IAAF World Championships
LONDON 2017

BIOMECHANICAL REPORT

FOR THE

IAAF World Championships
LONDON 2017

4 x 100 m Relay Women's

Dr Lysander Pollitt and Dr Athanassios Bissas
Carnegie School of Sport

Stéphane Merlino
IAAF Project Leader

LEEDS BECKETT UNIVERSITY

IAAF

Event Director Dr Lysander Pollitt		**Project Director** Dr Athanassios Bissas
Project Coordinator Louise Sutton		
Senior Technical Support		
Liam Gallagher	Aaron Thomas	Liam Thomas
Senior Research Officer Josh Walker	**Report Editor** Dr Catherine Tucker	**Analysis Support** Dr Lysander Pollitt
Logistics Dr Zoe Rutherford	**Calibration** Dr Brian Hanley	**Data Management** Nils Jongerius
Technical Support		
Ashley Grindrod Joshua Rowe	Ruth O'Faolain	Lewis Lawton Joe Sails
Data Analyst Dr Lysander Pollitt		
Project Team		
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Masalela Gaesenngwe Mike Hopkinson		Emily Gregg Parag Parelkar
Rachael Bradley Jamie French Philip McMorris William Shaw Dr Emily Williams	Amy Brightmore Callum Guest Maria van Mierlo James Webber Jessica Wilson Dr Stephen Zwolinsky	Helen Davey Ruan Jones Dr Ian Richards Jack Whiteside Lara Wilson

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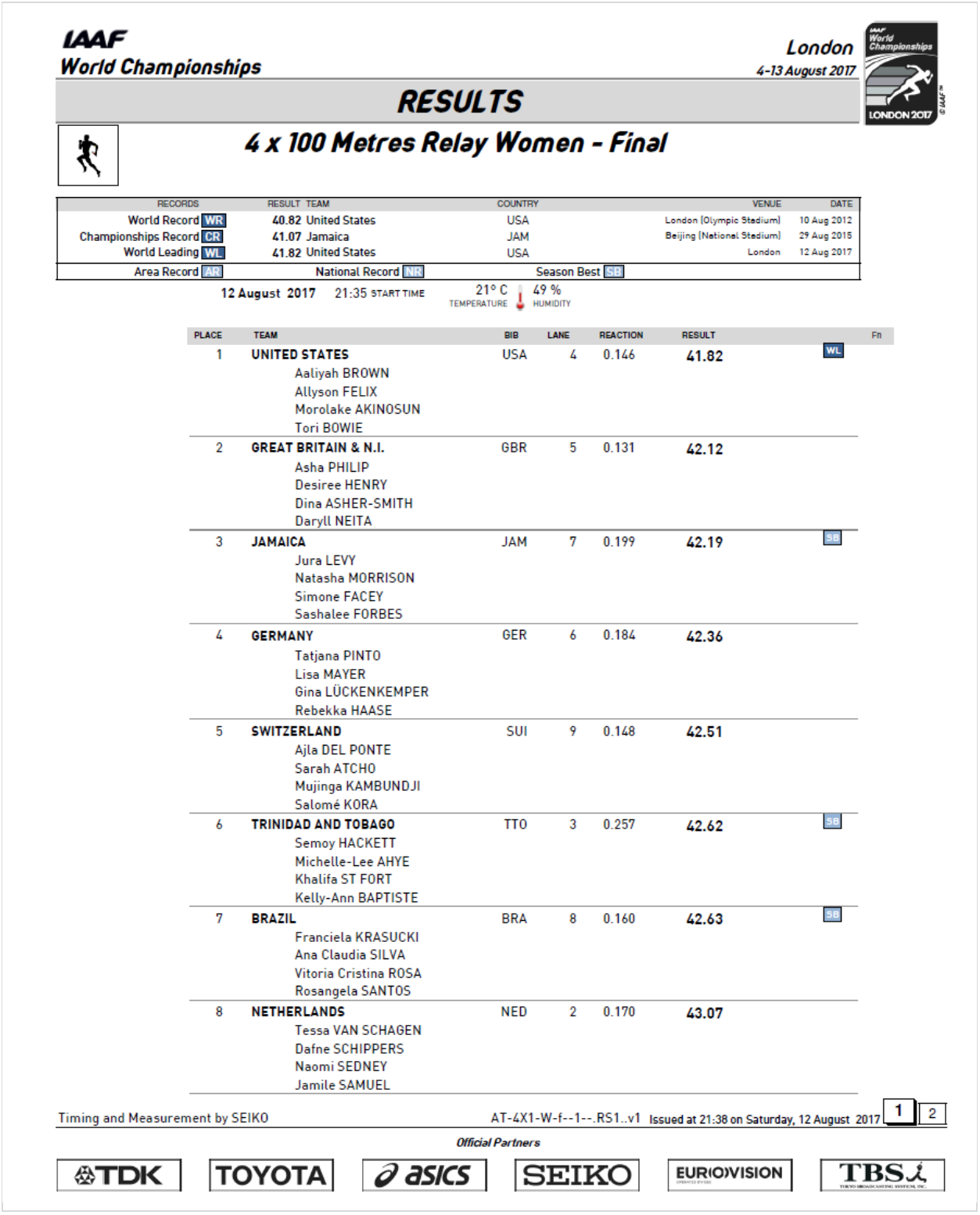
INTRODUCTION

Tori Bowie anchored the USA team home in a world-leading winning time of 41.82 s to secure her second gold medal of the championships. Great Britain and Northern Ireland secured the silver and Jamaica the bronze. Germany could not build upon their winning performance in the heats and finished fourth in a time of 42.36 s.



IAAF World Championships — London 4-13 August 2017

RESULTS

4 x 100 Metres Relay Women - Final

RECORDS	RESULT	TEAM	COUNTRY	VENUE	DATE
World Record WR	40.82	United States	USA	London (Olympic Stadium)	10 Aug 2012
Championships Record CR	41.07	Jamaica	JAM	Beijing (National Stadium)	29 Aug 2015
World Leading WL	41.82	United States	USA	London	12 Aug 2017

Area Record AR | National Record NR | Season Best SB

12 August 2017 21:35 START TIME 21° C TEMPERATURE 49 % HUMIDITY

PLACE	TEAM	BIB	LANE	REACTION	RESULT	Fn
1	**UNITED STATES** Aaliyah BROWN Allyson FELIX Morolake AKINOSUN Tori BOWIE	USA	4	0.146	**41.82**	WL
2	**GREAT BRITAIN & N.I.** Asha PHILIP Desiree HENRY Dina ASHER-SMITH Daryll NEITA	GBR	5	0.131	**42.12**	
3	**JAMAICA** Jura LEVY Natasha MORRISON Simone FACEY Sashalee FORBES	JAM	7	0.199	**42.19**	SB
4	**GERMANY** Tatjana PINTO Lisa MAYER Gina LÜCKENKEMPER Rebekka HAASE	GER	6	0.184	**42.36**	
5	**SWITZERLAND** Ajla DEL PONTE Sarah ATCHO Mujinga KAMBUNDJI Salomé KORA	SUI	9	0.148	**42.51**	
6	**TRINIDAD AND TOBAGO** Semoy HACKETT Michelle-Lee AHYE Khalifa ST FORT Kelly-Ann BAPTISTE	TTO	3	0.257	**42.62**	SB
7	**BRAZIL** Franciela KRASUCKI Ana Claudia SILVA Vitoria Cristina ROSA Rosangela SANTOS	BRA	8	0.160	**42.63**	SB
8	**NETHERLANDS** Tessa VAN SCHAGEN Dafne SCHIPPERS Naomi SEDNEY Jamile SAMUEL	NED	2	0.170	**43.07**	

Timing and Measurement by SEIKO — AT-4X1-W-f--1--.RS1..v1 Issued at 21:38 on Saturday, 12 August 2017 — 1 2

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METHODS

Nine vantage locations for camera placement were identified and secured in strategic locations around the stadium (Figure 1). To enable analysis of each transition, a series of nine interlinked training hurdles were positioned on the entry and exit line of each transition, as well as at the centre point of each transition to identify the 100, 200 and 300 m split positions on the track. Each hurdle was positioned so that the crossbar, covered with black and white tape, was aligned with the track's transverse line.

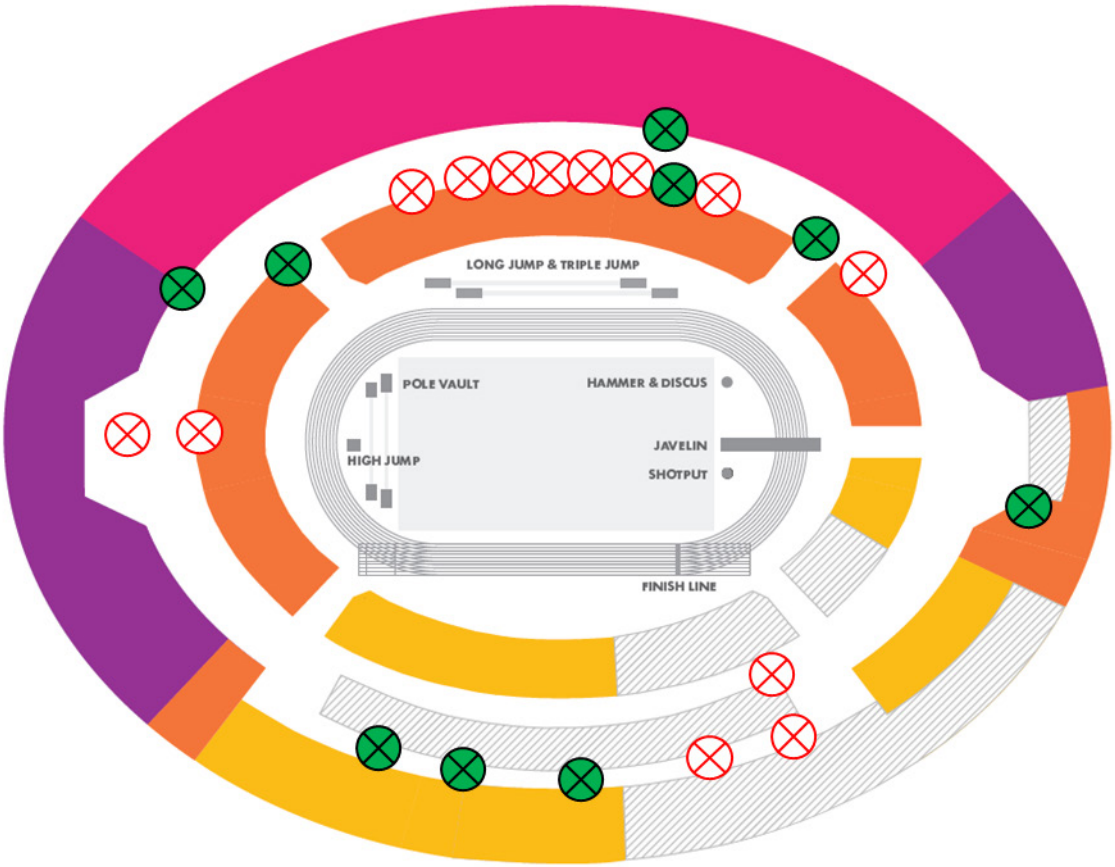

Figure 1. Camera layout (green in-filled circles) within the stadium for the 4x100 m relay women's.

A total of six high-speed cameras were employed to record the action during the 4x100 m relay heats and finals. These were: two Fastec TS3 cameras operating at 200 Hz (shutter speed: 1/1000; ISO: 1600; SXGA: 1280x1024 px) along with three Sony PXW-FS5 camera operating at 200 Hz (shutter speed: 1/1250; ISO: 1600; FHD: 1920x1080 px) and one Sony RX10 M3 camera operating at 100 Hz (shutter speed: 1/1250; ISO: 1600; FHD: 1920x1080 px). To provide additional footage, four Canon EOS 700D cameras operating at 60 Hz (shutter speed: 1/1250; ISO: 1600; SHD: 1280x720 px) were used.

Figure 2. Action from heat 1 of the 4x100 m relay women's.

Split times and transitional characteristics obtained within each transition were processed through SIMI Motion by using the 60, 100 and 200 Hz footage, respectively. The variables devised to describe performance within each transition are described below in Table 1.

Table 1. Variables selected to describe performance within and between each transition.

Variable	Definition
Transitional analysis	Key phases including baton entry, handover and baton exit (Figures 3-6).
Handover phase	Time between first and last contact of the baton between delivery and receiving legs.
Baton delivery phase	Time from baton entry to initial contact and start of the handover phase.
Baton receive phase	Time from last contact and end of the handover phase to baton exit.
Receiver entry	Time of receiver entry before baton entry.
Split times: Individual legs*	Time for each leg with baton (excludes handover phase).
Split times: 100 m splits	Time between 100 m track markings.
Variance	Variability in times across transitions determined by the coefficient of variation (CV%).

** individual legs may cover a distance greater or shorter than 100 m.*

Transitional analysis

Analysis of each transition is described based on the position of the baton at different phases within each transition. These are: Phase 1 – Baton entry (Figure 3); Phase 2 – Initial contact: handover of the baton begins (Figure 4); Phase 3 – Release: handover of the baton ends (Figure 5); and Phase 4 – Baton exit (Figure 6).

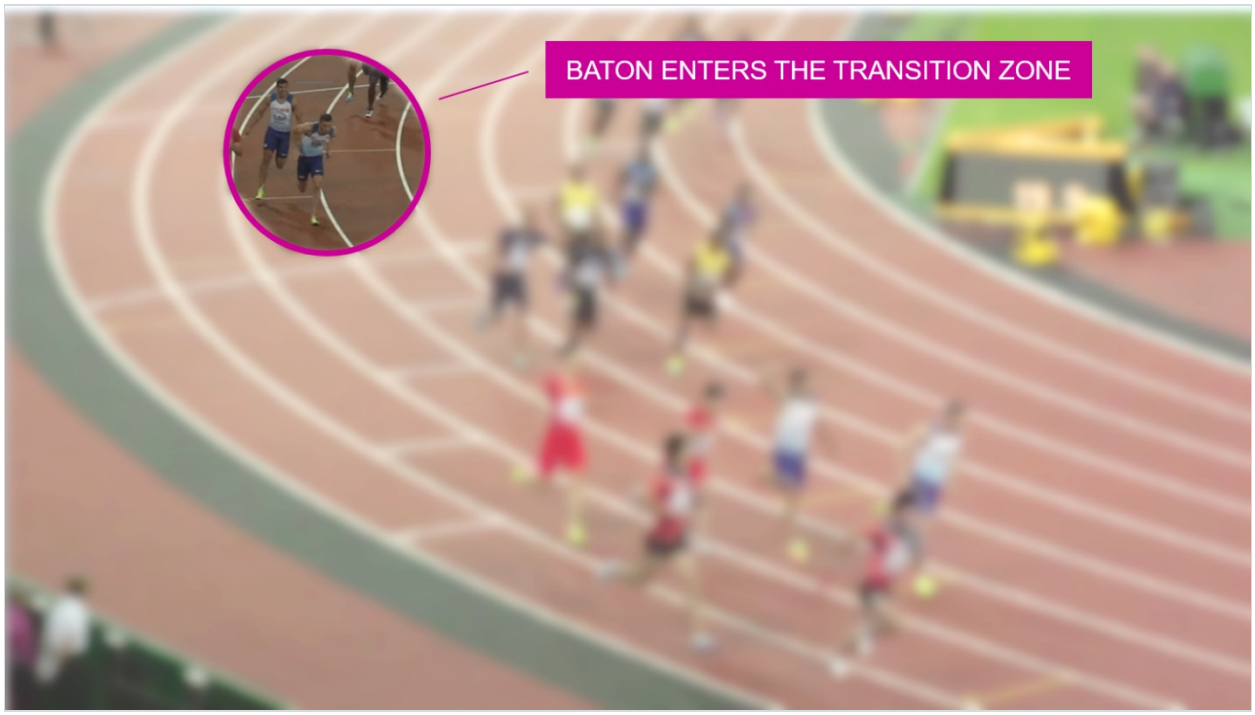

Figure 3. Phase 1: Baton entry - Baton enters the transition. Baton delivery phase begins.

Figure 4. Phase 2: Initial contact - Handover of the baton begins.

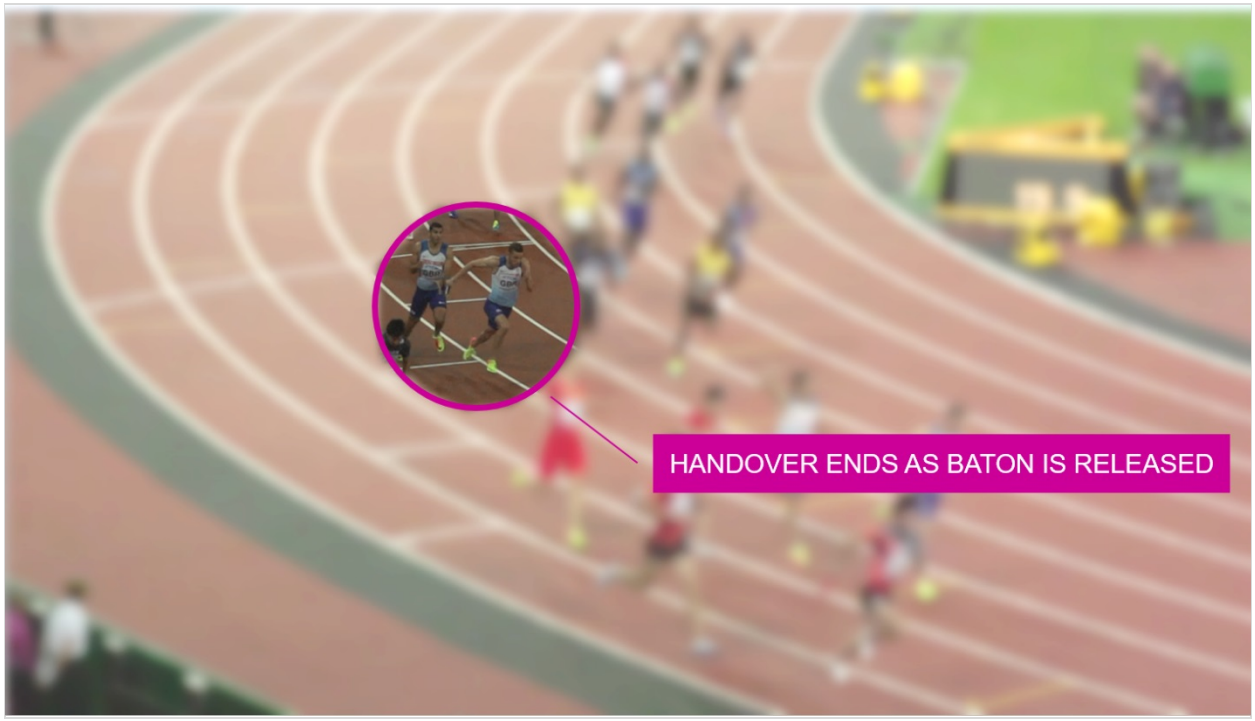

Figure 5. Phase 3: Release - Handover of the baton ends. Baton receive phase begins.

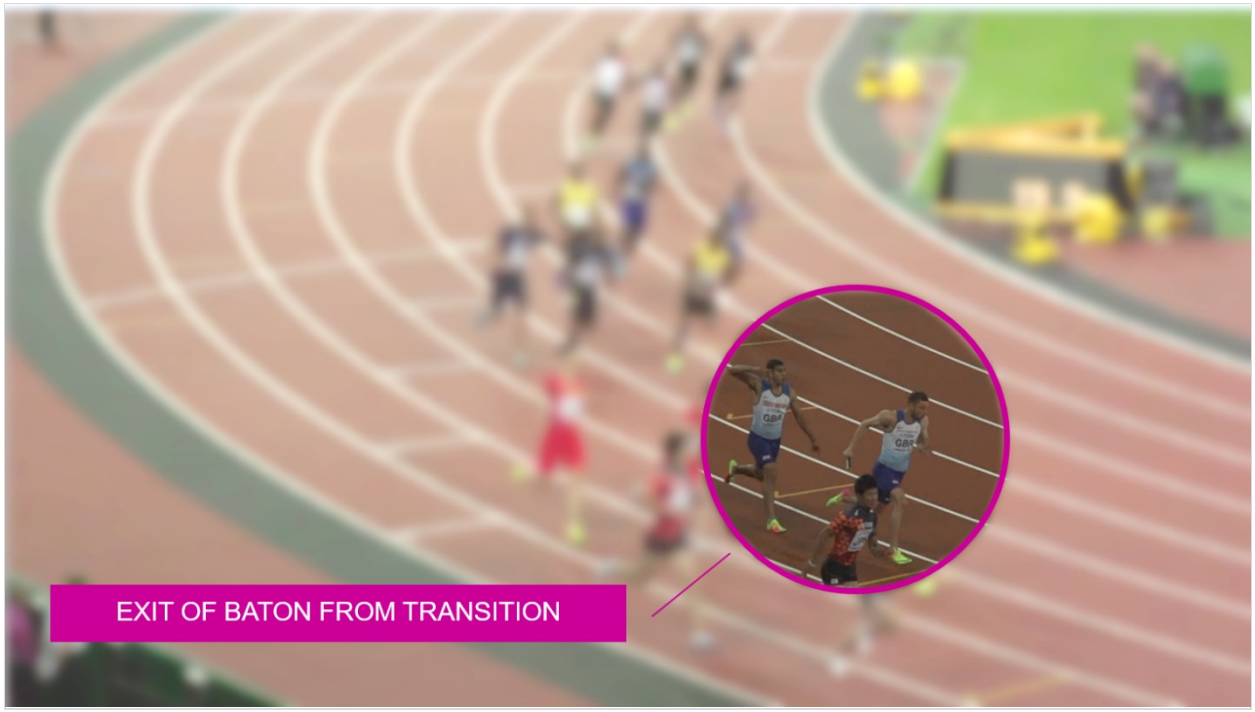

Figure 6. Phase 4: Baton exit - Baton exits the transition.

RESULTS – Final

Performance

The tables below display the season's (SB) and personal best (PB) times of each team competing in the final before the World Championships, and performance during the heats. (Table 2). These values are then compared to their performance in the final itself (Table 3).

Table 2. Individual season's (SB) and personal bests (PB), and performance during the heats.

Team	SB	*rank*	PB	*rank*	HEAT	*rank*	*notes*
UNITED STATES	42.12 s	*1*	40.82 s	*1*	**41.84 s**	*1*	*WL*
GREAT BRITAIN & N.I.	44.17 s	*8*	41.77 s	*4*	**41.93 s**	*2*	*SB*
JAMAICA	42.25 s	*2*	41.07 s	*2*	**42.50 s**	*5*	
GERMANY	42.25 s	*2*	41.37 s	*3*	**42.34 s**	*3*	
SWITZERLAND	42.53 s	*4*	42.53 s	*8*	**42.50 s**	*4*	*NR*
TRINIDAD & TOBAGO	42.94 s	*5*	42.03 s	*5*	**42.91 s**	*8*	*SB*
BRAZIL	42.97 s	*6*	42.29 s	*7*	**42.77 s**	*7*	*SB*
NETHERLANDS	43.02 s	*7*	42.04 s	*6*	**42.64 s**	*6*	*SB*

Key: *SB = season's best, PB = personal best, WL = world lead, NR = national record.*

Table 3. Comparison of each team's performance during the final compared to PB, SB and heats.

Athlete	FINAL	*notes*	vs. HEAT	vs. SB	vs. PB
UNITED STATES	**41.82 s**	*WL*	**–0.02 s**	**–0.30 s**	1.00 s
GREAT BRITAIN & N.I.	**42.12 s**		0.19 s	**–2.05 s**	0.35 s
JAMAICA	**42.19 s**	*SB*	**–0.31 s**	**–0.06 s**	1.12 s
GERMANY	**42.36 s**		0.02 s	0.11 s	0.99 s
SWITZERLAND	**42.51 s**		0.01 s	**–0.02 s**	**–0.02 s**
TRINIDAD & TOBAGO	**42.62 s**	*SB*	**–0.29 s**	**–0.32 s**	0.59 s
BRAZIL	**42.63 s**	*SB*	**–0.14 s**	**–0.34 s**	0.34 s
NETHERLANDS	**43.07 s**		0.43 s	0.05 s	1.03 s

Key: *NR = national record, WL = world lead, ER = European record, DNF did not finish.*

Positional analysis

Figure 7 shows the relative position of each team at each 100 m split throughout the race.

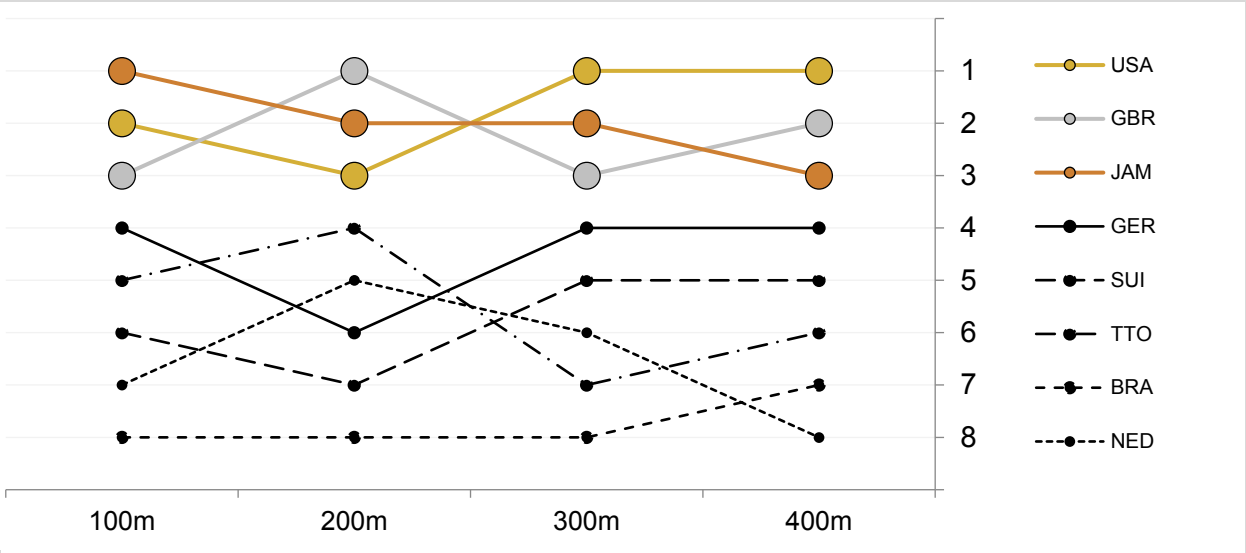

Figure 7. Positions of each team at each 100 m split.

Transition analysis

Throughout the following sections, the data presented illustrate key performance characteristics of all teams transferring the baton within each transition. To begin, Figures 8, 9 and 10 provide an overview of the whole transition relative to the leading team. Each highlight the duration of the baton with the delivery and receive legs, the handover, and the total transition time.

Following this, details of the relative duration (% transition time) of the delivery and receive legs are displayed for each team. The relative duration (% transition time) of the receive leg entering each transition before the baton is also presented. In addition, a breakdown of the time lost or gained on the winning team between transitions (Table 14) and within transitions (Table 15 and Figure 22) is presented.

Finally, split times for individual legs (minus handover durations), as well as for consecutive 100 m and 200 m are displayed for each team. Furthermore, for some sections, a comparison to the performance during the respective heats of each team involved in the final is included, along with the variance (calculated as the coefficient of variation [CV%]) across transitions.

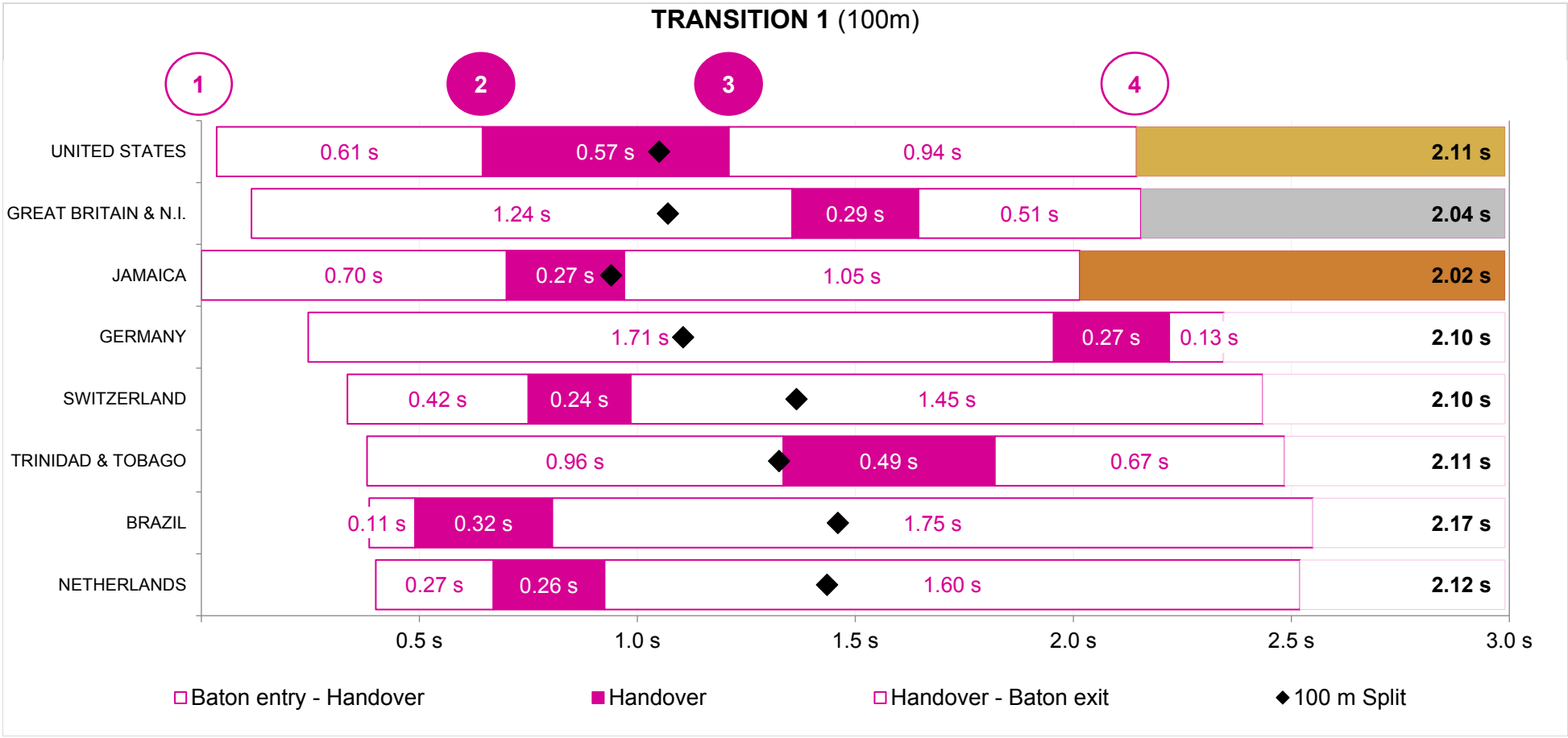

Figure 8. Analysis of timings and positions of each team within Transition 1. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. In addition, the raw values (3 decimal places) have been used for further calculations (e.g., coefficient of variation).*

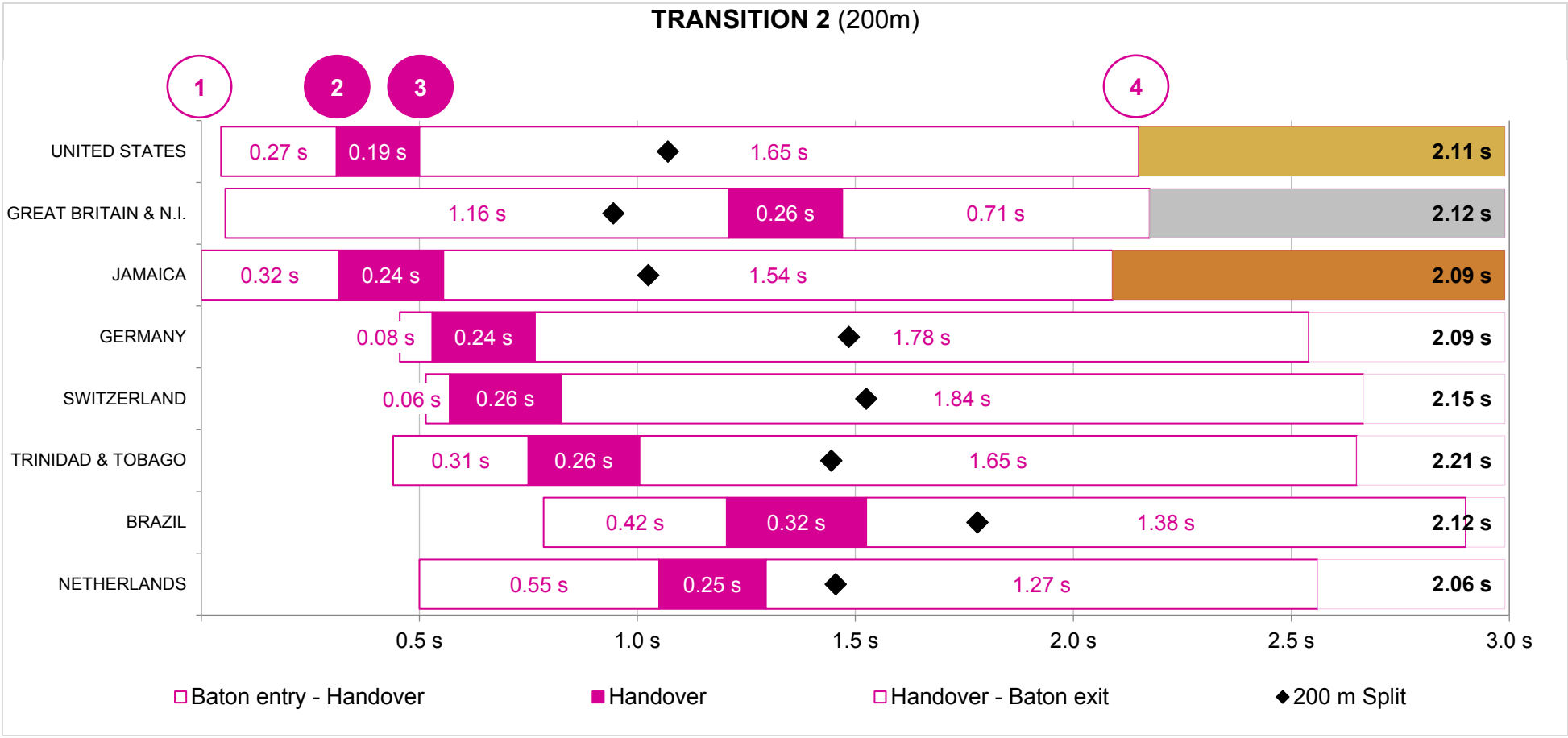

Figure 9. Analysis of timings and positions of each team within Transition 2. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. In addition, the raw values (3 decimal places) have been used for further calculations (e.g., coefficient of variation).*

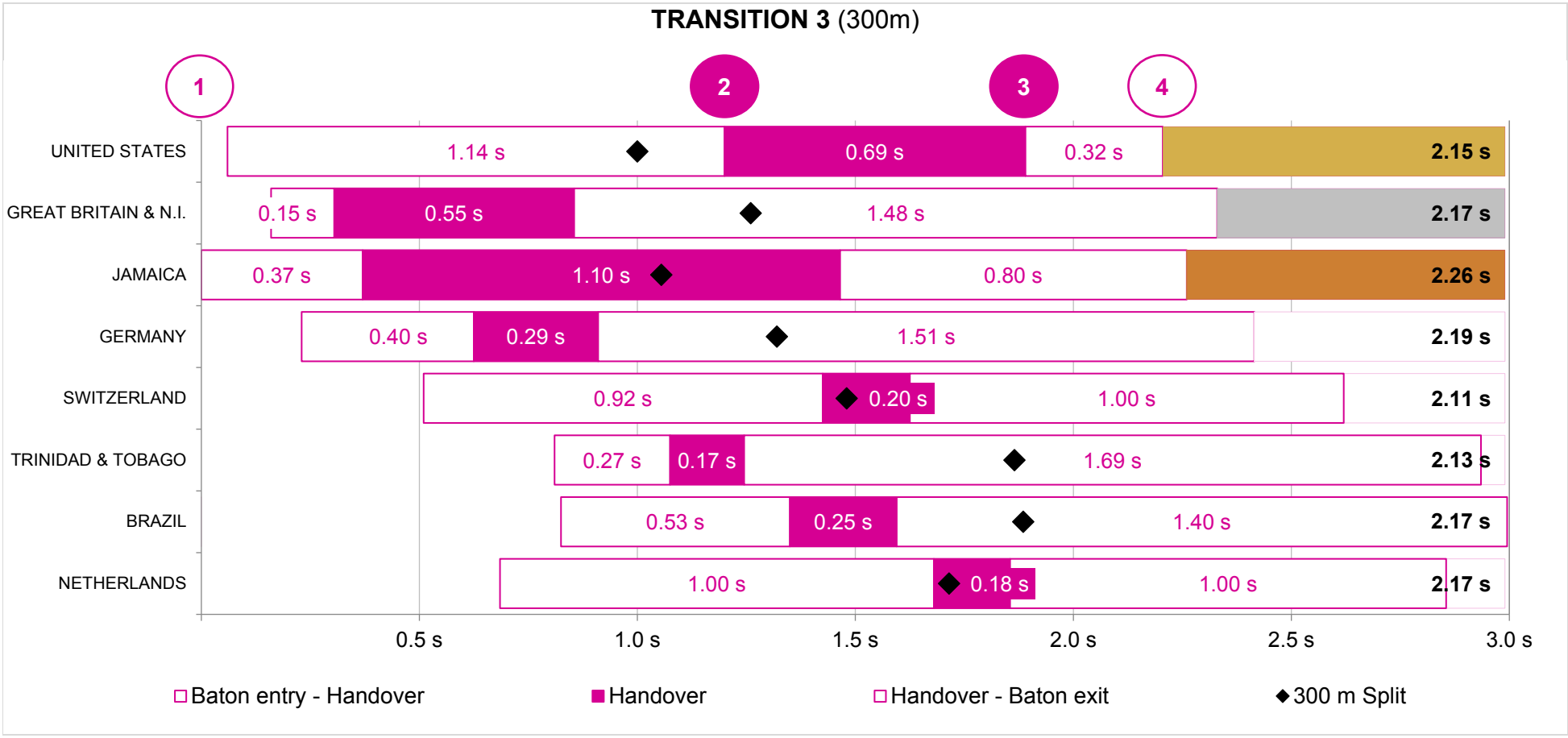

Figure 10. Analysis of timings and positions of each team within Transition 3. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. In addition, the raw values (3 decimal places) have been used for further calculations (e.g., coefficient of variation).*

Transition duration

Table 4 displays the duration of each individual transition as well as the total cumulative time spent within all three transitions, and relative to the result. Following this, Figure 11 shows the variance across all three transitions. In addition, this information during the respective heats of each team involved in the final is presented in Table 5, and the variance in Figure 12.

Table 4. Time spent within each transition during the final.

Team	**T1** (s)	**T2** (s)	**T3** (s)	**TOTAL**	*% result*
UNITED STATES	2.110	2.105	2.145	**6.360 s**	*15.2*
GREAT BRITAIN & N.I.	2.040	2.120	2.170	**6.330 s**	*15.0*
JAMAICA	2.015	2.090	2.260	**6.365 s**	*15.1*
GERMANY	2.100	2.085	2.185	**6.370 s**	*15.0*
SWITZERLAND	2.100	2.150	2.110	**6.360 s**	*15.0*
TRINIDAD & TOBAGO	2.105	2.210	2.125	**6.440 s**	*15.1*
BRAZIL	2.165	2.115	2.170	**6.450 s**	*15.1*
NETHERLANDS	2.120	2.060	2.170	**6.350 s**	*14.7*

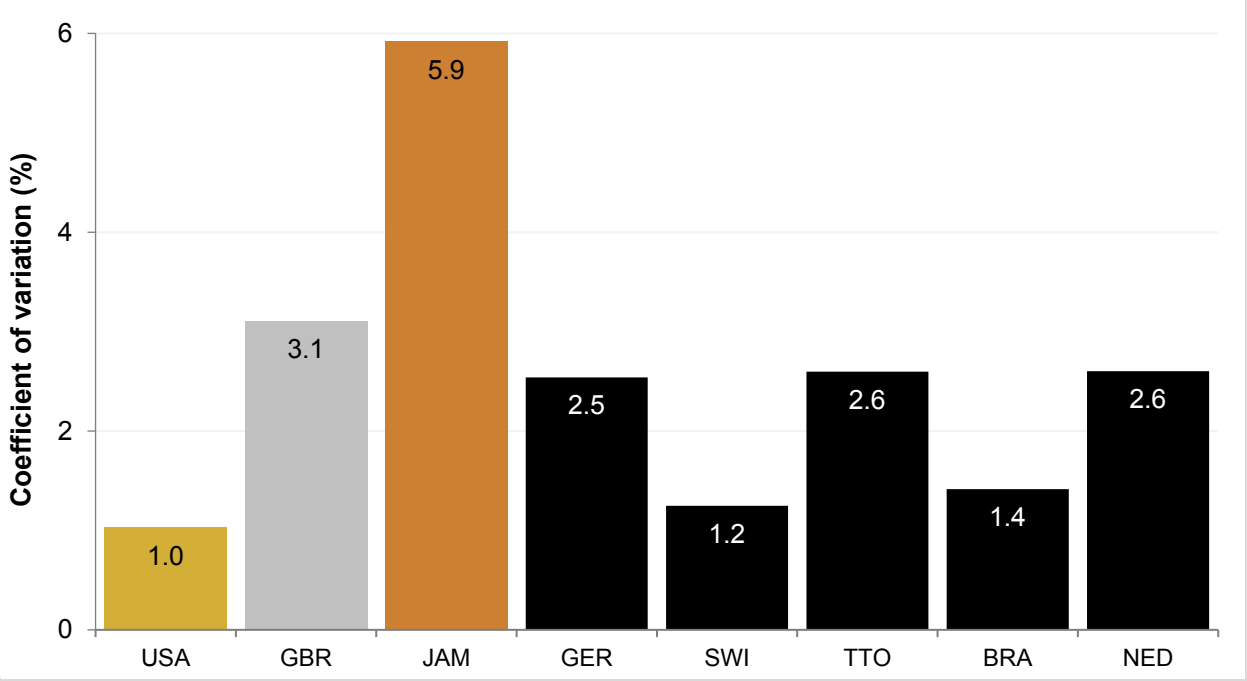

Figure 11. Variance (CV%) across total duration of each transition during the final.

Table 5 displays the duration of each individual transition as well as the total cumulative time spent within all three transitions, and relative to the result. The variance is presented in Figure 12. Data are displayed according to the finishing position within the final.

Table 5. Time spent within each transition during the respective heat of the finalists.

Team	**T1** (s)	**T2** (s)	**T3** (s)	**TOTAL**	*% result*
UNITED STATES	2.060	2.030	2.200	**6.290 s**	*15.0*
GREAT BRITAIN & N.I.	2.010	2.100	2.170	**6.280 s**	*15.0*
JAMAICA	2.080	2.280	2.265	**6.625 s**	*15.6*
GERMANY	2.120	2.225	2.220	**6.565 s**	*15.5*
SWITZERLAND	2.000	2.125	2.165	**6.290 s**	*14.8*
TRINIDAD & TOBAGO	2.155	2.285	2.255	**6.695 s**	*15.6*
BRAZIL	2.190	2.210	2.185	**6.585 s**	*15.4*
NETHERLANDS	2.050	2.200	2.160	**6.410 s**	*15.0*

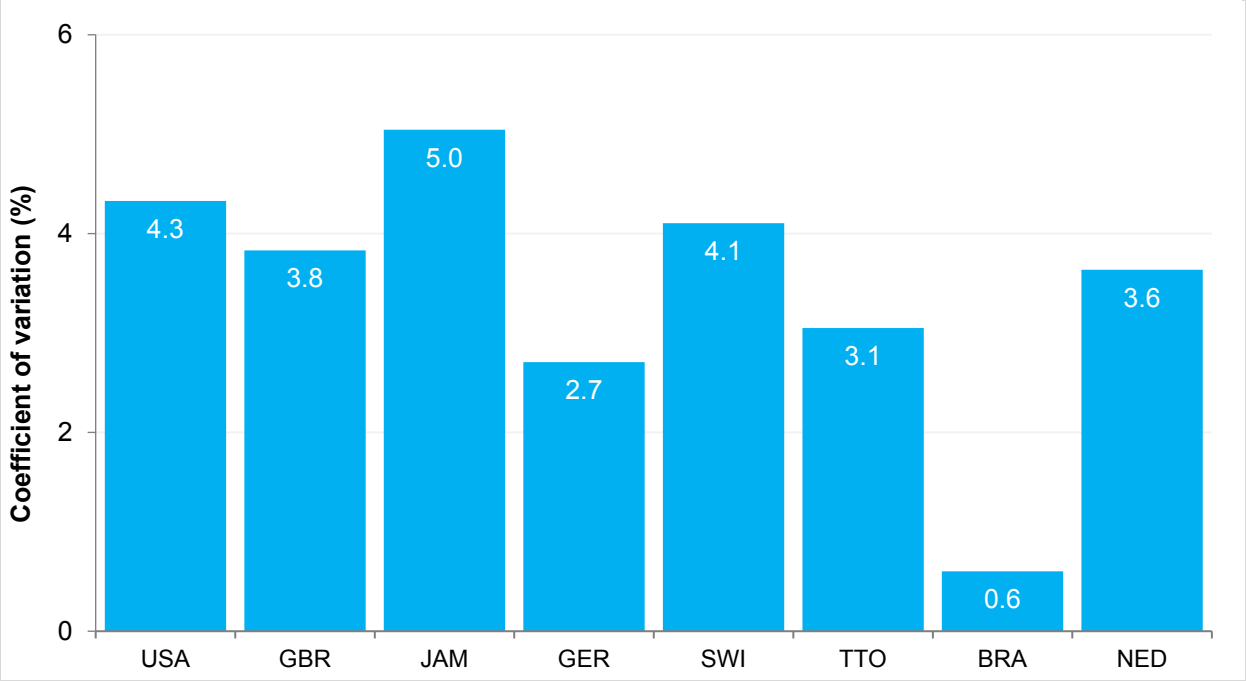

Figure 12. Variance (CV%) across total duration of each transition during the respective heats for all teams involved in the final.

Handover duration

Table 6 displays the total time of each handover within transitions, as well as the combined time across all three transitions as a total absolute time, and relative to the result. Following this, Figure 13 shows the variance across all three transitions. The relative time (% transition time) of each handover is shown in Figure 14. In addition, this information during the respective heats of each team involved in the final is presented in Table 7 and the variance across transitions in Figure 15.

Table 6. Handover duration within each transition during the final.

Team	**T1** (s)	**T2** (s)	**T3** (s)	**TOTAL**	*% result*
UNITED STATES	0.565	0.190	0.690	**1.445 s**	*3.5*
GREAT BRITAIN & N.I.	0.290	0.260	0.550	**1.100 s**	*2.6*
JAMAICA	0.270	0.240	1.095	**1.605 s**	*3.8*
GERMANY	0.265	0.235	0.285	**0.785 s**	*1.9*
SWITZERLAND	0.235	0.255	0.200	**0.690 s**	*1.6*
TRINIDAD & TOBAGO	0.485	0.255	0.170	**0.910 s**	*2.1*
BRAZIL	0.315	0.320	0.245	**0.880 s**	*2.1*
NETHERLANDS	0.255	0.245	0.175	**0.675 s**	*1.6*

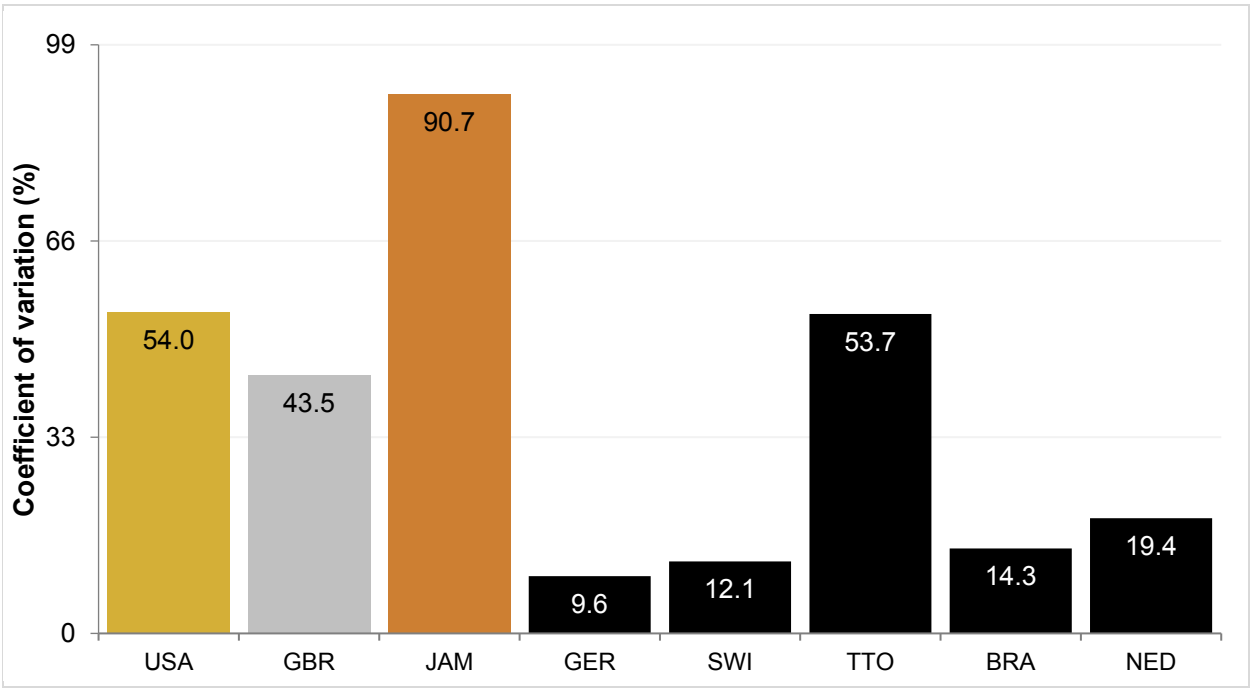

Figure 13. Variance (CV%) in handover duration across transitions during the final.

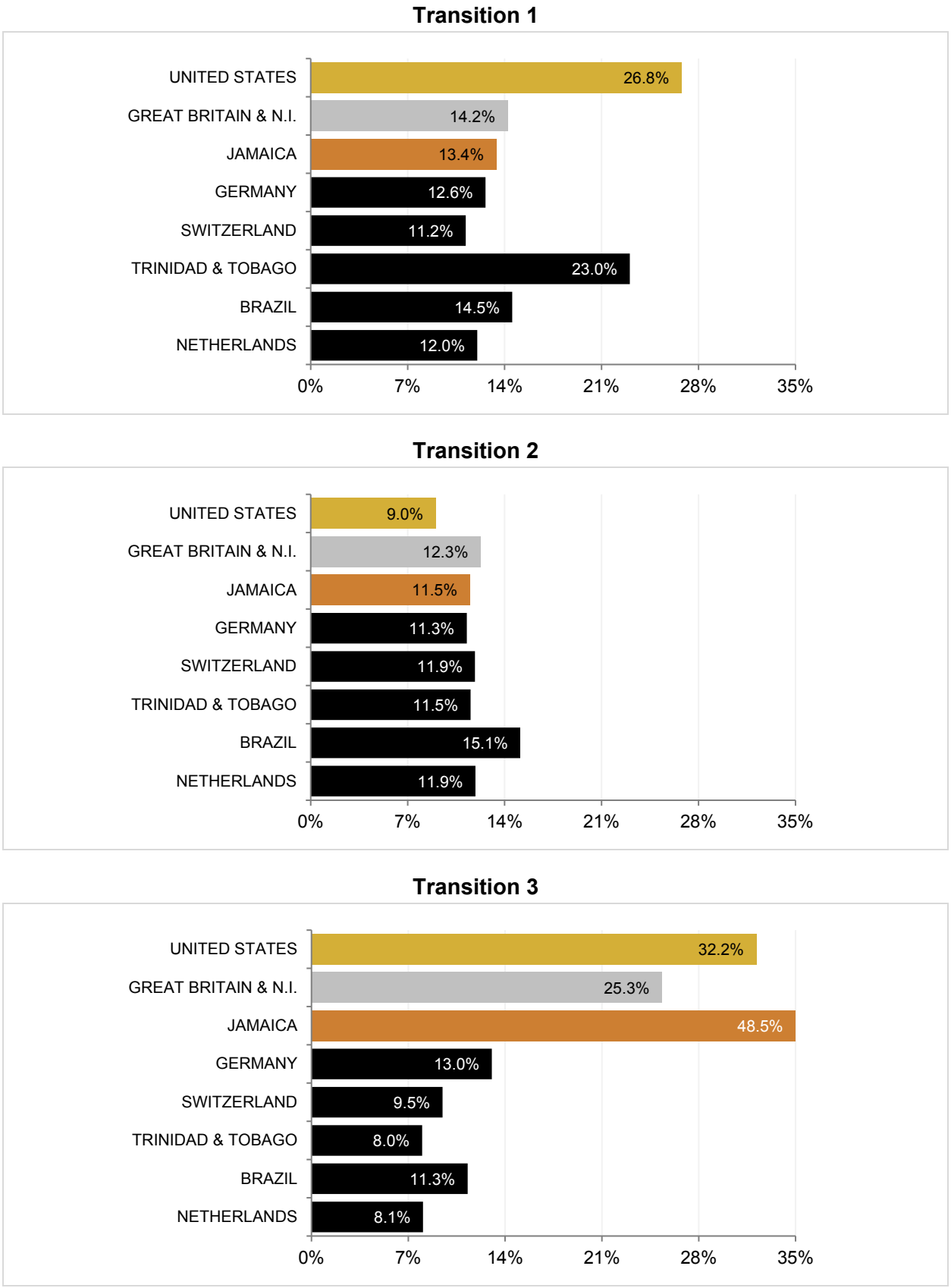

Figure 14. Duration of the handover phase as a percentage of the total transition time.

Table 7 shows the total time of each handover during the respective heat of each team involved in the final. Data are displayed according to the finishing position within the final.

Table 7. Handover duration within each transition during the respective heat of the finalists.

Team	**T1** (s)	**T2** (s)	**T3** (s)	**TOTAL**	*% result*
UNITED STATES	0.450	0.350	0.310	**1.110 s**	*2.7*
GREAT BRITAIN & N.I.	0.290	0.285	0.385	**0.960 s**	*2.3*
JAMAICA	0.280	0.380	0.775	**1.435 s**	*3.4*
GERMANY	0.365	0.490	0.370	**1.225 s**	*2.9*
SWITZERLAND	0.150	1.180	0.220	**1.550 s**	*3.6*
TRINIDAD & TOBAGO	0.210	0.660	0.290	**1.160 s**	*2.7*
BRAZIL	0.265	0.740	0.330	**1.335 s**	*3.1*
NETHERLANDS	0.230	0.505	0.175	**0.910 s**	*2.1*

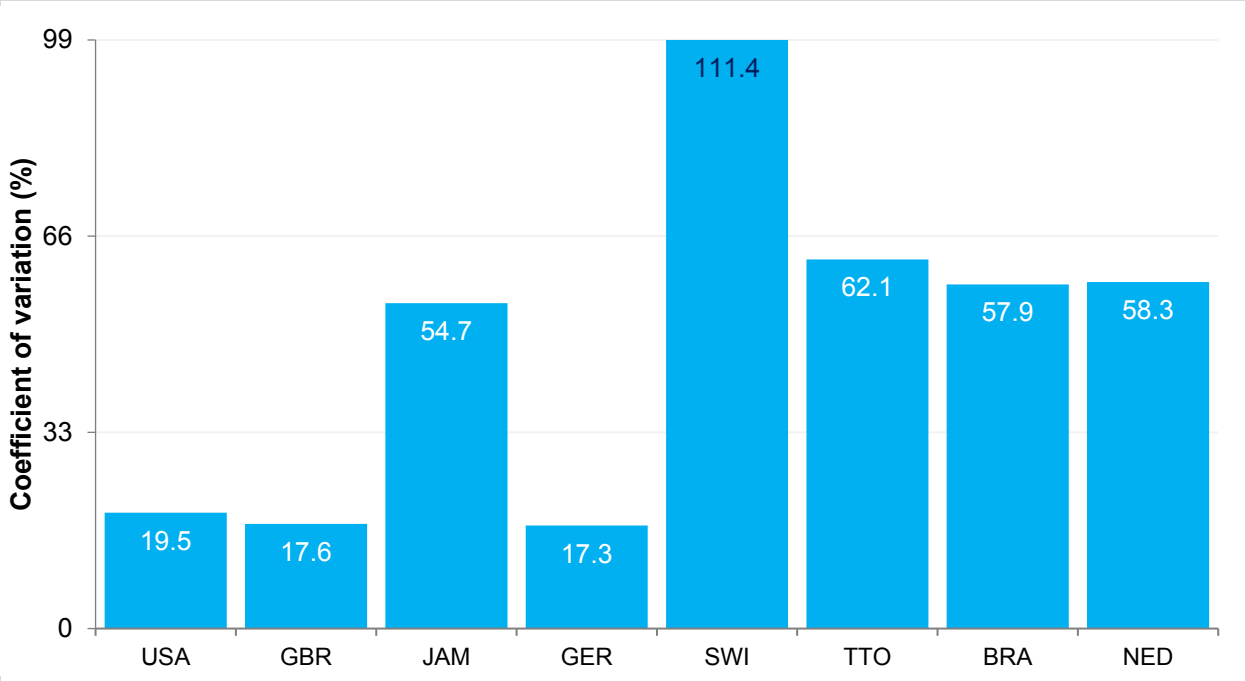

Figure 15. Variance (CV%) in handover duration across transitions during the respective heats for all teams involved in the final.

Baton delivery and receive phases within transitions

The following data display the relative time (% transition time) of the baton with the delivery and receive legs only within transitions for medallists (Figure 16) and non-medallists (Figure 17).

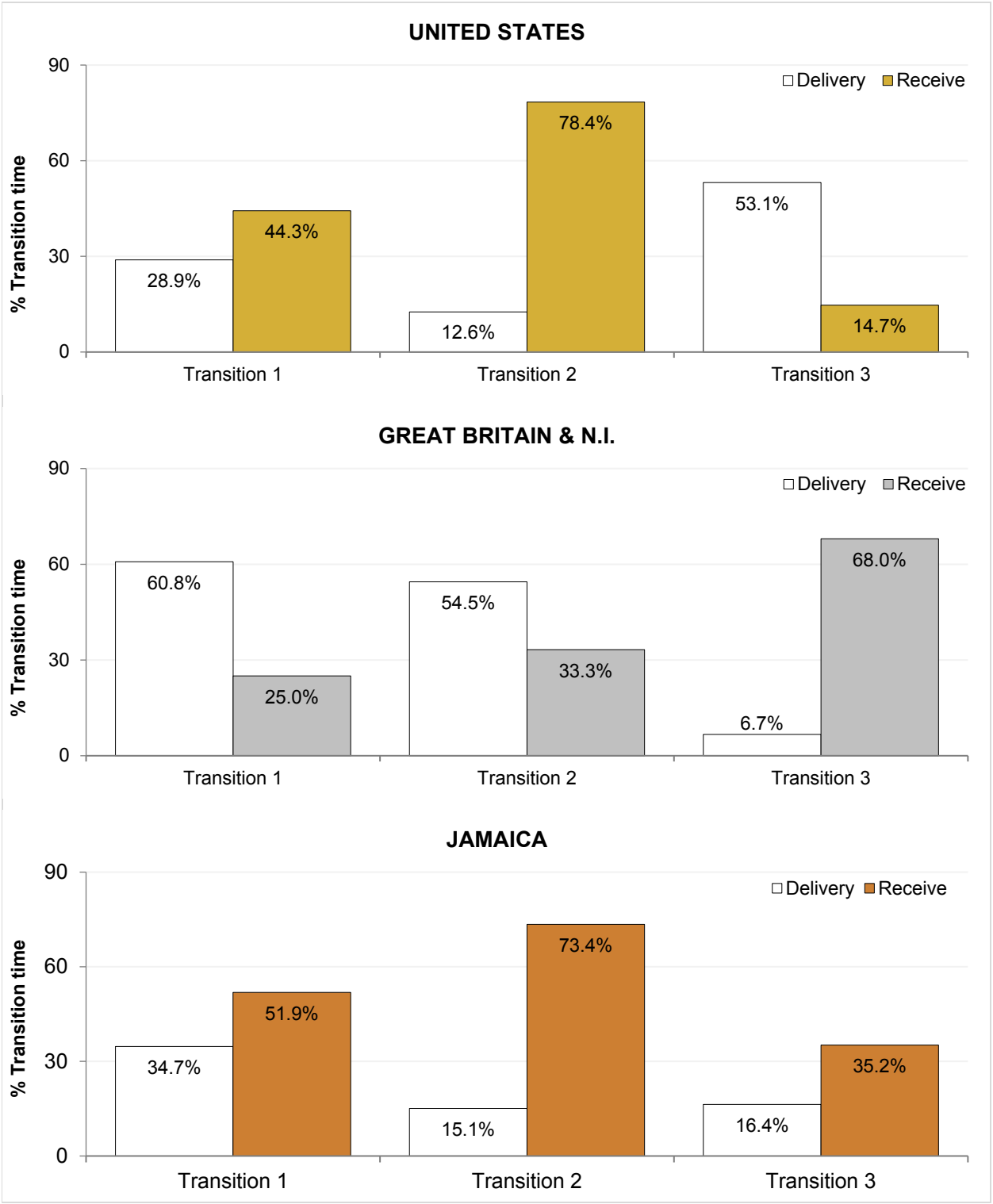

Figure 16. Relative time of baton with delivery and receive legs within transitions (medallists).

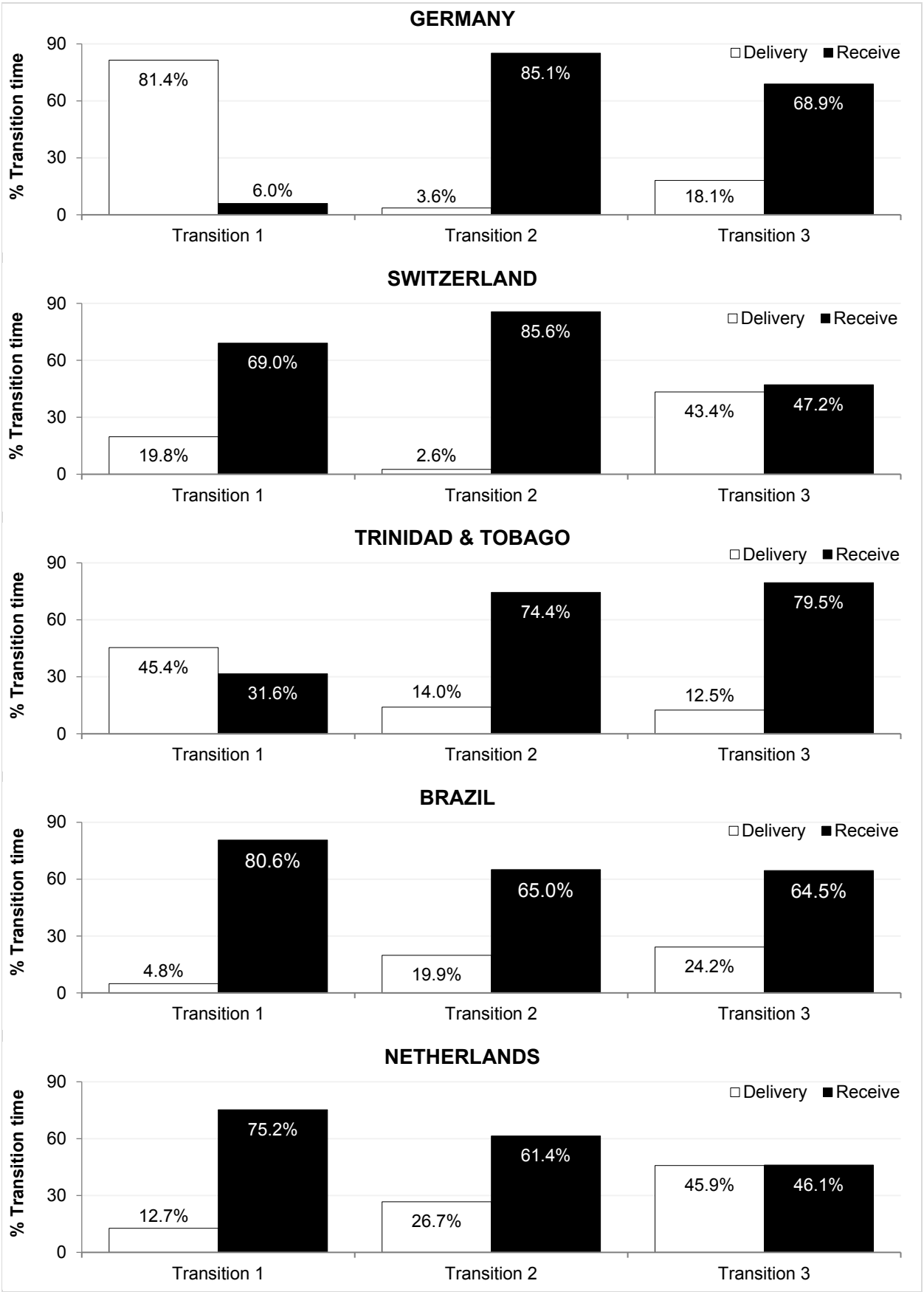

Figure 17. Relative time of baton with delivery and receive legs within transitions (non-medallists).
Note: *Percentages are displayed to 1 decimal place.*

Table 8 displays the total and relative time (relative to the total cumulative transition time (%TT)) of the baton with the delivery and receive phases (excluding the handover duration), as well as the ratio between both phases. The variance of both phases across all three transitions is displayed in Figure 18. In addition, these data from the respective heats of each team involved in the final are presented in Table 9 and the variance across transitions in Figure 19.

Table 8. Total time of baton spent with the delivery and receiving legs within transitions during the final.

	Delivery	*%TT*	Receive	*%TT*	*ratio*
UNITED STATES	2.015 s	*31.6%*	2.900 s	*45.5%*	*1.44*
GREAT BRITAIN & N.I.	2.540 s	*40.1%*	2.690 s	*42.5%*	*1.06*
JAMAICA	1.385 s	*21.7%*	3.375 s	*53.0%*	*2.44*
GERMANY	2.180 s	*34.2%*	3.405 s	*53.4%*	*1.56*
SWITZERLAND	1.385 s	*21.8%*	4.285 s	*67.4%*	*3.09*
TRINIDAD & TOBAGO	1.530 s	*23.7%*	4.000 s	*62.0%*	*2.61*
BRAZIL	1.050 s	*16.3%*	4.520 s	*70.0%*	*4.30*
NETHERLANDS	1.815 s	*28.6%*	3.860 s	*60.8%*	*2.13*

***Note**: Delivery = Leg responsible for baton entry into the transition; Receive = Leg responsible for baton exit after the handover; %TT = percentage of the total cumulative time spent within all three transitions.*

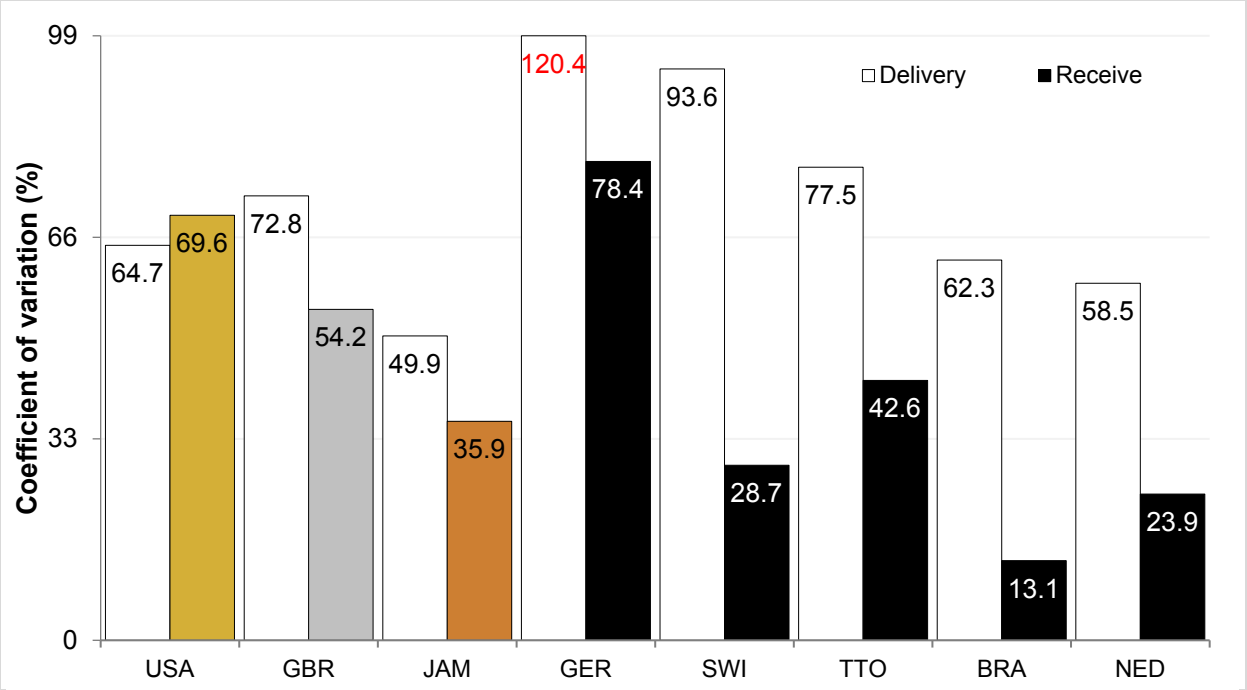

Figure 18. Variance (CV%) across transitions for delivery and receive leg times during the final.

Table 9 displays the total and relative time, relative to the total cumulative transition time (%TT), of the baton with the delivery and receive phases (excluding the handover duration), as well as the ratio between both phases during the respective heat of each team involved in the final. Data are displayed according to the finishing position within the final.

Table 9. Total time of the baton with the delivery and receiving legs within transitions during the heats.

	Delivery	*%TT*	Receive	*%TT*	*ratio*
UNITED STATES	1.615 s	*25.7%*	3.565 s	*56.7%*	*2.21*
GREAT BRITAIN & N.I.	1.900 s	*30.3%*	3.420 s	*54.5%*	*1.80*
JAMAICA	0.835 s	*12.6%*	4.355 s	*65.7%*	*5.22*
GERMANY	1.025 s	*16.2%*	4.315 s	*65.2%*	*4.03*
SWITZERLAND	1.955 s	*31.0%*	2.785 s	*44.2%*	*1.42*
TRINIDAD & TOBAGO	1.120 s	*16.0%*	4.415 s	*65.9%*	*3.94*
BRAZIL	1.230 s	*19.6%*	4.020 s	*61.0%*	*3.27*
NETHERLANDS	2.885 s	*45.0%*	2.615 s	*40.8%*	*0.91*

***Note**: Delivery = Leg responsible for baton entry into the transition; Receive = Leg responsible for baton exit after the handover; %TT = percentage of the total cumulative time spent within all three transitions.*

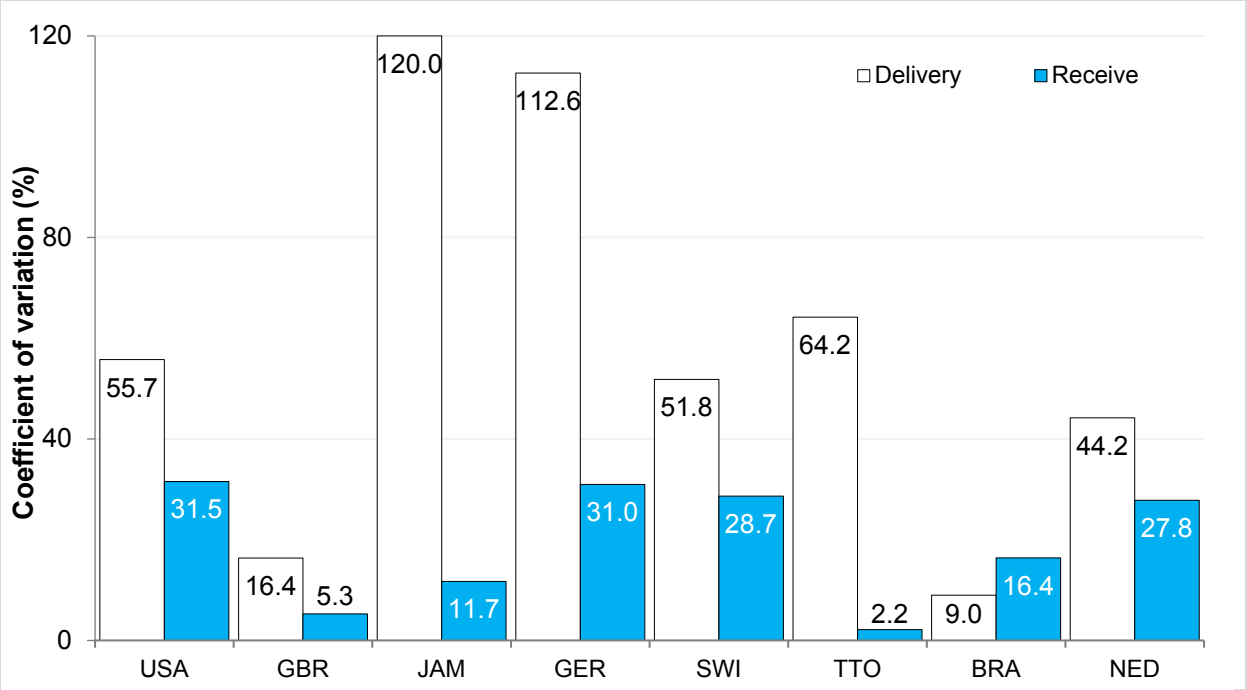

Figure 19. Variance (CV%) across transitions for delivery and receive leg times during the respective heats for all teams involved in the final.

Table 10 displays the relative time point (% transition time) at which each team crossed the 100 m split within each transition, and includes the variance across all three transition phases. In addition, these data for the respective heats of each team involved in final are shown in Table 11.

Table 10. Relative position of the baton crossing each 100 m split and variance during the final.

	T1 (%)	**T2** (%)	**T3** (%)	*variance*
UNITED STATES	48.1	48.7	43.8	*5.7%*
GREAT BRITAIN & N.I.	46.8	42.0	50.7	*9.4%*
JAMAICA	46.6	49.0	46.7	*2.9%*
GERMANY	41.0	49.4	49.9	*10.7%*
SWITZERLAND	49.0	47.0	46.0	*3.3%*
TRINIDAD & TOBAGO	44.9	45.5	49.6	*5.6%*
BRAZIL	49.7	47.0	48.8	*2.8%*
NETHERLANDS	48.8	46.4	47.5	*2.6%*

***Note**: variance calculated as the coefficient of variation (CV%).*

Table 11. Relative position of the baton crossing each 100 m split and variance during the heats.

	T1 (%)	**T2** (%)	**T3** (%)	*variance*
UNITED STATES	46.6	46.6	49.8	*3.9%*
GREAT BRITAIN & N.I.	49.2	48.1	48.6	*1.2%*
JAMAICA	47.6	48.0	50.8	*3.5%*
GERMANY	48.7	55.1	51.1	*6.2%*
SWITZERLAND	46.0	51.5	46.4	*6.4%*
TRINIDAD & TOBAGO	48.7	48.6	47.7	*1.2%*
BRAZIL	47.7	47.5	49.7	*2.5%*
NETHERLANDS	48.8	45.7	46.5	*3.4%*

***Note**: variance calculated as the coefficient of variation (CV%).*

Receiver entry into each transition

Table 12 displays the relative time (% transition time) the receiver spends within each transition before baton entry (i.e., delivery leg). The variance across transitions is presented in Figure 20. This information is also presented for the respective heats of each team involved in the final (Table 13 and Figure 21).

Table 12. Receiver entry into transition (% transition time) during the final.

	T1 (%)	**T2** (%)	**T3** (%)
UNITED STATES	9.2	9.3	16.8
GREAT BRITAIN & N.I.	10.8	18.2	3.7
JAMAICA	12.4	10.8	10.2
GERMANY	17.9	8.9	5.3
SWITZERLAND	9.5	7.9	11.8
TRINIDAD & TOBAGO	18.3	19.2	7.1
BRAZIL	5.8	12.1	7.8
NETHERLANDS	9.0	13.8	8.3

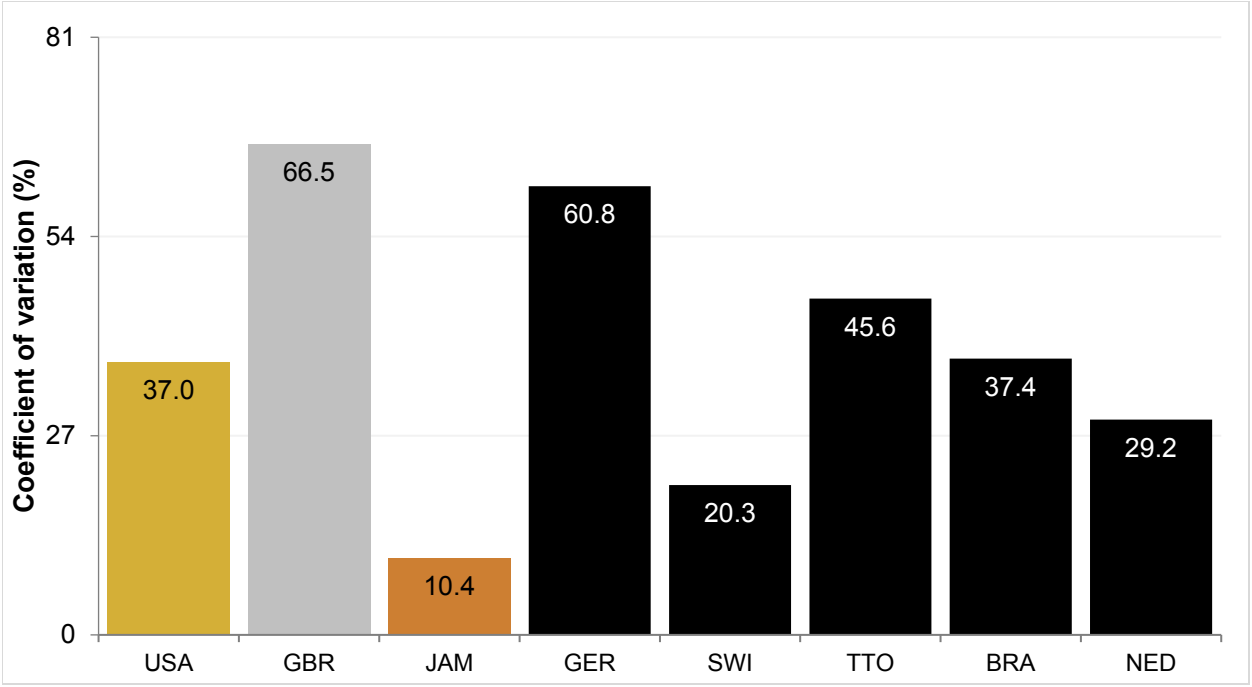

Figure 20. Variance (CV%) of the receiver entry times across transitions during the final.

Table 13 displays the relative time (% transition time) the receiver spends within each transition before baton entry (i.e., delivery leg) during the respective heat of each team involved in the final. The variance across transitions is then presented in Figure 21. Data are displayed according to the finishing position within the final.

Table 13. Receiver entry into transition (% transition time) during the respective heat of the finalists.

	T1 (%)	**T2** (%)	**T3** (%)
UNITED STATES	5.8	13.1	9.8
GREAT BRITAIN & N.I.	4.7	14.0	10.1
JAMAICA	11.8	15.1	0.0
GERMANY	0.9	7.0	3.4
SWITZERLAND	6.3	10.6	11.1
TRINIDAD & TOBAGO	10.2	7.2	11.1
BRAZIL	10.3	10.2	6.4
NETHERLANDS	4.1	10.7	10.6

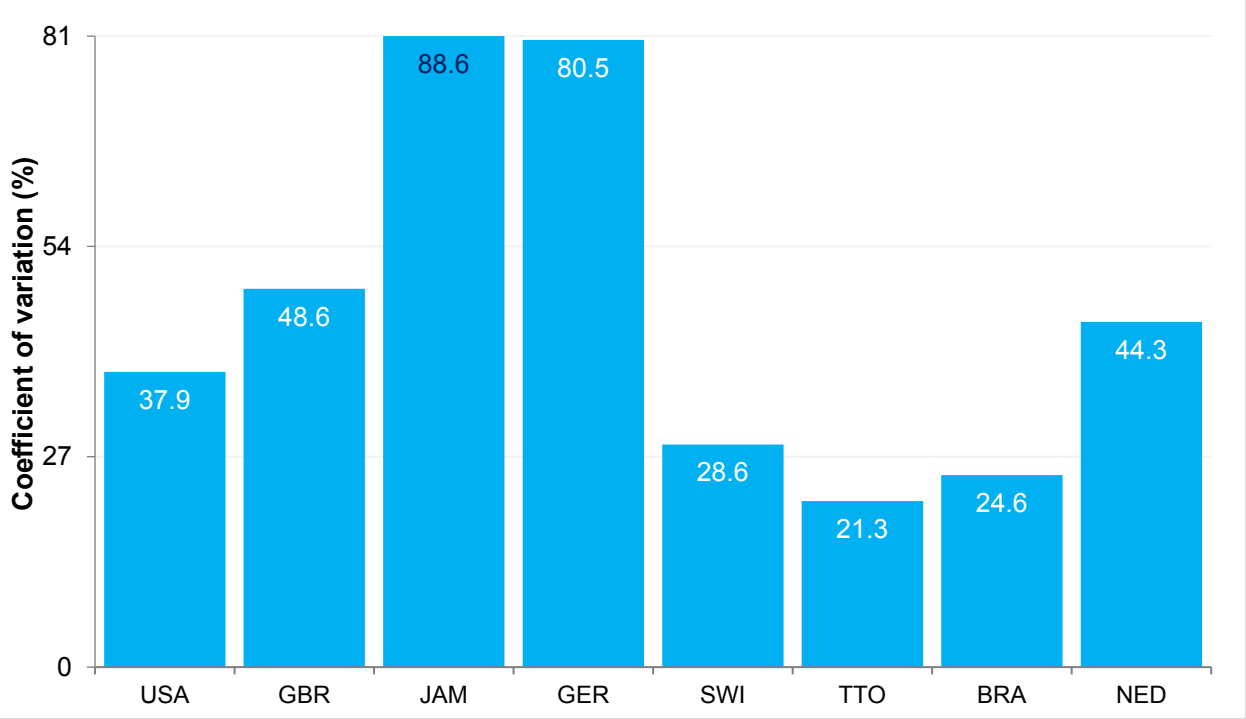

Figure 21. Variance (CV%) of the receiver entry times across transitions during the respective heat of each team involved in the final.

Time lost or gained between and within transitions

The following data displays the total time lost or gained outside and within transition zones. In particular, Table 14 shows time lost or gained relative to the gold medal winning team from the start to entry into the first transition zone, between transitions one and two, between transitions two and three, and between exit of third transition zone to the finish line. In addition, Table 15 displays the time lost or gained relative to the gold medal winning team within transition zones whereas Figure 22 displays the within transition data relative to the 100 m split position (i.e., for the last and initial 10 m of each leg).

Table 14. Time lost or gained on the gold medallist team outside transition zones.

Team	Start-T1 (s)	T1-T2 (s)	T2-T3 (s)	T3-Finish (s)	TOTAL	*result*
UNITED STATES	-	-	-	-	-	-
GREAT BRITAIN & N.I.	0.080	0.000	0.075	0.175	**0.330 s**	*0.30 s*
JAMAICA	**–0.035**	0.085	0.000	0.315	**0.365 s**	*0.37 s*
GERMANY	0.210	0.210	**–0.220**	0.330	**0.530 s**	*0.54 s*
SWITZERLAND	0.300	0.180	**–0.065**	0.275	**0.690 s**	*0.69 s*
TRINIDAD & TOBAGO	0.345	0.055	0.250	0.070	**0.720 s**	*0.80 s*
BRAZIL	0.350	0.335	0.015	0.020	**0.720 s**	*0.81 s*
NETHERLANDS	0.365	0.080	0.215	0.600	**1.260 s**	*1.25 s*

Note: *result = time differences at the finish. Time gained illustrated by negative number and bold font. Leg 1 includes reaction time.*

Table 15. Time lost or gained on the gold medal winning team within transition zones.

Team	**T1** (s)	**T2** (s)	**T3** (s)	TOTAL	*result*
UNITED STATES	-	-	-	-	-
GREAT BRITAIN & N.I.	**–0.070**	0.015	0.025	**−0.030 s**	*0.30 s*
JAMAICA	**–0.095**	**–0.015**	0.115	**0.005 s**	*0.37 s*
GERMANY	**–0.010**	**–0.020**	0.040	**0.010 s**	*0.54 s*
SWITZERLAND	**–0.010**	0.045	**–0.035**	**0.000 s**	*0.69 s*
TRINIDAD & TOBAGO	**–0.005**	0.105	**–0.020**	**0.080 s**	*0.80 s*
BRAZIL	0.055	0.010	0.025	**0.090 s**	*0.81 s*
NETHERLANDS	0.010	**–0.045**	0.025	**−0.010 s**	*1.25 s*

Note: *result = time differences at the finish. Time gained illustrated by negative number and bold font.*

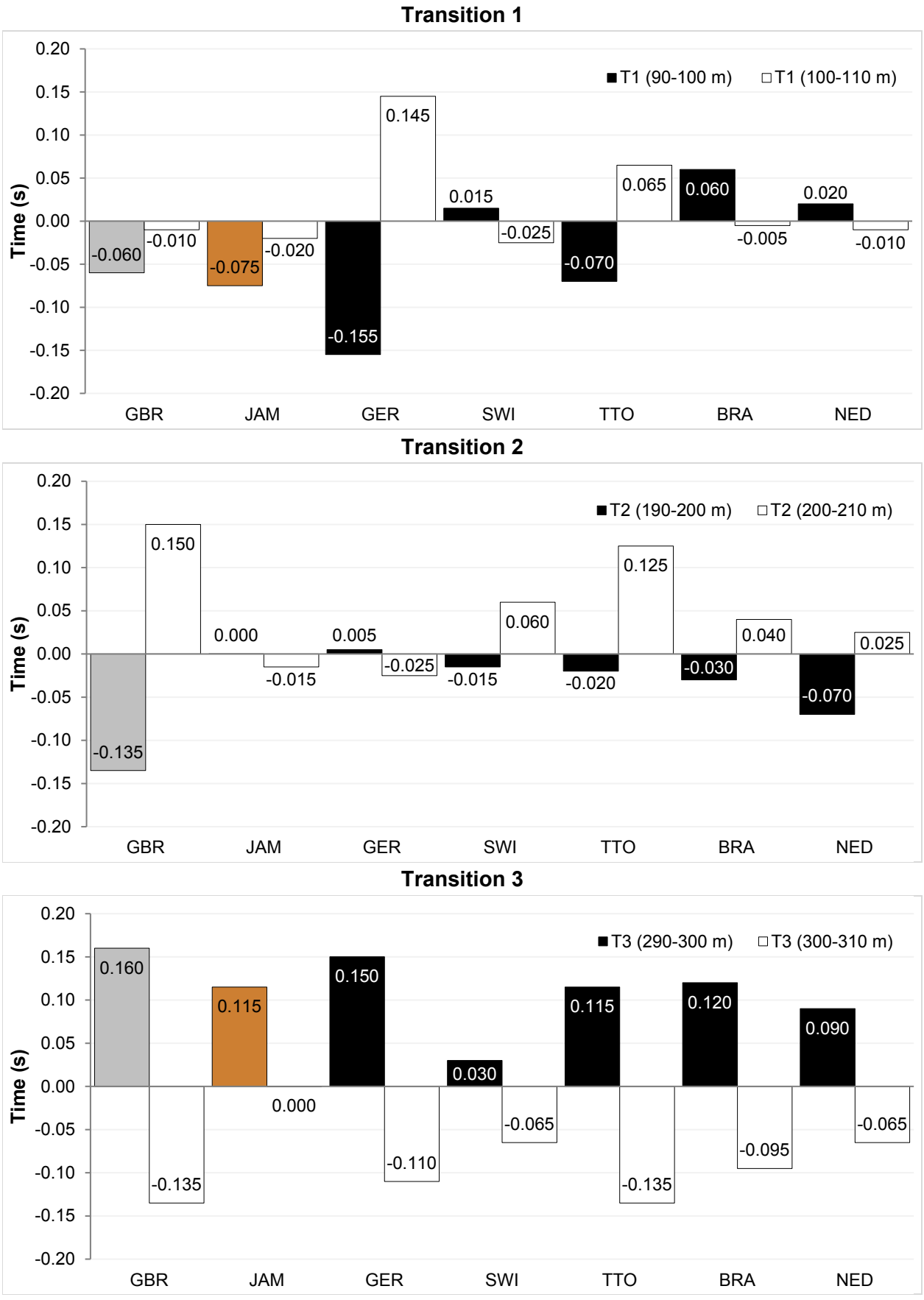

Figure 22. Time lost (+) or gained (-) on the gold medallists within transitions.

Split times: Individual legs

Figure 23 displays split times for individual legs (excluding the handover duration). Split times are also presented for consecutive 100 m (Figure 24) and 200 m splits (Figures 25 & 26).

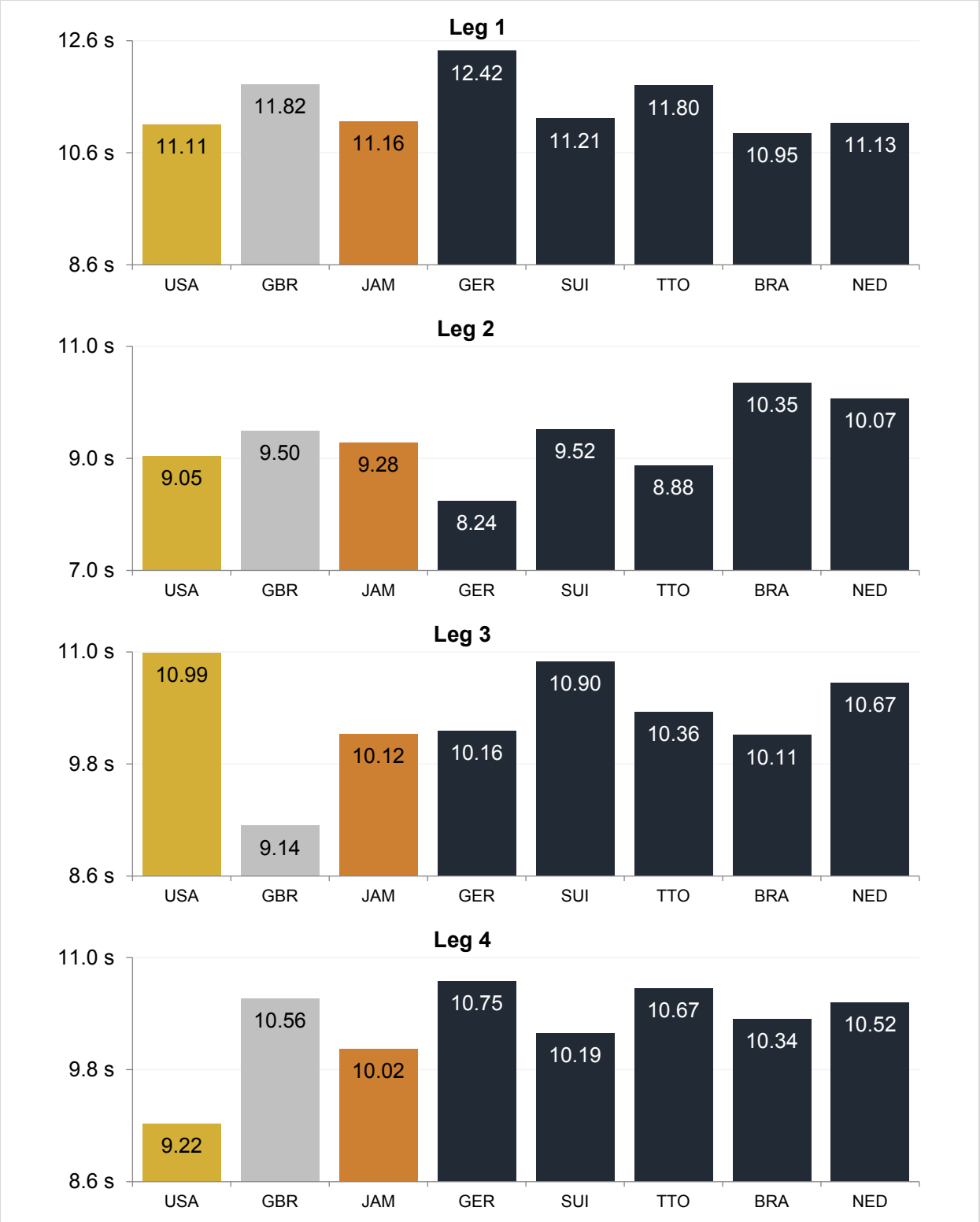

Figure 23. Split times for each individual leg excluding handover phase duration (Leg 1 minus reaction time).

Split times: 100 m splits

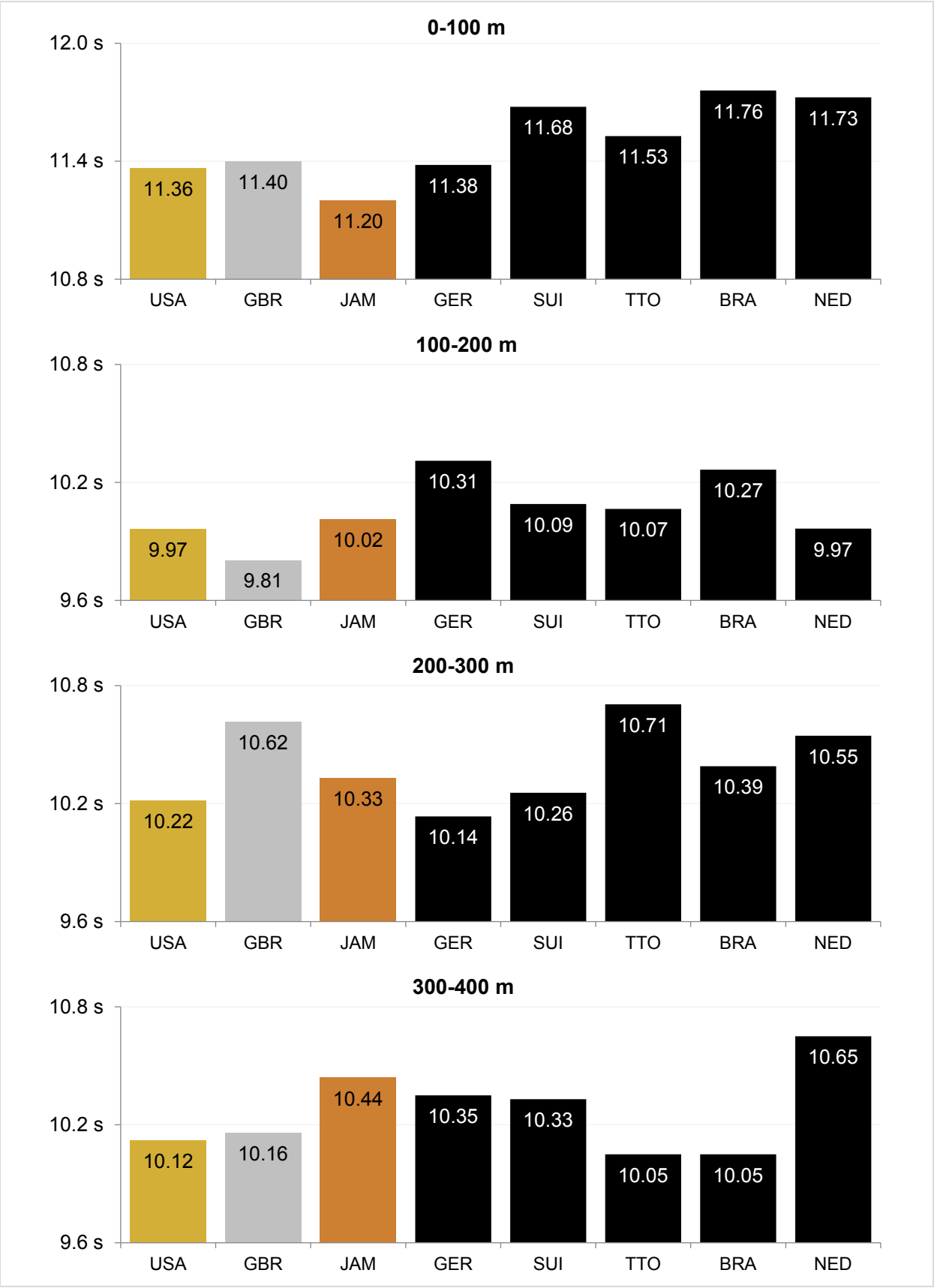

Figure 24. Team split times over consecutive 100 m (0-100 m minus reaction time).

Split times: 200 m splits

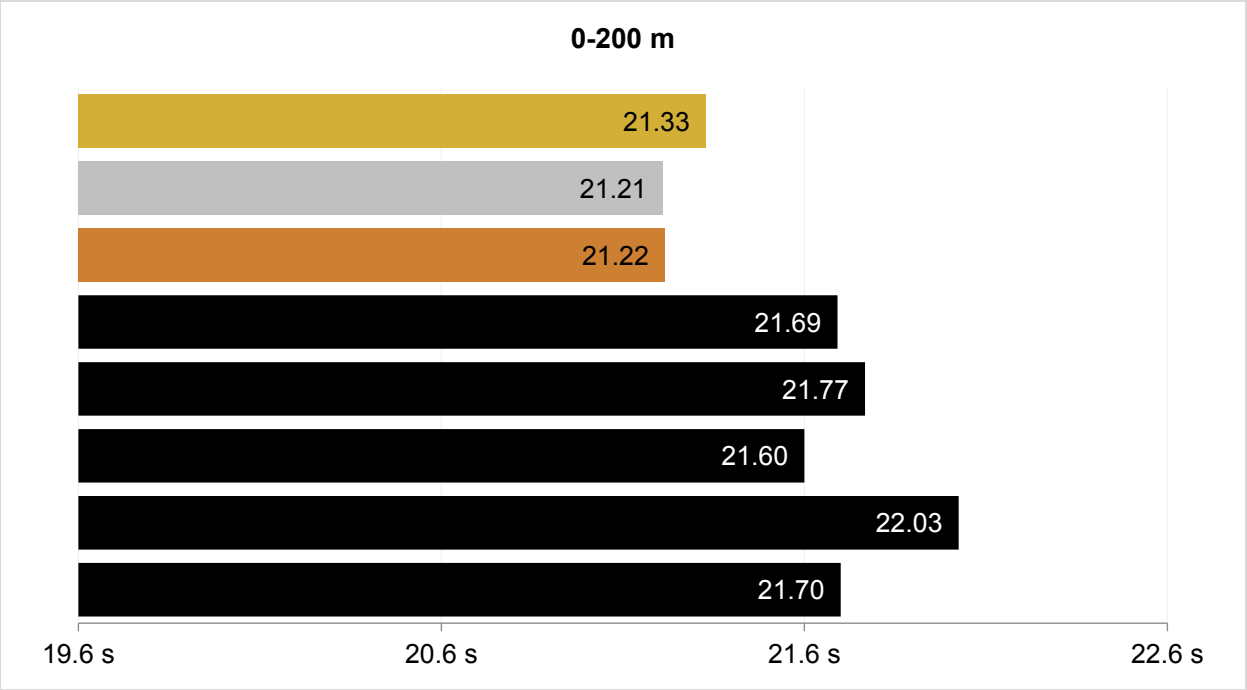

Figure 25. Team 0-200 m split times (minus reaction time).

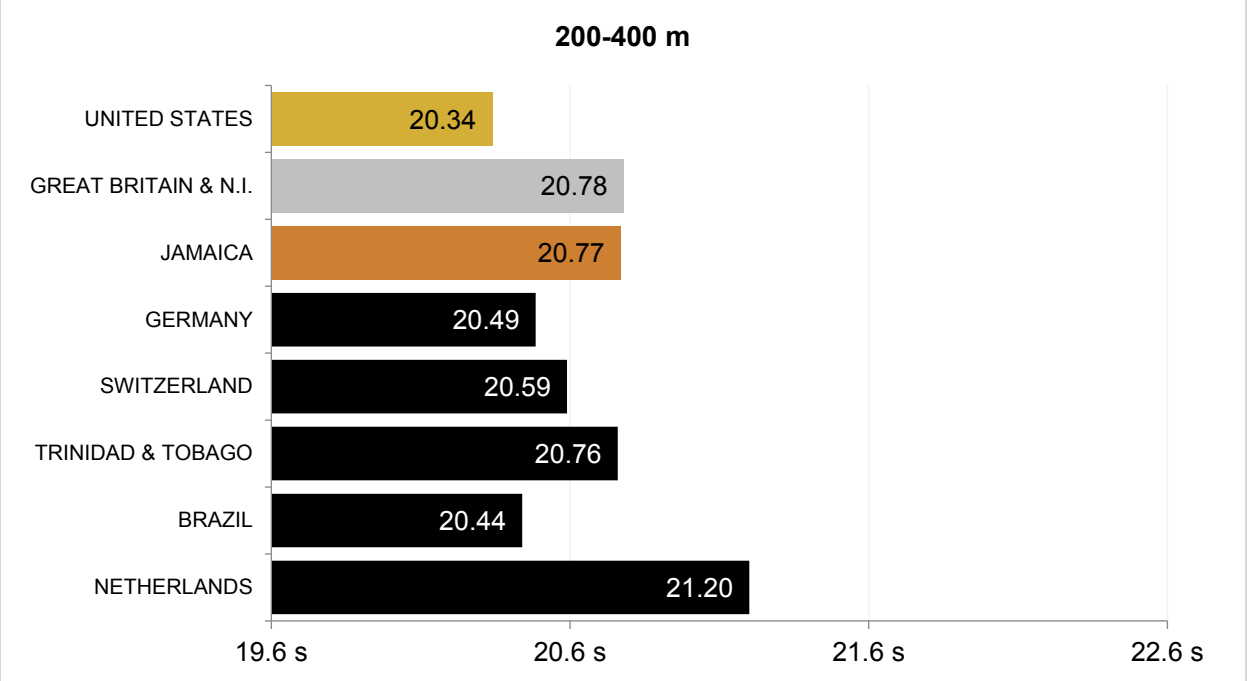

Figure 26. Team 200-400 m split times.

GOLD MEDALLIST: United States

	RT	100 m	200 m	300 m	RESULT
Final	0.146 s	11.51 s	21.48 s	31.69 s	**41.82 s**
Rank	*2nd*	*2nd*	*3rd*	*1st*	***1st***
vs. silver	+0.015 s	–0.02 s	+0.14 s	–0.26 s	–0.30 s
vs. bronze	–0.053 s	+0.11 s	+0.06 s	–0.05 s	–0.37 s
Semi-Final	0.159 s	11.35 s	21.39 s	31.64 s	**41.84 s**
Rank	*5th*	*1st*	*1st*	*1st*	***1st***

	0-100 m	100-200 m	0-200 m	200-300 m	300-400 m	200-400 m
Final	11.36 s	9.97 s	21.33 s	10.22 s	10.13 s	20.35 s
Rank	*2nd*	*=2nd*	*3rd*	*2nd*	*3rd*	*1st*
vs. silver	–0.04 s	+0.16 s	+0.13 s	–0.40 s	–0.04 s	–0.44 s
vs. bronze	+0.16 s	–0.05 s	+0.11 s	–0.11 s	–0.32 s	–0.43 s
Semi-Final	11.19 s	10.04 s	21.33 s	10.26 s	10.20 s	20.46 s
Rank	*1st*	*2nd*	*1st*	*2nd*	*4th*	*=2nd*

RESULTS: Heat 1

Performance

Table 16 below displays the ranking of each team before the World Championships across all teams qualifying for the heats, based on their season's (SB) and personal best (PB) times, and performance during the heats.

Table 16. Teams' ranking based on SB and PB, and performance during heat 1.

Team	*SB rank*	*PB rank*	HEAT	*notes*	vs. SB	vs. PB
UNITED STATES	*1*	*1*	**41.84 s**	*WL*	**–0.28 s**	1.02 s
GREAT BRITAIN & N.I.	*14*	*4*	**41.93 s**	*SB*	**–2.24 s**	0.16 s
SWITZERLAND	*4*	*13*	**42.50 s**	*NR*	**–0.04 s**	**–0.04 s**
NETHERLANDS	*7*	*8*	**42.64 s**	*SB*	**–0.38 s**	0.60 s
FRANCE	*11*	*5*	**42.92 s**	*SB*	**–0.84 s**	1.14 s
GHANA	*-*	*14*	**43.68 s**	*SB*	-	1.01 s
ECUADOR	*15*	*16*	**43.94 s**	*SB*	**–0.32 s**	0.06 s
NIGERIA	*12*	*12*	-	*DNS*	-	-

Key: *SB = season's best, PB = personal best, WL = world lead.*

Positional analysis

Figure 27 shows the relative position of each athlete at each 100 m split throughout the race.

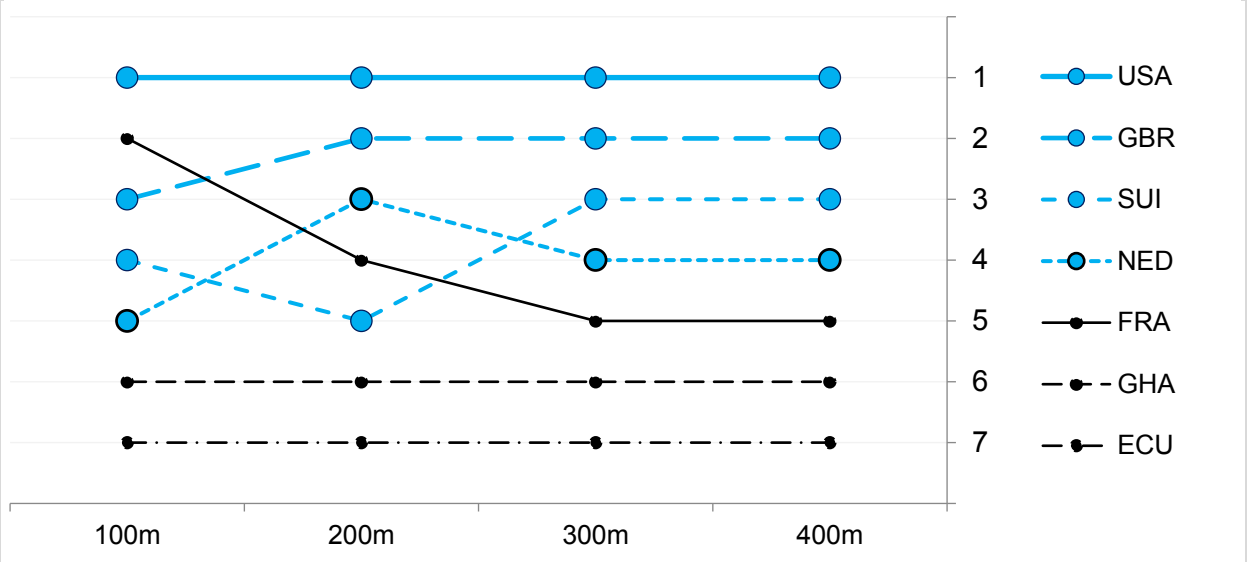

Figure 27. Positions at the end of each 100 m split.

Transition analysis

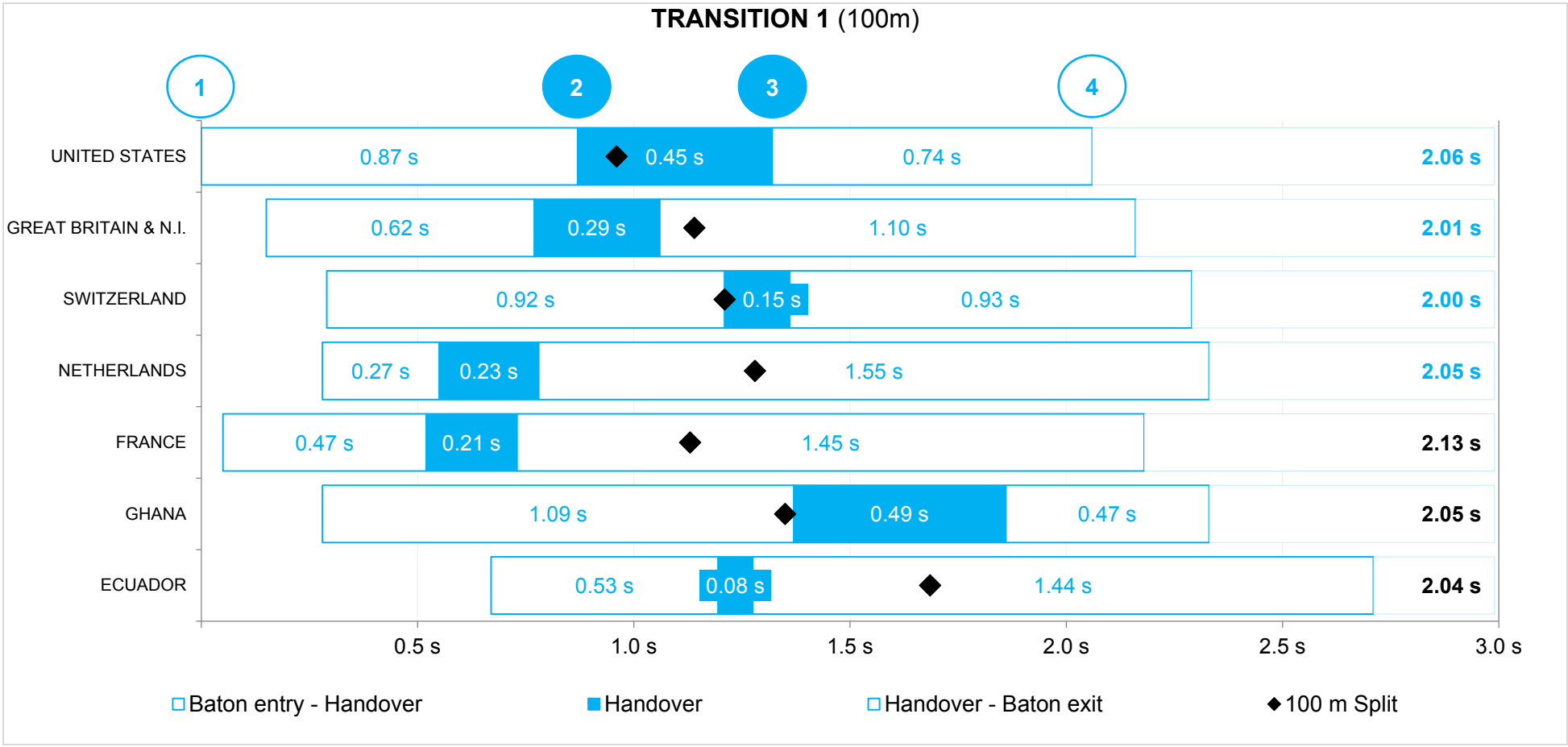

Figure 28. Analysis of timings and positions of each team within Transition 1. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase.*

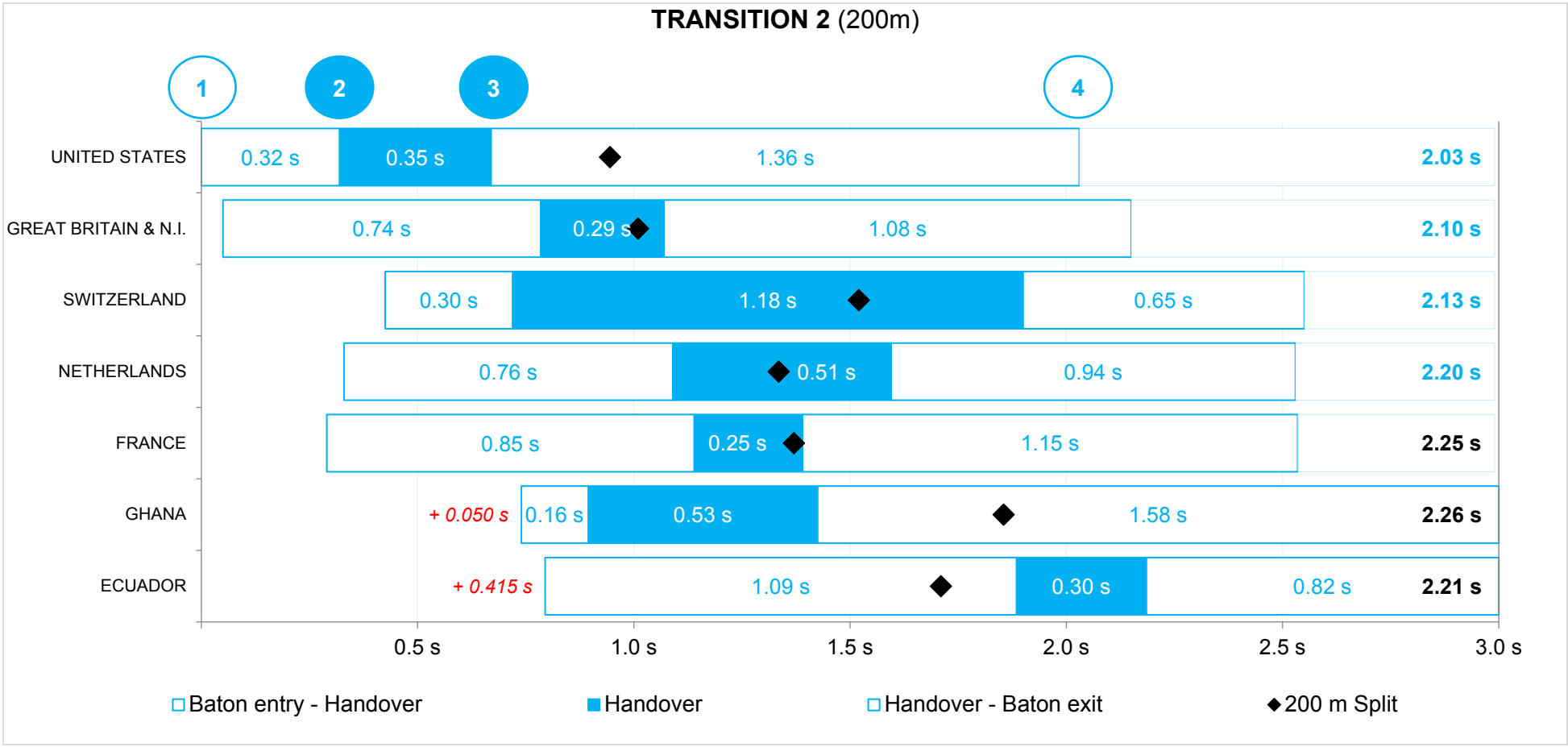

Figure 29. Analysis of timings and positions of each team within Transition 2. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: (a) Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. (b) Transition phases for Ghana and Ecuador are displayed earlier (red text) for illustration purposes.*

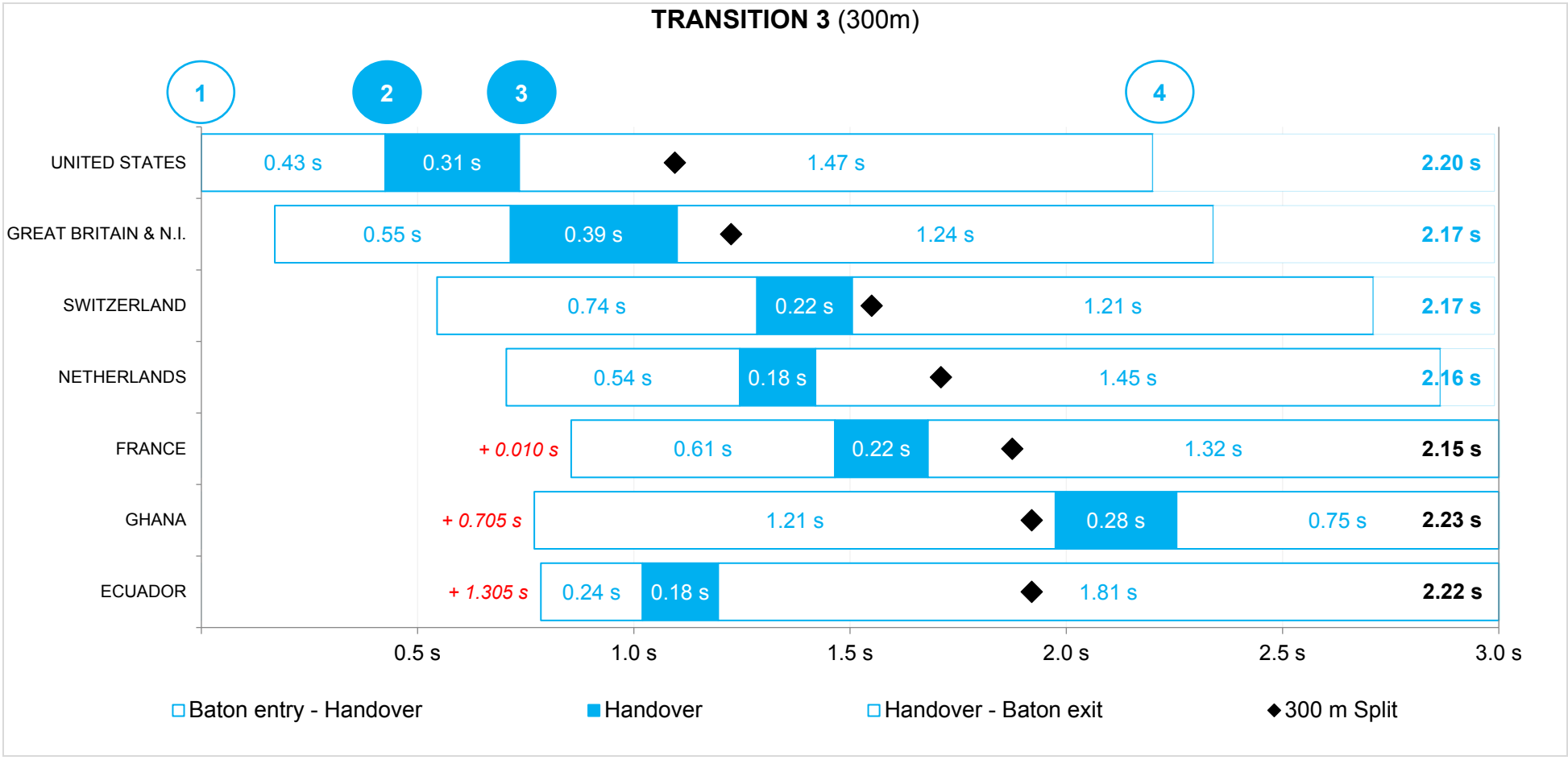

Figure 30. Analysis of timings and positions of each team within Transition 3. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: (a) Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. (b) Transition phases for Ghana and Ecuador are displayed earlier (red text) for illustration purposes.*

Handover duration

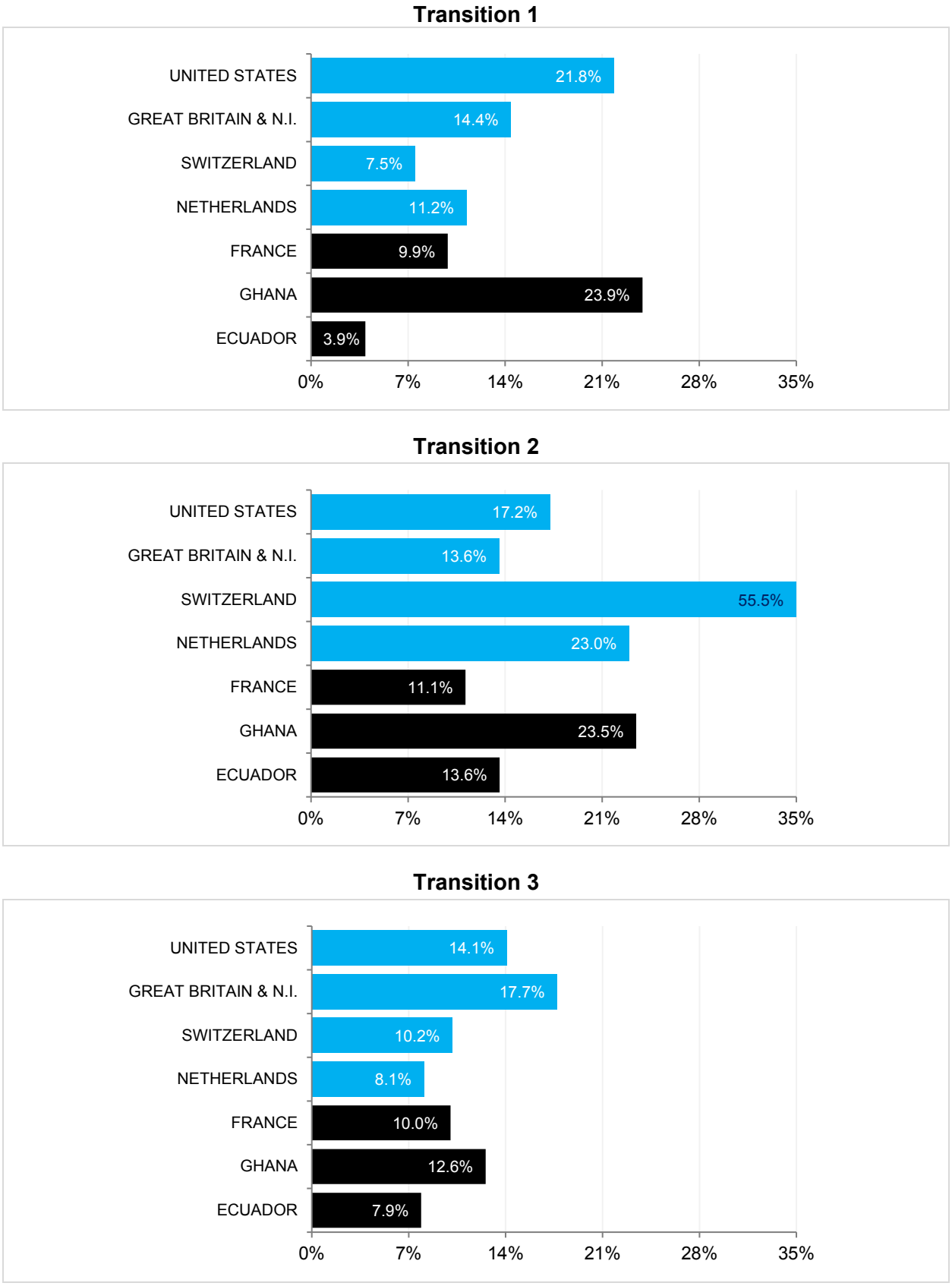

Figure 31. Duration of the handover phase as a percentage of the total transition time.

Time lost or gained between and within transitions

The following data displays the total time lost or gained outside and within transition zones. In particular, Table 18 shows time lost or gained relative to the gold medal winning team from the start to entry into the first transition zone, between transitions one and two, between transitions two and three, and between exit of third transition zone to the finish line. In addition, Table 17 displays the time lost or gained relative to the gold medal winning team within transition zones.

Table 17. Time lost or gained on the winning team within transition zones.

Team	**T1** (s)	**T2** (s)	**T3** (s)	**TOTAL**	*result*
UNITED STATES	-	-	-	-	-
GREAT BRITAIN & N.I.	**–0.050**	0.070	**–0.030**	**–0.010 s**	*0.09 s*
SWITZERLAND	**–0.060**	0.095	**–0.035**	**0.000 s**	*0.66 s*
NETHERLANDS	**–0.010**	0.170	**–0.040**	**0.120 s**	*0.80 s*
FRANCE	**0.070**	0.215	**–0.055**	**0.230 s**	*1.08 s*
GHANA	**–0.010**	0.230	0.030	**0.250 s**	*1.84 s*
ECUADOR	**–0.020**	0.175	0.015	**0.170 s**	*2.10 s*
NIGERIA	-	-	-	-	-

Note: *result = time differences at the finish. Time gained illustrated by negative number and bold font.*

Table 18. Time lost or gained on the winning team outside transition zones.

Team	**Start-T1** (s)	**T1-T2** (s)	**T2-T3** (s)	**T3-Finish** (s)	**TOTAL**	*result*
UNITED STATES	-	-	-	-	-	-
GREAT BRITAIN & N.I.	0.150	**–0.050**	0.050	**–0.050**	**0.100 s**	*0.09 s*
SWITZERLAND	0.290	0.195	0.025	0.145	**0.660 s**	*0.66 s*
NETHERLANDS	0.280	0.060	0.205	0.135	**0.680 s**	*0.80 s*
FRANCE	0.050	0.170	0.360	0.270	**0.850 s**	*1.08 s*
GHANA	0.280	0.520	0.545	0.245	**1.590 s**	*1.84 s*
ECUADOR	0.670	0.560	0.705	**–0.005**	**1.930 s**	*2.10 s*
NIGERIA	-	-	-	-	**-**	-

Note: *result = time differences at the finish. Leg time calculated from the exit (start for leg 1) and entry points of each transition. Leg 1 includes reaction time.*

Split times: Individual legs

Figure 32 displays split times for individual legs (excluding the handover duration). Split times are also presented for consecutive 100 m (Figure 33) and 200 m splits (Figures 34 & 35).

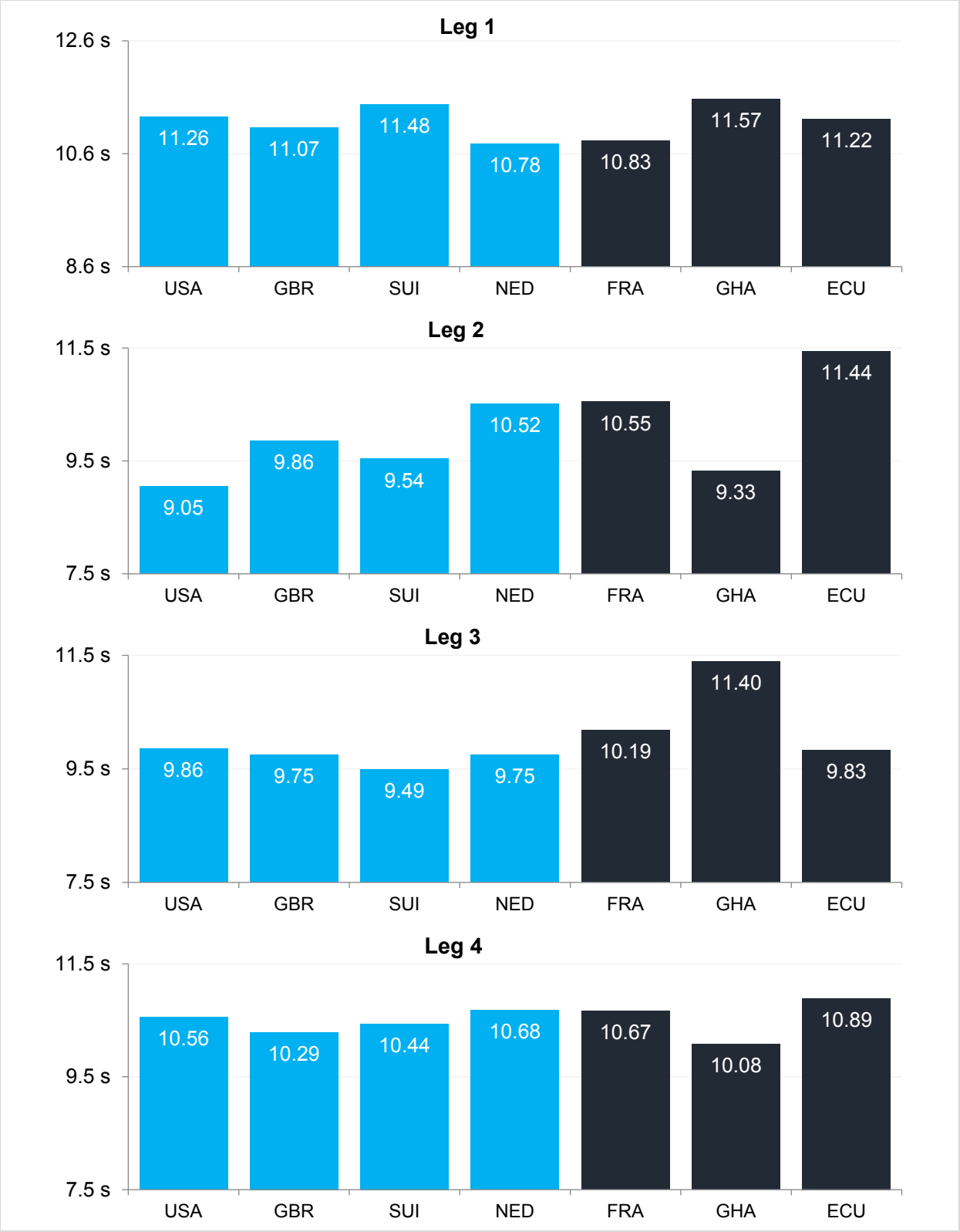

Figure 32. Split times for each individual leg (minus handover phase duration).

Split times: 100 m splits

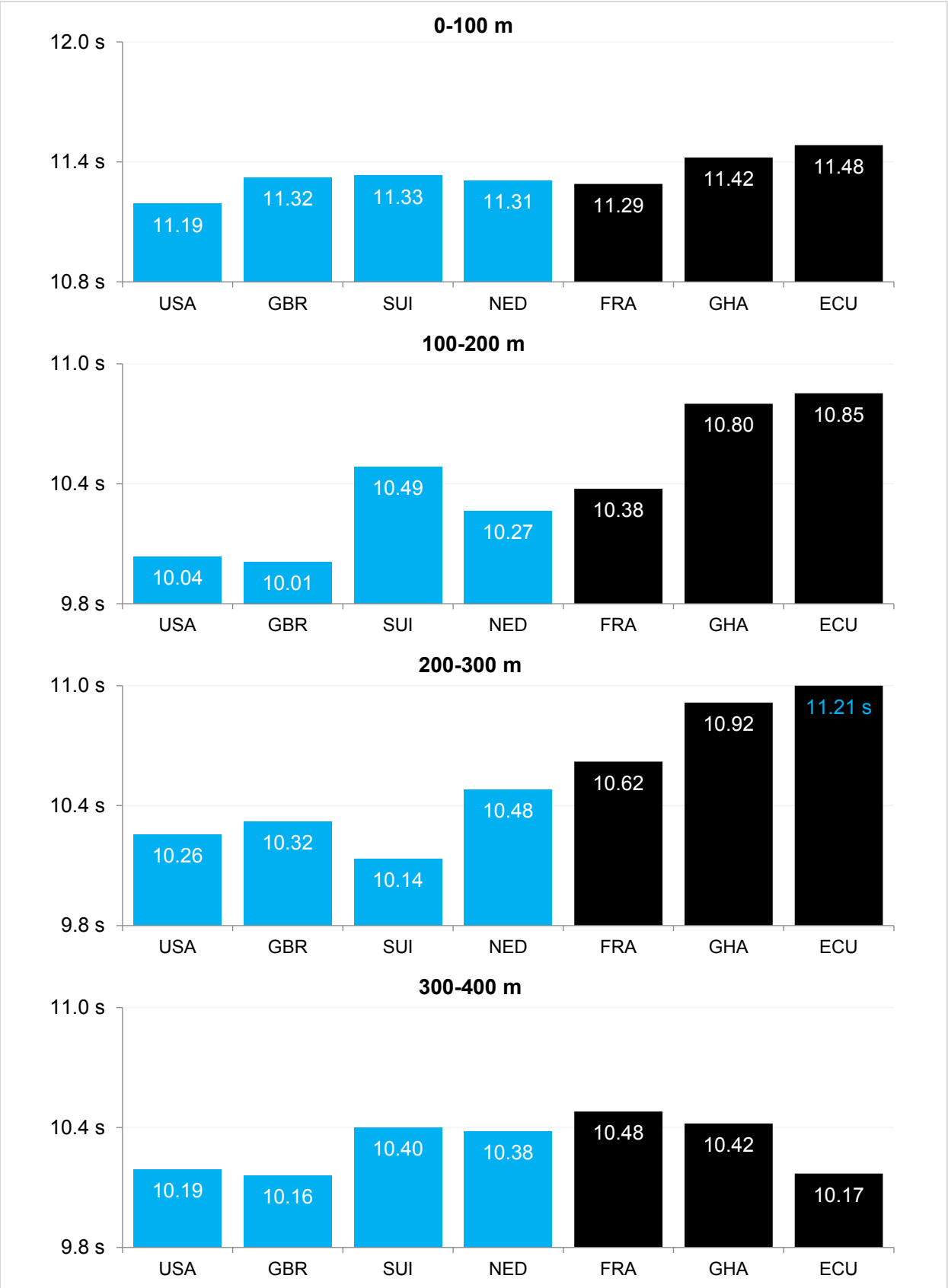

Figure 33. Team split times over consecutive 100 m (0-100 m minus reaction time).

Split times: 200 m splits

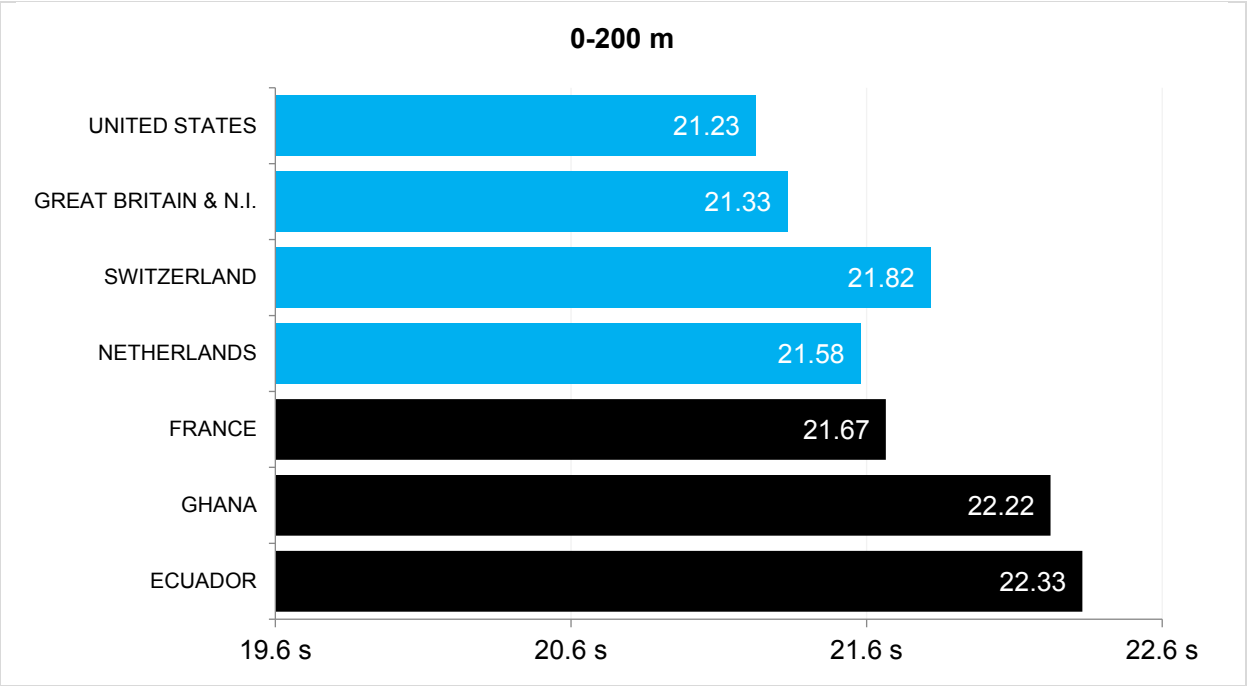

Figure 34. Team 0-200 m split times (minus reaction time).

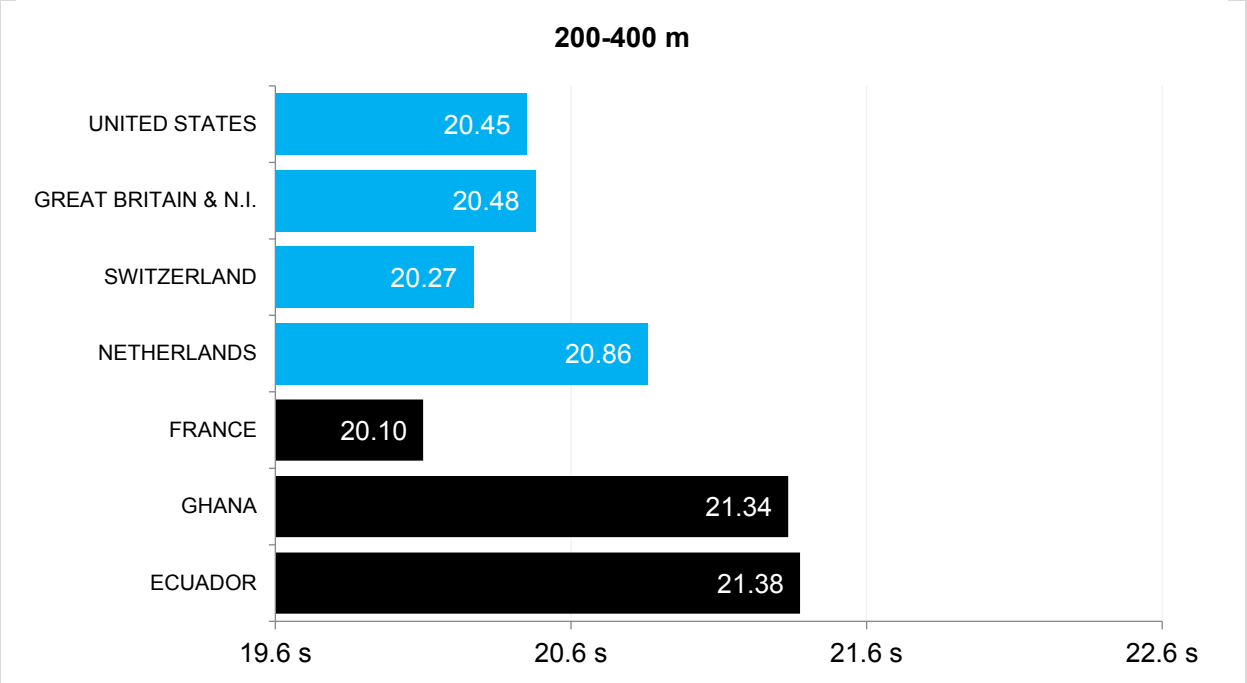

Figure 35. Team 200-400 m split times.

RESULTS: Heat 2

Performance

Table 19 below displays the ranking of each athlete before the World Championships across all teams qualifying for the heats, based on their season's (SB) and personal best (PB) times, and performance during the heat.

Table 19. Teams' ranking based on SB and PB, and performance during heat 2.

Team	*SB rank*	*PB rank*	HEAT	*notes*	vs SB	vs PB
GERMANY	*2*	*3*	**42.34 s**		0.09 s	0.97 s
JAMAICA	*2*	*2*	**42.50 s**		0.25 s	1.43 s
BRAZIL	*6*	*11*	**42.77 s**	*SB*	**–0.20 s**	0.48 s
TRINIDAD & TOBAGO	*5*	*7*	**42.91 s**	*SB*	**–0.03 s**	0.88 s
UKRAINE	*9*	*8*	**43.77 s**		0.68 s	1.73 s
KAZAKHSTAN	*8*	*15*	**45.47 s**		2.44 s	2.55 s
PR OF CHINA	*10*	*10*	-	*DQ*	-	-
BAHAMAS	*13*	*6*	-	*DNF*	-	-

Key: *Q = automatic qualifier, q = secondary qualifier, SB = season's best, DQ =disqualified, DNS = did not start*

Positional analysis

Figure 36 shows the relative position of each athlete at each 100 m split throughout the race.

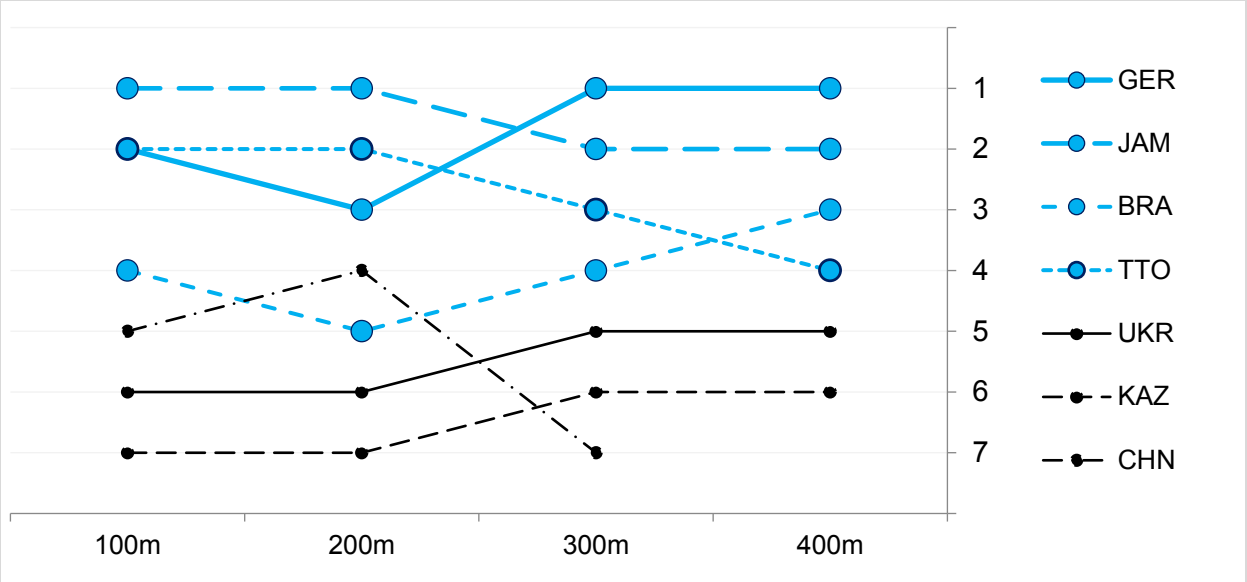

Figure 36. Positions at the end of each 100 m split.

Transition analysis

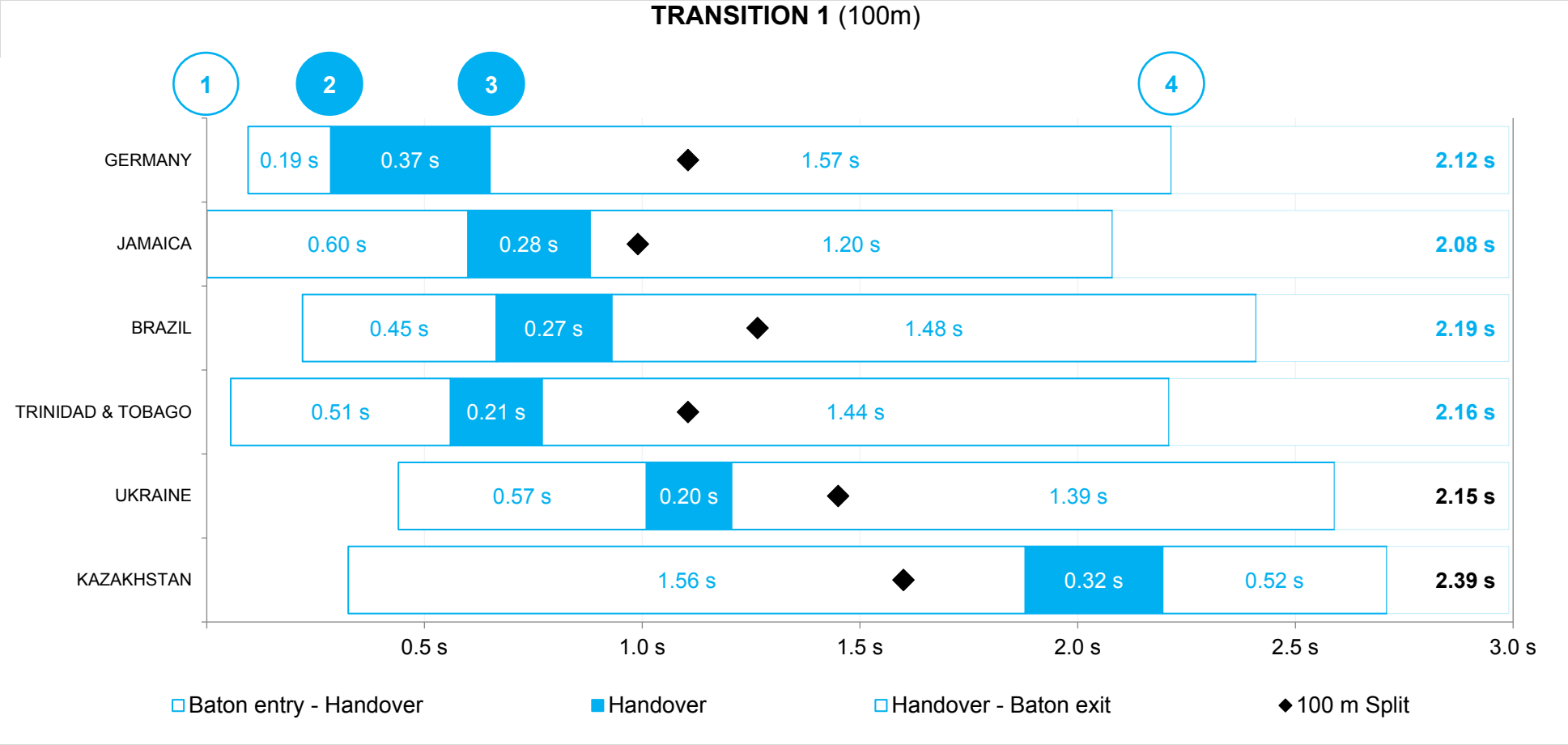

Figure 37. Analysis of timings and positions of each team within Transition 1. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase.*

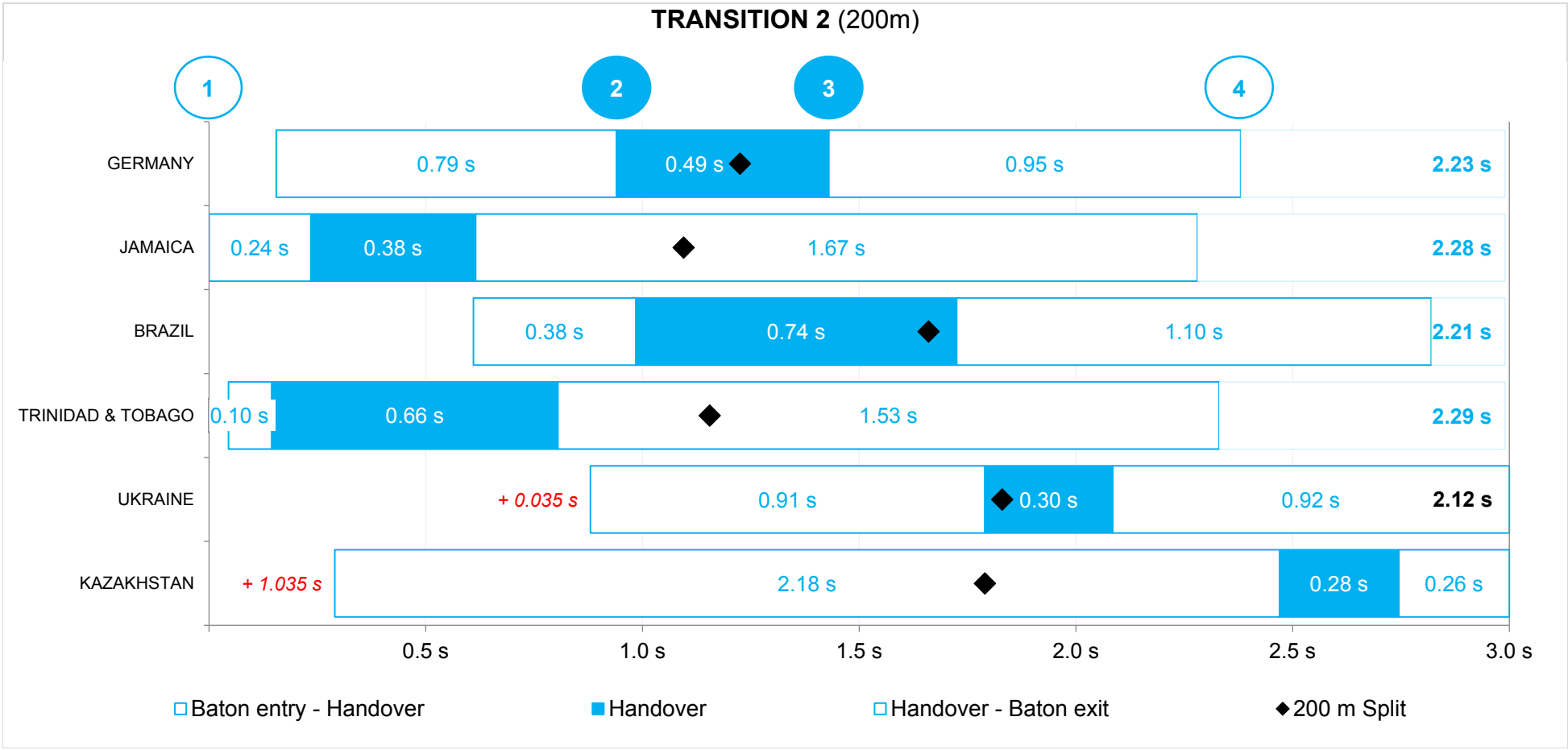

Figure 38. Analysis of timings and positions of each team within Transition 2. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: (a) Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. (b) Transition phases for Ukraine and Kazakhstan are displayed earlier (red text) for illustration purposes. Total transition time for Kazakhstan was 2.71 s.*

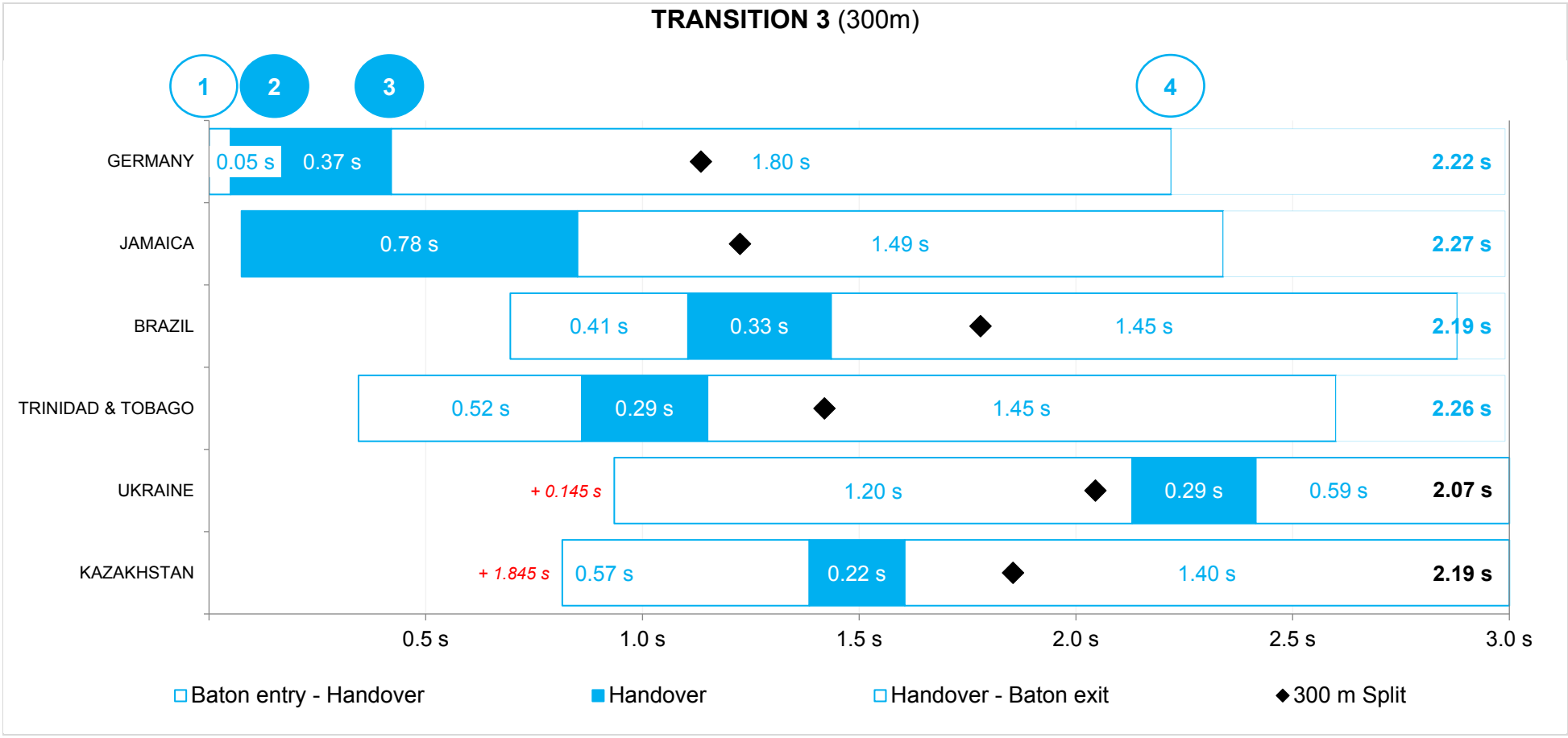

Figure 39. Analysis of timings and positions of each team within Transition 3. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

***Note**: (a) Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase. (b) Transition phases for Ukraine and Kazakhstan are displayed earlier (red text) for illustration purposes.*

Handover duration

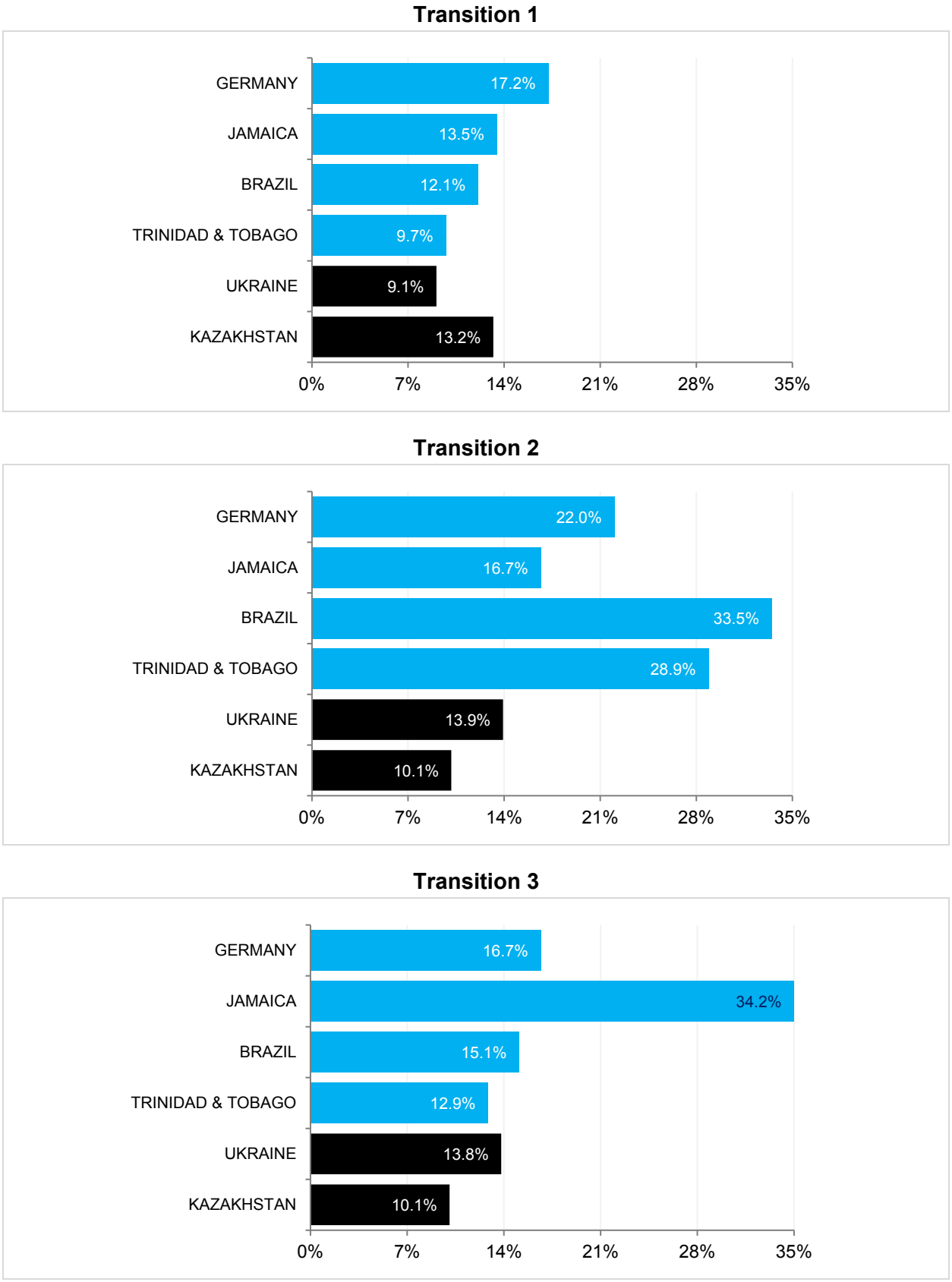

Figure 40. Duration of the handover phase as a percentage of the total transition time.

Time lost or gained between and within transitions

The following data displays the total time lost or gained outside and within transition zones. In particular, Table 21 shows time lost or gained relative to the gold medal winning team from the start to entry into the first transition zone, between transitions one and two, between transitions two and three, and between exit of third transition zone to the finish line. In addition, Table 20 displays the time lost or gained relative to the gold medal winning team within transition zones.

Table 20. Time lost or gained on the winning team within transition zones.

Team	**T1** (s)	**T2** (s)	**T3** (s)	**TOTAL**	*result*
GERMANY	-	-	-	-	-
JAMAICA	**–0.040**	0.055	0.045	**0.060 s**	*0.16 s*
BRAZIL	0.070	**–0.015**	**–0.035**	**0.020 s**	*0.43 s*
TRINIDAD & TOBAGO	0.035	0.060	0.035	**0.130 s**	*0.57 s*
UKRAINE	0.030	**–0.105**	**–0.155**	**–0.230 s**	*1.43 s*
KAZAKHSTAN	0.265	0.485	**–0.035**	**0.715 s**	*3.13 s*
PR OF CHINA	-	-	-	**-**	-
BAHAMAS	-	-	-	**-**	-

Note: *result = time differences at the finish. Time gained illustrated by negative number and bold font.*

Table 21. Time lost or gained on the winning team outside transition zones.

Team	**Start-T1** (s)	**T1-T2** (s)	**T2-T3** (s)	**T3-Finish** (s)	**TOTAL**	*result*
GERMANY	-	-	-	-	-	-
JAMAICA	**–0.095**	**–0.020**	0.175	0.040	**0.100 s**	*0.16 s*
BRAZIL	0.125	0.260	0.255	**–0.230**	**0.410 s**	*0.43 s*
TRINIDAD & TOBAGO	**–0.040**	0.105	0.395	0.190	**0.440 s**	*0.57 s*
UKRAINE	0.345	0.385	0.425	0.505	**1.660 s**	*1.43 s*
KAZAKHSTAN	0.230	0.675	1.005	0.505	**2.415 s**	*3.13 s*
PR OF CHINA	-	-	-	-	**-**	-
BAHAMAS	-	-	-	-	**-**	-

Note: *result = time differences at the finish. Leg time calculated from the exit (start for leg 1) and entry points of each transition. Leg 1 includes reaction time.*

Split times: Individual legs

Figure 41 displays split times for individual legs (excluding the handover duration). Split times are also presented for consecutive 100 m (Figure 42) and 200 m splits (Figure 43 and 44).

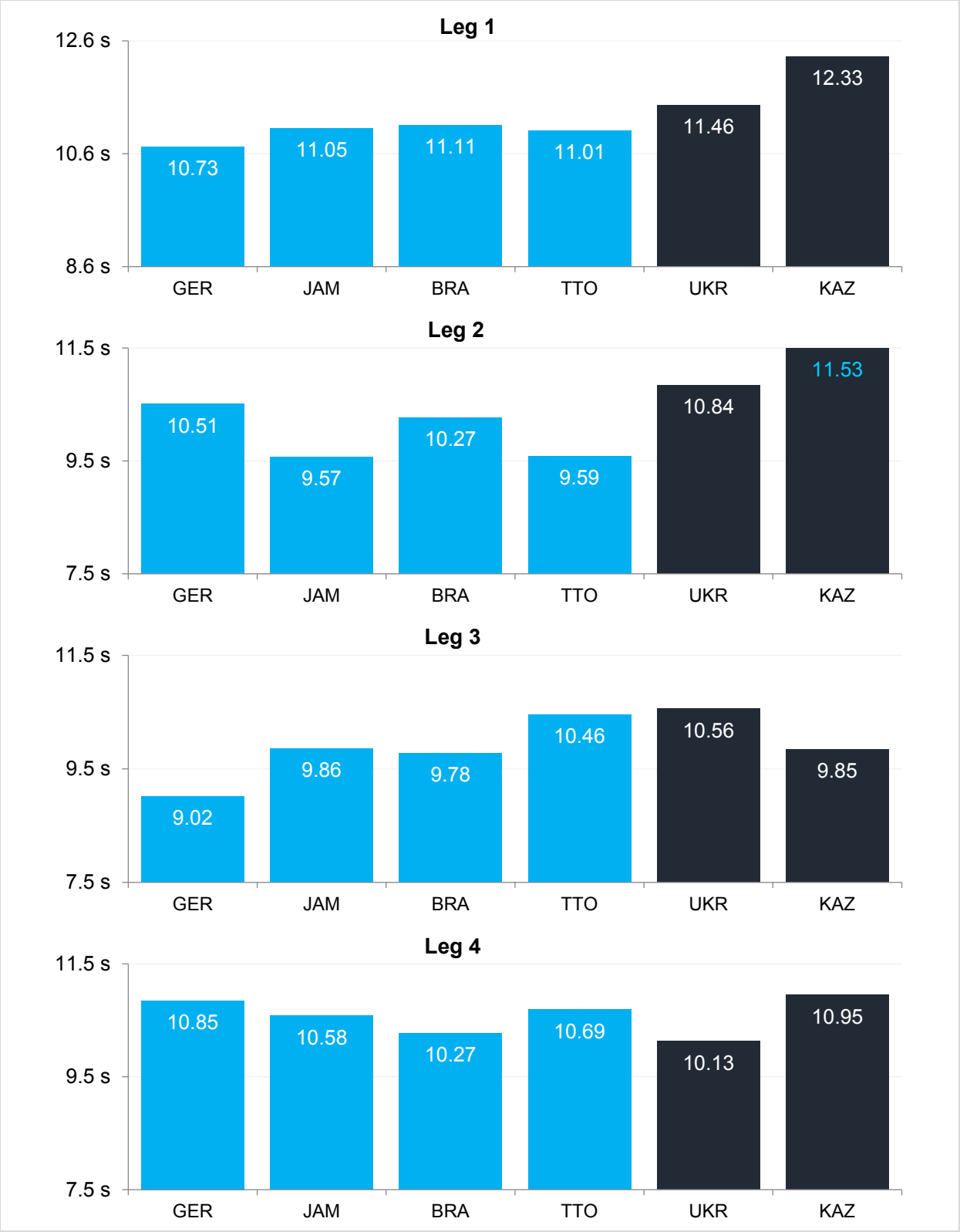

Figure 41. Split times for each individual leg (minus handover phase duration).

Split times: 100 m splits

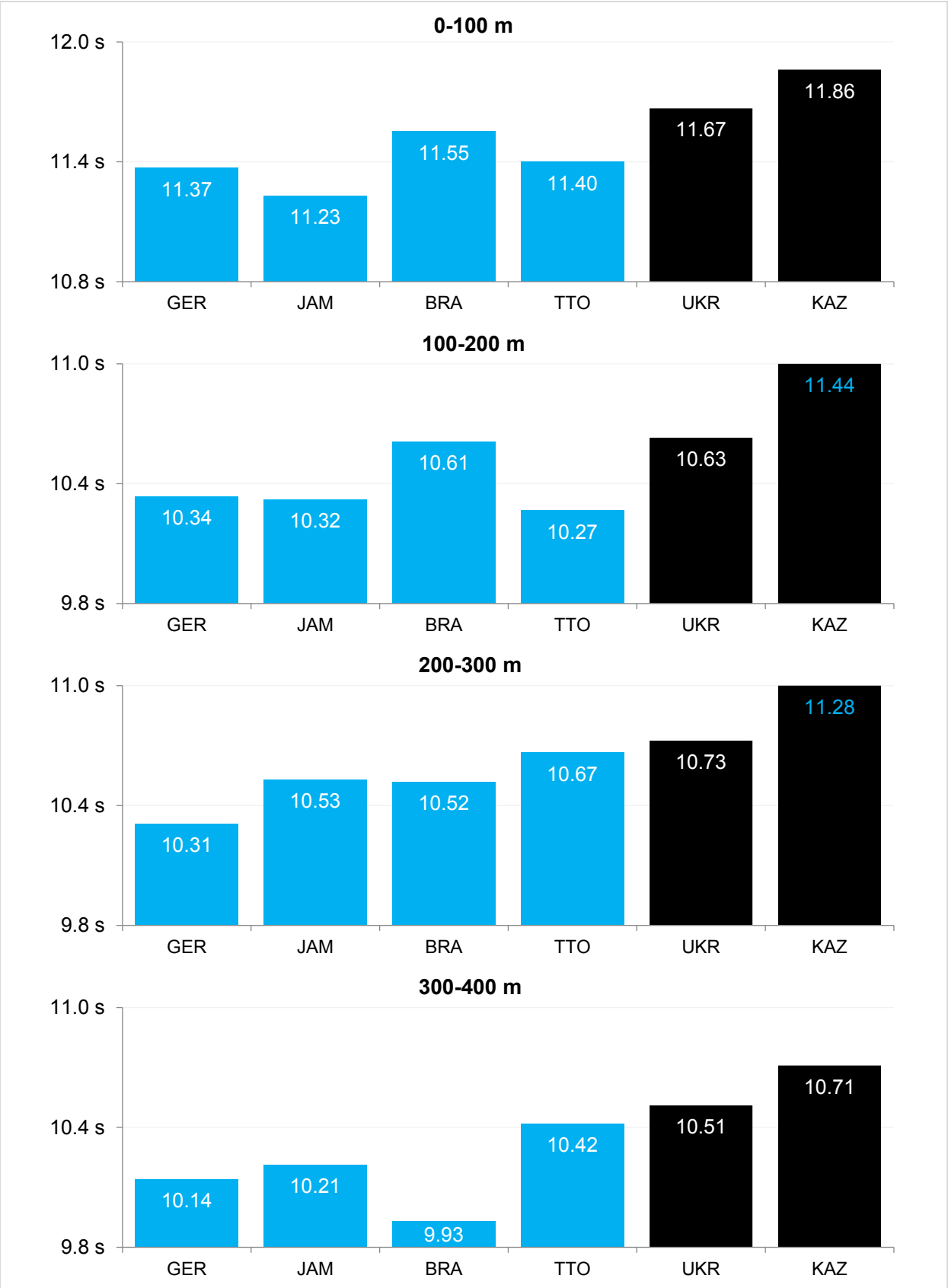

Figure 42. Team split times over consecutive 100 m (0-100 m minus reaction time).

Split times: 200 m splits

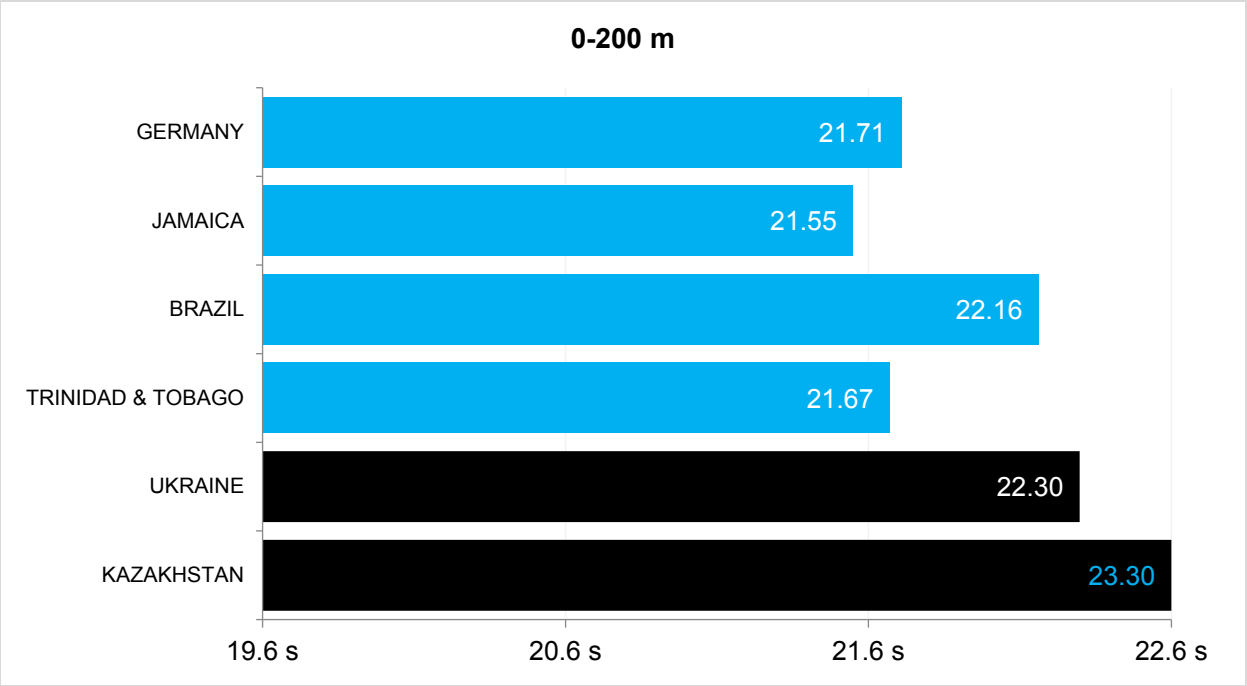

Figure 43. Team 0-200 m split times (minus reaction time).

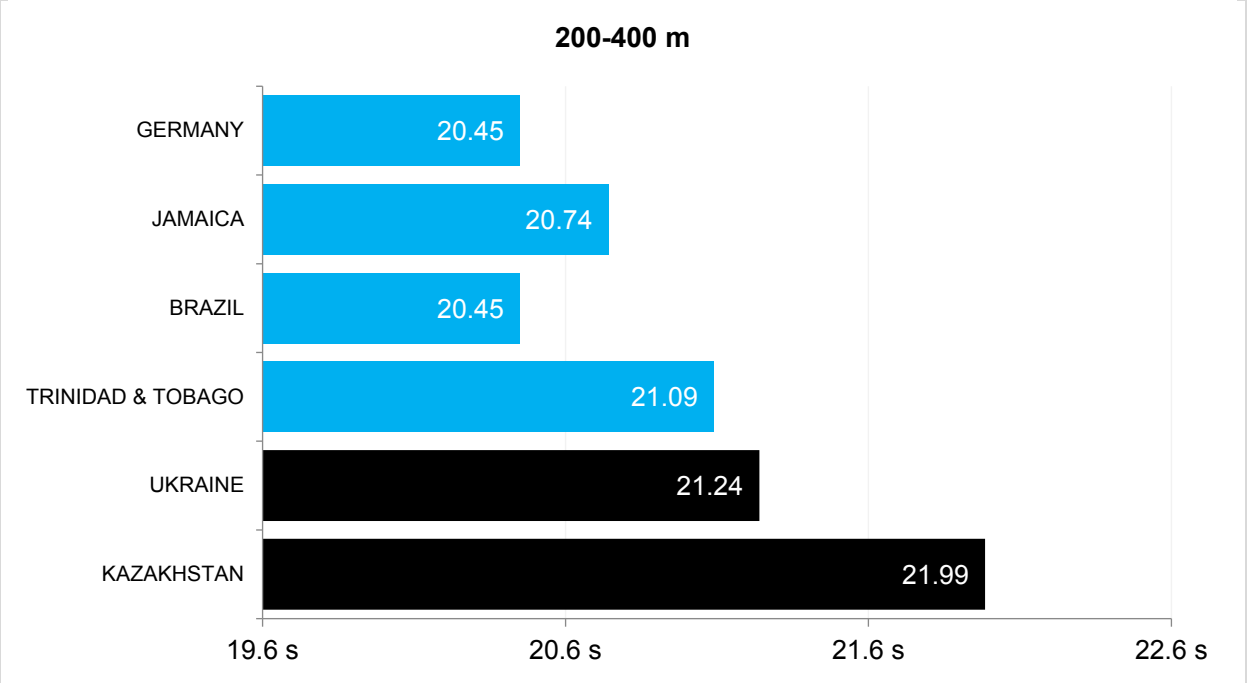

Figure 44. Team 200-400 m split times.

COMMENTARY

While the quickest teams during the heats secured the gold (United States, 41.84 s) and silver (Great Britain & N.I., 41.93 s) medals, the medal positions were ultimately determined by a scrappy handover and final transition. A lengthy handover (1.10 s) for Jamaica, accounting for almost half of the total time spend in transition (48.5%), resulted in the longest transition of the race (2.26 s), costing them their slender lead (0.06 s) coming into the transition. And while none of the medallists produced an efficient handover of the baton between the final two legs, it was the loss of momentum that proved costly for Jamaica; who were without Elaine Thompson. Had Jamaica produced the effectiveness displayed within the prior transitions (2.02 and 2.09 s), they likely would have maintained their lead to capture gold.

The impact of Jamaica's extended final transition is also illustrated by the highest variance (5.9%) across teams during the final. While the United States and Great Britain & N.I. improved their consistency in comparison to their performances during the heats, the final transition resulted in the longest transition time for all teams, apart from Switzerland. Nevertheless, for Switzerland, greater consistency in the final did not return an improvement in the total cumulative transition time and thus narrowly missed out on setting another national record which was recorded during the heats (i.e., 42.50 s). In contrast, despite greater efficiency within each transition, Germany could not improve upon the impressive performance displayed in winning their heat.

Germany also exhibited the highest consistency in handover duration (variance 9.6%). In contrast, the medallists could not reproduce the efficiency displayed in the heats. For Jamaica, the longer duration in transition 3 was associated with a longer handover duration. Moreover, a shorter handover did not necessarily ensure a shorter transition time. For example, although the United States recorded their quickest handover in transition 2 (0.190 s), the total transition time (2.105 s) was almost identical to that recorded for transition 1 (2.110 s) where the handover was almost three times as long (0.565 s). While this may indicate that handover duration is not the pivotal factor, the total cumulative handover time was lower for the non-medal winning teams which may suggest that a quick handover compromises running speed.

Because of the high levels of consistency for the time spent in transition, this report aimed to consider other key performance factors involved within each transition. It may even provide an indication of the tactics employed by each team. An effective handover within a transition should ensure that maximum speed is maintained; and ultimately minimise any loss in time. An ineffective handover could, however, occur due to many factors. Therefore, in addition to the duration of the transition and the handover, the duration of the delivery (i.e., baton entry to start of handover), and receive (i.e., end of handover to baton exit) legs, as well as the time spent in transition of the receive leg before baton entry were considered. This provides useful information about the

relative position each team completed the handover. It also enabled an analysis of where time was lost or gained on the winning team within each transition.

With respect to the duration of the delivery and receive legs within transitions, few trends can be observed. Some teams displayed a decrease in the delivery leg thus an increase in the duration of the receive leg over consecutive transitions (i.e. GBR, TTO), whereas some displayed the reverse trend to this (i.e., BRA, NED). The remaining teams recorded the shortest delivery, thus longest receive leg duration, within transition 2. This information ultimately highlights where the baton handover occurred and could in part reflect the tactics that were employed by each team. It could also reflect the strengths of individual athletes. For example, in general, the United States and Jamaica preferred to begin and complete the handover early in the transition, a tactic which may be employed to enhance the exit speed from the transition.

Nevertheless, the exit speed would however be compromised by an inefficient handover. This can be seen in transition 3 for both the United States and Jamaica. However, having individual 100m gold medallist in Torie Bowie, meant that the challenge from Great Britain & N.I. was nullified. To highlight the ineffective final handover for the USA, Bowie can be observed to turn and look back to check the position of the delivery leg (i.e., Akinosun). Another contributing factor could have been the change in line-up for the last leg in the final (i.e. Bowie for Washington). In contrast, Jamaica changed both their line-up and their running order to record a faster time than in the heats, whereas Great Britain & N.I. made no changes and were less effective than during the heats.

Another factor which may have prevented Great Britain & N.I. taking advantage within transition 3 was the notably earlier handover position compared to the heats (i.e., 6.7% vs. 25.2%), as well as the time spent by the receive leg in transition before baton entry (i.e., 3.7% vs. 10.1%). Despite similar transition durations, this earlier handover may have resulted in greater braking from the delivery leg and thus a reduction in the starting speed of the receive leg. Although Great Britain & N.I. were quicker than the United States in the second half of the transition (–0.135 s) the impact of this may be illustrated by a longer time spent in the first half of the transition (0.160 s) even though the United States could not complete an efficient handover.

In summary, the outcome of the women's final may have been different but for ineffective performances in the final transition. Likewise, an effective performance by the United States may have resulted in another world leading performance. The team of Aaliyah Brown, Allyson Felix, Morolake Akinosun and Bowie were significantly faster than all other teams (e.g. 0.330 s vs. Great Britain & N.I.) between transitions which highlights the importance of raw speed. As they were only marginally slower than other teams within transitions (i.e., max 0.095 s), they were clearly very effective within the transition and with the handover.

CONTRIBUTORS

Dr Lysander Pollitt is a Senior Lecturer in Sport and Exercise Biomechanics at Leeds Beckett University. His research interests primarily focus on neuromuscular biomechanics, particularly the impact of surface instability on performance. Previously, Lysander has provided applied biomechanical support to British Weight Lifting, including preparation for the 2012 Olympics in London. He was also an integral part of the development and implementation of the talent identification programme, which also aimed to increase awareness and enhance participation within the sport.

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.