EFFORT DISTRIBUTION IN THE 400 M HURDLES FOR MEN

Denislav Drashkov & Grigor Gutev
National Sports Academy "Vassil Levski", Sofia, Bulgaria

ABSTRACT
The 400 m hurdle race is a challenging event that combines speed, endurance, and technique. To clear the 10 hurdles, athletes must have high speed, a stable rhythm, effective technique, and endurance. Success requires striking a balance between speed and energy control. The race distance has four parts: the first 100 m is a fast start; the second 100 m focuses on high speed and smooth hurdling while conserving energy; the third 100 m brings fatigue, but runners must maintain rhythm (top hurdlers excel here); and the final 100 m, or "home stretch," is when athletes push through fatigue, adjusting strides to maximise effort and reach the finish line despite lactic acid buildup. Based on the above specifics, we aim to analyse running patterns in the 400 m hurdles for elite male athletes. We studied 80 athletes from 24 nations, all of whom are participants in the Olympic Games in Paris 2024. For the study, we analysed the lap and split times for clearing each hurdle and different parts of the race using the official time data provided by the Olympic Committee. Various statistical methods were employed for data processing, including descriptive statistics and correlation analysis. The outcomes present different race models applicable to elite hurdlers. The respondents' sports performance results range from 46,46 seconds to 51.02 seconds, with an average of 48,87 seconds. The fastest hurdle splits are generally found between the second and fifth hurdles. Based on lap times, fatigue influences the sports results after the seventh or eighth hurdle. This conclusion applies solely to elite hurdlers. Different parts of the race correlate variably with sports results, revealing different race models. We also found that, based on the sports results, there are different race models.

ORCID
Grigor Gutev
https://orcid.org/0000-0002-9806-7275

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INTRODUCTION

Research on the 400m hurdles has extensively examined pacing strategies, biomechanical characteristics, and training methodologies. For instance, Iskra et al. (2022) studied the temporal and spatial characteristics of pacing in elite female athletes, and a similar study was conducted in elite male athletes (2021), which also provided an extended analysis of stride patterns. Complementing this, Iwasaki & Nunome (2023) presented a model to predict interval times based on pacing strategy, while Tsiokanos et al. (2017) analysed race patterns in the women's short hurdle sprint.

Other analyses have focused on stride regulation, with Ozaki et al. (2019) investigating stride length and approach run, and Hase (2025) studying the effect of rhythm changes on sprint speed for women. The discipline has also been viewed through a detailed biomechanical lens by Iskra & Coh (2011). Meanwhile, Dimova & Naygin (2013) and Dimova (2017) have analyzed training approaches and competitive activity, respectively, in women's hurdle and 400m running.

Both male and female hurdlers typically use a quick start, sustain their speed through the middle, and push hard in the final phase. However, the way these phases are distributed and their intensity differ depending on sex, physique, and individual strategy. (Saraslanidis et al., 2011; Iskra et al., 2024) Based on this scientific interest and our research interests, we took the approach of studying running patterns in 400m hurdles.

Aim and Objective

We aim to analyze running patterns in the 400m hurdles for elite male athletes. We focus on presenting the distribution of effort among the elite 400 m men's hurdle athletes. The primary objective is to provide information that can be directly applied in sports practice for modelling running within the training process.

METHODOLOGY

We studied 80 athletes from 24 nations, all of whom are participants in the Olympic Games (OG) in Paris 2024. For this study, we analysed lap and split times for clearing each hurdle and for different parts of the race using official time data provided by the Olympic Committee.

A total of 36 individual athletes were examined, with 80 analysed cases, distributed as follows: 12 athletes recorded three results during the OG tournament, 20 athletes recorded two results, and only four hurdlers recorded one result.

Our study utilises official data from the Olympic Committee for the Paris 2024 Games, all of which were measured using the Omega timing system. Race segment splits and laps were determined using the Real-Time Tracking System (RTTS) (IOC, 2024). RTTS records about 2,000 data points per athlete per second during races, capturing instantaneous speed, position, acceleration, and other metrics. In hurdle events, split and lap times are recorded at the touchdown after clearing each hurdle (Omega, 2024). In our experience, this method provides more reliable data for both scientific analysis and practical sports applications.

In short, the study employed quantitative, observational analysis using official time-tracking data and statistical methods (descriptive and correlational) to evaluate pacing and effort distribution patterns.

RESULTS

We can observe that the studied cases feature the world elite in men's 400 m hurdles, not only because we examine participants in the Olympic Games. From Table 1, we see that the respondents' average is 48.87 seconds, with a range of 46.46 to 51.02 seconds. Based on the skewness and kurtosis indexes, we find that the results are normally distributed.

Table 1. *Descriptive statistics of studied cases*

	N	Range (R)	Min	Max	*Mean*	*SD*	Coeff. of variation (CV%)	Skewness	Kurtosis
Sport result (SR) in all studied cases (sec.)	80	4.56	46.46	51.02	48.87	0.83	1.71	-0.017	0.429

Table 2 presents descriptive statistics for the split times of all studied cases (a total of 80). It serves as a tool for monitoring effort distribution based on the experience of world elite hurdlers. The coefficient of variation for the start reaction is notably high. In the 400 m hurdles event, the start reaction is less critical compared to shorter sprints and hurdle races. Consequently, values among the world elite in this discipline range from 0.136 to 0.279 seconds.

Table 2. *400 m hurdles men split times (sec.) – descriptive statistics*

Measured in seconds	*N*	Range (R)	Min	Max	*Mean*	*SD*	Coeff. of variation (CV%)	Skewness	Kurtosis
Start Reaction	80	0.143	0.136	0.279	0.177	0.028	15.90	0.902	0.785
1st hurdle split	80	0.58	5.51	6.09	5.82	0.12	2.08	0.146	-0.322
2nd hurdle split	80	0.84	9.09	9.93	9.52	0.19	1.98	-0.041	-0.549
3rd hurdle split	80	1.08	12.73	13.81	13.28	0.25	1.90	-0.170	-0.555
4th hurdle split	80	1.41	16.41	17.82	17.11	0.33	1.90	-0.101	-0.418
5th hurdle split	80	1.78	20.18	21.96	21.07	0.39	1.86	-0.065	-0.270
6th hurdle split	80	2.23	24.03	26.26	25.18	0.47	1.87	-0.152	-0.066
7th hurdle split	80	2.70	27.99	30.69	29.46	0.56	1.89	-0.328	0.227
8th hurdle split	80	3.30	32.02	35.32	33.93	0.66	1.94	-0.520	0.500
9th hurdle split	80	3.71	36.39	40.10	38.59	0.72	1.88	-0.575	0.683
10th hurdle split	80	4.01	40.96	44.97	43.33	0.78	1.80	-0.391	0.423
Result	80	4.56	46.46	51.02	48.87	0.83	1.71	-0.017	0.429

The times for clearing different race sections (lap times) are shown in Table 2. Based on the average values, we can observe that the highest speeds are reached in the first quarter of the race distance – between the first and second hurdles, the second and third hurdles, and the third and fourth hurdles. Following this section, there is a decrease in horizontal speed, as indicated by lap times. This decrease in horizontal speed continues until the end of the race, with an even distribution.

Table 3. *400 m hurdles men's lap times (sec.) – descriptive statistics*

Measured in seconds	*N*	Range (R)	Min	Max	*Mean*	*SD*	Coeff. of variation (CV%)	Skewness	Kurtosis
1st hurdle lap	80	0.58	5.51	6.09	5.82	0.12	2.08	0.146	-0.322
1st-2nd lap	80	0.37	3.50	3.87	3.70	0.08	2.24	-0.238	-0.566
2nd-3rd lap	80	0.38	3.57	3.95	3.76	0.08	2.18	-0.039	-0.467
3rd-4th lap	80	0.39	3.67	4.06	3.83	0.09	2.31	0.222	-0.369
4th-5th lap	80	0.38	3.77	4.15	3.96	0.08	2.10	0.102	-0.404
5th-6th lap	80	0.48	3.83	4.31	4.12	0.10	2.51	-0.404	0.006
6th-7th lap	80	0.65	3.87	4.52	4.27	0.12	2.85	-0.557	0.668
7th-8th lap	80	0.73	4.00	4.73	4.47	0.14	3.09	-0.556	0.654
8th-9th lap	80	0.59	4.37	4.96	4.66	0.12	2.59	0.083	-0.176
9th-10th lap	80	0.65	4.47	5.12	4.74	0.13	2.82	0.610	0.367
10th-finish	80	1.34	5.07	6.41	5.54	0.23	4.12	1.131	2.451

The coefficient of variation (CV%) – see Figure 1 – reveals the individual differences in lap time distributions across the race distance. We observe the most significant differences in two sections: between the sixth and seventh, the seventh and eighth—at the apex; and the finish between the ninth and tenth hurdles and from the last hurdle to the final line. In our view, these are the sections that distinguish medal winners from qualifying athletes.

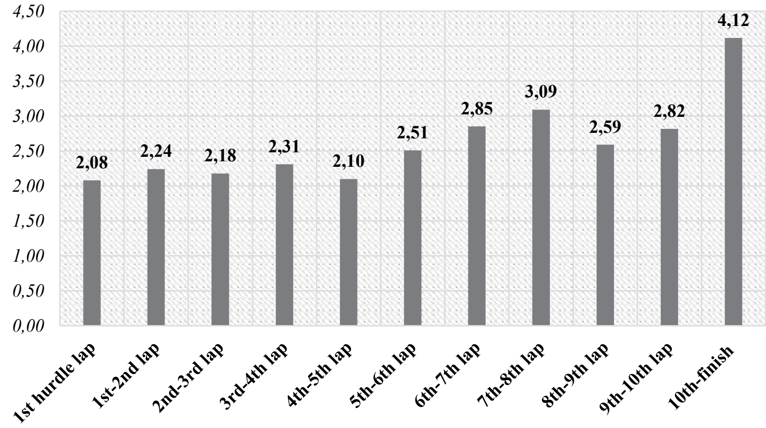

Figure 1. *Coefficient of variation (CV%) of lap times in the men's 400 m hurdles event*

The correlation between sports results and lap times, as well as the interrelations between different parts of the race distance, are presented in Table 4 and Figure 2.

The sport result correlates with the highest significance to the lap times between the fourth and ninth hurdles. This is proof of the importance of effort distribution in the races. Correlation with the last two to three intermediate times decreases due to differences in speed endurance among the studied hurdlers.

Table 4. *Correlation matrix illustrating the relationships between sport results and lap times between hurdles.*

	1st hurdle lap	1st-2nd lap	2nd-3rd lap	3rd-4th lap	4th-5th lap	5th-6th lap	6th-7th lap	7th-8th lap	8th-9th lap	9th-10th lap	10th-finish	Result
1st hurdle lap	1											
1st-2nd lap	.693**	1										
2nd-3rd lap	.545**	.810**	1									
3rd-4th lap	.528**	.685**	.872**	1								
4th-5th lap	.473**	.630**	.747**	.853**	1							
5th-6th lap	.441**	.525**	.615**	.647**	.833**	1						
6th-7th lap	.467**	.369**	.450**	.475**	.607**	.832**	1					
7th-8th lap	.425**	.353**	.418**	.432**	.516**	.716**	.887**	1				
8th-9th lap					.329**	.503**	.655**	.755**	1			
9th-10th lap						.288**	.365**	.446**	.749**	1		
10th-finish			-.261*						.311**	.624**	1	
Sport Result	.568**	.570**	.583**	.614**	.750**	.811**	.829**	.819**	.734**	.622**	.369**	1

*Note: **. Correlation is significant at the 0.01 level (2-tailed). / *. Correlation is significant at the 0.05 level (2-tailed).*

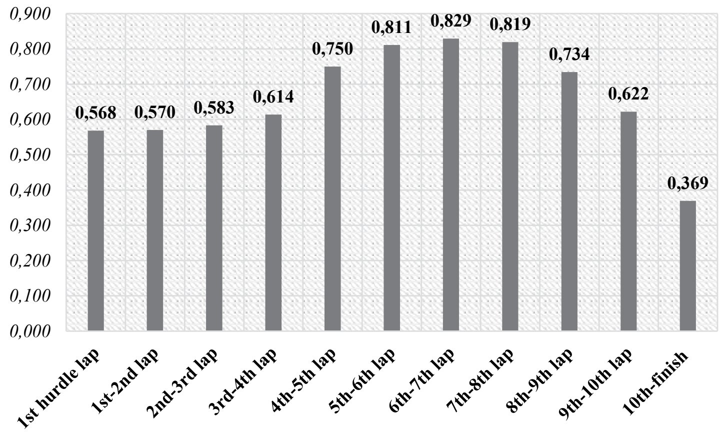

Figure 2. *Correlation between sport results (SR) and lap times (intermediate times)*

DISCUSSION

In the third part, the best athletes stand out; despite fatigue, they maintain a good rhythm and speed. If athletes can handle this segment efficiently and without losses, it sets a strong foundation for achieving a good sports result.

From the data provided, it is notable that there are two types of racing models. The first model is "sprinting"; the athlete relies on a quick first hurdle and achieves higher speeds up to the fifth obstacle. Accordingly, in the second part of the race (200-400m), physiological changes occur and fatigue sets in earlier. The second model involves athletes distributing their efforts evenly throughout the race and maintaining their initial speed for a more extended period, resulting in later fatigue.

The pacing and tactical behaviour of elite 400 m hurdlers continue to attract attention due to the event's complex interaction of speed, endurance, and rhythm control. Studies examining pacing profiles show that successful athletes use a flexible strategy that balances energy use across race segments while adjusting stride patterns and rhythm in response to fatigue and hurdle placement.

Thiel et al. (2012) highlighted that in Olympic-level events, pacing is not just a physiological strategy but also a tactical choice influenced by competitors' behaviour. Similarly, Menting et al. (2022) observed that pacing behaviour develops through experience and exposure to competitive situations, suggesting that elite hurdlers improve their distribution of effort over time through feedback and race modelling.

A recent study of the Paris 2024 Olympic Games showed that speed decline occurs primarily after the seventh hurdle, marking a transition where aerobic endurance and technical efficiency become decisive. These outcomes are consistent with earlier biomechanical and physiological research, which emphasises that elite hurdlers differentiate themselves by minimising deceleration in the final race segment. Finally, Weiss et al. (2016) contextualised these findings historically, noting that improvements in sprint and middle-distance performance stem from advances in training, technology, and understanding of pacing physiology — trends that continue to shape modern hurdle racing.

Conclusion

The distinction between the world's elite and other athletes appears in phases three and four, when maintaining stability despite fatigue and optimising energy use are essential.

Although there are different tactical approaches in elite 400 m running, all athletes exhibit similar effort distributions in the second and third hundred meters of the race.

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Corresponding author:
Grigor Gutev, PhD
National Sports Academy "Vassil Levski"
21, Acad. Stefan Mladenov str.
Sofia, Bulgaria
E-mail: gutev@nsa.bg

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