sub-max to max effort in the same conditions (acute evolution) or from a career progression, from younger years to elite level, and once in elite level from year to year basic (chronic evolution). While Schippers relies on both parameters, the world record holder Griffith-Joyner improved her times by increasing her step length so much that it compensated her step frequency decrease, whereas the 4th fastest woman all-time, Merlene Ottey displays the exact opposite trend.

Athlete	Meet	Time (s)	Step count	SL	SF	Reliance
F. Griffith-Joyner	1983 NC	22.23	100.5	1.99	4.52	SL reliant
	1988 OG	21.34	91.8	2.17	4.30	
M. Ottey	1980 OG	22.20	89.7	2.23	4.04	SF reliant
	1991 VD	21.64	91.4	2.18	4.22	

The observation of the improvement of the all-time bests shows that there is no rule regarding improving length or frequency, and following the natural tendency of the athlete seems to be the way to go (Levchenko, 1988; Hess, 1992). Tracking the numbers in various parts of the race, and at different times of the year gives hints to the coach of the inclination for improvement of a given athlete (Kersee, 1989), as well as the possible protective adaptations to workload and injuries.

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Coaching commentary – Ralph Mouchbahani

It is interesting to note that Marie-Josée Ta Lou ran a very fast bend and an even faster straight (see Figures 6 and 7). The average speed over consecutive 10 m splits throughout the home straight (Figure 9) also displays this. Athletes were managing to achieve these high velocities at 150 m, despite a relatively slow recovery of the swing leg (based on step rate, step length and step velocity at this stage in the race).

The graphs in Figures 10 and 11 (for the final) show step information of individual athletes during the first 10 m of the race, between 10-100 m and for the final 100 m. All these data may indicate that Ta Lou lost the race in the first 100 m and on the transition into top speed. The total number of steps taken during the race play a large role in mean velocity and maintenance of a high velocity throughout the race. These are strongly dependent on the quality mastery of the mechanics of sprinting.

The graph containing the time-series data for the resultant velocity of the foot centre of mass (Figure 16), as well as the data in Table 6, can be linked to the other data shown in the report. Furthermore, taking step velocity into consideration, one can reach the assumption that Ta Lou's relatively slow step velocity of 9.08 m/s around the middle of the home straight is compensated with a bigger effort during the last 40 m of the race, which is reflected in the 0.01 s faster second 100 m against Schippers.

Recommendations for training

Based on the interpretations of the data collected in this report, the following recommendations for training may be formed:

1. Mastery of proper running mechanics are the core of training.
2. Drills should be implemented to target the purpose of the different phases in the technical model:
    a. Push mechanics in drive and acceleration.
    b. Push fast(er) transition mechanics from acceleration to top speed.
    c. Step over drills, high speed mechanics focussing on quick heel recovery and active knee drive for active ground preparation.
3. Special endurance for maintenance of proper sprint mechanics in appropriate time and movement patterns focussing on stride frequency rather than stride length.
4. Speed endurance to replicate proper mechanics under stress (in competition).

Finally, it is important to generate high centre of mass velocities and to minimise the loss of velocity when special endurance and specific endurance aspects are the emphasis of a training session.

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 Catherine Tucker is a Senior Lecturer in Sport and Exercise Biomechanics at Leeds Beckett University. Catherine graduated with First Class Honours in Sport and Exercise Sciences from the University of Limerick and subsequently completed a PhD in sports biomechanics, also at the University of Limerick. Catherine's main research interests centre on the biomechanics of striking movements, particularly golf. She is also interested in movement variability with respect to gait and how it relates to movement outcome / injury reduction.

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.

Ralph Mouchbahani is a global master in implementing sport structures for federations within a high-performance environment. He is an editor of the IAAF Coaches Education and Certification System and a senior IAAF and DOSB lecturer with exceptional athletic technical knowledge and a passion for sport research. In his career, he has coached many elite athletes, including sprinters, helping them to achieve podium performances at several international competitions. Ralph is managing partner in Athletic-Solutions, a company that focuses on bringing Sport Science and Practice together to help coaches maximise their efforts.

Pierre-Jean Vazel is a sprint and throws coach at Athlétisme Metz Métropole club in France. PJ is a 5th year graduate in Fine Arts and has covered 2 Olympics, 9 World Championships and over 300 meetings as a coach or chronicler for Le Monde and IAAF website. Since 2004 he coached national champions from six countries including Olu Fasuba to the 100 m African Record (9.85 s) and 60 m world indoor title. PJ is co-author of the ALTIS Foundation course and has done many lectures on the history of sprint science and training.