



# BIOMECHANICAL REPORT

FOR THE

*IAAF World Championships*

**LONDON 2017**

**4 x 100 m Relay Men's**

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## INTRODUCTION

Despite victory in the previous six global championship 4x100 m relay finals, Jamaica could not produce the same form that has also resulted in World Record times. Instead, the British quartet of Chijindu Ujah, Adam Gemili, Danny Talbot and Nethaneel Mitchell-Blake dominated from start to finish. Spurred on by a stadium-vibrating crowd, Mitchell-Blake held off the challenge of individual silver 100 m medallist Christian Coleman to secure the gold medal.

RECORDS	RESULT	TEAM	COUNTRY	VENUE	DATE
World Record <b>WR</b>	36.84	Jamaica	JAM	London (Olympic Stadium)	11 Aug 2012
Championships Record <b>CR</b>	37.04	Jamaica	JAM	Deegu (DS)	4 Sep 2011
World Leading <b>WL</b>	37.47	Great Britain & N.I.	GBR	London	12 Aug 2017
Area Record <b>AR</b>					
		National Record <b>NIR</b>			
			Season Best <b>SB</b>		

**12 August 2017** 22:01 START TIME 21° C TEMPERATURE 49 % HUMIDITY

PLACE	TEAM	BIB	LANE	REACTION	RESULT	Fr
1	<b>GREAT BRITAIN &amp; N.I.</b> Chijindu UJAH Adam GEMILI Daniel TALBOT Nethaneel MITCHELL-BLAKE	GBR	7	0.124	<b>37.47</b>	<b>WL</b>
2	<b>UNITED STATES</b> Mike RODGERS Justin GATLIN Jaylen BACON Christian COLEMAN	USA	4	0.155	<b>37.52</b>	<b>SB</b>
3	<b>JAPAN</b> Shuhei TADA Shota IIZUKA Yoshihide KIRYU Kenji FUJIMITSU	JPN	9	0.173	<b>38.04</b>	<b>SB</b>
4	<b>PR OF CHINA</b> Zhiqiang WU Zhenye XIE Bingtian SU Peimeng ZHANG	CHN	8	0.151	<b>38.34</b>	
5	<b>FRANCE</b> Stuart DUTAMBY Jimmy VICAUT Mickaël-Méba ZÉZÉ Christophe LEMAITRE	FRA	6	0.151	<b>38.48</b>	
6	<b>CANADA</b> Gavin SMELLIE Aaron BROWN Brendon RODNEY Mobolade AJOMALE	CAN	2	0.156	<b>38.59</b>	
7	<b>TURKEY</b> Yigitcan HEKIMOGLU Jak Ali HARVEY Emre Zafer BARNES Ramil GULIYEV	TUR	3	0.151	<b>38.73</b>	
	<b>JAMAICA</b> Omar MCLEOD Julian FORTE Yohan BLAKE Usain BOLT	JAM	5	0.149	<b>DNF</b>	

Timing and Measurement by SEIKO AT-4X1-M-f--1--.RS1..v1 Issued at 22:04 on Saturday, 12 August 2017 1 2

Official Partners

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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.

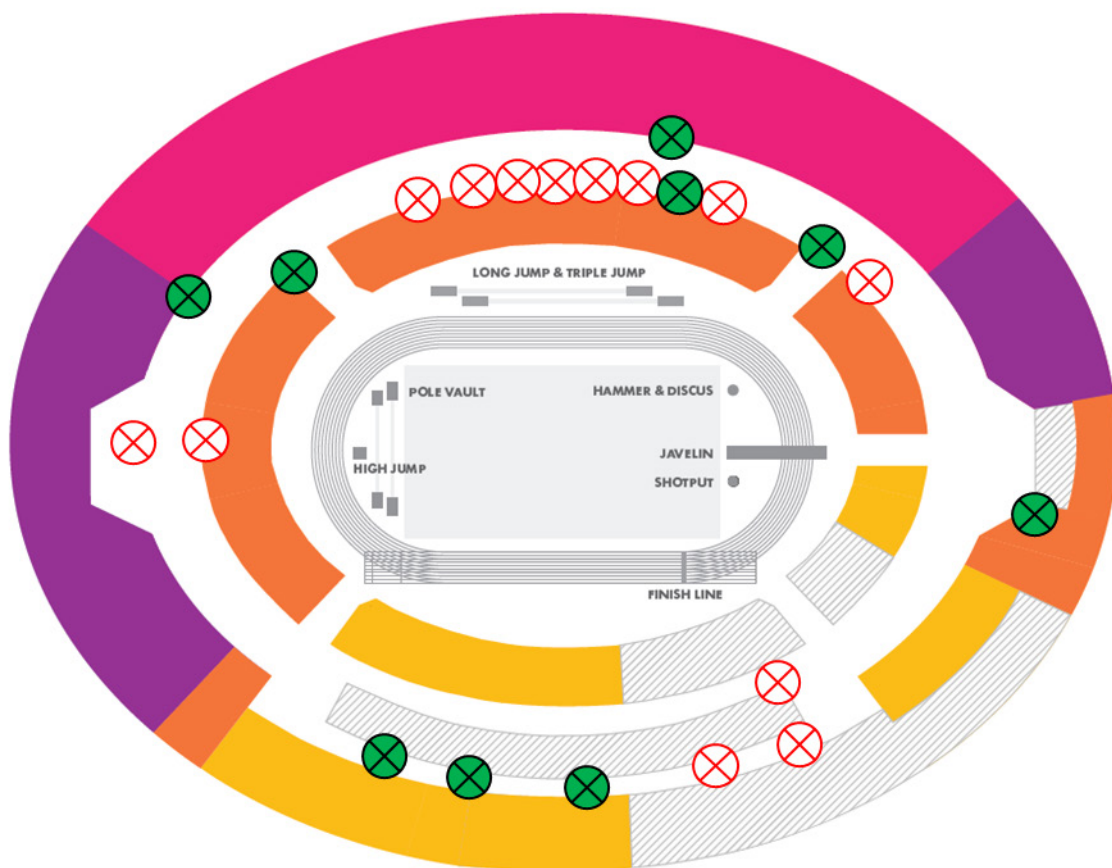


Figure 1. Camera layout (green in-filled circles) within the stadium for the 4x100 m relay men's.

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

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

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## 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).

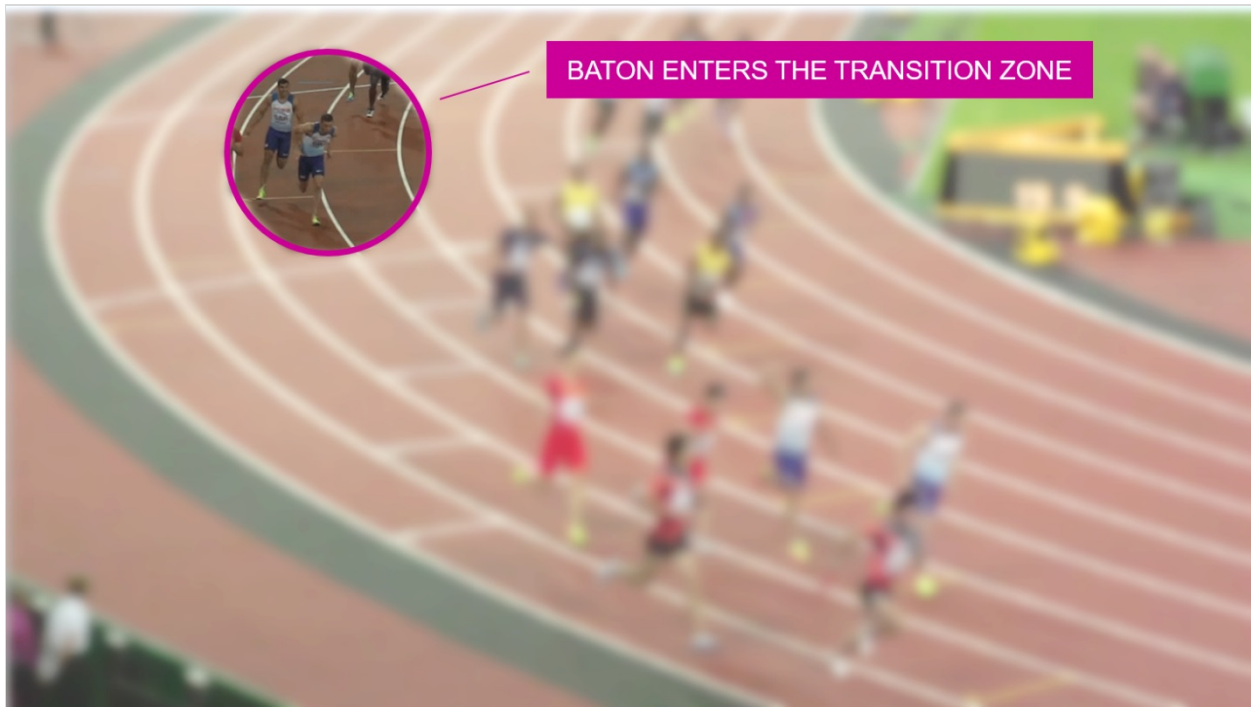


Figure 3. Phase 1: Baton entry - Baton enters the transition. Baton delivery phase begins.

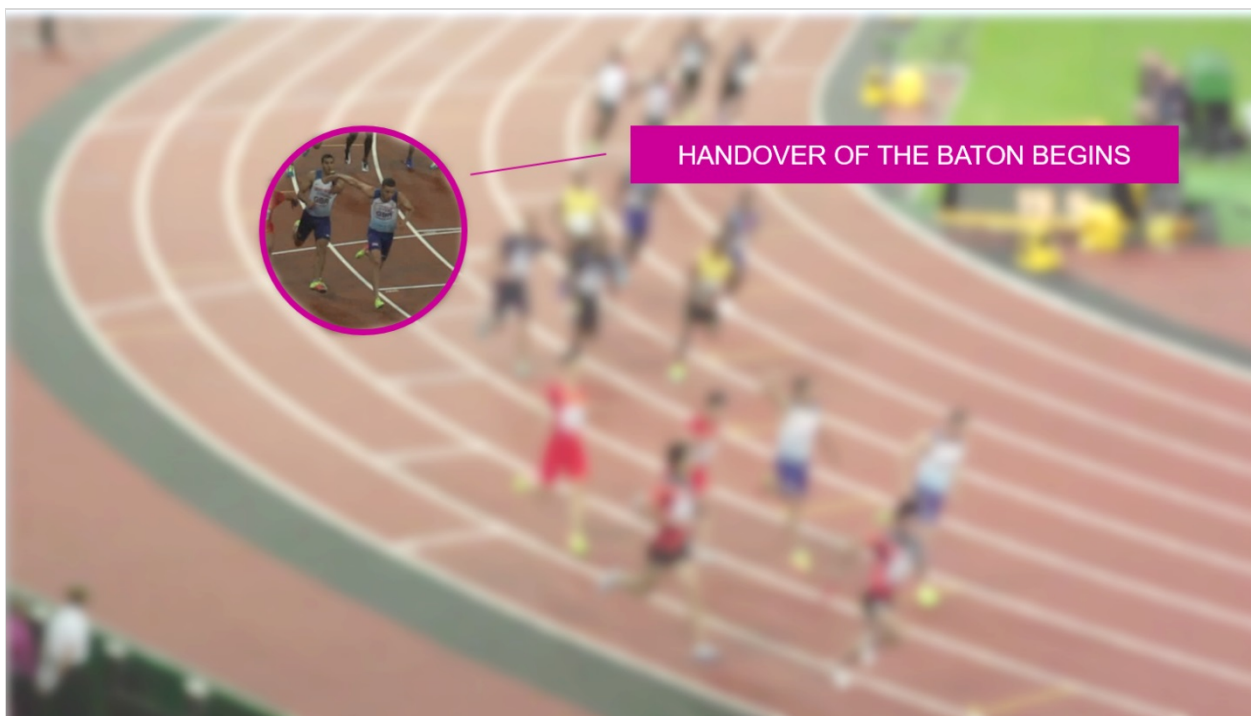


Figure 4. Phase 2: Initial contact - Handover of the baton begins.

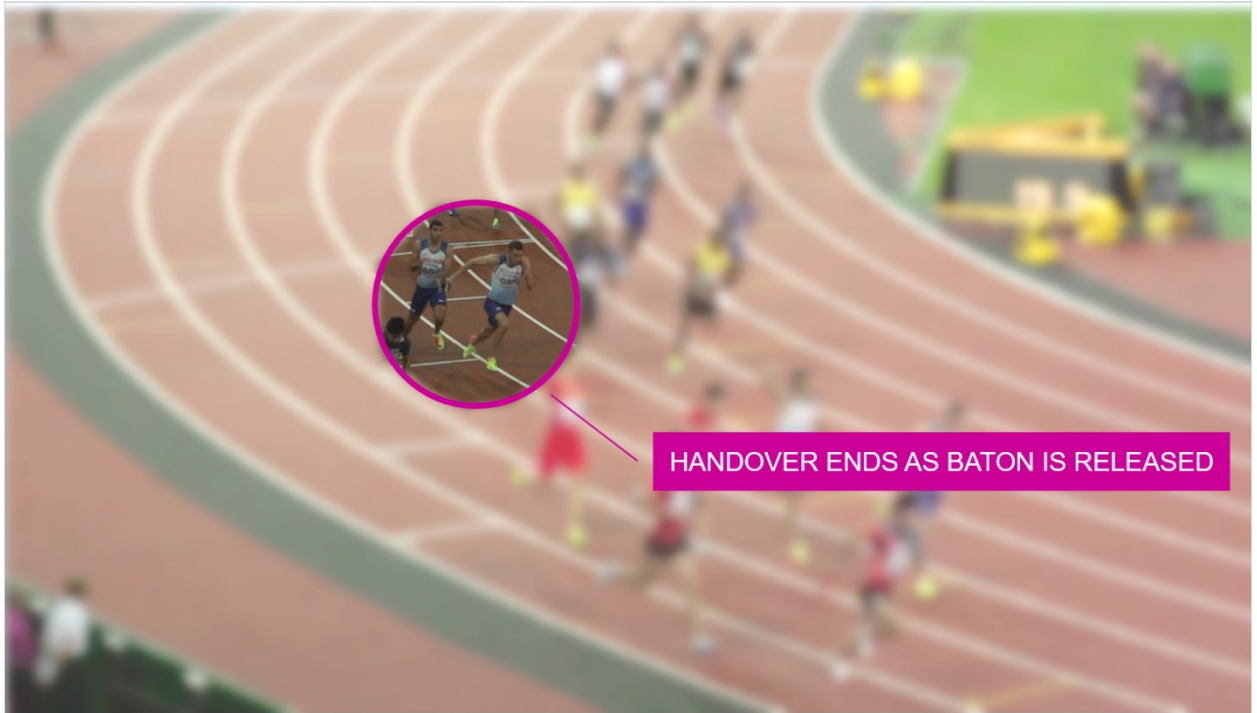


Figure 5. Phase 3: Release - Handover of the baton ends. Baton receive phase begins.

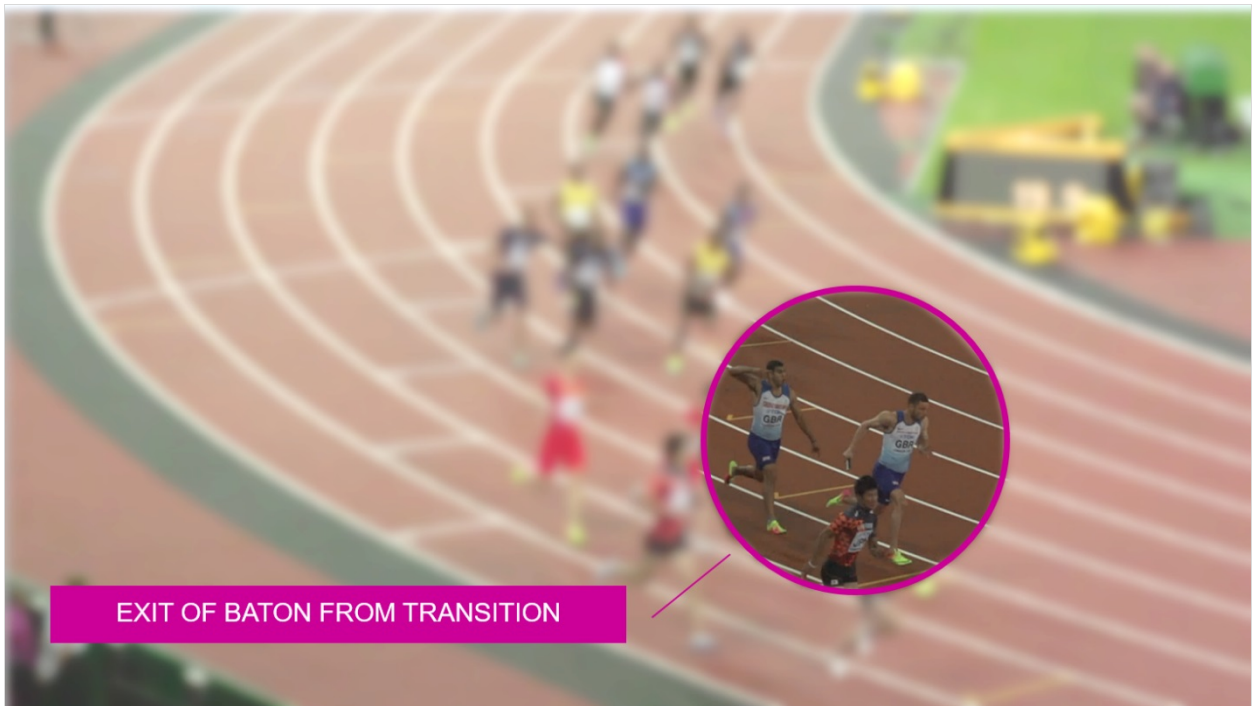


Figure 6. Phase 4: Baton exit - Baton exits the transition.

## 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
<b>GREAT BRITAIN &amp; N.I.</b>	38.08 s	1	37.73 s	5	<b>37.76 s</b>	2	SB
<b>UNITED STATES</b>	38.17 s	3	37.38 s	2	<b>37.70 s</b>	1	WL
<b>JAPAN</b>	39.07 s	7	37.60 s	3	<b>38.21 s</b>	6	SB
<b>PR OF CHINA</b>	38.19 s	4	37.82 s	7	<b>38.20 s</b>	5	
<b>FRANCE</b>	38.68 s	6	37.79 s	6	<b>38.03 s</b>	4	SB
<b>CANADA</b>	38.15 s	2	37.64 s	4	<b>38.48 s</b>	8	
<b>TURKEY</b>	39.15 s	8	38.30 s	8	<b>38.44 s</b>	7	SB
<b>JAMAICA</b>	38.59 s	5	36.84 s	1	<b>37.95 s</b>	3	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
<b>GREAT BRITAIN &amp; N.I.</b>	<b>37.47 s</b>	WL ER	<b>-0.29 s</b>	<b>-0.61 s</b>	<b>-0.26 s</b>
<b>UNITED STATES</b>	<b>37.52 s</b>	SB	<b>-0.18 s</b>	<b>-0.65 s</b>	0.14 s
<b>JAPAN</b>	<b>38.04 s</b>	SB	<b>-0.17 s</b>	<b>-1.03 s</b>	0.44 s
<b>PR OF CHINA</b>	<b>38.34 s</b>		0.14 s	0.15 s	0.52 s
<b>FRANCE</b>	<b>38.48 s</b>		0.45 s	<b>-0.20 s</b>	0.69 s
<b>CANADA</b>	<b>38.59 s</b>		0.11 s	0.44 s	0.95 s
<b>TURKEY</b>	<b>38.73 s</b>		0.29 s	<b>-0.42 s</b>	0.43 s
<b>JAMAICA</b>	-	DNF	-	-	-

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.

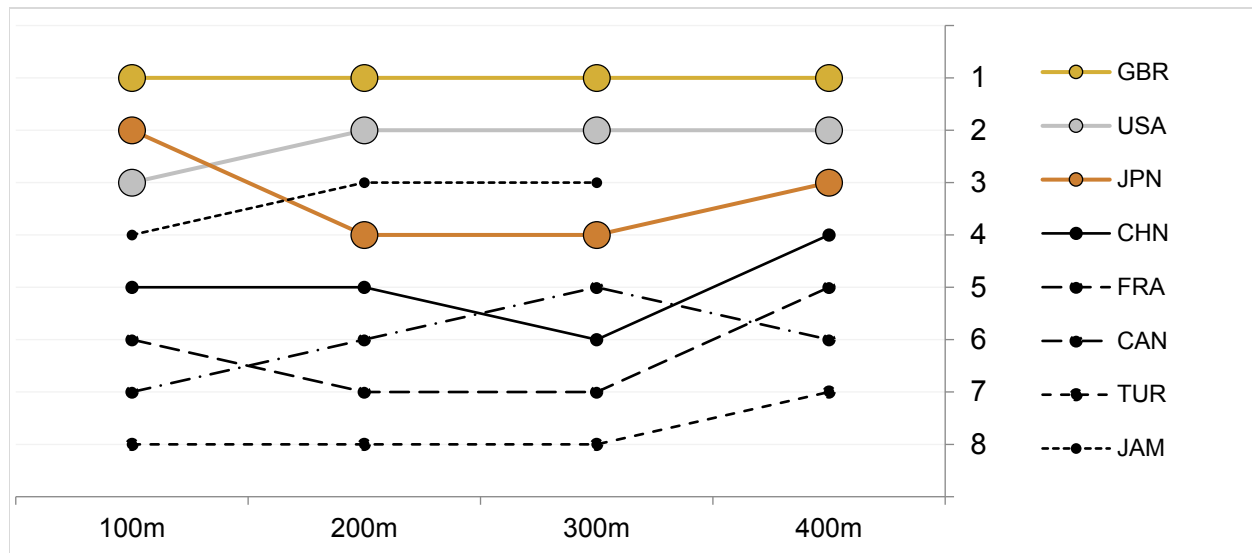


Figure 7. Positions of each team at each 100 m split.

## 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.

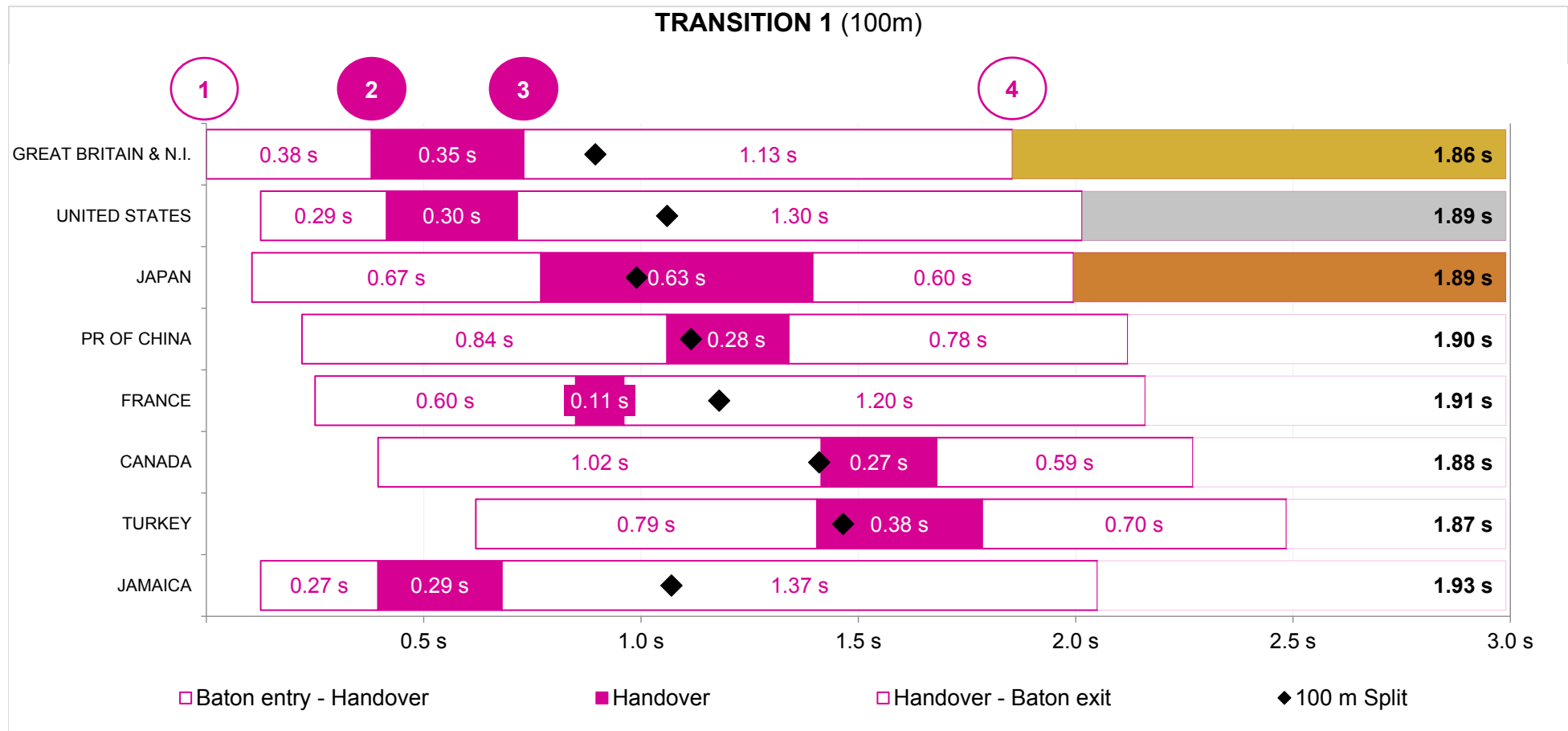


Figure 8. Analysis of timings and positions of each team within Transition 1. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

**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).

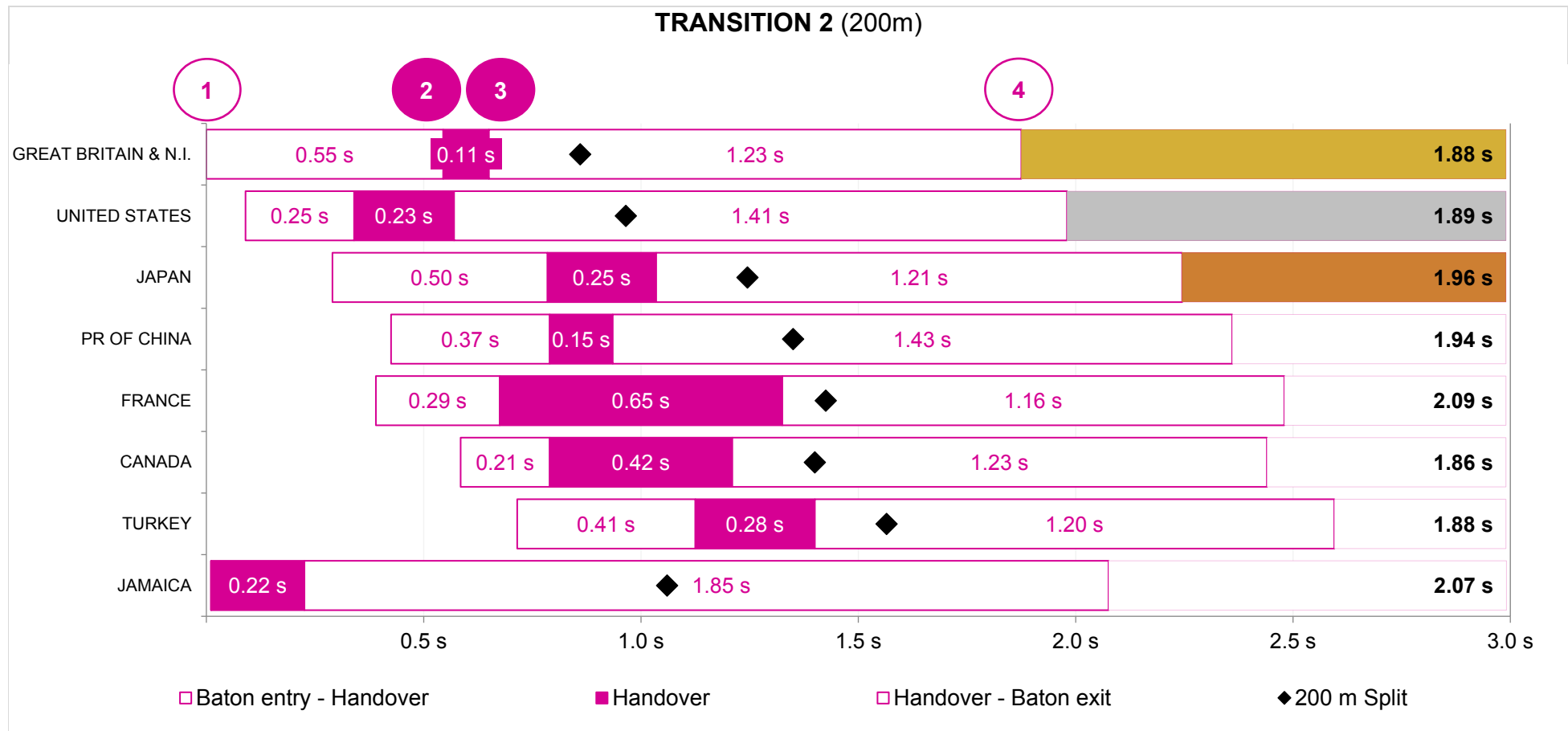


Figure 9. Analysis of timings and positions of each team within Transition 2. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

**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).

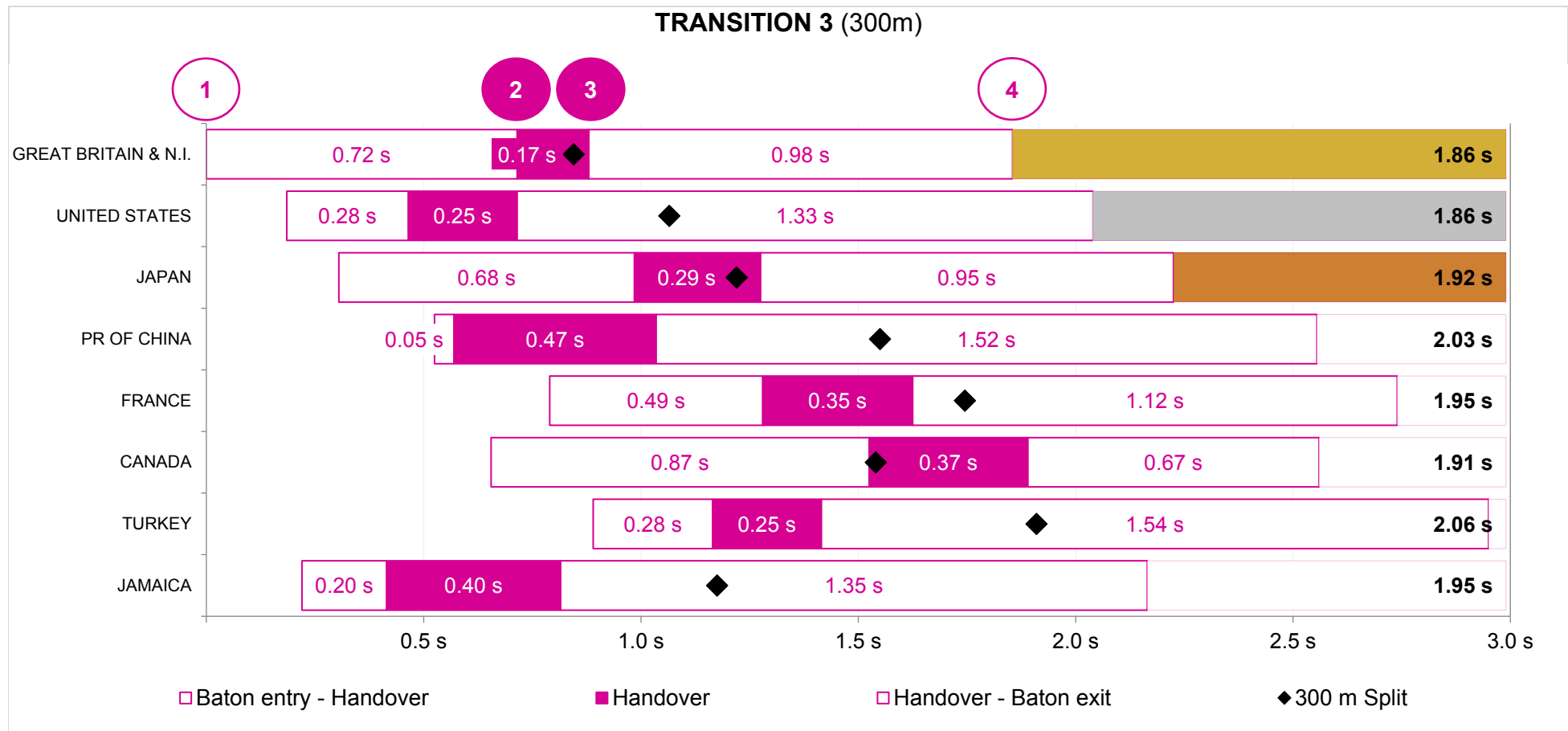


Figure 10. Analysis of timings and positions of each team within Transition 3. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

**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
<b>GREAT BRITAIN &amp; N.I.</b>	1.855	1.875	1.855	<b>5.585 s</b>	<b>14.9</b>
<b>UNITED STATES</b>	1.890	1.890	1.855	<b>5.635 s</b>	<b>15.0</b>
<b>JAPAN</b>	1.890	1.955	1.920	<b>5.765 s</b>	<b>15.2</b>
<b>PR OF CHINA</b>	1.900	1.935	2.030	<b>5.865 s</b>	<b>15.3</b>
<b>FRANCE</b>	1.910	2.090	1.950	<b>5.950 s</b>	<b>15.5</b>
<b>CANADA</b>	1.875	1.855	1.905	<b>5.635 s</b>	<b>14.6</b>
<b>TURKEY</b>	1.865	1.880	2.060	<b>5.805 s</b>	<b>15.0</b>
<b>JAMAICA</b>	1.925	2.065	1.945	<b>5.935 s</b>	<b>-</b>

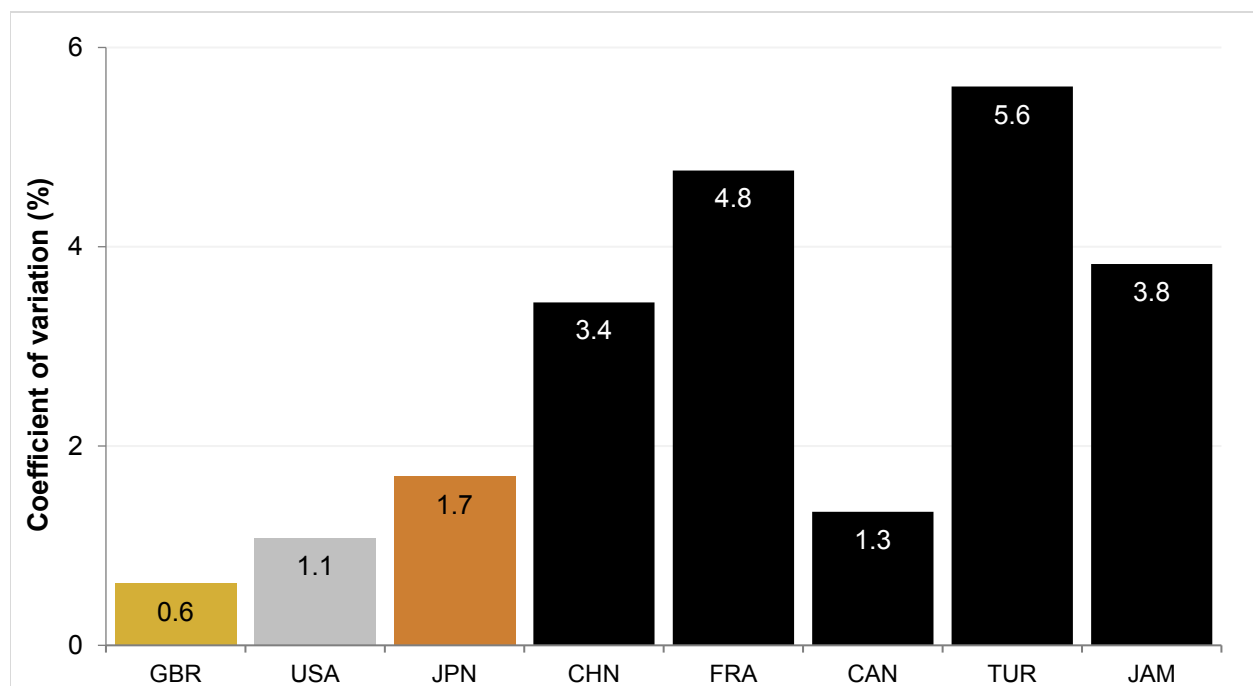


Figure 11. Variance (CV%) across total duration of each transition during the final.

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
<b>GREAT BRITAIN &amp; N.I.</b>	1.960	1.925	1.910	<b>5.795 s</b>	<b>15.3</b>
<b>UNITED STATES</b>	1.905	1.925	1.920	<b>5.750 s</b>	<b>15.3</b>
<b>JAPAN</b>	1.950	1.910	2.040	<b>5.900 s</b>	<b>15.4</b>
<b>PR OF CHINA</b>	1.860	1.905	1.950	<b>5.715 s</b>	<b>15.0</b>
<b>FRANCE</b>	1.920	1.985	1.925	<b>5.830 s</b>	<b>15.3</b>
<b>CANADA</b>	1.970	1.805	1.935	<b>5.710 s</b>	<b>14.8</b>
<b>TURKEY</b>	1.930	1.975	2.050	<b>5.955 s</b>	<b>15.5</b>
<b>JAMAICA</b>	1.995	1.960	2.000	<b>5.955 s</b>	<b>15.7</b>

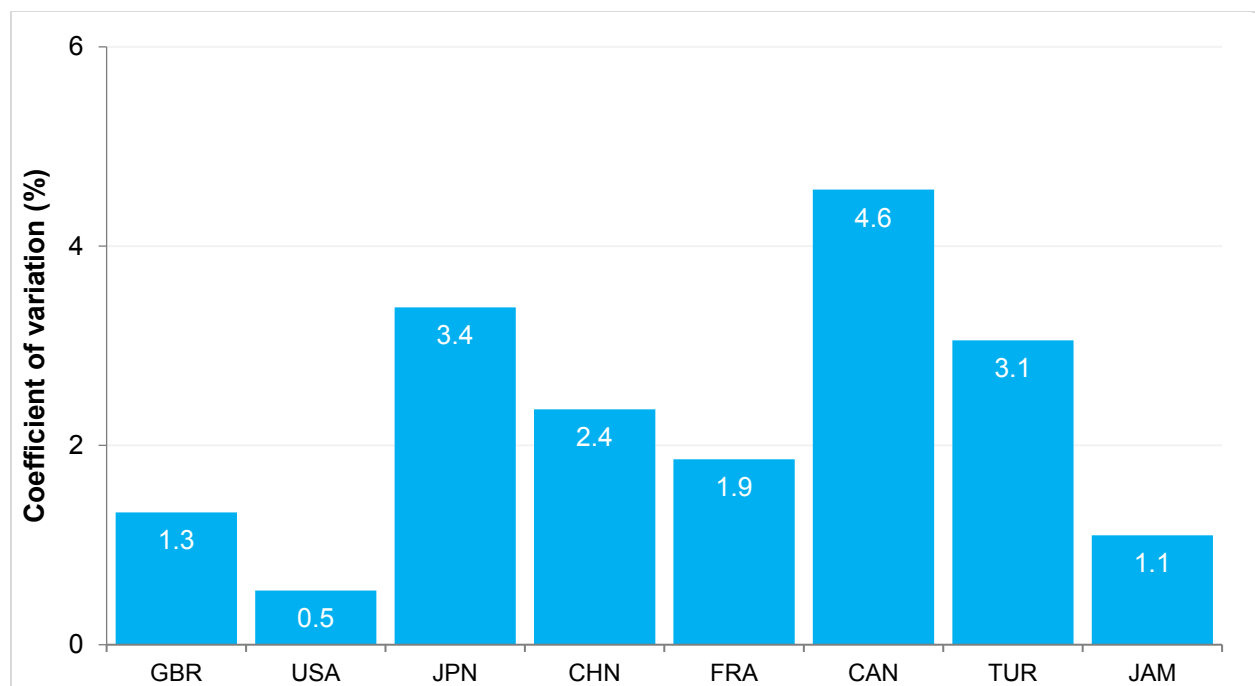


Figure 12. Variance (CV%) across total duration of each transition during the respective heats for all teams involved in the final.

## 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
<b>GREAT BRITAIN &amp; N.I.</b>	0.350	0.105	0.165	<b>0.620 s</b>	<b>1.7</b>
<b>UNITED STATES</b>	0.300	0.230	0.250	<b>0.780 s</b>	<b>2.1</b>
<b>JAPAN</b>	0.625	0.250	0.290	<b>1.165 s</b>	<b>3.1</b>
<b>PR OF CHINA</b>	0.280	0.145	0.465	<b>0.890 s</b>	<b>2.3</b>
<b>FRANCE</b>	0.110	0.650	0.345	<b>1.105 s</b>	<b>2.9</b>
<b>CANADA</b>	0.265	0.420	0.365	<b>1.050 s</b>	<b>2.7</b>
<b>TURKEY</b>	0.380	0.275	0.250	<b>0.905 s</b>	<b>2.3</b>
<b>JAMAICA</b>	0.285	0.215	0.400	<b>0.900 s</b>	<b>2.4</b>

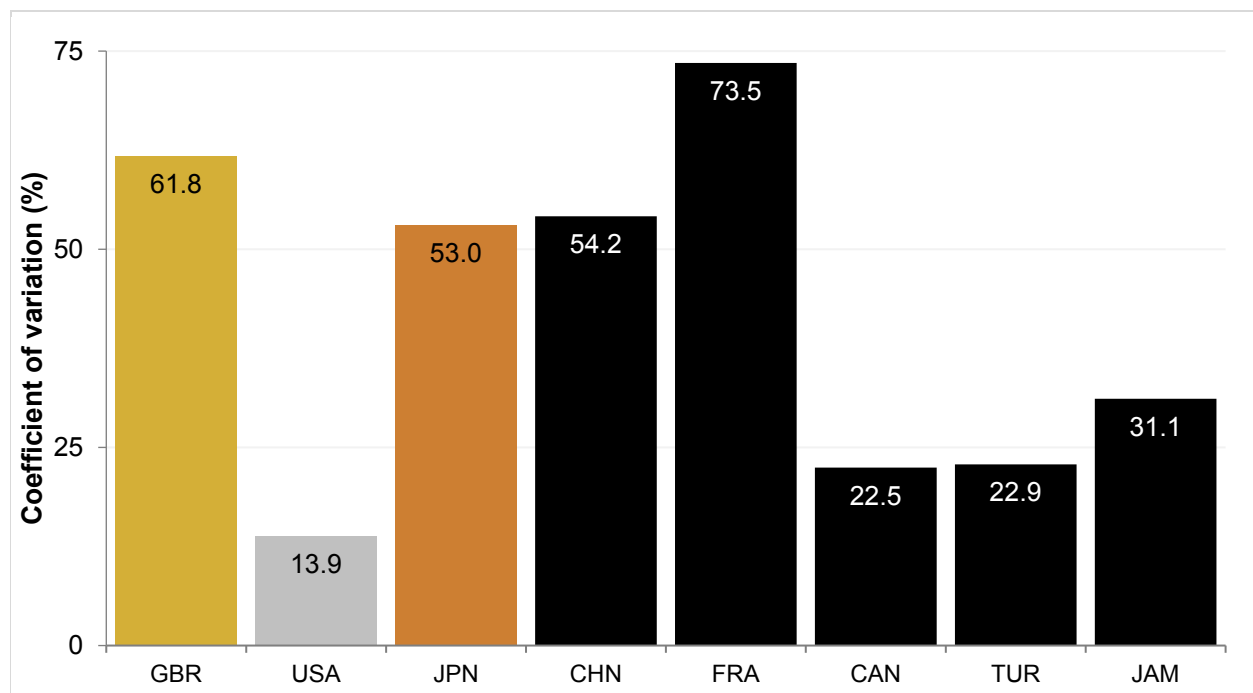
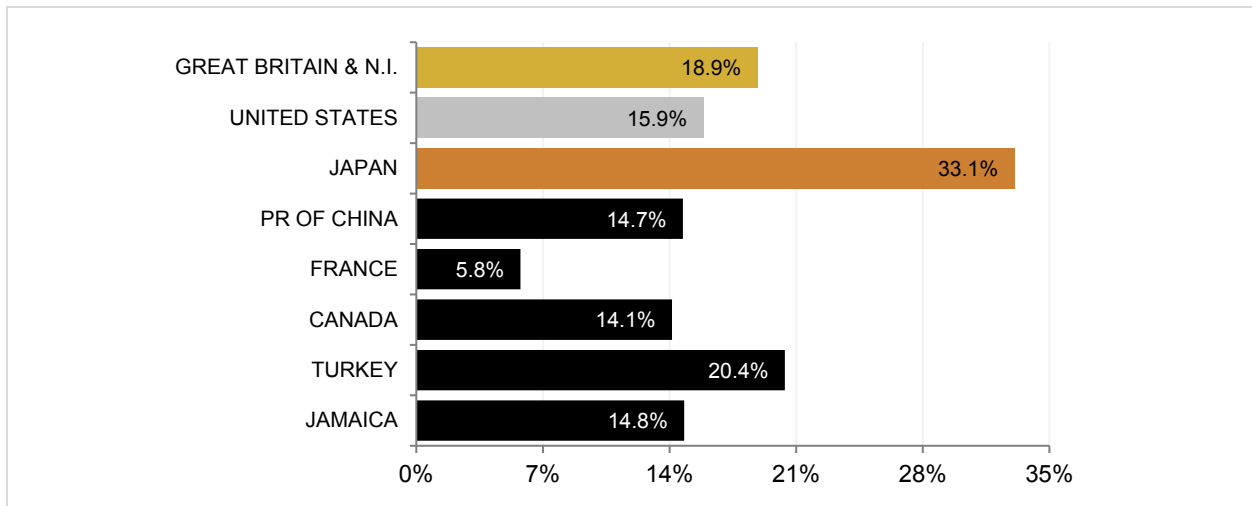
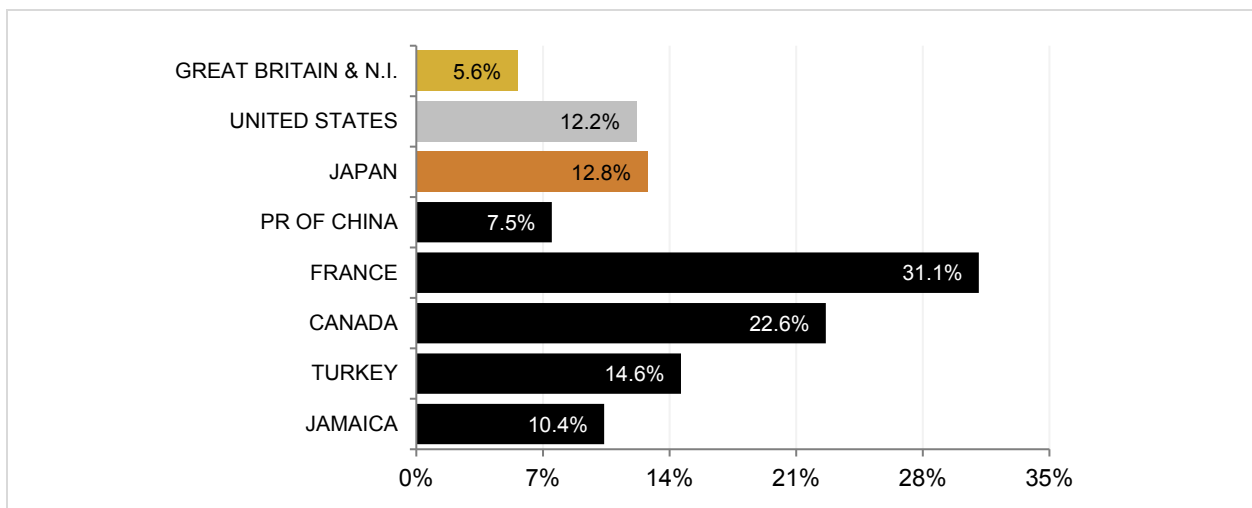


Figure 13. Variance (CV%) in handover duration across transitions during the final.

### Transition 1



### Transition 2



### Transition 3

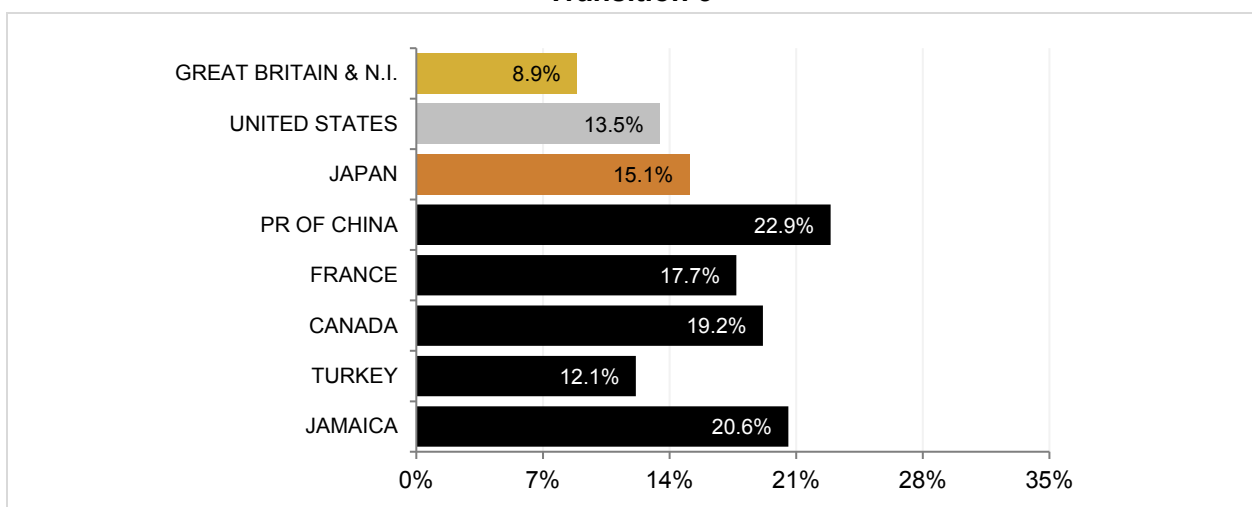


Figure 14. Duration of the handover phase as a percentage of the total transition time.

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
<b>GREAT BRITAIN &amp; N.I.</b>	0.195	0.210	0.510	<b>0.915 s</b>	<b>2.4</b>
<b>UNITED STATES</b>	0.195	0.250	0.325	<b>0.770 s</b>	<b>2.0</b>
<b>JAPAN</b>	0.250	0.575	0.165	<b>0.990 s</b>	<b>2.6</b>
<b>PR OF CHINA</b>	0.200	0.225	0.165	<b>0.590 s</b>	<b>1.5</b>
<b>FRANCE</b>	0.350	0.265	0.510	<b>1.125 s</b>	<b>3.0</b>
<b>CANADA</b>	0.325	0.150	0.335	<b>0.810 s</b>	<b>2.1</b>
<b>TURKEY</b>	0.305	0.330	0.335	<b>0.970 s</b>	<b>2.5</b>
<b>JAMAICA</b>	0.475	0.295	0.390	<b>1.160 s</b>	<b>3.1</b>

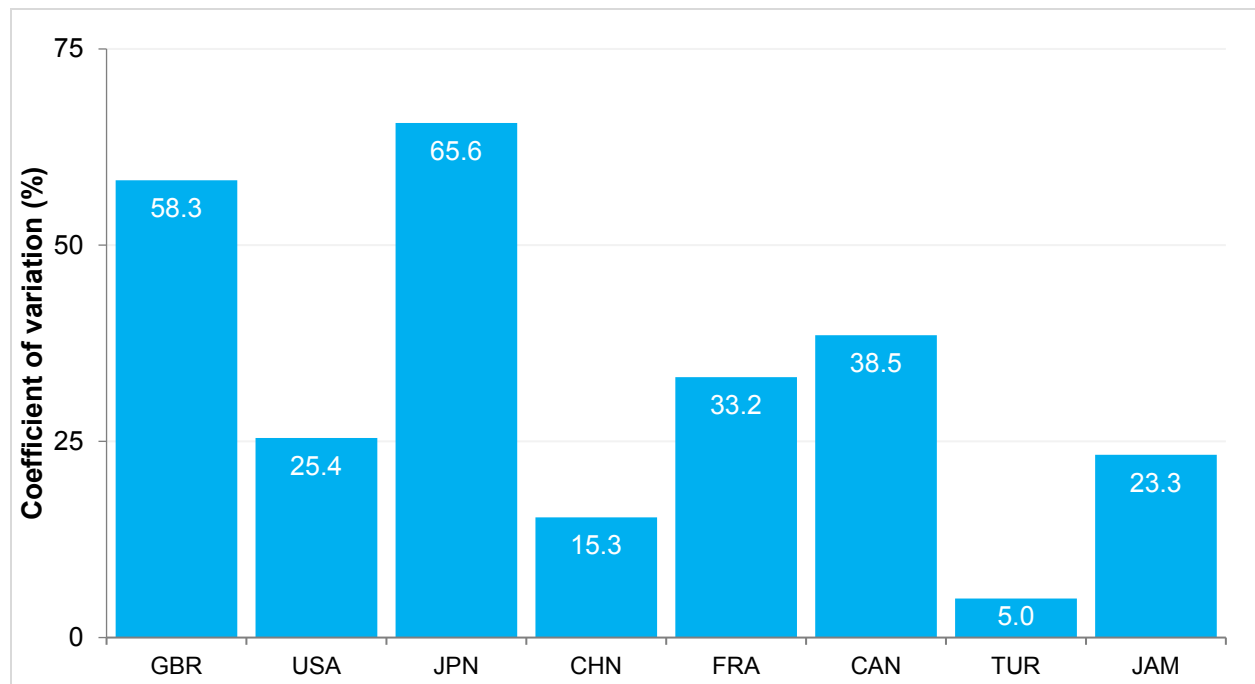


Figure 15. Variance (CV%) in handover duration across transitions during the respective heats for all teams involved in the final.

### 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).

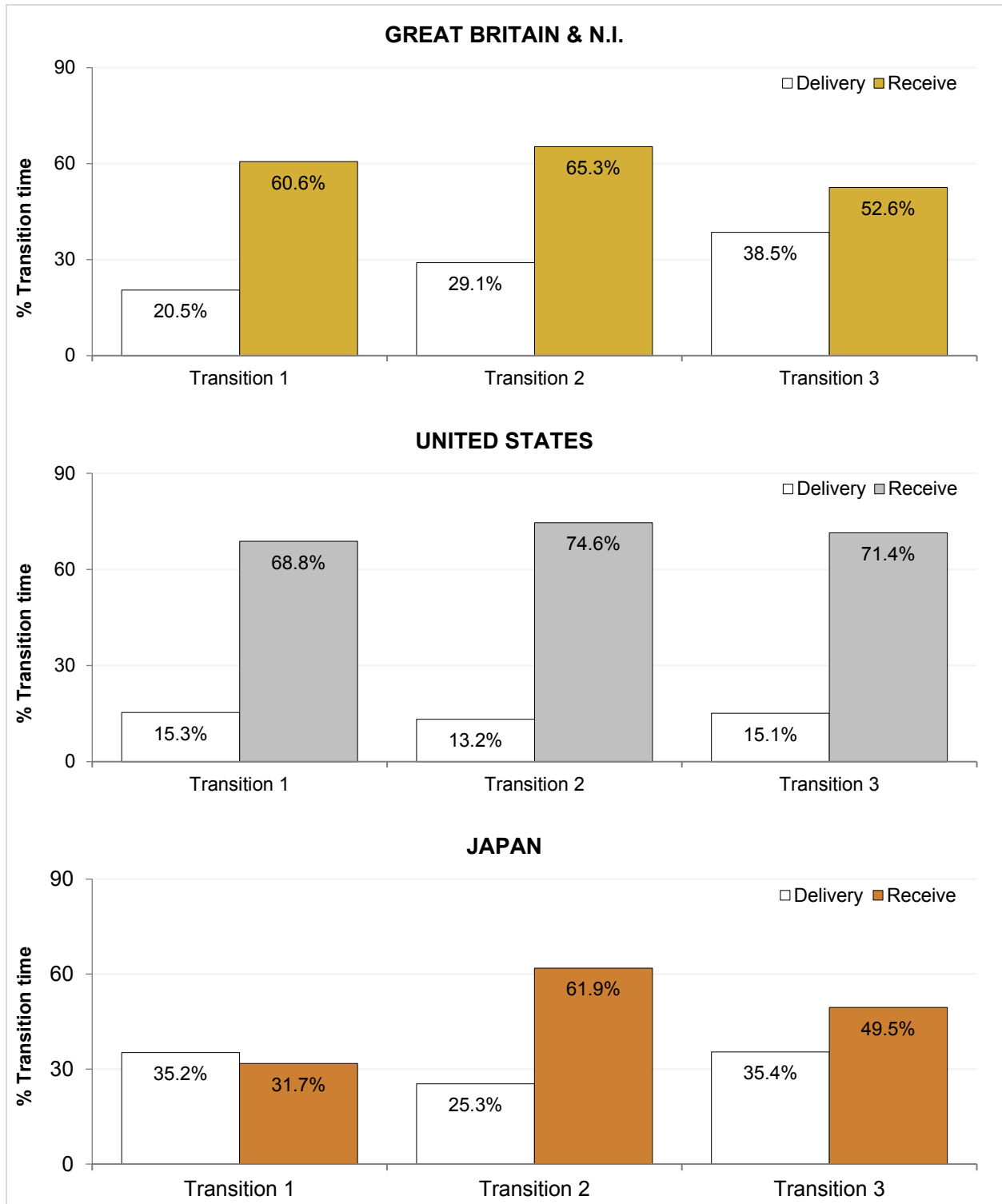


Figure 16. Relative time of baton with delivery and receive legs within transitions (medallists).

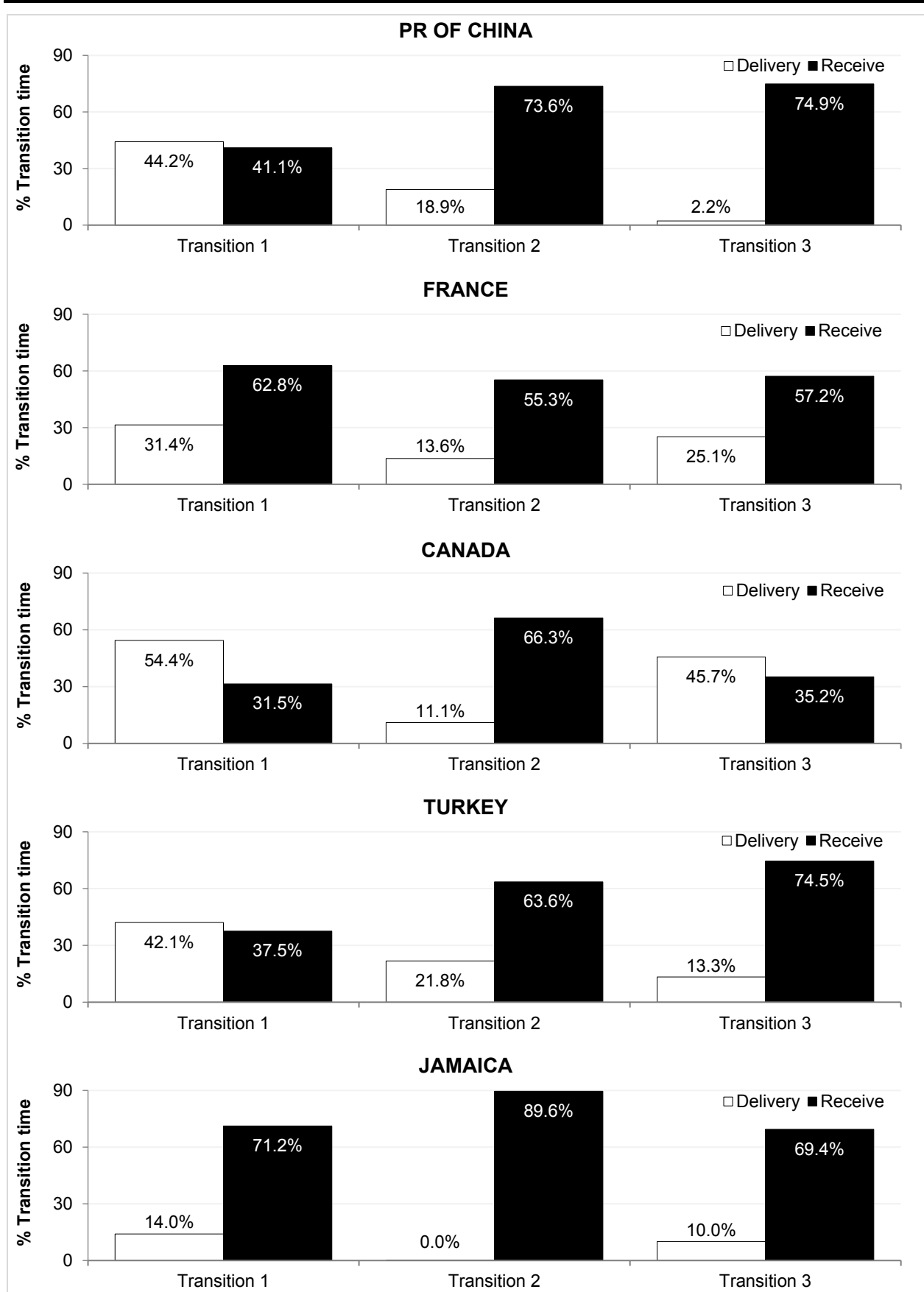


Figure 17. Relative time of baton with delivery and receive legs within transitions (non-medallists).

**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
<b>GREAT BRITAIN &amp; N.I.</b>	1.640 s	29.3%	3.325 s	59.4%	2.03
<b>UNITED STATES</b>	0.820 s	14.5%	4.035 s	71.5%	4.92
<b>JAPAN</b>	1.840 s	31.9%	2.760 s	47.8%	1.50
<b>PR OF CHINA</b>	1.250 s	21.3%	3.725 s	63.5%	2.98
<b>FRANCE</b>	1.375 s	23.1%	3.470 s	58.3%	2.52
<b>CANADA</b>	2.095 s	37.1%	2.490 s	44.1%	1.19
<b>TURKEY</b>	1.470 s	25.3%	3.430 s	59.0%	2.33
<b>JAMAICA</b>	0.465 s	7.8%	4.570 s	76.8%	9.82

*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.*

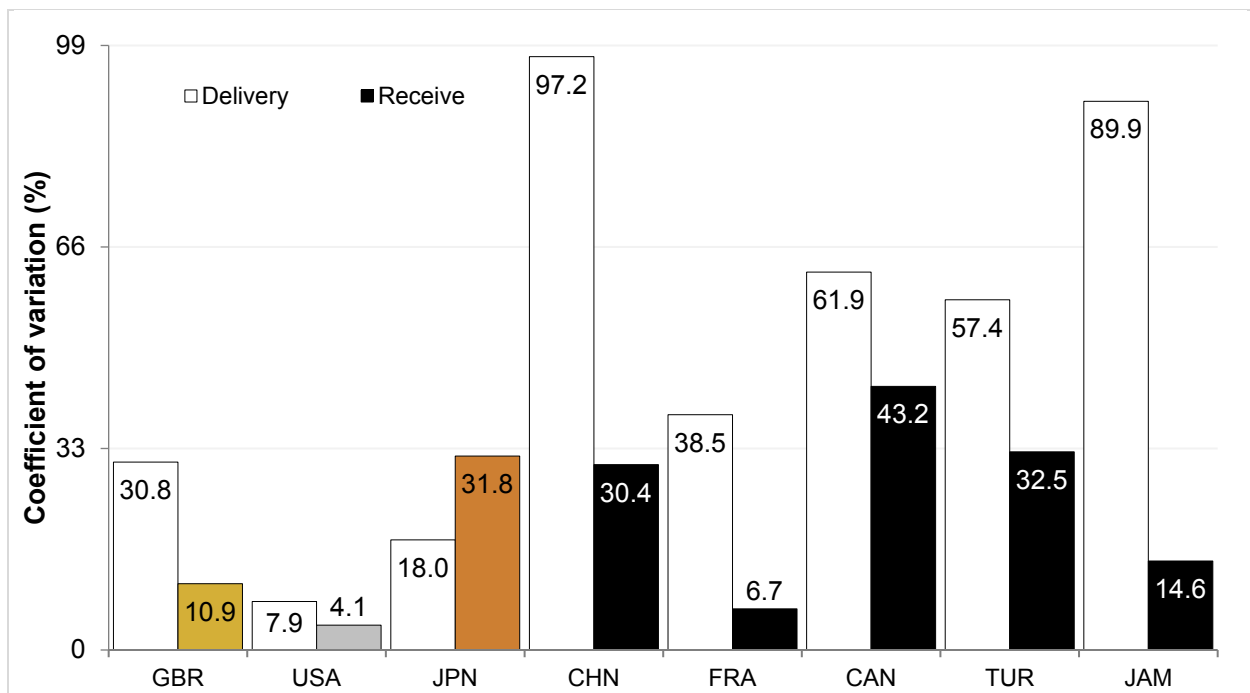


Figure 18. Variance (CV%) across transitions for delivery and receive leg times during the final.



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
<b>GREAT BRITAIN &amp; N.I.</b>	1.670 s	28.8%	3.210 s	55.3%	1.92
<b>UNITED STATES</b>	0.780 s	13.5%	4.200 s	72.9%	5.38
<b>JAPAN</b>	1.140 s	19.3%	3.770 s	63.9%	3.31
<b>PR OF CHINA</b>	1.805 s	31.6%	3.320 s	58.0%	1.84
<b>FRANCE</b>	1.775 s	30.4%	2.930 s	50.2%	1.65
<b>CANADA</b>	1.775 s	31.0%	3.125 s	54.6%	1.76
<b>TURKEY</b>	0.875 s	14.7%	4.120 s	69.1%	4.71
<b>JAMAICA</b>	0.790 s	13.3%	4.030 s	67.6%	5.10

**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.

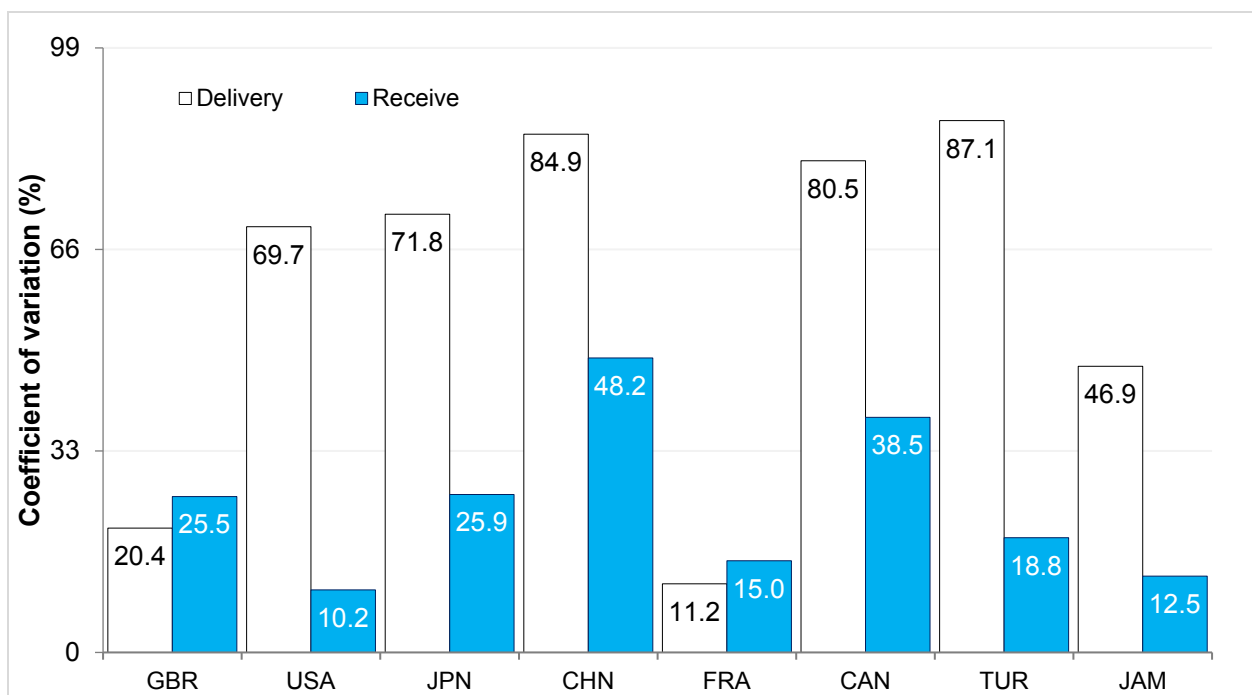


Figure 19. Variance (CV%) across transitions for delivery and receive leg times during the respective heats for all teams involved in the final.

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
<b>GREAT BRITAIN &amp; N.I.</b>	48.2	45.9	45.6	1.5%
<b>UNITED STATES</b>	49.5	46.3	47.4	1.6%
<b>JAPAN</b>	46.8	48.8	47.7	1.0%
<b>PR OF CHINA</b>	47.1	47.8	50.5	1.8%
<b>FRANCE</b>	48.7	49.5	49.0	0.4%
<b>CANADA</b>	54.1	43.9	46.5	5.3%
<b>TURKEY</b>	45.3	45.2	49.5	2.5%
<b>JAMAICA</b>	49.1	50.8	49.1	1.0%

*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
<b>GREAT BRITAIN &amp; N.I.</b>	49.7	37.8	47.1	13.9%
<b>UNITED STATES</b>	48.3	47.0	49.5	2.6%
<b>JAPAN</b>	48.2	40.5	50.2	11.1%
<b>PR OF CHINA</b>	51.6	46.7	47.9	5.2%
<b>FRANCE</b>	46.9	48.1	47.5	1.3%
<b>CANADA</b>	47.7	48.8	48.8	1.3%
<b>TURKEY</b>	45.6	47.3	49.8	4.4%
<b>JAMAICA</b>	47.6	46.7	49.0	2.4%

*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 (%)
<b>GREAT BRITAIN &amp; N.I.</b>	10.5	14.9	14.8
<b>UNITED STATES</b>	8.2	15.3	11.1
<b>JAPAN</b>	13.0	7.9	10.7
<b>PR OF CHINA</b>	11.3	10.9	1.7
<b>FRANCE</b>	9.4	6.7	6.9
<b>CANADA</b>	20.0	15.6	12.3
<b>TURKEY</b>	18.0	16.0	6.8
<b>JAMAICA</b>	9.4	4.8	8.2

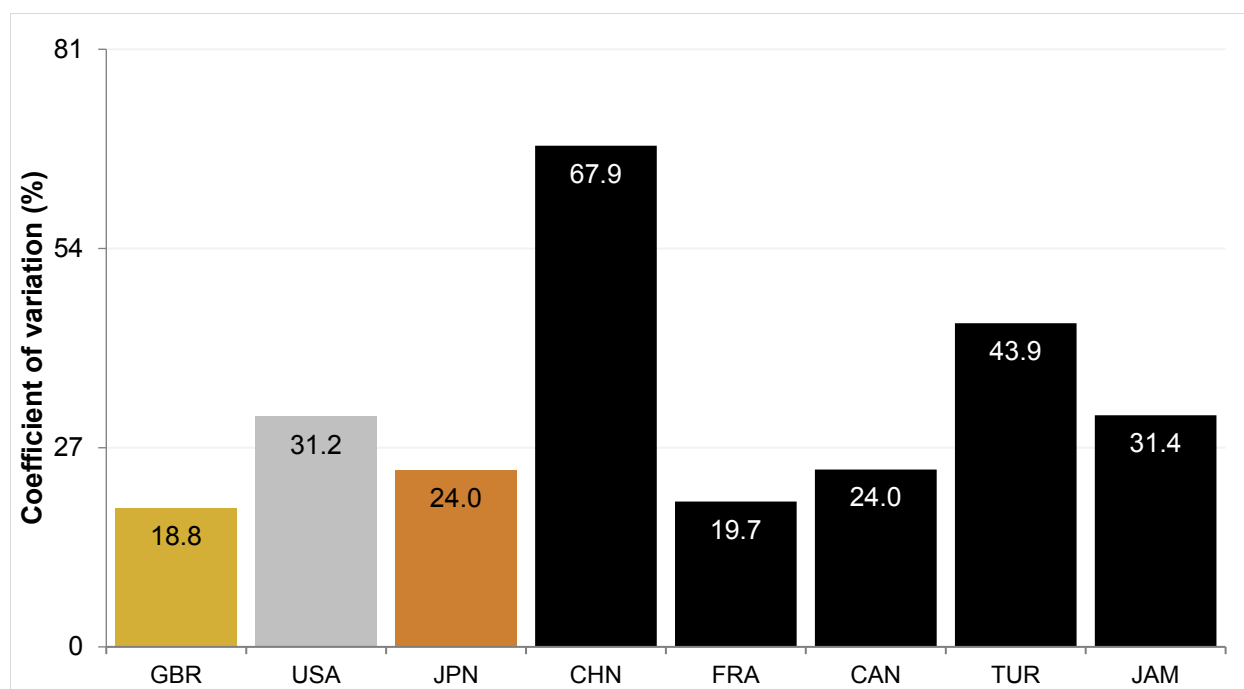


Figure 20. Variance (CV%) of the receiver entry times across transitions during the final.

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 (%)
<b>GREAT BRITAIN &amp; N.I.</b>	5.9	15.6	10.5
<b>UNITED STATES</b>	11.5	13.2	6.0
<b>JAPAN</b>	11.5	11.6	5.1
<b>PR OF CHINA</b>	18.8	14.2	9.7
<b>FRANCE</b>	12.2	11.1	8.8
<b>CANADA</b>	9.9	31.0	7.8
<b>TURKEY</b>	15.8	12.2	5.4
<b>JAMAICA</b>	11.3	17.9	6.8

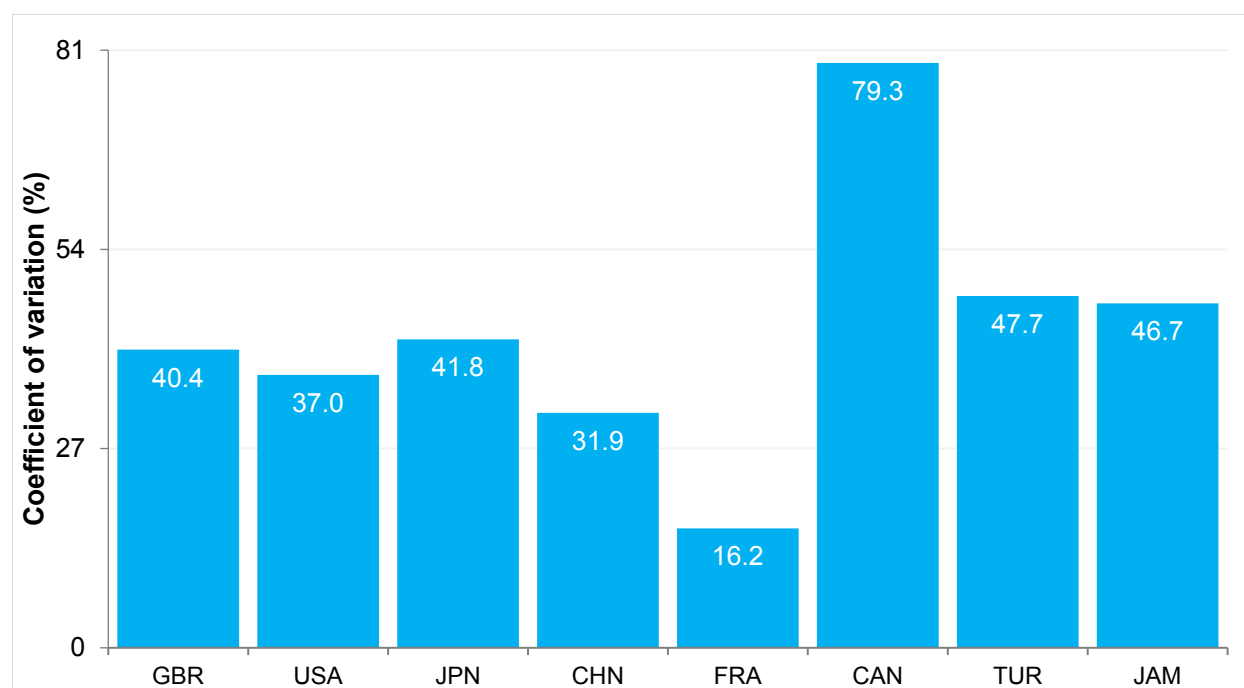


Figure 21. Variance (CV%) of the receiver entry times across transitions during the respective heat of each team involved in the final.

### 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
<b>GREAT BRITAIN &amp; N.I.</b>	-	-	-	-	-	-
<b>UNITED STATES</b>	0.125	<b>-0.070</b>	0.080	<b>-0.135</b>	<b>0.000 s</b>	<b>0.05 s</b>
<b>JAPAN</b>	0.105	0.150	<b>-0.065</b>	0.200	<b>0.390 s</b>	<b>0.57 s</b>
<b>PR OF CHINA</b>	0.220	0.160	0.040	0.170	<b>0.590 s</b>	<b>0.87 s</b>
<b>FRANCE</b>	0.250	0.085	0.185	0.125	<b>0.645 s</b>	<b>1.01 s</b>
<b>CANADA</b>	0.395	0.170	0.090	0.415	<b>1.070 s</b>	<b>1.12 s</b>
<b>TURKEY</b>	0.620	0.085	0.170	0.165	<b>1.040 s</b>	<b>1.26 s</b>
<b>JAMAICA</b>	0.125	<b>-0.185</b>	0.020	-	<b>-0.040 s</b>	-

*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
<b>GREAT BRITAIN &amp; N.I.</b>	-	-	-	-	-
<b>UNITED STATES</b>	0.035	0.015	0.000	<b>0.050 s</b>	<b>0.05 s</b>
<b>JAPAN</b>	0.035	0.080	0.065	<b>0.180 s</b>	<b>0.57 s</b>
<b>PR OF CHINA</b>	0.045	0.060	0.175	<b>0.280 s</b>	<b>0.87 s</b>
<b>FRANCE</b>	0.055	0.215	0.095	<b>0.365 s</b>	<b>1.01 s</b>
<b>CANADA</b>	0.020	<b>-0.020</b>	0.050	<b>0.050 s</b>	<b>1.12 s</b>
<b>TURKEY</b>	0.010	0.005	0.205	<b>0.220 s</b>	<b>1.26 s</b>
<b>JAMAICA</b>	0.070	0.190	0.090	<b>0.350 s</b>	-

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

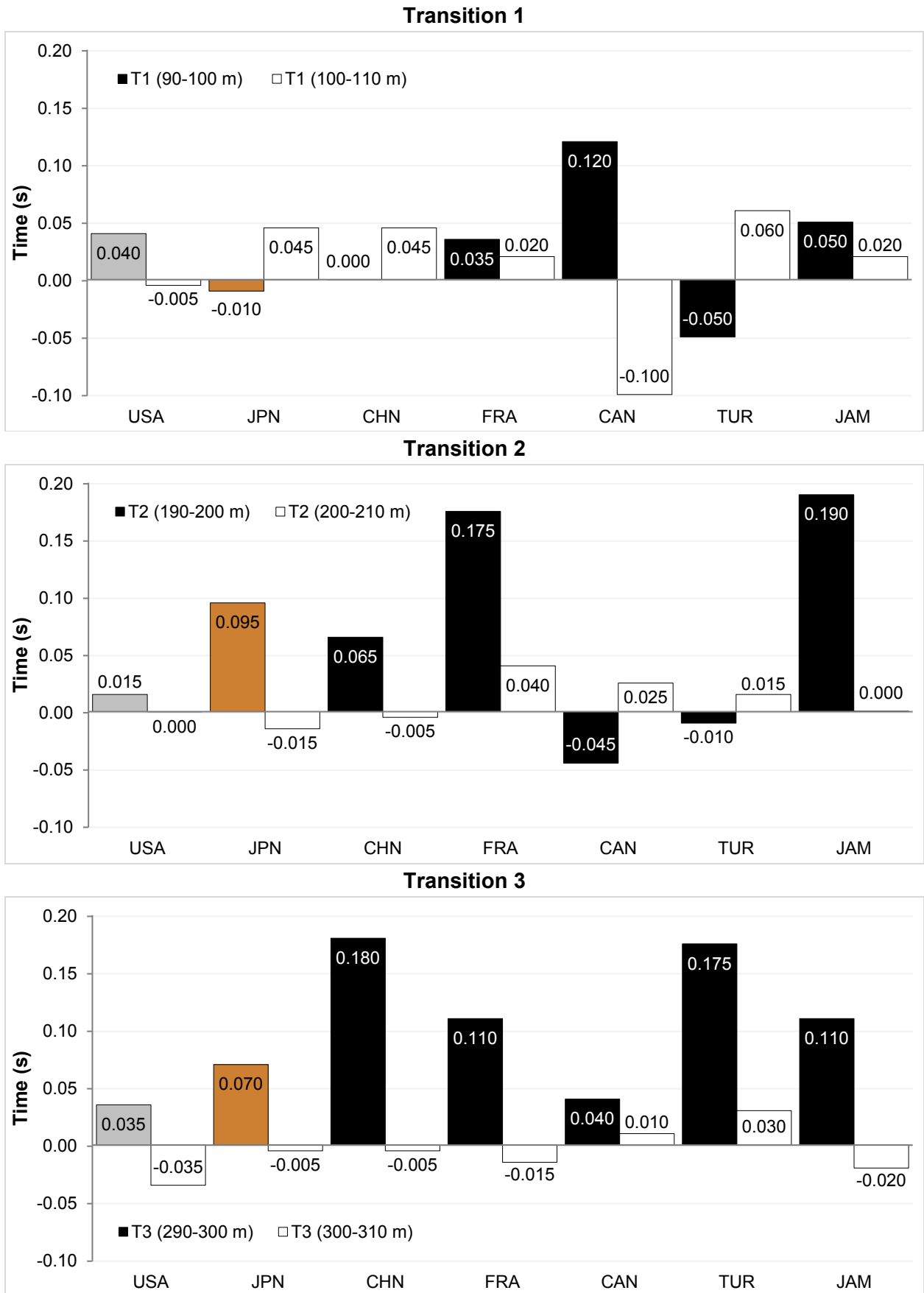


Figure 22. Time lost (+) or gained (-) on the gold medalists within transitions.

### 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).

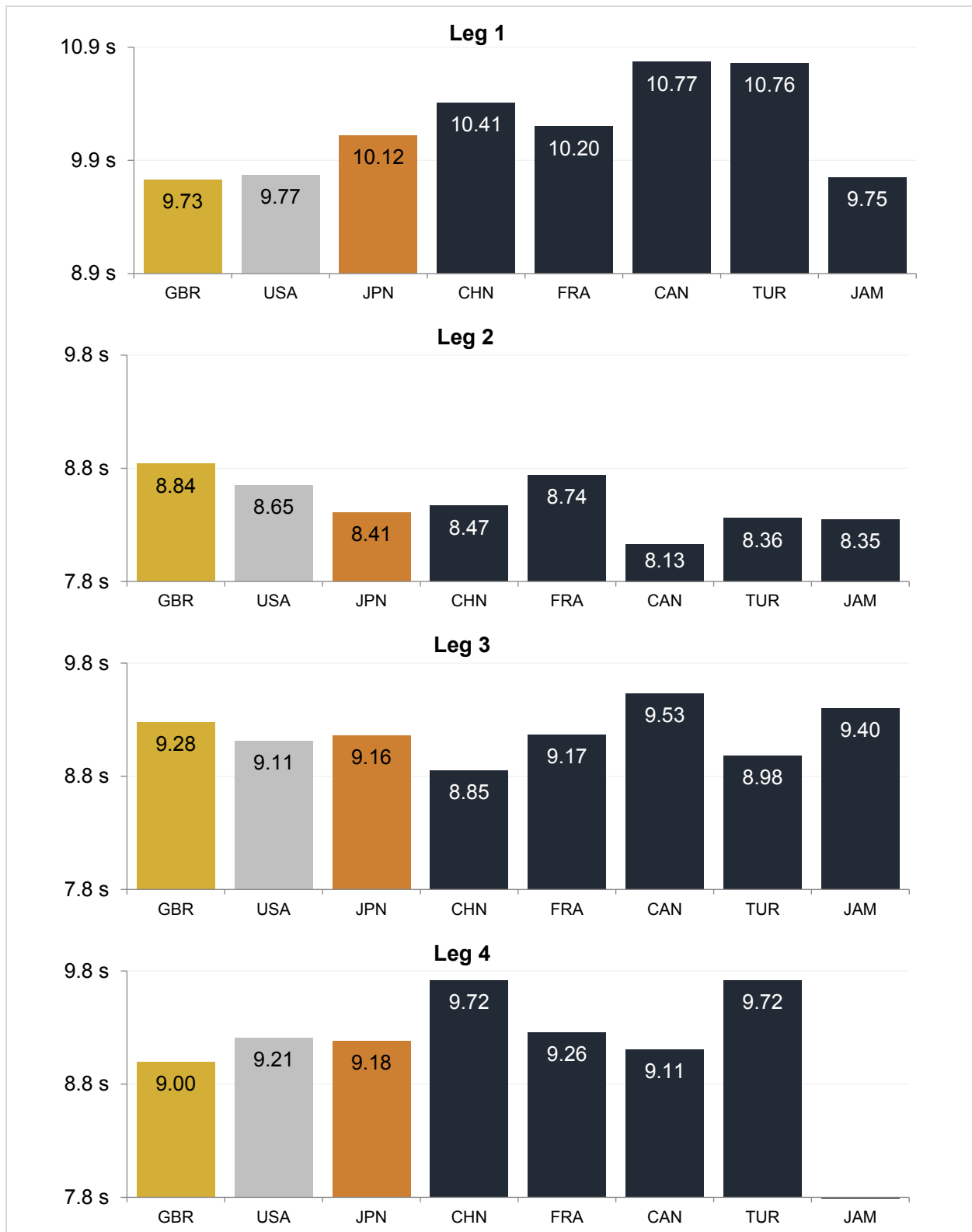


Figure 23. Split times for each individual leg excluding handover phase duration (Leg 1 minus reaction time).

### Split times: 100 m splits

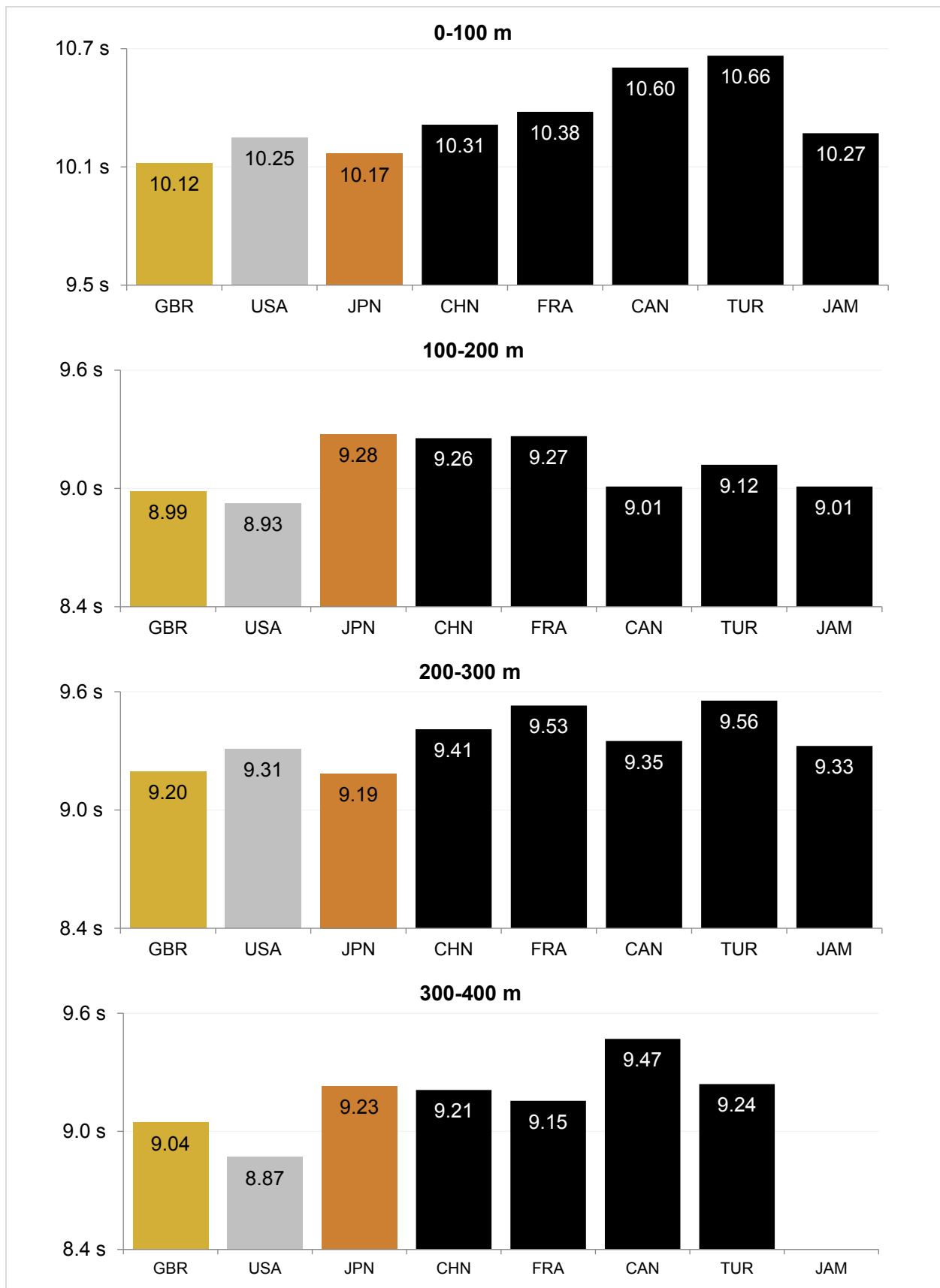


Figure 24. Team split times over consecutive 100 m (0-100 m minus reaction time).



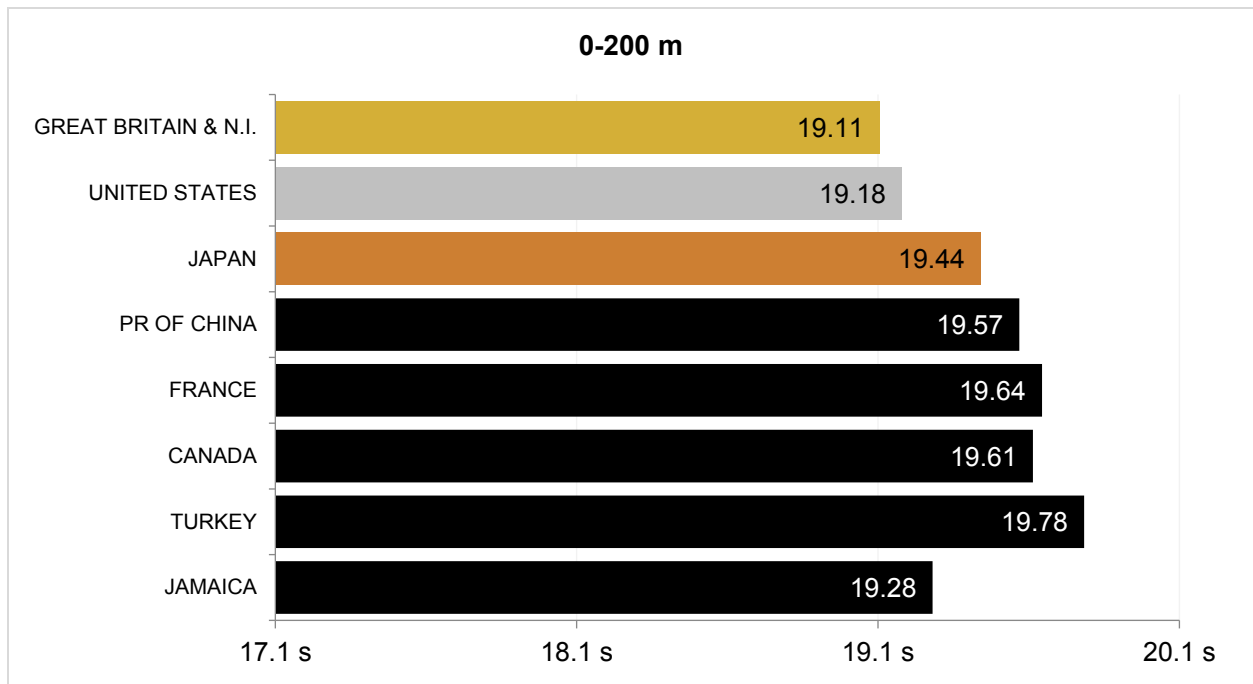
**Split times: 200 m splits**

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

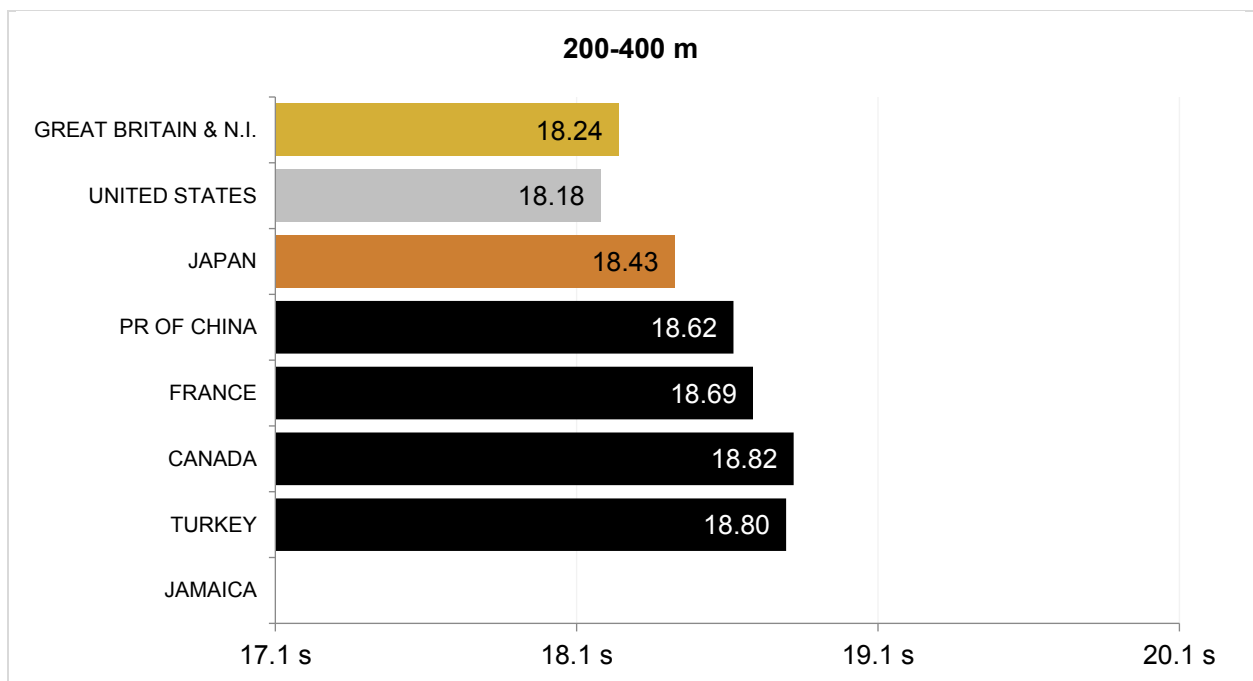


Figure 26. Team 200-400 m split times.

## GOLD MEDALLIST: Great Britain & N.I.



	RT	100 m	200 m	300 m	RESULT	
Final	0.124 s	10.25 s	19.23 s	28.43 s	<b>37.47 s</b>	
Rank	1 <sup>st</sup>	1 <sup>st</sup>	1 <sup>st</sup>	1 <sup>st</sup>	1 <sup>st</sup>	
vs. silver	-0.031 s	-0.16 s	-0.11 s	-0.22 s	-0.05 s	
vs. bronze	-0.049 s	-0.09 s	-0.39 s	-0.38 s	-0.57 s	
Semi-Final	0.145 s	10.38 s	19.33 s	28.62 s	37.76 s	
Rank	5 <sup>th</sup>	1 <sup>st</sup>	1 <sup>st</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	
	0-100 m	100-200 m	0-200 m	200-300 m	300-400 m	200-400 m
Final	10.12 s	8.99 s	19.11 s	9.20 s	9.04 s	18.24 s
Rank	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	2 <sup>nd</sup>	2 <sup>nd</sup>
vs. silver	-0.13 s	+0.06 s	-0.07 s	-0.11 s	+0.18 s	+0.07 s
vs. bronze	-0.05 s	-0.29 s	-0.33 s	+0.01 s	-0.19 s	-0.18 s
Semi-Final	10.23 s	8.96 s	19.19 s	9.29 s	9.14 s	18.43 s
Rank	3 <sup>rd</sup>	1 <sup>st</sup>	1 <sup>st</sup>	4 <sup>th</sup>	4 <sup>th</sup>	4 <sup>th</sup>

## 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
<b>UNITED STATES</b>	3	2	<b>37.70 s</b>	<i>WL</i>	<b>-0.47 s</b>	0.32 s
<b>GREAT BRITAIN &amp; N.I.</b>	1	6	<b>37.76 s</b>	<i>SB</i>	<b>-0.32 s</b>	0.03 s
<b>JAPAN</b>	11	3	<b>38.21 s</b>	<i>SB</i>	<b>-0.86 s</b>	0.61 s
<b>TURKEY</b>	13	14	<b>38.44 s</b>	<i>SB</i>	<b>-0.71 s</b>	0.14 s
<b>TRINIDAD &amp; TOBAGO</b>	10	4	<b>38.61 s</b>	<i>SB</i>	<b>-0.43 s</b>	0.99 s
<b>NETHERLANDS</b>	8	13	<b>38.66 s</b>	<i>SB</i>	<b>-0.05 s</b>	0.37 s
<b>AUSTRALIA</b>	12	12	<b>38.88 s</b>	<i>SB</i>	<b>-0.20 s</b>	0.71 s
<b>BARBADOS</b>	14	16	<b>39.19 s</b>		0.01 s	0.64 s

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.

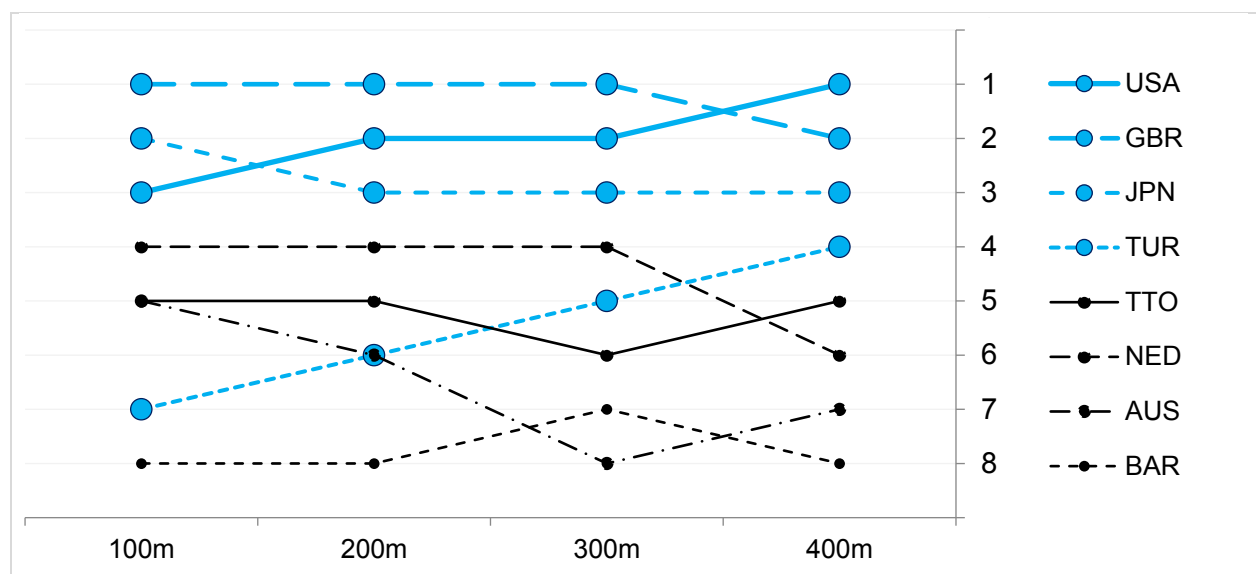


Figure 27. Positions at the end of each 100 m split.

## Transition analysis

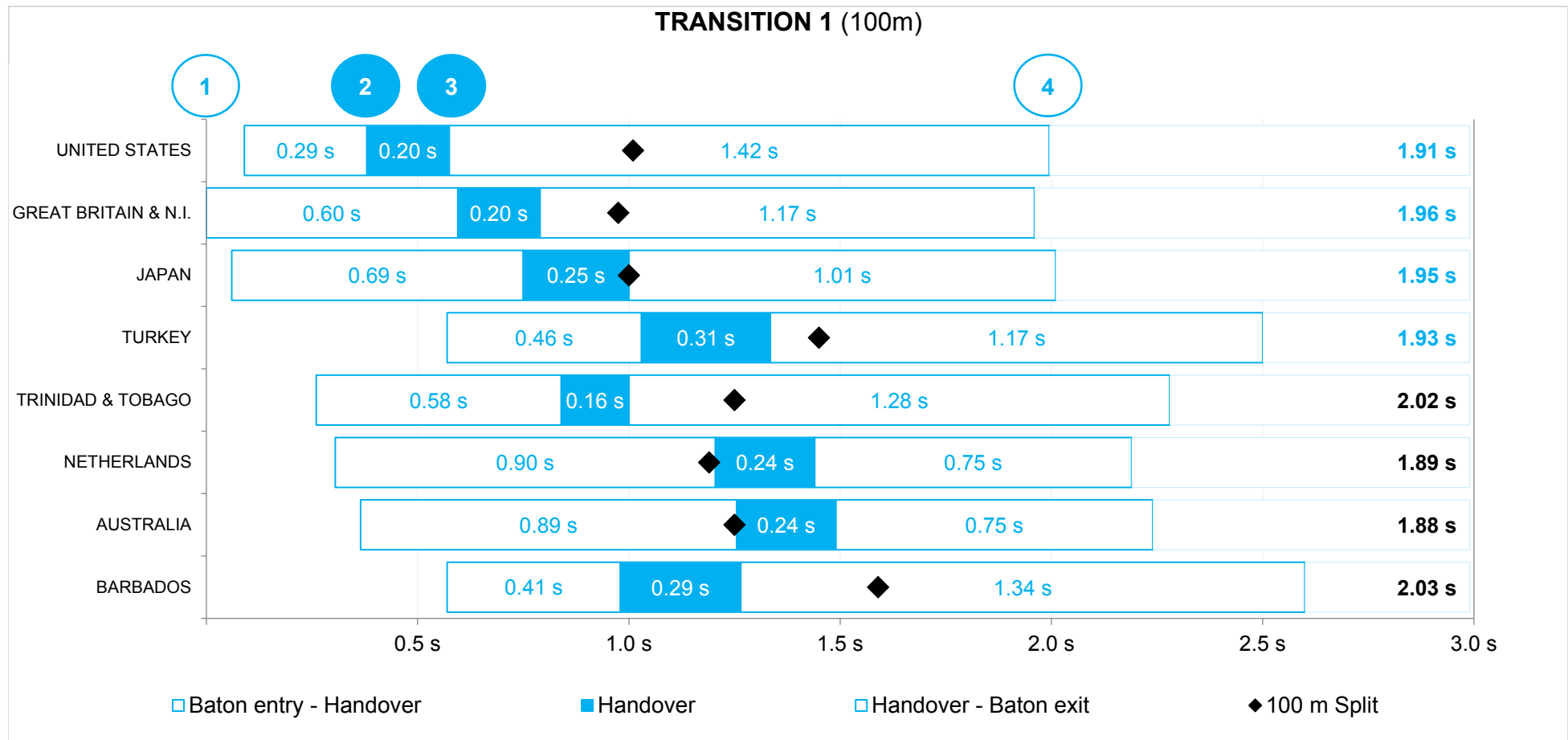


Figure 28. Analysis of timings and positions of each team within Transition 1. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit. **Note:** Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase.

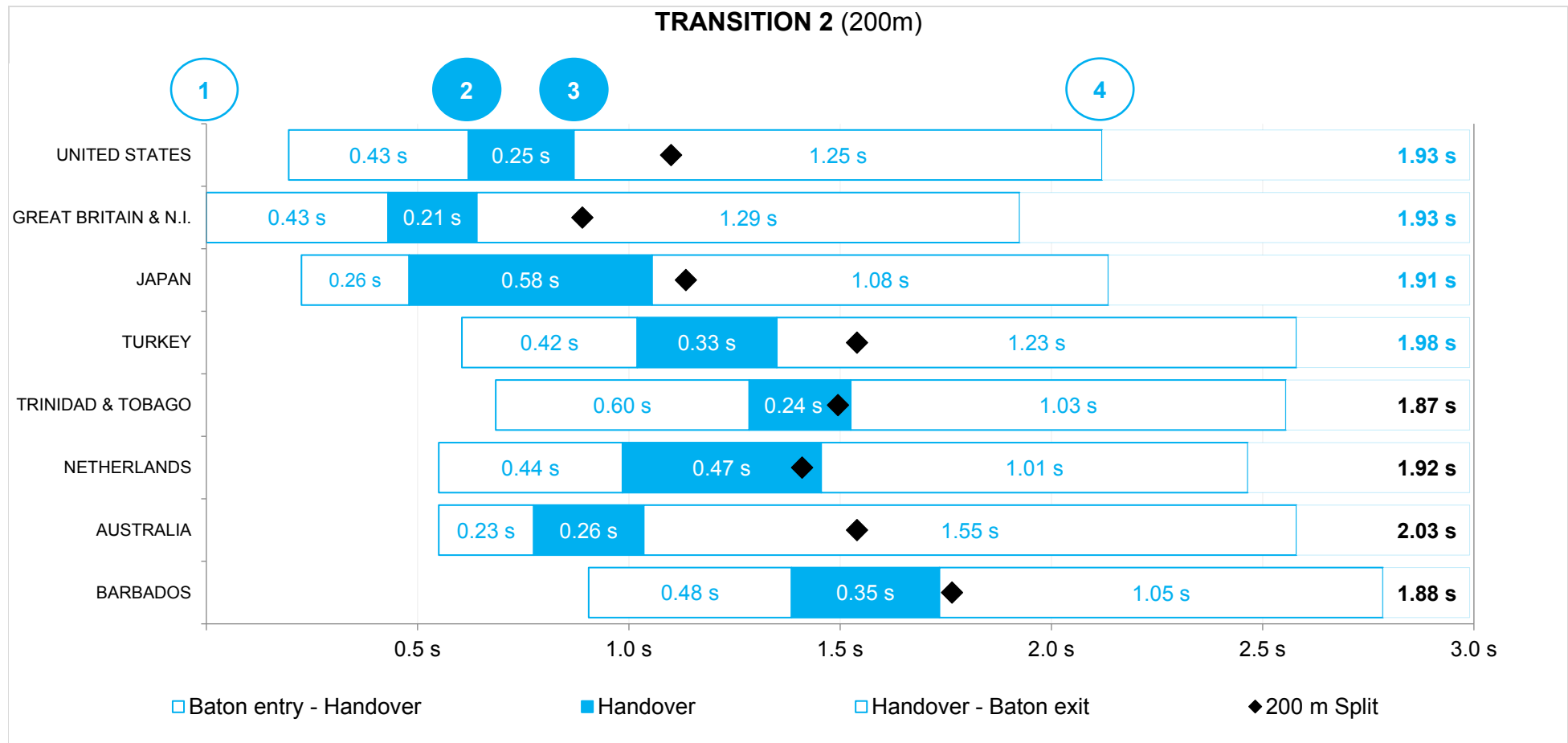


Figure 29. Analysis of timings and positions of each team within Transition 2. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

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

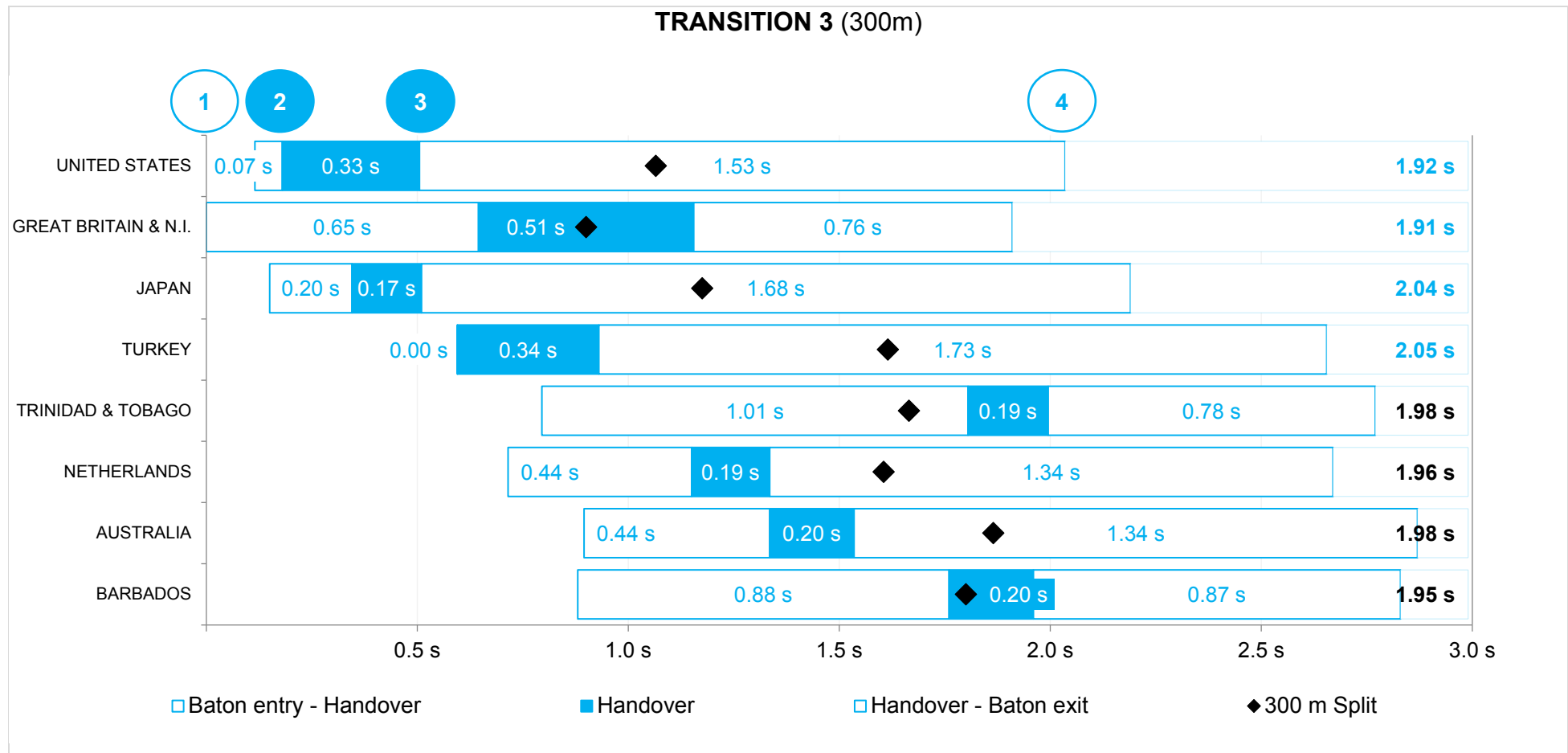
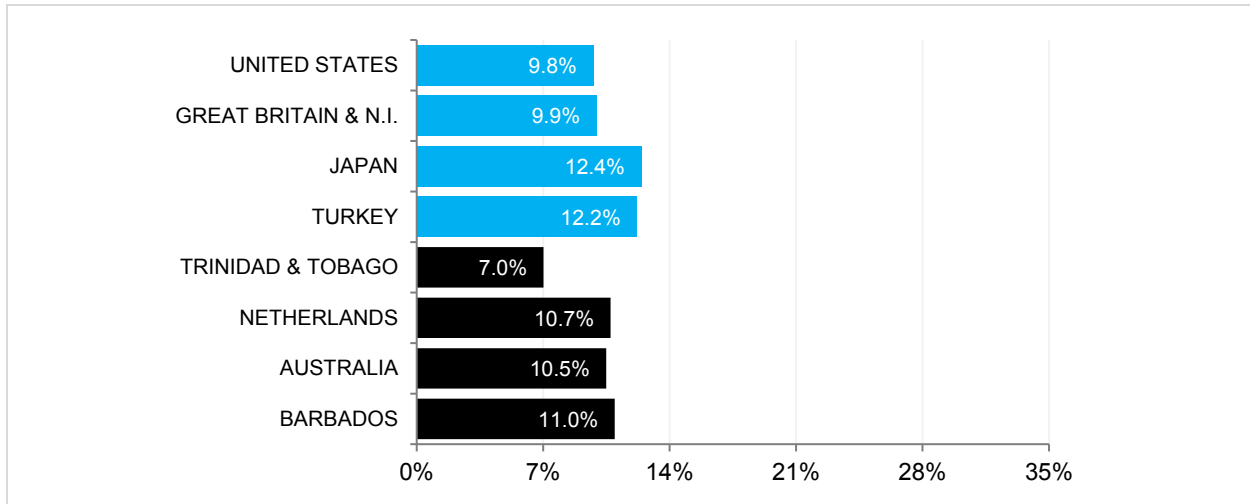


Figure 30. Analysis of timings and positions of each team within Transition 3. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

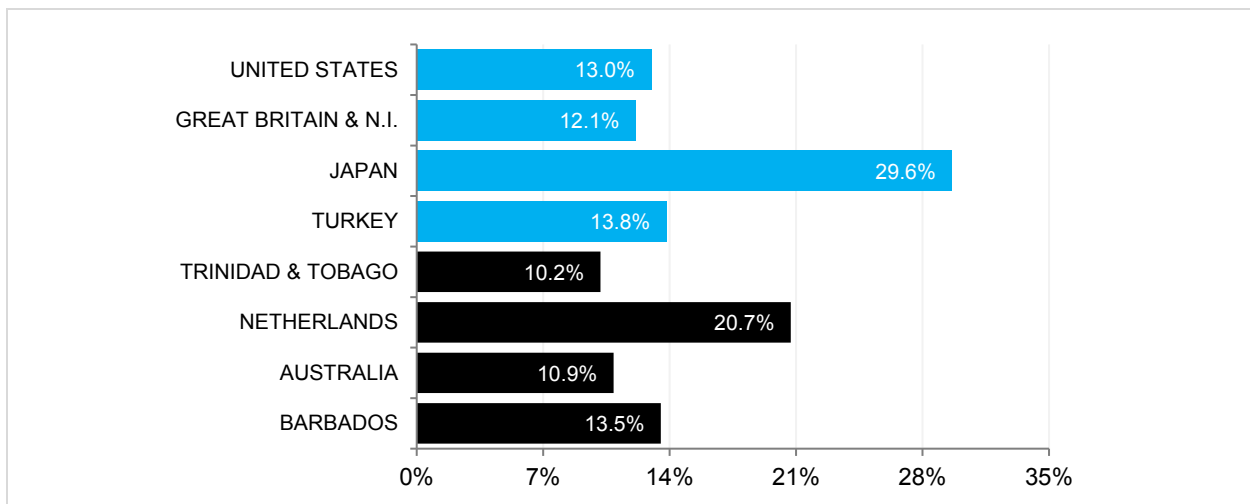
**Note:** Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase.

## Handover duration

### Transition 1



### Transition 2



### Transition 3

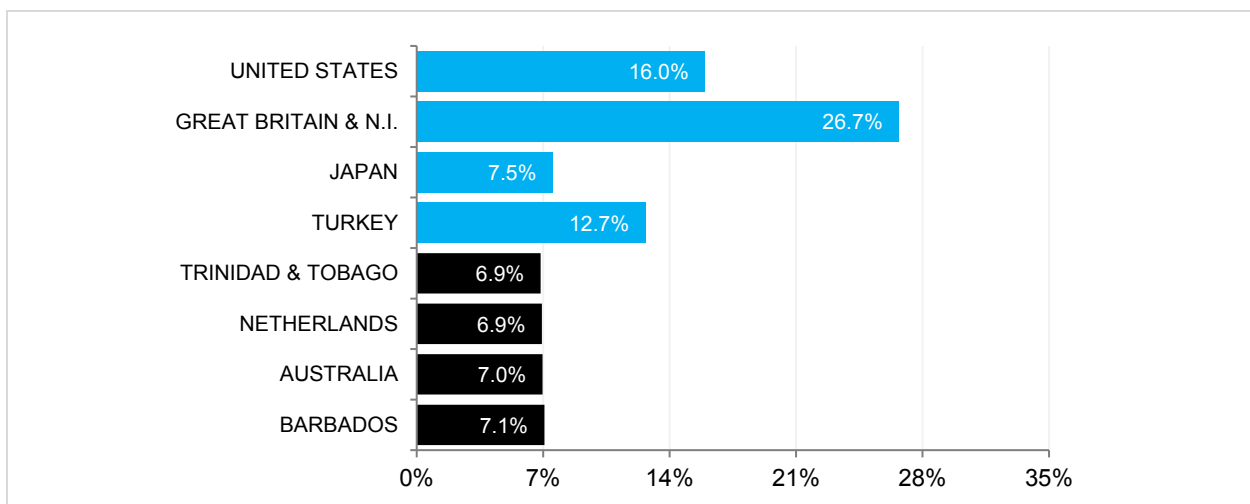


Figure 31. Duration of the handover phase as a percentage of the total transition time.

### 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
<b>UNITED STATES</b>	-	-	-	-	-
<b>GREAT BRITAIN &amp; N.I.</b>	0.055	0.000	<b>-0.010</b>	<b>-0.045 s</b>	<i>0.06 s</i>
<b>JAPAN</b>	0.045	<b>-0.015</b>	0.120	<b>0.150 s</b>	<i>0.51 s</i>
<b>TURKEY</b>	0.025	0.050	0.130	<b>0.205 s</b>	<i>0.74 s</i>
<b>TRINIDAD &amp; TOBAGO</b>	0.115	<b>-0.055</b>	0.055	<b>0.115 s</b>	<i>0.91 s</i>
<b>NETHERLANDS</b>	<b>-0.020</b>	<b>-0.010</b>	0.035	<b>0.005 s</b>	<i>0.95 s</i>
<b>AUSTRALIA</b>	<b>-0.035</b>	0.105	0.055	<b>0.130 s</b>	<i>1.18 s</i>
<b>BARBADOS</b>	0.125	-0.045	0.030	<b>0.110 s</b>	<i>1.49 s</i>

**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
<b>UNITED STATES</b>	-	-	-	-	-	-
<b>GREAT BRITAIN &amp; N.I.</b>	<b>-0.090</b>	<b>-0.160</b>	0.080	0.185	<b>0.015 s</b>	<i>0.06 s</i>
<b>JAPAN</b>	<b>-0.030</b>	0.015	0.020	0.355	<b>0.360 s</b>	<i>0.51 s</i>
<b>TURKEY</b>	0.480	<b>-0.095</b>	0.020	0.130	<b>0.535 s</b>	<i>0.74 s</i>
<b>TRINIDAD &amp; TOBAGO</b>	0.170	0.205	0.245	0.175	<b>0.795 s</b>	<i>0.91 s</i>
<b>NETHERLANDS</b>	0.215	0.160	0.255	0.320	<b>0.950 s</b>	<i>0.95 s</i>
<b>AUSTRALIA</b>	0.275	0.110	0.320	0.345	<b>1.050 s</b>	<i>1.18 s</i>
<b>BARBADOS</b>	0.480	0.105	0.100	0.695	<b>1.380 s</b>	<i>1.49 s</i>

**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).

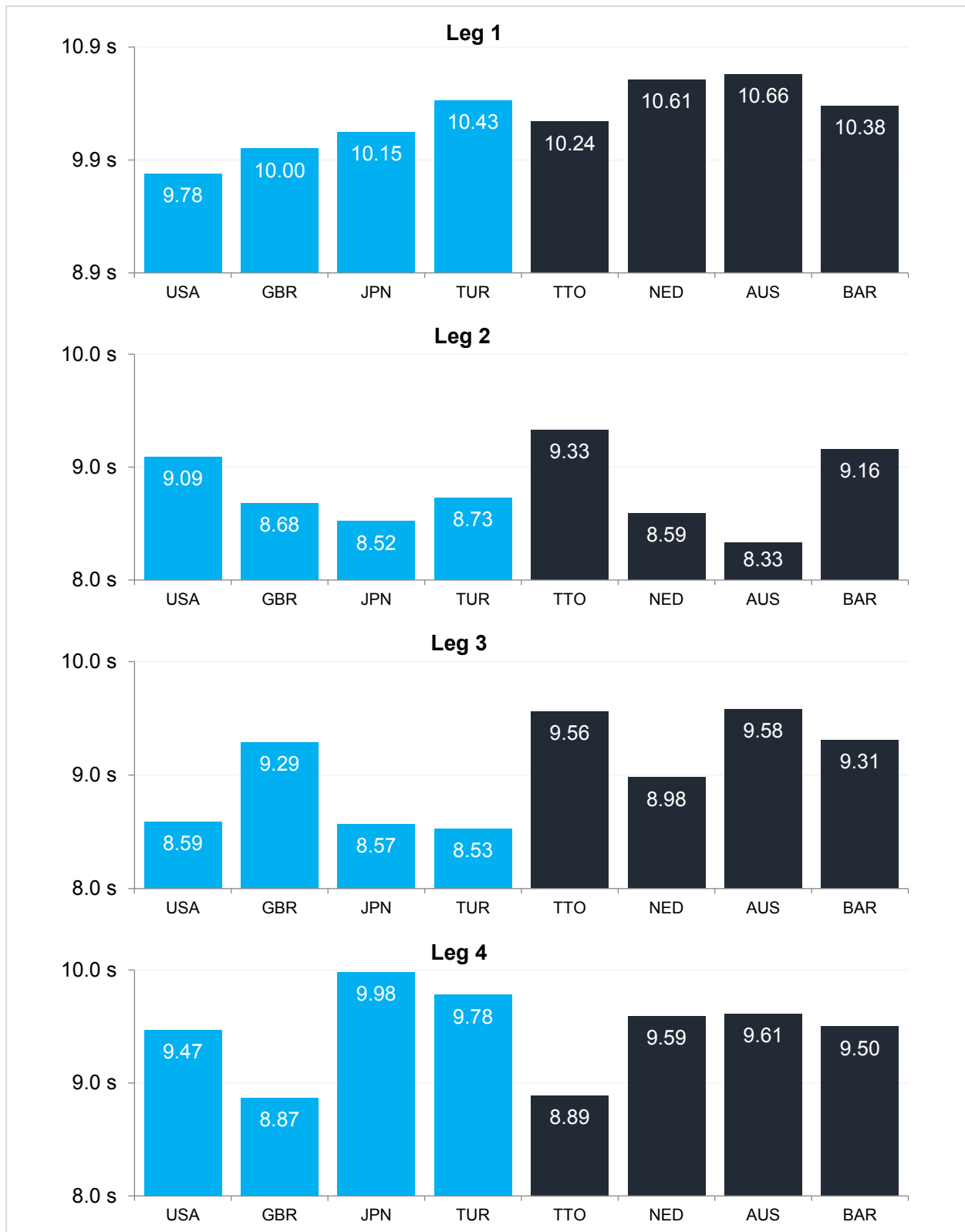


Figure 32. Split times for each individual leg (minus handover phase duration).

### Split times: 100 m splits

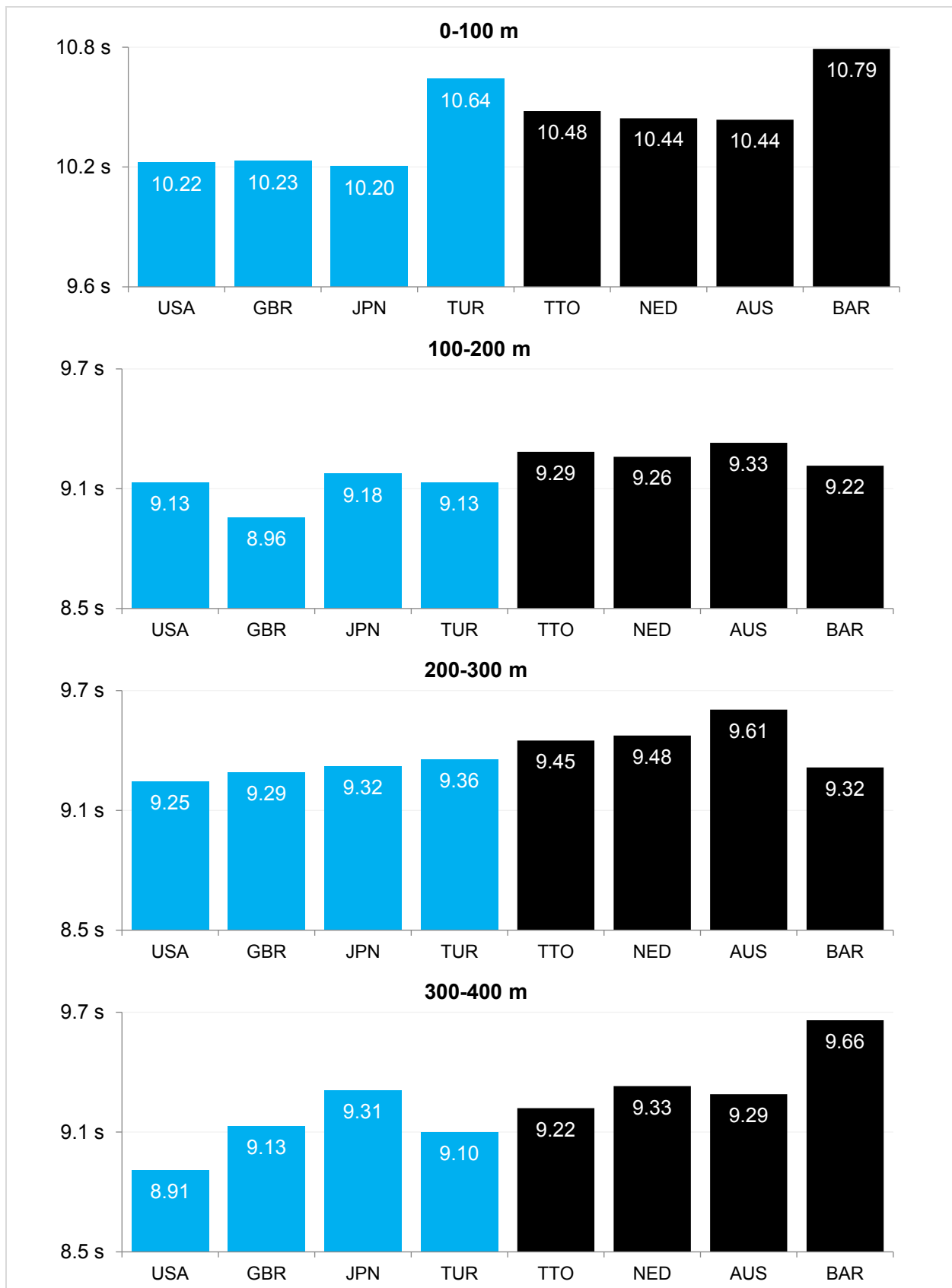


Figure 33. Team split times over consecutive 100 m (0-100 m minus reaction time).

### Split times: 200 m splits

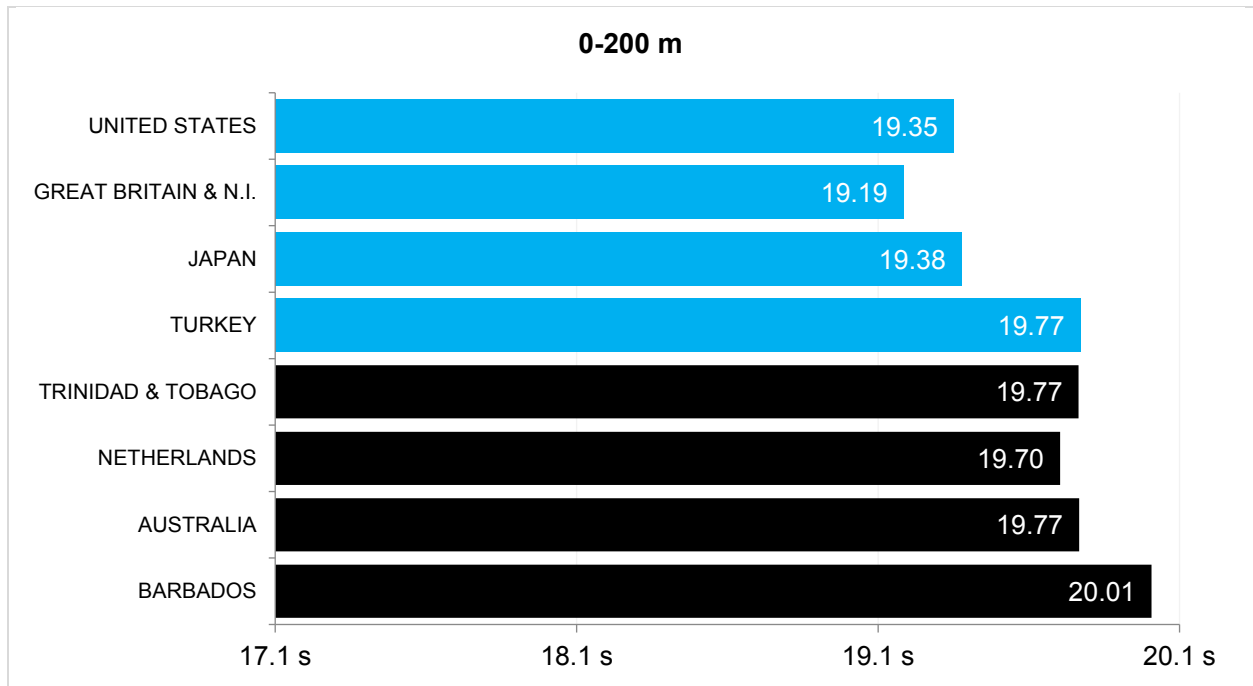


Figure 34. Team 0-200 m split times (minus reaction time).

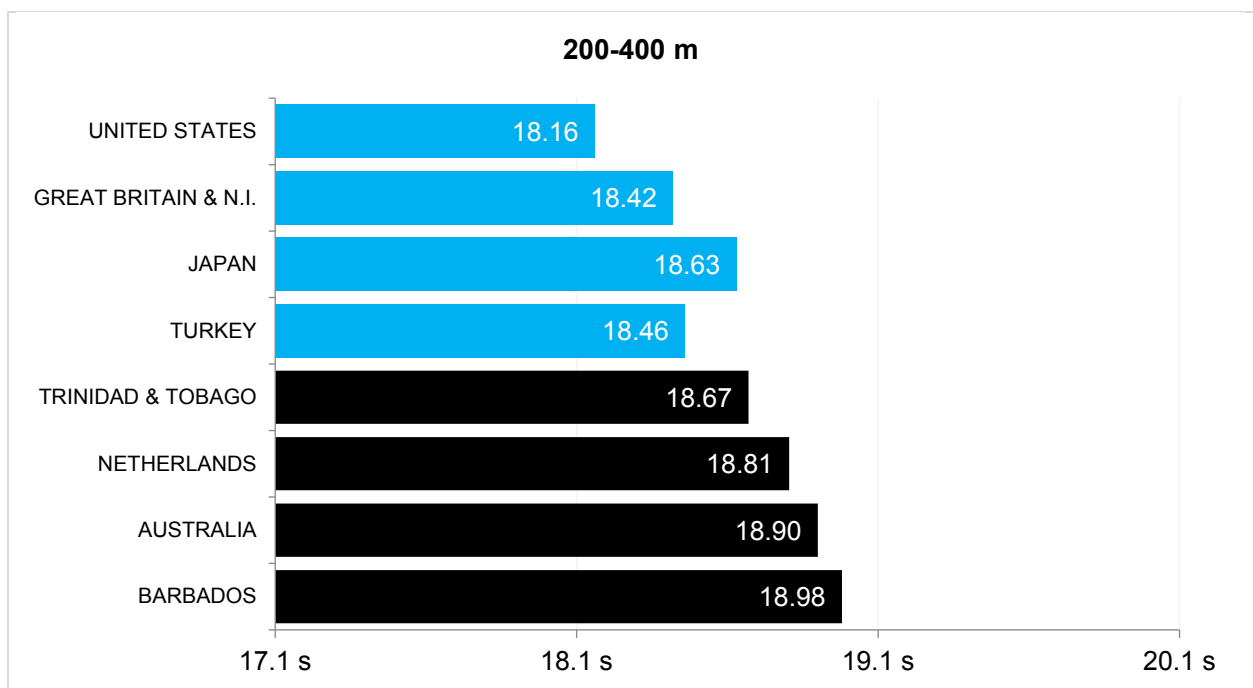


Figure 35. Team 200-400 m split times.

## 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
<b>JAMAICA</b>	6	1	<b>37.95 s</b>	<i>SB</i>	<b>-0.64 s</b>	1.11 s
<b>FRANCE</b>	7	7	<b>38.03 s</b>	<i>SB</i>	<b>-0.65 s</b>	0.24 s
<b>PR OF CHINA</b>	4	8	<b>38.20 s</b>		0.01 s	0.38 s
<b>CANADA</b>	2	5	<b>38.48 s</b>		0.33 s	0.84 s
<b>GERMANY</b>	5	11	<b>38.66 s</b>	.652*	0.35 s	0.63 s
<b>CUBA</b>	16	9	<b>39.01 s</b>	<i>SB</i>	<b>-0.66 s</b>	1.01 s
<b>BAHAMAS</b>	14	15	-	<i>DQ</i>	-	-
<b>ANTIGUA &amp; BARBUDA</b>	9	10	-	<i>DNS</i>	-	-

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

\* The splits in Figures 42-44 add to a total of 38.65 due to mathematical rounding.

### Positional analysis

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

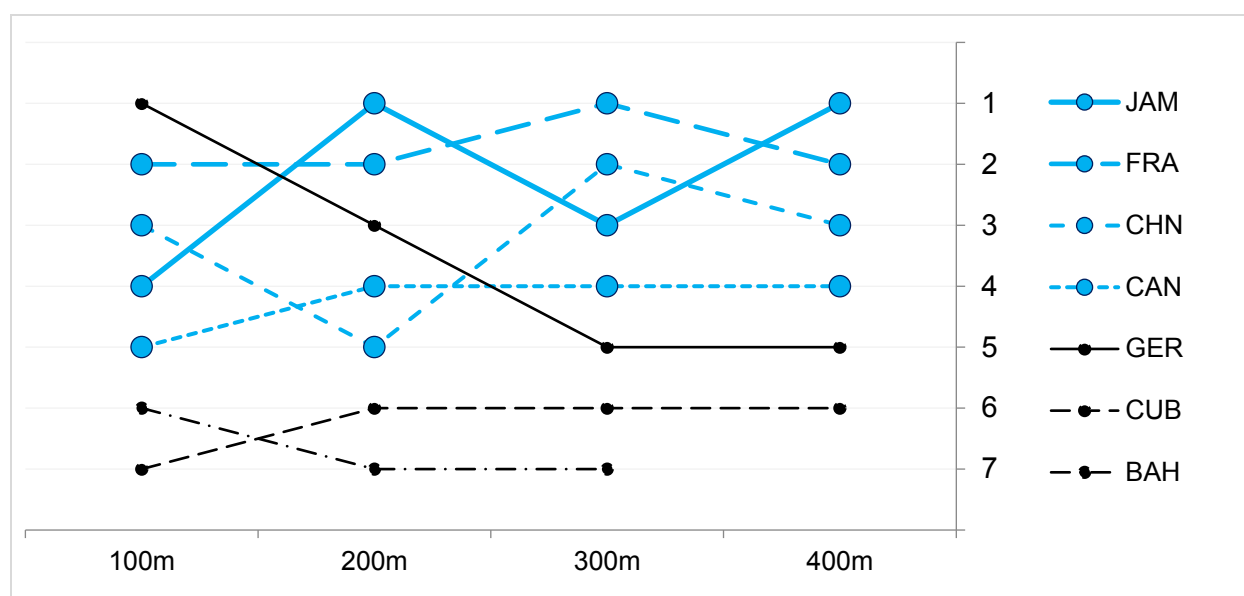


Figure 36. Positions at the end of each 100 m split.

## Transition analysis

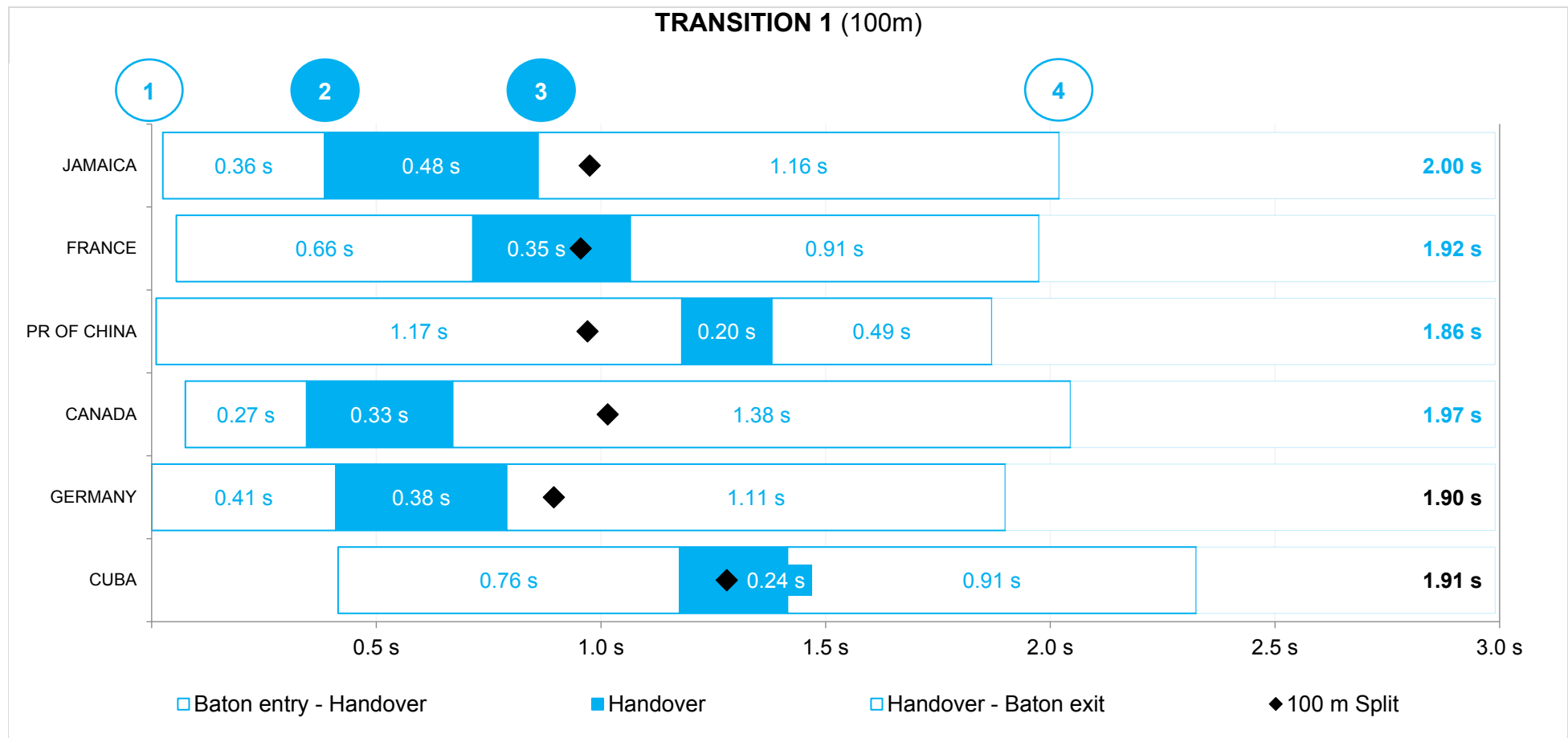


Figure 37. Analysis of timings and positions of each team within Transition 1. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

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

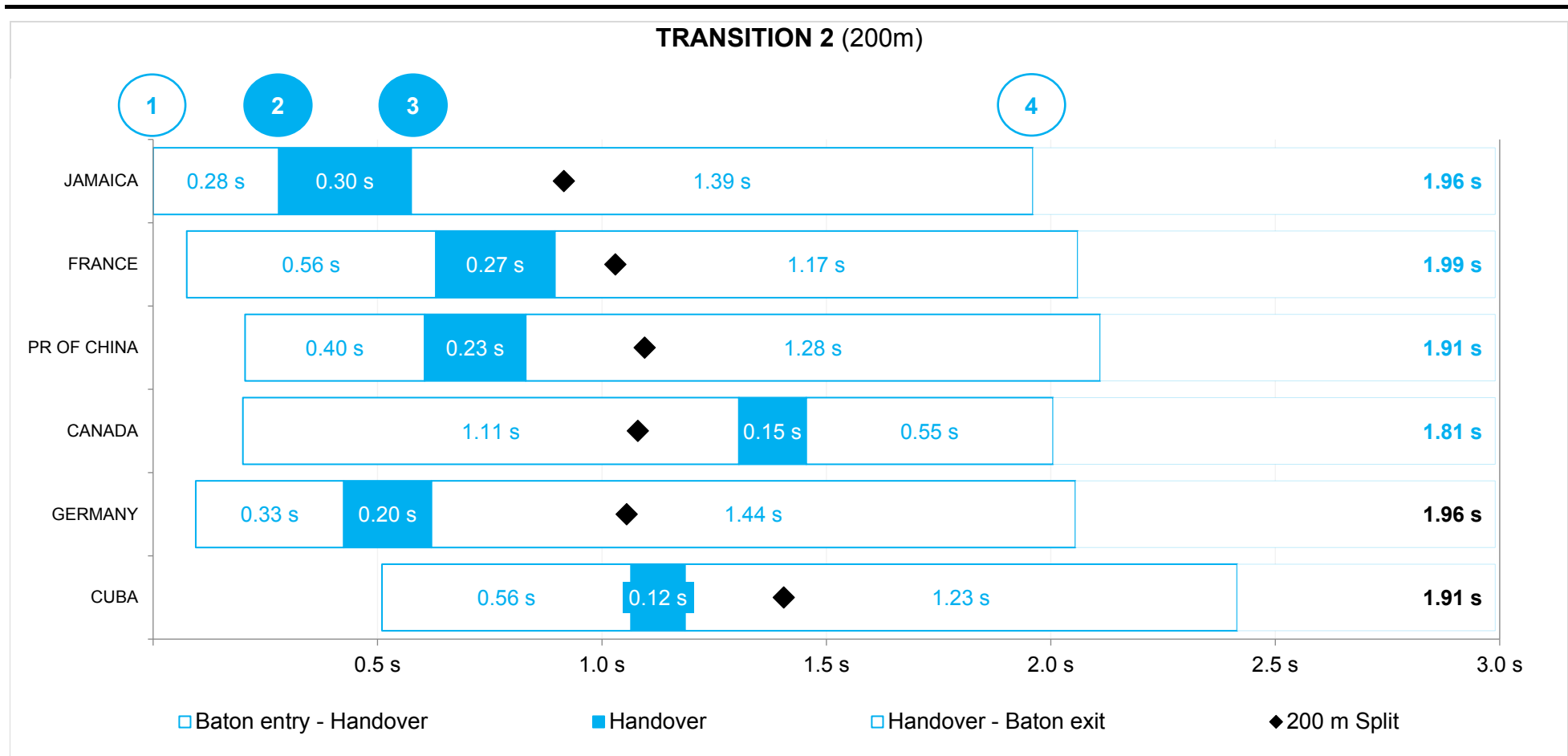


Figure 38. Analysis of timings and positions of each team within Transition 2. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit.

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

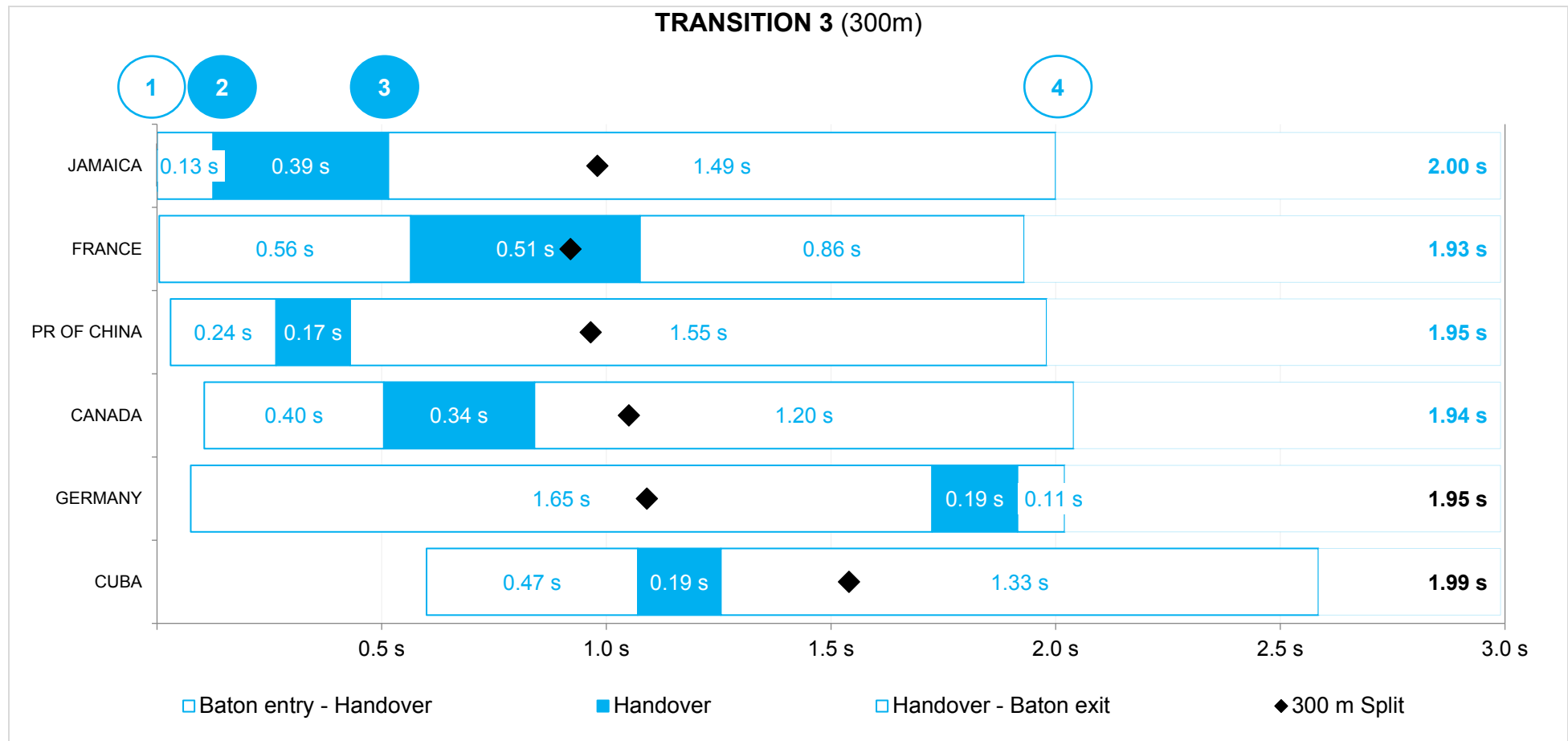
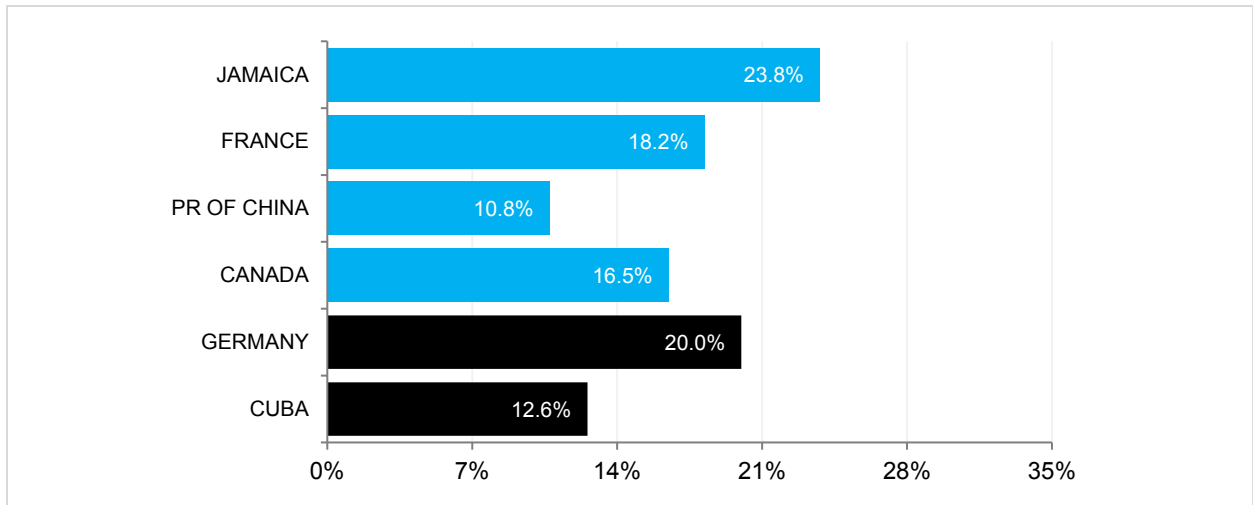


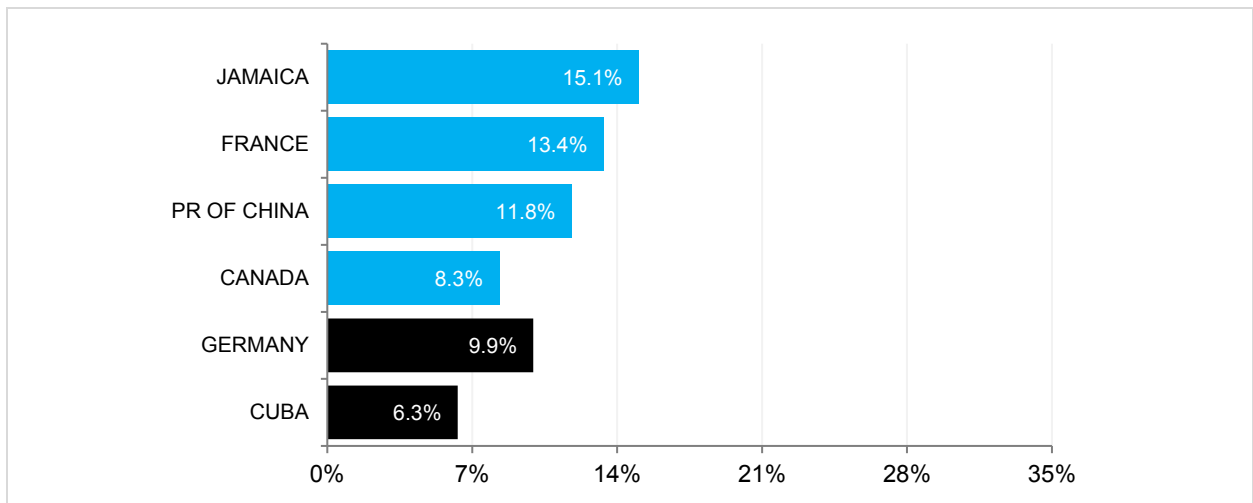
Figure 39. Analysis of timings and positions of each team within Transition 3. Phases as follows: (1) baton entry (2) handover starts (3) handover ends (4) baton exit. **Note:** Values rounded to 2 decimal places for illustrative purposes; thus, total transition times (bold) may appear different to the sum of each phase.

## Handover duration

### Transition 1



### Transition 2



### Transition 3

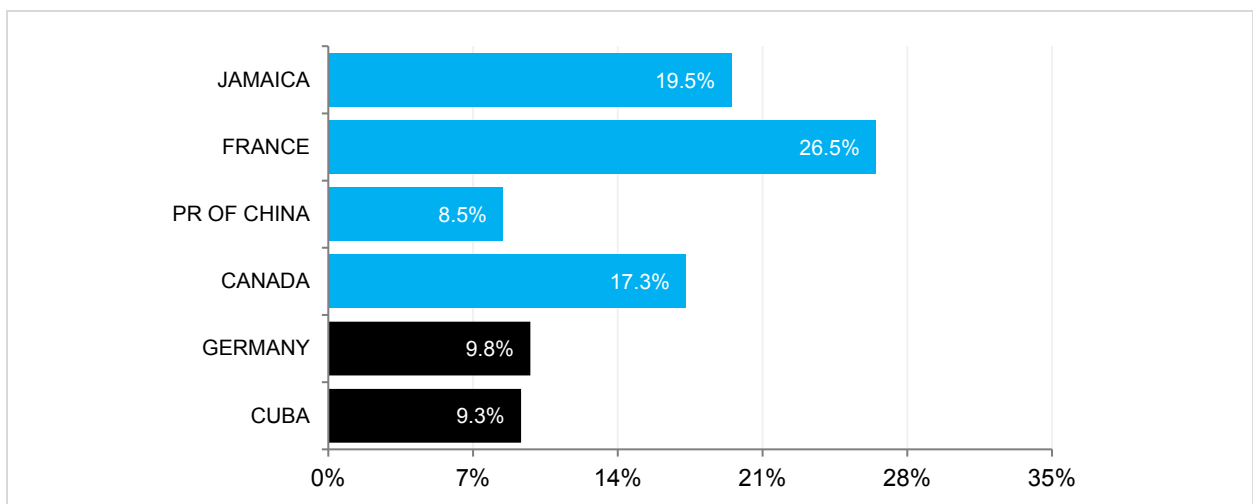


Figure 40. Duration of the handover phase as a percentage of the total transition time.



### 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
<b>JAMAICA</b>	-	-	-	-	-
<b>FRANCE</b>	<b>-0.075</b>	0.025	<b>-0.075</b>	<b>-0.125 s</b>	<i>0.08 s</i>
<b>PR OF CHINA</b>	<b>-0.135</b>	<b>-0.055</b>	<b>-0.050</b>	<b>-0.240 s</b>	<i>0.25 s</i>
<b>CANADA</b>	<b>-0.025</b>	<b>-0.155</b>	<b>-0.065</b>	<b>-0.245 s</b>	<i>0.53 s</i>
<b>GERMANY</b>	<b>-0.095</b>	0.000	<b>-0.055</b>	<b>-0.150 s</b>	<i>0.70 s</i>
<b>CUBA</b>	<b>-0.085</b>	<b>-0.055</b>	<b>-0.015</b>	<b>-0.155 s</b>	<i>1.06 s</i>
<b>BAHAMAS</b>	-	-	-	-	-
<b>ANTIGUA &amp; BARBUDA</b>	-	-	-	-	-

**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
<b>JAMAICA</b>	-	-	-	-	-	-
<b>FRANCE</b>	0.030	0.120	<b>-0.095</b>	0.150	<b>0.205 s</b>	<i>0.08 s</i>
<b>PR OF CHINA</b>	<b>-0.015</b>	0.355	<b>-0.120</b>	0.270	<b>0.490 s</b>	<i>0.25 s</i>
<b>CANADA</b>	0.050	0.175	0.060	0.490	<b>0.775 s</b>	<i>0.53 s</i>
<b>GERMANY</b>	<b>-0.025</b>	0.215	<b>-0.020</b>	0.680	<b>0.850 s</b>	<i>0.70 s</i>
<b>CUBA</b>	0.390	0.205	0.145	0.470	<b>1.215 s</b>	<i>1.06 s</i>
<b>BAHAMAS</b>	-	-	-	-	-	-
<b>ANTIGUA &amp; BARBUDA</b>	-	-	-	-	-	-

**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).

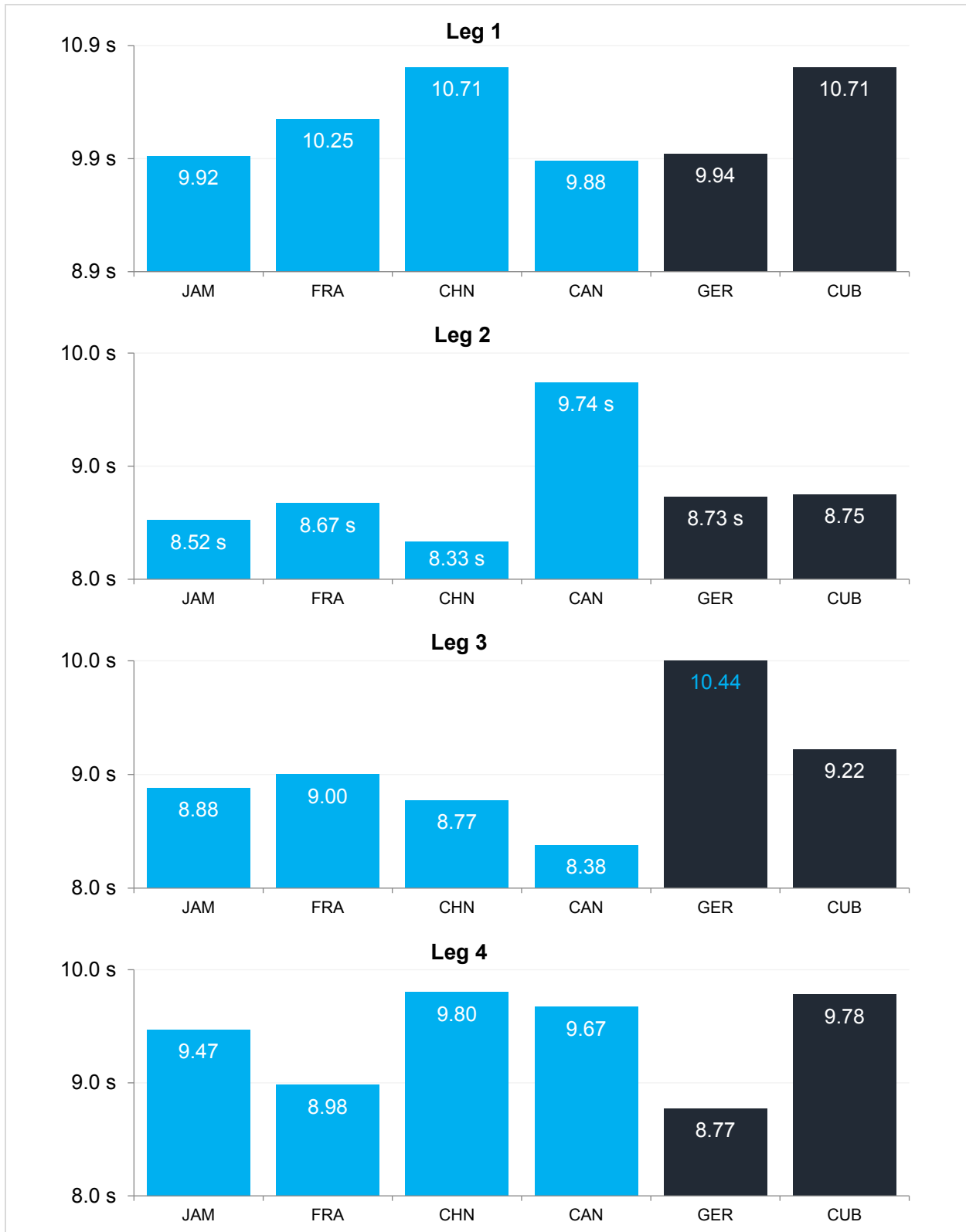


Figure 41. Split times for each individual leg (minus handover phase duration).

## Split times: 100 m splits

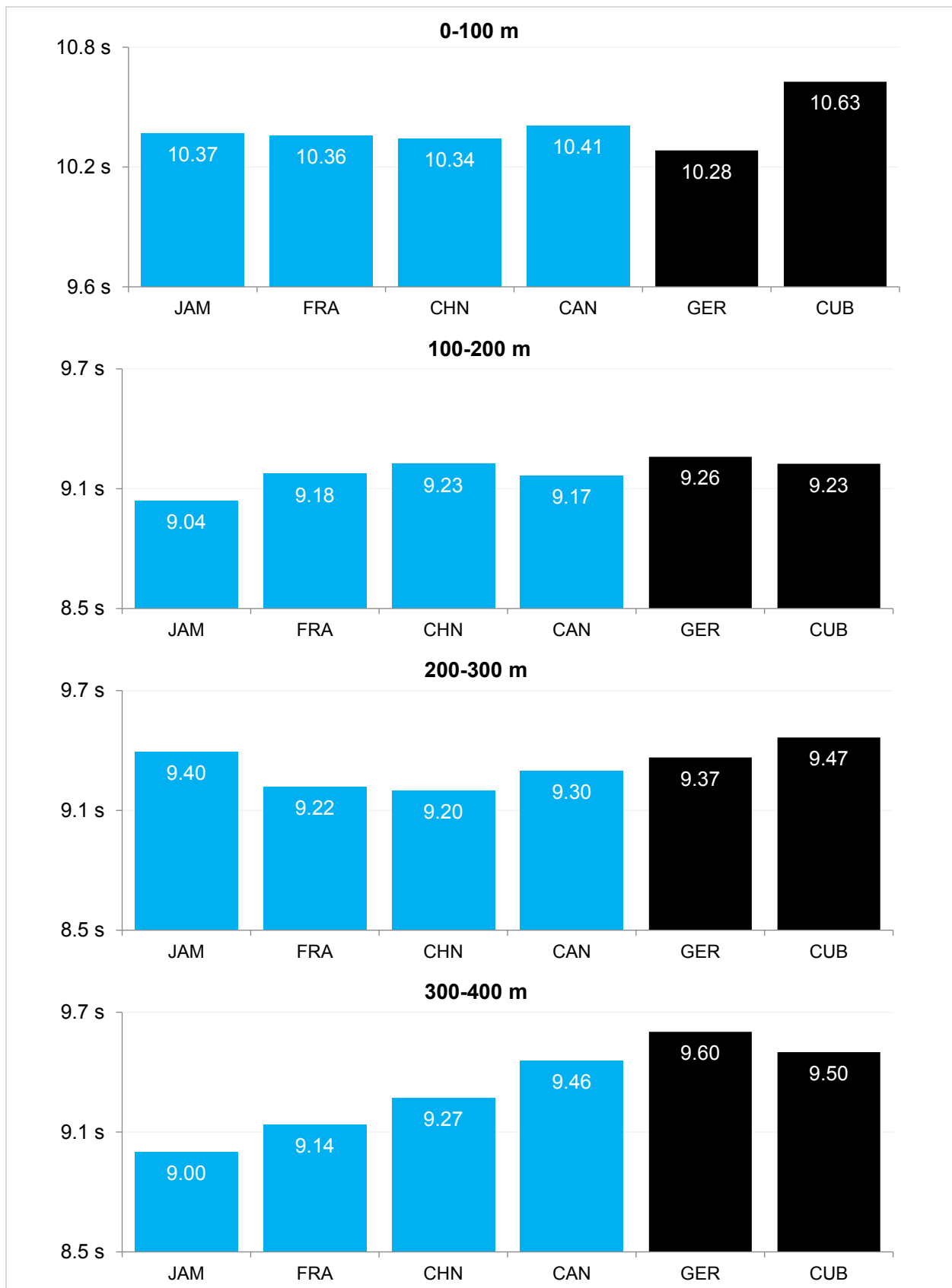


Figure 42. Team split times over consecutive 100 m (0-100 m minus reaction time).

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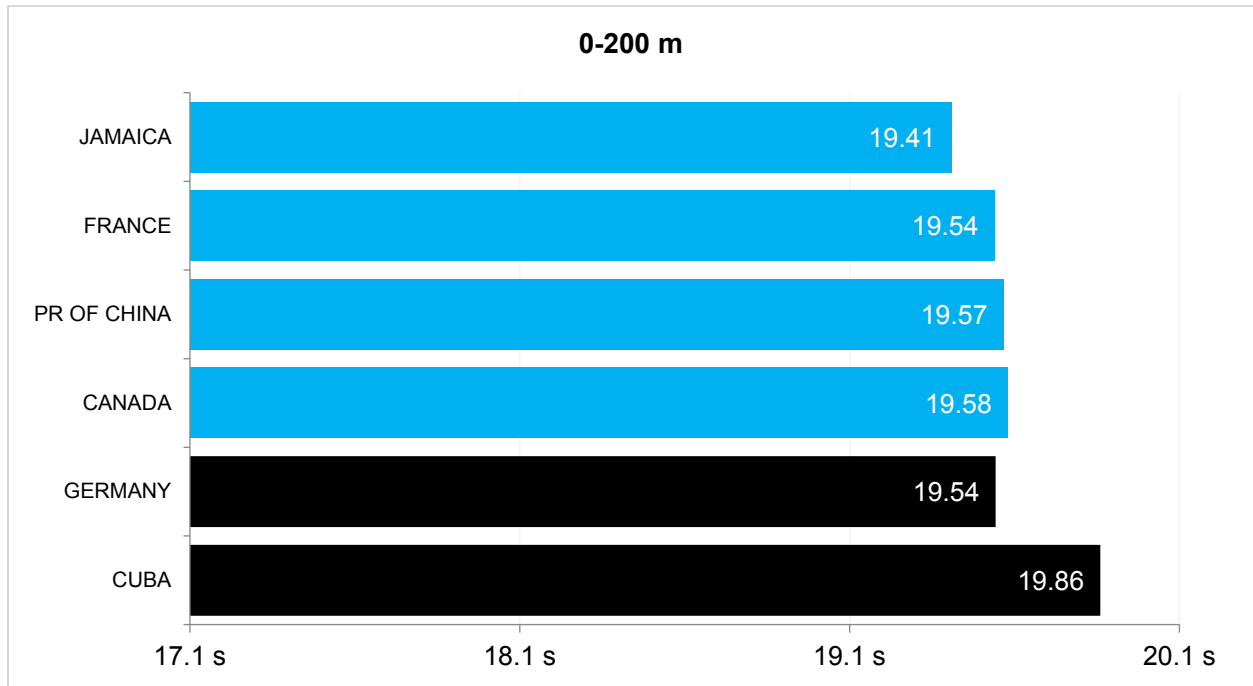
**Split times: 200 m splits**

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

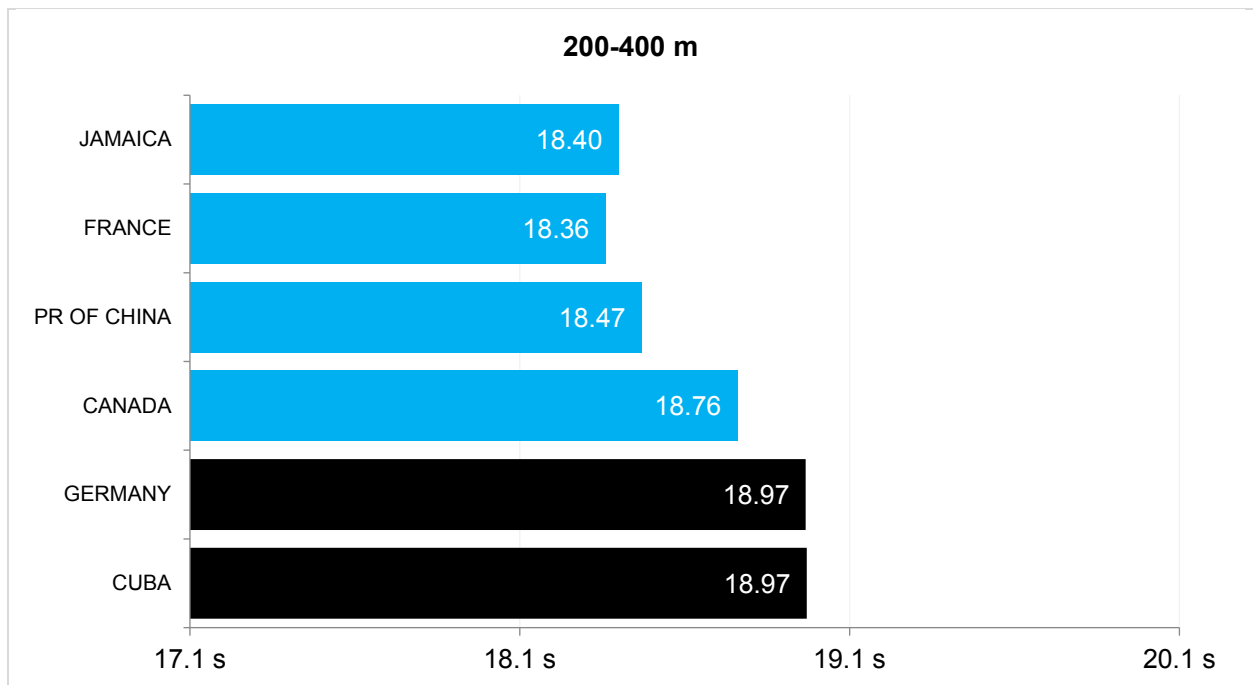


Figure 44. Team 200-400 m split times.

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## COMMENTARY

The winning time of 37.47 s for Great Britain & N.I. was an impressive achievement as in addition to a new world leading time and season's best, it meant a new personal best mark that eclipsed their own 18-year European record by 0.26 s; recorded at the 1999 World Championships in Sevilla. Christian Coleman anchored the United States home in 37.52 s for his second silver medal of the championships. Although Jamaica trailed Great Britain & N.I. out of the final transition by only three tenths, Bolt could not add to his 19 medals as he pulled up early in the home straight with severe hamstring cramps. Japan capitalised to secure bronze in 38.04 s. Great Britain & N.I. and the United States also recorded the fastest times during the heats, except for a role reversal. As in the heats, Great Britain & N.I. led from the start. However, in the final they were able to maintain this to the finish. Their chequered history of disqualification for poor handovers and dropped batons was vanquished by outstanding consistency within the transitions.

Great Britain & N.I.'s polished performance within transitions during the final was highlighted by a large improvement from the heats (0.210 s), and exceptional consistency (variance of 0.6%). Even though the United States also displayed similar consistency (variance 1.1%), they were slightly less efficient (0.115 s) in key elements contributing to the handover, which unfolded to be the pivotal factor as it accounted for the exact winning margin by the finish. Great Britain & N.I. were also notably more efficient than Jamaica within transitions (0.350 s), and despite Bolt's issue, it appears unlikely that even he could have changed the outcome of the race. Great Britain & N.I.'s improvement through transition 3 compared to their heat (-0.055 s) also enabled Mitchell-Blake to exit the transition with a greater margin to hold off the challenge of Coleman.

The time recorded by Great Britain & N.I. within transitions 1 and 3 (1.855 s), was the joint fastest time of the final, with Canada (transition 2) and the United States (transition 3). Interestingly, the most efficient transition of the championships was recorded by Canada during the heats (1.805 s), which also included the second fastest handover of the heats (0.150 s). However, the fastest handovers did not necessarily coincide with the fastest transition times. Great Britain & N.I. produced the fastest handover of the championship (0.105 s) within transition 2; their longest transition time (1.875 s) of the final. And despite identical times for transitions 1 and 3, the handover in transition 1 was more than double that of transition 3 (0.350 s vs. 0.165 s).

With respect to consistency, the lowest variance in handover duration during the final (13.9%) was recorded by the United States, yet this did not result in the quickest transition times. Nevertheless, the quick handover within the final transition for Great Britain & N.I., compared to the heats (0.165 s vs. 0.510 s), may have been a key factor that contributed to achieving a faster transition; which ultimately provided Mitchell-Blake with a large enough margin to hold off

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Coleman and secure gold. With clear inconsistencies across teams, the handover duration may therefore not be the pivotal factor to an efficient transition.

Another related key factor, could be the timing of the handover. For example, the United States (~15%) and Jamaica (<15%) began the handover early into each transition. By transition 3, this could serve to maximise the potential of the athletes running the final leg (Coleman and Bolt). Great Britain & N.I. on the other hand displayed a progressive trend over consecutive transitions (20.5% to 38.5%). In comparison to the United States and Jamaica, the later handover position in transition 3 may have enabled Mitchell-Blake to achieve an optimal running speed during the handover which ensured near maximal speed at transition exit.

It is also possible that Great Britain & N.I.'s tactics were to maximise their strengths whilst nullifying the strengths of their main challengers before the race (United States and Jamaica). Having their fastest athlete (Chijindu Ujah) on the first leg gave Great Britain & N.I. the lead into and out of transition 1. The challenge on the back and home straights was to minimise the loss in time to the United States who fielded the individual 100 m gold and silver medallists respectively (Justin Gatlin and Christian Coleman). This tactic may have been executed to perfection, as the time loss (0.205 s) was neutralised on the bends (i.e., legs 1 and 3).

Despite the unrivalled success in previous championships, Jamaica's key athletes (Blake and Bolt) were not in top form. Jamaica drafted in 110 m hurdles champion (Omar McLeod) to lead out, and while this saw an improvement from the heats in the 100 m split time (0.100 s) and an individual leg split time comparable to Great Britain & N.I. and the United States, they trailed Great Britain & N.I. into the transition (0.125 s) and were further behind by transition exit (0.195 s). By the time Yohan Blake exited transition 2 for Jamaica, greater efficiency within the transitions enabled Great Britain & N.I. to maintain this advantage. This difference cost Jamaica a combined loss of 0.350 s over the three transitions. A key influencing factor may have been the shorter time spent by the receive leg within the transition before baton entry (5-9%) compared to both Great Britain & N.I. (11-15%) and the United States (8-15%). It may have resulted in the delivery leg having to break and slow before handover to match the slower speed of the receive leg; a variable that may be an important consideration during future competitions.

In summary, the outcome of the men's relay was decided by greater efficiency throughout the transition phases. By completing the handover later in the transition, Great Britain & N.I. may have been able to maintain a higher consistency of running speed. Despite having individual gold and silver medallists from the individual 100 m, the approach to complete the handover early within the transition did not appear to allow the United States to take full advantage of this. For the other teams, including bronze medallists Japan, a consistent loss of time within transitions likely explains further time loss between the transitions.

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## 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.

