BIOMECHANICAL REPORT

FOR THE

IAAF World Championships

LONDON 2017

Long Jump Men's

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Table of Contents

Figures

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Tables

INTRODUCTION

The men's long jump final took place on the night of August 5th in good weather conditions. The final produced strong performances throughout the field and those who made the final three rounds had to jump well to secure the top eight positions. Coming into the final, South Africa's Luvo Manyonga and Rushwahl Samaai were strong contenders given they had the top two World Leading jumps. Manyonga's second round jump of 8.48 metres was not to be surpassed and secured him the gold medal. Jarrion Lawson of the USA jumped a season's best of 8.44 metres in the last round to ensure the silver medal. Manyonga's compatriot, Samaai, improved in the last round to 8.32 metres and secured the bronze medal at the expense of Aleksandr Menkov.

IAAF World Championships — London 4-13 August 2017

RESULTS
Long Jump Men - Final

RECORDS	RESULT	NAME	COUNTRY	AGE	VENUE	DATE
World Record WR	8.95	Mike POWELL	USA	28	Tokyo (Olympic Stadium)	30 Aug 1991
Championships Record CR	8.95	Mike POWELL	USA	28	Tokyo (Olympic Stadium)	30 Aug 1991
World Leading WL	8.65	Luvo MANYONGA	RSA	26	Potchefstroom (Puk McCarthur)	22 Apr 2017
Area Record AR	National Record NR		Personal Best PB		Season Best SB	

5 August 2017 — 20:05 START TIME — 21:32 END TIME
TEMPERATURE: 19° C / 19° C — HUMIDITY: 52 % / 49 %

PLACE	NAME	COUNTRY	DATE of BIRTH	ORDER	RESULT	1	2	3	ORDER	4	5	6
1	Luvo MANYONGA	RSA	8 Jan 91	2	8.48 +0.4	X -0.3	8.48 +0.4	8.32 +1.1	8	8.29 +0.6	8.17 +0.4	X -0.1
2	Jarrion LAWSON	USA	6 May 94	4	8.44 SB +0.6	8.37 -0.4	8.43 +0.2	8.40 +1.2	7	8.11 +1.0	8.31 +0.5	8.44 +0.6
3	Ruswahl SAMAAI	RSA	25 Sep 91	5	8.32 -0.1	8.25 -0.7	X +0.4	8.15 +0.6	5	X +0.3	8.27 +0.1	8.32 -0.1
4	Aleksandr MENKOV	ANA	7 Dec 90	9	8.27 0.0	8.27 0.0	X +0.4	X +0.7	6	X +0.5	X +0.6	X -0.3
5	Maykel MASSÓ	CUB	8 May 99	3	8.26 +0.8	X +0.7	8.11 +0.6	8.22 +1.0	3	X +0.5	8.26 +0.8	7.98 -0.3
6	Yuhao SHI	CHN	26 Sep 98	12	8.23 -0.3	7.93 +0.4	8.17 +0.8	X	1	7.74 +0.3	X +0.7	8.23 -0.3
7	Jianan WANG	CHN	27 Aug 96	7	8.23 +0.6	8.14 -0.1	8.23 +0.6	7.95 -0.1	4	8.00 +0.3	7.85 +0.8	7.89 +0.1
8	Michel TORNÉUS	SWE	26 May 86	10	8.18 +0.4	8.18 +0.4	X	X +1.0	2	X +1.0	7.92 +0.8	8.05 +0.3
9	Emiliano LASA	URU	25 Jan 90	11	8.11 +0.7	8.06 +0.1	X +0.8	8.11 +0.7				
10	Radek JUŠKA	CZE	8 Mar 93	6	8.02 +0.7	7.81 -0.5	8.02 +0.7	5.34 +0.5				
11	Fabrice LAPIERRE	AUS	17 Oct 83	1	7.93 +0.6	7.89 +0.7	7.93 +0.6	7.91 +0.8				
12	Damar FORBES	JAM	11 Sep 90	8	7.91 +0.6	7.61 +0.6	7.91 +0.6	7.85 +0.4				

Timing and Measurement by SEIKO — AT-LJ-M-f--A--.RS1..v1 — Issued at 21:33 on Saturday, 05 August 2017

Official Partners
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METHODS

Seven vantage locations for camera placement were identified and secured. These locations were situated in the stand along the back 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.
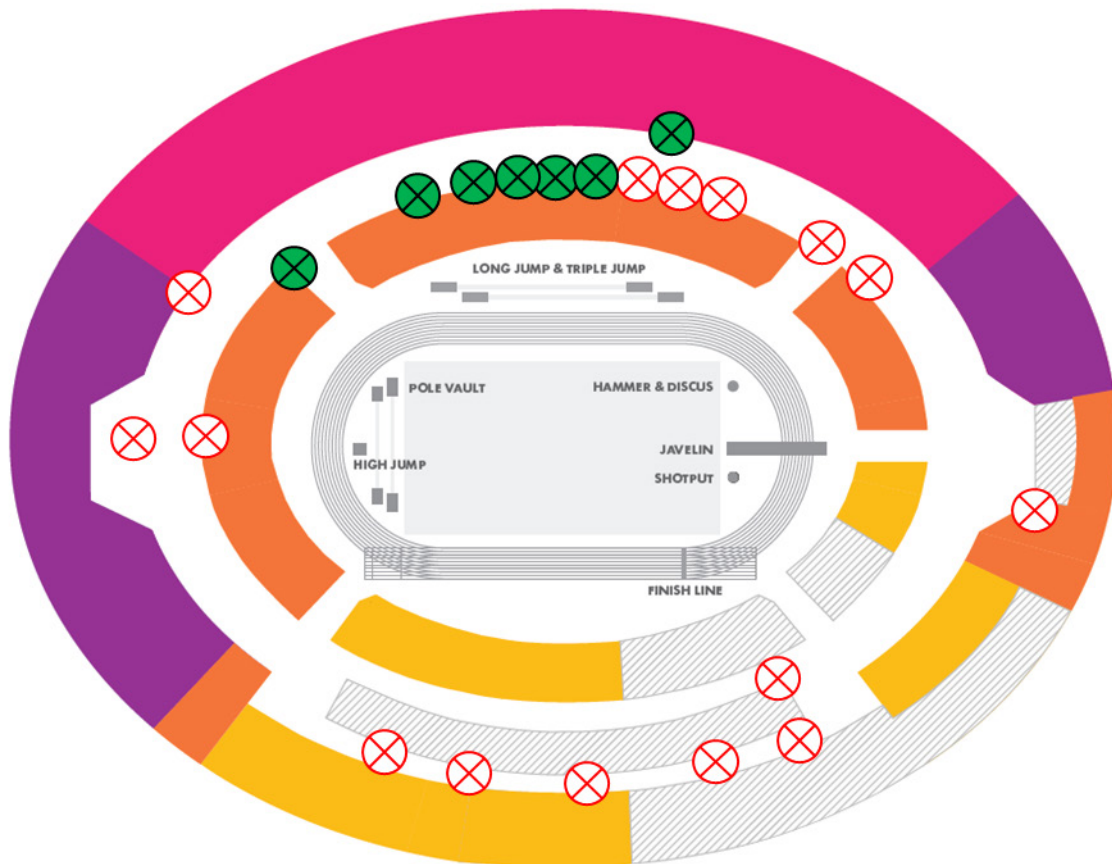
Figure 1. Camera locations within the stadium for the men's long jump final (shown in green).

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: 2500; 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. Four Canon EOS 700D cameras operating at 60 Hz (shutter speed: 1/1000; ISO: 1600; SHD: 1280x720 px) were positioned strategically along the runway with three of these being paired with a Sony PXW-FS5 camera each as a precaution against the unlikely event of data capture loss. A single Canon EOS-700D camera was positioned with its optical axis perpendicular to the landing pit to capture motion in the sagittal plane of landing. However, because of the lack of availability of this specific camera position during the final, it was not possible to analyse the landing position.

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 2. The calibration frame was constructed and filmed before and after the competition.
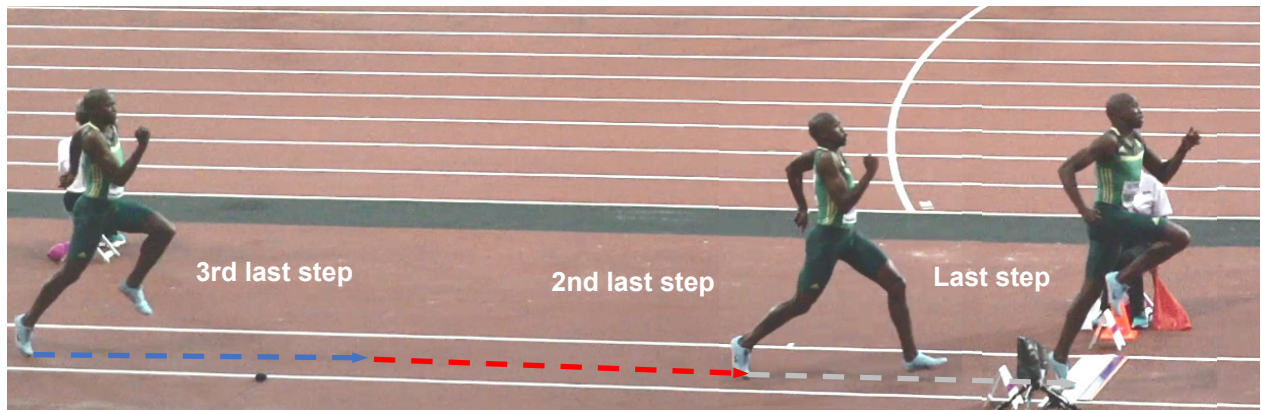
Figure 3. Last three steps in the approach phase of the long jump.

Table 1. Definitions of variables examined in the long jump.

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 (3rd last, 2nd last, last)	The length of the third-to-last, second-last and last approach steps measured from the foot tip in each step to the next foot tip.
Change in step length (3rd last / 2nd last and 2nd last / last)	The percentage difference in length between each step and the previous step.
Step width (3rd last, 2nd last, last)	The side-to-side displacement from the toe off of each step to the toe-off of the next step.
Velocity (3rd last step, 2nd last step, last step)	The mean horizontal (anteroposterior direction) velocity of the athlete measured during each of the last three steps 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 angle	The angle of the trunk relative to the horizontal and considered to be 90° in 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 at touchdown and take-off	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.

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 8.20 metres and the mean difference compared with their season's bests was −0.11 metres and compared with their personal bests was −0.20 metres.

Table 2. Competition results in comparison with athletes' personal bests (PB) and season's bests (SB) for 2017 (before the World Championships).

Athlete	Rank	Official distance (m)	SB (2017) (m)	Comparison with SB (m)	PB (m)	Comparison with PB (m)
MANYONGA	1	8.48	8.65	−0.17	8.65	−0.17
LAWSON	2	8.44	8.33	0.11	8.58	−0.14
SAMAAI	3	8.32	8.49	−0.17	8.49	−0.17
MENKOV	4	8.27	8.32	−0.05	8.56	−0.29
MASSÓ	5	8.26	8.33	−0.07	8.33	−0.07
SHI	6	8.23	8.31	−0.08	8.31	−0.08
WANG	7	8.23	8.29	−0.06	8.29	−0.06
TORNÉUS	8	8.18	8.30	−0.12	8.44	−0.26
LASA	9	8.11	8.19	−0.08	8.19	−0.08
JUŠKA	10	8.02	8.29	−0.27	8.29	−0.27
LAPIERRE	11	7.93	8.03	−0.10	8.40	−0.47
FORBES	12	7.91	8.29	−0.38	8.29	−0.38

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

Table 3 shows 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 0.06 metres.

Table 3. Distance characteristics of the individual best jumps.

Athlete	Analysed attempt	Official distance (m)	Effective distance (m)	Take-off loss (m)
MANYONGA	2	8.48	8.54	0.06
LAWSON	6	8.44	8.50	0.06
SAMAAI	6	8.32	8.35	0.03
MENKOV	1	8.27	8.35	0.08
MASSÓ	5	8.26	8.27	0.01
SHI	6	8.23	8.26	0.03
WANG	2	8.23	8.32	0.09
TORNÉUS	1	8.18	8.26	0.08
LASA	3	8.11	8.20	0.09
JUŠKA	2	8.02	8.10	0.08
LAPIERRE	2	7.93	8.00	0.07
FORBES	2	7.91	7.93	0.02

Approach phase analysis

Table 4 shows the step lengths of each finalists during their last three steps before the take-off board. The percentage change in step length from the third- to second-last, and in the second-last to last steps, is also presented. The mean change from the third-last to second-last step was an increase of 6%. The mean change from the second-last to last step was a decrease of 9%.

Table 4. Step length characteristics of the last three steps in each individual's best jump.

Step lengths of last three steps before take-off			Change in step length	
■3rd last step length (m) ■2nd last step length (m) ■Last step length (m)			3rd last / 2nd last (%)	2nd last / last) (%)
MANYONGA	2.38	2.61	2.12	+10	−19
LAWSON	2.37	2.56	2.31	+8	−10
SAMAAI	2.16	2.18	2.15	+1	−1
MENKOV	2.29	2.43	2.16	+6	−11
MASSÓ	2.28	2.49	2.17	+9	−13
SHI	2.15	2.37	2.15	+10	−9
WANG	2.11	2.29	2.16	+9	−6
TORNÉUS	2.34	2.53	2.15	+8	−15
LASA	2.32	2.33	2.27	0	−3
JUŠKA	2.68	2.71	2.51	+1	−7
LAPIERRE	2.40	2.37	2.16	−1	−9
FORBES	2.18	2.30	2.17	+6	−6

Table 5 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 0.090 seconds, for the second-last step was 0.113 seconds and the for the last step was 0.112 seconds. The mean flight time for the third-last step was 0.125 seconds, for the second-last step was 0.131 seconds and the for the last step was 0.073 seconds.

Table 5. Step times of the last three steps to the take-off board.

Athlete	3rd last step (s)	2nd last step (s)	Last step (s)
MANYONGA	0.225	0.245	0.185
LAWSON	0.215	0.250	0.200
SAMAAI	0.195	0.230	0.200
MENKOV	0.210	0.250	0.185
MASSÓ	0.215	0.250	0.190
SHI	0.210	0.230	0.205
WANG	0.190	0.230	0.190
TORNÉUS	0.210	0.255	0.190
LASA	0.225	0.225	0.200
JUŠKA	0.255	0.285	0.215
LAPIERRE	0.225	0.245	0.190
FORBES	0.205	0.230	0.190
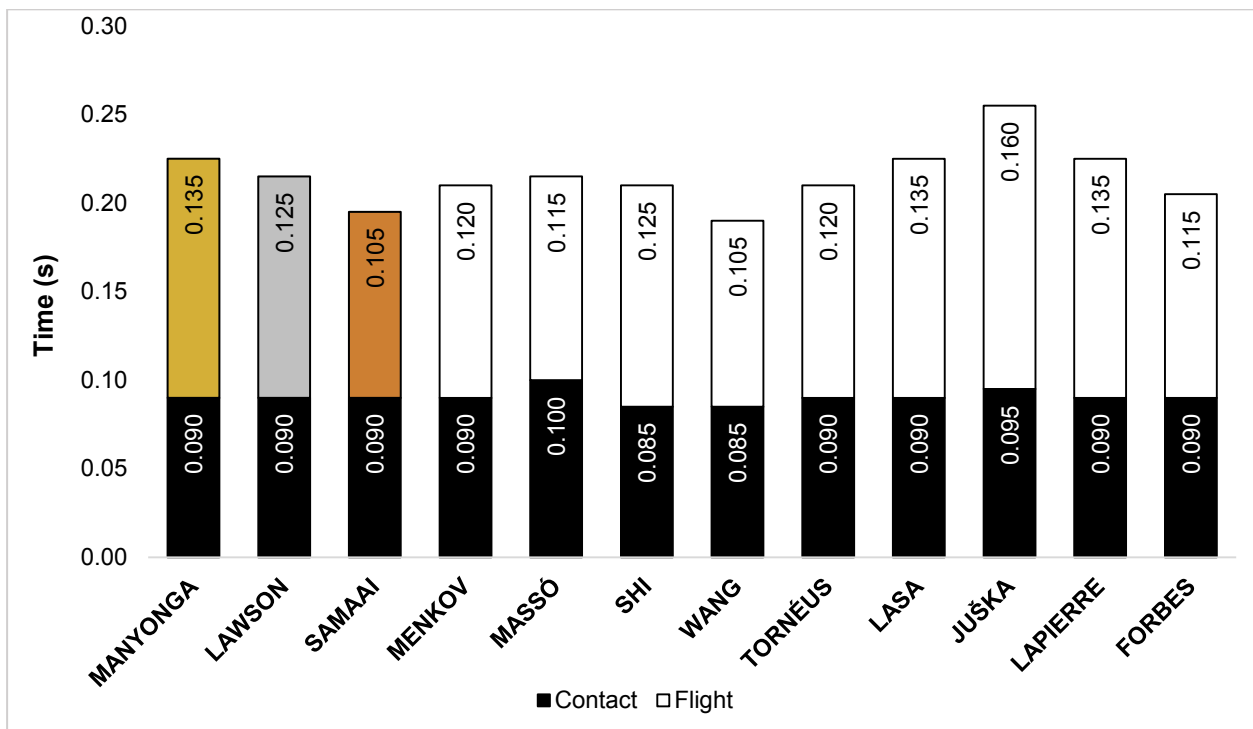
Figure 4. Contact and flight times for each finalist during the third-last step in their approach to the take-off board.
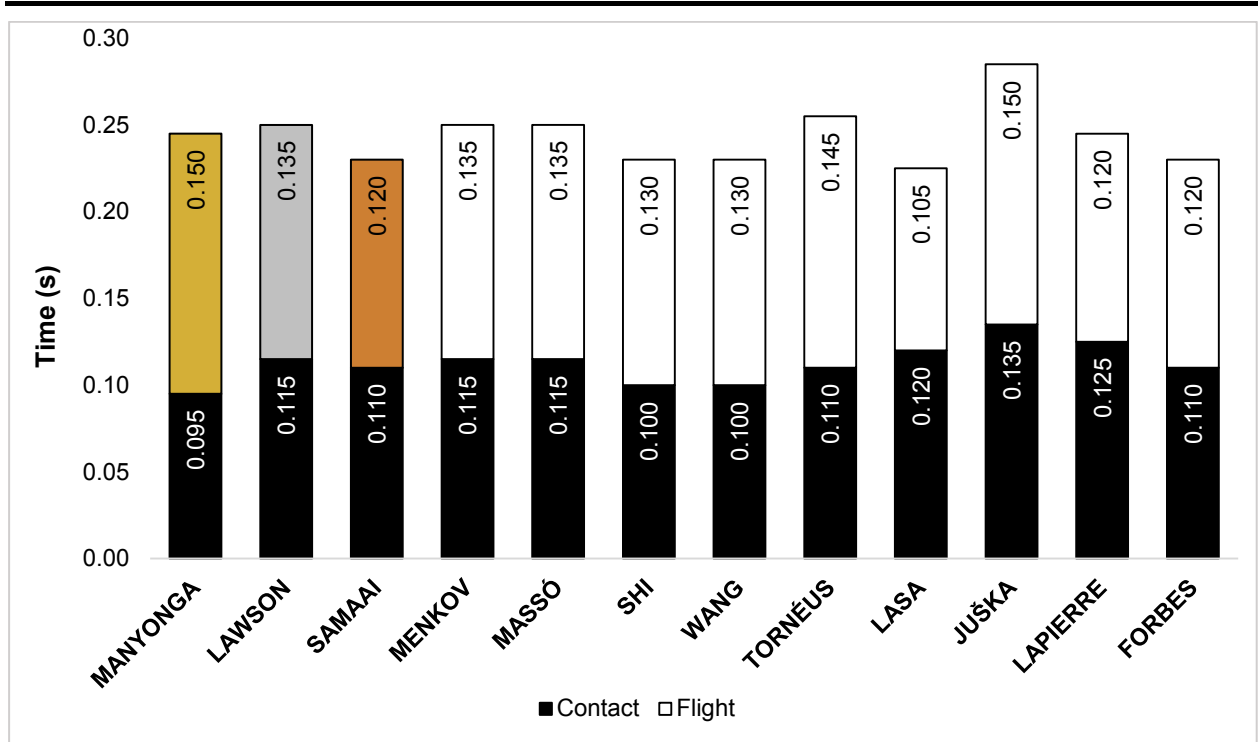
Figure 5. Contact and flight times for each finalist during the second-last step in their approach to the take-off board.
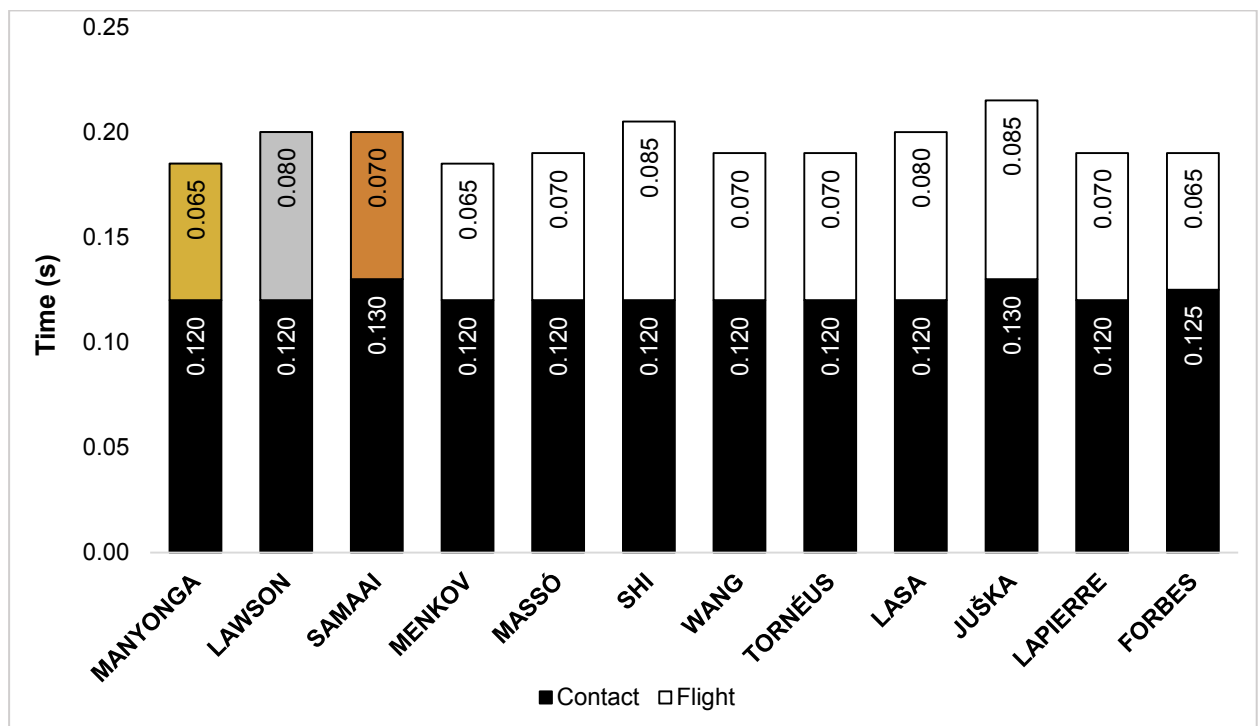
Figure 6. Contact and flight times for each finalist during the last step in their approach to the take-off board.

Table 6 shows the step width for each of the last three steps and changes between them.

Table 6. Step width for the last three steps along with the changes (Δ) between each step.

Athlete	3rd last step (m)	2nd last step (m)	Last step (m)	Δ 3rd – 2nd last step (m)	Δ 2nd last - last step (m)
MANYONGA	0.18	0.19	0.00	0.01	−0.19
LAWSON	0.16	0.27	0.15	0.11	−0.12
SAMAAI	0.09	0.20	0.02	0.11	−0.18
MENKOV	0.07	0.20	0.11	0.13	−0.09
MASSÓ	0.18	0.29	0.17	0.11	−0.12
SHI	0.30	0.32	0.15	0.02	−0.17
WANG	0.11	0.14	0.04	0.03	−0.10
TORNÉUS	0.24	0.27	0.18	0.03	−0.09
LASA	0.18	0.22	0.08	0.04	−0.14
JUŠKA	0.21	0.18	0.02	−0.03	−0.16
LAPIERRE	0.02	0.09	0.03	0.07	−0.06
FORBES	0.24	0.26	0.31	0.02	0.05

Note: Positive values for change in step width indicate an increase between steps and negative values indicate a reduction in step width between steps.

Figures 7 and 8 show the horizontal velocities for the last three steps for all finalists. The mean change in velocity from the third-last to second-last step was a reduction of 0.11 m/s. The mean change in velocity from the second-last to last step was a reduction of 0.64 m/s.

	3rd last step	2nd last step	Last step
MANYONGA	10.45	10.50	9.91
LAWSON	10.58	10.82	10.00
SAMAAI	10.51	10.15	9.64
MENKOV	10.59	10.22	9.70
MASSÓ	10.22	10.01	9.68
SHI	10.32	9.91	9.42
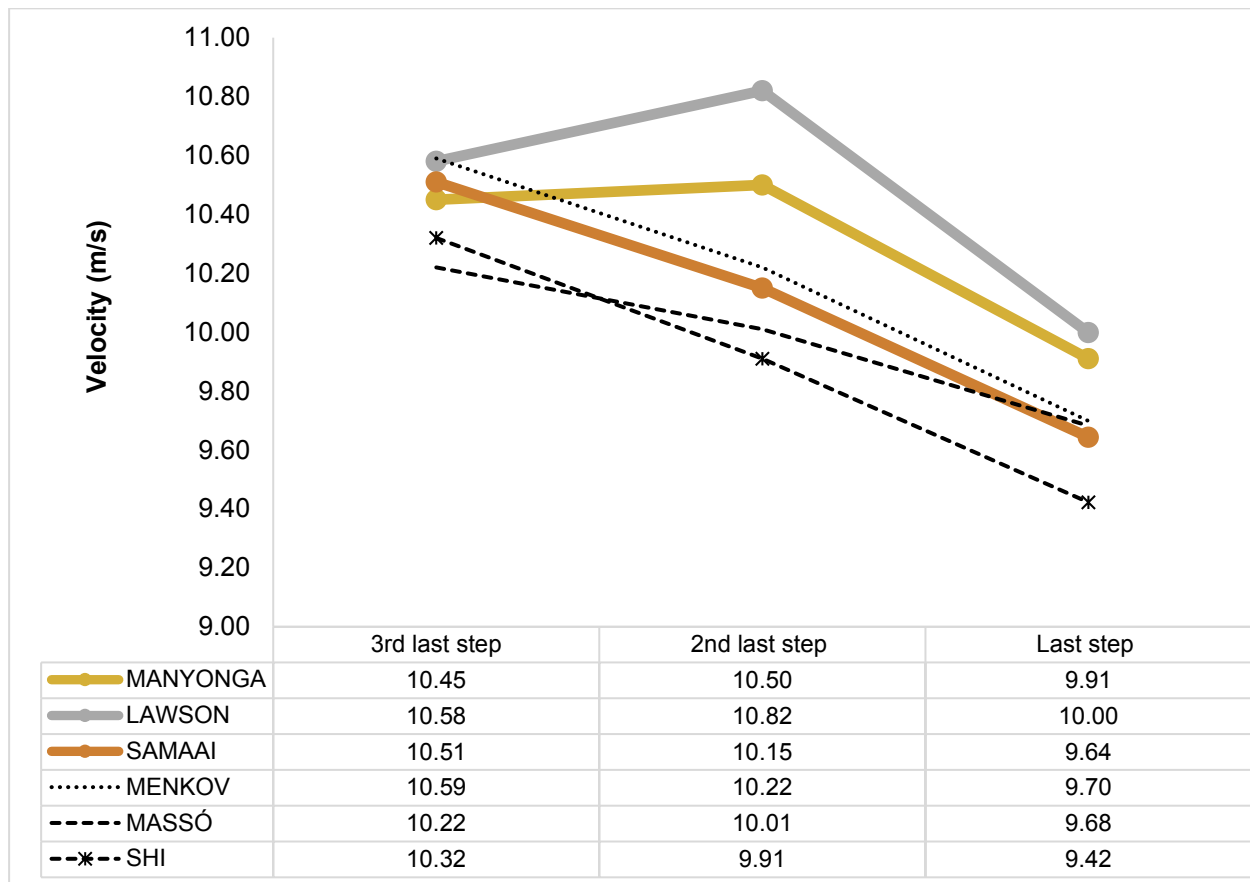
Figure 7. Change in horizontal velocity during the last three approach steps for the top six finishers.

	3rd last step	2nd last step	Last step
– + – WANG	10.47	10.38	9.86
– · – TORNÉUS	10.34	10.17	9.47
—▲— LASA	10.22	10.34	9.38
— — JUŠKA	10.07	10.32	9.36
–⬤– LAPIERRE	10.41	9.99	9.53
— ·· FORBES	10.29	10.35	9.51
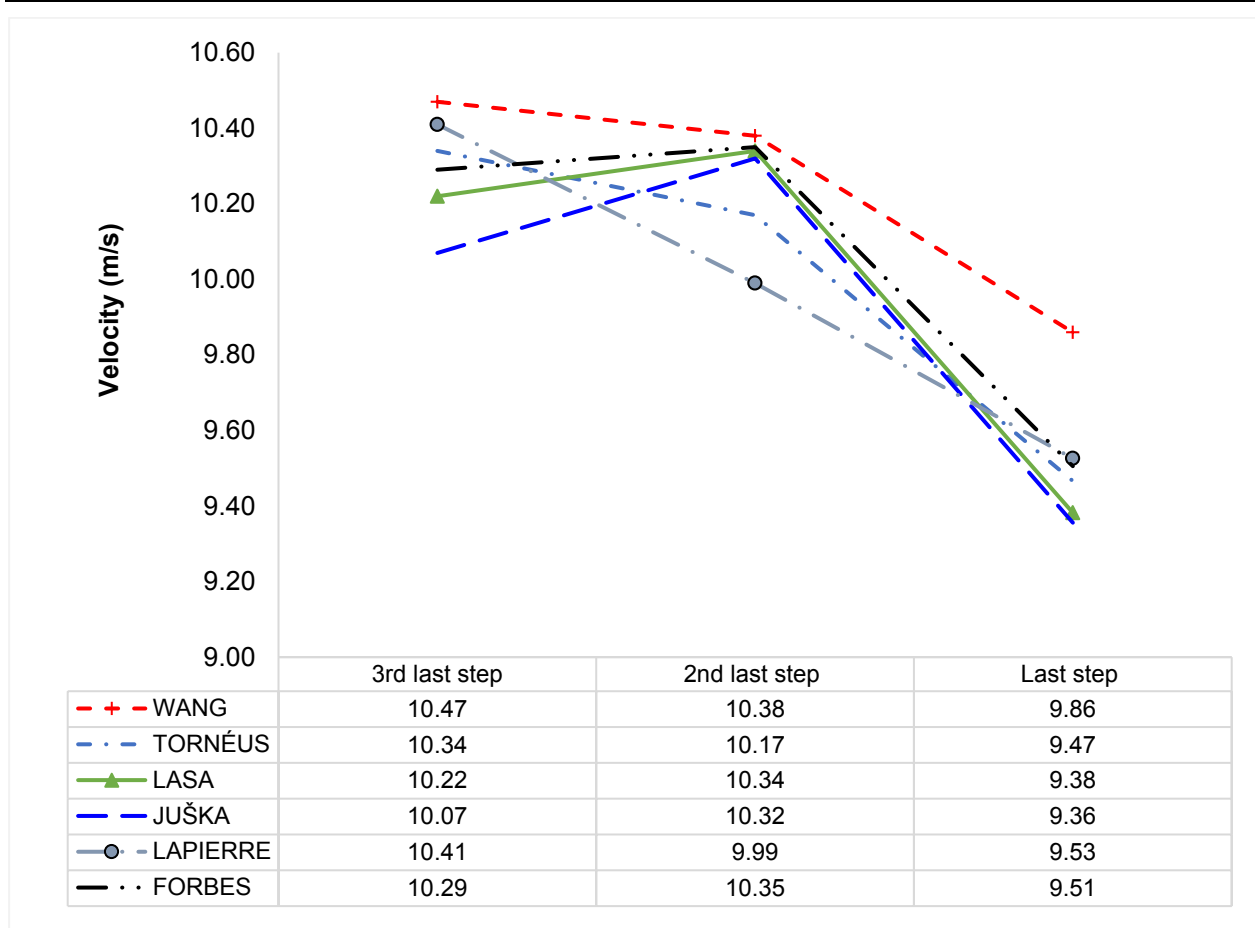
Figure 8. Change in horizontal velocity during the last three approach steps for the bottom six finishers.

Take-off analysis

Table 7 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 8.61 m/s, while the mean vertical velocity at TO was 3.85 m/s. The mean change in horizontal velocity was −1.81 m/s. The lowering of the CM during contact with the board is also displayed within the table. The mean lowering was 3 centimetres. Figure 9 shows the relationship between the horizontal (anteroposterior) and vertical velocity at take-off.

Table 7. CM 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)	CM lowering (cm)
MANYONGA	9.12	3.68	−1.58	9.83	5
LAWSON	9.56	3.51	−1.10	10.18	3
SAMAAI	7.98	3.87	−2.08	8.87	3
MENKOV	8.06	3.79	−2.80	8.91	2
MASSÓ	9.43	3.93	−0.53	10.22	4
SHI	8.28	4.06	−2.61	9.22	6
WANG	9.19	3.81	−2.28	9.95	5
TORNÉUS	7.82	3.84	−2.79	8.71	1
LASA	8.45	4.13	−1.41	9.41	2
JUŠKA	8.24	4.08	−1.47	9.19	4
LAPIERRE	8.49	3.80	−1.35	9.30	3
FORBES	8.74	3.71	−1.70	9.49	1
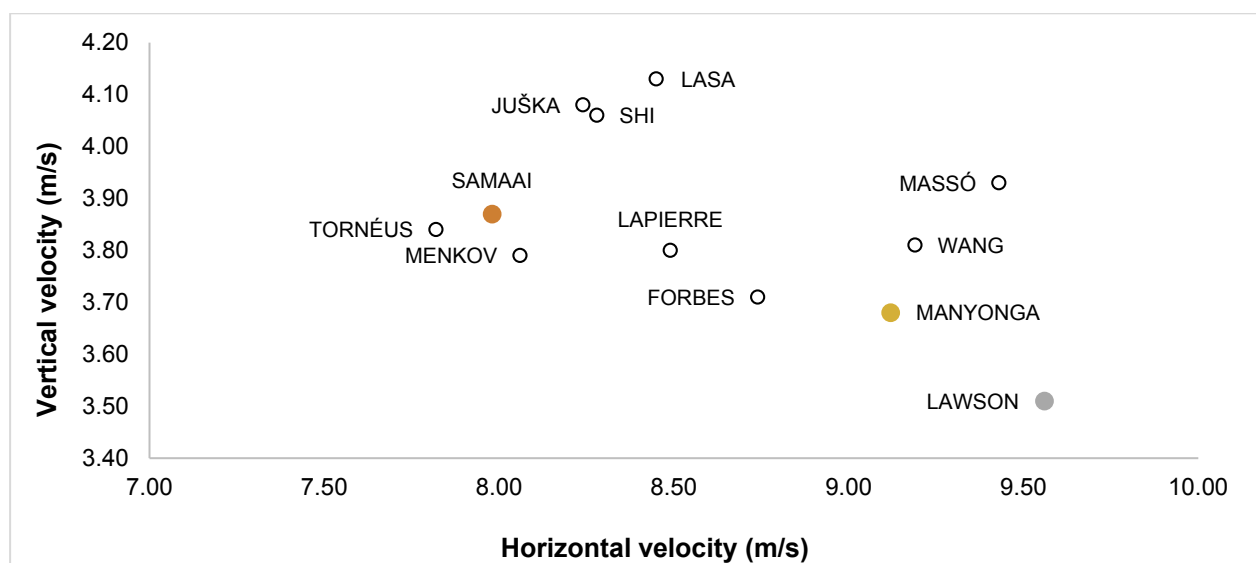
Figure 9. Scatterplot of horizontal (anteroposterior) vs. vertical velocity at take-off for all finalists.

The take-off angles for each athlete are shown in Table 8. The CM angle at take-off, the angle of the trunk, the inclination angle at touchdown on the board and take-off from the board are also shown. The mean take-off angle was 24.2°, the mean trunk angle at take-off was 90.3°, while the angle of the lead thigh at take-off was −16.5°. The mean body inclination angle at touchdown was −36.5°, while its value at take-off was 18.4°. The change in this angle from touchdown to take-off was 54.9°.

Table 8. Angular data of the CM, trunk and swinging leg for each athlete's individual best jump.

Athlete	TO angle (°)	Body inclination angle at TD (°)	Body inclination angle at TO (°)	Trunk angle at TO (°)	Lead thigh angle at TO (°)	Mean lead thigh angular velocity (°/s)
MANYONGA	22.0	−34.9	19.2	84.1	−16.3	574
LAWSON	20.2	−35.7	18.2	91.0	−15.4	472
SAMAAI	25.9	−36.7	21.8	82.7	−21.1	607
MENKOV	25.2	−35.9	20.0	91.6	−26.7	492
MASSÓ	22.6	−38.0	18.8	91.0	−18.2	626
SHI	26.1	−34.6	17.3	96.0	−19.0	476
WANG	22.5	−37.1	18.8	100.4	−9.6	565
TORNÉUS	26.2	−36.4	18.9	84.6	−6.8	612
LASA	26.0	−37.0	16.2	98.2	−16.5	504
JUŠKA	26.3	−37.5	16.8	85.5	−14.7	533
LAPIERRE	24.1	−36.0	16.3	93.9	−5.4	679
FORBES	23.0	−37.6	19.0	84.7	−28.1	381

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.

Table 9 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 173.5° while the mean minimum knee angle on the board was 139.3°. The mean knee range of motion was 34.2°. The mean rate of change of this knee angle was 536 °/s.

Table 9. Characteristics of the contact leg on the take-off board.

Athlete	Knee angle at TD (°)	Minimum knee angle (°)	Knee range of motion (°)	Mean knee angular velocity (°/s)
MANYONGA	177.5	142.6	34.9	−537
LAWSON	179.9	134.5	45.4	−606
SAMAAI	172.2	144.3	27.9	−699
MENKOV	176.1	151.7	24.4	−349
MASSÓ	165.5	128.0	37.5	−626
SHI	178.8	134.4	44.4	−592
WANG	169.3	143.0	26.3	−351
TORNÉUS	169.6	123.6	46.0	−574
LASA	169.4	158.7	10.7	−143
JUŠKA	172.5	139.9	32.6	−435
LAPIERRE	176.5	145.9	30.6	−764
FORBES	174.6	125.4	49.2	−757

Note: Negative angular velocity values for the knee indicate the knee is flexing.

CM trajectories (vertical)

Figures 10-13 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.
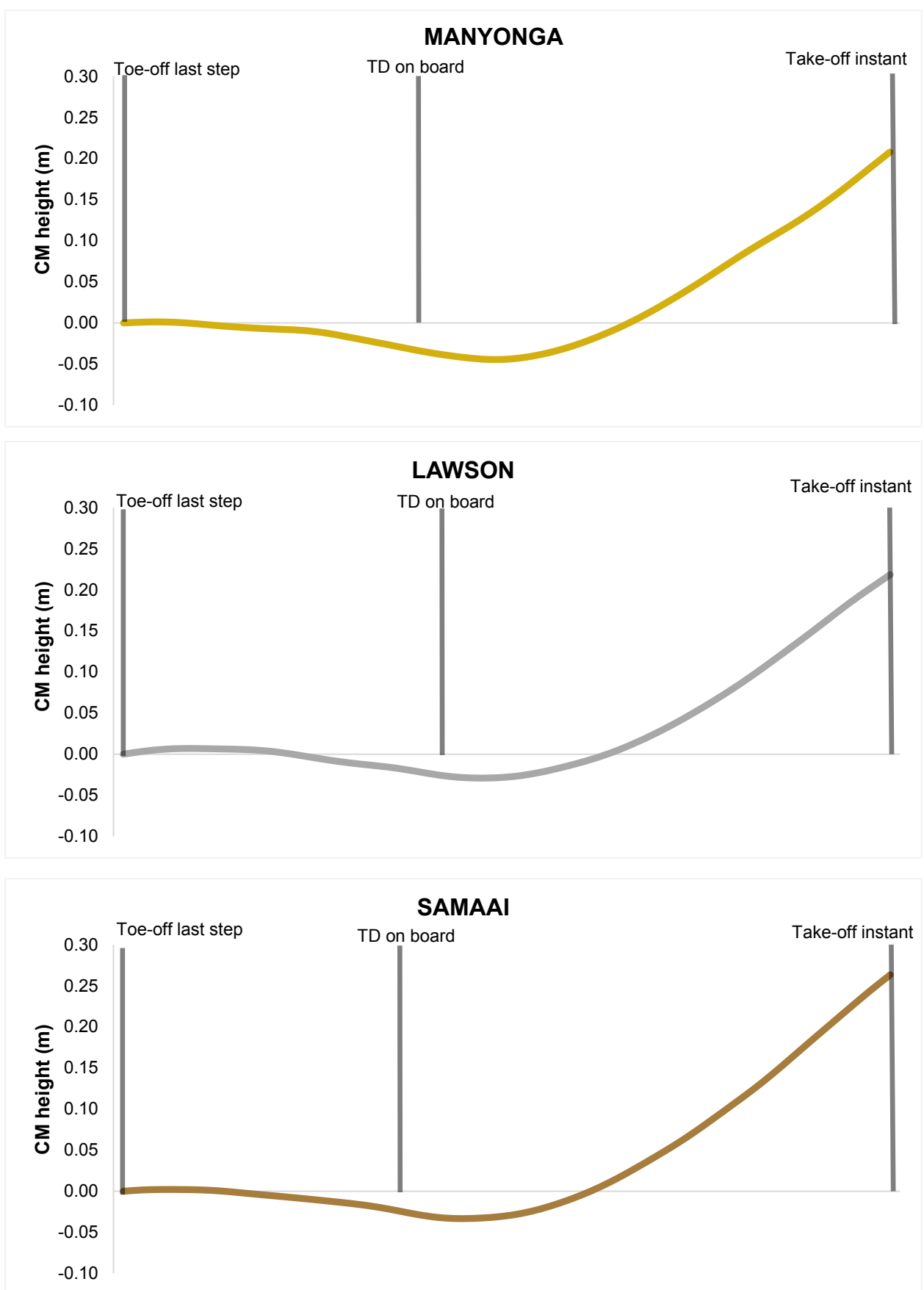
Figure 10. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board for the medallists.

MENKOV

Toe-off last step   TD on board   Take-off instant

CM height (m)

0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10

MASSÓ

Toe-off last step   TD on board   Take-off instant

CM height (m)

0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10

SHI

Toe-off last step   TD on board   Take-off instant

CM height (m)

0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
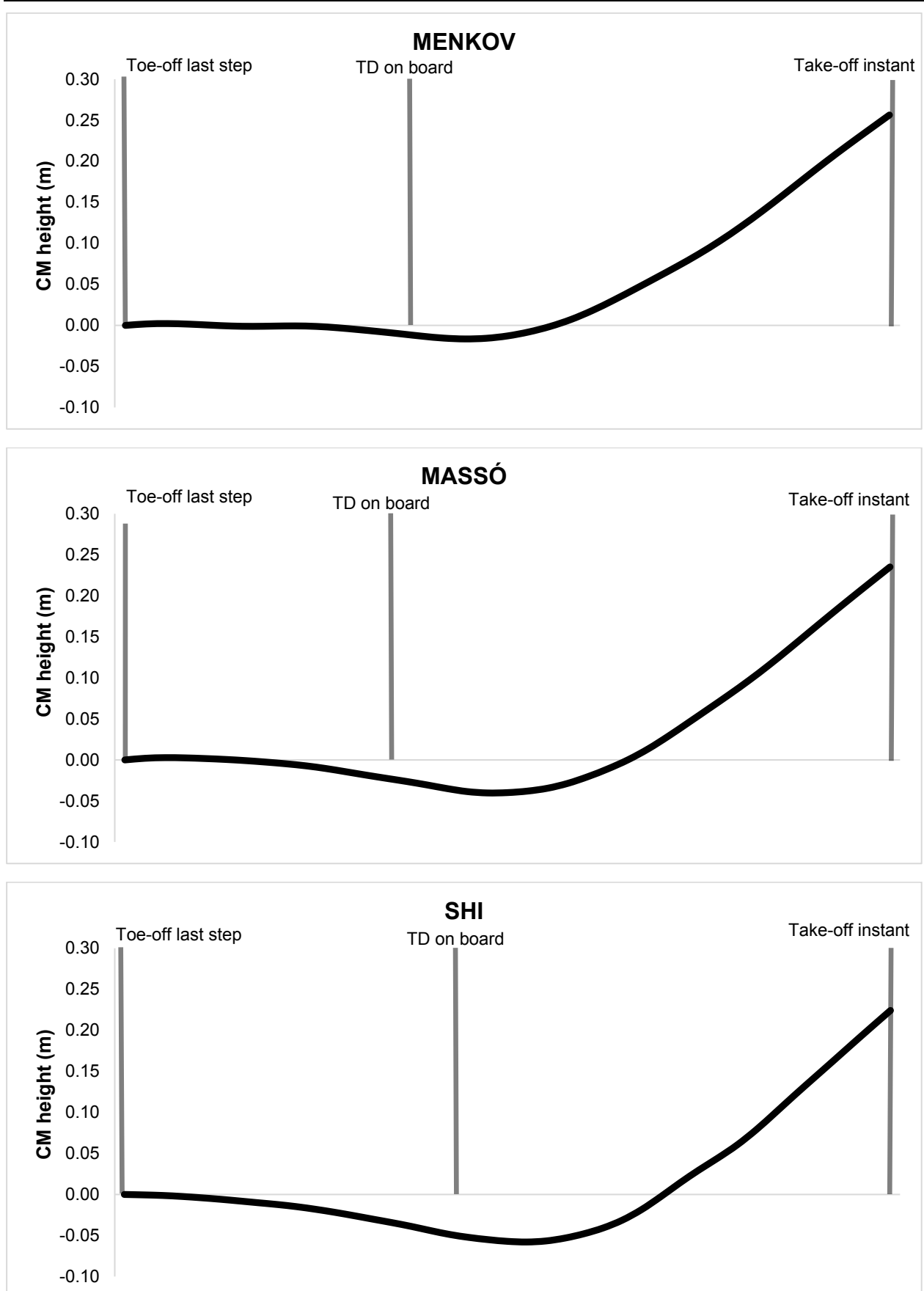
Figure 11. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board for the fourth, fifth and sixth placed athletes.
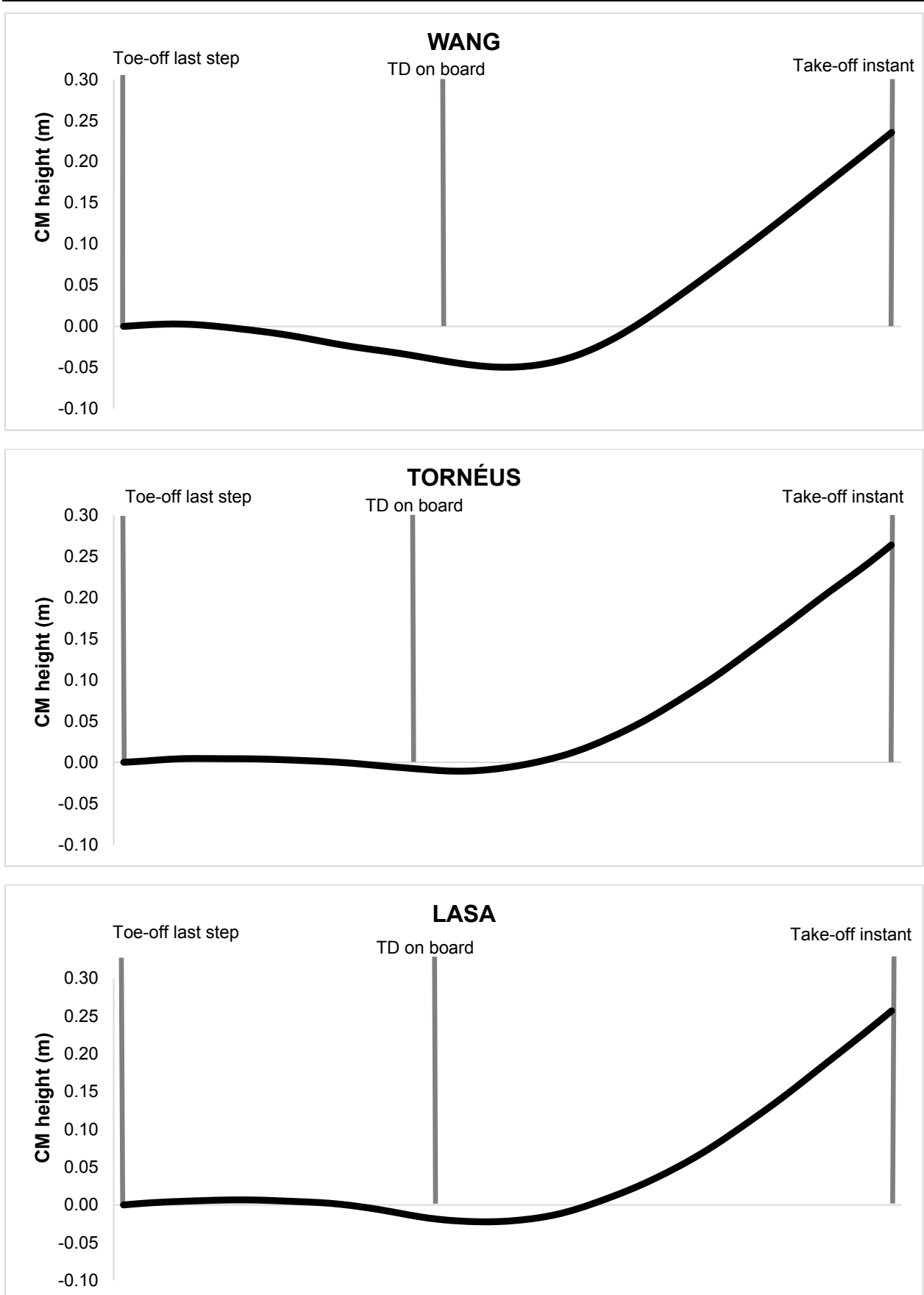
Figure 12. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board seventh, eighth and ninth placed athletes.
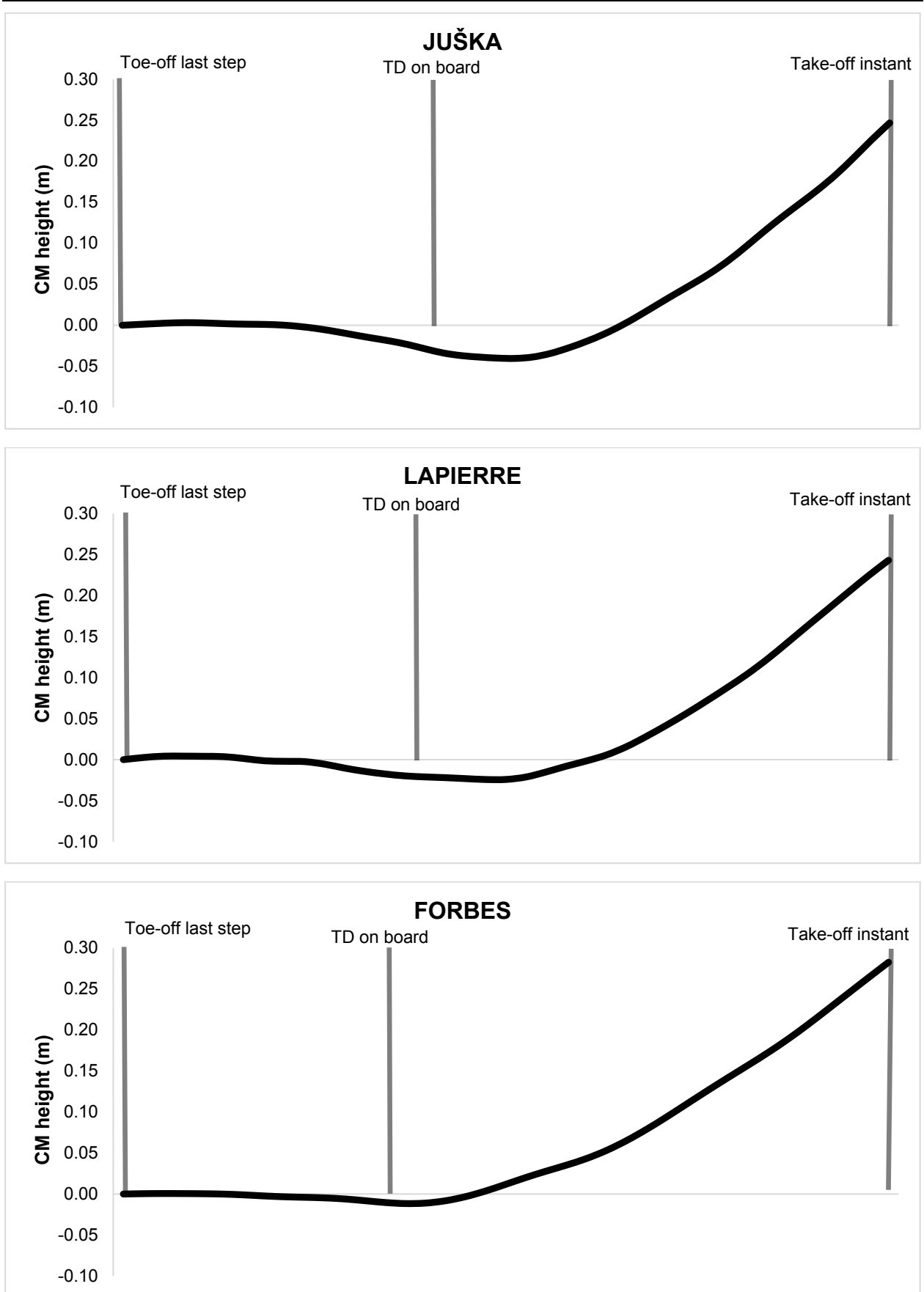
Figure 13. Change in the height of the CM from touchdown (TD) of the last step until the instant of take-off from the board tenth, eleventh and twelfth placed athletes.

CM trajectories (aerial perspective)

Figures 14-17 show the changes in the horizontal (mediolateral and anteroposterior) CM position (blue line) during the last step to the take-off board. Please note that the black filled in rectangle indicates the position of the take-off board and the dashed black lines refer to the events of touchdown of the last step (TD last step), toe-off of the last step (TO last step), touchdown on the board (TD on board) and take-off from the board (Take-off).
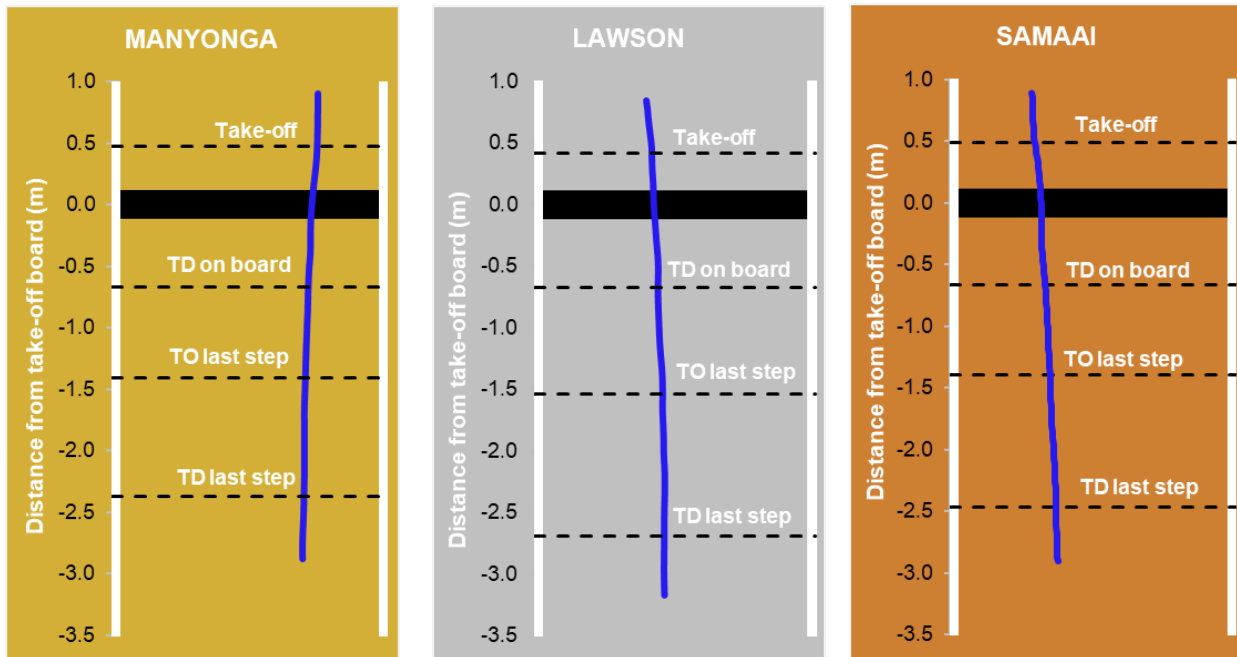
Figure 14. Horizontal CM trajectory (mediolateral and anteroposterior directions) for the gold (Manyonga), silver (Lawson) and bronze (Samaai) medallists during the last step before take-off.
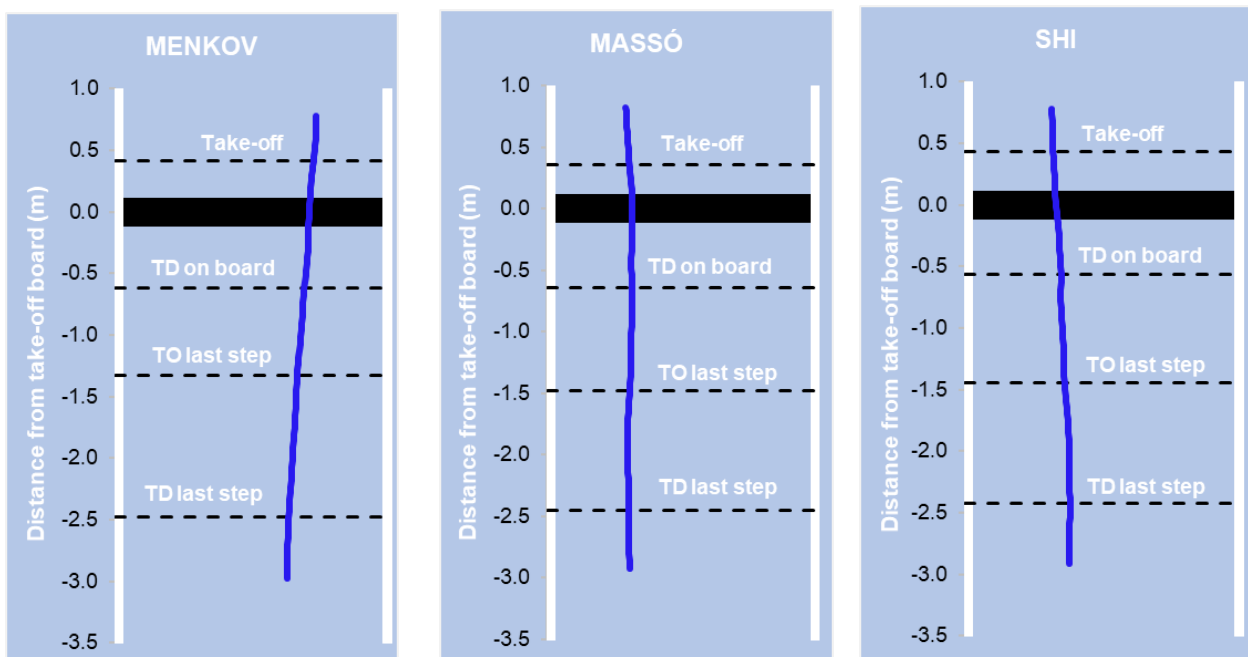
Figure 15. Horizontal CM trajectory (mediolateral and anteroposterior directions) for the fourth (Menkov), fifth (Massó) and sixth (Shi) placed athletes during the last step before take-off.
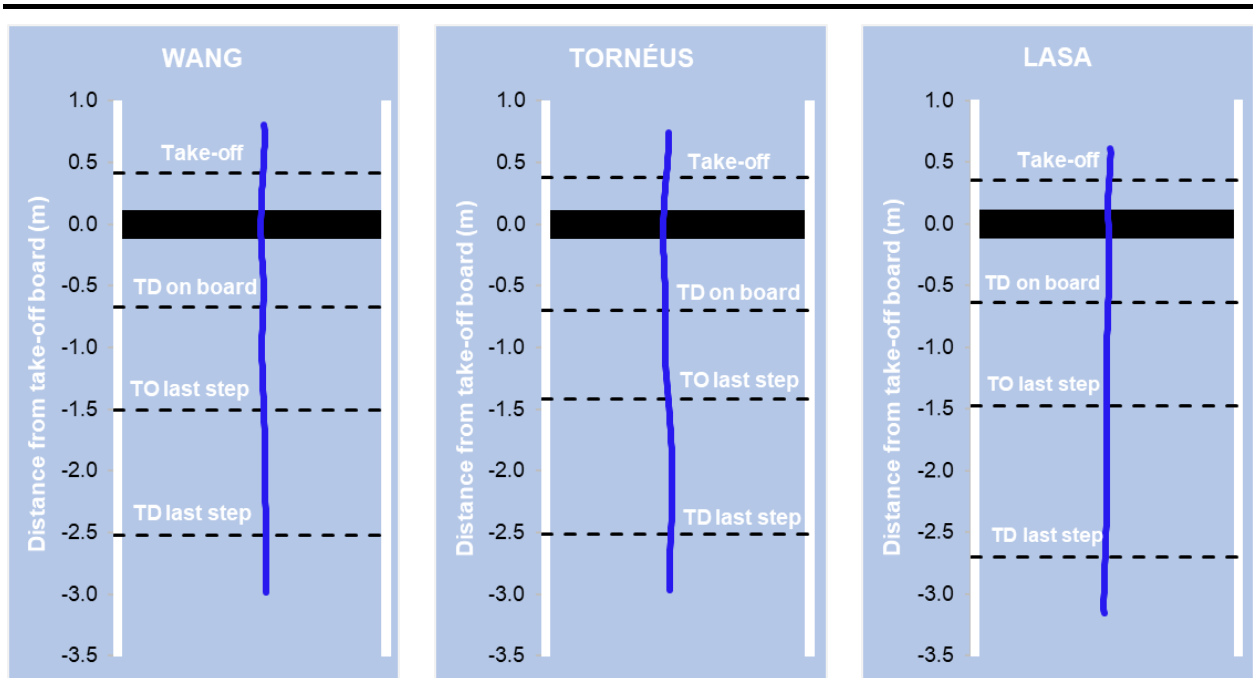
Figure 16. Horizontal CM trajectory (mediolateral and anteroposterior directions) for the seventh (Wang), eighth (Tornéus) and ninth (Lasa) placed athletes during the last step before take-off.
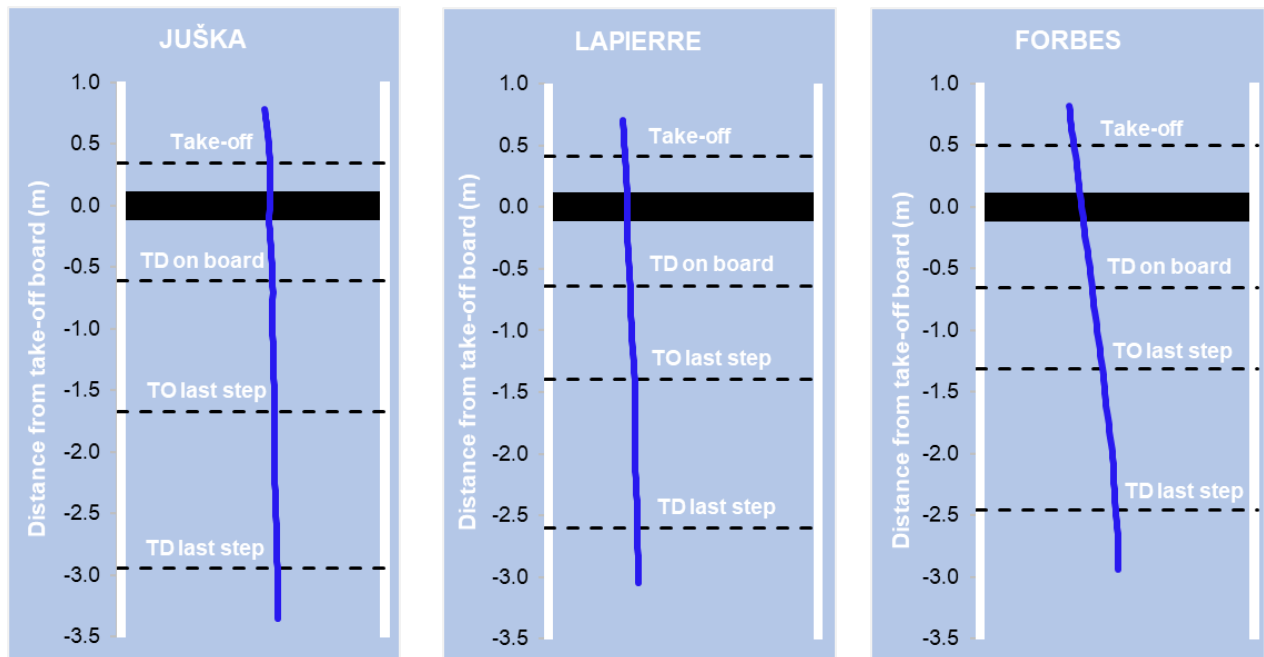
Figure 17. Horizontal CM trajectory (mediolateral and anteroposterior directions) for the tenth (Juška), eleventh (Lapierre) and twelfth (Forbes) placed athletes during the last step before take-off.

COACH'S COMMENTARY

The aim of the long jump is simply to run as fast possible and to jump as high as possible from the take-off board. It demands strong legs for jumping from the board as well as being able to coordinate the movements of take-off, flight and landing. This report focussed on the crucial elements of the run-up (approach phase) and take-off. The velocities reached on the runway are similar to those of a sprinter (velocities in the men's final ranged from 9.91 – 10.82 m/s in the third-last and second-last steps) but, unlike the sprinter, the long jumper has to control their speed in approaching the take-off board and place their foot as accurately as possible on the take-off board.

The development of high velocities, coupled with the short contact time of take-off (0.120 – 0.130 s) in the run up, means that the athletes' take-off angles will never reach the theoretical optimum angle for the longest possible range. Therefore, the take-off angles are much less that that (men's final range: 20.2° – 26.3°).

The transition to from the approach phase (run-up) to take-off is probably one of the most important elements of long jumping technique. To jump the longest distance, the athlete must have a large horizontal velocity at the end of the run-up and the foot placed as accurately as possible on the take-off board. Most of the finalists, apart from Lapierre, used the typical strategy of a longer penultimate step and a shorter last step to prepare for take-off. Most athletes increased their step length between the third-last and second-last steps (mean increase 6%) whereas for the last step, there was a mean reduction in step length of 9%. Manyonga, the gold medallist, had the largest reduction in step length at 19% for the last step. This approach of a longer penultimate and shorter last step can lower the height of the centre of mass (CM) in the penultimate step and therefore allow the athlete to have a higher take-off height in the last step. Manyonga had one of the largest changes in step length and also had one of the largest CM lowering values (Table 9). This could be a deliberate strategy on the part of Manyonga to increase his CM height at take-off and thereby increase his vertical velocity without losing too much horizontal velocity at take-off.

The purpose of the contact phase on the take-off board is to gain lift (vertical velocity) while retaining as much horizontal velocity as possible. It was interesting that second-placed Lawson had the largest value of 9.56 m/s for horizontal velocity at take-off yet the lowest vertical velocity (3.51 m/s) at this point. He also had the second lowest loss in horizontal velocity (1.10 m/s).

Menkov only had one measured jump in the entire final and finished in an agonising fourth position. On the take-off board, he lost 8 centimetres which if he had reduced to 2 centimetres would have resulted in him getting the bronze medal. He lost the most velocity of any competitor on the board (2.8 m/s). His knee angular velocity (how quickly the knee angle reduced) was the

second lowest of the finalists. This relatively slow movement in his standing leg may indicate a lack of eccentric strength necessary to prevent a loss in horizontal velocity while trying to increase vertical velocity. This phase on the take-off board may require development to ensure better, more accurate foot placement along with more explosive movement from it. He may well be regularly in contention for medals if this becomes consistently better.

Shi, who finished in sixth place, had one of the largest vertical velocities at take-off and had the largest value for CM lowering. Again, a deliberate strategy to is possible here to increase take-off velocity in the vertical as he had a large knee range of motion (44.4°) from contacting the board to reaching his minimum knee position. However, this was coupled with a loss in horizontal velocity of 2.61 m/s on the take-off board so perhaps he needs to work more on trying to maintain this horizontal velocity on the board.

Overall from this analysis, it is clear that high velocities in the run-up phase helps the athlete prepare for take-off. The transition to take-off is crucial and accurate placement of the take-off foot on the board can mean the difference between winning a medal and not (as in the case of Menkov).

CONTRIBUTORS

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Toni Minichiello is a coach for British Athletics. He has worked with a number of elite and senior athletes, most notably Olympic gold medallist and triple World Champion Jessica Ennis-Hill, whom he coached from the age of 15 years old. In 2012, Toni won the BBC Sports Personality of the Year Coach Award. Toni has also been awarded the accolade of UK Sports Coach of the Year and was inducted into the Fellowship of Elite Coaches in 2014.