IAAF World Indoor Championships
BIRMINGHAM 2018
1–4 MARCH

BIOMECHANICAL REPORT

FOR THE

IAAF™

WORLD INDOOR CHAMPIONSHIPS 2018

Long Jump Men

Dr Catherine Tucker and Dr Athanassios Bissas
Carnegie School of Sport

Stéphane Merlino
IAAF Project Leader

LBU LEEDS BECKETT UNIVERSITY

IAAF™

Correspondence:

Dr Athanassios Bissas

Head of Sport & Exercise Biomechanics, Carnegie School of Sport

Leeds Beckett University

Fairfax Hall, Headingley Campus

Leeds, UK, LS6 3QT

Email: A.Bissas@leedsbeckett.ac.uk

Released:

February 2019

Please cite this report as:

Tucker, C.B., Bissas, A. and Merlino, S. (2019). *Biomechanical Report for the IAAF World Indoor Championships 2018: Long Jump Men.* Birmingham, UK: International Association of Athletics Federations.

Event Director		Project Director
Dr Catherine Tucker		Dr Athanassios Bissas
Project Coordinator		
Louise Sutton		
Senior Technical and Logistical Support		
Liam Gallagher	Aaron Thomas	Liam Thomas
Calibration	**Report Editors**	**Data Management**
Dr Brian Hanley	Josh Walker	Nils Jongerius
	Dr Catherine Tucker	Josh Walker
Data Analysts		
Dr Catherine Tucker	Liam Thomas	Panos Ferentinos
Project Team		
Dr Tim Bennett	Dr Mark Cooke	Dr Alex Dinsdale
Helen Gravestock	Dr Lysander Pollitt	Dr Gareth Nicholson
Masalela Gaesenngwe	Emily Gregg	Parag Parelkar
	Dr Giorgos Paradisis (*National and Kapodistrian University of Athens*)	
Scott Bingham	Iain Findlay	Dr Ian Richards
Jessica Thomas	Sarah Walker	Nathan Woodman
Coaching Commentary		
Teddy Tamgho		

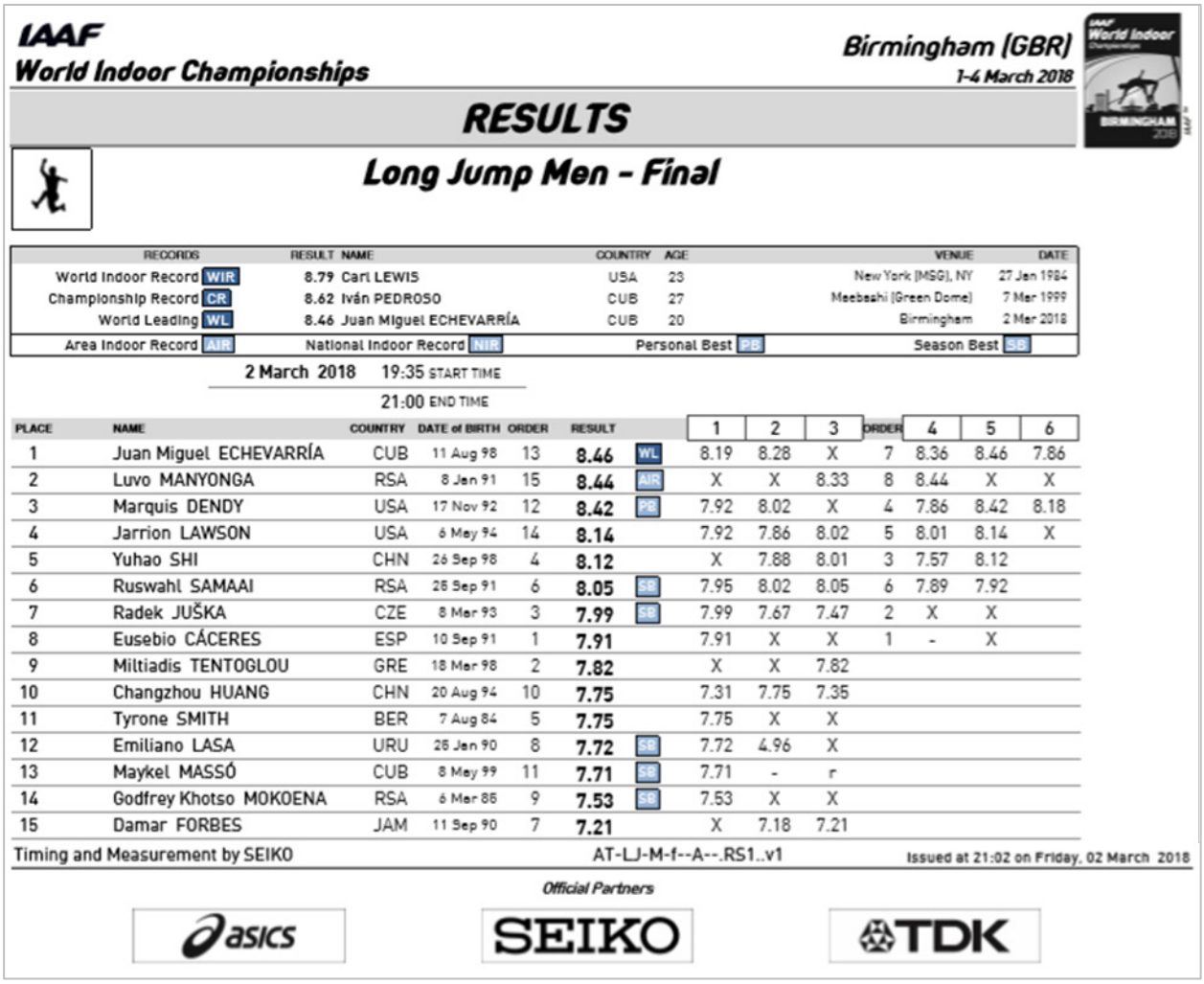
Table of Contents

Figures

Tables

INTRODUCTION

The men's long jump took place on the evening of Friday 2nd March. It was a fiercely contested event with Cuba's Juan Miguel Echevarría emerging victorious at the end over the current World Champion, Luvo Manyonga of South Africa. There was a mere four centimetres separating the medallists in a compelling contest. From the opening round Echevarría led, however Manyonga took the lead in the third round with a jump of 8.33 metres. Manyonga further improved on this jump in round 4 with an effort of 8.44 metres. Echevarría responded in the fifth round with a leap of 8.46 metres to take the lead, a lead that would not be relinquished in the final round. Marquis Dendy finished in third place with a fifth round jump of 8.42 metres, just four centimetres short of the winning jump.



IAAF World Indoor Championships — Birmingham (GBR) 1-4 March 2018

RESULTS

Long Jump Men - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Indoor Record WIR	8.79	Carl LEWIS	USA	23	New York (MSG), NY	27 Jan 1984
Championship Record CR	8.62	Iván PEDROSO	CUB	27	Maebashi (Green Dome)	7 Mar 1999
World Leading WL	8.46	Juan Miguel ECHEVARRÍA	CUB	20	Birmingham	2 Mar 2018

Area Indoor Record AIR | National Indoor Record NIR | Personal Best PB | Season Best SB

2 March 2018 19:35 START TIME

21:00 END TIME

PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT		1	2	3	ORDER	4	5	6
1	Juan Miguel ECHEVARRÍA	CUB	11 Aug 98	13	8.46	WL	8.19	8.28	X	7	8.36	8.46	7.86
2	Luvo MANYONGA	RSA	8 Jan 91	15	8.44	AIR	X	X	8.33	8	8.44	X	X
3	Marquis DENDY	USA	17 Nov 92	12	8.42	PB	7.92	8.02	X	4	7.86	8.42	8.18
4	Jarrion LAWSON	USA	6 May 94	14	8.14		7.92	7.86	8.02	5	8.01	8.14	X
5	Yuhao SHI	CHN	26 Sep 98	4	8.12		X	7.88	8.01	3	7.57	8.12	
6	Ruswahl SAMAAI	RSA	26 Sep 91	6	8.05	SB	7.95	8.02	8.05	6	7.89	7.92	
7	Radek JUŠKA	CZE	8 Mar 93	3	7.99	SB	7.99	7.67	7.47	2	X	X	
8	Eusebio CÁCERES	ESP	10 Sep 91	1	7.91		7.91	X	X	1	-	X	
9	Miltiadis TENTOGLOU	GRE	18 Mar 98	2	7.82		X	X	7.82				
10	Changzhou HUANG	CHN	20 Aug 94	10	7.75		7.31	7.75	7.35				
11	Tyrone SMITH	BER	7 Aug 84	5	7.75		7.75	X	X				
12	Emiliano LASA	URU	26 Jan 90	8	7.72	SB	7.72	4.96	X				
13	Maykel MASSÓ	CUB	8 May 99	11	7.71	SB	7.71	-	r				
14	Godfrey Khotso MOKOENA	RSA	6 Mar 86	9	7.53	SB	7.53	X	X				
15	Damar FORBES	JAM	11 Sep 90	7	7.21		X	7.18	7.21				

Timing and Measurement by SEIKO — AT-LJ-M-f--A--.RS1..v1 — Issued at 21:02 on Friday, 02 March 2018

Official Partners

asics SEIKO TDK

METHODS

Six vantage locations for camera placement were identified and secured. These locations were situated in the stand along the home straight in line with the runway. A calibration procedure was conducted before and after each competition. A rigid cuboid calibration frame was positioned on the run up area multiple times over discrete predefined areas along the runway to ensure an accurate definition of a volume within which athletes completed their last three steps before take-off until landing.

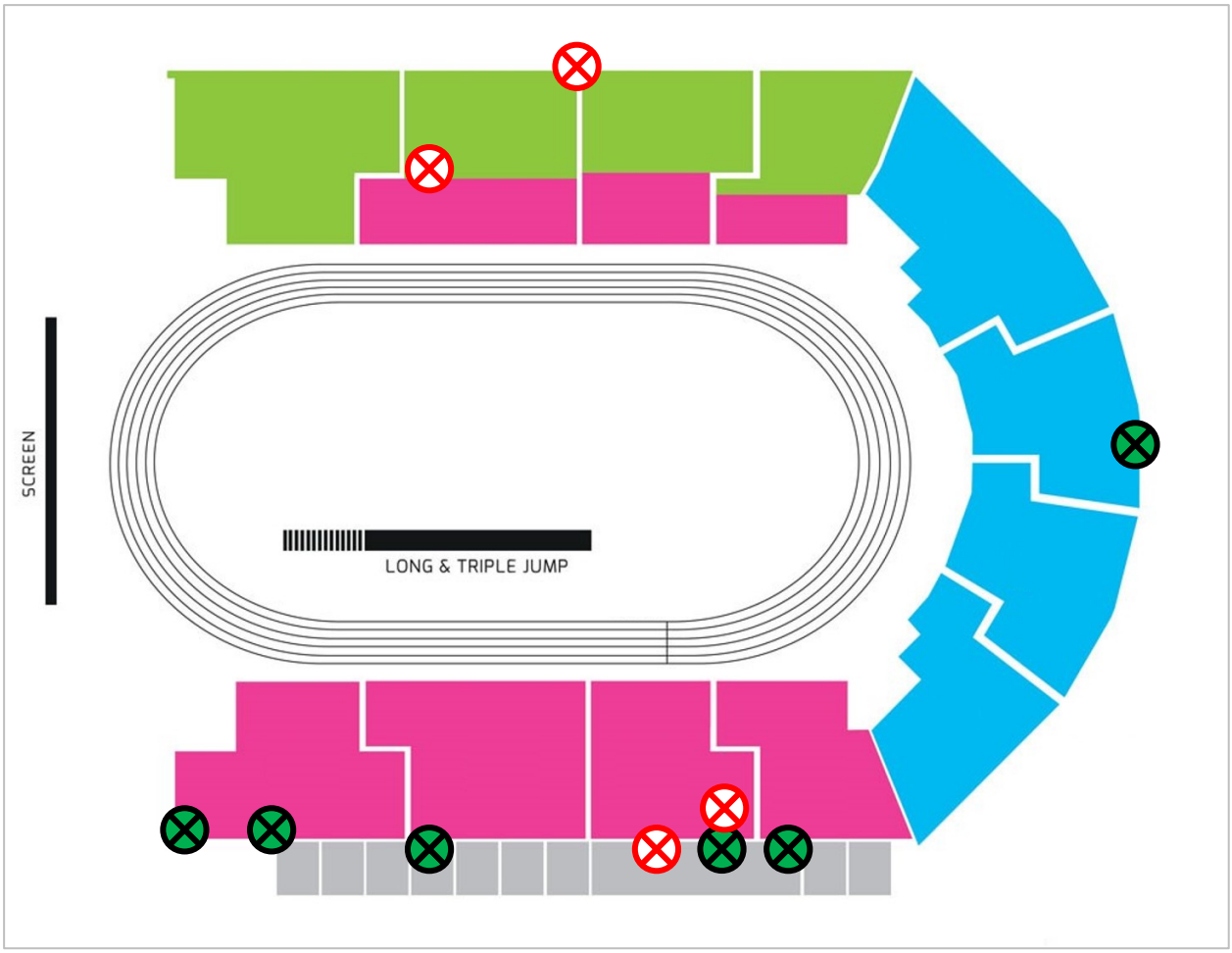


Figure 1. Camera layout for the men's long jump indicated by green-filled circles.

Seven cameras were used to record the action during the long jump final. Three Sony PXW-FS5 cameras operating at 200 Hz (shutter speed: 1/1750; ISO: 2000-4000; FHD: 1920x1080 px) were used to capture the motion of athletes as they moved through the calibrated area of the run-up and take-off. However, because of a lack of availability of an optimal camera position during the men's final it was only possible to fully capture the last step of the run-up and take-off from the board. Four Sony RX10 M3 cameras operating at 100 Hz (shutter speed: 1/1000; ISO: 2000-3600; FHD: 1920x1080 px) were positioned strategically along the runway with two of these being paired with a Sony PXW-FS5 camera each as a precaution against the unlikely event of data

capture loss. In addition, there was one RX10 M3 camera operating at 250 Hz for capturing the temporal characteristics of the approach steps. The other two Sony RX10 M3 cameras were positioned to focus on the landing pit to capture the instant of landing.

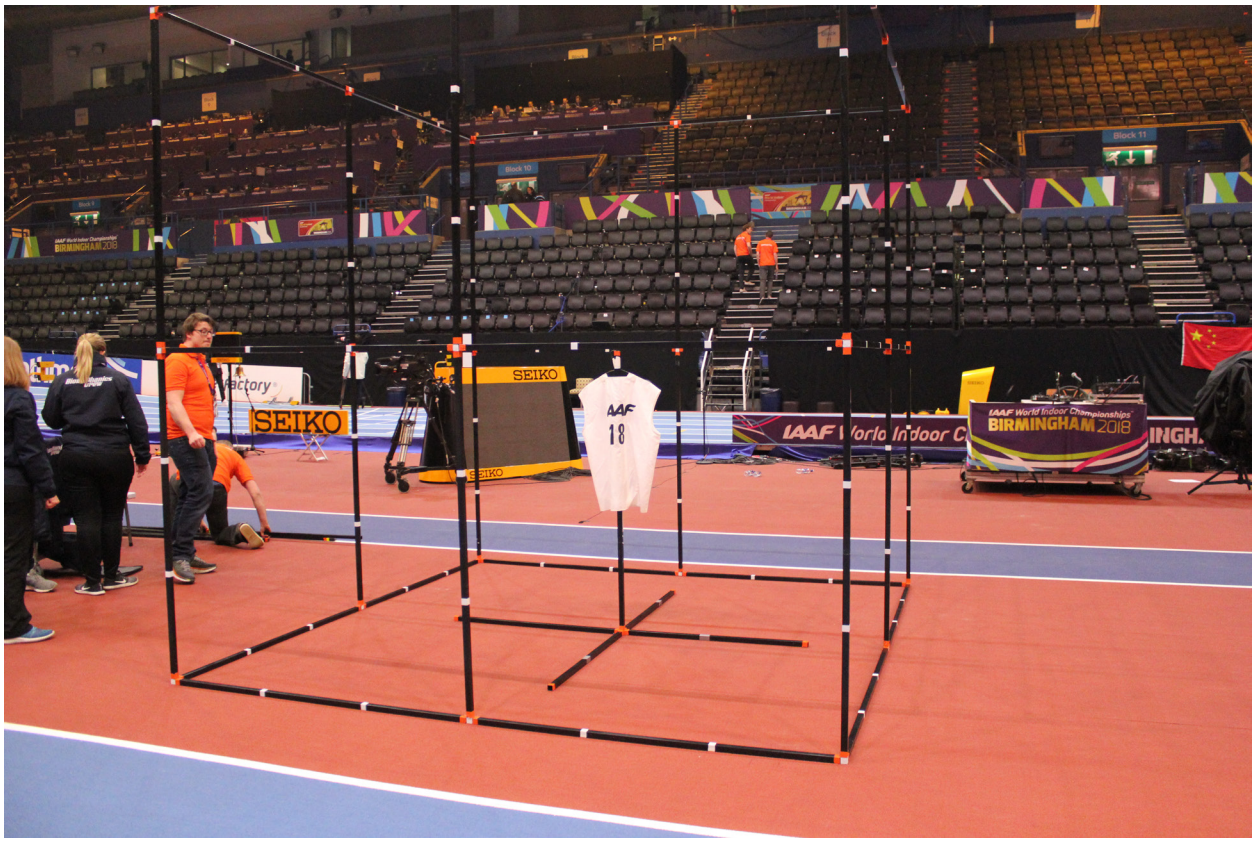


Figure 2. The calibration frame was constructed and filmed before and after the competition.

The video files were imported into SIMI Motion (SIMI Motion version 9.2.2, Simi Reality Motion Systems GmbH, Germany) and were manually digitised by a single experienced operator to obtain kinematic data. An event synchronisation technique (synchronisation of four critical instants) was applied through SIMI Motion to synchronise the two-dimensional coordinates from each camera involved in the recording. Digitising started 15 frames before the beginning of the step 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 (e.g., right knee joint) 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 jump 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 (CM). 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.

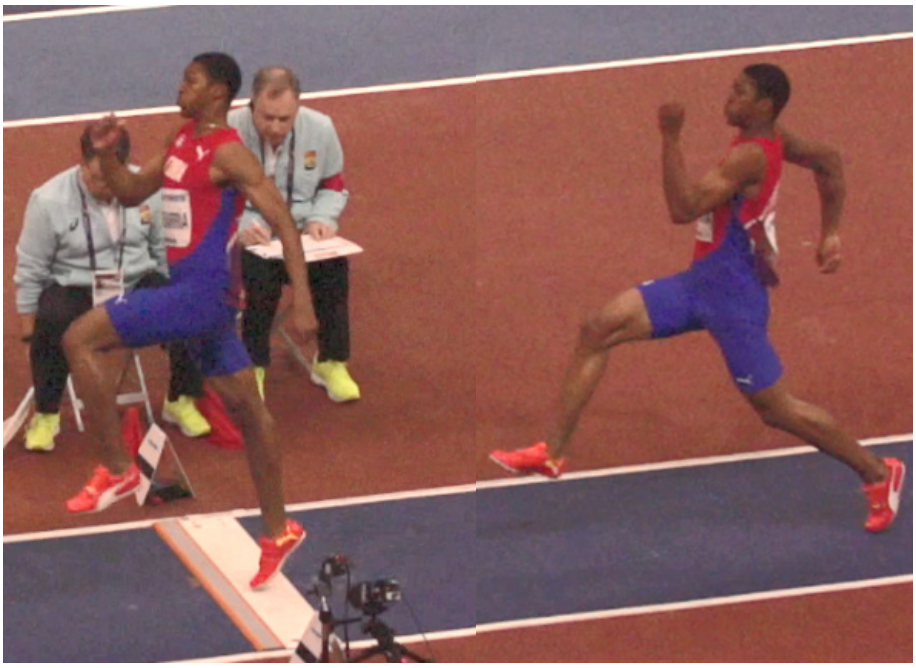


Figure 3. Last step approach for the men's long jump.

Table 1. Definition of variables analysed in the long jump final.

Variable	Definition
Official distance	The official distance published in the results.
Effective distance	The distance measured from the tip of the foot at take-off to the take-off board plus the official distance.
Take-off loss	The distance from the foot tip (take-off foot) to the front edge of the take-off board.
Step length (last step)	The length of the last approach step measured from the foot tip in the previous step to the next foot tip.
Velocity (last step)	The mean horizontal (anteroposterior direction) velocity of the athlete measured during the last step before take-off.
Horizontal velocity at take-off	The athlete's horizontal centre of mass (CM) velocity (anteroposterior direction) at the instant of take-off.
Vertical velocity at take-off	The velocity in the vertical direction of the athlete's CM at the instant of take-off.
Loss in horizontal velocity	The change in horizontal velocity from touchdown (TD) on the board to take-off from the board.
CM lowering	The reduction in CM height from take-off of the last step to the minimum CM height during contact with the board.
Contact time (last three steps)	The time spent in contact during the support phase of the last three steps.
Trunk lean angle	The angle of the trunk relative to the horizontal at the instant of touchdown and take-off and considered to be 0° in the upright position. A negative value indicates they are behind the upright position and a positive value indicates they are in front of the upright position.
Take-off angle	The angle of the athlete's CM at take-off from the board relative to the horizontal.
Body inclination angle	The angle of a line between the athlete's CM and contact foot relative to the vertical at the instant of touchdown and take-off.
Knee angle	The angle between the thigh and lower leg and considered to be 180° in the anatomical

	standing position. This was measured at TD on the board and when it reached its minimum on the take-off board.
Knee range of motion	The change in knee angle from TD on the board to its minimum while on the take-off board.
Knee angular velocity	The mean rate of change of the knee angle from touchdown on the board to reaching its minimum on the board.
Thigh angle of swing leg	The angle of the thigh of the swinging leg measured from the horizontal at take-off.
Thigh angular velocity of swing leg	The mean angular velocity of the thigh of the swinging leg from initial contact to take-off from the board.
Landing distance	The distance from the athlete's heel to the centre of mass at the first contact in the pit.
Landing loss	The distance between the first contact point in the sand and the point to which the measurement was made. A value of zero indicates no landing loss.

Note: *CM = centre of mass.*

RESULTS

Overall analysis

Table 2 shows the official best distance of each athlete alongside a comparison with their personal and season's bests. The mean jump distance was 7.93 metres and the mean difference compared with their season's bests was −0.03 metres and compared with their personal bests was −0.25 metres.

Table 2. Competition results in comparison with athletes' personal bests (PB) and season's bests (SB) for 2018 (before World Championships).

Athlete	Rank	Official distance (m)	SB (2018) (m)	Comparison with SB (m)	PB (m)	Comparison with PB (m)
ECHEVARRÍA	1	8.46	8.34	0.12	8.34	0.12
MANYONGA	2	8.44	8.40	0.04	8.40	0.04
DENDY*	3	8.42	8.22	0.20	8.41	0.01
LAWSON	4	8.14	8.38	−0.24	8.39	−0.25
SHI	5	8.12	8.16	−0.04	8.16	−0.04
SAMAAI	6	8.05	-	-	8.18	−0.13
JUŠKA	7	7.99	7.99	0.00	8.10	−0.11
CÁCERES	8	7.91	7.97	−0.06	8.16	−0.25
TENTOGLOU	9	7.82	7.95	−0.13	7.95	-0.13
HUANG	10	7.75	7.99	−0.24	8.21	−0.46
SMITH	11	7.75	7.77	−0.02	7.83	−0.08
LASA	12	7.72	7.66	0.06	7.94	−0.22
MASSÓ	13	7.71	-	-	8.33	−0.62
MOKOENA	14	7.53	-	-	8.18	−0.65
FORBES	15	7.21	8.07	−0.86	8.21	−1.00

Note: *Negative values represent a shorter jump in the World Championship final compared with the PB and SB.*

**Each athlete's best jump was analysed, except for Dendy, whose second-best attempt was analysed.*

Table 3 shows some distance characteristics of each athlete's best jumps in relation to their effective distance and distance lost at the take-off board. The mean loss at the take-off board was 0.094 metres.

Table 3. Distance characteristics of the individual best jumps.

Athlete	Analysed attempt	Official distance (m)	Effective distance (m)	Take-off loss (m)
ECHEVARRÍA	5	8.46	8.487	0.027
MANYONGA	4	8.44	8.442	0.002
DENDY*	6	8.18	8.190	0.010
LAWSON	5	8.14	8.233	0.093
SHI	5	8.12	8.211	0.091
SAMAAI	3	8.05	8.202	0.152
JUŠKA	1	7.99	8.050	0.060
CÁCERES	1	7.91	7.947	0.037
TENTOGLOU	3	7.82	8.026	0.206
HUANG	2	7.75	7.910	0.160
SMITH	1	7.75	7.804	0.054
LASA	1	7.72	7.765	0.045
MASSÓ	1	7.71	7.789	0.079
MOKOENA	1	7.53	7.597	0.067
FORBES	3	7.21	7.541	0.331

***Note**: The take-off distances were provided by deltatre.*

**Each athlete's best jump was analysed, except for Dendy, whose second-best attempt was analysed.*

Approach phase analysis

Table 4 shows the step time of the last three steps for each athlete. Figures 4-6 show the flight and contact times of each of those last three steps to the take-off board. The mean contact time for the third-last step was 0.094 seconds, for the second-last step was 0.114 seconds and the for the last step was 0.121 seconds. The mean flight time for the third-last step was 0.123 seconds, for the second-last step was 0.132 seconds and the for the last step was 0.074 seconds.

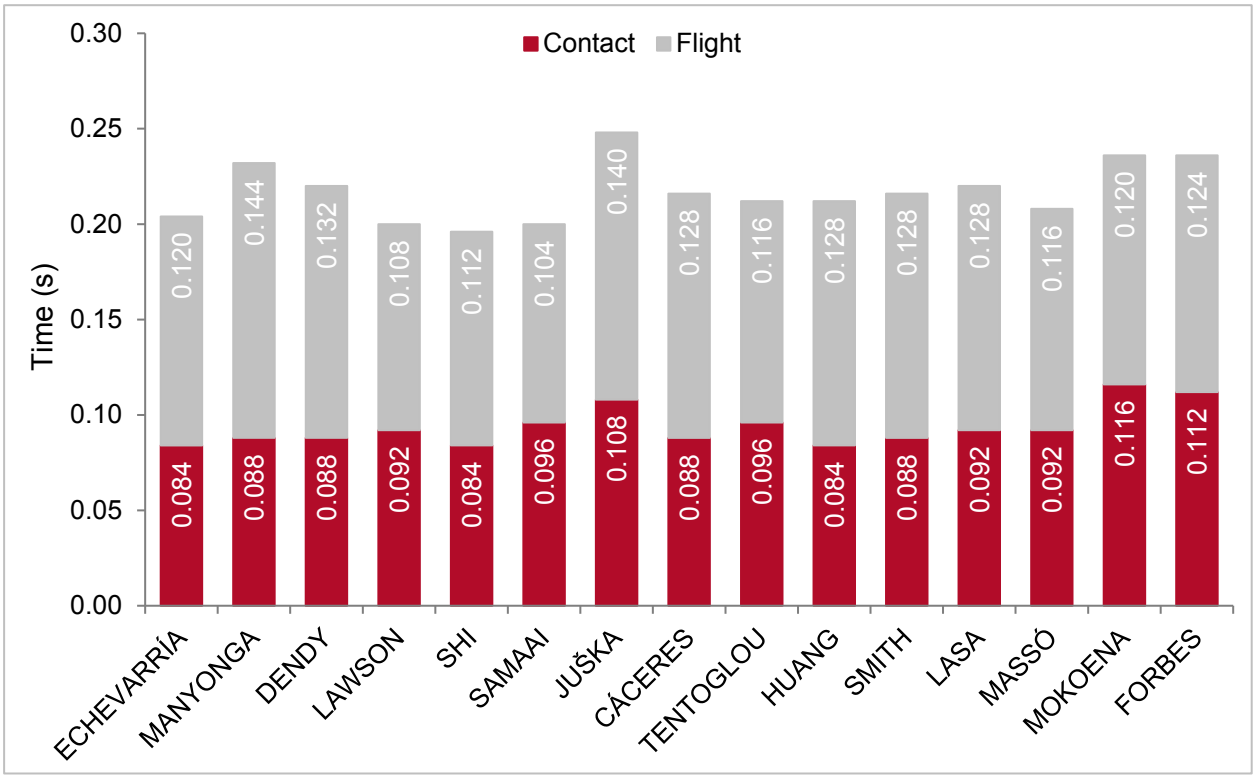


Figure 4. Contact and flight times for each finalist during the third-last step in their approach to the take-off board.

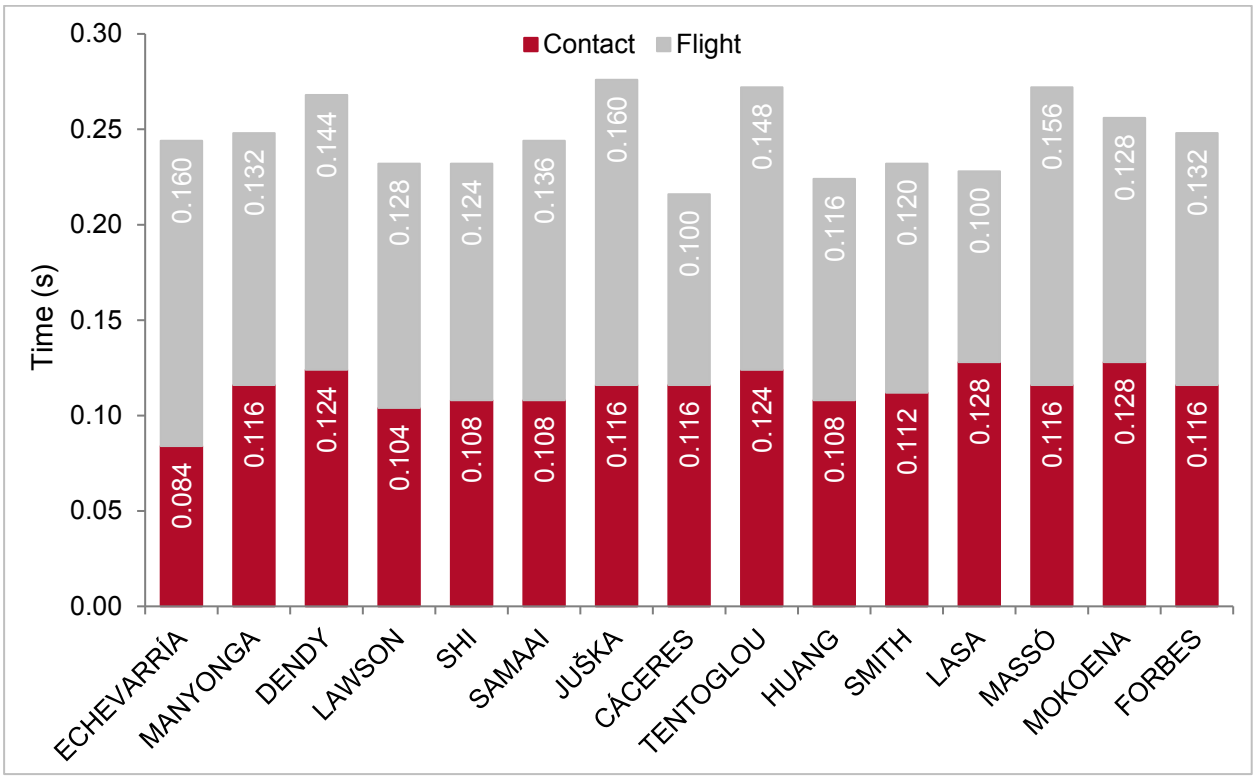


Figure 5. Contact and flight times for each finalist during the second-last step in their approach to the take-off board.

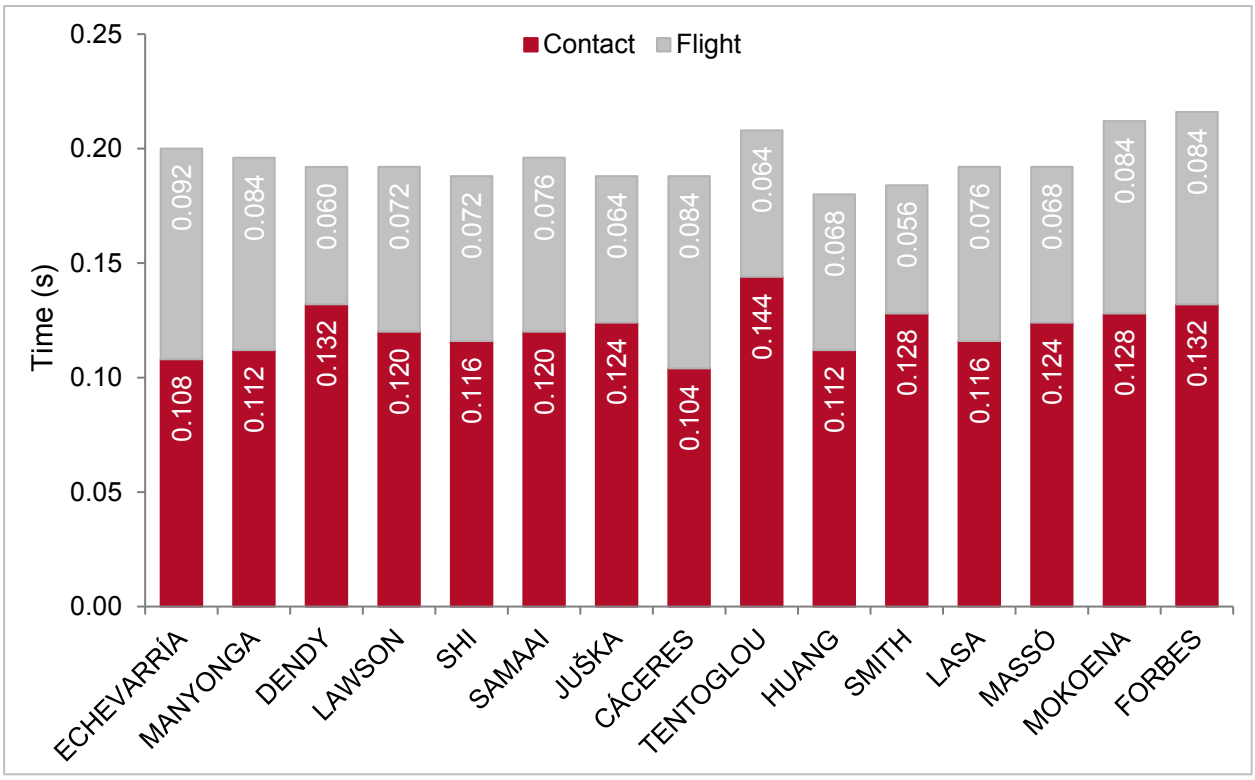


Figure 6. Contact and flight times for each finalist during the last step in their approach to the take-off board.

Table 4. Step times of the last three steps to the take-off board.

Athlete	3rd last step	2nd last step	Last step
ECHEVARRÍA	0.204	0.244	0.200
MANYONGA	0.232	0.248	0.196
DENDY	0.220	0.268	0.192
LAWSON	0.200	0.232	0.192
SHI	0.196	0.232	0.188
SAMAAI	0.200	0.244	0.196
JUŠKA	0.248	0.276	0.188
CÁCERES	0.216	0.216	0.188
TENTOGLOU	0.212	0.272	0.208
HUANG	0.212	0.224	0.180
SMITH	0.216	0.232	0.184
LASA	0.220	0.228	0.192
MASSÓ	0.208	0.272	0.192
MOKOENA	0.236	0.256	0.212
FORBES	0.236	0.248	0.216

Table 5 shows the step length and velocity of the last step. The mean step length was 2.18 metres while the mean last step velocity was 9.54 m/s.

Table 5. Step length and velocity (mean) of the last step.

Athlete	Step length (m)	Velocity (m/s)
ECHEVARRÍA	2.27	9.67
MANYONGA	2.28	9.86
DENDY	2.13	9.84
LAWSON	2.21	9.75
SHI	2.07	9.59
SAMAAI	2.22	9.71
JUŠKA	2.13	9.33
CÁCERES	2.15	9.97
TENTOGLOU	2.18	9.43
HUANG	2.06	9.51
SMITH	2.03	9.37
LASA	2.17	9.29
MASSÓ	2.03	9.23
MOKOENA	2.39	9.24
FORBES	2.36	9.34

Take-off analysis

Table 6 shows the velocity components of the CM at take-off along with the loss in horizontal velocity during contact with the take-off board. The mean horizontal velocity at TO was 8.67 m/s, while the mean vertical velocity at TO was 3.63 m/s. The mean change in horizontal velocity was −1.41 m/s. The mean take-off angle was 22.7°. Figure 7 shows the relationship between the horizontal (anteroposterior) and vertical velocity at take-off.

Table 6. CM angle at take-off and velocities (horizontal, vertical and resultant) during the final step and at take-off.

Athlete	Horizontal velocity at TO (m/s)	Vertical velocity at TO (m/s)	Change in horizontal velocity (TD – TO) (m/s)	Resultant velocity at TO (m/s)	TO angle (°)
ECHEVARRÍA	8.61	4.20	−1.41	9.58	26.0
MANYONGA	8.93	3.83	−1.39	9.72	23.2
DENDY	9.11	3.45	−1.32	9.74	20.8
LAWSON	9.12	3.22	−1.05	9.67	19.4
SHI	8.64	3.83	−1.56	9.45	23.9
SAMAAI	8.95	3.49	−1.34	9.61	21.3
JUŠKA	8.36	3.63	−1.78	9.11	23.5
CÁCERES	9.18	3.47	−0.96	9.81	20.7
TENTOGLOU	8.51	3.37	−1.72	9.15	21.6
HUANG	8.93	3.68	−0.96	9.66	22.1
SMITH	8.50	3.79	−1.53	9.31	24.0
LASA	8.10	3.81	−1.83	8.95	25.2
MASSÓ	8.44	3.76	−1.44	9.24	24.0
MOKOENA	8.23	3.47	−1.62	8.93	22.9
FORBES	8.43	3.39	−1.25	9.09	21.9

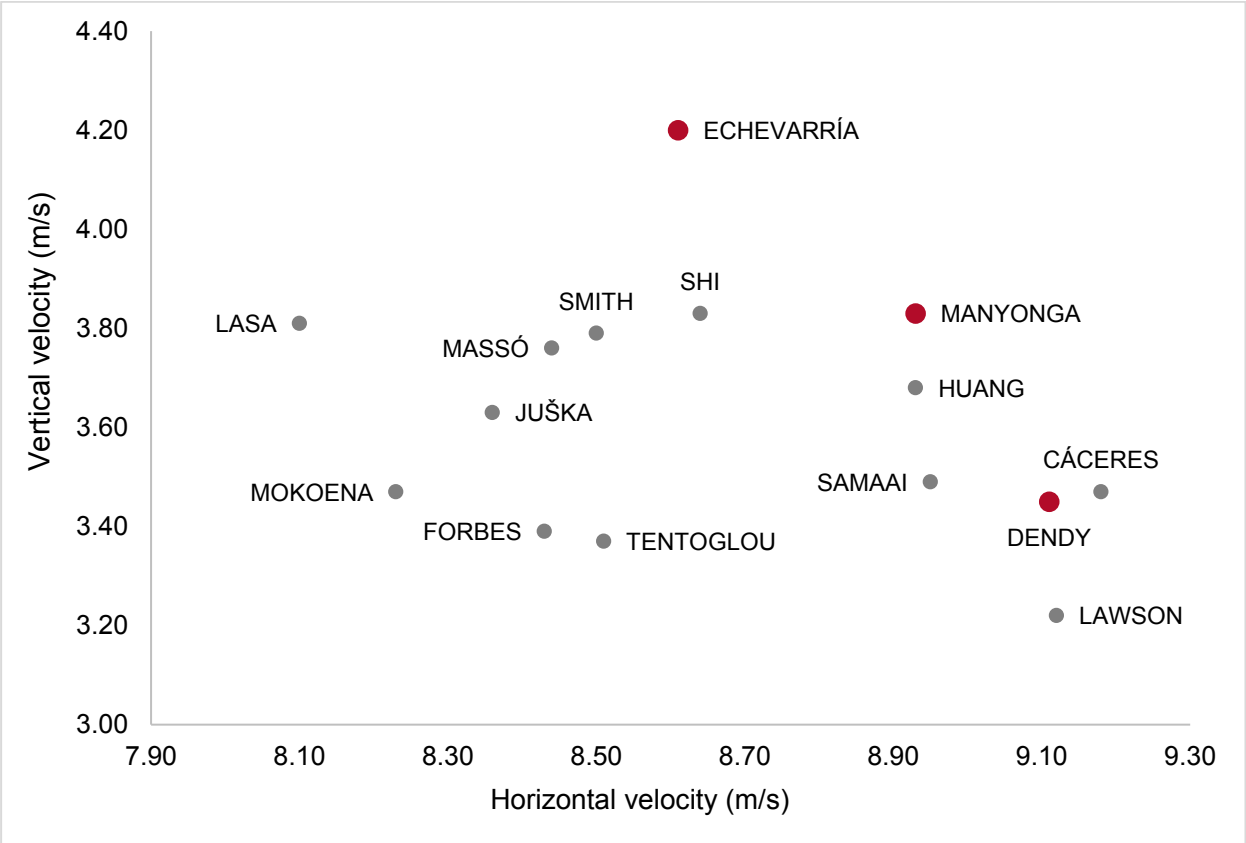


Figure 7. Scatterplot of horizontal (anteroposterior) vs. vertical velocity at take-off for all finalists.

The angles of the trunk and body inclination angle at touchdown on the board and take-off from the board are presented in Table 7. The mean trunk angle at touchdown was −5.6°, and at take-off was 0.8°. The mean body inclination angle at touchdown was −34.7°, while its value at take-off was 18.0°. The change in this angle from touchdown to take-off was 52.6°. The angle of the lead thigh at take-off was −16.2°.

Table 7. Angular data of the trunk and swinging leg for each athlete's individual best jump.

Athlete	Body inclination angle at TD (°)	Body inclination angle at TO (°)	Trunk angle at TD (°)	Trunk angle at TO (°)	Lead thigh angle at TO (°)	Mean lead thigh angular velocity (°/s)
ECHEVARRÍA	−32.2	13.5	−16.3	−6.4	−20.0	486
MANYONGA	−33.4	18.8	−4.6	−2.3	−7.5	635
DENDY	−35.3	20.1	0.3	4.7	−14.6	470
LAWSON	−35.1	20.7	0.2	−2.3	−24.2	451
SHI	−33.8	19.2	−7.2	−5.2	−19.8	532
SAMAAI	−33.6	20.6	−5.9	10.4	−18.8	595
JUŠKA	−36.2	17.1	−8.8	−2.7	−12.6	586
CÁCERES	−29.8	16.5	−2.8	0.2	−8.0	704
TENTOGLOU	−39.3	22.7	−5.2	2.8	−8.4	484
HUANG	−31.9	15.3	−8.8	2.9	−17.0	507
SMITH	−38.0	18.4	−5.3	−4.0	−16.0	490
LASA	−36.6	14.3	−5.9	−9.4	−14.8	593
MASSÓ	−34.7	18.6	−9.0	1.7	−8.3	580
MOKOENA	−34.6	16.6	−5.0	−2.2	−20.2	477
FORBES	−35.6	17.0	0.7	−0.7	−33.1	363

Note: *A negative body inclination angle indicates that the CM is behind the foot at contact. A negative lead thigh angle means the thigh is below the horizontal. A negative trunk angle indicates that trunk is extended beyond the upright position while a positive trunk angle indicates the trunk angle is flexed beyond the upright position.*

Table 8 displays the knee angle at touchdown (TD) and the minimum knee angle achieved on the board. The mean knee angle at TD on the board was 165.9° while the mean minimum knee angle on the board was 137.4°. The mean knee range of motion was 28.6°. The mean rate of change of this knee angle was −478 °/s. The mean lowering of the CM height was 3 centimetres.

Table 8. Characteristics of the contact leg on the take-off board and the CM vertical displacement during the final step.

Athlete	Knee angle at TD (°)	Minimum knee angle (°)	Knee range of motion (°)	Mean knee angular velocity (°/s)	CM lowering (cm)
ECHEVARRÍA	171.2	149.2	22.0	−489	8
MANYONGA	168.6	137.5	31.1	−518	4
DENDY	168.2	141.4	26.8	−383	3
LAWSON	162.8	124.8	38.0	−633	4
SHI	162.0	135.2	26.8	−447	3
SAMAAI	165.2	131.8	33.4	−514	4
JUŠKA	165.3	140.6	24.7	−412	3
CÁCERES	169.5	150.8	18.7	−416	2
TENTOGLOU	162.0	120.5	41.5	−553	2
HUANG	172.2	148.8	23.4	−669	4
SMITH	161.4	136.1	25.3	−460	2
LASA	162.1	134.5	27.6	−460	3
MASSÓ	169.3	129.8	39.5	−527	4
MOKOENA	168.8	144.1	24.7	−329	4
FORBES	160.1	135.3	24.8	−354	1

Note: *Negative angular velocity values for the knee indicate the knee is flexing as this is the period from touchdown to reaching their minimum knee angle.*

Landing analysis

Table 9 shows the angles of the trunk, hip and knee on landing with the sand. The loss in landing is also shown. The largest landing loss was by Manyonga at 0.33 metres. Six other athletes also recorded a loss on landing. The mean hip angle at landing was 95.4°. The mean knee angle was 131.1°, while the mean trunk angle was 1.5°. Figure 8 shows the landing distance by each athlete. The mean landing distance was 0.67 metres.

Table 9. Landing characteristics in the men's long jump final.

Athlete	Hip angle (°)	Knee angle (°)	Trunk angle (°)	Landing loss (m)
ECHEVARRÍA	110.1	153.8	−7.1	0.19
MANYONGA	85.0	131.9	7.6	0.33
DENDY	129.9	117.8	−14.6	0.00
LAWSON	111.3	117.6	3.9	0.12
SHI	81.3	135.2	9.3	0.09
SAMAAI	61.1	140.8	31.5	0.00
JUŠKA	69.9	134.9	20.3	0.00
CÁCERES	-	-		-
TENTOGLOU	107.6	138.8	−7.2	0.00
HUANG	93.1	112.8	−8.0	0.00
SMITH	100.5	125.1	2.5	0.00
LASA	101.5	124.2	−16.9	0.16
MASSÓ	107.8	120.0	−18.7	0.00
MOKOENA	83.1	136.5	9.7	0.30
FORBES	93.7	146.5	8.4	0.04

***Note**: It was not possible to measure the landing characteristics of Cáceres. A negative trunk angle indicates that trunk is extended beyond the upright position while a positive trunk angle indicates the trunk angle is flexed beyond the upright position.*

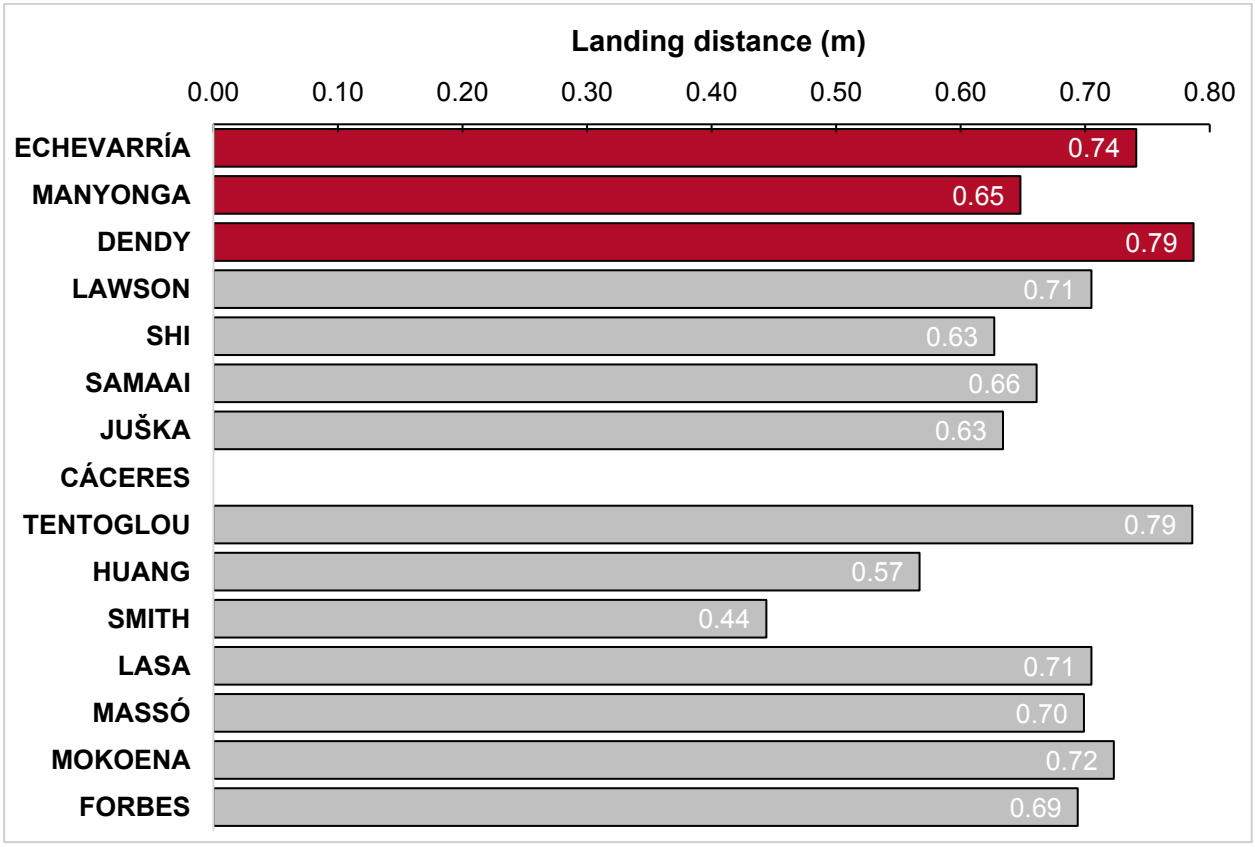


Figure 8. The landing distances for each finalist in the men's long jump.

CM trajectories (vertical)

Figures 9-13 on the following pages show the changes in the height of the CM from toe-off of the last step until take-off from the board. These data have been normalised to the height of the CM at toe-off of the last step.

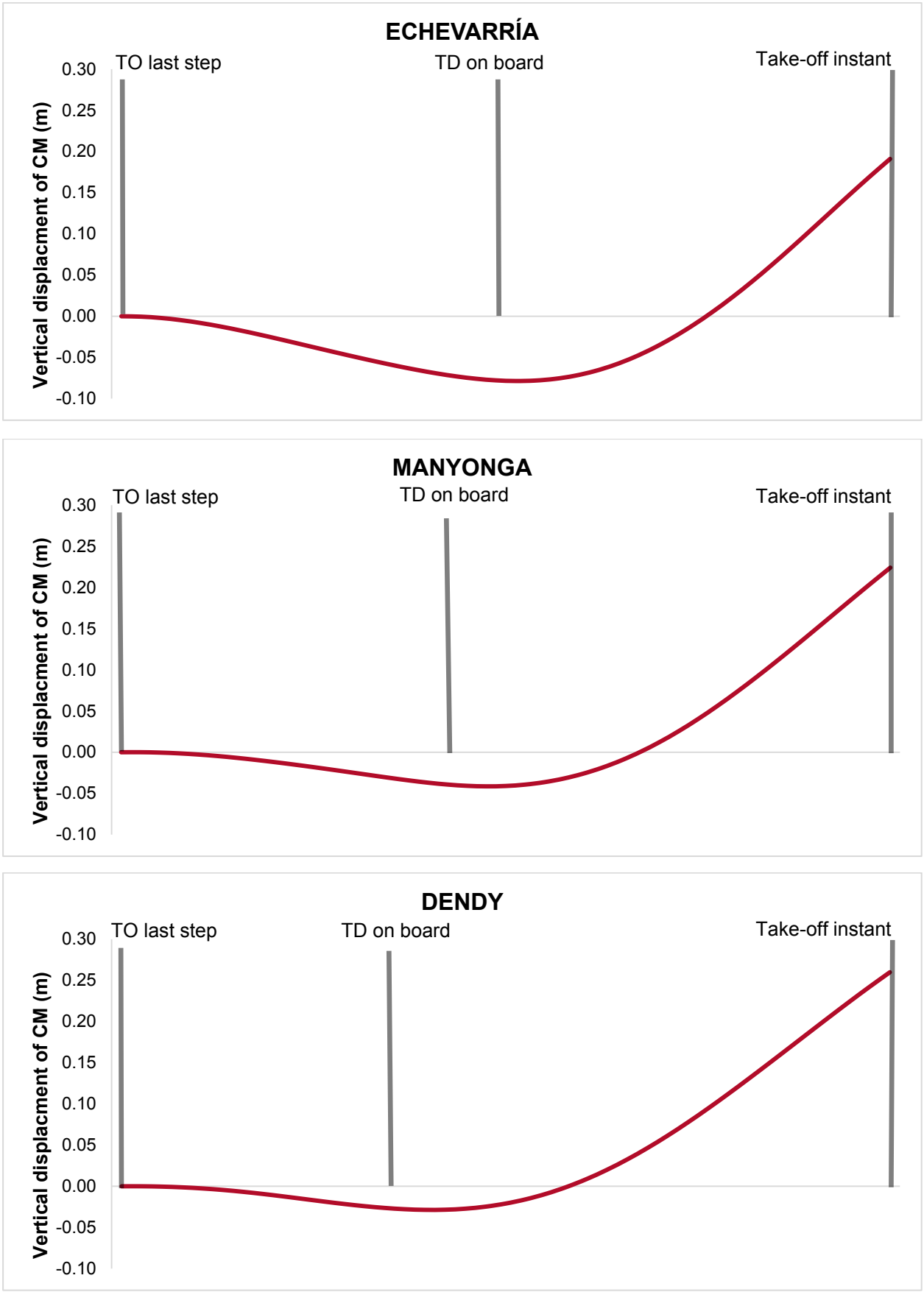


Figure 9. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board for the medallists.

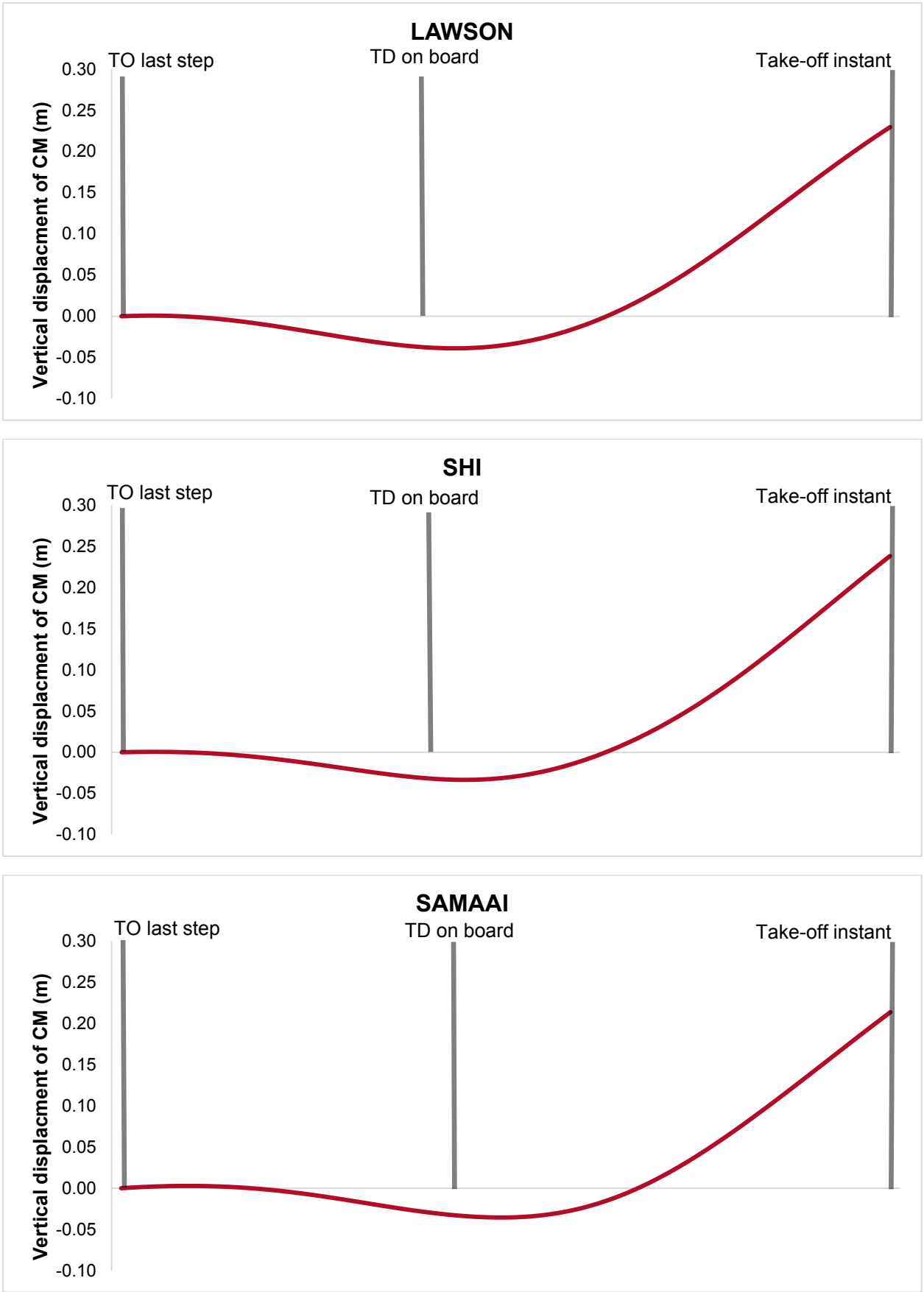


Figure 10. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board for the fourth, fifth and sixth placed athletes.

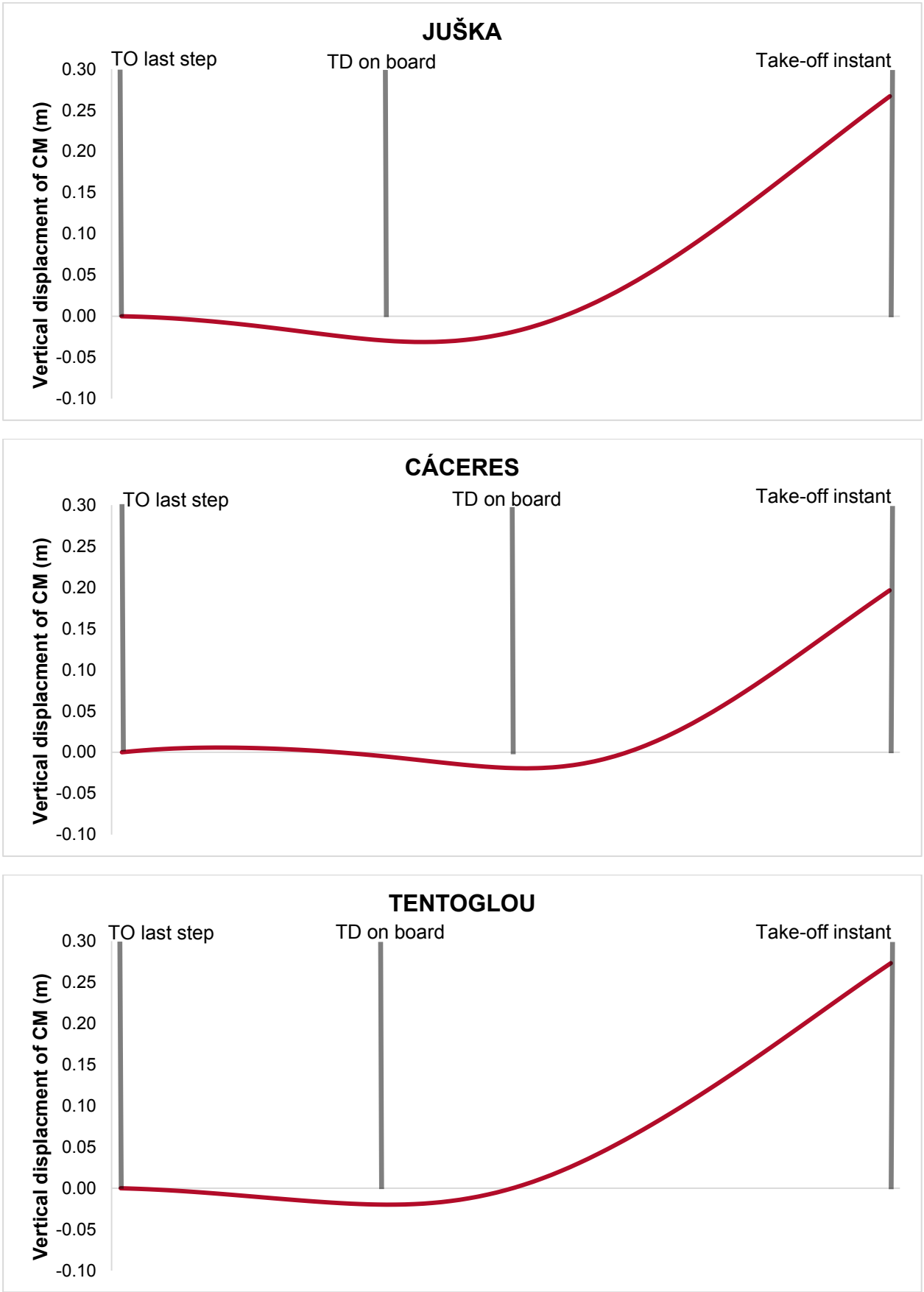


Figure 11. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board seventh, eighth and ninth placed athletes.

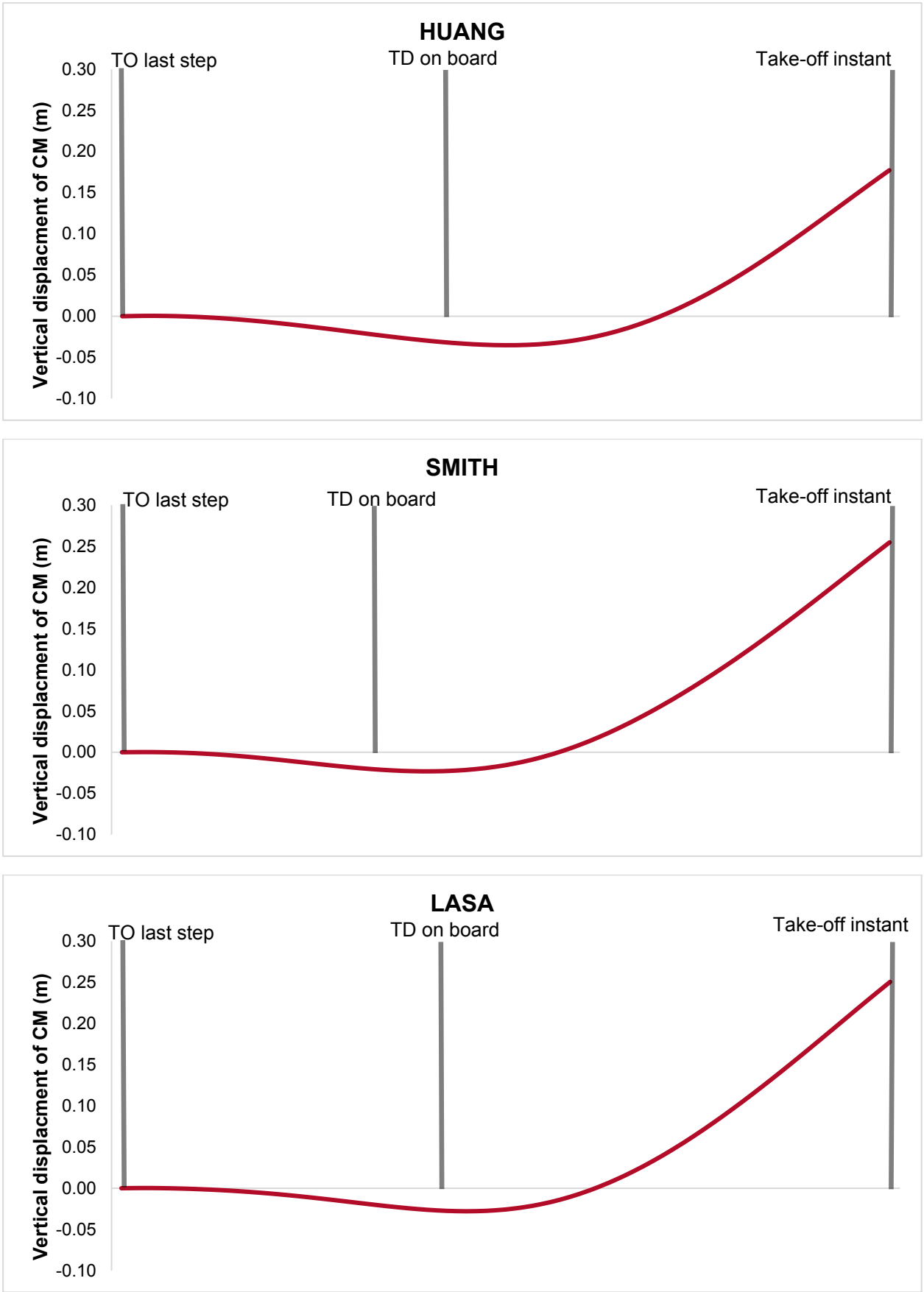


Figure 12. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board tenth, eleventh and twelfth placed athletes.

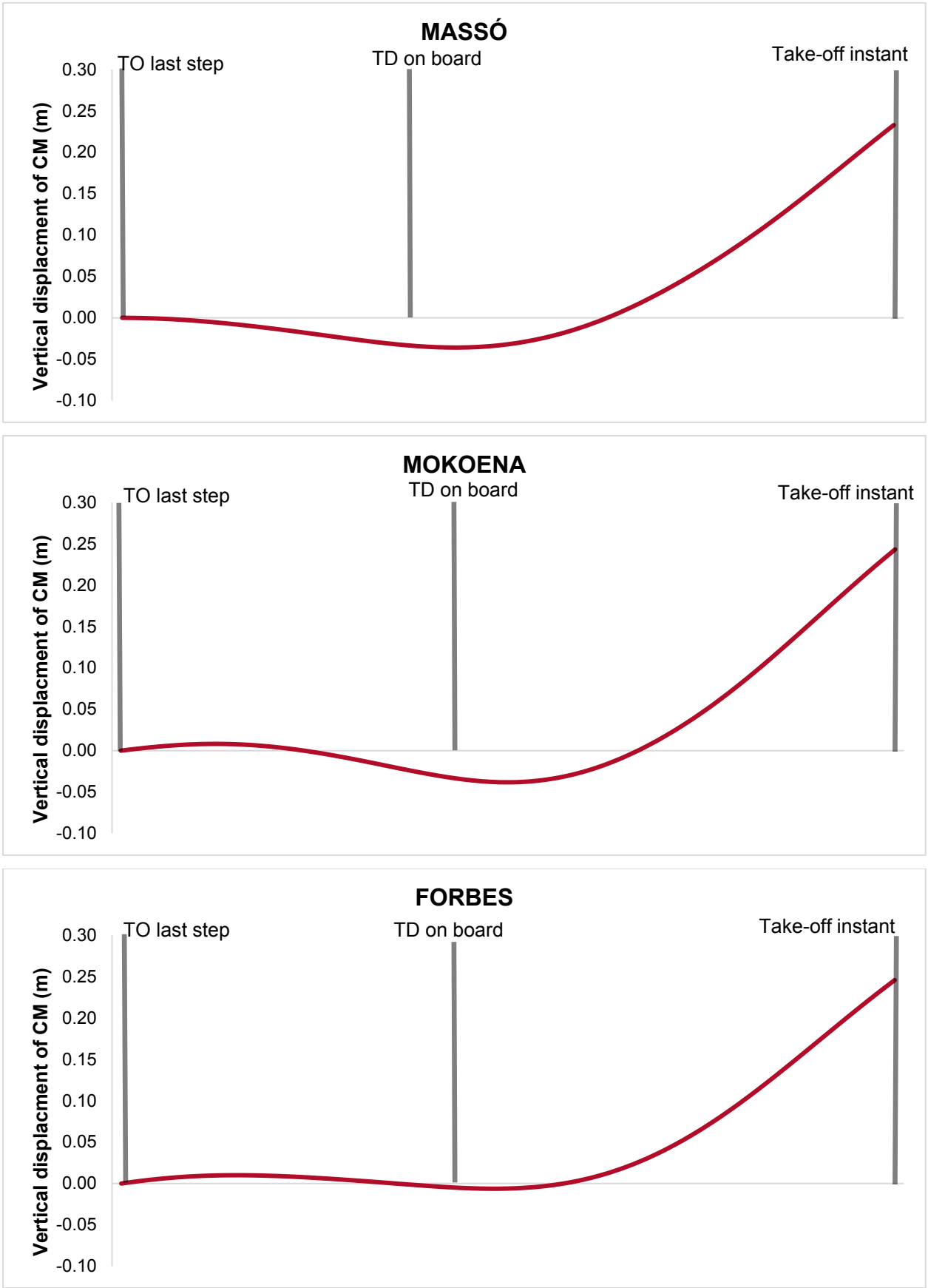


Figure 13. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board thirteenth, fourteenth and fifteenth placed athletes.

COACH'S COMMENTARY

Introduction

The long jump is a simple event in appearance, but the details involved in its execution are much more complex.

The aim is to produce the maximum amount of horizontal velocity in the aim of transfer it during the impulse (we then talk about optimal velocity). This implies a limited loss of velocity on the board; since the potential distance is already determined at take-off, the jump technique (hang, 1 step ½ hitch kick or 1 step ½ hitch kick) allows: 1) a good balance during the flight and 2) an optimum landing.

Two styles have always been seen:

- Energy production style (velocity). A wording often used by Americans, this method focuses on the velocity generated during the run-up. Examples of who has used this style would be: Carl Lewis, World Indoor Record holder 8.76 m, also 8.91 m wind assisted outdoors), Mike Powell (World Record holder 8.95 m).
- Energy restitution style (force). A style more exploited by Soviet training system, restitution consists in searching for strong stances to prepare for take-off. The angle at take-off is in theory larger than for the production style users. Examples: Cuban Ivan Pedroso (8.62 m indoors, 8.71 m outdoors, also 8.96 m wind assisted).

The commentary of the Birmingham 2018 medallists will be split in two parts:

- Analysis and comparison of the biomechanical findings
- Propositions of directions of work for each jumper

Analysis and comparison of the biomechanical findings

<u>Presentation of the athletes:</u>

J.M Echevarría (PBs 8.28 m in 2017, 8.68 m in 2018) born in 1998 in Cuba, 1.88 m height, he is a pure product of Cuban school, coached by Osorio, himself an international jumper in long jump. His striking progression occurs as Manyonga seemed to have taken over the event.

L. Manyonga born in 1991 in South Africa, 1.86 m height, had ups and downs in his career before an unexpected comeback in 2017 by taking World Championships gold, the world leading mark (PB 8.62 m) and the Diamond League victory.

Marquis Dendy (8.42 PB), born in 1992 in the USA, 1.91 m of height, has mixed triple jump and long jump for a large part of his career. However, from his Achilles tendon rupture in June 2016, he chose to focus on long jump, without excluding the possibility to comeback to triple jump.

Choice of relevant data

The elements I chose for my analysis are:

- CM trajectory
- Landing distance
- Landing loss
- Mean knee angular velocity (°/s)
- Table 6
- Table 4
- Figure 3,4,5

a. Comparison of data

Athlete	Official (m)	Landing loss + TO loss (m)	Potential distance (m)
ECHEVARRÍA	8.46	0.19 + 0.02	8.67
MANYONGA	8.44	0.33 + 0.02	8.79
DENDY	8.42 (8.18 analysed)	0.00 + 0.01	8.19

Before going into the analysis of the elements that resulted in the length of the jump, it's best to focus on the official and potential distances (landing loss + TO loss + official distance). We can observe that Dendy is the one who lost the least distance during the whole jump (only 0.01 m), while Manyonga and Echevarría had significant losses: 0.35 m and 0.21 m, respectively. That included 0.33 and 0.19 m losses on the landing only. Cross-checking these numbers with the video of the jumps, a breaking in the progression of the hips is noticeable, thus it becomes obvious that the landing part has been neglected in the performance.

From the analysis of the selected kinematic parameters, we can explicitly find 3 different styles: Echevarría relies upon the take-off angle, Dendy on velocity and Manyonga falling in between these two cases.

Echevarría 8.46 m

Echevarría possesses the most vertically oriented jump (huge angle of 26° and vertical velocity at TO of 4.20 m/s). Indeed, his has very long and large step time for the las step of 0.200 s (larger than Manyonga and Dendy), flight time for the second last step of 0.160 s (largest of all competitors) and trunk angle at TD, while his Horizontal velocity at TO (8.61 m/s) and body inclination angle at TD and TO are lower comparatively to other jumpers. All these findings converge towards the observation that the way Echevarría takes the ground in advance at touch down, results in a loss of horizontal velocity in favour to more vertical orientation. Figures 3 and 4 show that flight times for those two steps (0.120 s and 0.160 s) get longer, revealing that he is markedly preparing the take-off in advance. Meanwhile, Manyonga reduces that flight time, and Dendy shows only a slight increase.

Dendy 8.42 m (analysed jump: 8 19 m)

Dendy is the fastest of all medallists on the board: horizontal velocity at TO was 9.11 m/s. He's also the one who takes-off with the lowest height: vertical velocity at TO was 3.45 m/s, angle 20.8°. His style is in favour of a minimum loss of velocity: change in horizontal velocity TD-TO of 1.32 m/s versus 1.39 m/s and 1.41 m/s for Echevarría and Manyonga. This information is reinforced by looking at his body inclination angle at TD and TO and trunk angulation, all larger than his rivals. An interesting point to note: the mean angular velocity around his knee is slower that the other medallists (-383 °/s). Out of context, this data could be interpreted in contradiction with what we've just said, but we should keep in mind that Dendy is the tallest and has the longest segments.

Manyonga 8.44 m

His style doesn't fit into any extreme model, as it falls in between Echevarría and Dendy. *(Data for the two best jumpers ever are shown when available: Mike Powell 8.95 m WR - 8.98 m effective distance - and Carl Lewis 8.91 m - official & effective - adapted from Fukashiro & al. 1994).*

- Change in horizontal velocity TD - TO: 1.39 m/s (Echevarría 1.41 m/s; Dendy 1.32 m/s)
- TO angle: 23.2° (Echevarría 26°; Dendy 20.8°; Powell 23.1°; Lewis 18.3°)

- Horizontal velocity at TO: 8.93 m/s (Echevarría 8.61 m/s; Dendy 9.11 m/s; Powell 9.09 m/s; Lewis 9.72 m/s)
- Vertical velocity at TO: 3.83 m/s (Echevarría 4.20 m/s; Dendy 3.45 m/s; Powell 3.70 m/s; Lewis 3.22 m/s)
- Body inclination angle at TD &TO: −33.4° TD and 18.8° TO (Echevarría −32.2° and 13.5°; Dendy −35.3° and 20.1°; Powell −40° and 13°; Lewis −36° and 19°)
- Trunk angle at TD & TO: 94.6° TD and 92.3° TO (Echevarría 106.3° TD and 96.3° TO; Dendy 89.7° TD and 85.3° TO; Powell 102.7° and 80.1°; Lewis 90.2° and 82.2°)

All these comparisons tend to show that Manyonga is the most balanced jumper while Echevarría and Dendy are the antithesis. We can hypothesis that Manyonga got inspired by these two extremes and has adapted it to his own style, or this balance is the expression of his inner physical qualities. Regarding Deny and Echevarría, we can assume that their options are the results of their respective schools of jumping (velocity oriented for the American, force oriented for the Cuban).

Potential improvements for these jumpers

After the exam of the kinematic data and the videos of these 3 jumpers, it's possible to formulate a couple of areas for each of them to improve their performances.

Echevarría: While using a typical Cuban style, we have observed through other videos that he can sprint very fast. With his natural qualities of solidity on the ground, he could try to be less inclined to slow down for preparing a higher take-off, and have a better horizontal velocity maintenance. There are also some centimetres to grab in the landing phase. In this aspect it would be interesting to have the data for his 8.83 m wind-assisted jump.

Dendy: Being the antithesis of Echevarría, it would seem logical to think that Dendy should try to increase his take-off angle. However, this jump was measured at 8.19 m, and the video shows that he comes into the board in an uncomfortable way (too close to the board), which can't result in an optimum jump. His 8.42 m jump looked much better and the analysis may have shown different trend.

Manyonga: The most balanced of all, his work axis doesn't necessitate big changes. However, it would be desirable to improve his landing, as this part is objectively the reason why he lost the world indoor title.

Conclusion

After the formulation of the technical challenge of this event, and the description of the two major styles (opposition between production and restitution), it was possible to compare the differences in medallists in Birmingham, and bring hypothesis for improvements.

A striking point still needs to be mentioned: we have almost exclusively discussed the approach of the board and the impulse, but what about this neglected element: the use of energy?

Indeed, when such landing losses are recorded (0.33 m for Manyonga, 0.19 m for Echevarría), the number 1 priority shouldn't be to focus on this part of the jump? Potentially, Manyonga could have jumped 8.77 m and Echevarría 8.65 m. What about their landing losses during their personal best jumps? If we imagine that Manyonga had the same loss during his 8.62 m PB, the results would have been 8.95 m and he would co-hold the world record with Mike Powell...

CONTRIBUTORS

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.

Triple jump specialist since 2005, Teddy Tamgho is the current world record holder in the discipline. In 2013, he became world champion with 18.04 m and the third man in the history to cross the 18 metre mark. Alongside his athletic career, Teddy has been evolving since 2014 as a coach. He founded his training group 'Team T' and coaches a talented group of 8 athletes including Hugues Zango actual world leading performer (17.58 m) and Rouguy Diallo (14.39 m) former world junior champion.