BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

3,000 m Steeplechase Women's

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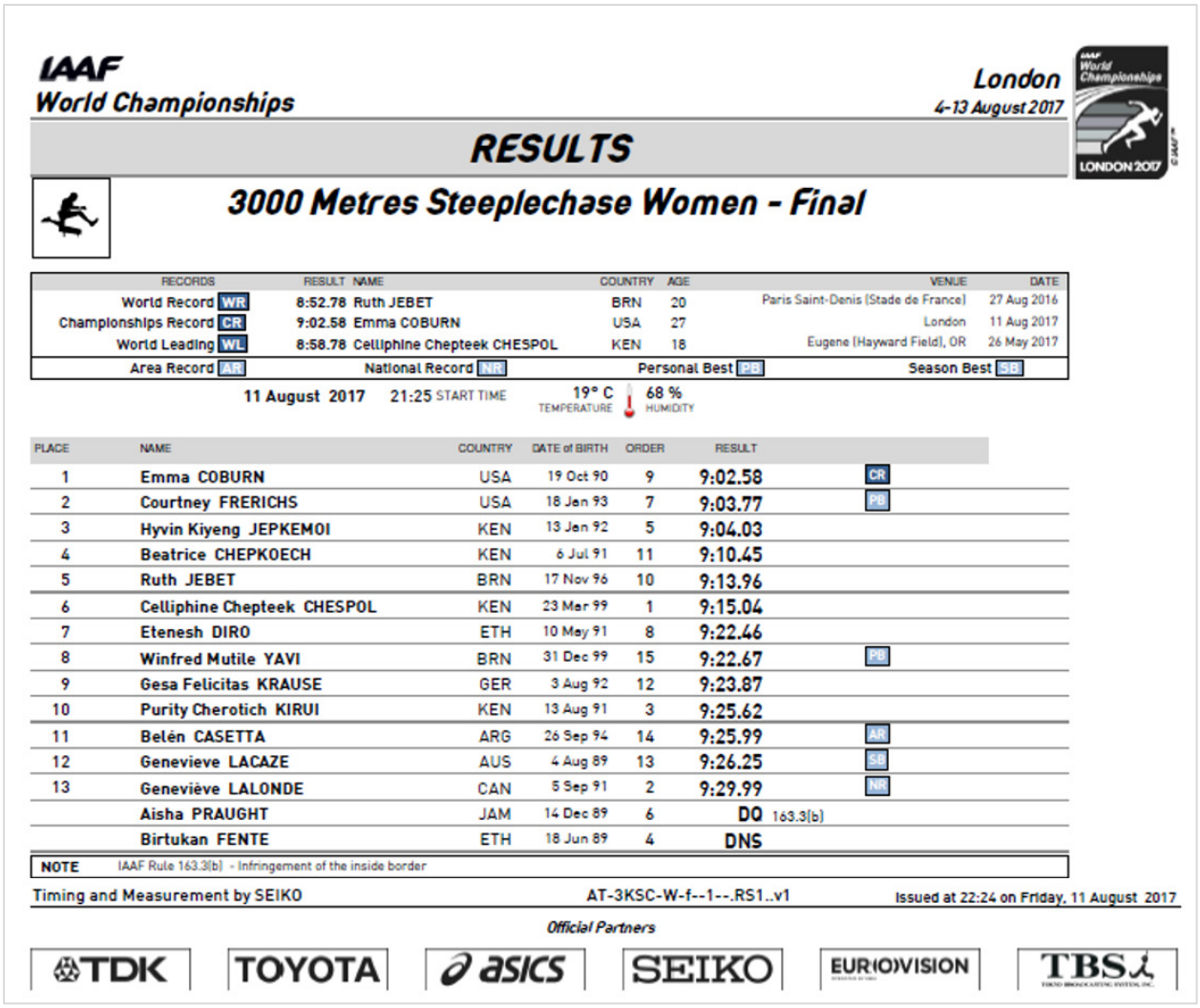
INTRODUCTION

The women's steeplechase final took place on August 11th on a relatively cool evening. Coburn's winning time of 9:02.58 was a Championship Record with her US compatriot and silver medallist Frerichs also achieving a personal best time; it was the first 1-2 finish for the USA in a global final of a distance event since 1912. The two Americans approached the final water jump level with Jepkemoi but their superior approach and clearance gave them an advantage entering the home straight that they maintained to the finish. Chepkoech, who finished fourth, made the highly unusual mistake of forgetting to cut in off the regular 400 m track to take the water jump on the second lap, and lost valuable time in retracing her steps to cross it. Further down the finishing places, Yavi also ran a personal best time, as did Casetta (a South American Area Record) and Lalonde (a Canadian record). The results for all finishers are shown below.



IAAF World Championships — London 4-13 August 2017

RESULTS

3000 Metres Steeplechase Women - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	8:52.78	Ruth JEBET	BRN	20	Paris Saint-Denis (Stade de France)	27 Aug 2016
Championships Record CR	9:02.58	Emma COBURN	USA	27	London	11 Aug 2017
World Leading WL	8:58.78	Celliphine Chepteek CHESPOL	KEN	18	Eugene (Hayward Field), OR	26 May 2017

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

11 August 2017 21:25 START TIME 19° C TEMPERATURE 68 % HUMIDITY

PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT	
1	Emma COBURN	USA	19 Oct 90	9	9:02.58	CR
2	Courtney FRERICHS	USA	18 Jan 93	7	9:03.77	PB
3	Hyvin Kiyeng JEPKEMOI	KEN	13 Jan 92	5	9:04.03	
4	Beatrice CHEPKOECH	KEN	6 Jul 91	11	9:10.45	
5	Ruth JEBET	BRN	17 Nov 96	10	9:13.96	
6	Celliphine Chepteek CHESPOL	KEN	23 Mar 99	1	9:15.04	
7	Etenesh DIRO	ETH	10 May 91	8	9:22.46	
8	Winfred Mutile YAVI	BRN	31 Dec 99	15	9:22.67	PB
9	Gesa Felicitas KRAUSE	GER	3 Aug 92	12	9:23.87	
10	Purity Cherotich KIRUI	KEN	13 Aug 91	3	9:25.62	
11	Belén CASETTA	ARG	26 Sep 94	14	9:25.99	AR
12	Genevieve LACAZE	AUS	4 Aug 89	13	9:26.25	SB
13	Geneviève LALONDE	CAN	5 Sep 91	2	9:29.99	NR
	Aisha PRAUGHT	JAM	14 Dec 89	6	DQ 163.3(b)	
	Birtukan FENTE	ETH	18 Jun 89	4	DNS	

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

Timing and Measurement by SEIKO AT-3KSC-W-f--1--.RS1..v1 Issued at 22:24 on Friday, 11 August 2017

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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.

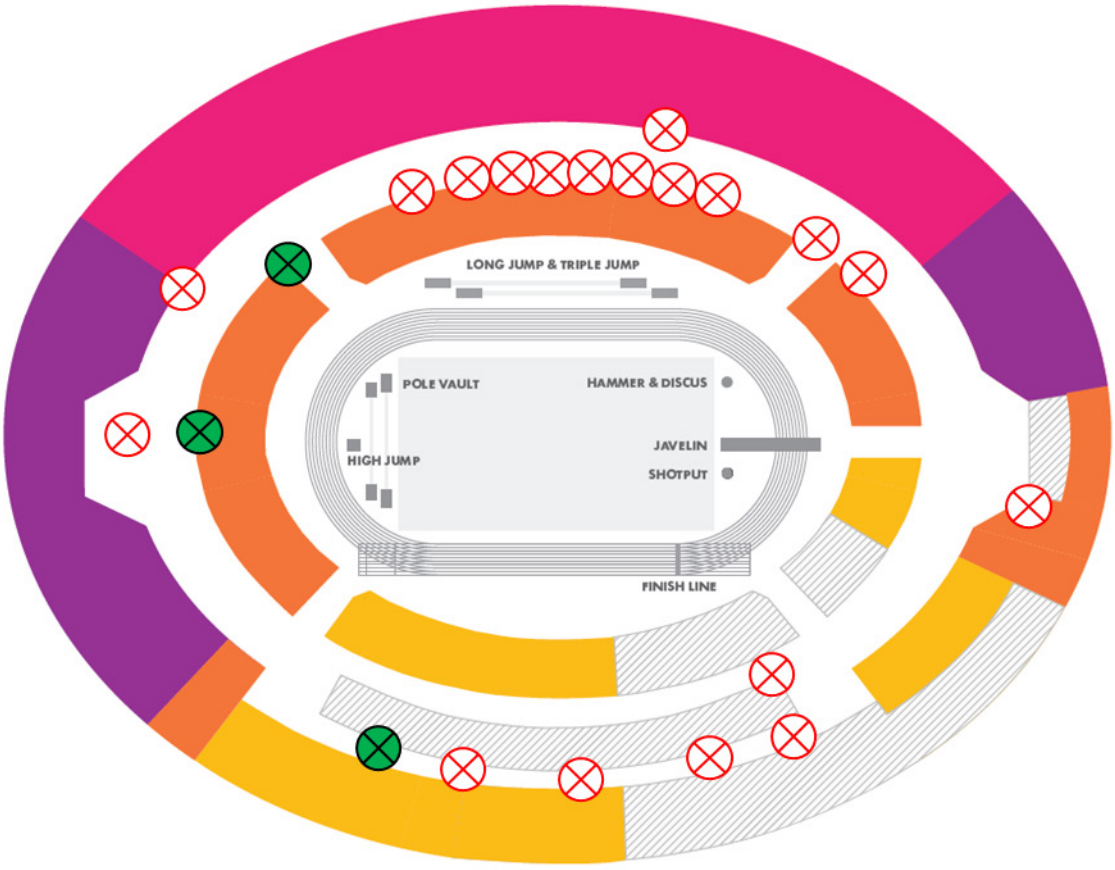

Figure 1. Camera positions for the women's 3,000 m steeplechase final (shown in green).

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 second lap of the women's final.

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.

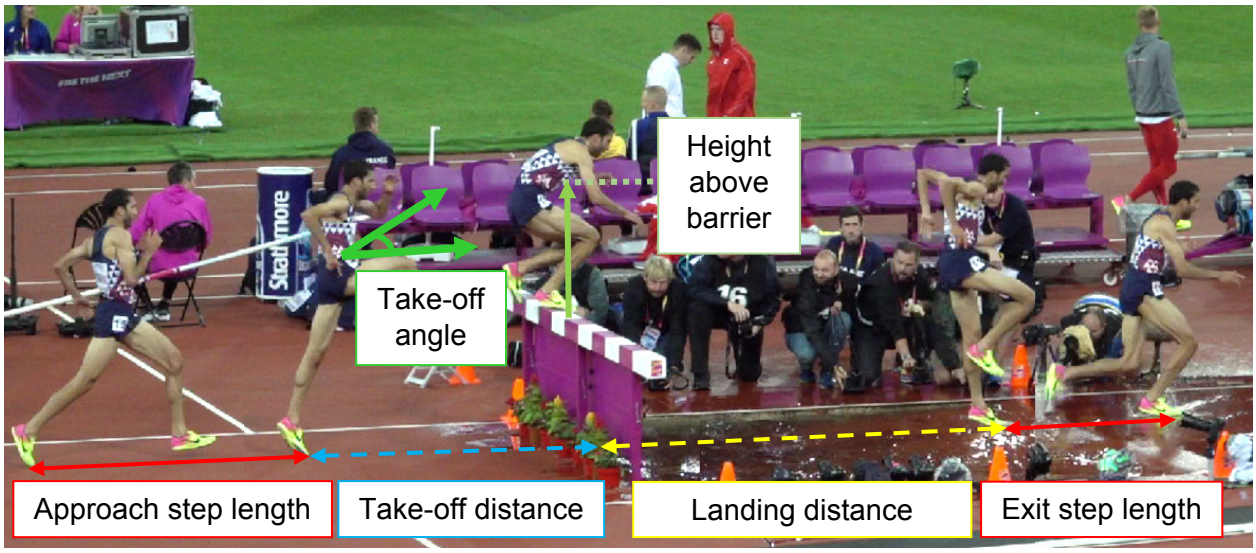

Figure 4. Visual representation of some of the variables calculated.

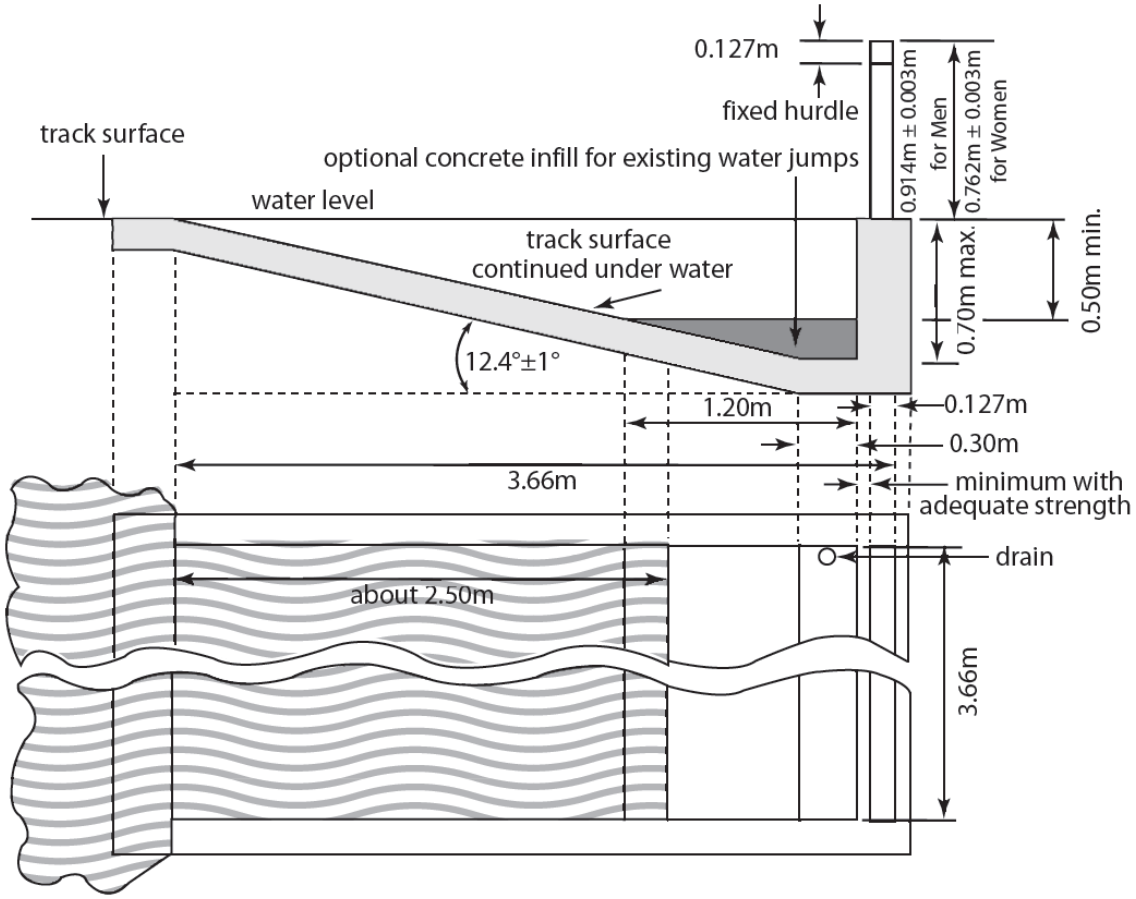

Figure 5. Official dimensions of the water jump (from 'IAAF Competition Rules 2017-2018').

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
COBURN	9:07.63	5	9:07.96	5	9:27.42	6
FRERICHS	9:19.09	10	9:19.09	8	9:25.14	3
JEPKEMOI	9:00.01	3	9:00.12	2	9:39.89	16
CHEPKOECH	9:00.70	4	9:00.70	3	9:19.03	1
JEBET	8:52.78	1	9:01.99	4	9:19.52	2
CHESPOL	8:58.78	2	8:58.78	1	9:27.35	5
DIRO	9:13.25	6	9.13.25	6	9:31.87	10
YAVI	9:22.82	12	9.22.82	11	9:28.00	8

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)
COBURN	9:02.58	CR	–5.05	–5.38	–24.84
FRERICHS	9:03.77	PB	–15.32	–15.32	–21.37
JEPKEMOI	9:04.03		4.02	3.91	–35.86
CHEPKOECH	9:10.45		9.75	9.75	–8.58
JEBET	9:13.96		21.18	11.97	–5.56
CHESPOL	9:15.04		16.26	16.26	–12.31
DIRO	9:22.46		9.21	9.21	–9.41
YAVI	9:22.67	PB	–0.15	–0.15	–5.33

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.

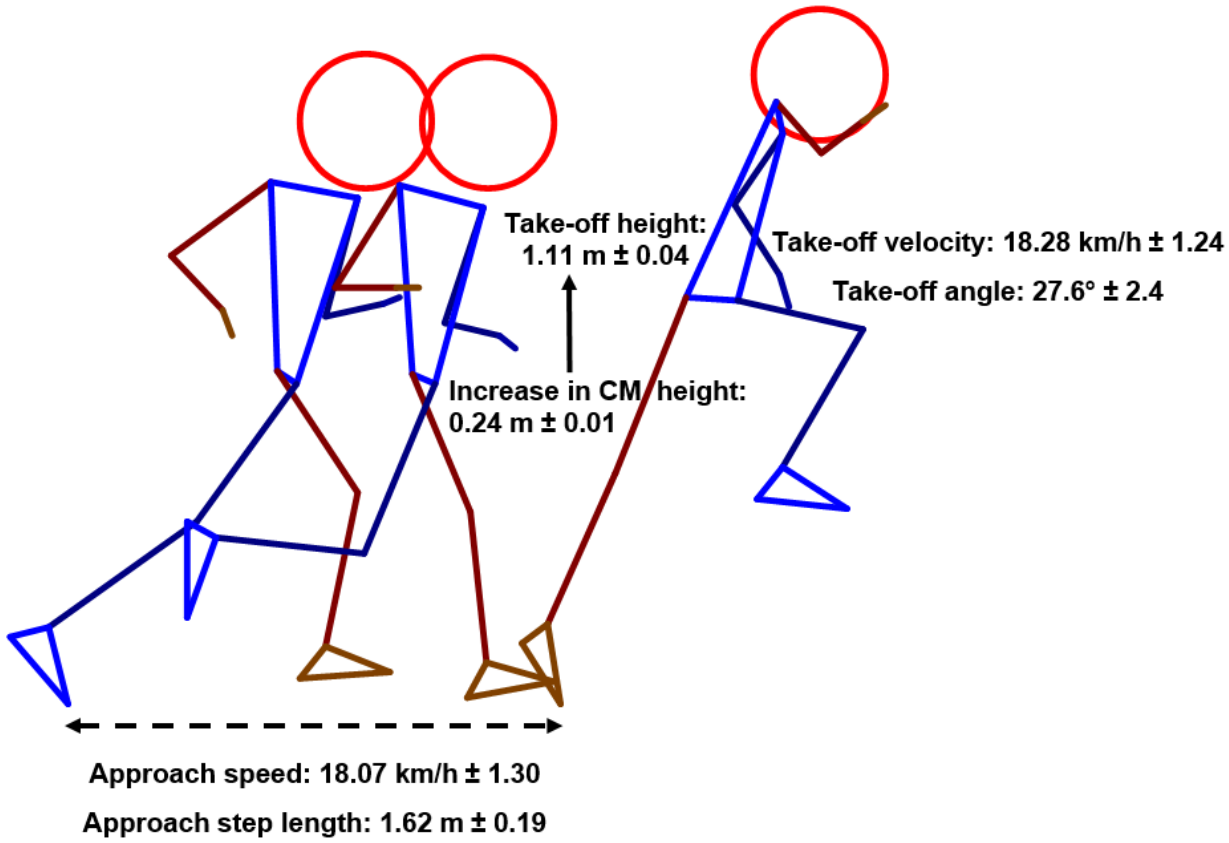

Figure 6. Mean approach and take-off characteristics before the water jump barrier.

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 (°)
COBURN	20.31	1.86	0.25	1.15	20.31	26.1
FRERICHS	18.57	1.57	0.24	1.13	18.36	22.9
JEPKEMOI	16.23	1.32	0.25	1.08	16.69	29.2
CHEPKOECH	18.62	1.93	0.23	1.16	18.22	28.7
JEBET	16.87	1.55	0.25	1.08	17.15	30.4
CHESPOL	18.87	1.62	0.23	1.07	19.70	28.2
DIRO	17.92	1.52	0.24	1.14	18.43	26.4
YAVI	17.17	1.61	0.24	1.07	17.38	28.8

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. The 'height of hip' and 'distance to hip' variables are not represented in Figure 7.

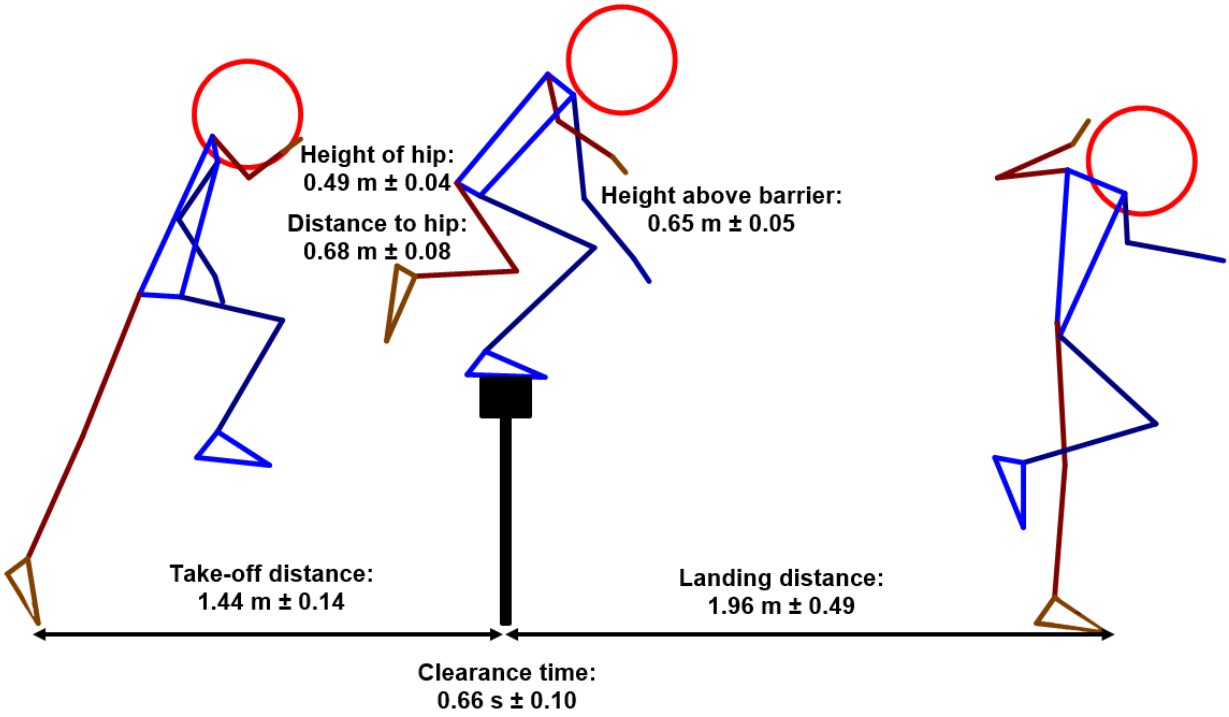

Figure 7. Mean clearance characteristics over the water jump barrier.

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)
COBURN	1.65	0.56	0.72	0.73	2.83	0.82
FRERICHS	1.38	0.45	0.66	0.65	2.57	0.72
JEPKEMOI	1.24	0.48	0.55	0.62	1.61	0.60
CHEPKOECH	1.52	0.53	0.72	0.66	1.59	0.61
JEBET	1.41	0.49	0.63	0.57	1.57	0.57
CHESPOL	1.61	0.52	0.75	0.66	1.89	0.64
DIRO	1.33	0.47	0.61	0.62	1.60	0.55
YAVI	1.41	0.44	0.77	0.66	2.00	0.80

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.

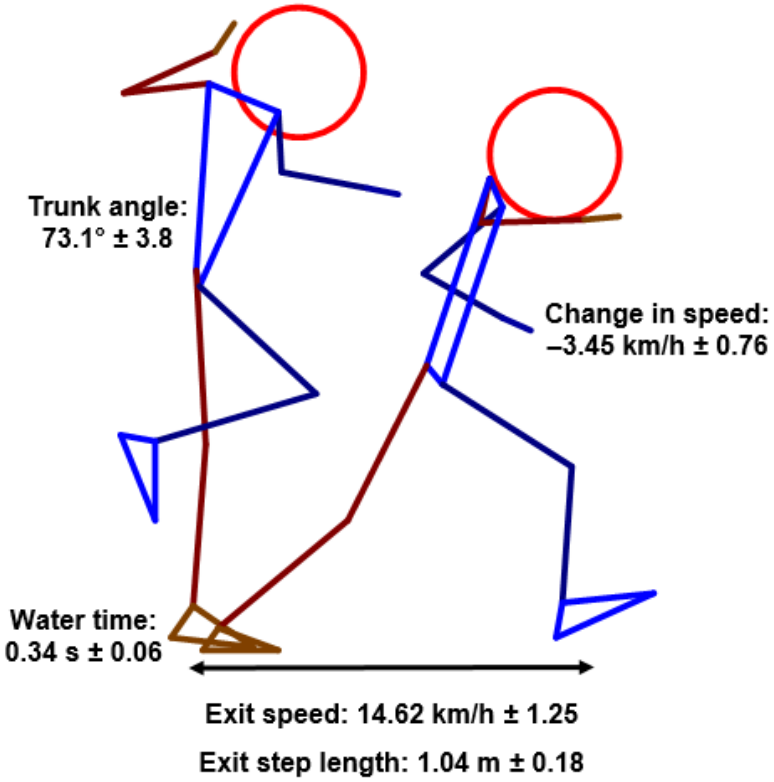

Figure 8. Mean landing and exit characteristics after the water jump barrier.

Table 6. Landing and exit step variables.

	Speed (km/h)	Step length (m)	Water time (s)	Trunk angle (°)
COBURN	16.45	1.01	0.23	75.8
FRERICHS	15.96	1.15	0.27	74.6
JEPKEMOI	13.74	0.98	0.37	70.6
CHEPKOECH	14.25	0.95	0.39	68.4
JEBET	13.80	1.12	0.41	79.3
CHESPOL	15.21	1.19	0.34	75.1
DIRO	14.85	1.25	0.37	72.5
YAVI	12.68	0.68	0.37	68.7

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)
COBURN	1st	1st	–3.86
FRERICHS	3rd	2nd	–2.61
JEPKEMOI	2nd	3rd	–2.48
CHEPKOECH	4th	4th	–4.37
JEBET	5th	5th	–3.06
CHESPOL	6th	6th	–3.66
DIRO	8th	8th	–3.07
YAVI	7th	7th	–4.49

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 Yavi).

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
COBURN	1.08	0.95	1.64	0.59
FRERICHS	0.92	0.81	1.50	0.67
JEPKEMOI	0.85	0.80	1.03	0.63
CHEPKOECH	1.13	0.89	0.93	0.55
JEBET	0.94	0.86	0.95	0.68
CHESPOL	0.99	0.99	1.16	0.73
DIRO	0.90	0.79	0.94	0.74
YAVI	-	-	-	-

COMMENTARY

The women's steeplechase final was one of the most exciting and talked-about races of the World Championships, with an early mistake by Chepkoech compounded by several athletes falling soon afterwards, culminating in a dramatic finish where Jepkemoi lost considerable ground at the last water jump and allowed the US pair of Coburn and Frerichs to get clear of her. Jepkemoi was level with the leaders entering the last water jump but because she slowed before the barrier her take-off speed was reduced and consequently she was one of the slowest leaving the water. Jepkemoi's slower approach to the barrier might have occurred because she very visibly shortened her stride to make sure she took off at an advantageous distance before the barrier. It is obviously important for athletes to take off from the right position before the barrier so that they don't either fail to reach it properly, or take off so closely that they must stretch upwards and lose forward momentum. The optimal distance depends not only on how tall the athlete is, but also how fast they are moving at the time. The fact that Jepkemoi had the shortest distance despite cutting her stride shows how close she was to getting too near to the barrier and shows how important it is to develop the skill of approaching the barrier correctly.

One of the stand-out features of the US athletes' water jump clearances compared with their rivals was their superior landing distances. Coburn and Frerichs landed approximately 1.20 m and 1.00 m further than their nearest in rivals in 3rd, 4th and 5th, respectively. It was noticeable that the shorter landing distances resulted from athletes such as Jebet and Chepkoech pushing very little off the barrier and practically just 'falling' into the water. This meant that most of these athletes spent substantial time with their feet in the water and typically took two steps to get out of it, meaning that they spent more time overcoming the extra resistance the water provided, as well as having to run up more of the slope that forms the base of the water jump. Although the steeplechase is an endurance event where physiological characteristics are important to be able to complete the distance quickly, developing effective water jump clearance technique is key to making sure that medals are not 'lost in the water'.

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.