



BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

200 m Men's

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INTRODUCTION

On Thursday 10th August, the men's 200 m final was built-up around the ambitions of Wayde Van Niekerk to complete 'the double' and the highly anticipated showdown with Botswana's Isaac Makwala; the world leader with 19.77 s. It was also the first World Championship final not to feature Usain Bolt since 2003, and the elimination of Yohan Blake in the semi-finals meant there was no Jamaican representative. Bolt also lost one of his many records as Japan's Abdul Hakim Sani Brown became the youngest men's 200 m finalist. Nevertheless, it was Ramil Guliyev, who, after leading into the home straight held off the field to win a time of 20.09 s; became his country's first world gold medallist. It was also the first men's 200 m final for 20 years not to feature a medallist from the USA or Jamaica. Van Niekerk, who only reached the final as the slowest non-automatic qualifier (20.28 s), secured the silver medal by the smallest of margins crossing the line at 20.106 s just one thousandth of a second ahead of the 23-year-old Jereem Richards of Trinidad and Tobago. Richards, seventh entering the home straight, recorded the quickest second 100 m split (9.70 s) to push van Niekerk close. Great Britain's 23-year-old Nethaneel Mitchell-Blake finished fourth in 20.24 s.

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	19.19	Usain BOLT	JAM	23	Berlin (Olympiastadion)	20 Aug 2009
Championships Record CR	19.19	Usain BOLT	JAM	23	Berlin (Olympiastadion)	20 Aug 2009
World Leading WL	19.77	Isaac MAKWALA	BOT	31	Madrid (Moretelez)	14 Jul 2017
Area Record AR		National Record NR		Personal Best PB		Season Best SB

10 August 2017 21:52 START TIME 18° C TEMPERATURE 60 % HUMIDITY -0.1 m/s WIND

PLACE	NAME	COUNTRY	DATE OF BIRTH	LANE	RESULT	REACTION	Fr
1	Ramil GULIYEV	TUR	29 May 90	5	20.09	0.165	
2	Wayde VAN NIEKERK	RSA	15 Jul 92	3	20.11 (.106)	0.156	
3	Jereem RICHARDS	TTO	13 Jan 94	7	20.11 (.107)	0.149	
4	Nethaneel MITCHELL-BLAKE	GBR	2 Apr 94	2	20.24	0.147	
5	Ameer WEBB	USA	19 Mar 91	9	20.26	0.148	
6	Isaac MAKWALA	BOT	29 Sep 86	6	20.44	0.170	
7	Abdul Hakim SANI BROWN	JPN	6 Mar 99	8	20.63	0.162	
8	Isiah YOUNG	USA	5 Jan 90	4	20.64	0.148	

Timing and Measurement by SEIKO AT-200-M-f--1--.RS1..v1 Issued at 21:55 on Thursday, 10 August 2017

Official Partners

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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.

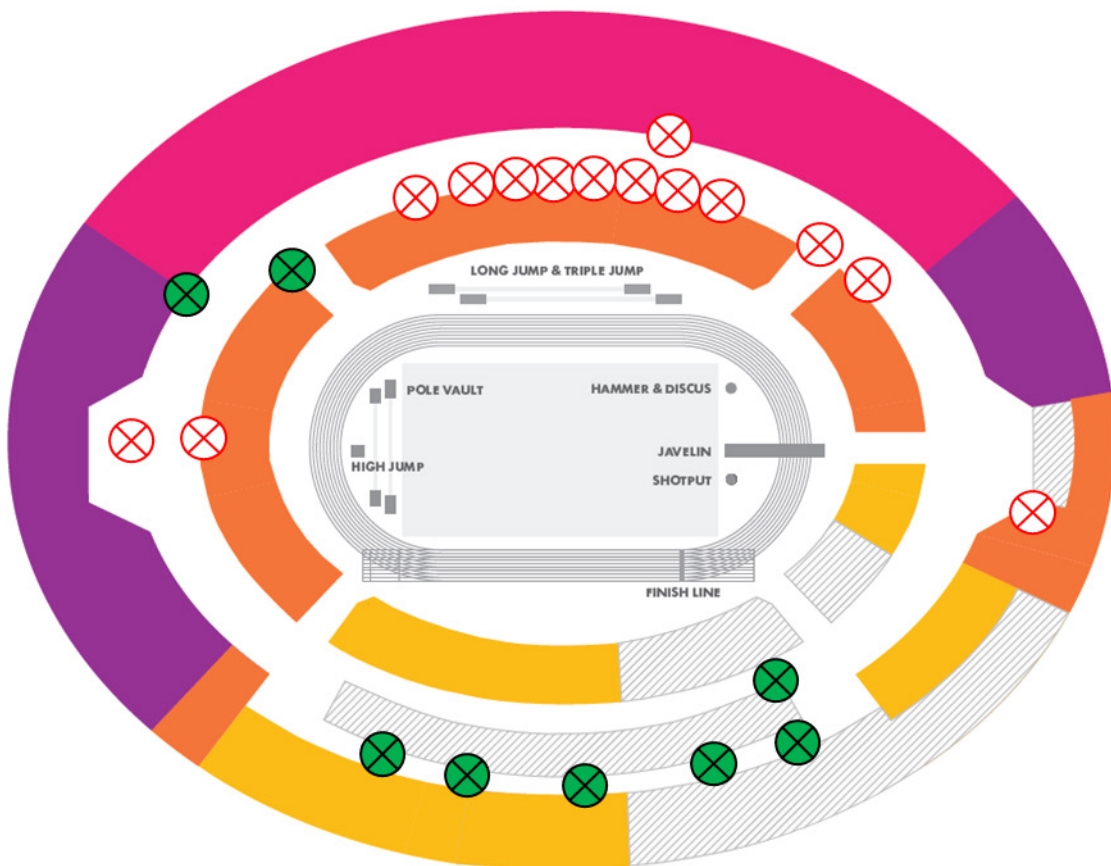


Figure 1. Camera layout within the stadium for the men's 200 m indicated by green in-filled circles.

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.

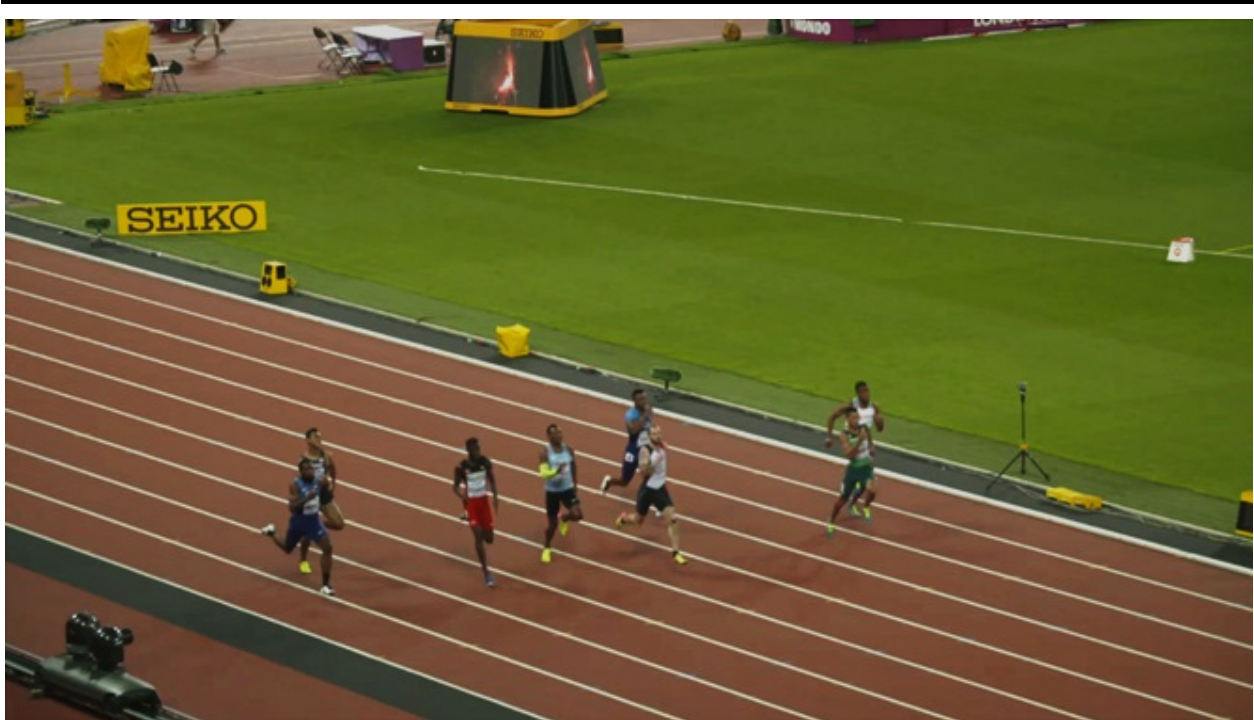


Figure 4. Action from the 200 m men's final.

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. <i>Note: angle taken at toe-off only.</i>
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
GULIYEV	20.08 s	5	19.88 s	5	20.17 s	4	
VAN NIEKERK	19.84 s	2	19.84 s	2	20.28 s	7	
RICHARDS	19.97 s	3	19.97 s	7	20.14 s	2	
MITCHELL-BLAKE	20.04 s	4	19.95 s	6	20.19 s	5	
WEBB	20.09 s	6	19.85 s	3	20.22 s	6	
MAKWALA	19.77 s	1	19.77 s	1	20.14 s	2	
SANI BROWN	20.32 s	8	20.32 s	8	20.43 s	8	
YOUNG	20.14 s	7	19.86 s	4	20.12 s	1	SB

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
GULIYEV	20.09 s		-0.08 s	0.01 s	0.21 s
VAN NIEKERK	20.11 s	.106 s	-0.17 s	0.27 s	0.27 s
RICHARDS	20.11 s	.107 s	-0.03 s	0.14 s	0.14 s
MITCHELL-BLAKE	20.24 s		0.05 s	0.20 s	0.29 s
WEBB	20.26 s		0.04 s	0.17 s	0.41 s
MAKWALA	20.44 s		0.30 s	0.67 s	0.67 s
SANI BROWN	20.63 s		0.20 s	0.31 s	0.31 s
YOUNG	20.64 s		0.52 s	0.50 s	0.78 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.

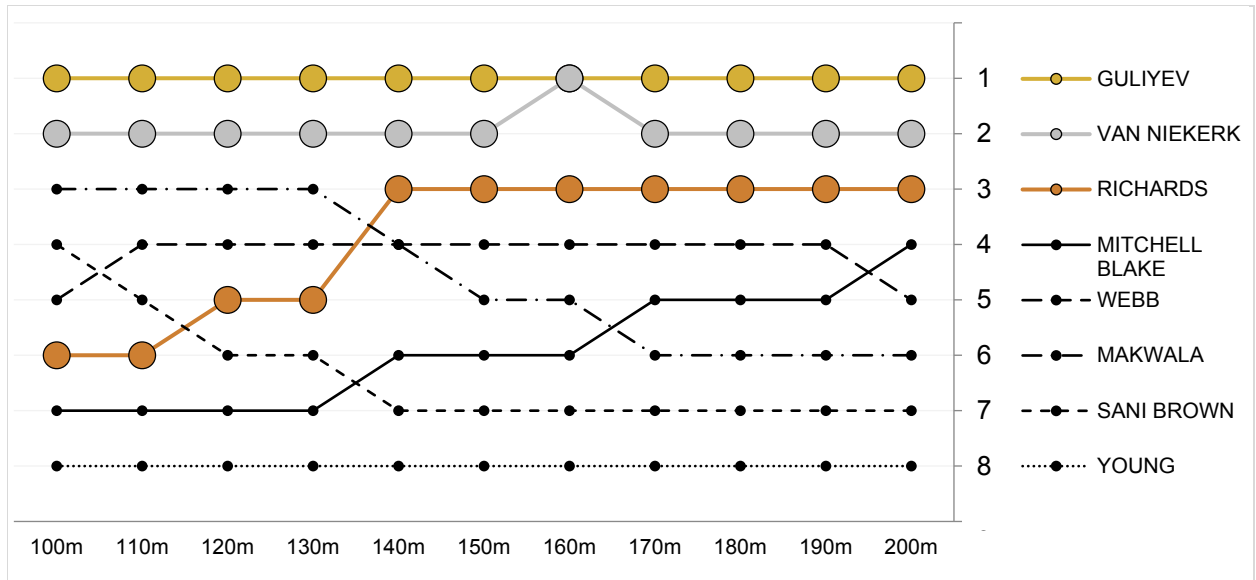


Figure 5. Positions at the beginning of the home straight and at the end of each 10 m split.

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 (*).

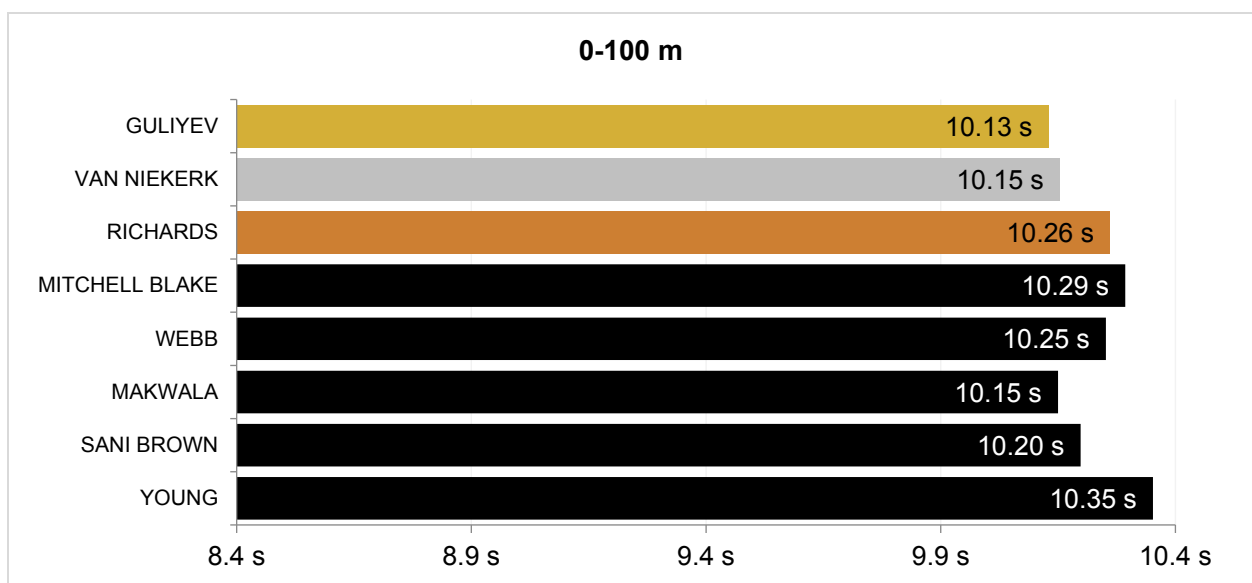


Figure 6. Individual 0-100 m split times (minus reaction time).

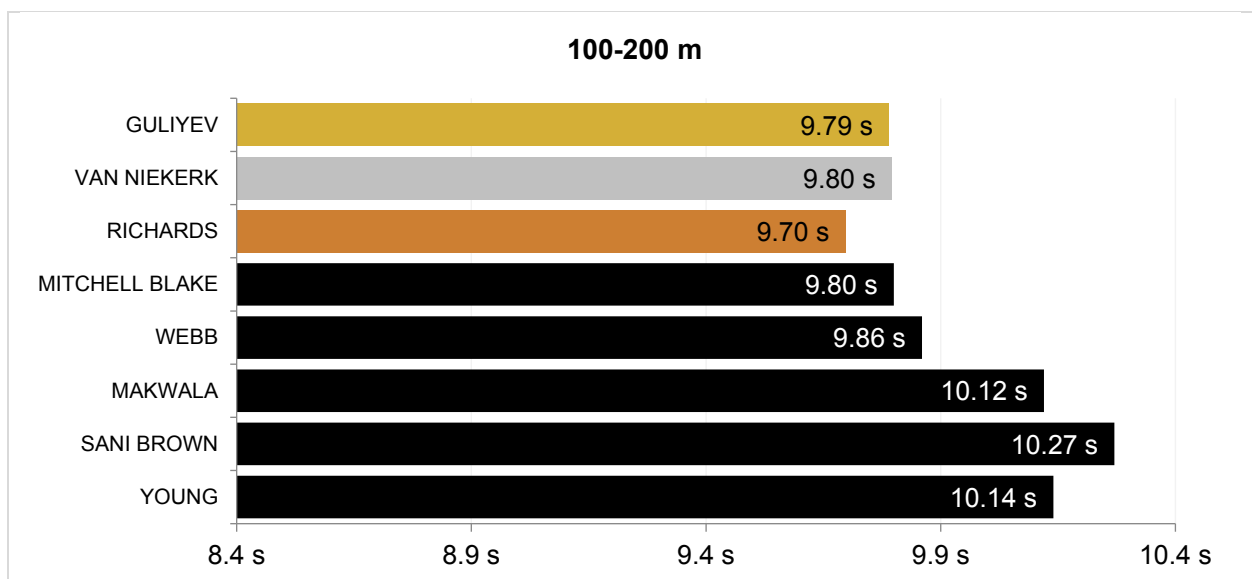


Figure 7. Individual 100-200 m split times.

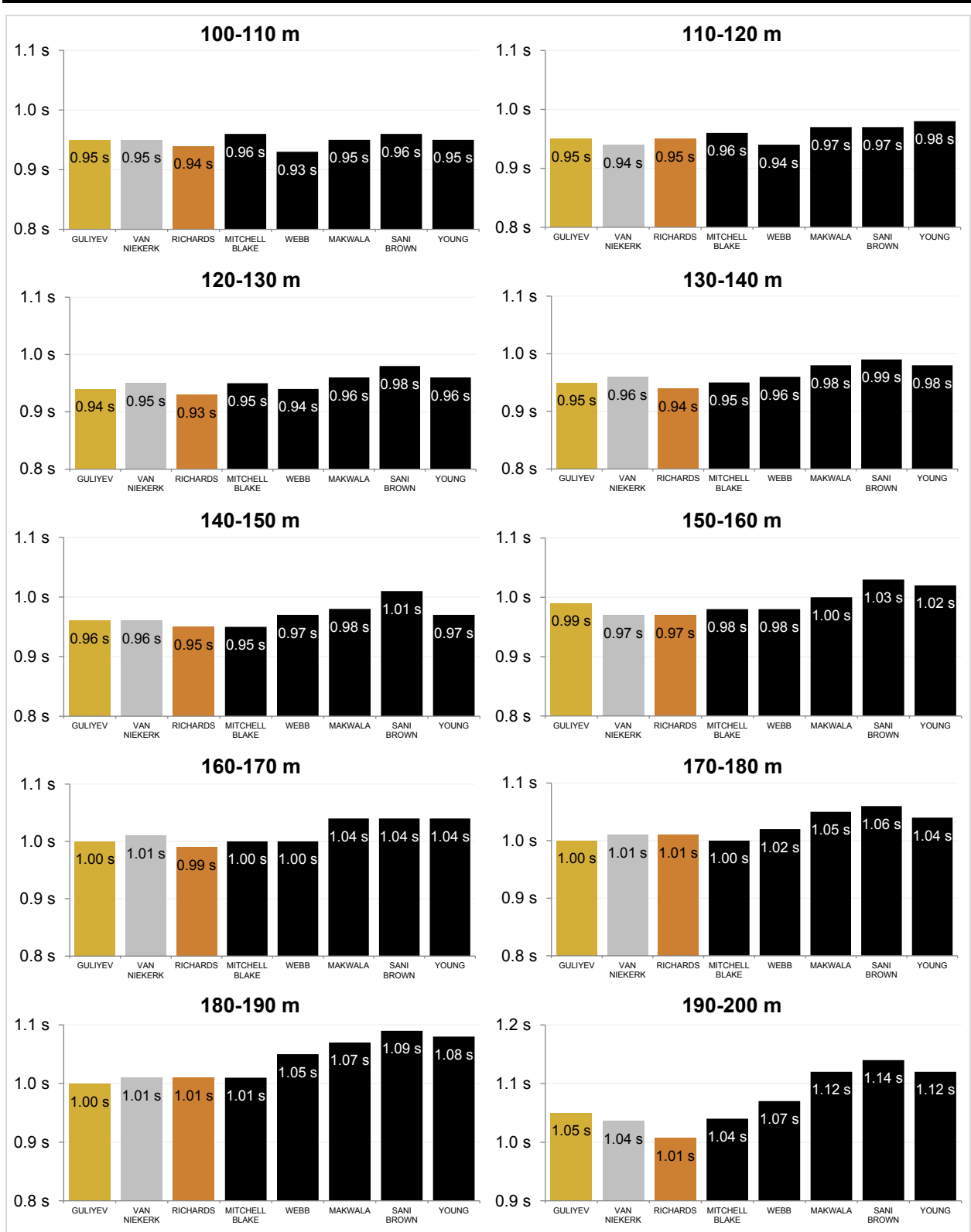


Figure 8. Individual consecutive 10 m split times throughout the home straight.

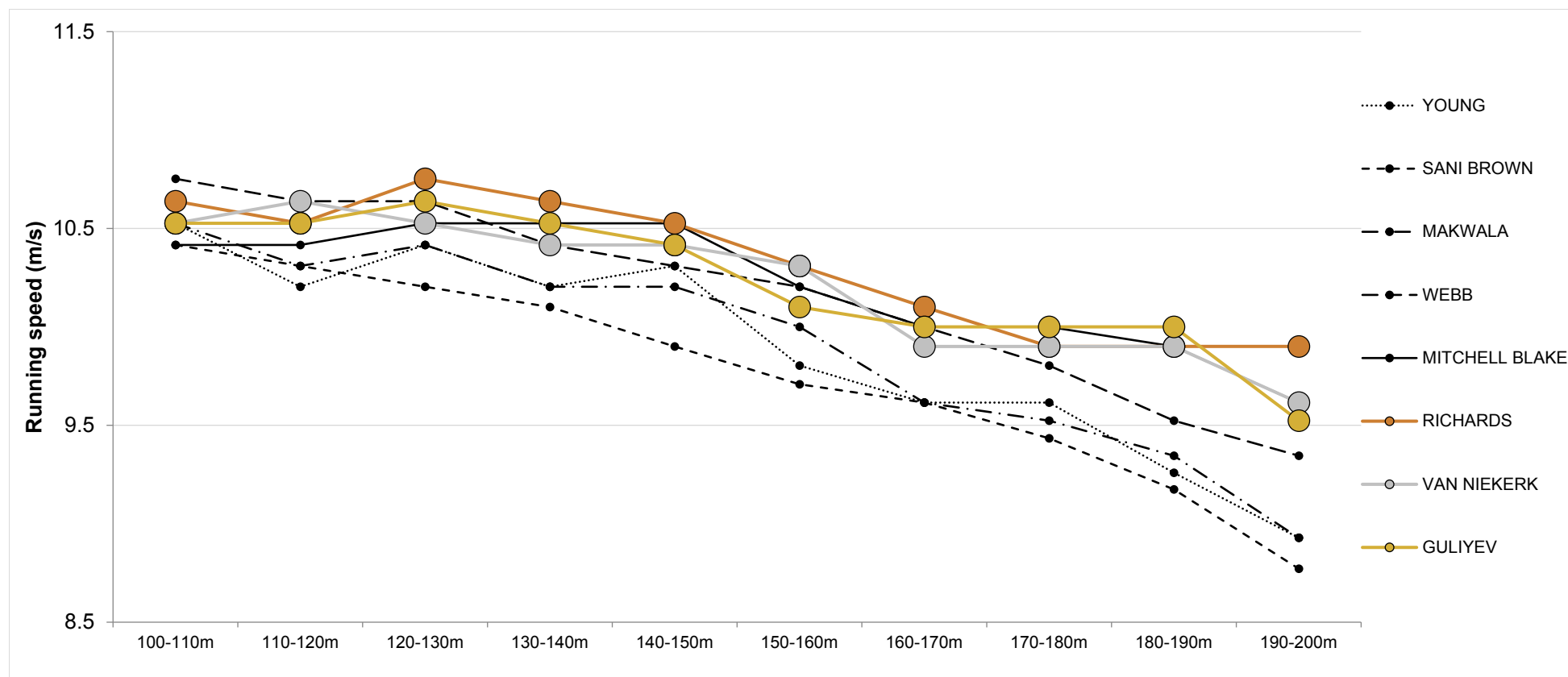


Figure 9. Mean running speed during each 10 m split throughout the home straight.

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.

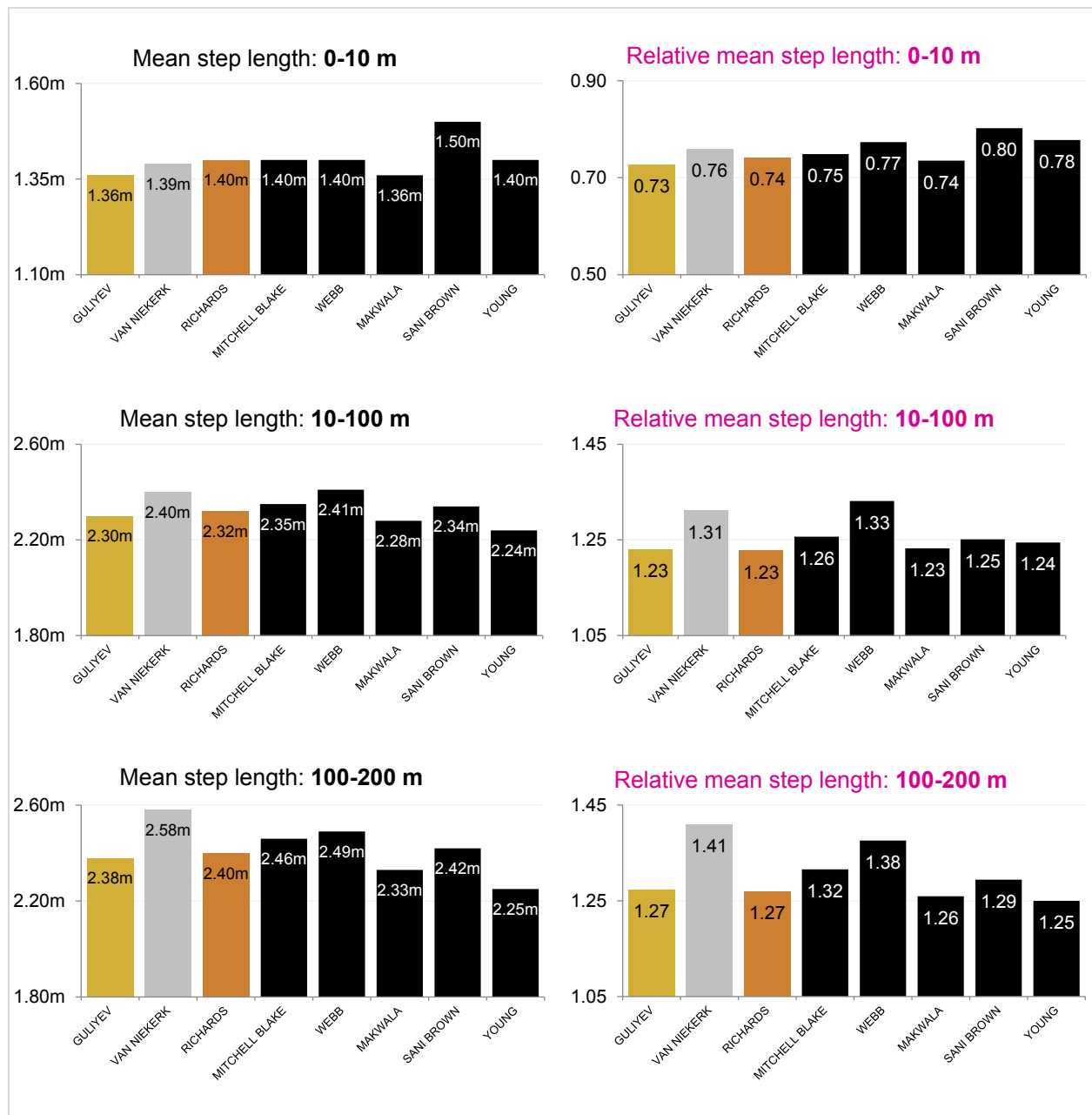


Figure 10. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

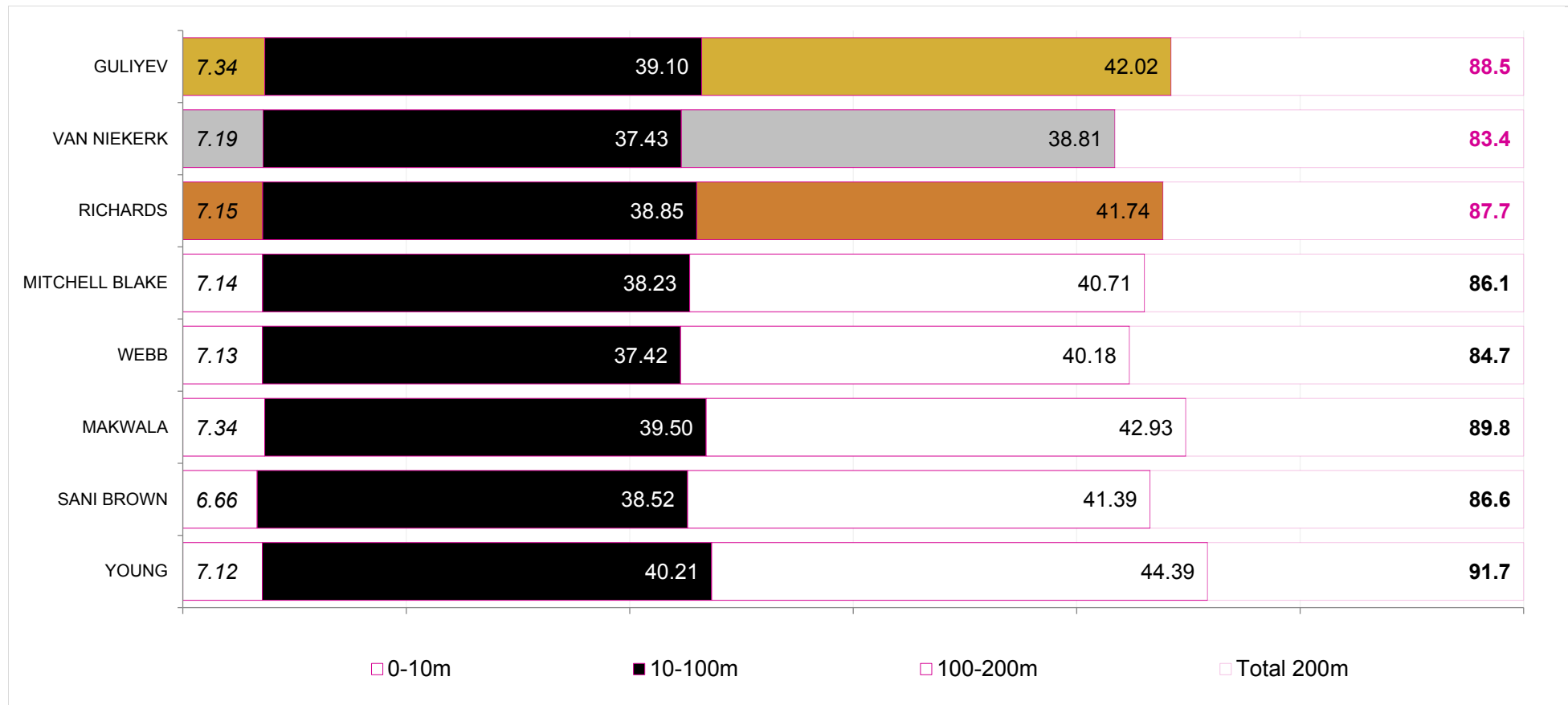


Figure 11. Total number of steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

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

GOLD MEDALLIST: Ramil Guliyev



	RT	0-100 m	100-200 m	RESULT	
Final	0.165 s	10.13 s	9.79 s	20.09 s	
Rank	3 rd	1 st	1 st	1st	
vs. silver	+ 0.009 s	-0.02 s	-0.01 s	-0.016 s	
vs. bronze	+ 0.016 s	-0.13 s	+ 0.09 s	-0.017 s	
Semi-Final	0.167 s	10.15 s	9.85 s	20.17 s	
Rank	16 th	3 rd	6 th	4th	
	100-120 m	120-140 m	140-160 m	160-180 m	180-200 m
Final	1.90 s	1.89 s	1.95 s	2.00 s	2.05 s
Rank	4 th	2 nd	5 th	1 st	=3 rd
vs. fastest	+ 0.01 s	+ 0.02 s	+ 0.03 s	+ 0.04 s	-0.03 s
vs. silver	+ 0.01 s	-0.02 s	+ 0.02 s	-0.02 s	0.00 s
vs. bronze	-0.04 s	+ 0.02 s	+ 0.03 s	0.00 s	-0.03 s
Semi-Final	1.87 s	1.88 s	1.96 s	2.01 s	2.13 s
Rank	=3 rd	5 th	12 th	6 th	7 th

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
GULIYEV	10.60	4.42	2.40	1.28
VAN NIEKERK	10.40	4.00	2.60	1.42
RICHARDS	10.48	4.35	2.41	1.28
MITCHELL-BLAKE	10.42	4.22	2.47	1.32
WEBB	10.54	4.28	2.46	1.36
MAKWALA	10.02	4.34	2.31	1.25
SANI BROWN	9.94	4.11	2.42	1.29
YOUNG	10.09	4.41	2.29	1.27

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

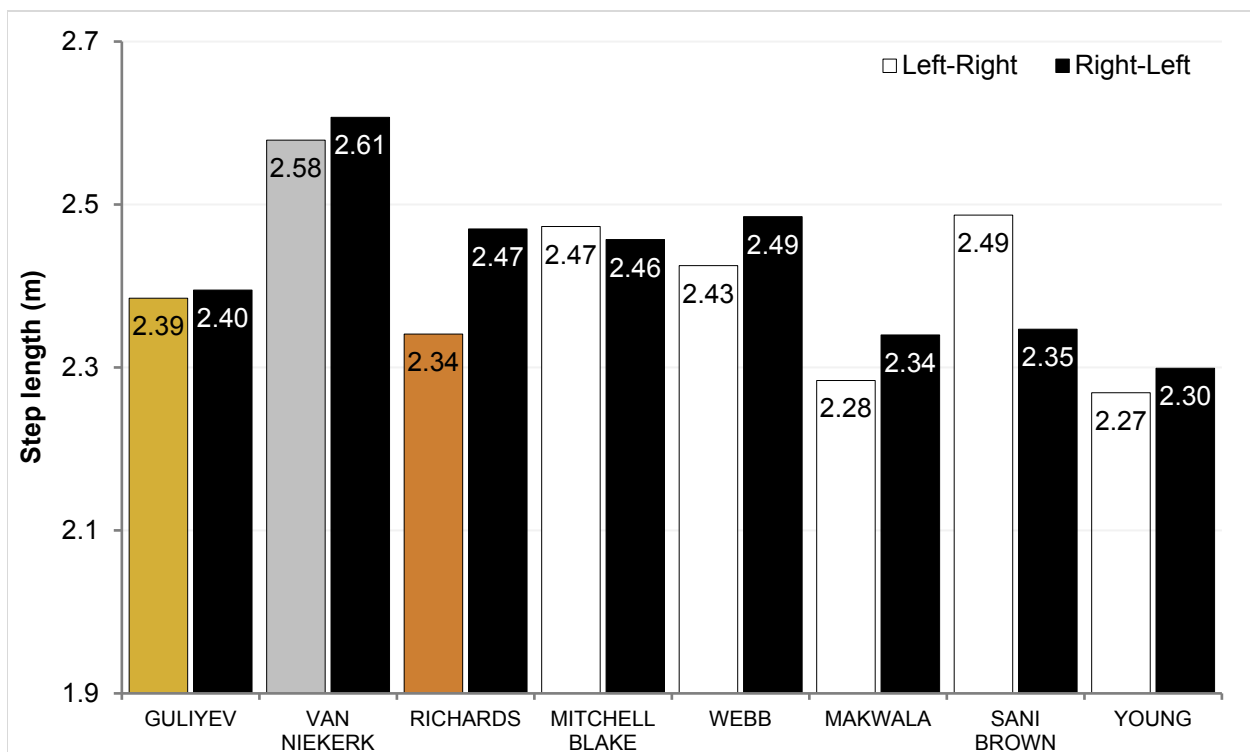


Figure 12. Step lengths for each of the finalists around 150 m.

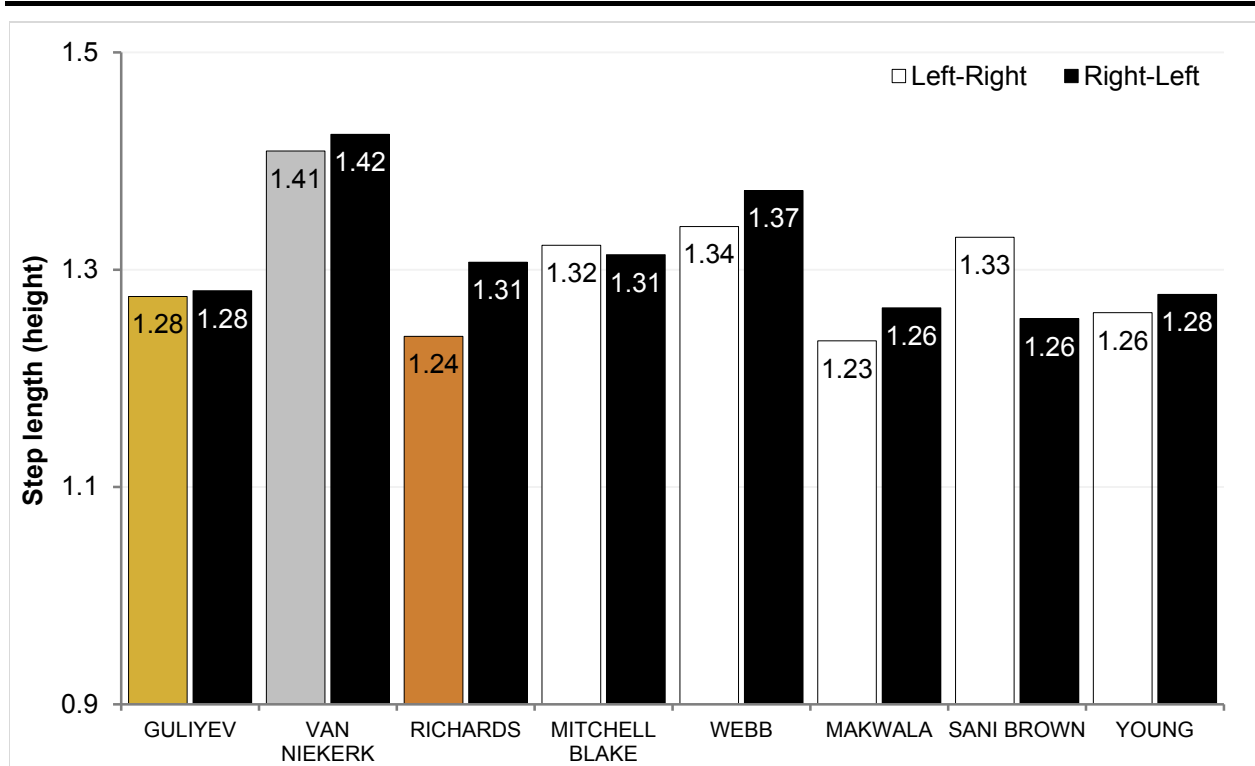


Figure 13. Relative (height) step lengths for each of the finalists around 150 m.

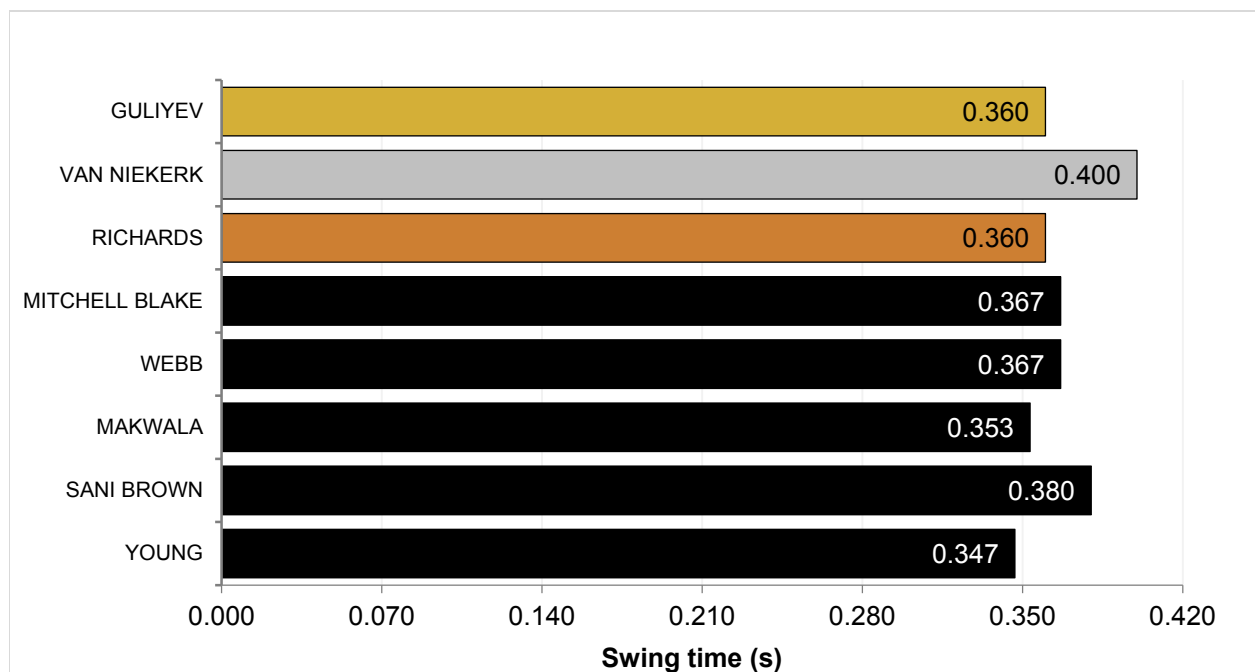


Figure 14. Swing times for each of the finalists around 150 m.

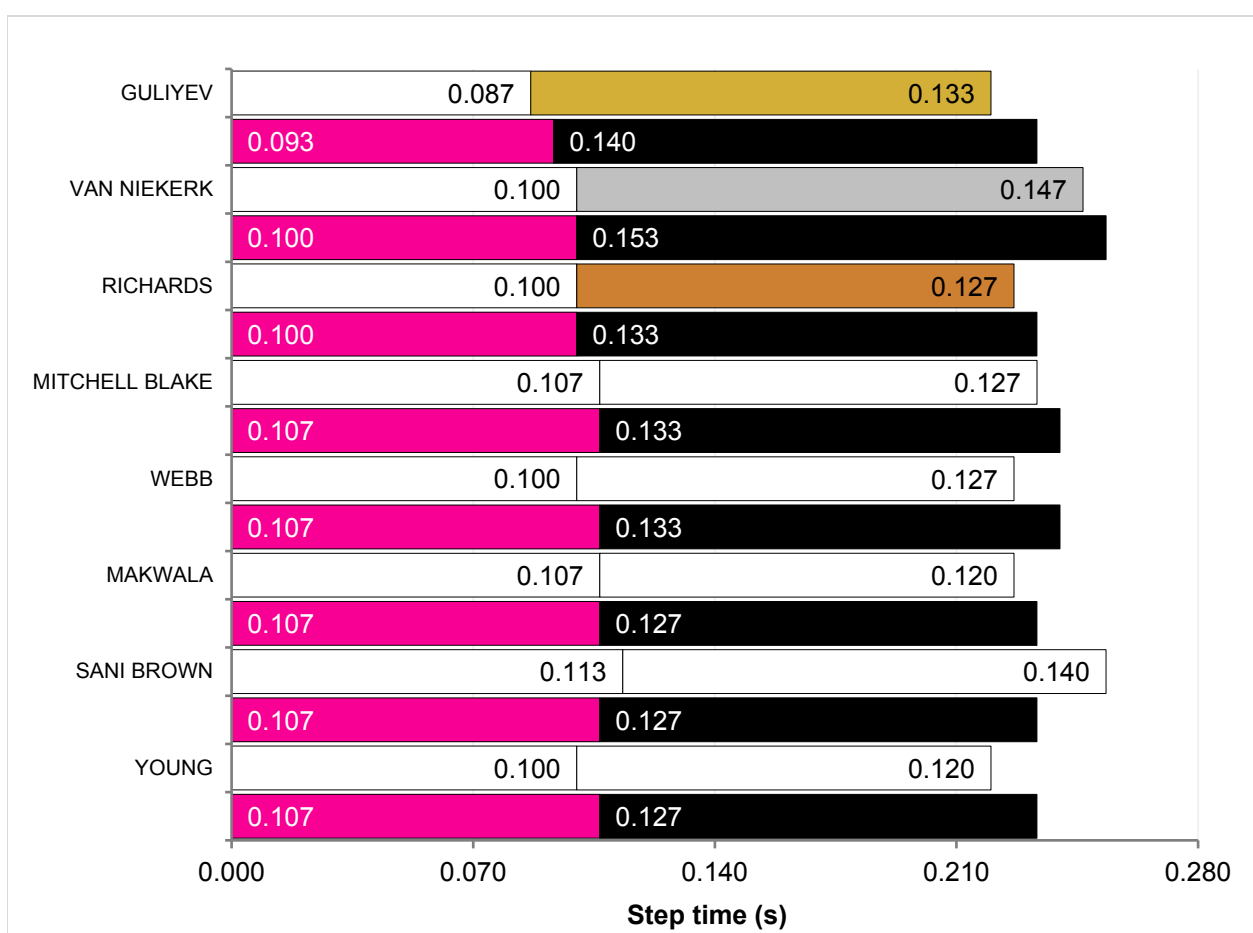


Figure 15. Individual contact and flight times for each of the finalists around 150 m. For each athlete, the top column (black text) represents the left foot contact and left-to-right flight time, and the bottom column (white text) represents the right foot contact (pink shading) and right-to-left flight 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
GULIYEV	0.28 / 15	0.39 / 21	0.53 / 28	0.49 / 26
VAN NIEKERK	0.38 / 21	0.40 / 22	0.60 / 33	0.57 / 31
RICHARDS	0.40 / 21	0.37 / 19	0.55 / 29	0.54 / 29
MITCHELL-BLAKE	0.41 / 22	0.43 / 23	0.62 / 33	0.58 / 31
WEBB	0.45 / 25	0.49 / 27	0.58 / 32	0.51 / 28
MAKWALA	0.44 / 24	0.42 / 23	0.57 / 31	0.55 / 30
SANI BROWN	0.48 / 26	0.46 / 25	0.57 / 31	0.54 / 29
YOUNG	0.41 / 23	0.45 / 25	0.54 / 30	0.54 / 30

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.

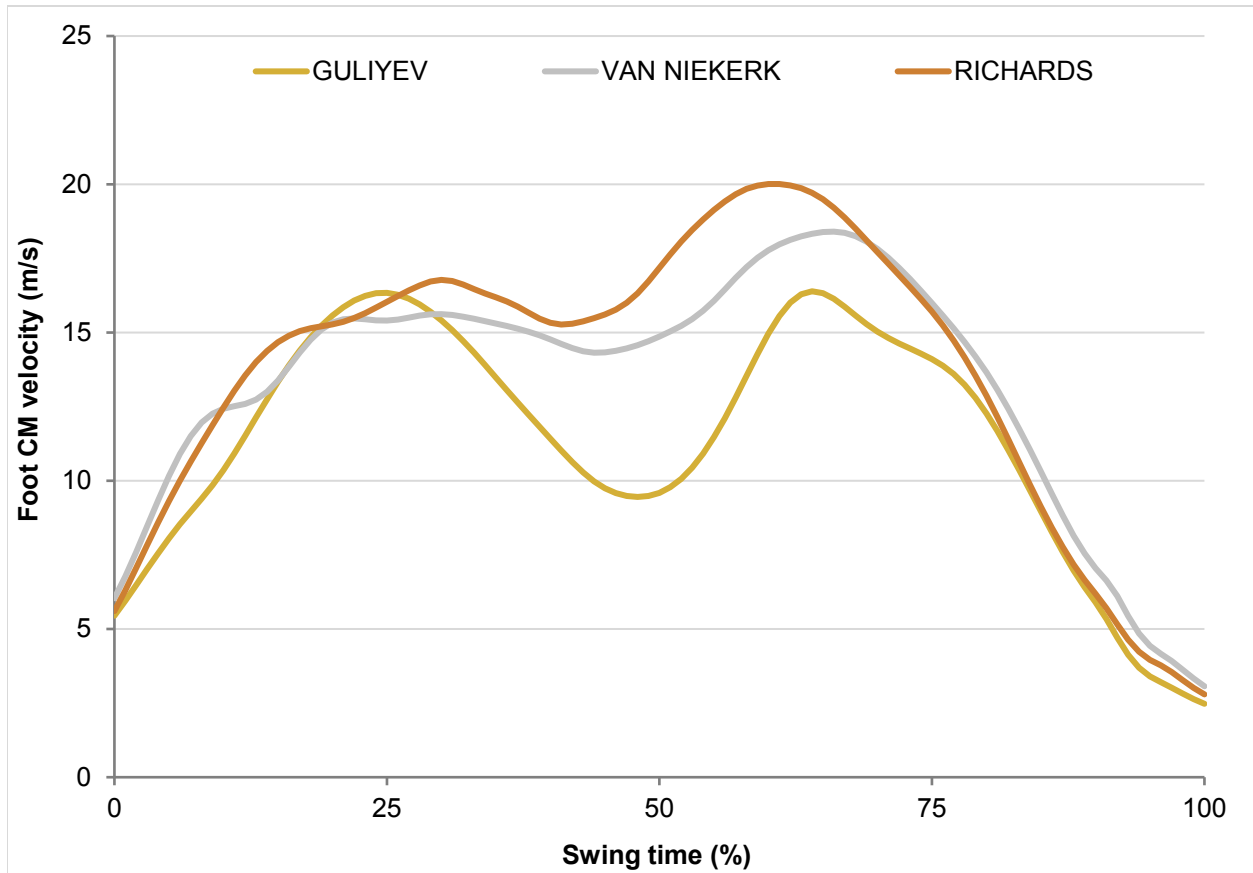


Figure 16. Resultant foot centre of mass (CM) velocity during the swing phase for the medallists, displayed as a percentage of swing time.

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)	%
GULIYEV	5.31	15	16.39	64
VAN NIEKERK	7.85	8	18.40	66
RICHARDS	8.33	11	20.01	60

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

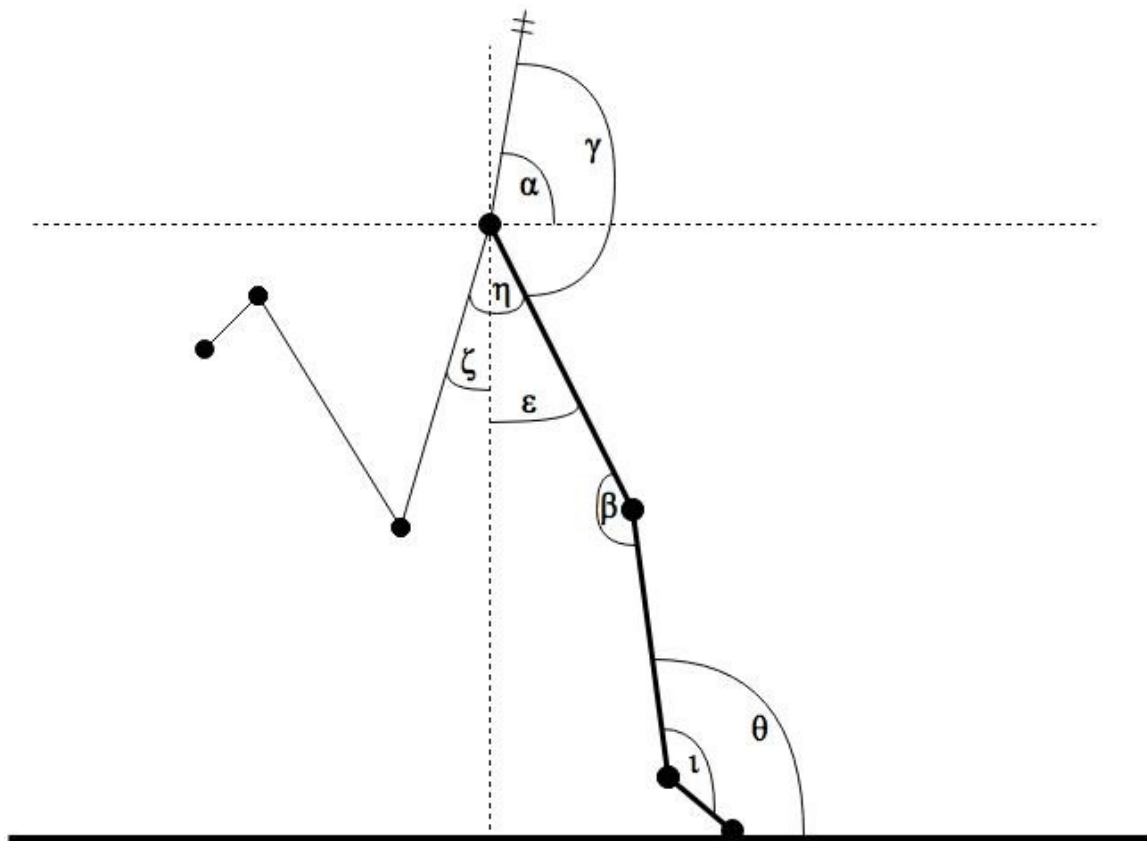


Figure 17. Body schematic denoting joint angles measured at touchdown. This does not represent any athlete's posture but is merely for illustration purposes.

Table 7. Joint angles at touchdown for the medallists.

	GULIYEV		VAN NIEKERK		RICHARDS	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	80.7	82.2	82.7	79.2	86.3	83.8
β	163.2	175.8	156.3	153.9	160.2	162.9
γ	156.7	158.6	145.7	147.9	153.7	152.1
ϵ	15.3	18.1	25.9	28.0	23.1	24.2
ζ	19.2	7.7	10.2	11.2	6.5	9.3
η	3.9	-10.4	-15.7	-16.8	-16.6	-14.9
θ	96.7	104.5	100.5	97.4	100.9	98.9
ι	114.8	122.2	119.6	112.7	117.7	122.3

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.

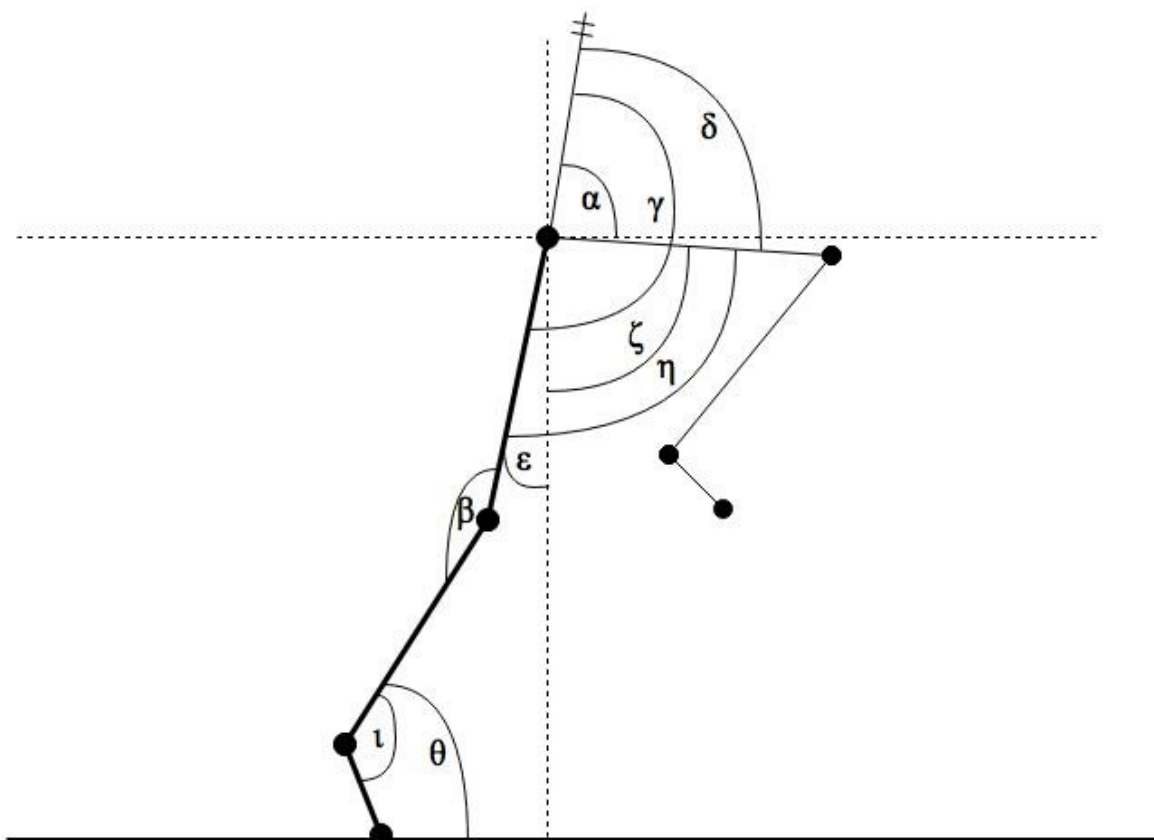


Figure 18. Body schematic denoting joint angles measured at toe-off. This does not represent any athlete's posture but is merely for illustration purposes.

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

	GULIYEV		VAN NIEKERK		RICHARDS	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	83.2	82.4	86.2	83.2	86.4	87.6
β	156.7	155.2	157.8	158.8	165.4	159.7
γ	190.9	196.7	202.7	205.1	211.8	206.5
δ	123.4	135.1	112.3	119.0	121.0	113.4
ϵ	-24.7	-23.3	-30.1	-26.4	-30.5	-27.4
ζ	60.6	42.6	66.5	58.1	64.4	68.9
η	85.3	65.9	96.6	84.5	94.9	96.3
θ	45.0	42.1	38.0	43.1	45.2	42.9
ι	126.0	106.2	118.2	132.9	132.6	114.6

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.

	MITCHELL-BLAKE		WEBB		MAKWALA		SANI BROWN		YOUNG	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	80.5	81.9	78.0	75.1	87.8	84.7	77.6	77.3	82.0	81.8
β	165.7	148.2	160.0	151.7	164.4	149.1	164.6	158.7	157.8	158.5
γ	146.6	145.6	145.4	139.7	159.7	158.9	143.2	149.4	148.7	146.2
ε	21.8	31.6	22.6	21.4	21.9	25.1	27.1	24.2	25.1	29.2
ζ	18.0	10.4	-4.6	-18.6	-1.3	4.1	11.3	9.4	14.4	-0.7
η	-3.8	-21.2	-27.2	-40.0	-23.2	-21.0	-15.8	-14.8	-10.7	-29.9
θ	101.2	93.9	110.9	101.6	97.7	99.3	103.9	93.9	102.6	98.4
ι	129.0	113.4	112.8	108.5	112.9	103.3	117.0	111.9	113.0	112.9

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.

	MITCHELL-BLAKE		WEBB		MAKWALA		SANI BROWN		YOUNG	
	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)	Left (°)	Right (°)
α	83.3	85.7	85.7	84.9	86.3	84.9	85.0	79.5	86.3	84.2
β	157.7	161.6	170.6	158.5	161.9	159.3	159.3	141.2	159.0	150.0
γ	194.0	201.0	202.0	206.2	203.2	206.2	198.4	196.4	194.0	201.0
δ	106.3	109.7	135.3	129.1	124.2	121.0	119.0	107.9	116.4	118.9
ε	-24.5	-27.1	-32.4	-26.1	-28.1	-25.1	-26.4	-12.3	-26.5	-19.0
ζ	72.7	70.0	47.9	47.5	56.5	62.5	62.2	65.9	65.8	62.4
η	97.2	97.1	80.3	73.6	84.6	87.6	88.6	78.2	92.3	81.4
θ	43.3	44.7	47.6	44.0	43.9	45.1	43.8	39.6	42.9	41.8
ι	149.3	139.7	142.6	119.0	147.5	140.1	139.1	134.8	128.9	137.7

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
YOUNG	10	7	20.12 s	SB Q	-0.02 s	0.26 s
MAKWALA	1	2	20.14 s	Q	0.37 s	0.37 s
MITCHELL-BLAKE	6	9	20.19 s	q	0.15 s	0.24 s
LIMA	17	20	20.56 s		0.26 s	0.26 s
IIZUKA	23	14	20.62 s	.612 s*	0.21 s	0.50 s
TORTU	21	23	20.62 s	.613 s*	0.27 s	0.27 s
SIMBINE	3	9	20.62 s	.618 s	0.67 s	0.67 s
GREAUX	12	16	20.65 s		0.46 s	0.46 s
DWYER	9	3	20.69 s		0.58 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.

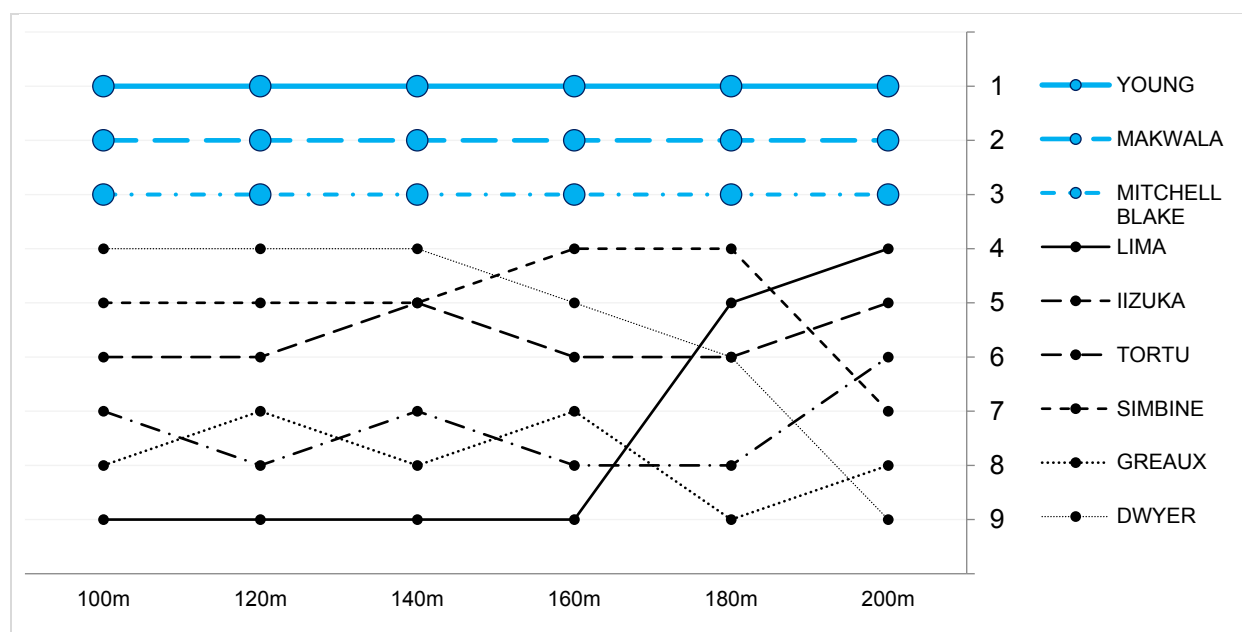


Figure 19. Positions at the beginning of the home straight and at each 20 m split.

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.

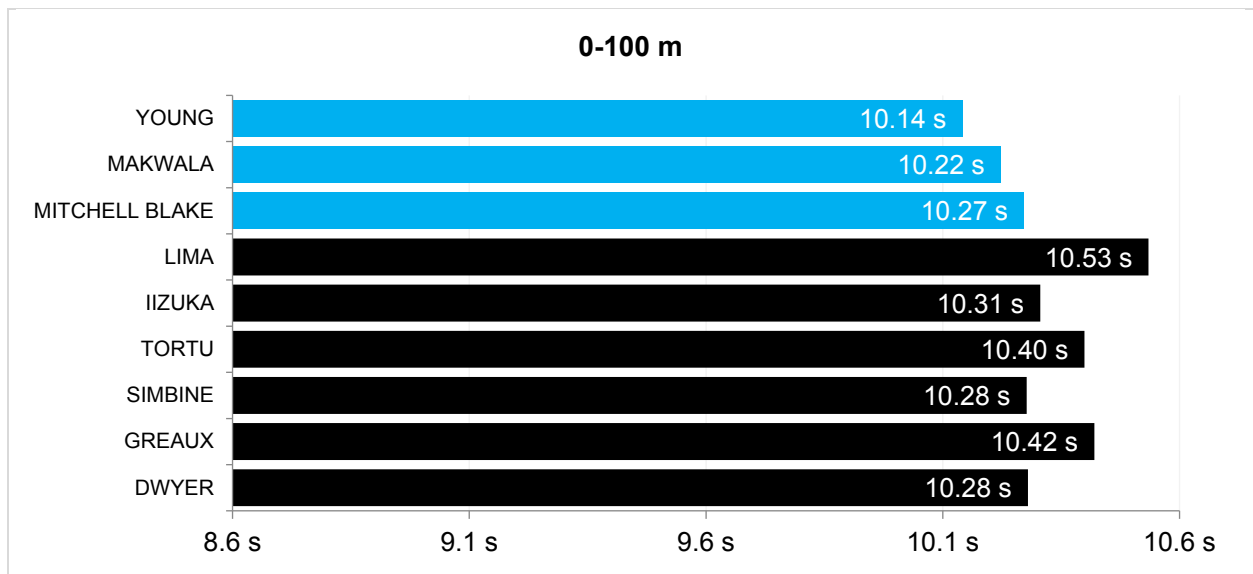


Figure 20. Individual 0-100 m split times (minus reaction time).

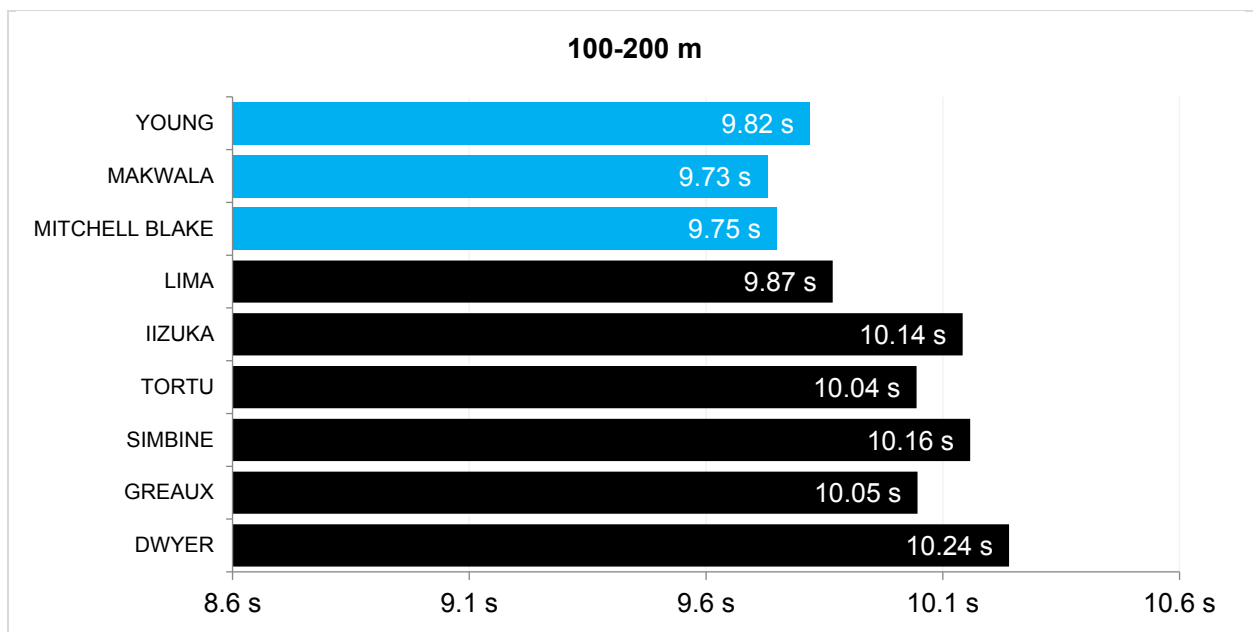


Figure 21. Individual 100-200 m split times.

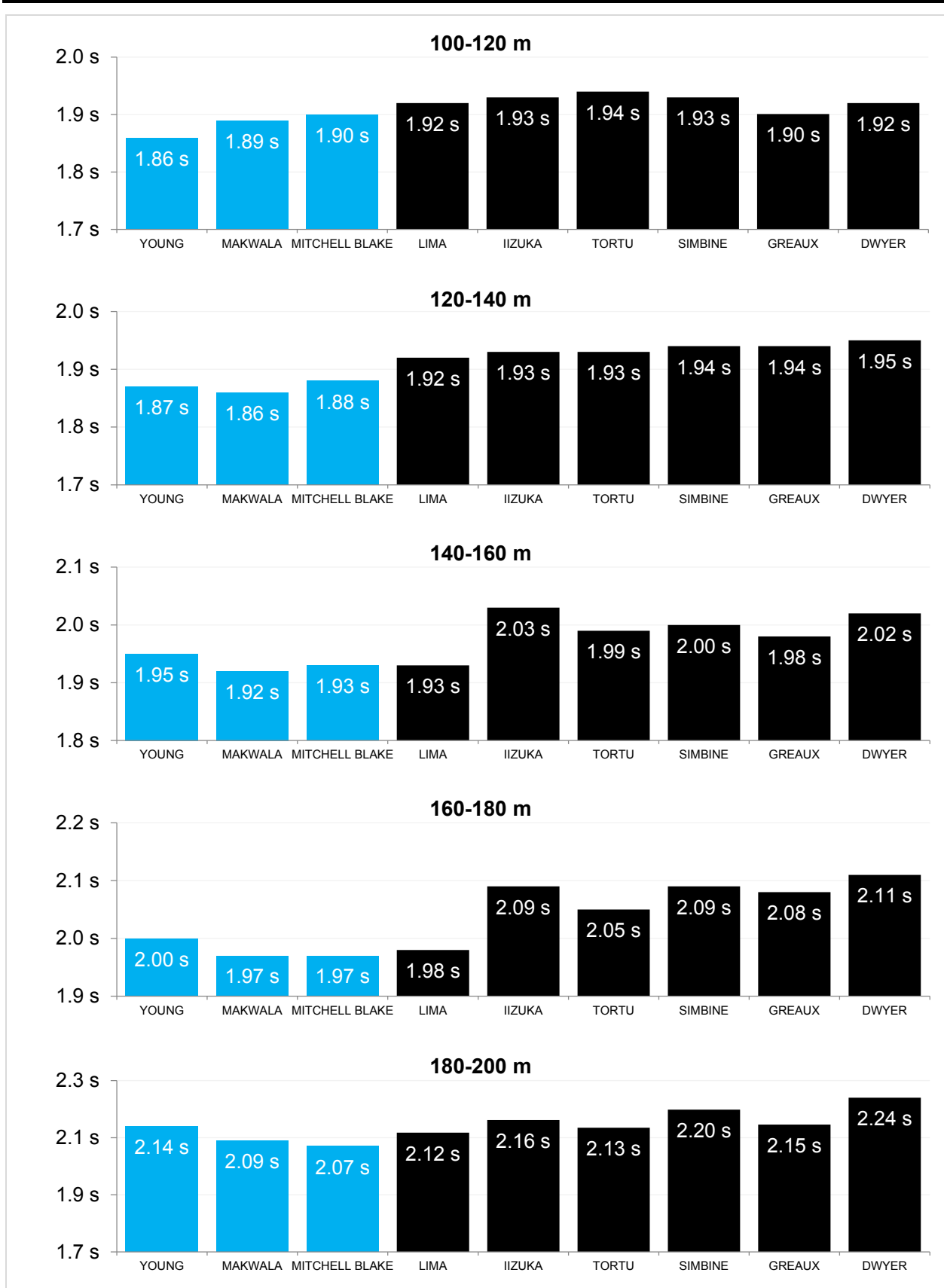


Figure 22. Individual consecutive 20 m split times during the home straight.

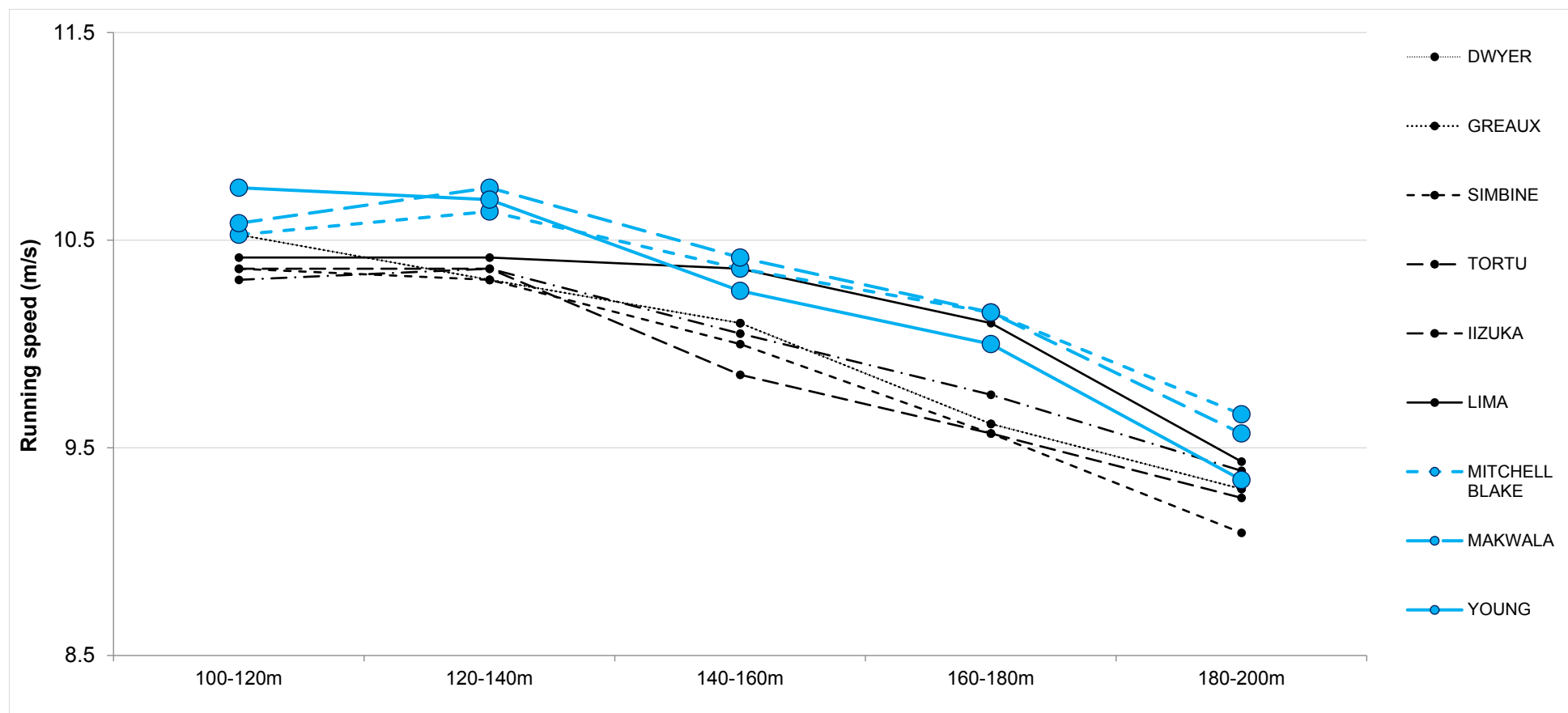


Figure 23. Mean running speed during each 20 m split throughout the home straight.

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.

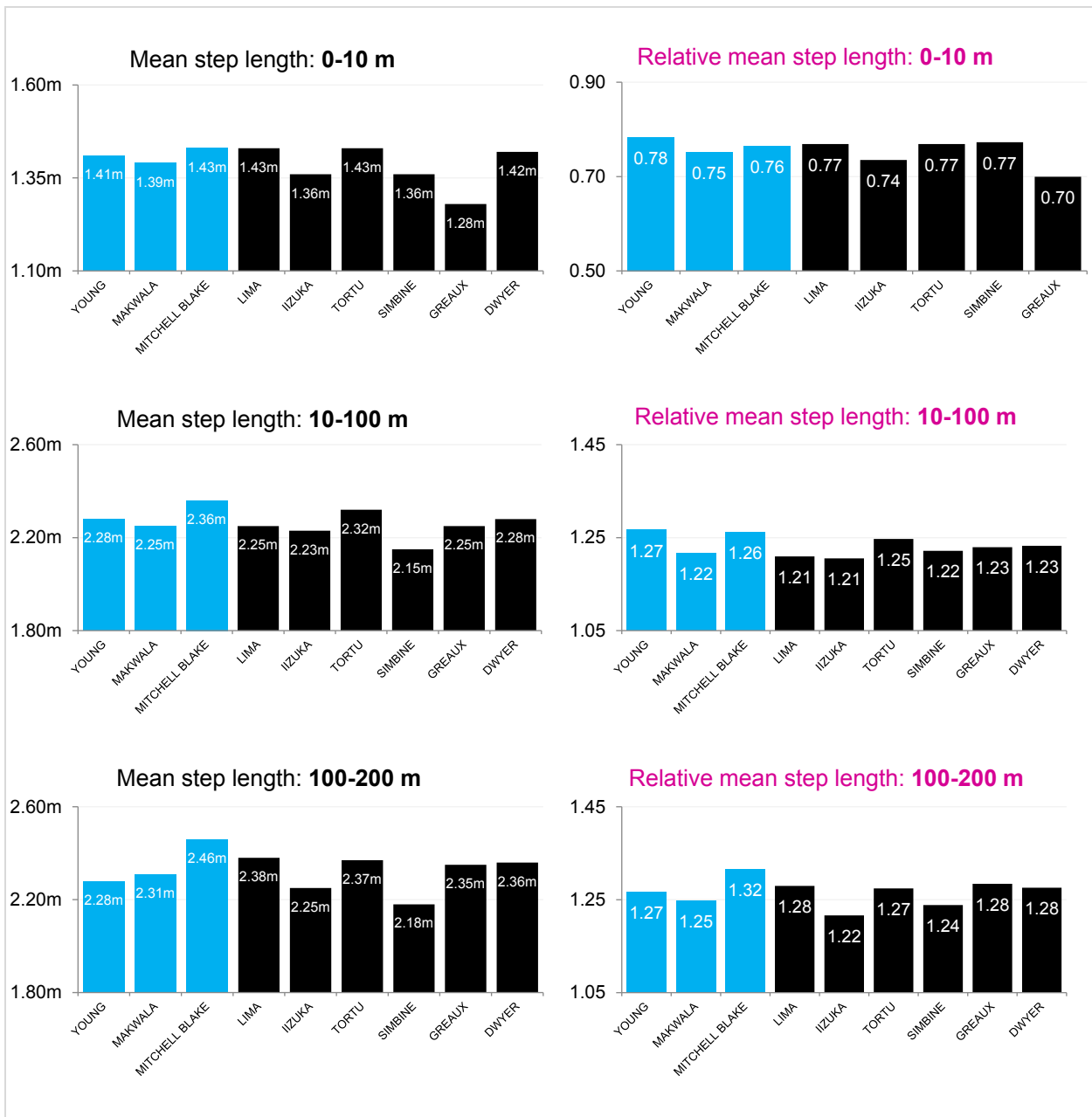


Figure 24. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

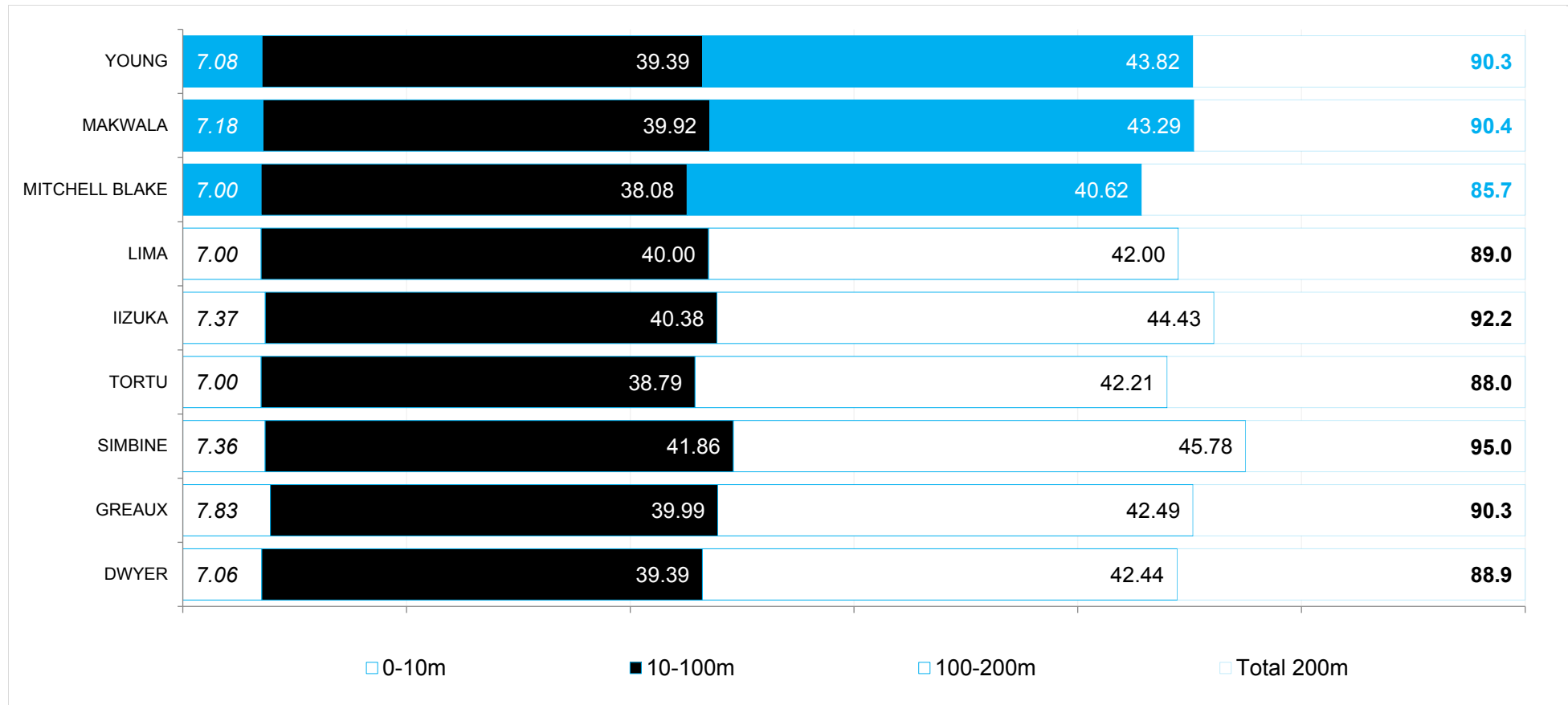


Figure 25. Total completed steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

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
RICHARDS	4	11	20.14 s	Q	0.17 s	0.17 s
SANI BROWN	18	21	20.43 s	Q	0.11 s	0.11 s
BLAKE	4	1	20.52 s		0.55 s	1.26 s
SIAME	15	19	20.54 s		0.25 s	0.25 s
KING	14	18	20.59 s		0.32 s	0.32 s
VOLKO	19	22	20.61 s		0.28 s	0.28 s
HUGHES	13	12	20.85 s		0.63 s	0.83 s
WILSON	22	24	21.22 s		0.85 s	0.85 s

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.

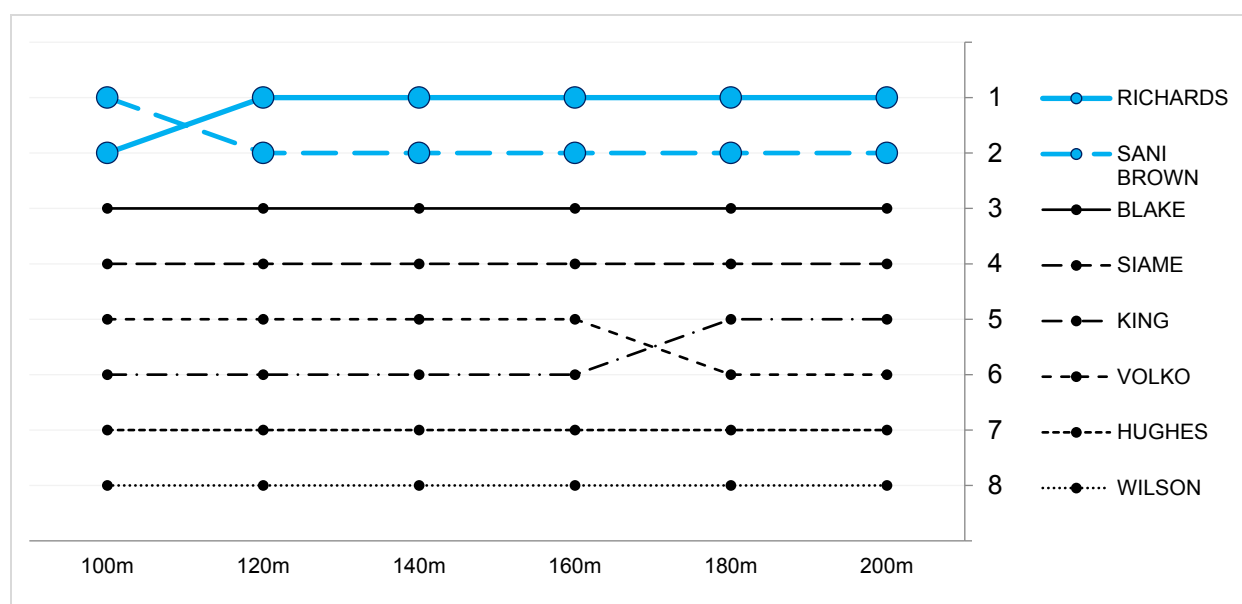


Figure 26. Positions at the beginning of the home straight and each 20 m split.

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.

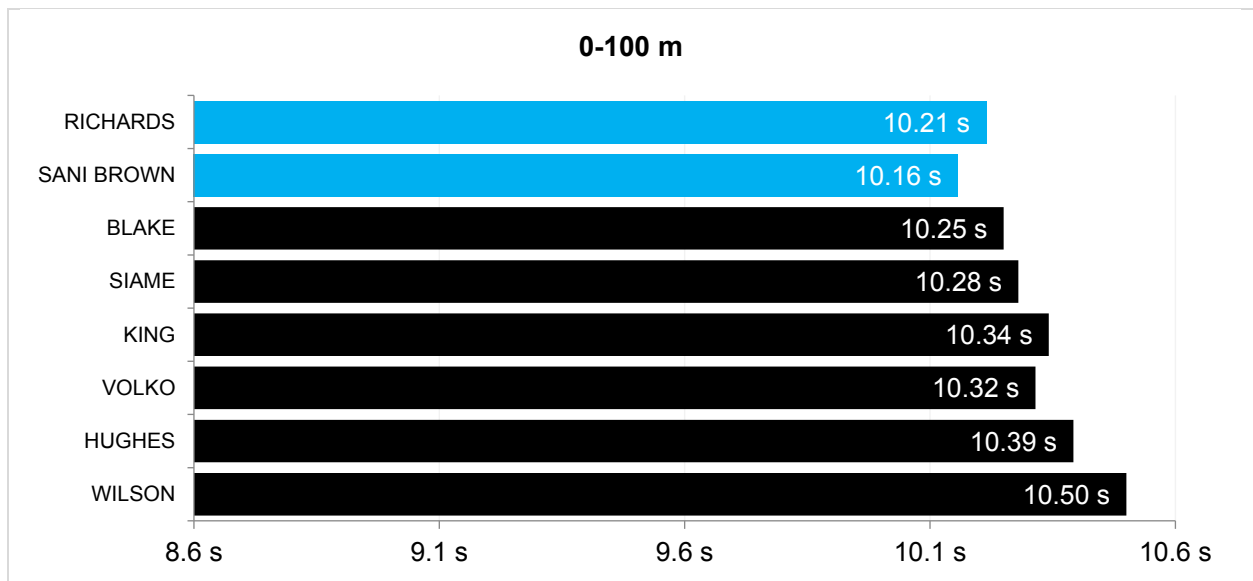


Figure 27. Individual 0-100 m split times (minus reaction time).

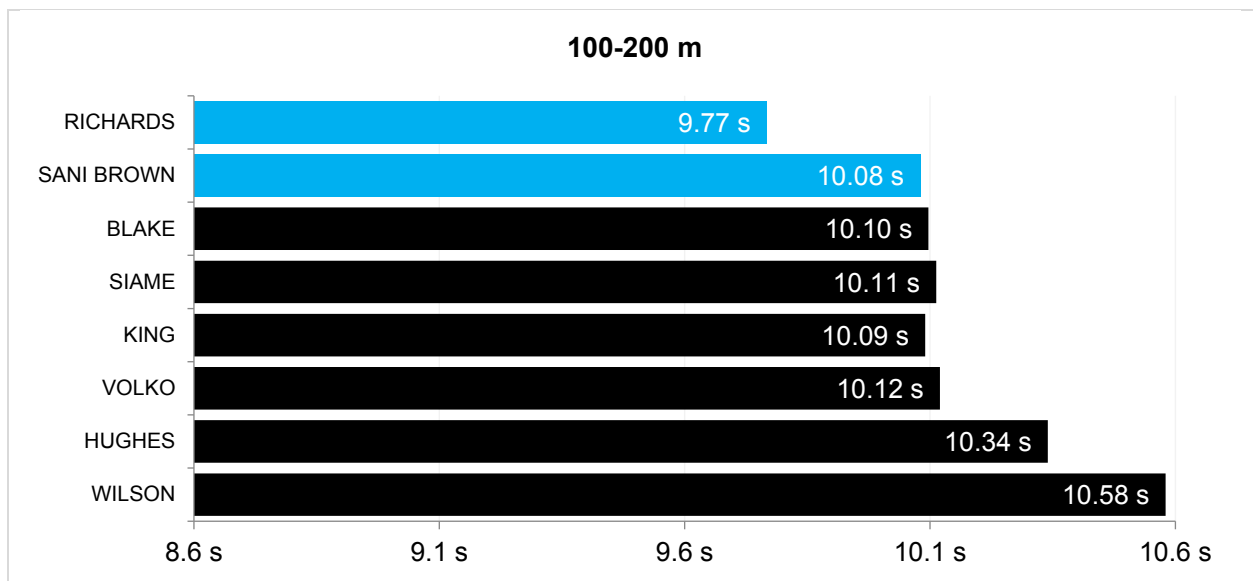


Figure 28. Individual 100-200 m split times.

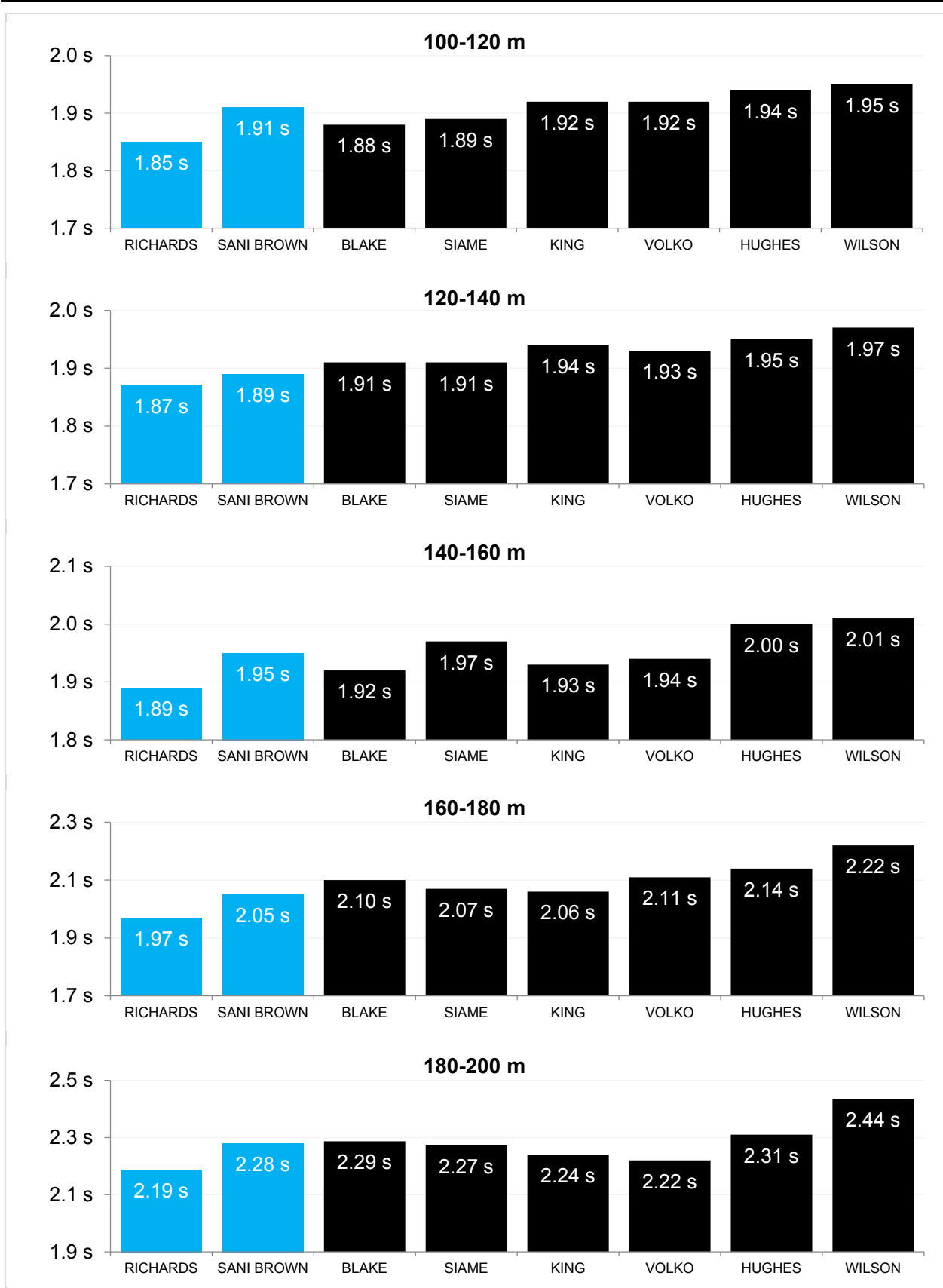


Figure 29. Individual consecutive 20 m split times during the home straight.

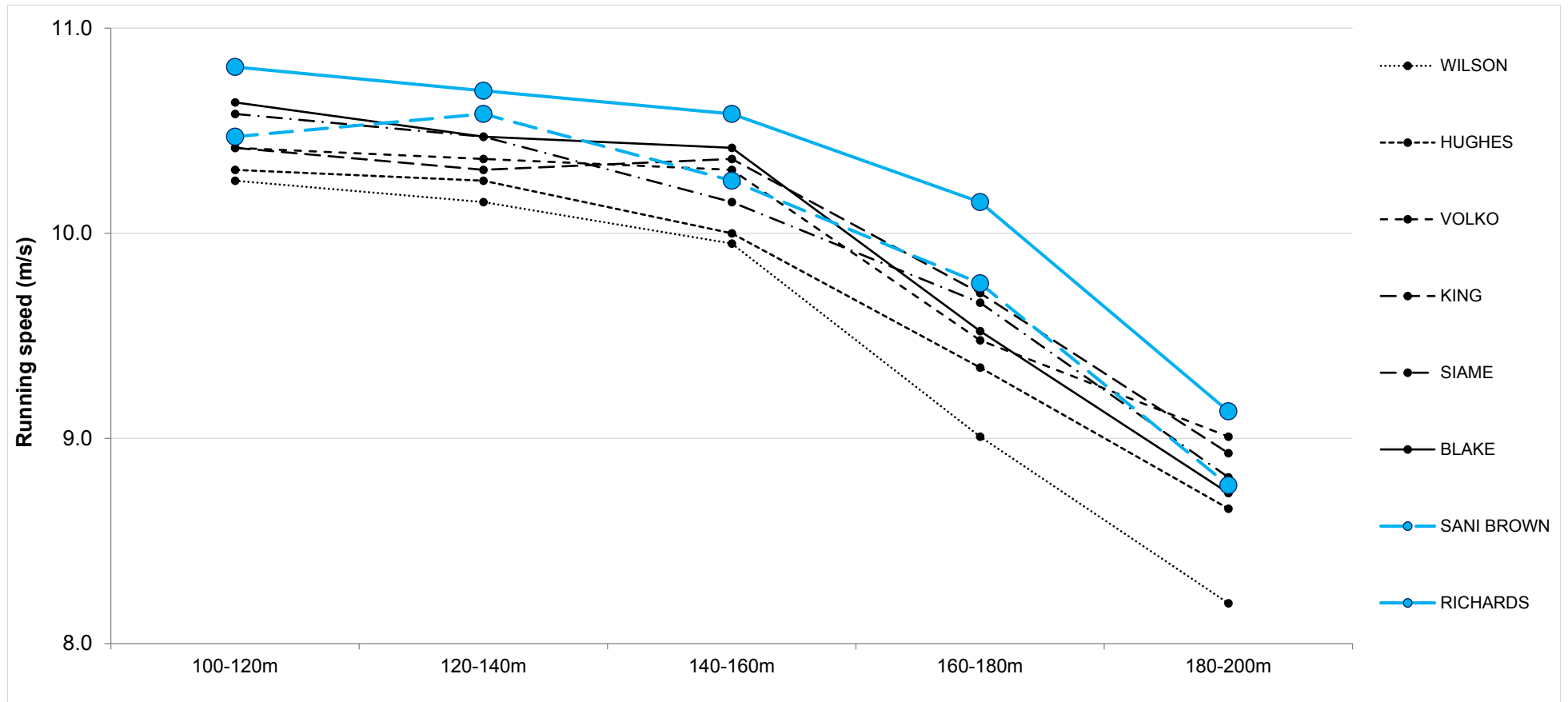


Figure 30. Mean running speed during each 20 m split throughout the home straight.

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.

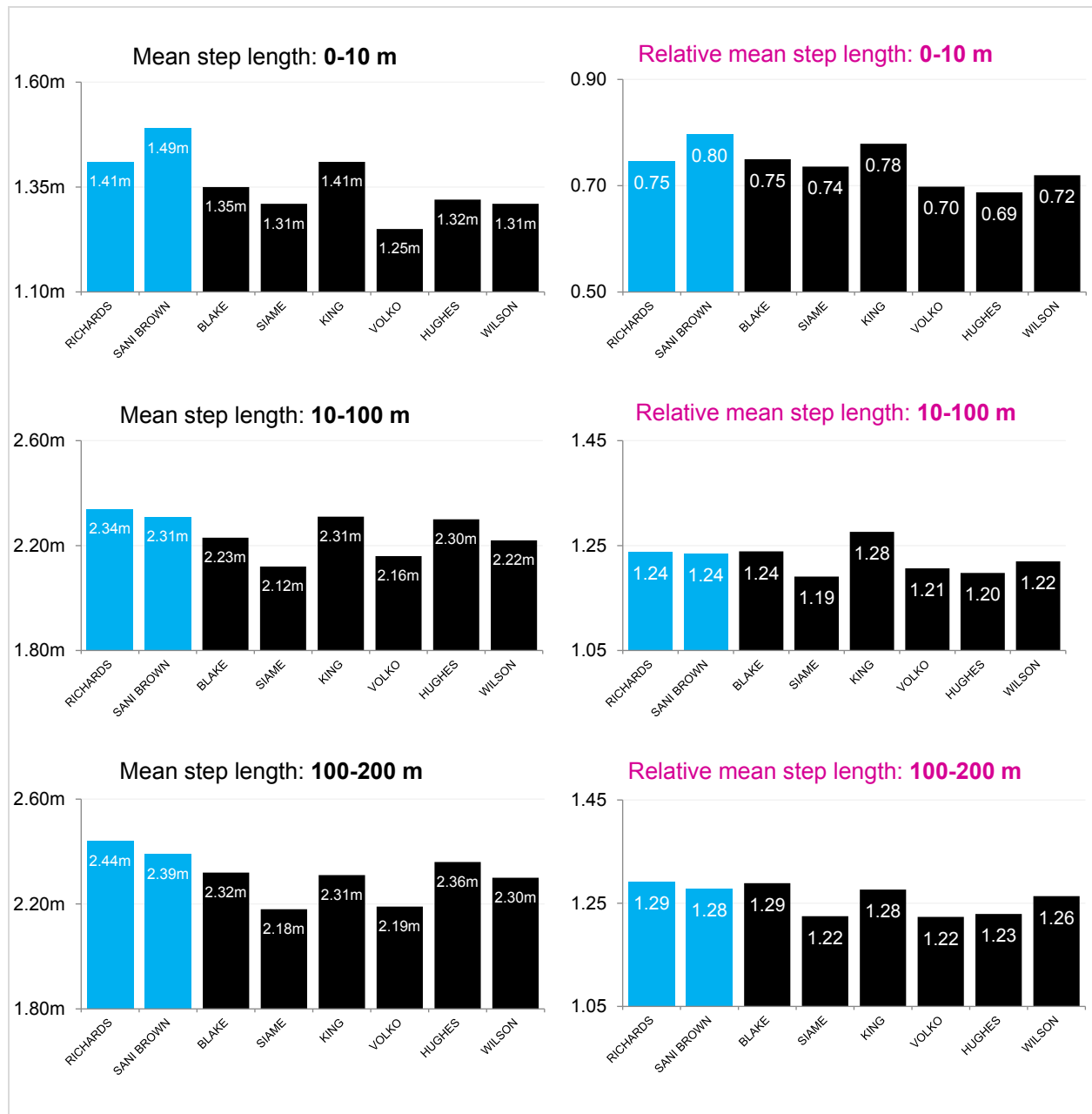


Figure 31. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

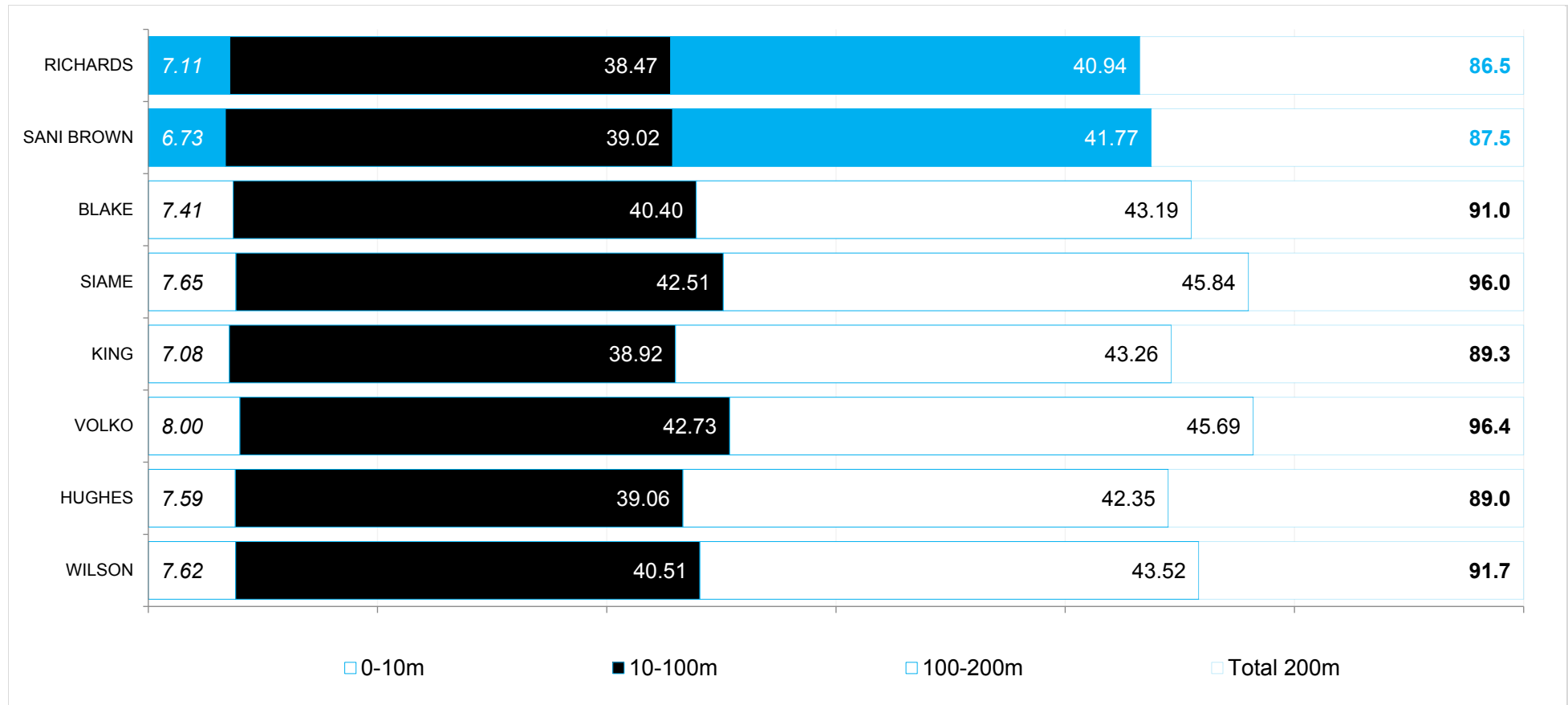


Figure 32. Total completed steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

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
GULIYEV	7	8	20.17 s	Q	0.09 s	0.29 s
WEBB	8	6	20.22 s	Q	0.13 s	0.37 s
VAN NIEKERK	2	5	20.28 s	q	0.44 s	0.44 s
LEMAITRE	15	3	20.30 s		0.01 s	0.50 s
TALBOT	11	15	20.38 s		0.22 s	0.22 s
TSÁKONAS	19	13	20.73 s		0.40 s	0.64 s
GEORGE	24	25	20.74 s		0.33 s	0.33 s
KOFFI HUA	24	17	20.80 s		0.39 s	0.55 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.

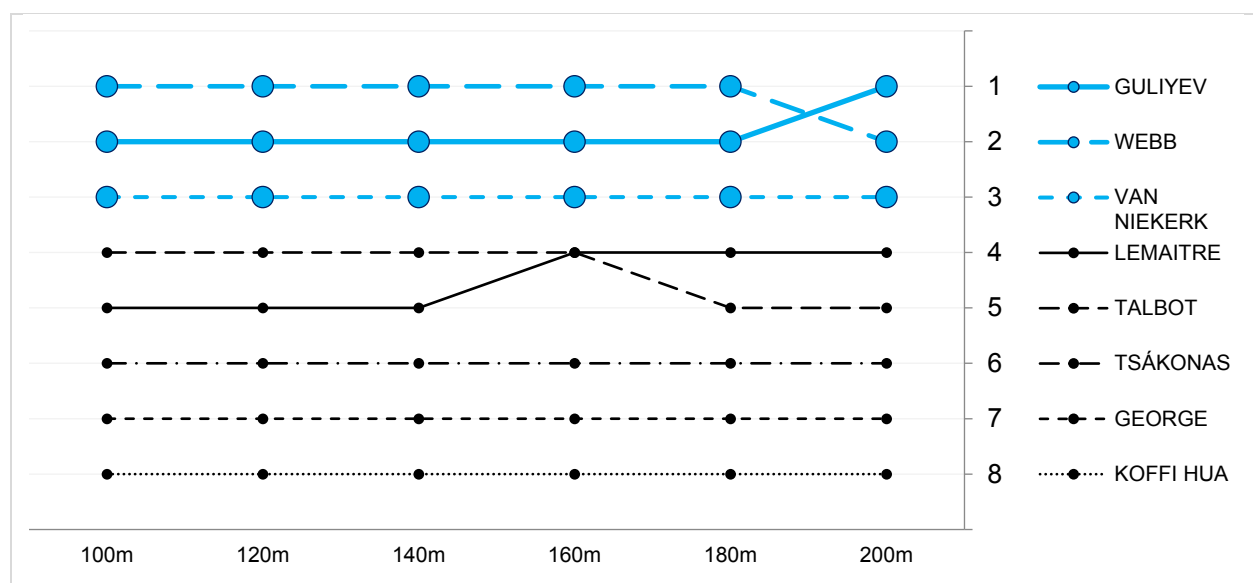


Figure 33. Positions at the beginning of the home straight and each 20 m split.

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.

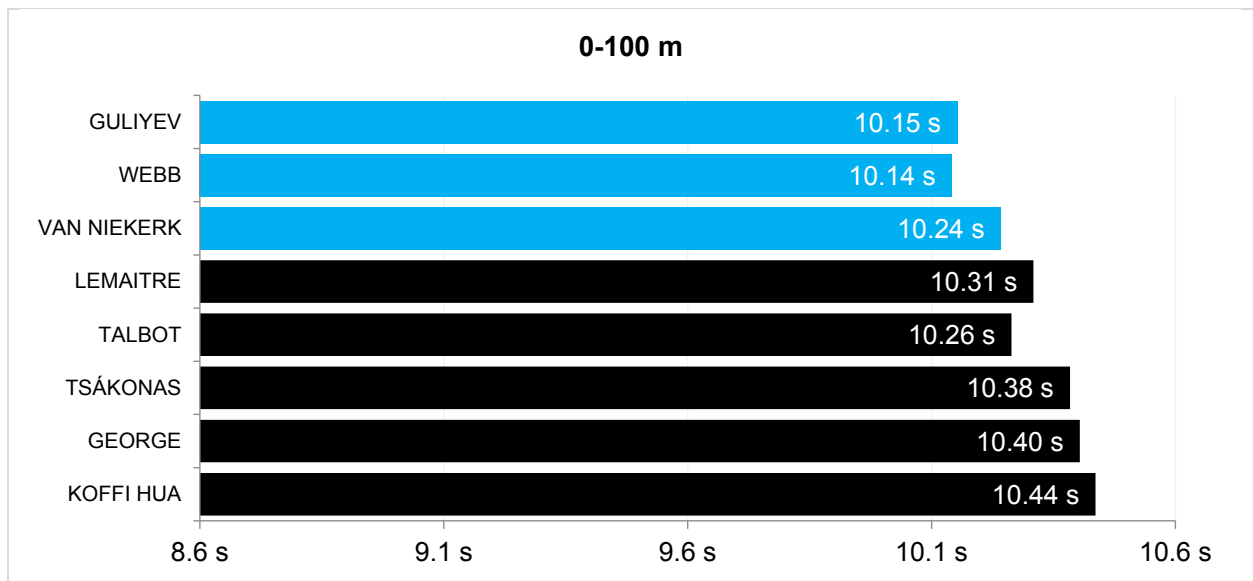


Figure 34. Individual 0-100 m split times (minus reaction time).

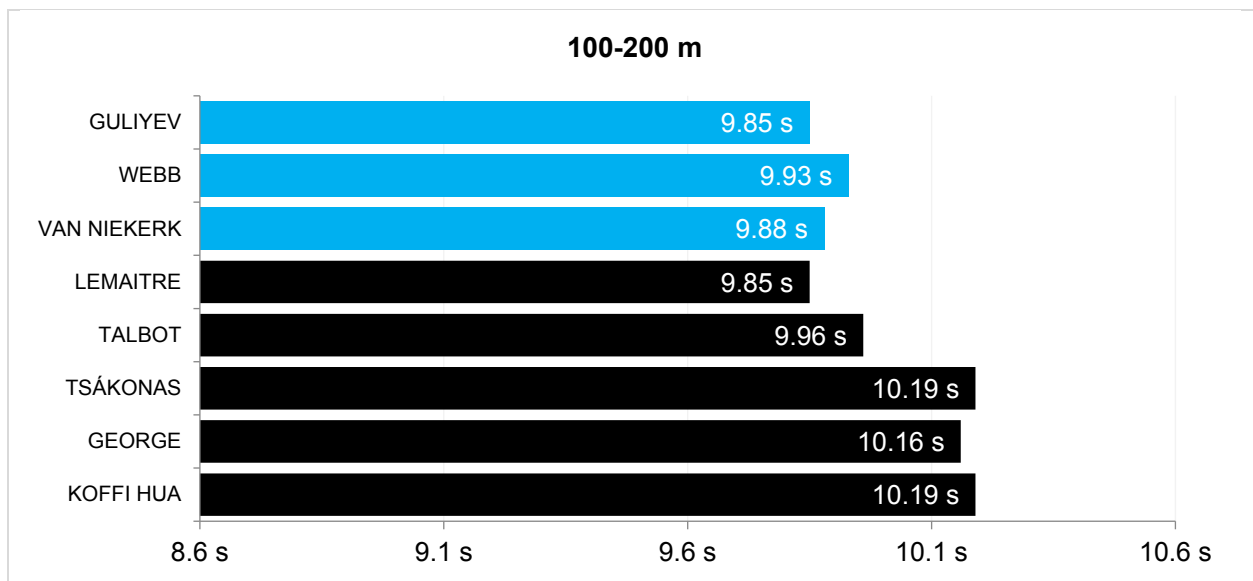


Figure 35. Individual 100-200 m split times.

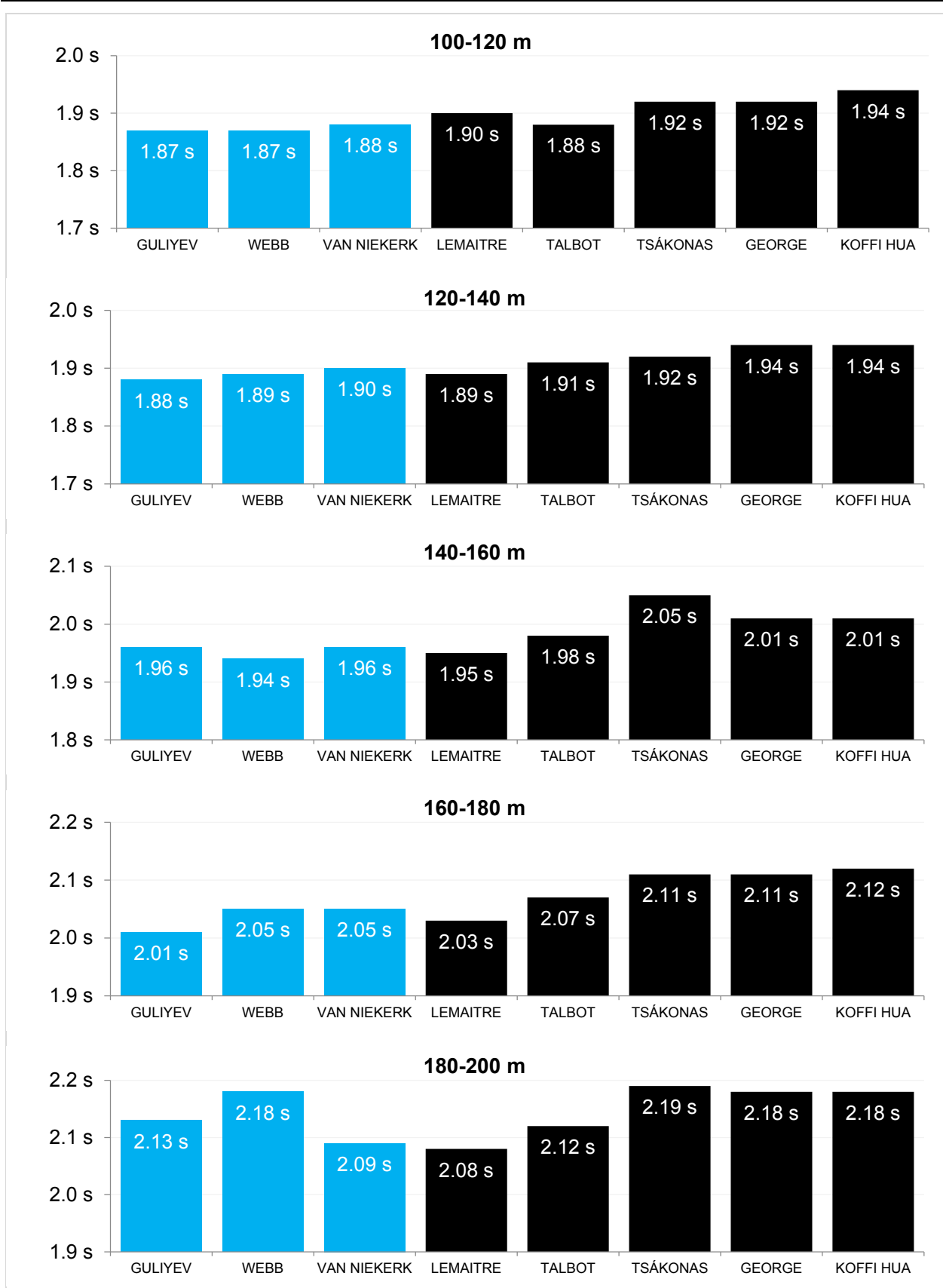


Figure 36. Individual consecutive 20 m split times during the home straight.

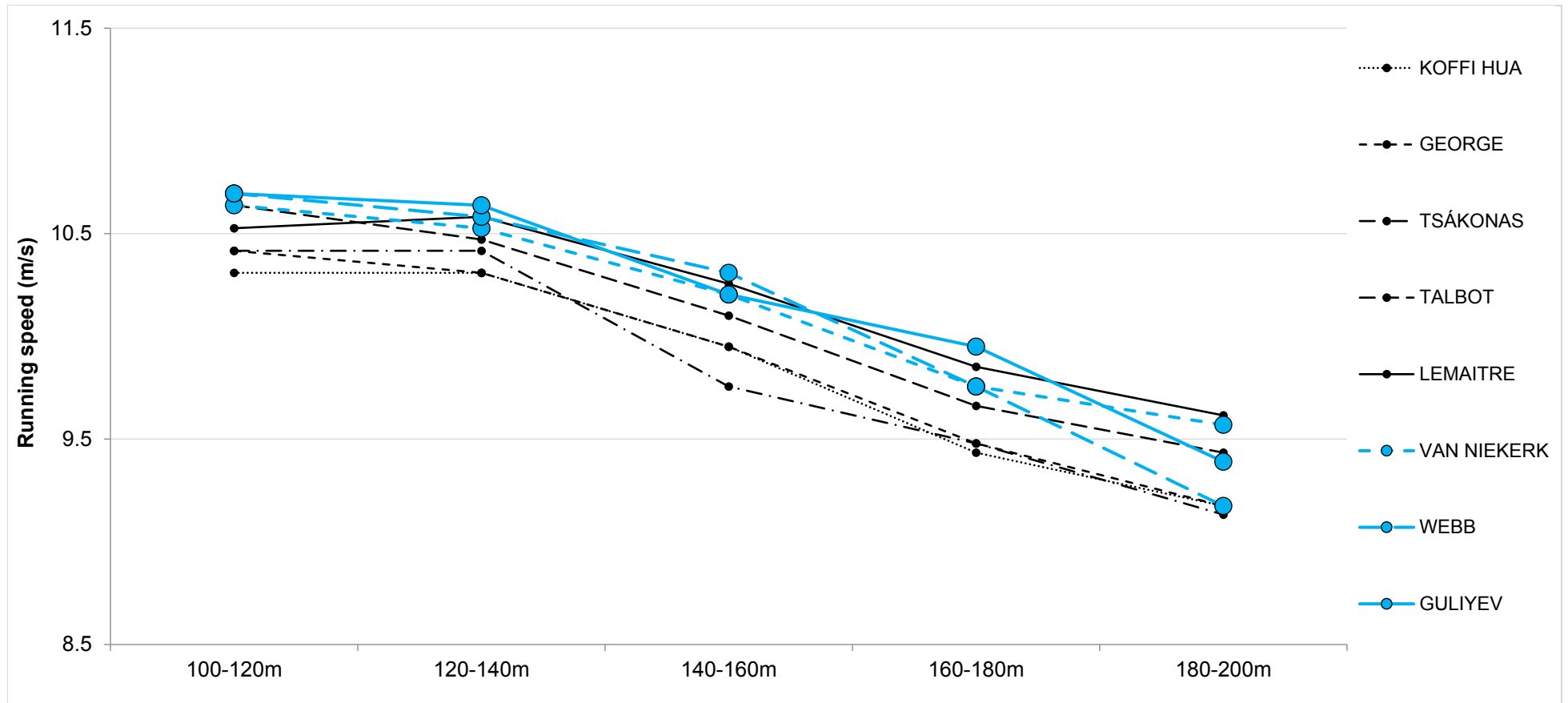


Figure 37. Mean running speed during each 20 m split throughout the home straight.

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.

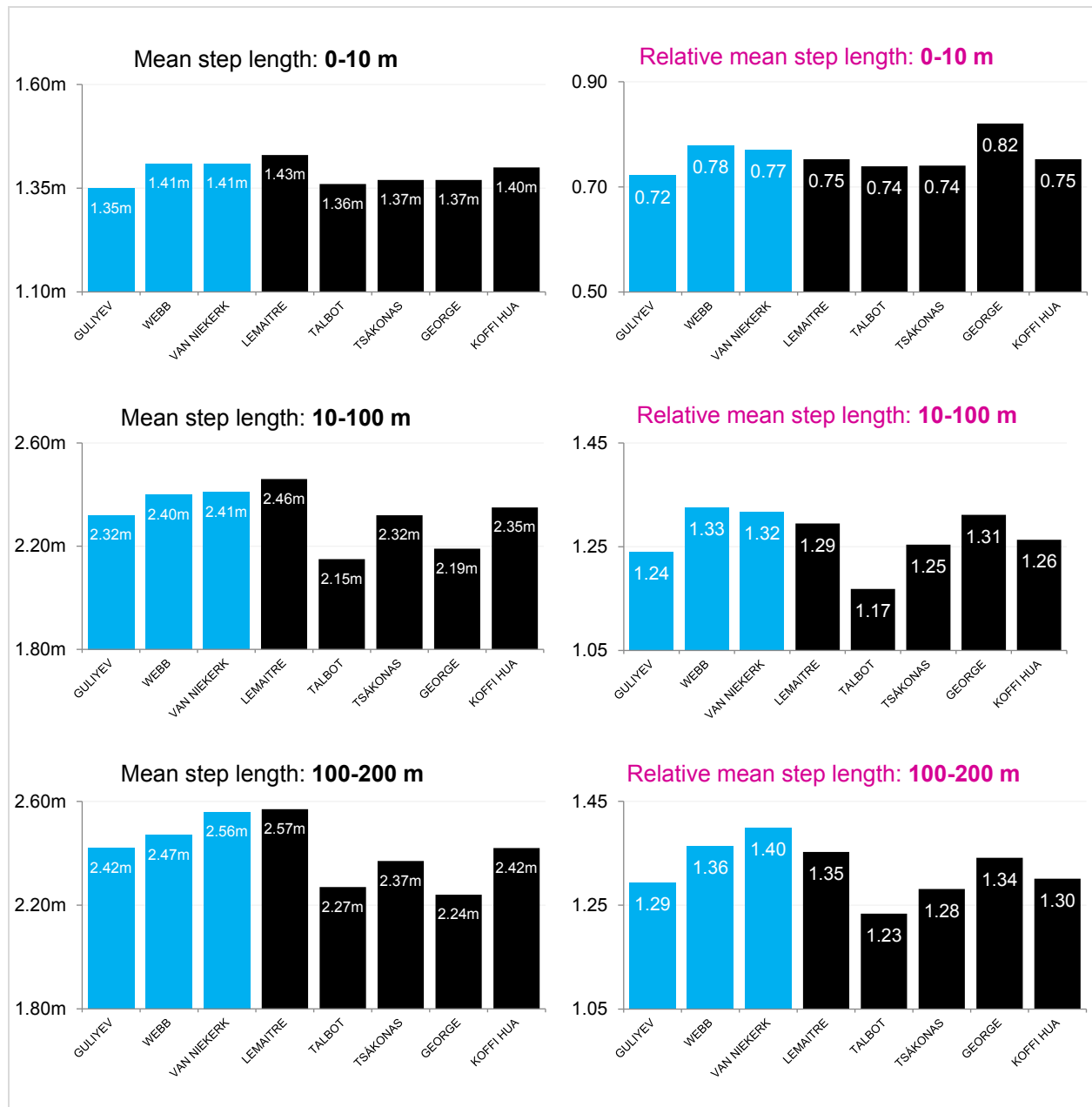


Figure 38. Mean and relative (height) step length during the initial 10 m, 10-100 m and 100-200 m intervals.

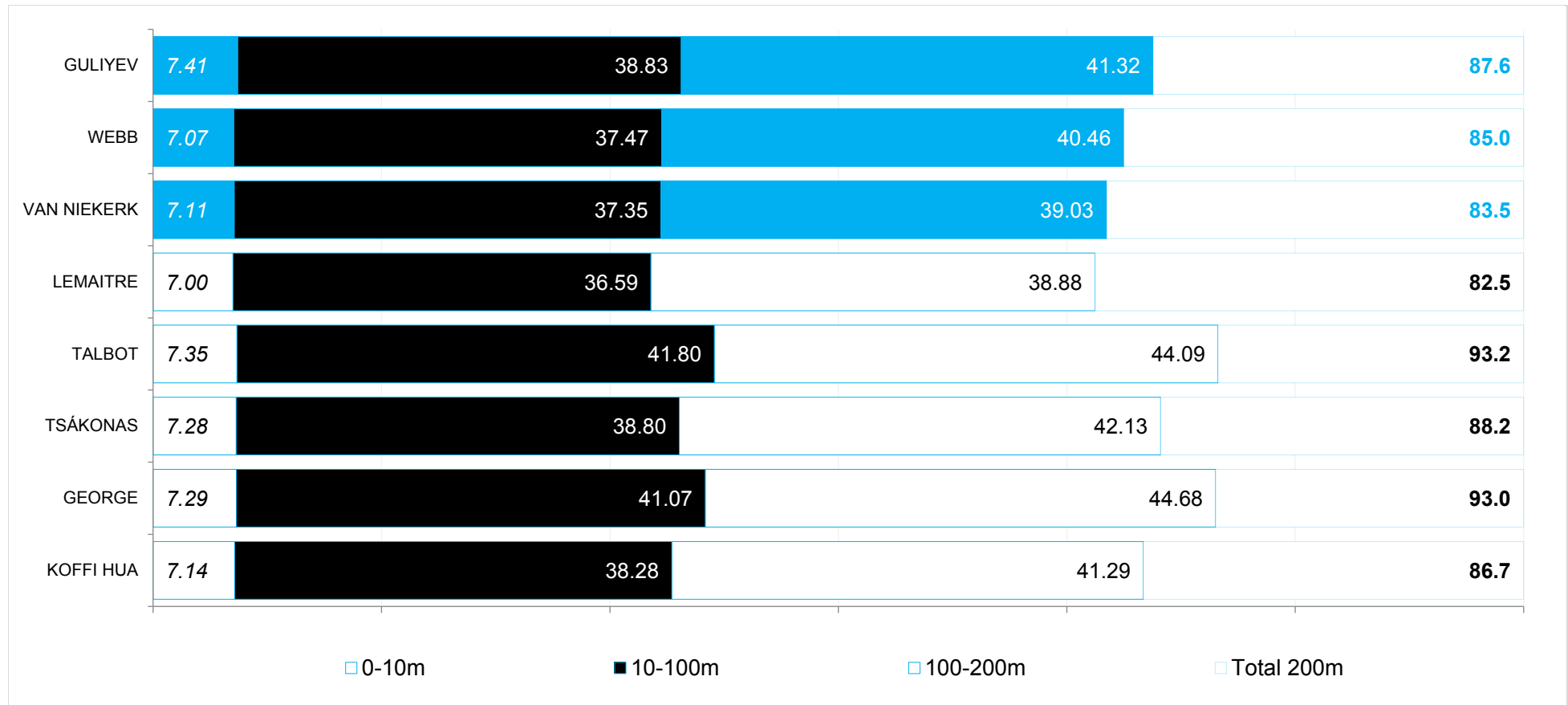


Figure 39. Total completed steps during the race, within the initial 10 m, between 10 and 100 m and 100 and 200 m intervals.

COACH'S COMMENTARY

Historical analysis and coaching commentary – Pierre-Jean Vazel

This commentary on London's 200 m report will provide training information about the finalists in order to illustrate and put into perspective the biomechanical findings on speed endurance.

Speed endurance abilities of 200-400 m types

Information regarding the speed endurance training was gathered from the top six finalists of the London 200 m or from their coaches. Two of them, Wayde van Niekerk (silver medallist) and Isaac Makwala (6th place), were also finalists at 400 m and obviously these 200-400 m types are the ones who have used the longest runs in practice. However, it did not seem to provide them with the ability to run the last segments of the 200 m final faster than the others, or display a lower deceleration rate. Indeed, running the 200 m less than 20 s requires covering the last 50 m over 10 m/s under fatigue, a velocity that is also reached during a 400 m race, but before fatigue sets in. This is shown in the analysis of the four fastest 400 m runners. First, van Niekerk was over 10 m/s in the 50-200 m section of his 43.03 s world record race (43.03 s in Rio 2016, Yamamoto, 2016). In addition, Michael Johnson did so in the 50 to 150 m section (43.18 s in Sevilla 1999, Ferro, 2001), Butch Reynolds 50 to 100 m (43.29 s in Zürich 1988) and Jeremy Wariner in the 45 to 115 m section (43.45 s in Osaka 2007, Mochida, 2010). In these sections, the runners are in the “comfort zone”, trying to run as smooth and relaxed as possible, which is different from the effort expenditure necessary in the finish of a 200 m.

The structure of the stride reflects this search for economy during the 400 m vs. efficiency during the 200 m. For instance, van Nierkerk ran the 100-200 m section of his 400 m final in London in 9.93 s, or at 10.07 m/s, with a 2.65 m step length at a rate of 3.80 Hz. During the 200 m final, he covered that 100-200 m section marginally faster, 9.80 s or 10.20 m/s, but with less amplitude, 2.58 m at a higher rate of 3.95 Hz. Interestingly, two of the fastest 400 m runners ever, Reynolds and Wariner, never ran under 20 s at 200 m. As indicated in the 400 m commentary of the London's 2017 report, one of the main features of successful 400 m runners is the ability to prevent a high drop in step frequency in the 300-400 m section. Reynolds and Wariner excelled in this area, but doing so at velocities ranging between 8.5 and 8.9 m/s, which is very different to what is found during the 200 m. This specialisation and adaptation for 400 m did not allow them to be able to produce a step frequency high enough under less fatigued conditions, which is necessary for reaching higher top-speed velocity.

Van Niekerk has improved his running velocity at 200 m, by increasing his step rate from his personal best whilst a teenager until his current lifetime best, the same as what he did at 400 m (cf. commentary of London's 200 m report). His reliance on step frequency was further demonstrated in London as his slower time was explained by a lower rate.

Progression of Wayde van Niekerk.

Meet	Age	Time (s)	No. of steps	Step length (m)	Step rate (Hz)
WJ 2010	18	21.02	82.8	2.42	3.94
Kingston 2017	24	19.84	83.4	2.40	4.20
London 2017	24	20.11	83.4	2.40	4.15

Note: WJ = World Junior Championships.

The world champion Ramil Guliyev also displays a similar reliance on step rate rather than step length.

Progression of Ramil Guliyev.

Meet	Age	Time (s)	No. of steps	Step length (m)	Step rate (Hz)
Beijing 2008	18	20.66	88.0	2.27	4.26
Zagreb 2015	25	19.88	88.2	2.27	4.44
London 2017	27	20.09	88.5	2.26	4.41

Of all the finalists from measurements at 150 m, Guliyev had the highest rate (Table 4) as he was the only one to produce contact times below 0.100 s (Figure 15). Contact times of 0.10-0.11 s were reported for the 1984 Olympic Games gold and silver medallists, Carl Lewis 19.80 s and Kirk Baptiste 19.96 s at 125 m and 180 m (Mann, 1985). Guliyev managed to do so in preparing a quick leg recovery with an abbreviated leg extension to terminate the non-productive latter portion of ground contact (Mann, 1985), as measured at toe-off by the smallest distance of the foot relative to the athlete's body (Table 5) and one of the smallest knee angle among the finalists. This led to an efficient swing of the leg as evidenced by the smallest angle between thighs at touchdown (η angle, Table 7). This is in line with what was measured in Michael Johnson at the 1991 World Championships (Ito, 1994). These mechanical features of the leg motion are close to the model for top speed at 100 m (Tiupa, 1988), implying that Guliyev displays very good speed endurance with little modifications on his step parameters. A study on the 200 m 2003 World Championship medallist, Shingo Suetsugu (Kijima, 2005) found that the main difference between his sprint stride at maximum velocity during 100 m (11.5 m/s for a 10.13 s result) and at 150 m into a 200 m (11.0 m/s for 20.03 s) was in the angular velocity of knee flexion when the heel goes under the gluteus, and of the leg extension when the foot moves further away in front of the body.

This illustrates that one should not focus exclusively on what happens during the contact phase; the swing of the leg also needs to be analysed to understand the mechanical adaptation of stride during fatigue.

While step rate seems to have a high importance for success in speed endurance, athletes with step length reliance have also found success, the main example being Usain Bolt, current world record holder with 19.19 s.

Progression of Usain Bolt.

Meet	Age	Time (s)	No. of steps	Step length (m)	Step rate (Hz)
WJ 2002	15	20.58	85.1	2.35	4.13
Berlin WC 2009	22	19.19	80.0	2.50	4.17

Note: WJ = World Junior Championships.

Speed endurance training of 100-200 m types

The fastest finisher of London's 200 m final was Jereem Richards with a last 100 m time of 9.70 s. Whilst he has never run a 100 m in competition and is a useful 400 m runner (45.21 s and a flying-started 43.60 s in the 4x400 m relay to win gold medal in London for Trinidad and Tobago), he cannot really be considered as a 400 m specialist as he has never taken part in the individual 400 m in championships. His training personal bests of 14.6 s at 150 m, 25.9 s at 250 m and 31.6 s at 300 m (hand timing), provide a good balance between the speed and speed endurance required for 200 m, as he moved up in position from 5th at 130 m to 3rd place in London's final. Nethaneel Mitchell-Blake also had a strong finish, as he was 7th at 130 m and eventually placed 4th. He has run the 400 m only once in his career, a good 46.55 s in 2016, but is more of a short sprint specialist with a 9.99 s at 100 m. His training times are virtually the same as Richards, 14.6 s at 150 m and 25.9 s at 250 m, but he has never been timed at 300 m. Ameer Webb is the only other top-6 finisher in London to have no training reference at 300 m. He has only ran 250 m on a couple of occasions in the past years, and has generally used distances longer than 150 m in segment style, according to his coach Stuart McMillan. His best is a very fast 25.6 s, which was ran a week before a 9.90 s and 19.91 s double in Walnut, CA in April 2016. Although the average velocity of a 250 m race is significantly slower than of a 200 m, it is an interesting specific workout as the first 200 m is run at sub-maximum effort (20.2 s for Webb's training race). Yet, this was close to competitive time at 200 m and the last 50 m is covered at full effort under fatigue, as velocities are close to what are found in the last segments of the 200 m race, more than what could be found in 300 or 400 m races. The times given by the top 6 finalists range between 25.5 s and 25.9 s for 250 m, and from 14.2 s to 14.8 s at 150 m. To run sub-20 s in competition, 300

m times may not be required, however it seems necessary to have run under 15 s 150 m and 26 s at 250 m during the preparation, although a very fast 150 m could compensate a slower 250 m, and vice-versa. However, from a larger collection of training data from world-class sprinters, the 250 m training times are more related to 200 m results in competition than 150 m times. Indeed, the Figure 9 shows that velocity curves drop after 150 m, confirming previous split analysis during the 1987 and 2007 World Championships (Moravec, 1990; Tsuchie, 2010).

Besides these time trials, examples of significant speed endurance workouts were kindly given by two of the finalists who have more a 100-200 m profile, having run under 10 s and 20 s, rather than 200-400 m:

- Example A, running for time: two sets of two reps of 200 m, with 5- and 12-minute rests in between runs, all timed between 21 s and 21.4 s.
- Example B, running for distance: three races in segments with about 15 minutes of rest: first race 24 s run split in 7 s smooth, 8 s a little faster and 9 s fast; second one is 6, 7 and 8 s of the same progressive acceleration, and last rep is 5, 6 and 7 s.

As discussed before, a 150 m time-trial is not enough to predict success in 200 m competition. As an illustration, a former world champion who still is in the all-time top 10 performers at 100 m and 200 m, has a training best of 14.3 s at 150 m, but has been able to do 3 of them in 14.5 s average with 8 minutes rest, which was more representative of his speed endurance abilities.

In 1979, six days before breaking the world record in 19.72 s, which still stands as a European record, Italian Pietro Mennea was doing 6 reps of 80 m in 8.4-8.5 s with 2 minutes rest, followed by 10 minutes rest and one 200 m in 20.7 s, followed by 12 minutes rest and one 250 m in 27.3 s (Mennea 2011). Contemporary methods of training seem to have shift towards less repetition and faster pace than used before.

The present report provides a unique collection of biomechanical data recorded during the speed endurance phase. It will help coaches to assess the individual needs of their athletes and plan specific workouts for the requirements of the 200 m race in competition.

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Coaching commentary – Ralph Mouchbahani

Looking at the data in the semi-finals, it confirms that speed-dominance is more important than endurance-dominance through the ability of mastering the technical model throughout the race. The winner, Gulyev, based his achievement on a fast first 100 m, increasing frequency in the second 100 m, which was reflected through the number of steps taken in the second 100 m, relative to the other qualifiers from this semi-final (Figure 39). Similar patterns were seen in the final for the gold and silver medallists. Gulyev and van Niekerk based their rankings on a fast first 100 m, which is also shown in the number of steps taken (Figure 11).

In the final, the data collected for podium finishers reflects the technical execution of the stride, showing that the quick recovery of the swing leg at touchdown (small negative angle) is important for ground contact times. The quick recovery is reflected in the swing leg velocities from toe-off to touchdown (see Figure 16 and Table 6).

The data shown in Table 4 (step length, step rate and step velocity), as well as the contact and flight time data (Figure 15) show the importance of securing short contact times. This, in return confirms that the mastery of sprinting mechanics is reflected by these athletes. The average speed over consecutive 10 m splits throughout the home straight backs up this statement.

Consequences for training

1. Special endurance and specifically speed endurance should only back up the maintenance of speed ability but cannot compensate for a lack of speed.
2. A fast bend based on proper running mechanics secures the maintenance of velocity and limited loss to the finish.
3. Active preparation of the ground contact is crucial for short ground contact in consequence.
4. The focus in the final 50 m of the race is on maintaining stride frequency rather than stride length.

Recommendations for training

It would be recommended to master technique first, with special endurance to back up the ability to reproduce the technical model over the duration of the race, and speed endurance to expose competition demands.

Focus on the technical model in the bend:

1. Acceleration drills into the bend: fast bounds, single bounds, emphasising single track mechanics versus dual track mechanics on the straight.
2. Transition mechanics: shuffle, combined bounds-shuffle or shuffle-step over mechanics drills in the bend and from the bend onto the straight, switching from single track to dual track.
3. Maintenance mechanics: step over drills with quick heel recovery underneath the body and step over mechanics with active knee drive, focussing on maintaining frequency and not length of the stride (hot track image).

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