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# Biomechanical Analysis of the Sprint and Hurdles Events at the 2009 IAAF World Championships in Athletics

By Rolf Graubner and Eberhard Nixdorf

(Translated from the original German by Jürgen Schiffer)


## ABSTRACT

*The 2009 IAAF World Championships in Athletics in Berlin presented German sport scientists with a rare opportunity to study the world's best athletes in a top-level competition at a venue close to home. A team of 18 researchers from six institutions around the country planned, organised and carried out a major biomechanics research project at the championships with the support of the German athletic federation (DLV) and the IAAF. The project's objectives included making detailed analysis of the finals of all the individual sprint and hurdle events for both men and women. Video recordings using digital camcorders positioned in the stands around the track were made in order to obtain split times of the races and study other aspects such as stride length and stride frequency. In addition, laser measurement systems were used to obtain continuous velocity measurements in the men's 100m final. This report, prepared specially for NSA, provides analysis and commentary on the data obtained by the project team, with sections on each of the events. In addition, there is a special analysis of the men's 100m final based on the laser measurement data.*



## AUTHORS

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## Introduction

The 2009 IAAF World Championships in Athletics in Berlin presented German sport scientists with a rare opportunity to study the world's best athletes in a top-level competition at a venue close to home and thereby carry on a tradition of scientific work at major athletics events stretching back more than 30 years. With the support of the IAAF and the German athletic federation (DLV), a team of 18 researchers from six institutions around the country planned, organised and carried out a major

athletics events stretching back more than 30 years. With the support of the IAAF and the German athletic federation (DLV), a team of 18 researchers from six institutions around the country planned, organised and carried out a major biomechanics research project at the championships. The aim was to gather data in order to support athletes and coaches in their efforts to optimise training and improve competition performance.

Following the world record performances of Usain Bolt (JAM) and other great performances one year earlier at the Olympic Games in Beijing, there was great anticipation surrounding both the men's and women's sprint and hurdles events in Berlin, and these, naturally, became a focus for the project team. Their objectives included making detailed analysis of the finals of all these events, plus the earlier rounds in most cases. Video recordings using digital camcorders positioned in the stands around the track were made to obtain split times of the races and study other aspects. Much of the data gathered by the project team was made available during the championships in Berlin and a complete compilation was published on the IAAF website in the following months.

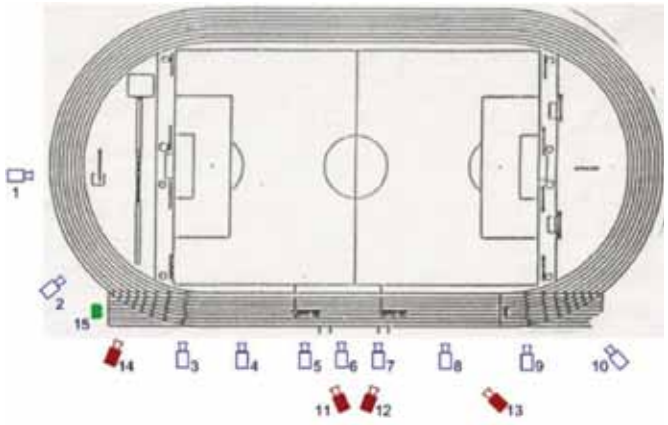
The purpose of this report is to provide additional analysis and commentary. In the following sections, each of the individual sprint and hurdle events is covered. In addition, there is a special analysis, based on data from the laser measurement equipment, of the men's 100m final, where Bolt bettered, the record he set in Beijing.

The video measurement team consisted of Rolf Graubner (Martin-Luther University Halle-Wittenberg, Germany), Dr. Ralf Buckwitz (Olympic Training Centre Berlin), Mirko Landmann (Martin-Luther University Halle-Wittenberg, Germany) and Anja Starke (Martin-Luther University Halle-Wittenberg, Germany).

## Measurement Methods

The basic equipment system selected for the project consisted of eight static CCTV colour cameras recording at 50Hz, which were aligned orthogonally to the running track at 10 positions, alternating depending on the event, and up to four semi-professional 3CCD cameras used for panning (see Figure 1). This system was chosen both for the fact that it could provide data that could be quickly analysed and presented to the public and for its cost effectiveness, making it possible to study a wide range of events at the championships.

The video signals were provided using manual selective switches, a video timer (ForA VTG-33 with synchronisation through the starting signal, which was supplied by the competition




Positions 1-10:
Positions of the static cameras

Positions 11-14:
Positions of the pan video cameras

Positions 15:
3x LAVEG

*Figure 1: Schematic presentation of camera positions used at the 2009 IAAF World Championships in Athletics*

time measurement system/SEIKO) and a signal converter (Canopus ADVC 100) and then recorded on up to three notebook PCs. A single cable system for electric power supply and signal transmission was used and all the cameras were connected to a central unit in the grandstand by a cable over 800m long.

Because of the exact synchronisation of the timers with the start, no additional measures for the event synchronisation of the video signals were necessary. The CCTV cameras used included an automatic system-internal synchronisation (Gen-Lock) via the joint electric power supply modules.

The positions of the cameras are shown in Figure 1 and the allocation of the cameras to the various events is given in Table 1.

All the races in all the sprint and hurdle events, including the relevant disciplines in the combined events, were recorded and analysed, with the occasional exception of weaker performances in the first two rounds. An overview of the analyses performed is given in Table 2a and Table 2b. Further, specific information on the methods and procedures used in each of the events is given in the relevant sections below.

In addition to the video recording system, three laser measurement systems were used to obtain continuous velocity measurements in the 100m finals. Further details of the method and a special analysis of the men's 100m final based on the data obtained are provided in a special report (see page 24).

*Table 1: Allocation of the cameras to the events and switching sequence of shots at the 2009 IAAF World Championships in Athletics*

| | |
|---|---|
| 100m | 4 / 5 / 7 / 8 + 13 |
| 200m | 1 / 3 / 6 +11 |
| 400m | 11 / 3 / 11 +12 |
| 4x100m | 11 / 2 / 3 / 6 + 12 + 14 |
| | "/" = sequential stepping |

| | |
|---|---|
| 100/110mH | 13 |
| 400mH | 11 + 12 |
| 4x400m | 11/3 x (9/11) + 13/10/13 |
| | "+" = separate shot |

*Table 2a: Overview of the analyses for the studied women's events at the 2009 IAAF World Championships in Athletics*

| **Women** | **100m** | **200m** | **400m** | **100m H** | **400m H** | **4x100m** | **4x400m** | **7Hep.** |
|---|---|---|---|---|---|---|---|---|
| Rounds | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 disciplines |
| Athletes | 30 | 28 | 27 | 17 | 14 | 8 | 8 | 21 |
| Analyses | 84 | 55 | 28 | 40 | 32 | 11 | 9 | 40 |
| Total | | | | | | | | **299** |

*Table 2b: Overview of the analyses for the studied men's events at the 2009 IAAF World Championships in Athletics*

| **Men** | **100m** | **200m** | **400m** | **110m H** | **400m H** | **4x100m** | **4x400m** | **10Dec.** |
|---|---|---|---|---|---|---|---|---|
| Rounds | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 3 disciplines |
| Athletes | 58 | 32 | 28 | 24 | 14 | 9 | 9 | 26 |
| Analyses | 121 | 75 | 52 | 49 | 31 | 11 | 9 | 64 |
| Total | | | | | | | | **412** |

## The 100 Metres

### *Methods and Procedures*

The video measurement system for the 100m races used four of the cameras described in Figure 1 to obtain data at uniform intervals of 20m (no. 4 = 20m / no. 5 = 40m / no. 7 = 60m / no. 8 = 80m). Using this method normally enables the recording of all participants in a race at all four measuring positions because of sufficiently long interval times, and it also enables a fast evaluation because of the direct synchronisation of the video timers with the start. In the semi-finals and finals, additional video recordings were made with Camera 13. This data was used for the analysis of stride lengths and stride rates.

### *Results and Comments – Men*

As at the 2008 Olympic Games, the men's 100m final was dominated by Usain Bolt. In Berlin he improved the world record he set in Beijing by 0.11 sec to 9.58 sec (see Table 3). It was the largest improvement ever of the 100m world record. In second place, Tyson Gay (USA) set a national record of 9.71 sec, just 0.02 sec slower than the previous world mark, to become the second fastest man ever. In general, the finalists demonstrated a very high performance level. The average of the first three placed runners was 9.71 sec, far better than ever achieved previously (for comparison, the average for the first three in the final at the 2004 Olympic Games was 9.86 sec; in the 2008 Olympic Games it was 9.83 sec). Leaving place 8 (Patton (USA), 10.34 sec) out of consideration, the average time for the first seven placers was 9.86 sec, the first time a mark below 9.90 sec had been achieved (2004 Olympic Games: 9.93 sec; 2008 Olympic Games: 9.92 sec).

The split and interval times for the finalists are given in Table 4. Figure 4 shows Bolt's position at each of the four split points. The screen shots illustrate his comprehensive performance in all sections of the race. Unlike previous top-level sprinters (i.e. Carl Lewis, Donovan Bailey), Bolt matches, or beats, his competitors in the acceleration phase of the race. In the phases of maximal velocity and sprint-specific endurance, he sets new standards.

Bolt's performance differs considerably from other athletes with respect to the times for measured intervals in the race. He recorded best values for 10m sections of 0.83 sec and in individual cases 0.82 sec (where comparative analysis is influenced by the problem of measurement and margin of error, see page 24). In the Berlin, he achieved a time of 3.28 sec for the 40-80m section, which corresponds with four successive 10m intervals in 0.82 sec (average velocity: 12.2 m/sec).

*Table 3: Results of the men's 100m final at the 2009 IAAF World Championships in Athletics*

**100 Metres - Men's Final**

16 August 2009 – 21:35 Wind: 0.9 m/sec

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Usain Bolt (JAM) | 9.58 | WR | 0.146 | 4 |
| 2 | Tyson Gay (USA) | 9.71 | NR | 0.144 | 5 |
| 3 | Asafa Powell (JAM) | 9.84 | SB | 0.134 | 6 |
| 4 | Daniel Bailey (ANT) | 9.93 | | 0.129 | 3 |
| 5 | Richard Thompson (TRI) | 9.93 | SB | 0.119 | 8 |
| 6 | Dwain Chambers (GBR) | 10.00 | SB | 0.123 | 1 |
| 7 | Marc Burns (TRI) | 10.00 | SB | 0.165 | 2 |
| 8 | Darvis Patton (USA) | 10.34 | | 0.149 | 7 |

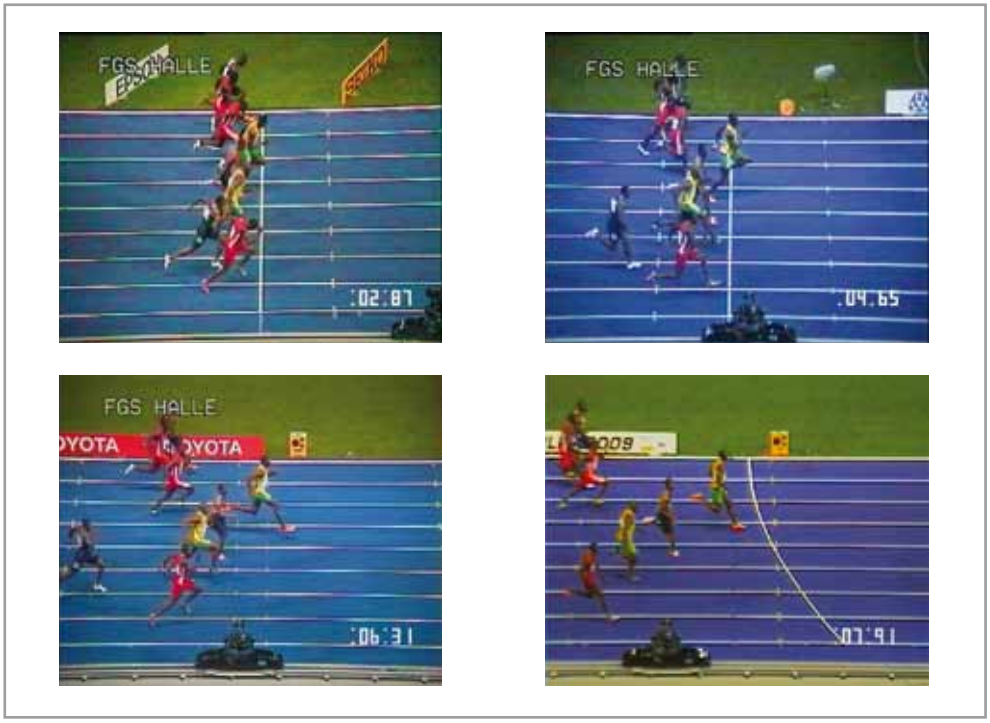



*Figure 2: Screenshots of the four split times (sec) of Usain Bolt in the 100m final at the 2009 IAAF World Championships in Athletics*

*Table 4: Split and interval times (sec) of the men's 100m final at the 2009 IAAF World Championships in Athletics*

| | RT | 20m | 40m | 60m | 80m | 100m | 20-40m | 40-60m | 60-80m | 80-100m |
|---|---|---|---|---|---|---|---|---|---|---|
| Bolt | 0.146 | 2.88 | 4.64 | 6.31 | 7.92 | **9.58** | 1.76 | 1.67 | 1.61 | 1.66 |
| Gay | 0.144 | 2.92 | 4.70 | 6.39 | 8.02 | **9.71** | 1.78 | 1.69 | 1.63 | 1.69 |
| Powell | 0.134 | 2.91 | 4.71 | 6.42 | 8.10 | **9.84** | 1.80 | 1.71 | 1.68 | 1.74 |
| Bailey | 0.129 | 2.92 | 4.73 | 6.48 | 8.18 | **9.93** | 1.81 | 1.75 | 1.70 | 1.75 |
| Thompson | 0.119 | 2.90 | 4.71 | 6.45 | 8.17 | **9.93** | 1.81 | 1.74 | 1.72 | 1.76 |
| Burns | 0.165 | 2.94 | 4.76 | 6.52 | 8.24 | **10.00** | 1.82 | 1.76 | 1.72 | 1.76 |
| Chambers | 0.123 | 2.93 | 4.75 | 6.50 | 8.22 | **10.00** | 1.82 | 1.75 | 1.72 | 1.78 |
| Patton | 0.149 | 2.96 | 4.85 | 6.65 | 8.42 | **10.34** | 1.89 | 1.80 | 1.77 | 1.92 |

*Table 5: Stride analysis for Usain Bolt in the 100m final at the 2009 IAAF World Championships in Athletics*

| | Interval time [sec] | Average stride length [m] | Average stride frequency [strides/sec] |
|---|---|---|---|
| 0-20m | 2.89 | 1.78 | 3.89 |
| 20-40m | 1.75 | 2.52 | 4.54 |
| 40-60m | 1.67 | 2.67 | 4.49 |
| 60-80m | 1.61 | 2.77 | 4.49 |
| 80-100m | 1.66 | 2.85 | 4.23 |

Using the data obtained from the final in Berlin, a question that was frequently discussed after the 2008 Olympic Games can be acceptably answered: What could Bolt have achieved in Beijing if he had run through the finish line without slowing to celebrate? In the analyses of Beijing (http//www.sportscientists.com), an 80m split time of 7.96 sec is given, which is 0.04 sec slower than the same split in Berlin. It is reasonable to assume that he could have finished the race at the same velocity as he did in Berlin and therefore, it is possible to estimate that his time in the 2008 Olympic final running at full effort through the finish could have been 9.63 sec.

An outstanding characteristic of Bolt can be identified on the basis of the analysis of his strides (see Table 5). Whereas his stride frequency can be considered as quite normal for a sprinter of his body height, his average stride length of up to 2.85m is a novum and meant that his total number of strides for the race was 40.92. This, ultimately, is the biomechanical explanation of his performance advantage.

## Laser Measurement Analysis of the Men's 100 Metres Final

The laser measurement team consisted of Eberhard Nixdorf (Olympic Training Centre Hessen) Falk Schade (Olympic Training Centre Rhein-Arena), Regine Isele (Olympic Training Centre Hessen), and Luis Mendoza (Olympic Training Centre Hessen)

### *Introduction*

In addition to the video-based analyses, three laser measurement systems (LAVEG Sport and LEM 300, JenOptik) were used during the men's 100m final. These use laser distance measurement to determine the distance to an object at any point in time, i.e. the sprinters, during the whole race. From the distance-time curve, the split and interval times can be calculated at a finer resolution (10m intervals) as well as the mean interval velocities and the momentary velocities.

Due to the completely differing measurement approach, the split times determined through the method of laser distance measurement can be expected to differ slightly from those obtained through video-based measurement.

### *Methodology*

The procedure is based on the infrared laser measurement of the distance to the athlete. Since the wavelength of the emitted light is in the invisible range, the measuring point itself cannot directly be seen on the athlete. During the measurement, a precise lens and a cross-hair is used to focus on a point in the athlete's lumbar region and to follow that point during the complete run, right through the finish. The measurement is conducted at 50Hz (LAVEG Sport) and 100Hz (LEM 300), i.e., according to their type of construction, the systems measure 50 or 100 distances to the targeted object per second.

The raw data are filtered using a digital Butterworth low-pass filter (cut-off 7 Hz). In doing so, the intracyclical velocity changes of the running strides are maintained (blue curve). This data is used to calculate the 10m split times, the 10m interval times and the 10m interval velocities. The calculation of the first 10m interval velocity (V0-10) is done without taking into account the reaction time. Because of the start from behind the starting line, this section is slightly longer than 10m. This effect could not be taken into account so that for the start section a distance of 10m was assumed and for the calculation of the interval time only the reaction time was subtracted.

Using a harder low-pass filter (cut-off 1 Hz), the intracyclical velocity changes can be completely filtered out, so that the momentary velocity without the cycle effects (red curve) is the only information left. Now, the maximal velocity and the place where the maximal velocity is reached as well as the corresponding values for 99% of the maximal velocity can be easily calculated.

The calculation of the velocities is made by simple differentiation from the distance measurement. As no linkage was possible, the synchronisation with the official time measurement was made using the run through the finish line.

The three laser measurement systems were operated at a distance of about 15m behind the starting blocks from the spectator areas. The height was between 2.3m and 2.7m above the starting line to get over a fence and an advertising board. Each system was calibrated, so that the different heights and distances to the starting line could be compensated for.

## Note on Measurement Accuracy

Although ideally, the results of the video split-time measurement and the LAVEG laser measurement should generally lead to identical results, there can be slight differences, which are due to the shortcomings of the technical measurement systems and the people conducting the measurements.

In the video measurement there are two noteworthy sources of error:

1) Errors with the adjustment of the cameras orthogonally aligned with the running track. This source of error was only of inferior importance in the present analysis, because the distance between the cameras and the running track was more than 100m (a deviation of 1m in the position of the camera corresponds with a deviation of 1cm in the position of the athlete to be measured on the track = ca. 1/1000s).

2) Because of the 50Hz frame rate there are minimally measurable differences of 0.02 sec, which require an interpolation in the case of slight deviations (0.01 sec) from the measurement position. Although the subjective factor of the evaluator is of a certain importance in the interpolation, this can generally be compensated for through experience.

In laser measurement systems there are also two fundamental sources of error:

1) Inaccuracies in targeting and tracking the athlete over the complete measurement distance.

2) Deviations in the calculation of parameters as a result of the smoothing procedure that must be applied to the original measurement values (choice of smoothing factor).

Although there is no intention to continue the error discussion on a scientific level any longer, it must be stated that, with a cross-comparison of results from the two measurement procedures, an immanent error measure of at least 0.01 sec must be assumed for each procedure. Therefore, a difference of 0.02 sec in total for any result should not be worth discussing. This means that, on the basis of error consideration, a content-related discussion of deviations of 0.01 sec between two 10m interval times is generally pointless.

## Results

*Table A: Split times (sec) of the medallists in the men's 100m final at the 2009 IAAF World Championships in Athletics*

| Name | T10 | t20 | t30 | t40 | t50 | t60 | t70 | t80 | T90 | t100 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bolt | 1.88 | 2.88 | 3.78 | 4.64 | 5.47 | 6.29 | 7.10 | 7.92 | 8.74 | 9.58 |
| Gay | 1.91 | 2.93 | 3.84 | 4.70 | 5.54 | 6.36 | 7.19 | 8.02 | 8.86 | 9.71 |
| Powell | 1.88 | 2.90 | 3.83 | 4.71 | 5.56 | 6.40 | 7.24 | 8.09 | 8.95 | 9.84 |

*Table B: Interval times (sec) of the medallists in the men's 100m final at the 2009 IAAF World Championships in Athletics*

| Name | T10 | T20 | t30 | t40 | t50 | t60 | t70 | t80 | T90 | t100 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bolt | 1.88 | 1.00 | 0.90 | 0.86 | 0.83 | 0.82 | 0.81 | 0.82 | 0.82 | 0.84 |
| Gay | 1.92 | 1.02 | 0.91 | 0.86 | 0.84 | 0.82 | 0.83 | 0.83 | 0.84 | 0.85 |
| Powell | 1.88 | 1.02 | 0.93 | 0.88 | 0.85 | 0.84 | 0.84 | 0.85 | 0.86 | 0.89 |

*Table C: Mean interval velocities (m/sec) of the medallists in the men's 100m final at the 2009 IAAF World Championships in Athletics*

| Name | V0-10 | V10-20 | V20-30 | V30-40 | V40-50 | V50-60 | V60-70 | V70-80 | V80-90 | V90-100 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bolt | 5.77 | 9.99 | 11.11 | 11.63 | 12.08 | 12.20 | 12.29 | 12.17 | 12.17 | 11.96 |
| Gay | 5.63 | 9.80 | 11.04 | 11.65 | 11.85 | 12.16 | 12.09 | 12.05 | 11.93 | 11.76 |
| Powell | 5.73 | 9.78 | 10.79 | 11.41 | 11.75 | 11.90 | 11.84 | 11.80 | 11.61 | 11.20 |

*Table D: Maximum velocity (99% and 100%] and location of maximum velocity of the medallists in the men's 100m final at the 2009 IAAF World Championships in Athletics*

| Name | V99% [m/sec] | location [m] | Vmax [m/sec] | location [m] |
|---|---|---|---|---|
| Bolt | 12.22 | 51.27 | 12.34 | 67.90 |
| Gay | 12.09 | 52.45 | 12.20 | 55.23 |
| Powell | 11.87 | 52.55 | 11.99 | 53.75 |

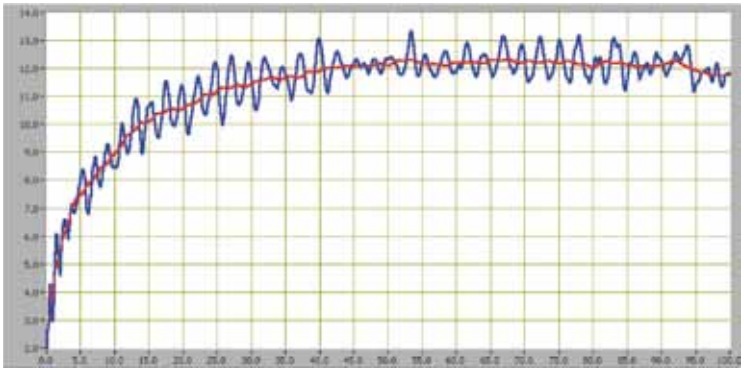


*Figure A: Momentary velocity vs location for Usain Bolt in the men's 100m final at the 2009 IAAF World Championships in Athletics*

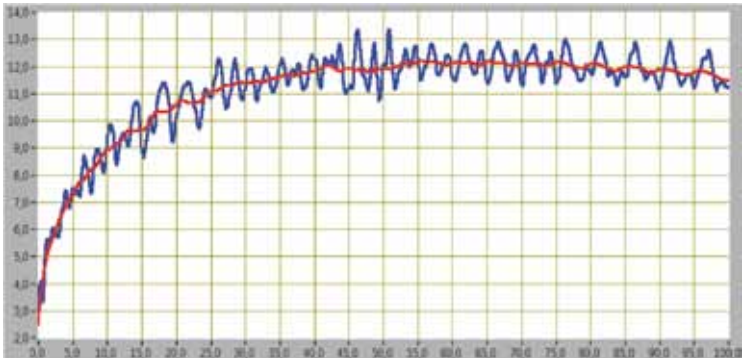


*Figure B: Momentary velocity vs location for Tyson Gay in the men's 100m final at the 2009 IAAF World Championships in Athletics*

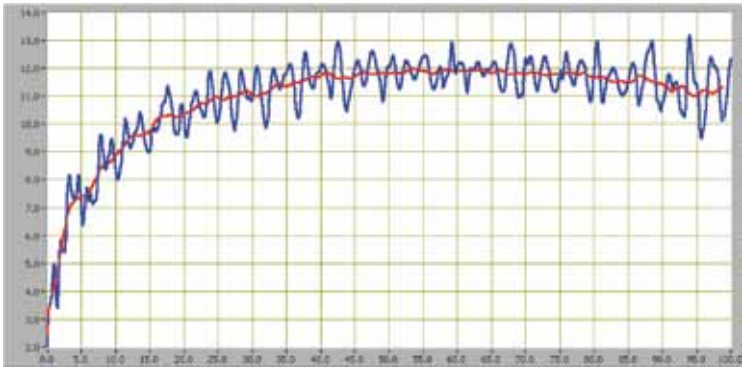


*Figure C: Momentary velocity vs location for Asafa Powell in the men's 100m final at the 2009 IAAF World Championships in Athletics*

In the starting phase (V0-10), Bolt and Powell were a little faster than Gay. But already in the next interval (V10-20), Bolt's interval velocity is greater than the others. Between 30m and 40m, Gay once again slightly surpassed Bolt's interval velocity but thereafter Bolt runs faster than the other two in all the following intervals. Gay and Powell reach their highest interval velocities of 12.16 m/sec and 11.90 m/sec, respectively, between 50m and 60m. Bolt achieves his highest interval velocity of 12.29 m/sec only in the next interval, V60-70 but already in the V40-50 interval he had reached an interval velocity faster than 12m/sec. Gay also ran faster than 12 m/sec in the three intervals from 50m to 80m. Powell did not reach 12 m/sec in any interval and his maximum interval velocity was measured as 11.90 m/sec in the V50-60 interval. In nine out of 10 intervals, Bolt's interval velocity was greater than that of Gay and in all intervals it was faster than that of Powell.

The exact calculation of the maximum speed indicates that all three medallists achieved 99% of their maximum speed between the 51m and 53m marks. Bolt then reaches his maximum speed only at about 68m, while Gay reaches his at about 55m. Powell's maximum running speed and the value for 99% are close to each other at about 53m.

Data were collected from the men's 100m final at the 1997 IAAF World Championships in Athletics using the same method of laser distance measurement processed using a similar approach (Müller & Hommel, 1997). According to this data, the winner Maurice Greene's (USA) maximum running velocity and that of second placer Donavan Bailey (CAN) were slightly lower than the values of the present study. Neither was able to reach the values of the 2009 medallists with regard to the interval velocities or maximum running speed.

They also reached their maximum running speed later than Gay and Powell: Greene (final time: 9.86 sec) reached 11.87 m/sec at about 58m, while Bailey (final time: 9.91 sec) reached 11.87 m/sec, too, at about 62m.

### *Results and Comments – Women*

As with the men, the women's 100m final Berlin was of very high quality, with the winner Shelly-Ann Fraser-Price (JAM) achieving the fourth fastest time in history and the best mark for comparable competitions since the year 2000 (see Table 10). The mean time for the first three was 10.79 sec and it was 10.95 sec for all eight finalists, the first time this value has been below 11.00 sec.

However, in comparison to Jeter and especially Stewart, Fraser-Price's early acceleration advantage of 0.09 sec (at 30 and 40m) is more pronounced than her velocity loss from 60m to the finish line.

As far as the position of the fastest sections is concerned, there is an analogy with the men, even though previous studies lead to the assumption that women tend to achieve their definite velocity maximum earlier in the race.

The average velocities calculated for the 20m intervals are in the same range of instantaneous velocities obtained using LAVEG laser equipment. Here, Stewart's mean velocity of 10.75 m/sec for the 20m from 60m to 80m is an absolute top value.

The split and interval times for the finalists are given in Table 11. The comparison between the medal winners shows interesting individual dispositions of the 100m performance structure. Fraser-Price, had a very high acceleration ability, which is particularly clear in the calculated 30m time of 4.02 sec – a value that is almost at the same level as that of male sprinters with a performance ability in the 10.40 sec-10.60 sec range. Although Stewart (JAM) and Jeter (USA) achieved approximately the same velocity level as Fraser-Price in the 40-60m section of the better semi-final race, they were then able to accelerate even more and then to maintain their pace (see Table 12, Table 13 and Table 14).

The stride analysis (see Table 15) leads to an expected result. The two shorter sprinters, Fraser-Price (body height: 1.60m) and Jeter

*Table 10: Results of the women's 100m final at the 2009 IAAF World Championships in Athletics*

**100 Metres - Women's Final**

17 August 2009 – 21:35 Wind: 0.1 m/sec

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Shelly-Ann Fraser-Price (JAM) | 10.73 | WL | 0.146 | 3 |
| 2 | Kerron Stewart (JAM) | 10.75 | PB | 0.170 | 4 |
| 3 | Carmelita Jeter (USA) | 10.90 | | 0.160 | 5 |
| 4 | Veronica Campbell-Brown (JAM) | 10.95 | SB | 0.135 | 6 |
| 5 | Lauryn Williams (USA) | 11.01 | SB | 0.158 | 8 |
| 6 | Debbie Feguson-Mckenzie (BAH) | 11.05 | | 0.130 | 2 |
| 7 | Chandra Sturrup (BAH) | 11.05 | | 0.137 | 7 |
| 8 | Aleen Bailey (JAM) | 11.16 | | 0.173 | 1 |

*Table 11: Split and interval times (sec) of the women's 100m final at the 2009 IAAF World Championships in Athletics*

| | RT | 20m | 40m | 60m | 80m | 100m | 20-40m | 40-60m | 60-80m | 80-100m |
|---|---|---|---|---|---|---|---|---|---|---|
| Fraser-Price | 0.146 | 3.03 | 4.98 | 6.88 | 8.77 | 10.73 | 1.95 | 1.90 | 1.89 | 1.96 |
| Stewart | 0.170 | 3.11 | 5.07 | 6.96 | 8.82 | 10.75 | 1.96 | 1.89 | 1.86 | 1.93 |
| Jeter | 0.160 | 3.13 | 5.09 | 7.01 | 8.91 | 10.90 | 1.96 | 1.92 | 1.90 | 1.99 |
| Campbell-Brown | 0.135 | 3.12 | 5.12 | 7.06 | 8.97 | 10.95 | 2.00 | 1.94 | 1.91 | 1.98 |
| Williams | 0.158 | 3.14 | 5.13 | 7.08 | 9.00 | 11.01 | 1.99 | 1.95 | 1.92 | 2.01 |
| Ferguson-McKenzie | 0.130 | 3.15 | 5.16 | 7.12 | 9.06 | 11.05 | 2.01 | 1.96 | 1.94 | 1.99 |
| Sturrup | 0.137 | 3.11 | 5.11 | 7.07 | 9.02 | 11.05 | 2.00 | 1.96 | 1.95 | 2.03 |
| Bailey | 0.173 | 3.24 | 5.27 | 7.23 | 9.18 | 11.16 | 2.03 | 1.96 | 1.95 | 1.98 |

*Table 12: Split and interval times (sec) of the women's 100m medallists in their semi-finals at the 2009 IAAF World Championships in Athletics*

| | RT | 20m | 40m | 60m | 80m | 100m | 20-40m | 40-60m | 60-80m | 80-100m |
|---|---|---|---|---|---|---|---|---|---|---|
| Fraser-Price | 0.156 | 3.06 | 5.03 | 6.94 | 8.84 | 10.79 | 1.97 | 1.91 | 1.90 | 1.95 |
| Jeter | 0.144 | 3.12 | 5.09 | 7.00 | 8.89 | 10.83 | 1.97 | 1.91 | 1.89 | 1.94 |
| Stewart | 0.155 | 3.09 | 5.06 | 6.94 | 8.87 | 10.84 | 1.97 | 1.88 | 1.93 | 1.97 |

(body height: 1.63m), exhibit a higher stride frequency than Stewart (body height: 1.74m), whereas Stewart shows a correspondingly greater stride length and subsequently a lower total number of strides for the 100m distance. However, in comparison to female sprinters of a similar body height, Fraser-Price and Jeter exhibit a well developed stride length: in the past, for comparable female sprinters (e.g. Gladisch-Möller, 1987) exemplary frequency values > 5/sec were measured on the one hand and significantly shorter stride lengths on the other hand. As compared with the measurements obtained at the 2008 World Athletics Final 2008 in Stuttgart (Fraser-Price 10.94m, Stewart 11.06m), a significant improvement of both parameters was found.

*Table 13: Comparison of selected intervals of the women's 100m medallists at the 2009 IAAF World Championships in Athletics (The data for Jeter is from her semi-final race.)*

| | 30m [sec] | 20-60m [sec] | 60-100m [sec] | dV [m/sec] |
|---|---|---|---|---|
| Fraser-Price | 4.02 | 3.85 | 3.85 | 10.39 |
| Stewart | 4.11 | 3.85 | 3.79 | 10.55 |
| Jeter (SF) | 4.12 | 3.88 | 3.83 | 10.44 |

*Table 14: Maximal velocities and their positions for the women's 100m medallists at the 2009 IAAF World Championships in Athletics (The data for Jeter is from her semi-final race.)*

| | dt 20m [sec] | Interval | V max [m/sec] |
|---|---|---|---|
| Fraser-Price | 1.89 | 60-80m | 10.58 |
| Stewart | 1.86 | 60-80m | 10.75 |
| Jeter (SF) | 1.89 | 60-80m | 10.58 |

*Table 15: Stride analysis for the medallists in the women's 100m final at the 2009 IAAF World Championships in Athletics*

| | Number of strides | 0-20m | | 20-40m | | 40-60m | | 60-80m | | 80-100m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SL | SF | SL | SF | SL | SF | SL | SF | SL | SF |
| Fraser-Price | 49.58 | 1.59 | 4.15 | 2.09 | 4.91 | 2.19 | 4.82 | 2.18 | 4.86 | 2.20 | 4.65 |
| Jeter | 47.46 | 1.59 | 4.05 | 2.17 | 4.70 | 2.28 | 4.65 | 2.33 | 4.62 | 2.42 | 4.29 |
| Stewart | 49.48 | 1.52 | 4.21 | 2.10 | 4.83 | 2.22 | 4.71 | 2.22 | 4.76 | 2.27 | 4.54 |

SL = Stride Length [m], SF = Stride Frequency [sec]

## The 200 Metres

### *Methods and Procedures*

The analysis for the 200m races was made from video split-time measurements using three cameras (no. 1 = 50m/no. 3 = 100m/no. 6 = 150) so that the performance was divided into four equal sections of 50m each. As in the 100m, additional video recordings (camera 13) were made in the finals for the stride length and stride frequency analysis.

### *Results and Comments – Men*

As in the 100m, the men's 200m final in Berlin was dominated by Usain Bolt. Again he shattered his own world record from Beijing, this time running 19.19 sec into a slight headwind of -0.3 m/sec. His margin over second placer Alonso (PAN) was 0.62 sec, greater than the sum total of the winning margins of the five previous editions of the race. Bolt's dominance was all the more impressive when one considers that it was the strongest 200m field ever: the mean time of the three medallists was 19.62 sec, the first five placers finished below 20.00 sec and the mean time of all finalists was 20.05 sec (see Table 16).

The 100m split and 50m interval times for the finalists are given in Table 17 and Table 18.

For the athletes placed 6-8 the split times presented are from their semi-finals, where they ran faster. As in earlier analyses, the fastest interval for all the participants was the section from 50m to 100m.

Bolt's ability to run the bend is very atypical for an athlete who is 1.96m tall. As can be seen in Table 17, at the 50m point in Berlin he was already 0.1 sec ahead of the Mullings (JAM), the second fastest. By the 100m split, the lead had increased to 0.23 sec (9.92 sec to 10.15 sec for Crawford (USA)). It is almost certain Bolt was the first person to run the first 100m in a 200m below 10.00 sec in his 19.30 sec world record race in Beijing in 2008 (9.98 sec – 9.32 sec); in Berlin, he was even faster for both halves of the race (9.92 sec - 9.27 sec).

The strength of the previous world record holder, Michael Johnson, who ran 19.32 sec, was the second half of the race (10.13 sec – 9.19 sec).

Of the three finalists who were slower than in their semi-final races (Clark (USA), Guliyev (AZE) and Alerte FRA)), it can be said that the main difference for them was in the second half of the race (Clark 9.83 sec - 10.01 sec; Alerte 9.85 sec - 10.03 sec) while Guliyev ran the first 100m 0.34 sec slower than in the semi-final.

*Table 16: Results of the men's 200m final at the 2009 IAAF World Championships in Athletics*

**200 Metres - Men's Final**

20 August 2009 – 20:35 Wind: 0.3 m/sec

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Usain Bolt (JAM) | 19.19 | WR | 0.133 | 5 |
| 2 | Alonso Edward (PAN) | 19.81 | AR | 0.179 | 6 |
| 3 | Wallace Spearmon (USA) | 19.85 | SB | 0.152 | 4 |
| 4 | Shawn Crawford (USA) | 19.89 | SB | 0.148 | 8 |
| 5 | Steve Mullings (JAM) | 19.98 | PB | 0.146 | 3 |
| 6 | Charles Clark (USA) | 20.39 | | 0.158 | 7 |
| 7 | Ramil Guliyev (AZE) | 20.61 | | 0.165 | 1 |
| 8 | David Alerte (FRA) | 20.68 | | 0.161 | 2 |

*Table 17: Split times (sec) of the 100m sections in the men's 200m final at the 2009 IAAF World Championships in Athletics*

| | Result | 0-100m | Diff. | 100-200m |
|---|---|---|---|---|
| Bolt | 19.19 | 9.92 | 0.65 | 9.27 |
| Edward | 19.81 | 10.37 | 0.93 | 9.44 |
| Spearmon | 19.85 | 10.42 | 0.99 | 9.43 |
| Crawford | 19.89 | 10.15 | 0.41 | 9.74 |
| Mullings | 19.98 | 10.20 | 0.42 | 9.78 |
| | | | | |
| Clark | 20.27 | 10.44 | 0.61 | 9.83 |
| Guliyev | 20.28 | 10.43 | 0.58 | 9.85 |
| Alerte | 20.45 | 10.60 | 0.75 | 9.85 |


Women's 200m final – **50m**
Lane 6: Allyson Felix - 6.25 sec

Women's 200m final – **100m**
Lane 5: Veronica Campbell-Brown - 11.14 sec


Women's 200m final – **150m**
Lane 6: Allyson Felix -16.38 sec


Women's 200m final – pan shot

*Figure 6: Example analyses of the women's 200m final at the 2009 IAAF World Championships in Athletics*

The performance of the first two of these athletes strengthens the common belief among experts that success in a major event final can be realised only if there is a constant improvement of performance from round to round.

The most important information provided by the velocity analysis is that Bolt was able to run two 50m sections at an average velocity of more than 11m/sec (50-150m: 11.31 m/sec), and that be sides Bolt only Crawford with (11.03 m/sec) could do this for the same sec-

*Table 18: 50m interval times (sec) for the men's 200m at the 2009 IAAF World Championships in Athletics (places 1-5 from the final, places 6-8 from semi-final)*

| | Result | 0-50m | 50-100m | 100-150m | 150-200m |
|---|---|---|---|---|---|
| Bolt | 19.19 | 5.60 | 4.32 | 4.52 | 4.75 |
| Edward | 19.81 | 5.88 | 4.49 | 4.63 | 4.81 |
| Spearmon | 19.85 | 5.89 | 4.53 | 4.64 | 4.79 |
| Crawford | 19.89 | 5.73 | 4.42 | 4.65 | 5.09 |
| Mullings | 19.98 | 5.70 | 4.50 | 4.73 | 5.05 |
| Clark | 20.27 | 5.84 | 4.60 | 4.76 | 5.07 |
| Guliyev | 20.28 | 5.85 | 4.58 | 4.78 | 5.07 |
| Alerte | 20.45 | 5.94 | 4.66 | 4.80 | 5.05 |

*Table 19: Mean velocity (m/sec) of the 50m sections in the men's 200m final at the 2009 IAAF World Championships in Athletics*

| | 0-50m | 50-100m | 100-150m | 150-200m |
|---|---|---|---|---|
| Bolt | 8.93 | 11.57 | 11.06 | 10.53 |
| Edward | 8.50 | 11.14 | 10.80 | 10.40 |
| Spearmon | 8.49 | 11.04 | 10.78 | 10.44 |
| Crawford | 8.73 | 11.31 | 10.75 | 9.82 |
| Mullings | 8.77 | 11.11 | 10.57 | 9.90 |
| Clark | 8.56 | 10.87 | 10.50 | 9.86 |
| Guliyev | 8.55 | 10.92 | 10.46 | 9.86 |
| Alerte | 8.42 | 10.73 | 10.42 | 9.90 |

*Table 20: Stride analysis for Usain Bolt in the 100m final at the 2009 IAAF World Championships in Athletics*

| | Number of strides | 0-50m | | 50-100m | | 100-150m | | 150-200m | |
|---|---|---|---|---|---|---|---|---|---|
| | | SL | SF | SL | SF | SL | SF | SL | SF |
| Bolt | 79.88 | 2.14 | 4.17 | 2.61 | 4.43 | 2.66 | 4.16 | 2.69 | 3.91 |

SL = Stride Length [m], SF = Stride Frequency [strides/sec]

tion of the race. The three medal winners differ from the other participants primarily through their performance in the fourth 50m section (dv >10m/sec).

The comparison of the stride analysis of Bolt's 100m and 200m races (Table 5 and Table 20) leads to the assumption that he deliberately started the 200m race in a more conservative way than he did in the 100m. The stride lengths in the first part of the 200m are in the area of 91-95% of the maximal value of the 100m race, which tends to disprove the assumed submaximal character of the 200m race. It seems that in the 200m, Bolt aimed to achieve an even stride length pattern. The significant difference of the mean velocity between the second and the fourth 50m sections (decrease of approximately 9%) can be understood on the basis of the change of the stride frequency.

### *Results and Comments – Women*

The performances in the women's 200m final in Berlin were not of an exceptional character. Although the time of 22.02 sec for the winner Allyson Felix (USA) and the mean time of 22.26 sec for the medal winners were of a comparatively high level, the 22.59 sec mean time of all the finalists was only moderate (see Table 21).

With the exception of Felix, the performances of all the finalists were worse than what they were able to do in the semi-finals. That is why our analysis and comments here is largely based on the seven better semi-final performances. Interestingly, only two of the Berlin women's 100m finalists made it to the 200m final (Campbell-Brown (JAM) and Ferguson-McKenzie (BAH)). This might suggest that the entire competition was too great a burden for most of the participants. However, it is not entirely plausible, because, contrary to earlier competitions and compared with the men's competition, there were only three rounds. Moreover, the semi-finals and final were held on separate days. Except for Felix, whose performance is not discussed here, and Campbell-Brown, all other finalists demonstrated worse performances for both of the two 100m sections in the final compared to what they did in the semi-finals. Since there are relatively small differences between the first and second 100m split times (see Table 22), it is the general level of speed endurance that deserves a critical comment, particularly as far as its repeatability in multiple runs within a major event is concerned.

Looking at the 50m interval times in Table 23, we see that times below 5.00 sec in the second section (50-100m) are conspicuous with three athletes. The winner, Felix, reached a velocity of 10.18 m/sec in the final. In the 50-150m section, she also reached a partial time of 10.12 sec, which in a 4x100m relay race would constitute an outstanding leg. By comparison, in the relay analysis, times below 10.00 sec and 10.12 sec could only be measured for the 100m final runners Ferguson-McKenzie and Stewart, while the partial times for the other two flying distances remained clearly behind the aforementioned value of Felix. This is also due to the baton exchanges taking place in these sections. Felix's performance is all the more remarkable because she tends to the 400m rather than the 100m (she was not even a member of the US 4x100m relay team). This orientation is also certainly a reason for her dominance in the fourth 50m interval.

*Table 21: Results of the women's 200m final at the 2009 IAAF World Championships in Athletics*

**200 Metres - Women's Final**

21 August 2009 – 21:40 Wind: -0.1 m/sec

| | Athlete (Country) | Mark [sec] | Reaction Time [sec] | Lane |
|---|---|---|---|---|
| 1 | Allyson Felix (USA) | 22.02 | 0.173 | 6 |
| 2 | Veronica Campbell-Brown (JAM) | 22.35 | 0.184 | 5 |
| 3 | Debbie Feguson-McKenzie (BAH) | 22.41 | 0.171 | 4 |
| 4 | Muna Lee (USA) | 22.48 | 0.174 | 3 |
| 5 | Anneisha McLaughlin (JAM) | 22.62 | 0.178 | 8 |
| 6 | Simone Facey (JAM) | 22.80 | 0.163 | 7 |
| 7 | Emily Freeman (GBR) | 22.98 | 0.141 | 2 |
| 8 | Eleni Artymata (CYP) | 23.05 | 0.176 | 1 |

*Table 22: Comparison of the 100m intervals between the final and semi-finals in the women's 200m at the 2009 IAAF World Championships in Athletics (SF = semi-final)*

| | Round | Wind [m/sec] | Result [sec] | 0-100m [sec] | Difference [sec] | 100-200m [sec] |
|---|---|---|---|---|---|---|
| Felix | Final | -0.1 | 22.02 | 11.16 | -0.30 | 10.86 |
| | SF 2 | 0.3 | 22.44 | 11.34 | -0.24 | 11.10 |
| Campbell-Brown | Final | -0.1 | 22.35 | 11.14 | 0.07 | 11.21 |
| | SF 1 | 0.5 | 22.29 | 11.23 | -0.17 | 11.06 |
| Ferguson-McKenzie | Final | -0.1 | 22.41 | 11.29 | -0.17 | 11.12 |
| | SF 1 | 0.5 | 22.24 | 11.21 | -0.18 | 11.03 |
| Lee | Final | -0.1 | 22.48 | 11.25 | -0.02 | 11.23 |
| | SF 3 | 0.5 | 22.30 | 11.23 | -0.16 | 11.07 |
| McLaughlin | Final | -0.1 | 22.62 | 11.43 | -0.24 | 11.19 |
| | SF 2 | 0.3 | 22.55 | 11.39 | -0.23 | 11.16 |
| Facey | Final | -0.1 | 22.80 | 11.39 | 0.02 | 11.41 |
| | SF 3 | 0.5 | 22.58 | 11.39 | -0.20 | 11.19 |
| Freeman | Final | -0.1 | 22.98 | 11.47 | 0.04 | 11.51 |
| | SF 1 | 0.5 | 22.64 | 11.40 | -0.16 | 11.24 |
| Artymata | Final | -0.1 | 23.01 | 11.70 | -0.39 | 11.31 |
| | SF 1 | 0.5 | 22.64 | 11.57 | -0.50 | 11.07 |

Individual better time

*Table 23: 50m interval times (sec) for the best runs of the finalists in the women's 200m at the 2009 IAAF World Championships in Athletics (SF = data from semi-final)*

| | Result | 0-50m | 50-100m | 100-150m | 150-200m |
|---|---|---|---|---|---|
| Felix | 22.02 | 6.25 | 4.91 | 5.22 | 5.64 |
| Campbell-Brown (SF) | 22.29 | 6.25 | 4.98 | 5.29 | 5.77 |
| Ferguson-McKenzie (SF) | 22.24 | 6.19 | 5.02 | 5.33 | 5.70 |
| Lee (SF) | 22.30 | 6.26 | 4.97 | 5.30 | 5.77 |
| McLaughlin (SF) | 22.55 | 6.38 | 5.01 | 5.30 | 5.86 |
| Facey (SF) | 22.58 | 6.31 | 5.08 | 5.39 | 5.80 |
| Freeman (SF) | 22.64 | 6.29 | 5.11 | 5.39 | 5.85 |
| Artymata (SF) | 22.64 | 6.46 | 5.11 | 5.35 | 5.72 |

*Table 24: Mean velocities (m/sec) for the 50m intervals in the best runs of the finalists in the women's 200m at the 2009 IAAF World Championships in Athletics (SF = semi-final)*

| | 0-50m | 50-100m | 100-150m | 150-200m |
|---|---|---|---|---|
| Felix | 8.00 | 10.18 | 9.60 | 8.85 |
| Campbell-Brown (SF) | 8.00 | 10.04 | 9.45 | 8.67 |
| Ferguson-McKenzie (SF) | 8.08 | 9.96 | 9.38 | 8.77 |
| Lee (SF) | 7.99 | 10.06 | 9.43 | 8.67 |
| McLaughlin (SF) | 7.84 | 9.98 | 9.43 | 8.53 |
| Facey (SF) | 7.92 | 9.84 | 9.28 | 8.62 |
| Freeman (SF) | 7.95 | 9.78 | 9.28 | 8.55 |
| Artymata | 7.74 | 9.78 | 9.35 | 8.74 |

## The 400 Metres

### *Methods and Procedures*

The analysis of the 400m races was conducted as a split-time measurement with three video cameras and two recording systems. Camera no. 11 was used to record the outer four lanes and the 250m (no. 1), 300m (no. 3), and 350m (no. 6) measuring points on one system while camera no. 12 was used to record lanes 1-4 independently on a second system. Thus, it was possible to break down the performance into four identical intervals of 100m each. In addition, if required, an analysis of the 50m intervals could be conducted.

However, this option was used only in selected cases, since the lane markings at 50m and 150m were barely visible for the evaluation in the video footage, which, as far as the split times determined at these measuring points, requires the assumption of an error tolerance of 0.04 sec.

### *Results and Comments – Men*

Compared to other major events in the last decade, the performances in the men's 400m final were generally poor (Table 25). Although winner LaShawn Merritt's (USA) 44.06 sec performance was at a very high level and the world leading time for the year, only second placed Jeremy Warnier (USA) was also below 45.00 sec, which has not been the case in any recent comparable competition. The 44.56 sec average time of the three medallists is fairly good because of Merritt's respectable performance but the average time of all the finalists, 45.19 sec, is the slowest in the reference period.

However, this does not accurately reflect the quality of the finalists, since some of the athletes in places 3-8 achieved significantly better performances in the semi-finals. Therefore, the comments made with regard to the women's 200m competition could be repeated here. Therefore, analysis of the better performances in the semi-finals by the athletes placed 3-8 are also taken into account here.

Table 26 demonstrates that, with the exception of Merritt and Wariner, the finalists hit their performance peaks in the semi-finals while achieving the qualification for the final. Consideration of the performances in Round 1 also leads to a result hardly expected and strengthens the semi-final peak thesis: only two of the six runners placed 3-8 in the final show an improvement between the Round 1 result and the final, while the other four in some cases show a marked deterioration.

Table 27 provides an interesting insight into the course of the final and shows the very different individual realisation of the race. It is clear that the winner, Merritt, dominated the second half of the race. However, during the first two sections he was only slightly behind the leaders. One can also notice that Brown (BAH) ran the first 200m much too fast (in his faster semi-final he was 21.72 sec), which in turn had a significantly negative impact on the final 100m, where he lost third place, which he had occupied until then, to Quow (TRI). Quow in turn started the race atypically slow for a 400m runner. He ran almost identical halves, which resulted in him being the fastest over the last 100m. The silver medallist, Wariner, de

*Table 25: Results of the men's 400m final at the 2009 IAAF World Championships in Athletics*

**400 Metres - Men's Final**

21 August 2009 – 22:00

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | LaShawn Merritt (USA) | 44.06 | WL | 0.161 | 4 |
| 2 | Jeremy Wariner (USA) | 44.60 | SB | 0.162 | 6 |
| 3 | Renny Quow (TRI) | 45.02 | | 0.195 | 3 |
| 4 | Tabarie Henry (ISV) | 45.42 | | 0.162 | 7 |
| 5 | Chris Brown (BAH) | 45.47 | | 0.161 | 5 |
| 6 | David Gillick (IRL) | 45.53 | | 0.148 | 2 |
| 7 | Michael Bingham (GBR) | 45.56 | | 0.172 | 8 |
| 8 | Leslie Djhone (FRA) | 45.90 | | 0.151 | 1 |

*Table 26: Comparison (sec) of the three competition rounds of the men's 400m at the 2009 IAAF World Championships in Athletics*

| | Round 1 | Diff. | Semi-final | Diff. | Final |
|---|---|---|---|---|---|
| Merritt | 45.23 | 0.86 | 44.37 | 0.31 | 44.06 |
| Wariner | 45.54 | 0.85 | 44.69 | 0.09 | 44.60 |
| Quow | 45.21 | 0.68 | 44.53 | -0.49 | **45.02** |
| Henry | **45.14** | 0.17 | 44.97 | -0.45 | 45.42 |
| Brown | 45.53 | 0.58 | 44.95 | -0.52 | **45.47** |
| Gillick | 45.54 | 0.66 | 44.88 | -0.65 | 45.53 |
| Bingham | **45.54** | 0.80 | 44.74 | -0.82 | 45.56 |
| Djhone | **45.20** | 0.40 | 44.80 | -1.10 | 45.90 |

Individual best

*Table 27: Split times, interval times and rankings in the men's 400m final at the 2009 IAAF World Championships in Athletics*

| | 100m Time [sec] | Rank | 200m Time [sec] | Rank | 300m Time [sec] | Rank | 400m Time [sec] | Rank | 100-200m Time [sec] | Rank | 200-300m Time [sec] | Rank | 300-400m Time [sec] | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Merritt | 11.14 | 3 | 21.49 | 3 | 32.30 | 1 | **44.06** | ***1*** | 10.35 | 2 | 10.81 | 1 | 11.76 | 2 |
| Wariner | 10.98 | 1 | 21.41 | 2 | 32.34 | 2 | **44.60** | ***2*** | 10.43 | 3 | 10.93 | 3 | 12.26 | 4 |
| Quow | 11.70 | 8 | 22.43 | 8 | 33.32 | 7 | **45.02** | ***3*** | 10.73 | 8 | 10.89 | 2 | 11.70 | 1 |
| Henry | 11.18 | 4 | 21.83 | 4 | 33.17 | 5 | **45.42** | ***4*** | 10.65 | 5 | 11.34 | 6 | 12.25 | 3 |
| Brown | 10.98 | 1 | 21.31 | 1 | 32.53 | 3 | **45.47** | ***5*** | 10.33 | 1 | 11.22 | 5 | 12.94 | 8 |
| Gillick | 11.24 | 6 | 21.83 | 4 | 33.18 | 6 | **45.53** | ***6*** | 10.59 | 4 | 11.35 | 7 | 12.35 | 5 |
| Bingham | 11.19 | 5 | 21.84 | 6 | 33.02 | 4 | **45.56** | ***7*** | 10.65 | 6 | 11.18 | 4 | 12.54 | 7 |
| Djhone | 11.34 | 7 | 22.04 | 7 | 33.46 | 8 | **45.90** | ***8*** | 10.70 | 7 | 11.42 | 8 | 12.44 | 6 |

Split /Interval best


Men's 400m final, **200m**/lanes 5-8
Lane 5: Chris Brown/21.31 sec


Men's 400m final, **200m**/lanes 1-4
Lane 4: LaShawn Merritt/21.49 sec


Women's 400m final, **250m**
Lane 5: Antonina Krivoshapka/29.59 sec


Women's 400m final, **300m**
Lane 3: Sanya Richards/35.62 sec

*Figure 7: Example analysis from the 400m finals at the 2009 IAAF World Championships in Athletics*

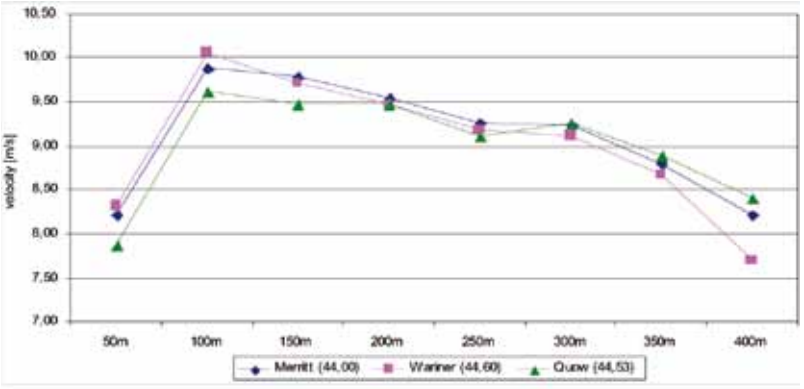



*Figure 8: Velocity course of the medallists' best runs in the men's 400m at the 2009 IAAF World Championships in Athletics*

*Table 28: Comparison of the first and second half times (sec) of the best races for the top 10 men in the 400m at the 2009 IAAF World Championships in Athletics (SF = semi-final)*

| | 400m | 1st 200m | Diff. | 2nd 200m |
|---|---|---|---|---|
| Merrit | **44.06** | 21.49 | 1.08 | 22.57 |
| Wariner | **44.60** | 21.41 | 1.78 | 23.19 |
| Quow (SF) | **44.53** | 22.09 | 0.35 | 22.44 |
| Henry (SF) | **44.97** | 21.91 | 1.15 | 23.06 |
| Brown (SF) | **44.95** | 21.72 | 1.51 | 23.23 |
| Gillick (SF) | **44.88** | 21.80 | 1.28 | 23.08 |
| Bingham (SF) | **44.74** | 21.84 | 1.06 | 22.90 |
| Djhone (SF) | **44.80** | 21.87 | 1.06 | 22.93 |
| Collazo (SF) | **44.93** | 21.56 | 1.81 | 23.37 |
| Miller (SF) | **44.99** | 21.99 | 1.01 | 23.00 |

*Table 29: Mean velocities (m/sec) of the 50m sections of the medallists' best runs in the men's 400m at the 2009 IAAF World Championships in Athletics (SF = semi-final)*

| | 0-50m | 50-100m | 100-150m | 150-200m | 200-250m | 250-300m | 300-350m | 350-400m |
|---|---|---|---|---|---|---|---|---|
| Merritt - 44.06 | 8.22 | 9.88 | 9.78 | 9.54 | 9.26 | 9.24 | 8.80 | 8.22 |
| Wariner - 44.60 | 8.32 | 10.06 | 9.71 | 9.47 | 9.17 | 9.12 | 8.67 | 7.70 |
| Quow - 44.53 (SF) | 7.89 | 9.62 | 9.49 | 9.47 | 9.12 | 9.26 | 8.90 | 8.42 |

livered almost identical races in the semi-final and final, but he demonstrated a perceptible weakness in the fourth section, where in the final he lost exactly half a second to Merritt.

When comparing the first and second 200m sections (see Table 28), the extreme values for the difference stand out (Wariner, Quow and Collazo). However, when Wariner's performance is compared to his winning 2007 World Championship run in Osaka, where he achieved a significantly better end-time (43.45 sec), a marked deterioration is noticeable in both halves (20.91 sec – 22.54 sec; difference: 1.63 sec). Figure 8 again illustrates that Wariner slowed down dramatically during the last 50m, while Quow caught up significantly from approximately 270m on.

The 50m section data (Table 29) supports some statements about the velocity course of the medallists. In the second interval Wariner was the only one of the three who ran faster than 10 m/sec (Brown was the only other finalist to do so 50-100m: 10.08 m/sec, 100-150m: 9.90 m/sec, 150-200m: 9.47 m/sec) and he shows the largest variation in velocity among runners considered here: 2.36 m/sec. If one ignores the first section, Quow shows a velocity fluctuation of only 1.20 m/sec, while with Merritt it is 1.66 m/sec.

### *Results and Comments – Women*

The 10-year comparison of the women's 400m final in Berlin is quite different than with the men. Because of Richards' top-level winning performance of 49.00 sec, three additional results below 50.00 sec and place 8 with 50.65 sec, best values are achieved with regard to both the mean time of the medal winners, 49.34 sec, and of the entire final field, 49.94 (see Table 30).

In Table 31 we see that half the athletes repeated or improved their semi-final performances in the final and of the four with slower final performances, three had semi-final performances below 50.00 sec (Kirivoshapka (RUS): 49.67 sec –> 49.71 sec; Dunn (USA): 49.95 sec –> 50.35 sec; Montsho (BOT): 49.89 sec –> 50.65 sec). This underlines the overall strength of the competition.

*Table 30: Results of the women's 400m final at the 2009 IAAF World Championships in Athletics*

**400 Metres - Women's Final**

18 August 2009 – 19:35

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Sanya Richards (USA) | 49.00 | WL | 0.164 | 3 |
| 2 | Sherika Williams (JAM) | 49.32 | PB | 0.194 | 4 |
| 3 | Antonia Krivoshapka (RUS) | 49.71 | | 0.187 | 5 |
| 4 | Novlene Williams-Mills (JAM) | 49.77 | SB | 0.214 | 6 |
| 5 | Christine Ohuruogu (GBR) | 50.21 | SB | 0.231 | 7 |
| 6 | Debbie Dunn (USA) | 50.35 | | 0.275 | 1 |
| 7 | Anastaslya Kapachinskaya (RUS) | 50.53 | | 0.220 | 2 |
| 8 | Amantle Monsho (BOT) | 50.65 | | 0.212 | 8 |

*Table 31: Comparison (sec) of the three competition rounds of the women's 400m at the 2009 IAAF World Championships in Athletics*

| | Round 1 | Diff. | Semi-final | Diff. | Final |
|---|---|---|---|---|---|
| Richards | 51.06 | 0.85 | 50.21 | 1.21 | 49.00 |
| Williams | 51.23 | 1.72 | 49.51 | 0.19 | 49.32 |
| Krivoshapka | 51.03 | 1.36 | 49.67 | -0.04 | 49.71 |
| Williams-Mills | 51.55 | 1.67 | 49.88 | 0.11 | 49.77 |
| Ohuruogu | 51.30 | 0.95 | 50.35 | 0.14 | 50.21 |
| Dunn | 51.13 | 1.18 | 49.95 | -0.40 | 50.35 |
| Kapachinskaya | 51.17 | 0.87 | 50.30 | -0.23 | 50.53 |
| Montsho | 50.65 | 0.76 | 49.89 | -0.76 | 50.65 |

A comparison is made between the semi-finals and the final in terms of split times in Table 32. We can see that in both races the eventual winner, Richards, led from start to finish: she was the only one who ran the first 100m below 12.00 sec and in the final she was the first to reach all the other measuring points. In fact, she got away from her opponents in the first and third 100m sections, while in both races presented, the second 100m sections were dominated by Krivoshapka. Among the other participants, there were only slight shifts in place, which are without any informative value. One positive aspect that can be ascribed to the winner on the basis of her superiority in the fourth section: she finished the semi-final restraining herself (13.80 sec – 13.38 sec) and this way certainly saved power for the final.

It is striking that a number of runners approached the first 200m in the final much more slowly than in the semi-final, which is the primary reason for the deterioration of the time in the final as compared to the semi-final for four athletes. For clarification, the smaller comparative differences in the respective second halves and the much smaller differences between the first and second half of the race in the final can be pointed out (Montsho, Kapachinskaya).

Once more, the analysis of the velocity courses in Table 33 proves in detail the statements that have been made previously. Outstanding are the values for the second 50m sections of Richards and Williams, both of whom ran at a mean velocity of more than 9 m/sec. It is illustrated once again that Richards has her greatest

*Table 32: Comparison of the 1st and 2nd 200m and 100m sections [sec] in the final and semi-finals for the finalists in the women's 400m at the 2009 IAAF World Championships in Athletics*

| | RT | 400m | 0- 200m | Diff. | 200-400m | 100m | 100-200m | 200-300m | 300-400m |
|---|---|---|---|---|---|---|---|---|---|
| Richards | 0.164 | 49.00 | 23.50 | 2.00 | 25.50 | *11.81* | 11.69 | *12.12* | 13.38 |
| | 0.192 | 50.21 | 24.15 | 1.91 | 26.06 | 12.08 | 12.07 | 12.26 | 13.80 |
| Williams | 0.194 | 49.32 | 23.76 | 1.80 | 25.56 | 12.07 | 11.69 | 12.24 | *13.32* |
| | 0.208 | 49.51 | 24.05 | 1.41 | 25.46 | 12.30 | 11.75 | 12.15 | 13.31 |
| Krivoshapka | 0.187 | 49.71 | 23.59 | 2.53 | 26.12 | 12.13 | *11.46* | 12.31 | 13.81 |
| | 0.180 | 49.67 | 23.76 | 2.15 | 25.91 | 12.26 | 11.50 | 12.35 | 13.56 |
| Williams-Mills | 0.214 | 49.77 | 24.00 | 1.77 | 25.77 | 12.36 | 11.64 | 12.18 | 13.59 |
| | 0.226 | 49.88 | 23.96 | 1.96 | 25.92 | 12.33 | 11.63 | 12.29 | 13.63 |
| Ohuruogu | 0.231 | 50.21 | 24.32 | 1.57 | 25.89 | 12.56 | 11.76 | 12.44 | 13.45 |
| | 0.204 | 50.35 | 24.43 | 1.49 | 25.92 | 12.51 | 11.92 | 12.49 | 13.43 |
| Dunn | 0.275 | 50.35 | 23.94 | 2.47 | 26.41 | 12.19 | 11.75 | 12.55 | 13.86 |
| | 0.189 | 49.95 | 23.70 | 2.55 | 26.25 | 12.08 | 11.62 | 12.38 | 13.87 |
| Kapachinskaya | 0.220 | 50.53 | 24.39 | 1.75 | 26.14 | 12.54 | 11.85 | 12.53 | 13.61 |
| | 0.247 | 50.30 | 24.08 | 2.14 | 26.22 | 12.37 | 11.71 | 12.41 | 13.81 |
| Montsho | 0.212 | 50.65 | 24.47 | 1.71 | 26.18 | 12.38 | 12.09 | 12.58 | 13.60 |
| | 0.220 | 49.89 | 23.74 | 2.41 | 26.15 | 12.20 | 11.54 | 12.52 | 13.63 |

Individual best | *Final best* | Semi-final best

advantage in the first 100m, while her other sections have approximately the level of the respective best section values of the finalists, without standing out particularly. The differences between the velocities in the slowest and fastest 50m intervals of all four runs analysed are within a narrow range of 0.21 m/sec (Richards 2.01 m/sec; Krivoshapka 1.80 m/sec), resulting in great similarities in the velocity courses of the four runners, which is illustrated in Figure 9.

*Table 33: Mean velocities (m/sec) of the 50m sections of the four best runs in the women's 400m at the 2009 IAAF World Championships in Athletics (sf = semi final)*

| | 0-50m | 50-100m | 100-150m | 150-200m | 200-250m | 250-300m | 300-350m | 350-400m |
|---|---|---|---|---|---|---|---|---|
| Richards - 49.00 | 7.89 | 9.14 | 8.77 | 8.35 | 8.35 | 8.16 | 7.85 | 7.13 |
| Williams - 49.32 | 7.59 | 9.12 | 8.77 | 8.35 | 8.25 | 8.09 | 7.84 | 7.20 |
| Krivoshapka - 49.67 (sf) | 7.47 | 8.98 | 8.88 | 8.52 | 8.26 | 7.94 | 7.59 | 7.17 |
| Williams-Mills - 49.77 | 7.44 | 8.87 | 8.70 | 8.49 | 8.38 | 8.05 | 7.70 | 7.04 |

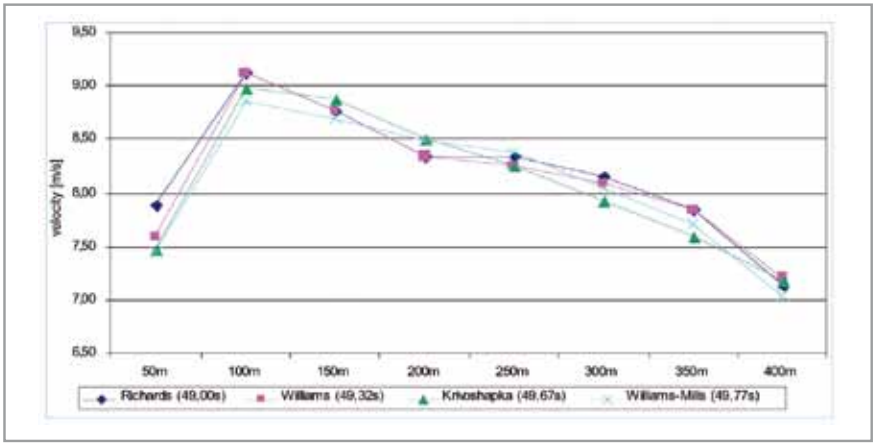



*Figure 9: Velocity course of the four best runs in the women's 400m at the 2009 IAAF World Championships in Athletics*

## The 100 Metres and 110 Metres Hurdles

### *Methods and Procedures*

The analysis of the women's 100m hurdles and the men's 110m hurdles were based on video recordings with a pan video camera (no. 13), which were made on a system similar to the one used for the other events. The analysis included an evaluation of the hurdle split times (from touchdown to touchdown behind the hurdle) and the hurdle flight times for the medallists and a calculation of the average speeds for the hurdle intervals. Unfortunately, the present video recordings cannot be used to make statements about the take-off and landing distances. Neither can they be used for technique analysis.

### *Results and Comments - Men*

Compared to the finals of major athletics events from the year 2000, performances in the men's 110m hurdle final in Berlin were of a rather average level (see Table 34). This applies equally to the winner Brathwaite's (BAR) time of 13.14 sec (the slowest of all recent finals), the average time of the medallists (13.14 sec) and average time of the finalists (13.32 sec). It is true that two of the most powerful athletes in previous years were not present due to injury, having dropped out in the preliminary round - Robles (CUB) - or not starting at all - Liu (CHN). Because of the performance level, this analysis is limited mainly to the three medallists, whose performances were barely distinguishable.

In Table 35 we can see that although the eventual winner, Brathwaite, was with the leading runners from the first hurdle and alone at the front from hurdle 5. In dominating the first half of the race his velocity course was characterised by an almost perfect continuity, even though he had a contact at the first hurdle. He was also the only runner in the final who went below 1.00 sec in two sections. However, he could not achieve a significant lead. In the run-in to the finish line, Trammel (USA) and Payne (USA) were able to catch up to within a hundredth of a second. They were helped by the fact that Brathwaite contacted hurdle 7 and had rhythm difficulties in the following interval, which can be seen from the long flight time over hurdle 8.

When watching the video, Payne's run gives the overall impression of being rounded and harmonious with only a slight contact at hurdle 7.

However, the velocity curve gives a slightly different impression. Trammell, managed to maintain an almost unchanged duration of hurdle clearance (from the take-off before to the touchdown after the hurdle) throughout the race and a similar velocity to the other medallists (Figure 11 and Figure 12) despite five,

sometimes violent hurdle contacts during the second half of the race (Table 36).

The remaining finalists did not exhibit any marked peculiarities. Those in places 4-6 – Sharman (GBR), Wignall (JAM), Svoboda (CZE) – basically repeated their semi-final performances in the final. In particular, Sharman's run was technically sound without any hurdle contacts, while Svoboda only managed to clear the eighth hurdle without contact and conveys a technically inconsistent impression. The runners placed 7-8 could not match their semi-final performances.

Because of the small margins between the final times of the three medallists, it is necessary to look at the start and the reaction times. We can see that Payne achieved a very good reaction time, but Trammell's relatively slow reaction suggest that he would have had a chance to win had he been able to match Payne.

It must be mentioned that reaction time is primarily a parameter of the timing system with the aim of detecting a false start (false start control apparatus according to rule 161.2). For this purpose a threshold value pressure switch in the rail of the starting block is used that is triggered in

*Table 34: Results of the men's 110m hurdles final at the 2009 IAAF World Championships in Athletics*

**110 Metres Hurdles- Men's Final**

20 August 2009 – 20:55 Wind 0.1 m/sec

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Ryan Brathwaite (BAR) | 13.14 | NR | 0.157 | 4 |
| 2 | Terrence Trammell (USA) | 13.15 | | 0.141 | 5 |
| 3 | David Payne (USA) | 13.15 | | 0.122 | 3 |
| 4 | William Sharman (GBR) | 13.30 | PB | 0.125 | 6 |
| 5 | Maurice Wignall (JAM) | 13.31 | SB | 0.155 | 8 |
| 6 | Petr Svoboda (CZE) | 13.38 | | 0.144 | 7 |
| 7 | Dwight Thomas (JAM) | 13.56 | | 0.145 | 2 |
| 8 | Wei Ji (CHN) | 13.57 | | 0.144 | 1 |


110m H Men/Final – 1st Hurdle


100m H Women/Final – 7th Hurdle

*Figure 10: Examples for the hurdles analysis (100m hurdles/110m hurdles)*

*Table 35: Hurdle split-times and intervals (sec) in the men's 110m hurdles final at the 2009 IAAF World Championships in Athletics*

| | RT | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | 110m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brathwaite | 0.157 | **2.54** | 3.60 | **4.61** | **5.60** | **6.59** | **7.60** | **8.62** | **9.65** | **10.70** | **11.74** | **13.14** |
| | | | 1.06 | 1.01 | 0.99 | 0.99 | 1.01 | 1.02 | 1.03 | 1.05 | 1.04 | 1.40 |
| Trammell | 0.141 | 2.56 | 3.60 | **4.61** | **5.60** | 6.60 | 7.62 | 8.63 | 9.66 | 10.71 | 11.77 | 13.15 |
| | | | 1.04 | 1.01 | 0.99 | 1.00 | 1.02 | 1.01 | 1.03 | 1.05 | 1.06 | 1.38 |
| Payne | 0.122 | **2.54** | **3.58** | **4.61** | 5.61 | 6.62 | 7.64 | 8.66 | 9.69 | 10.74 | 11.78 | 13.15 |
| | | | 1.04 | 1.03 | 1.00 | 1.01 | 1.02 | 1.02 | 1.03 | 1.05 | 1.04 | 1.37 |
| Sharman | 0.150 | **2.54** | 3.60 | 4.62 | 5.64 | 6.65 | 7.68 | 8.73 | 9.78 | 10.84 | 11.91 | 13.30 |
| | | | 1.06 | 1.02 | 1.02 | 1.01 | 1.03 | 1.05 | 1.05 | 1.06 | 1.07 | 1.39 |
| Wignall | 0.151 | 2.61 | 3.66 | 4.70 | 5.72 | 6.75 | 7.78 | 8.81 | 9.85 | 10.90 | 11.98 | 13.31 |
| | | | 1.05 | 1.04 | 1.02 | 1.03 | 1.03 | 1.03 | 1.04 | 1.05 | 1.08 | 1.33 |
| Svoboda | 0.144 | 2.58 | 3.62 | 4.64 | 5.66 | 6.69 | 7.74 | 8.77 | 9.82 | 10.87 | 11.94 | 13.38 |
| | | | 1.04 | 1.02 | 1.02 | 1.03 | 1.05 | 1.03 | 1.05 | 1.05 | 1.07 | 1.44 |
| Dwight | 0.145 | 2.66 | 3.73 | 4.77 | 5.80 | 6.84 | 7.88 | 8.90 | 9.95 | 11.00 | 12.14 | 13.56 |
| | | | 1.07 | 1.04 | 1.03 | 1.04 | 1.04 | 1.02 | 1.05 | 1.05 | 1.14 | 1.42 |
| Ji0.144 | 2.68 | 3.77 | 4.80 | 5.84 | 6.86 | 7.92 | 8.96 | 10.02 | 11.09 | 12.17 | 13.57 | |
| | | | 1.09 | 1.03 | 1.04 | 1.02 | 1.06 | 1.04 | 1.06 | 1.07 | 1.08 | 1.40 |

**Bold = Leader**

*Table 36: Hurdle flight times (sec) of the medallists in the men's 110m hurdles final at the 2009 IAAF World Championships in Athletics*

| | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Brathwaite | ***0.32*** | 0.33 | 0.35 | 0.33 | 0.31 | 0.31 | ***0.31*** | 0.42 | 0.33 | 0.32 |
| Trammell | 0.38 | 0.37 | 0.37 | 0.35 | 0.34 | ***0.33*** | ***0.33*** | ***0.33*** | ***0.34*** | ***0.34*** |
| Payne | 0.35 | 0.35 | 0.36 | 0.35 | 0.35 | 0.35 | ***0.35*** | 0.35 | 0.36 | 0.36 |

**Bold = *Contact with hurdle***

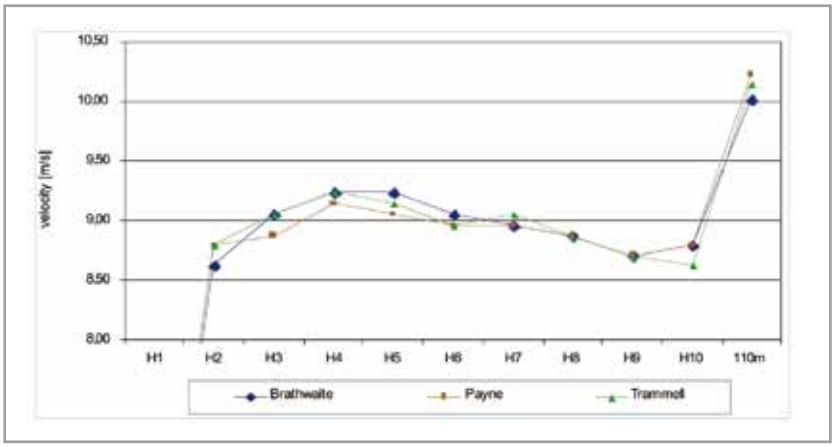



*Figure 11: Velocity course of the medallists in the men's 110m hurdles final at the 2009 IAAF World Championships in Athletics*

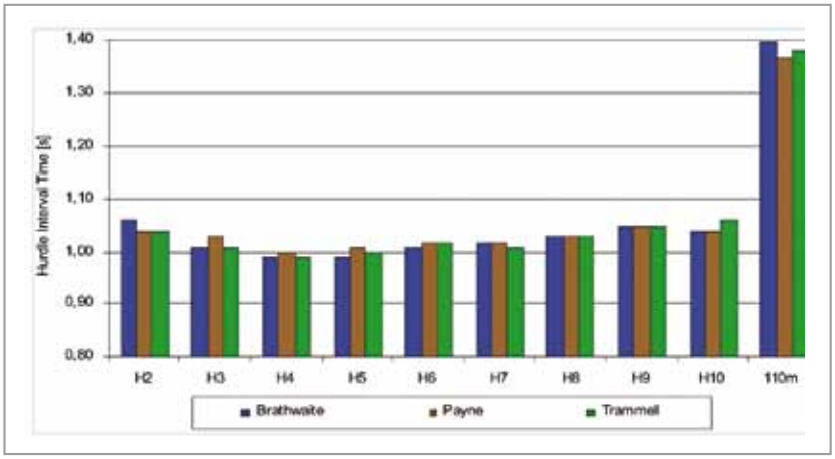



*Figure 12: Hurdle interval times of the medallists in the men's 110m hurdles final at the 2009 IAAF World Championships in Athletics*

the case of horizontal forces acting against the running direction. This threshold value is normally set by the timing system providers to >= 300N, so that the athlete cannot trigger the false start function unintentionally by his or her pre-tension in the "ready" position. This implies that, in theory, a reaction before the time threshold value of 0.1 sec, which is not registered by the system, can occur at force levels below 300N. This is why visual impression continues to be important for starters. The pressure switch threshold value can also be used to describe why very fast reaction times (<200 ms) can occur, especially in the 400m and 400m hurdles: these athletes usually demonstrate a less dynamic force development at the starting block than 100m or 100/110m hurdle runners, so that they reach 300N later, even though they might well react in normal time.

### *Results and Comments - Women*

Unlike for the men's race, the result of the women's 100m hurdles final can be categorised as thoroughly positive when compared to the major events since 2000. The 12.51 sec winning performance by Foster-Hylton (JAM), the average time of the medallists (12.53 sec), and the average time for the first seven (12.65 sec) all indicate a high level of performance (see Table 37).

This evaluation is based on the final result plus in two cases on the semi-final performance. One reason for this is because Harper (USA), who only placed seventh in the final after striking the second hurdle, ran the absolute best time of the competition in the semi-final. The second reason is that Felicien (CAN), one of the fastest qualifiers for the final, stumbled slightly after the first hurdle and finished the race only at a slow pace (possibly because of an injury).

As far as Foster-Hylton is concerned, one can notice in Table 38 that she accelerated a little slower than most of the other finalists. On the other hand, with two intervals of 0.95 sec (mean velocity: 8.95 m/sec) she achieved the highest speed of the race. Importantly, she reached the fastest time intervals for each of the last five hurdles in the final. Ennis-London (JAM), Lopez-Schliep (CAN) and Felicien reached slightly slower best interval times of 0.96 sec and exhibited more uniform velocity profiles over the course of the race.

The assessment of the winner applies equally to Harper's semi-final run, which was characterised by a high degree of perfection and she even had the chance to achieve a better time. She did not run at 100% effort from the 8th hurdle to the finish line, because it was clear that she had reached the final. The visual impression when viewing the video corroborates this statement. We estimate that a time of 12.45 sec would have been possible with a full effort.

In the five best runs covered in this analysis, the hurdle clearance times (Table 39) for Harper and Foster-Hylton are somewhat similar, and they are in the range of previous analyses. The other three runners tend to have longer flight times. There were no hurdle contacts. Of the remaining participants, only McLellan (AUS) and Powell (USA) had problems clearing the hurdles without contact. Apparently the spaces between the last three hurdles become too large due to their declining performance capacity.

*Table 37: Results of the women's 100m hurdles final at the 2009 IAAF World Championships in Athletics*

**100 Metres Hurdles - Women's Final**

19 August 2009 – 21:15 Wind 0.2 m/sec

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Brigitte Foster-Hylton (JAM) | 12.51 | SB | 0.157 | 4 |
| 2 | Priscilla Lopes-Schliep (CAN) | 12.54 | | 0.128 | 6 |
| 3 | Delloreen Ennis-London (JAM) | 12.55 | SB | 0.142 | 8 |
| 4 | Derval O'Rourke (IRL) | 12.67 | NR | 0.128 | 1 |
| 5 | Sally McLellan (AUS) | 12.70 | | 0.139 | 7 |
| 6 | Ginnie Powell (USA) | 12.78 | | 0.146 | 2 |
| 7 | Dawn Harper (USA) | 12.81 | | 0.164 | 5 |
| 8 | Perdita Felician (CAN) | 15.53 | | 0.151 | 3 |

*Table 38: Hurdle split-times and intervals (sec) in the women's 110m hurdles at the 2009 IAAF World Championships in Athletics*

| | RT | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | 100m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foster-Hylton | 0.157 | 2.60 | 3.60 | 4.59 | 5.56 | 6.51 | ***7.46*** | ***8.43*** | ***9.41*** | ***10.39*** | ***11.40*** | **12.51** |
| | | | 1.00 | 0.99 | 0.97 | 0.95 | 0.95 | 0.97 | 0.98 | 0.98 | 1.01 | 1.11 |
| Lopes-Schliep | 0.128 | 2.56 | 3.58 | 4.58 | 5.57 | 6.54 | 7.50 | 8.47 | 9.46 | 10.44 | 11.46 | **12.54** |
| | | | 1.02 | 1.00 | 0.99 | 0.97 | 0.96 | 0.97 | 0.99 | 0.98 | 1.02 | 1.08 |
| Ennis-London | 0.142 | 2.60 | 3.60 | 4.58 | 5.54 | ***6.50*** | 7.47 | 8.44 | 9.43 | 10.44 | 11.46 | **12.55** |
| | | | 1.00 | 0.98 | 0.96 | 0.96 | 0.97 | 0.97 | 0.99 | 1.01 | 1.02 | 1.09 |
| O'Rourke | 0.128 | 2.58 | 3.57 | ***4.55*** | 5.53 | 6.52 | 7.51 | 8.49 | 9.50 | 10.52 | 11.58 | **12.67** |
| | | | 0.99 | 0.98 | 0.98 | 0.99 | 0.99 | 0.98 | 1.01 | 1.02 | 1.06 | 1.09 |
| McLellan | 0.139 | ***2.55*** | ***3.56*** | ***4.55*** | ***5.52*** | 6.51 | 7.48 | 8.46 | 9.46 | 10.48 | 11.51 | **12.70** |
| | | | 1.01 | 0.99 | 0.97 | 0.99 | 0.97 | 0.98 | 1.00 | 1.02 | 1.03 | 1.19 |
| Powell | 0.146 | 2.60 | 3.62 | 4.60 | 5.56 | 6.52 | 7.50 | 8.50 | 9.51 | 10.55 | 11.63 | **12.78** |
| | | | 1.02 | 0.98 | 0.96 | 0.96 | 0.98 | 1.00 | 1.01 | 1.04 | 1.08 | 1.15 |
| Harper | 0.164 | 2.58 | 3.58 | 4.60 | 5.61 | 6.60 | 7.59 | 8.58 | 9.60 | 10.63 | 11.68 | **12.81** |
| | | | 1.00 | 1.02 | 1.01 | 0.99 | 0.99 | 0.99 | 1.02 | 1.03 | 1.05 | 1.13 |
| | | | | | | | | | | ***Bold = Leading position*** | | |
| Semi-final performances | | | | | | | | | | | | |
| Harper | 0.161 | 2.54 | 3.55 | 4.52 | 5.48 | 6.43 | 7.38 | 8.36 | 9.33 | 10.34 | 11.37 | **12.48** |
| | | | 1.01 | 0.97 | 0.96 | 0.95 | 0.95 | 0.98 | 0.97 | 1.01 | 1.03 | 1.11 |
| Felicien | 0.151 | 2.62 | 3.64 | 4.62 | 5.60 | 6.57 | 7.54 | 8.51 | 9.47 | 10.47 | 11.50 | **12.58** |
| | | | 1.02 | 0.98 | 0.98 | 0.97 | 0.97 | 0.97 | 0.96 | 1.00 | 1.03 | 1.08 |

*Table 39: Hurdle flight times (sec) for selected finalists in the women's 110m hurdles at the 2009 IAAF World Championships in Athletics (SF = semi-final)*

| | RT | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Harper (SF) | | 0.28 | 0.29 | 0.29 | 0.29 | 0.30 | 0.29 | 0.30 | 0.30 | 0.33 | 0.34 |
| Foster-Hylton | | 0.30 | 0.28 | 0.28 | 0.29 | 0.29 | 0.28 | 0.28 | 0.31 | 0.30 | 0.31 |
| Lopes-Schliep | | 0.32 | 0.33 | 0.32 | 0.34 | 0.33 | 0.32 | 0.32 | 0.32 | 0.31 | 0.33 |
| Ennis-London | | 0.33 | 0.31 | 0.31 | 0.30 | 0.30 | 0.31 | 0.32 | 0.33 | 0.33 | 0.33 |
| Felicien (SF) | | 0.31 | 0.32 | 0.31 | 0.32 | 0.34 | 0.34 | 0.33 | 0.30 | 0.32 | 0.35 |
| | | | | | | | | | Bold = **Contact with hurdle** | | |

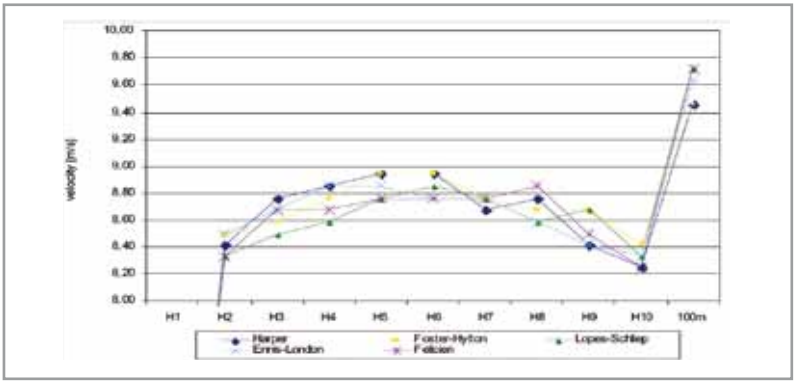



*Figure 13: Velocity course for selected finalists in the women's 110m hurdles at the 2009 IAAF World Championships in Athletics (Semi-final data for Harper and Felicien)*

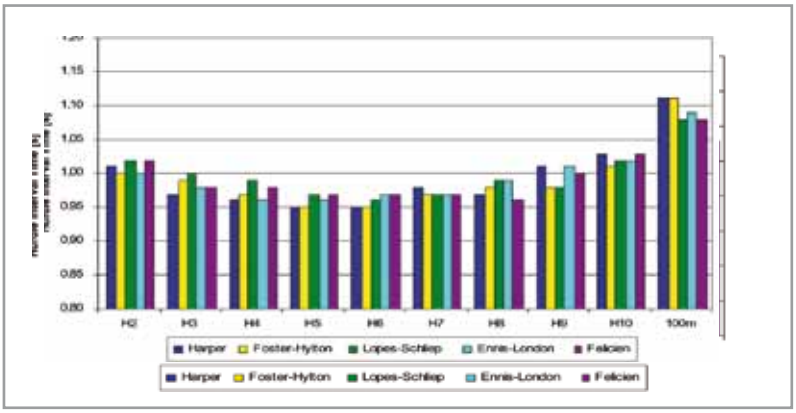



*Figure 14: Hurdle interval times for selected finalists in the women's 110m hurdles at the 2009 IAAF World Championships in Athletics (Semi-final data for Harper and Felicien)*

## The 400 Metres Hurdles

### *Methods and Procedures*

The analysis of the 400m races was conducted as a split-time measurement with three video cameras and two recording systems. Camera no. 11 was used to record the outer four lanes and the 250m (no. 1), 300m (no. 3) and 350m (no. 6) measuring points on one system while camera no. 12 was used to record lanes 1-4 independently on a second system. The data extracted from the video recordings included the determination of the hurdle interval times (from touchdown to touchdown after the hurdle) and the hurdle rhythm (number of intermediate hurdle steps). Based on these measurements, the average velocities for the hurdle intervals were calculated.

### *Results and Comments - Men*

Compared to the results from other major events over the last 10 years, the men's 400m hurdles final in Berlin can be regarded as fairly good, as seven participants achieved a time below 49.00 sec (see Table 39). The average time for the medallists was 48.07 sec and for the top seven was 48.32 sec. The 8th participant (Sanchez (PUR) the World Champion in 2001 and 2003) finished the race after stumbling at the first hurdle (the distance before the hurdle was too long) with a time not worth talking about. For this reason, his semi-final run, where he achieved a performance that was worth a medal, was used for the analysis.

In Table 40 we can see that although the eventual winner, Clement, dominated the race nearly throughout, the runner-up, Culson (PUR), and the fourth-placed runner, Gordon (TRI), were always only a short distance behind. The ex-World Champion, Jackson (USA), had a significant lead already at the first hurdle, but immediately thereafter he reduced his tempo, which had possibly been too fast for him. At times he was three-quarters of a second behind the leaders, but then he significantly caught up from the 6th hurdle to place third. When approaching the finish line, both the winner and the second-placed runner also managed to increase their velocity.

When considering the hurdle rhythms, Clement stands out, because he completed all intervals using a 13-stride rhythm (Tables 41, 42). All other athletes present a very varied picture. Besides Jackson and Green (GBR) who both started with a 14-stride rhythm, all participants started with a 13-stride rhythm and changed to a 14-stride rhythm and sometimes even to a 15-stride rhythm at different hurdles. In these switches no noticeable changes of the hurdle interval times are evident, so that it can be said that all the finalists have such good hurdle technique with both legs that no significant effects on the speed course could be registered. Sanchez achieved the highest velocity in a hurdle interval (9.59 m/sec) during his semi-final.

*Table 40: Results of the men's 400m hurdles final at the 2009 IAAF World Championships in Athletics*

**400 Metres Hurdles - Men's Final**

18 August 2009 – 20:50

| | Athlete (Country) | Mark [sec] | Reaction Time [sec] | Lane |
|---|---|---|---|---|
| 1 | Kerron Clement (USA) | 47.91 WL | 0.176 | 3 |
| 2 | Javier Culson (PUR) | 48.09 NR | 0.187 | 8 |
| 3 | Bershawn Jackson (USA) | 48.23 | 0.141 | 5 |
| 4 | Jehue Gordon (TRI) | 48.26 NR | 0.172 | 2 |
| 5 | Periklis Iakovakis (GRE) | 48.42 SB | 0.189 | 7 |
| 6 | Danny McFarlane (JAM) | 48.65 | 0.162 | 1 |
| 7 | David Green (GBR) | 48.68 | 0.148 | 6 |
| 8 | Felix Sanchez (PUR) | 59.11 | 0.171 | 4 |

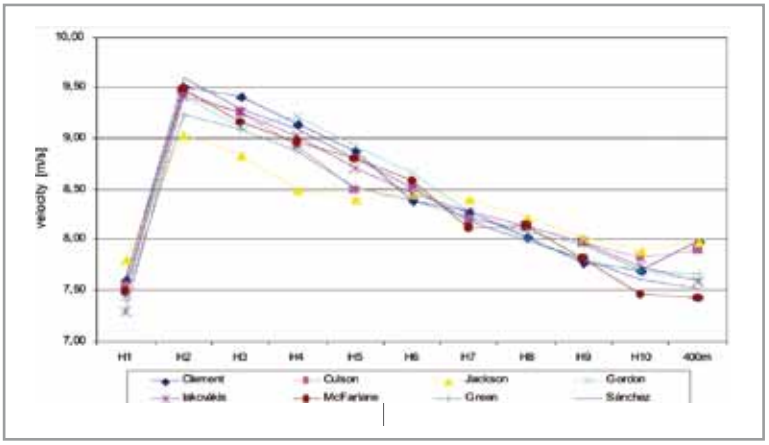



*Figure 15: Velocity course for the finalists in the men's 400m hurdles at the 2009 IAAF World Championships in Athletics (Semi-final data for Sanchez)*

*Table 41: Hurdle split and interval times (sec) for the men's 400m hurdles at the 2009 IAAF World Championships in Athletics (SF = semi-final performance)*

| | RT | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | 100m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clement | 0.176 | 5.92 | ***9.60*** | ***13.32*** | ***17.15*** | ***21.09*** | ***25.26*** | ***29.49*** | ***33.85*** | ***38.35*** | ***42.90*** | **47.91** |
| | | | 3.68 | 3.72 | 3.83 | 3.94 | 4.17 | 4.23 | 4.36 | 4.50 | 4.55 | 5.01 |
| Culson | 0.187 | 5.97 | 9.67 | 13.45 | 17.37 | 21.49 | 25.60 | 29.87 | 34.17 | 38.56 | 43.03 | **48.09** |
| | | | 3.70 | 3.78 | 3.92 | 4.12 | 4.11 | 4.27 | 4.30 | 4.39 | 4.47 | 5.06 |
| Jackson | 0.141 | ***5.76*** | 9.63 | 13.59 | 17.71 | 21.87 | 26.01 | 30.17 | 34.43 | 38.79 | 43.22 | **48.23** |
| | | | 3.87 | 3.96 | 4.12 | 4.16 | 4.14 | 4.16 | 4.26 | 4.36 | 4.43 | 5.01 |
| Gordon | 0.172 | 6.04 | 9.76 | 13.60 | 17.40 | 21.32 | 25.36 | 29.59 | 33.96 | 38.44 | 43.00 | **48.26** |
| | | | 3.72 | 3.84 | 3.80 | 3.92 | 4.04 | 4.23 | 4.37 | 4.48 | 4.56 | 5.26 |
| Iakovákis | 0.189 | 6.17 | 9.89 | 13.67 | 17.55 | 21.57 | 25.71 | 29.94 | 34.24 | 38.63 | 43.15 | **48.42** |
| | | | 3.72 | 3.78 | 3.88 | 4.02 | 4.14 | 4.23 | 4.30 | 4.39 | 4.52 | 5.27 |
| McFarlane | 0.162 | 6.01 | 9.70 | 13.52 | 17.42 | 21.40 | 25.48 | 29.79 | 34.09 | 38.57 | 43.26 | **48.65** |
| | | | 3.69 | 3.82 | 3.90 | 3.98 | 4.08 | 4.31 | 4.30 | 4.48 | 4.69 | 5.39 |
| Greene | 0.148 | 6.07 | 9.86 | 13.71 | 17.65 | 21.76 | 25.93 | 30.19 | 34.52 | 38.92 | 43.46 | **48.68** |
| | | | 3.79 | 3.85 | 3.94 | 4.11 | 4.17 | 4.26 | 4.33 | 4.40 | 4.54 | 5.22 |
| Sánchez (SF) | 0.154 | 5.93 | 9.58 | 13.35 | 17.20 | 21.18 | 25.29 | 29.56 | 33.94 | 38.42 | 43.02 | **48.34** |
| | | | 3.65 | 3.77 | 3.85 | 3.98 | 4.11 | 4.27 | 4.38 | 4.48 | 4.60 | 5.32 |

***Bold = Leading position***

*Table 42: Hurdle rhythms (strides) for the men's 400m hurdles at the 2009 IAAF World Championships in Athletics (SF = semi-final performance)*

| | H1-2 | H2-3 | H3-4 | H4-5 | H5-6 | H6-7 | H7-8 | H8-9 | H9-10 |
|---|---|---|---|---|---|---|---|---|---|
| Clement | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| Culson | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 14 | 14 |
| Jackson | 14 | 14 | 14 | 14 | 15 | 15 | 15 | 15 | 15 |
| Gordon | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 14 | 14 |
| Iakovákis | 13 | 13 | 13 | 13 | 14 | 14 | 14 | 14 | 15 |
| McFarlane | 13 | 13 | 13 | 13 | 13 | 14 | 14 | 14 | 15 |
| Green | 14 | 14 | 14 | 14 | 14 | 15 | 15 | 15 | 15 |
| Sánchez (SF) | 13 | 13 | 13 | 13 | 13 | 14 | 14 | 15 | 15 |

*Table 43: Results of the women's 400m hurdles final at the 2009 IAAF World Championships in Athletics*

**400 Metres Hurdles - Women's Final**

21 August 2009 – 22:00

| | Athlete (Country) | Mark [sec] | | Reaction Time [sec] | Lane |
|---|---|---|---|---|---|
| 1 | Melaine Walker (JAM) | 52.42 | CR | 0.142 | 4 |
| 2 | Lashinda Demus (USA) | 52.96 | | 0.159 | 5 |
| 3 | Josanne Lucas (TRI) | 53.20 | NR | 0.186 | 3 |
| 4 | Kalise Spencer (JAM) | 53.56 | PB | 0.149 | 6 |
| 5 | Tiffany Williams (USA) | 53.83 | SB | 0.161 | 2 |
| 6 | Natalya Atyukh (RUS) | 54.11 | SB | 0.205 | 7 |
| 7 | Anastaslya Rabchenyuk (UKR) | 54.78 | | 0.206 | 8 |
| 8 | Angela Morosanu (ROU) | 55.04 | | 0.183 | 1 |

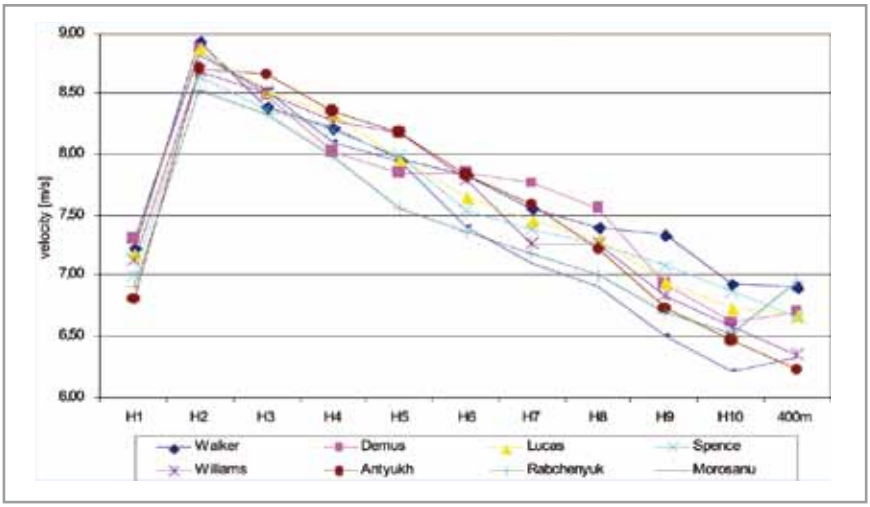



*Figure 16: Velocity course for the finalists in the women's 400m hurdles at the 2009 IAAF World Championships in Athletics*

*Table 44: Hurdle split and interval times (sec) for the women's 400m hurdles final at the 2009 IAAF World Championships in Athletics*

| | RT | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | 100m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Walker | 0.142 | 6.23 | 10.15 | 14.32 | 18.58 | 22.98 | ***27.45*** | 32.08 | 36.81 | ***41.58*** | ***46.63*** | 52.42 |
| | | | 3.92 | 4.17 | 4.26 | 4.40 | 4.47 | 4.63 | 4.73 | 4.77 | 5.05 | 5.79 |
| Demus | 0.159 | ***6.16*** | ***10.11*** | ***14.23*** | 18.59 | 23.05 | 27.51 | ***32.02*** | ***36.65*** | 41.70 | 46.99 | 52.96 |
| | | | 3.95 | 4.12 | 4.36 | 4.46 | 4.46 | 4.51 | 4.63 | 5.05 | 5.29 | 5.97 |
| Lucas | 0.186 | 6.26 | 10.20 | 14.30 | ***18.50*** | ***22.90*** | 27.47 | 32.17 | 36.97 | 42.01 | 47.21 | 53.20 |
| | | | 3.94 | 4.10 | 4.20 | 4.40 | 4.57 | 4.70 | 4.80 | 5.04 | 5.20 | 5.99 |
| Spencer | 0.149 | 6.43 | 10.48 | 14.66 | 18.93 | 23.31 | 27.95 | 32.69 | 37.51 | 42.45 | 47.55 | 53.56 |
| | | | 4.05 | 4.18 | 4.27 | 4.38 | 4.64 | 4.74 | 4.82 | 4.94 | 5.10 | 6.01 |
| Williams | 0.161 | 6.31 | 10.34 | 14.45 | 18.68 | 22.96 | 27.45 | 32.27 | 37.09 | 42.21 | 47.53 | 53.83 |
| | | | 4.03 | 4.11 | 4.23 | 4.28 | 4.49 | 4.82 | 4.82 | 5.12 | 5.32 | 6.30 |
| Antyukh | 0.205 | 6.61 | 10.63 | 14.67 | 18.86 | 23.14 | 27.61 | 32.22 | 37.07 | 42.27 | 47.68 | 54.11 |
| | | | 4.02 | 4.04 | 4.19 | 4.28 | 4.47 | 4.61 | 4.85 | 5.20 | 5.41 | 6.43 |
| Rabchenyuk | 0.206 | 6.51 | 10.61 | 14.81 | 19.19 | 23.82 | 28.58 | 33.45 | 38.45 | 43.67 | 49.03 | 54.78 |
| | | | 4.10 | 4.20 | 4.38 | 4.63 | 4.76 | 4.87 | 5.00 | 5.22 | 5.36 | 5.75 |
| Morosanu | 0.183 | 6.17 | 10.14 | 14.24 | 18.56 | 22.97 | 27.70 | 32.63 | 37.70 | 43.08 | 48.71 | 55.04 |
| | | | 3.97 | 4.10 | 4.32 | 4.41 | 4.73 | 4.93 | 5.07 | 5.38 | 5.63 | 6.33 |

***Bold = Leading position***

*Table 45: Hurdle rhythms strides for the women's 400m hurdles final at the 2009 IAAF World Championships in Athletics*

| | H1-2 | H2-3 | H3-4 | H4-5 | H5-6 | H6-7 | H7-8 | H8-9 | H9-10 |
|---|---|---|---|---|---|---|---|---|---|
| Walker | 15 | 15 | 15 | 15 | 15 | 16 | 16 | 16 | 17 |
| Demus | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 17 | 17 |
| Lucas | 14 | 14 | 14 | 14 | 15 | 15 | 15 | 16 | 16 |
| Spencer | 14 | 14 | 14 | 14 | 15 | 15 | 15 | 15 | 15 |
| Williams | 15 | 15 | 15 | 15 | 15 | 16 | 16 | 17 | 17 |
| Antyukh | 15 | 15 | 15 | 15 | 15 | 16 | 16 | 17 | 17 |
| Rabchenyuk | 15 | 15 | 15 | 16 | 16 | 16 | 16 | 17 | 18 |
| Morosanu | 14 | 14 | 15 | 14 | 15 | 15 | 15 | 16 | 17 |

### *Results and Comments - Women*

When compared with the results achieved in major athletics events during the last decade, the women's 400m hurdles final in Berlin can be considered as a highlight. Melanie Walker (JAM) set a championship record with her time of 52.42 sec and for the first time two female athletes went below 53.00 sec at a World Championships or Olympic Games (see Table 43). This consequently led to best values for the mean time of the medallists (52.86 sec) and the finalists (53.73 sec).

In the final, six of the participants were able to improve on their performances in the semi-final. The case of the silver medallist, Lashinda Demus (USA), can be considered somewhat tragic. She started as the favourite, having been fastest in the semi-finals, and was in the lead two times at a total of five hurdles. However, she lost her leading position at the 8th hurdle when she switched from a 15- to a 17-stride rhythm, which led to a slowing down at the 9th hurdle (the interval from hurdle 8 to 9 was 0.42 sec slower than the interval from hurdle 7 to 8) and enabled Walker to take over the lead and to win the race.

From Table 44 we see that the winner, Walker, dominated with regard to two aspects: she achieved the fastest hurdle interval with a time of 3.92 sec for hurdle 1-2 (mean velocity: 8.85 m/sec) and she had the smallest loss in velocity from hurdle 5 to hurdle 10. In this part of the race, her interval times increased by only 0.65 sec, whereas for Demus and Lucas (TRI) there were increases of 0.83 sec and 0.80 sec respectively.

When comparing the rhythm pattern of all finalists (Table 45), one must surmise that Demus was the only runner who was not able to clear the hurdles leading with both legs. The same weakness could be observed in the semi-final. In other runners, sometimes up to three rhythm changes (Rabchenyuk (UKR)) could be observed.

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