IAAF World Championships
LONDON 2017

BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

3,000 m Steeplechase Men's

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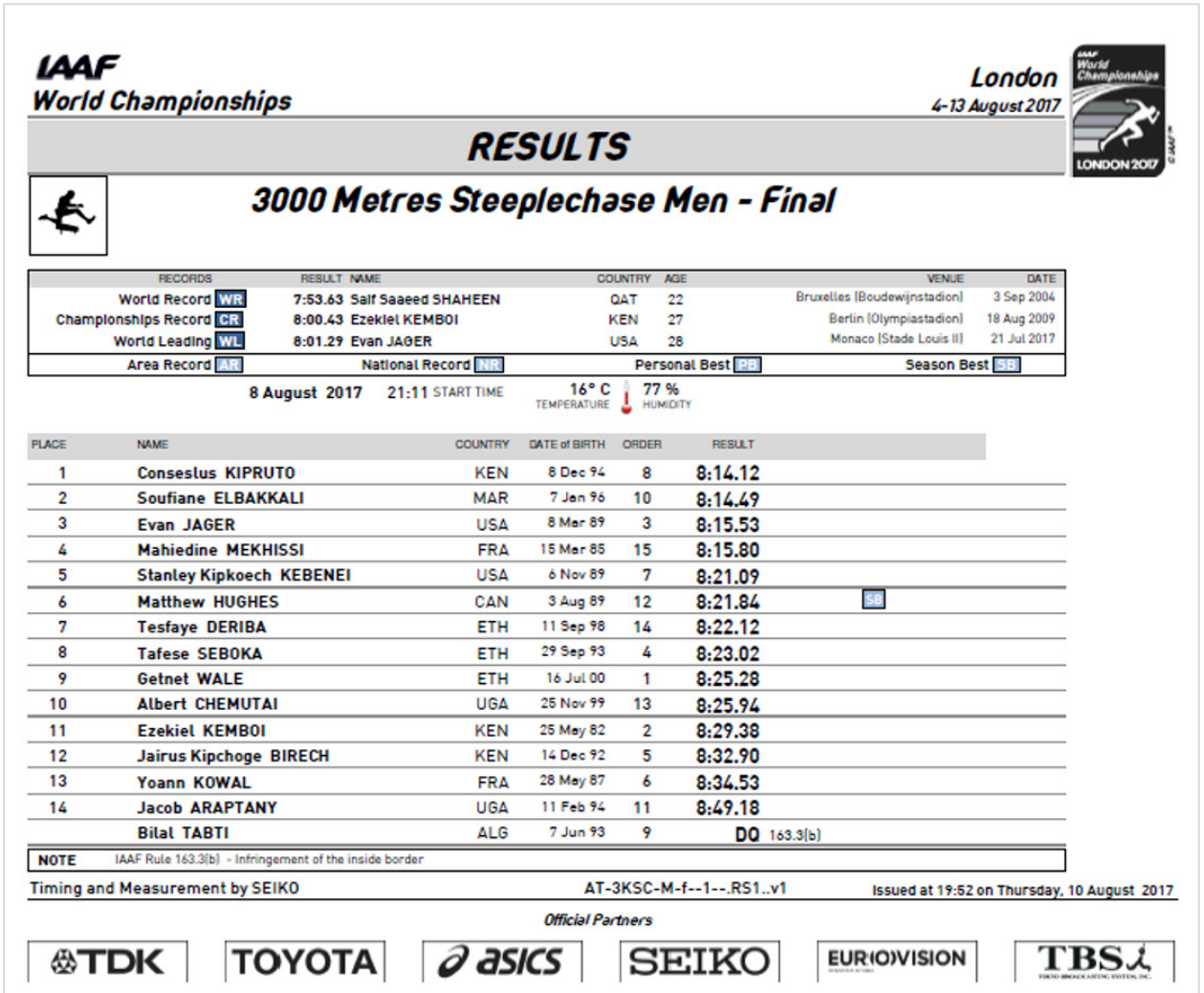
INTRODUCTION

The men's steeplechase final took place on August 8th on a cool evening. The medallists had all won their respective heats coming into the final, with the Olympic Champion, Kirputo, finishing one place higher than in the previous World Championships in 2015. Jager, the silver medallist from the 2016 Olympics, finished third behind Elbakkali, the Moroccan 21-year-old, who achieved a podium position for the first time in a global final having finished fourth in the Olympic final. Jager's World Leading time of 8:01.29, set the previous month, was not threatened during this tactical race, and only Matthew Hughes, who finished 6th, set a season's best time. The results for all finishers are shown below.



IAAF World Championships — London 4-13 August 2017

RESULTS

3000 Metres Steeplechase Men - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	7:53.63	Saif Saaeed SHAHEEN	QAT	22	Bruxelles (Boudewijnstadion)	3 Sep 2004
Championships Record CR	8:00.43	Ezekiel KEMBOI	KEN	27	Berlin (Olympiastadion)	18 Aug 2009
World Leading WL	8:01.29	Evan JAGER	USA	28	Monaco (Stade Louis II)	21 Jul 2017

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

8 August 2017 21:11 START TIME 16° C TEMPERATURE 77 % HUMIDITY

PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT	
1	Conseslus KIPRUTO	KEN	8 Dec 94	8	8:14.12	
2	Soufiane ELBAKKALI	MAR	7 Jan 96	10	8:14.49	
3	Evan JAGER	USA	8 Mar 89	3	8:15.53	
4	Mahiedine MEKHISSI	FRA	15 Mar 85	15	8:15.80	
5	Stanley Kipkoech KEBENEI	USA	6 Nov 89	7	8:21.09	
6	Matthew HUGHES	CAN	3 Aug 89	12	8:21.84	SB
7	Tesfaye DERIBA	ETH	11 Sep 98	14	8:22.12	
8	Tafese SEBOKA	ETH	29 Sep 93	4	8:23.02	
9	Getnet WALE	ETH	16 Jul 00	1	8:25.28	
10	Albert CHEMUTAI	UGA	25 Nov 99	13	8:25.94	
11	Ezekiel KEMBOI	KEN	25 May 82	2	8:29.38	
12	Jairus Kipchoge BIRECH	KEN	14 Dec 92	5	8:32.90	
13	Yoann KOWAL	FRA	28 May 87	6	8:34.53	
14	Jacob ARAPTANY	UGA	11 Feb 94	11	8:49.18	
	Bilal TABTI	ALG	7 Jun 93	9	DQ 163.3(b)	

NOTE IAAF Rule 163.3(b) - Infringement of the inside border

Timing and Measurement by SEIKO AT-3KSC-M-f--1--.RS1..v1 Issued at 19:52 on Thursday, 10 August 2017

Official Partners

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METHODS

Three vantage locations for camera placement were identified and secured. One location was situated on the broadcasting balcony along the home straight (near the 100 m start line), one was situated in the stand to the rear of the water jump (near the 200 m start line) and the third was in the stand to the right of the athletes as they crossed the water jump barrier. Three Sony RX10 M3 cameras, operating at 100 Hz (shutter speed: 1/1250; ISO: 1600; FHD: 1920x1080 px), were placed in the chosen locations.

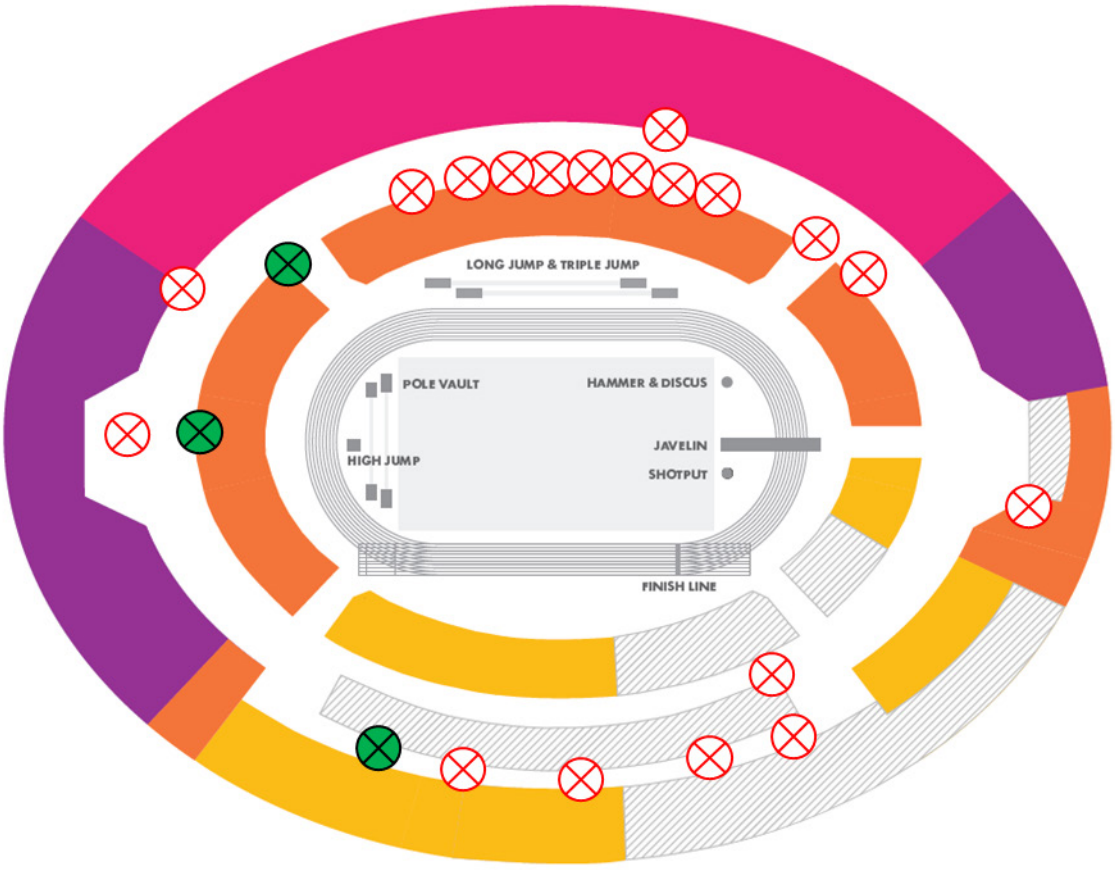

Figure 1. Camera positions for the men's 3,000 m steeplechase final (shown in green).

To calibrate the area around the water jump, a rigid cuboid calibration frame was positioned on the running track before and after the water jump barrier to ensure an accurate definition of a volume within which the athletes ran and jumped. The base of the calibration frame was large enough to span the water jump entirely. This approach produced many non-coplanar control points per individual calibrated volume and facilitated the construction of a global coordinate system.

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

The video files were imported into SIMI Motion (SIMI Motion version 9.2.2, Simi Reality Motion Systems GmbH, Germany) and 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. Digitising started 15 frames before the beginning of the stride and completed 15 frames after to provide padding during filtering. Each file was first digitised frame by frame and upon completion adjustments were made as necessary using the points over frame method, where each point was tracked through the entire sequence. 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 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.

De Leva's (1996) body segment parameter models were used to obtain data for the whole body centre of mass. A recursive second-order, low-pass Butterworth digital filter (zero phase-lag) was employed to filter the raw coordinate data. The cut-off frequencies were calculated using residual analysis. 3D still mode analysis was employed for several kinematic variables for some athletes where digitising the whole body was not possible. On occasion, dropout occurred where joint positions were not visible, and estimations were made by the operator. 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 3. Action from the last lap of the men's final. Kipruto (right) was the only athlete not to place his foot on the barrier.

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

Variable	Definition
Approach speed	The mean speed of the centre of mass during the last step before take-off.
Approach step length	The distance covered from toe-off of one foot to toe-off of the other foot (i.e., the take-off foot).
Increase in height	The difference in centre of mass height between landing and take-off during the last foot contact.
Take-off height	The height of the centre of mass at take-off.
Take-off velocity	The velocity of the centre of mass at take-off.
Take-off angle	The take-off angle (relative to the ground) of the centre of mass at take-off.
Take-off distance	The distance from the foot tip of the take-off foot to the water jump barrier (halfway between its edges, i.e., 6.3 cm from the near edge).
Height of hip relative to barrier	The height of the ipsilateral hip relative to the top of the barrier when the athlete's foot first contacted it.
Distance to hip from barrier	The distance of the ipsilateral hip from the middle of the barrier (i.e., 6.3 cm from the near edge) when the athlete's foot first contacted it.
Height above barrier	The height of the centre of mass above the barrier when it was directly above it.
Clearance time	The total time from take-off before the barrier until the first contact made with the water.
Landing distance	The distance from the foot tip of the landing foot (first contact with the water) to the centre of the water jump barrier.
Trunk angle	The angle of the trunk at landing (lower values indicate more forward lean).
Water time	The duration of time spent by the athlete's landing foot under water.
Exit speed	The mean speed of the centre of mass during the first step exiting the water after landing.
Exit step length	The distance covered from toe-off of the landing foot to first contact with the ground by the other foot when leaving the water jump.
Change in speed	The change in speed between the approach step and the exit step.

Figure 4 provides a visual representation of some of the variables calculated; Figure 5 shows the official dimensions of the water jump.

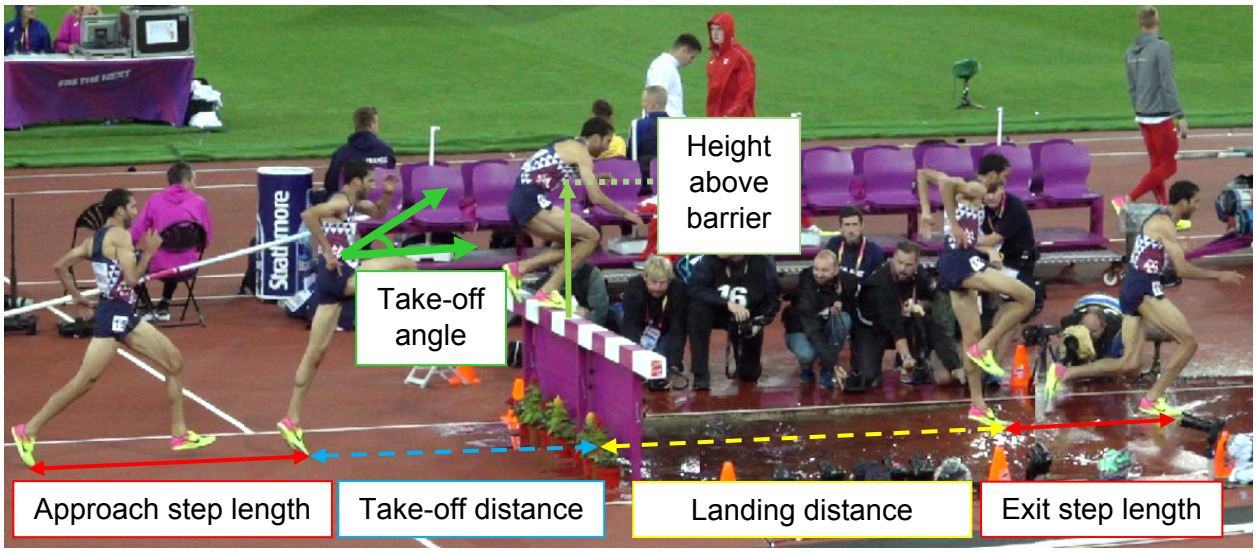

Figure 4. Visual representation of some of the variables calculated.

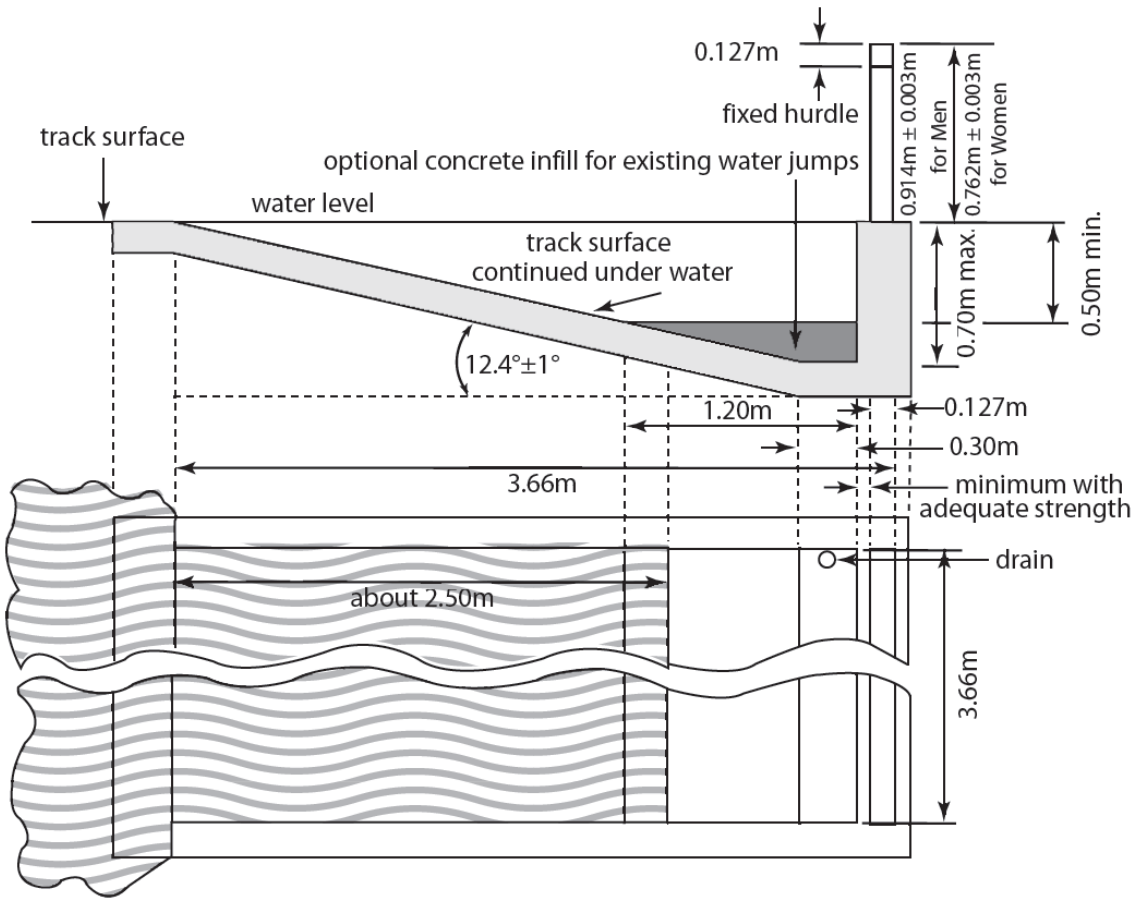

Figure 5. Official dimensions of the water jump (from 'IAAF Competition Rules 2018-2019').

RESULTS

Table 2 summarises the personal best (PB) and season's best (SB) times of each of the top eight finishers before the final and their ranking amongst all finalists (for PB, SB and also for the heats). Table 3 shows the comparison between their result in the final and their PB, SB and heat times.

Table 2. Individual personal best (PB) and season's best (SB) times before the final, and their performance in the heats.

	PB	Rank	SB	Rank	Heats	Rank
KIPRUTO	8:00.12	4	8:04.63	2	8:23.80	10
ELBAKKALI	8:05.12	6	8:05.12	3	8:22.60	5
JAGER	8:00.45	5	8:01.29	1	8:20.36	1
MEKHISSI	8:00.09	3	8:14.67	9	8:22.83	6
KEBENEI	8:08.30	7	8:08.30	5	8:24.19	12
HUGHES	8:11.64	8	8:24.79	15	8:24.79 (SB)	13
DERIBA	8:13.33	12	8:13.33	8	8:25.33	14
SEBOKA	8:13.22	11	8:13.22	7	8:20.48	2

Table 3. Comparison between the final result and PB, SB and heat times before the final.

	Result	Notes	vs PB (s)	vs SB (s)	vs heats (s)
KIPRUTO	8:14.12		14.00	9.49	–9.68
ELBAKKALI	8:14.49		9:37	9.37	–8.11
JAGER	8:15.53		15.08	14.24	–4.83
MEKHISSI	8:15.80		15.71	1.13	–7.03
KEBENEI	8:21.09		12.79	12.79	–3.10
HUGHES	8:21.84	SB	10.20	–2.95	–2.95
DERIBA	8:22.12		8.79	8.79	–3.21
SEBOKA	8:23.02		9.90	9.90	2.54

Figure 6 shows the shows the mean values for take-off variables of the top eight athletes during the last water jump, whereas Table 4 shows the values for each individual runner (because Kipruto was obscured, it was not possible to analyse him in any great detail).

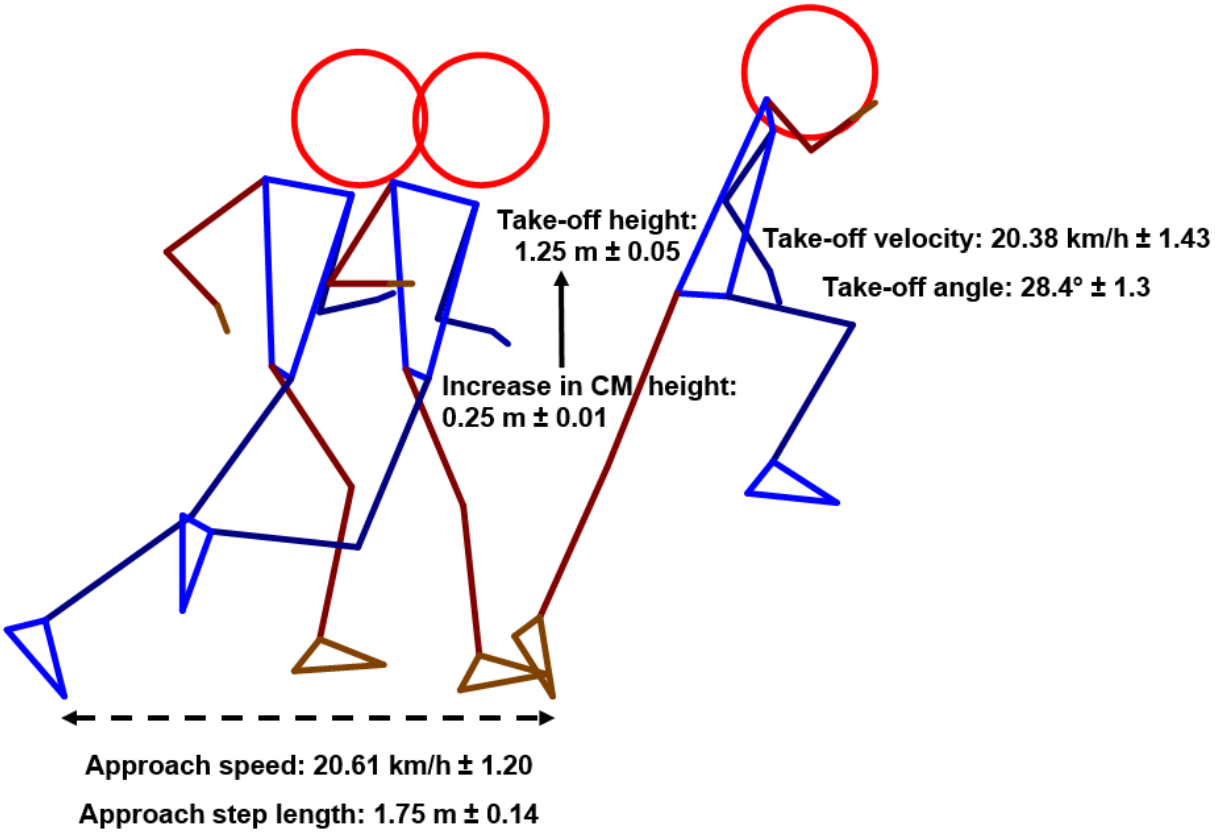

Figure 6. Mean approach and take-off characteristics before the water jump barrier.

Table 4. Approach step and take-off variables.

	Speed (km/h)	Step length (m)	Increase in height (m)	Take-off height (m)	Take-off velocity (km/h)	Take-off angle (°)
KIPRUTO	-	1.72	-	-	-	-
ELBAKKALI	21.08	1.60	0.26	1.30	21.04	28.7
JAGER	20.39	1.87	0.23	1.26	20.26	29.5
MEKHISSI	22.78	1.81	0.25	1.31	22.47	25.9
KEBENEI	20.75	1.89	0.27	1.21	20.13	28.2
HUGHES	18.81	1.58	0.25	1.22	18.24	29.6
DERIBA	20.40	1.65	0.26	1.25	21.44	27.4
SEBOKA	20.02	1.88	0.25	1.18	19.08	29.4

Figure 7 shows the shows the mean values for clearance variables of the top eight athletes during the last water jump, whereas Table 5 shows the values for each individual runner (because Kipruto was obscured, it was not possible to analyse him in any great detail). The 'height of hip' and 'distance to hip' variables are not represented in Figure 6.

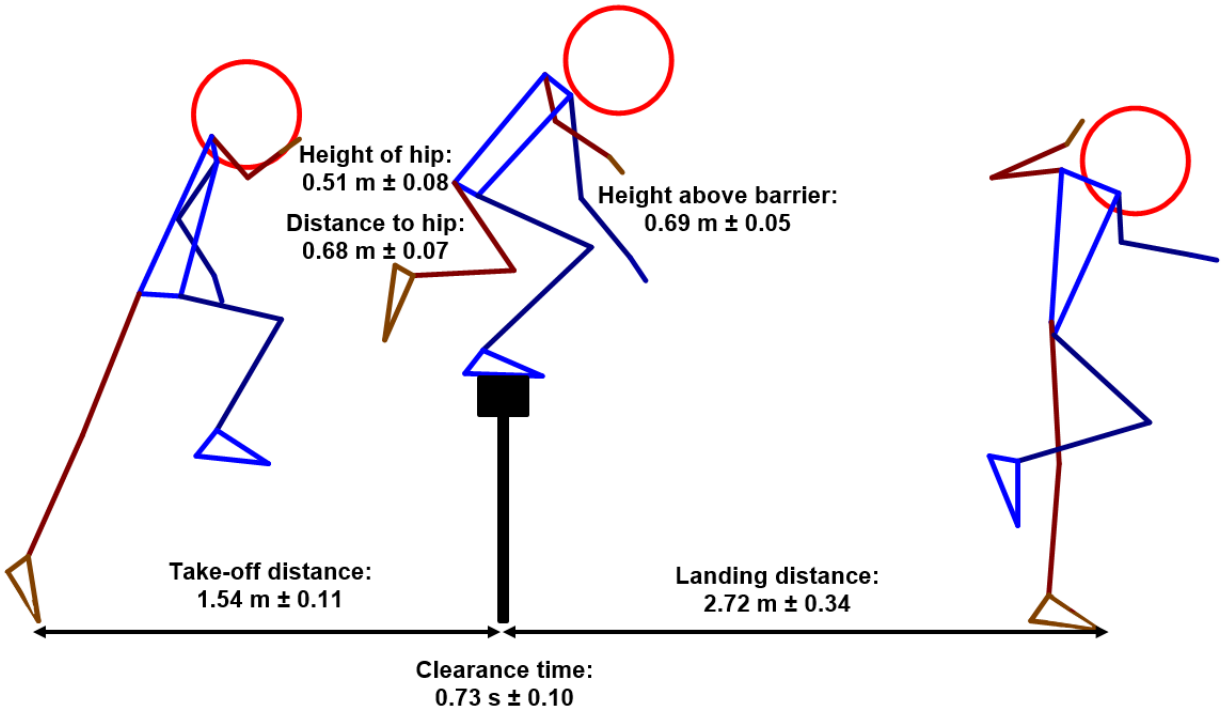

Figure 7. Mean clearance characteristics over the water jump barrier.

Table 5. Water jump clearance variables.

	Take-off distance (m)	Hip height (m)	Hip distance (m)	Height above barrier (m)	Landing distance (m)	Clearance time (s)
KIPRUTO	1.50	-	-	-	2.22	0.53
ELBAKKALI	1.54	0.57	0.64	0.74	2.82	0.70
JAGER	1.49	0.59	0.58	0.73	2.95	0.79
MEKHISSI	1.69	0.60	0.65	0.75	3.33	0.78
KEBENEI	1.67	0.48	0.79	0.65	2.61	0.73
HUGHES	1.39	0.45	0.66	0.65	2.78	0.82
DERIBA	1.59	0.47	0.76	0.66	2.39	0.68
SEBOKA	1.41	0.40	0.69	0.62	2.68	0.81

Figure 8 shows the shows the mean values for clearance variables of the top eight athletes during the last water jump, whereas Table 6 shows the values for each individual runner (because Kipruto was obscured, it was not possible to analyse him in any great detail).

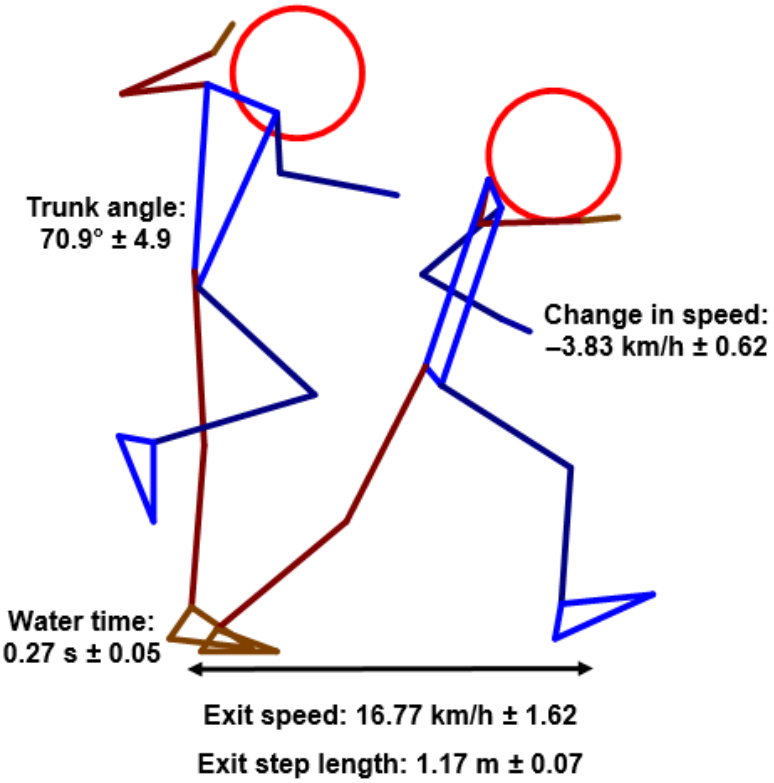

Figure 8. Mean landing and exit characteristics after the water jump barrier.

Table 6. Landing and exit step variables.

	Speed (km/h)	Step length (m)	Water time (s)	Trunk angle (°)
KIPRUTO	-	-	0.29	-
ELBAKKALI	17.66	1.23	0.28	78.2
JAGER	16.87	1.26	0.22	67.3
MEKHISSI	19.65	1.15	0.18	66.1
KEBENEI	16.80	1.20	0.28	75.7
HUGHES	14.93	1.08	0.30	72.8
DERIBA	16.54	1.14	0.34	65.7
SEBOKA	14.96	1.11	0.29	70.2

Table 7 shows the differences between the athletes' race positions before and after the last water jump (if any), and their change of speed between the approach step and the exit step.

Table 7. Approach-exit differences.

	Approach position	Exit position	Change in speed (km/h)
KIPRUTO	1st	1st	-
ELBAKKALI	2nd	2nd	–3.43
JAGER	3rd	3rd	–3.52
MEKHISSI	4th	4th	–3.14
KEBENEI	5th	5th	–3.95
HUGHES	6th	6th	–3.88
DERIBA	7th	7th	–3.86
SEBOKA	8th	8th	–5.06

Table 8 shows the approach and exit step lengths, as well as the take-off and landing distances, relative to body height (standing height data were not available for Deriba).

Table 8. Step length and positional data relative to body height (body height = 1.00).

	Approach step length	Take-off distance	Landing distance	Exit step length
KIPRUTO	-	0.88	1.30	-
ELBAKKALI	0.85	0.82	1.50	0.66
JAGER	1.01	0.80	1.59	0.68
MEKHISSI	0.95	0.89	1.75	0.60
KEBENEI	1.09	0.96	1.50	0.69
HUGHES	0.88	0.77	1.55	0.60
DERIBA	-	-	-	-
SEBOKA	1.06	0.80	1.52	0.62

COMMENTARY

Being able to negotiate the water jump successfully is one of the key skills of world-class steeplechasing. Although most elite steeplechasers hurdle the normal barriers (that is, they don't make contact with them), most do land on the water jump barrier and use it to propel themselves as far across the water as possible. In the men's final, the gold medallist Kipruto was an exception to this, hurdling the water jump barrier instead. Although we do not have all of his data, we can still see that he landed in the deepest water of the top 8 athletes (silver medallist Elbakkali managed an extra 60 cm, and third-placed Jager an extra 73 cm, compared with Kipruto). Kipruto's shorter landing distance did mean he had by far the shortest clearance time, as expected, but this did not seem to affect him too greatly as he did not spend much longer in the water than his main rivals, and was able to hold onto his leading position when entering the home straight. Mekhissi's landing distance of 3.33 m meant he almost cleared the water entirely; this was particularly impressive as he lost the least amount of speed during the clearance phase, and left the water with a faster pace than any other analysed athlete. However, he was too far behind the medallists to catch them, and indeed the order in which the athletes approached the water jump was the same as when they left it.

Although there were some differences in approach variables (such as those related to the size of the athletes, such as step length), overall these elite steeplechasers adopted relatively similar take-off positions. The range found for the increase in centre of mass height was only 4 cm, and there was similarly only a small range found for take-off angle (less than 4°). The similarity of these values showed that there is little to differentiate between medallists, or between the top three and others in the top 8. This does not mean that water jump technique (or any barrier technique) is not important, but that the development of the skills unique to steeplechasing should be developed very closely with the physiological requirements of the event. Indeed, the success or failure to clear barriers like the water jump effectively can come down to how fresh or fatigued the athlete is when clearing it, and thus the evaluation of water jump technique needs to take into account the whole race performance and tactics.

Acknowledgements

We would like to thank Pascal Dobert for his assistance and comments on this report.

CONTRIBUTORS

Dr Brian Hanley is a Senior Lecturer in Sport and Exercise Biomechanics. Brian's particular research interests are in the area of elite athletics, especially race walking and distance running, as well as the pacing profiles adopted by endurance athletes. He is also interested in musculotendon profiling of athletes to appreciate internal limiting and contributing factors affecting performance, in addition to longitudinal studies measuring the technical development of junior athletes as they progress to become senior athletes.

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.

Pascal Dobert is Assistant Coach at the Bowerman Track Club who works with a number of world-class athletes such as Courtney Frerichs and Evan Jager. He coaches alongside Jerry Schumacher, and within this training group he works specifically on technical aspects of crossing the barriers and strength training. He is also a former steeplechase runner who competed at the 1999 World Championships and the 2000 Olympic Games.