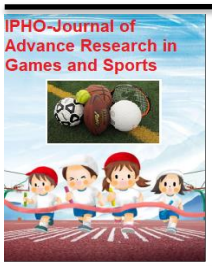

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VELOCITY PATTERN AND RACE PACE STRATEGIES OF400M SPRINT ELITE ATHLETES' WORLD ATHLETICS CHAMPIONSHIPS-BUDAPEST 2023

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ABSTACT

This study aims to identify pacing strategies profile men and women of 400m sprint focusing on key variables such as velocity pattern, split times and performance.The researcher used the descriptive method and ANOVA. The research sample consisted of (41)men and
(48) women participating in heats, semi-final and final of 400m sprint.The researcher used SPSS v29 and Excelversion 2021 in processing data and chart analysis. The data collected from official website ofWorld Athletics Championship Budapest 2023.The resultsshowedthat there are no differences between men and womenathletes in the 400-meter race patternduring the race in four stages analyzed in the study, which indicates the use of the same strategies at the beginning of the race or near its peak velocity, exceeding the average speed typically observed. The fastest speeds were recorded during in 2nd100 meters, followed by a strategic avoidance of a significant slowdown in the 3rd100 meters, which is often attributed to fatigue. However, a noticeable decline in speed was evident in the 4th100 meters,with a difference in total time, which may be due to physiological variables and biological differences between men and women.

Keywords: *Pacing Strategies, Velocity pattern, 400m race, Budapest 2023.*

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INTRODUCTION:

The 400-meter event has often been described as a “tweener” meaning it incorporates elements of sprinting and distance running in an unconventional manner. Unlike shorter sprints (100m and 200m), the 400m includes complexities like prolonged high intensity work. In particular, an athlete’s pacing, which refers to how effort is distributed within the race, is a critical variable in performance.

Small variations in performance often play a crucial role in determining the results of competitions, making it essential to gather information on the most effective ways to utilize limited energy resources. Despite the clear significance of pacing in athletic performance, there is a surprising scarcity of research focused on this area. The 400-meter race stands out as one of the most challenging events in athletics, situated between sprinting and middle-distance running.

In this event, athletes must achieve a high speed while applying an efficient technique, and they must also maintain the ideal technical aspects of their stride, even when faced with extreme fatigue. The ability to balance these demands is critical for success in the 400-meter run, highlighting the need for further exploration into pacing strategies and energy management in competitive events.

At the World Athletics Championship or the most elite competitions, pacing strategies can greatly affect the final results. Exposing these strategies reveals the understanding of the race's energy requirements, the energy expenditure and the element of endurance that is required in this tough event.

Elite 400m athletes adopt predominantly front-loaded or positive split pacing strategies, characterized by achieving peak velocities (50-150m) early in the race and managing a progressive deceleration, with the critical 200-300m segment heavily influencing final performance outcomes, as supported by studies from elite World Athletics Championship(Yong, 2008;Xiao-ping, 2004;Yao-xin, 2003;Ramadan, 2014).

The predominant strategy positive splits, with peak velocity typically reached between the 50-150m mark followed by controlled deceleration after 200m(Yong, 2008,Xiao-ping, 2004,Ming, 2006,Yao-xin, 2003). And critical segment: The 200-300m phase is decisive for maintaining a high velocity, with an athlete's ability to minimize deceleration here correlating strongly with final performance(Yong, 2008;Ramadan, 2014;GRGIĆ et al., 2019 ;Martín-Acero et al., 2021;Iwańska et al., 2021).

The stride dynamics of elite athletes preserve stride length into later stages and adapt stride frequency early in the race (peaks at 50-100m) to maintain velocity (Xiao-ping, 2004).And the fatigue impactinduced deceleration correlates with muscle activity asymmetry and reductions in stride length during the last 100m, linked to lactate buildup and aerobic system reliance.

Inaddition, some tactical consideration as outer lanes require better early pacing control due to less competitive visual cues, while inner lanes demand higher energy efficiency through curves and individualized strategiesallowtailored pacing that maximizes stride efficiency and minimizes fatigue effects over segments.(Duffield et al., 2005a; 2005b).

The women’s pacing strategies are observed in elite females, with smaller differences between peak and minimum split times compared to men(Lin, 2002;Li-bo,2004;Ramadan,2014)Faster starting segments in women also correlate with higher overall placements in the 400m(Lin, 2002; Li-bo, 2004; Yu, 2007).

PURPOSE:

The aim of the study is to identify the racing model followed by elite men and women athletes during the three rounds of 400m race sprint (heats - semi-final - final) to achieve a medal in the World Athletics Championships - Budapest 2023.

METHODS:

In this study,The researcher analyzed 400 m race data that were recorded by world Athletics, who control the data, during the world Athletics Championships inBudapest 2023. The focus is on the split times and the distribution of effort across the 400-meter segments of the race. Data including both men’s and women’s races, were analyzed to identify common patterns in pacing strategies in World Athletics Championships “Budapest 2023” 19-27 /8/2023

Dependent variables: The performance of top-level men and women athletes in the race 400, The individual times of the athletes in the predetermined sections of the track, as well as their pace strategy.

Research Design: the race distance was divided into 4 stages of 400m sprint each of100m, analyzing the split time and total time of the athletes, their respective pace strategies were determined, which revealed the tactics used by the athletes during the round race, using one wayanalysis of variance with LSD post hoc test used to determine differences between the 100m splits, Significance was set at P< 0.05 level. Values are shown as Mean ±SD.

SAMPLE:

The research sample consisted of (41) men and (48) women participating in heats (41,48), semi-final(22,24) and final(7,7) of 400m sprint race inWorld Athletics Championships "Budapest 2023"19-27 /8/2023, Race data were obtained fromrace analysis available results on official website of world athletics, including reaction time (RT) split time, time, and personal best(PB). In addition, video footage of races was analyzed to assess the technical aspects of pacing, such as acceleration, top speed maintenance, and deceleration(World Athletics).

RESULTS:

TABLE 1. Average, SD of Reaction Time, Split time, Velocity and performance's men

Round	Variable	Reaction Time	1st 100m	2nd 100m	3rd 100m	4th 100m	400mMark
Heats (41)	Time(s)	0.18±0.02	11.34±0.19	10.37±0.21	11.31±0.20	12.25±0.39	45.27±0.60
	Velocity(m/s-1)		8.82±0.15	9.65±0.19	8.84±0.16	8.17±0.25	8.84±0.12
Semi-Final (22)	Time(s)	0.17±0.02	11.13±0.14	10.24±0.22	11.39±0.18	12.29±0.37	45.05±0.58
	Velocity(m/s-1)		8.99±0.12	9.77±0.20	8.78±0.14	8.14±0.25	8.88±0.11
Final (7)	Time(s)	0.17±0.02	11.23±0.14	10.22±0.16	10.97±0.31	12.22±0.28	44.63±0.40
	Velocity(m/s-1)		8.90±0.11	9.79±0.15	9.12±0.27	8.19±0.18	8.96±0.08

TABLE 2. Average, SD of Reaction Time, Split time, Velocity and performance' swomen

Round	Variable	Reaction Time	1st 100m	2nd 100m	3rd 100m	4th 100m	400mMark
Heats (41)	Time(s)	0.18±0.02	11.34±0.19	10.37±0.21	11.31±0.20	12.25±0.39	45.27±0.60
	Velocity(m/s-1)		8.82±0.15	9.65±0.19	8.84±0.16	8.17±0.25	8.84±0.12
Semi-Final (22)	Time(s)	0.17±0.02	11.13±0.14	10.24±0.22	11.39±0.18	12.29±0.37	45.05±0.58
	Velocity(m/s-1)		8.99±0.12	9.77±0.20	8.78±0.14	8.14±0.25	8.88±0.11
Final (7)	Time(s)	0.17±0.02	11.23±0.14	10.22±0.16	10.97±0.31	12.22±0.28	44.63±0.40
	Velocity(m/s-1)		8.90±0.11	9.79±0.15	9.12±0.27	8.19±0.18	8.96±0.08

The mean time difference for men and women (Table 1,2) In the heats and semi-final roundReflecting a common observation, the 4th100m split was significantly slower than the other three splits (p<.05). They also showed final round reflecting a common observation, the 2nd100m split was significantly faster than the other three splits (p<.05).

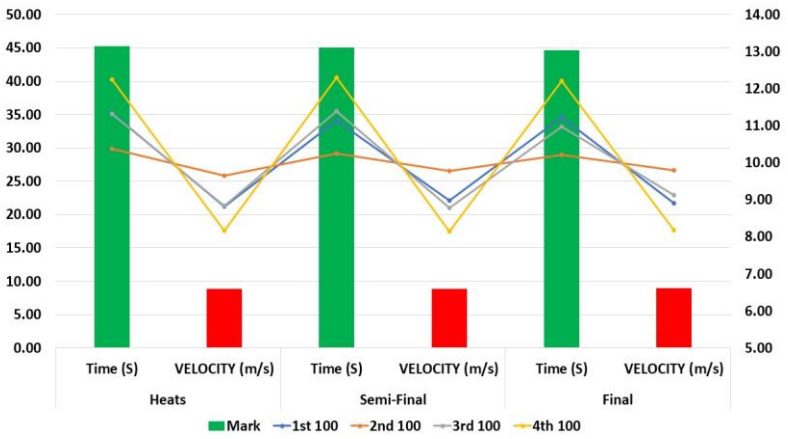

Figure 1.Illustrates the average velocity of the men and women 100m split time, split velocityand final time. Interestingly, the 2nd split is significantly faster than the even split in all rounds, and the 4thsplit in both is significantly slower than the even split, and significantly slower than the other three splits (*p*<.05) in all rounds.

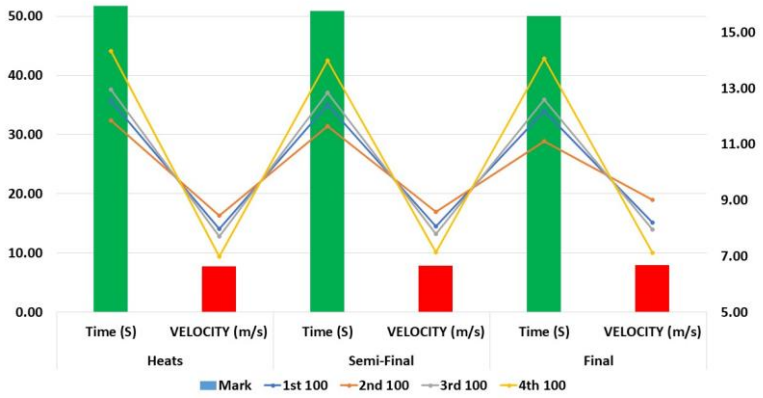

Figure 2.Illustrates the average velocity of the women 100m split time, split velocity and final time. Interestingly, the 2nd split is significantly faster than the even split in all rounds, and the 4th split in both is significantly slower than the even split, and significantly slower than the other three splits (p<.05) in all rounds.

TABLE 3. Position, Personal Best, Reaction Time, final Time and percentage of Personal Best for 400m sprint men (heats, semifinal, final) winner in Budapest 2023

Pos.	Name		Final			Semi-Final			Heats		
		PB	RT	Time	% PB	RT	Time	% PB	RT	Time	% PB
1	Antonio WATSON	44.54	0.165	44.22	-0.72	0.158	44.13	-0.92	0.169	44.77	0.52
2	Matthew HUDSON	44.35	0.151	44.31	-0.09	0.167	44.26	-0.20	0.177	44.69	0.77
3	Quincy HALL	44.41	0.192	44.37	-0.09	0.176	44.43	0.05	0.181	44.86	1.01
4	Vernon NORWOOD	44.35	0.163	44.39	0.09	0.181	44.26	-0.20	0.194	44.87	1.17
5	Sean BAILEY	44.43	0.169	44.96	1.19	0.165	44.94	1.15	0.183	46.98	5.74
6	Håvard Bentdal	44.86	0.199	45.08	0.49	0.190	44.7	-0.36	0.218	44.39	-1.05
7	Wayde VAN	43.03	0.171	45.11	4.83	0.178	44.65	3.76	0.185	44.57	3.58

Table 3. indicates the reaction time, which ranged between (0.151s - 0.218s).Also contained the personal best performance and racetime in the different rounds and the percentage of racetimeachievement attributed to the personal best performance in the qualifiers, semi-finals, and finals.

TABLE 4.100M Splits of 400m sprint men winner in Budapest 2023.

Name	Heats				Semifinal				Final			
	1st	2nd10	3rd10	4th	1st	2nd10	3rd10	4th	1st	2nd10	3rd10	4th
	100	0	0	100	100	0	0	100	100	0	0	100
Antonio WATSON	11.4	10.2	11.2	12.0	11.1	9.9	11.1	12.0	11.4	10.1	10.3	12.4
Matthew HUDSON	11.2	10.1	11.1	12.3	11.0	10.1	11.2	12.0	11.1	9.98	10.9	12.3
Quincy HALL	11.4	10.4	11.3	11.8	11.2	10.3	11.0	11.9	11.4	10.2	10.9	11.9
Vernon NORWOOD	11.3	10.3	11.2	12.1	11.2	10.3	11.5	11.3	11.2	10.2	11.0	12.0
Sean BAILEY	11.4	10.5	11.4	11.9	11.1	10.3	11.5	12.0	11.2	10.5	11.2	12.1
Håvard Bentdal	11.4	10.1	10.9	12.0	11.2	10.1	11.5	11.9	11.4	10.3	11.3	12.2
Wayde VAN	11.2	10.1	11.3	12.0	10.9	10.1	11.3	12.3	11.1	10.3	11.1	12.7

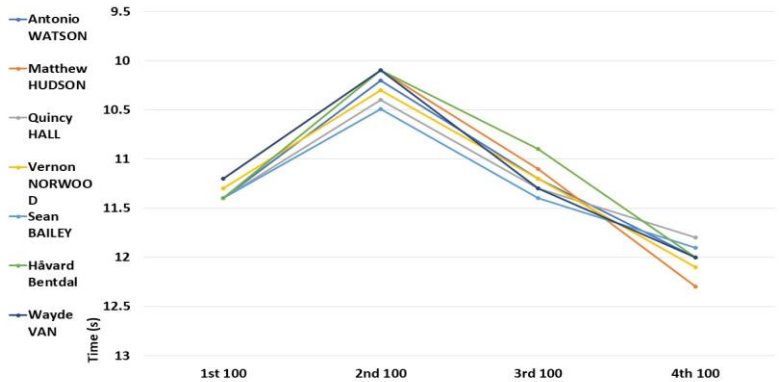

Figure 3. Men'ssplit performance time 400m sprint (Heats).

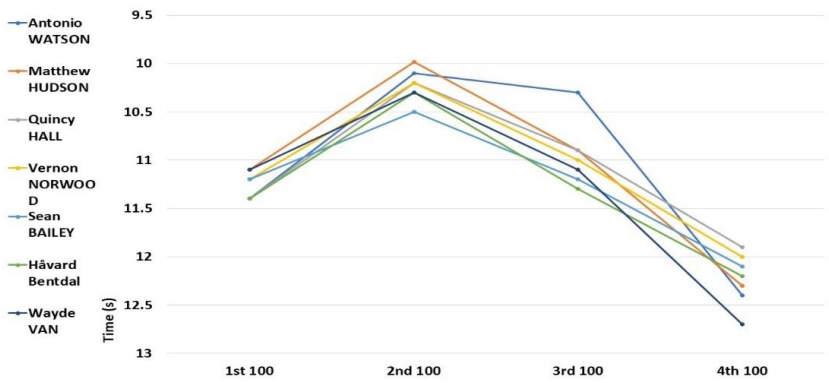

Figure 4. Men'ssplit performance time 400m sprint (Semi-Final).

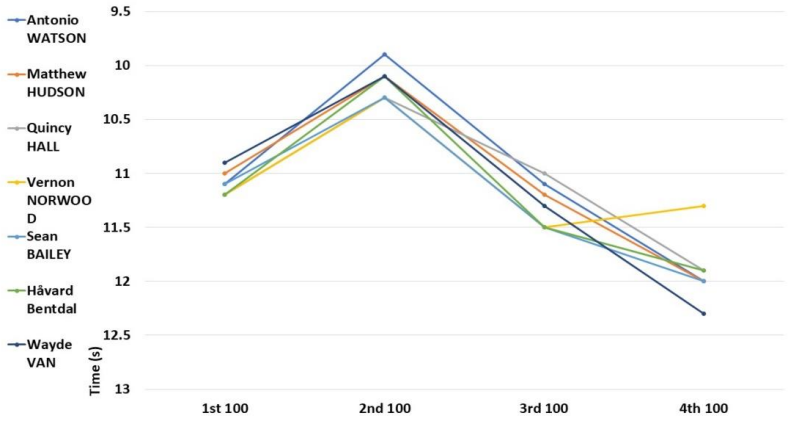

Figure 5. Men'ssplit performance time 400m sprint (Final).
Figure 3,4,5. Illustrates the men 400m split time in the heats, semifinal and final as a same pattern.

TABLE 5. Position, Personal Best, Reaction Time, final Time and percentage of Personal Best for 400m sprint women (heats, semifinal, final) winner in Budapest 2023.

Pos.	Name		Final			Semi-Final			Heats		
		PB	RT	Time	% PB	RT	Time	% PB	RT	Time	% PB
1	Marileidy PAULINO	48.76	0.200	48.76	-0.45	0.187	49.54	1.14	0.168	49.9	1.88
2	Natalia KACZMAREK	49.57	0.168	49.57	0.18	0.173	49.5	0.04	0.183	50.02	1.09
3	Sada WILLIAMS	49.6	0.183	49.6	-0.30	0.191	49.58	-0.34	0.181	50.78	2.07
4	Rhasidat ADELEKE	50.13	0.181	50.13	1.89	0.161	49.87	1.36	0.190	50.8	3.25
5	Cynthia BOLINGO	50.33	0.190	50.33	0.28	0.184	49.96	-0.46	0.145	50.29	0.20
6	Lieke KLAVER	50.33	0.145	50.33	1.04	0.177	49.87	0.12	0.167	50.52	1.43
7	Candice MCLEOD	51.08	0.167	51.08	3.17	0.206	50.62	2.24	0.167	50.37	1.74

Table 5. indicates the reaction time, which ranged between (0.145s - 0.206s).Also contained the personal best performance and racetime in the different rounds and the percentage of racetime achievement attributed to the personal best performance in the heats, semi-finals, and finals

It was noted that the competitors with advanced positions and participants in the finals had their best achievement in the semi-finals. This may be due to the fact that the semi-finals are a pivotal stage in which competitors try to qualify for the final round, while in the qualifications, experienced competitors try to obtain either first or second place to guarantee qualification for the final round, regardless of the record level. In the final round, competitors were guaranteed to obtain a position from first to eighth in the world, so the most difficult round is the semi-final, in which athletes try to qualify for the final round, which makes this round achieve the best digital performance among all the rounds in the race.

TABLE 6.100M Splits of 400m sprint women winner in Budapest 2023.

Name	Heats				Semifinal				Final			
	1st 100	2nd100	3rd100	4th 100	1st 100	2nd100	3rd100	4th 100	1st 100	2nd100	3rd100	4th 100
Marileidy PAULINO	12.4	11.5	12.3	13.7	12.3	11.4	12.4	13.5	12.3	11.1	12	13.4
Natalia KACZMAREK	12.4	11.4	12.9	13.4	12.2	11.4	12.6	13.3	12.3	11.2	12.5	13.7
Sada WILLIAMS	12	11.3	12.7	14.8	12.2	11.7	12.3	13.4	12.1	11.4	12.4	13.7
Rhasidat ADELEKE	12.5	11.6	12.9	13.8	12.5	11.7	12.4	13.2	12.2	11.3	12.4	14.2
Cynthia BOLINGO	12.5	11.6	12.8	13.5	12.2	11.5	12.8	13.5	12.2	11.5	12.6	14
Lieke KLAVER	12.2	11.6	13.0	13.8	12.2	11.4	12.6	13.7	12.0	11.1	12.6	14.7
Candice MCLEOD	12.5	11.6	12.6	13.8	12.6	11.6	12.8	13.7	12.4	10.3	13.8	14.7

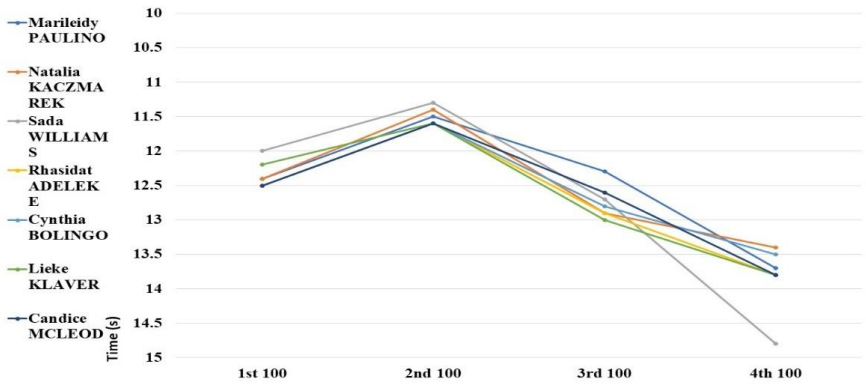

Figure 6. Women'ssplit performance time 400m sprint (Heats).

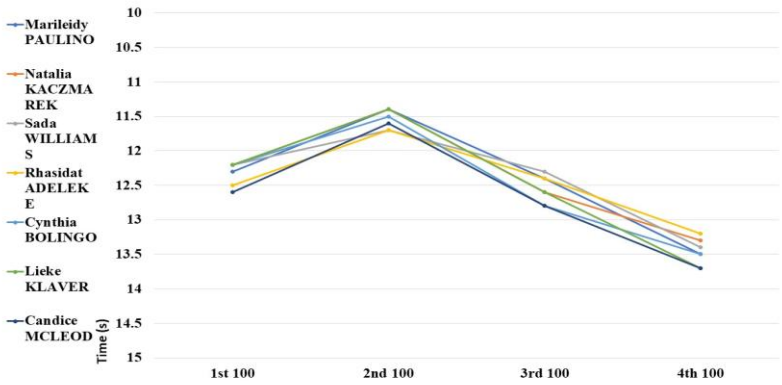

Figure 7. Women's split performance time 400m sprint (Semi-Final).

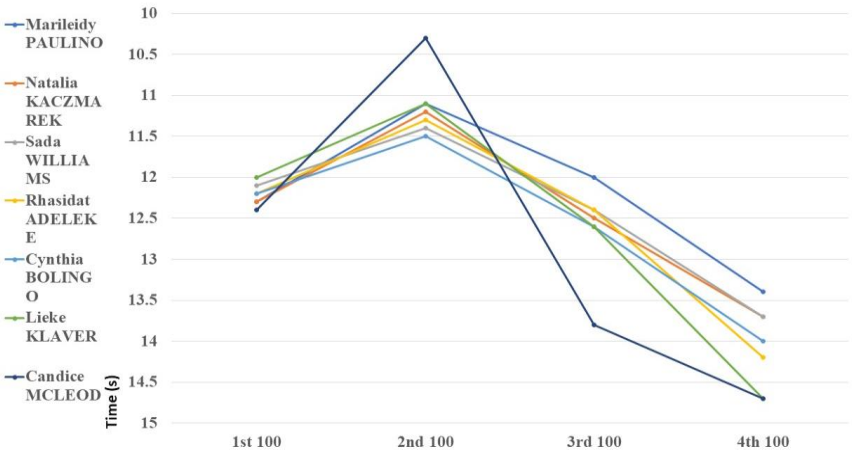

Figure 8. Women's split performance time 400m sprint (Final).
Figure 6,7,8.Illustrates the women 400m split time in the heats, semifinal and final as a same pattern.

DISCUSSION:

There is ongoing debate about the best pacing strategies for 400-meter athletes. For sprint races longer than 291 meters, it has been suggested that the optimal method of utilizing the available energy pools is a brief maximal effort start, followed by an equal pace sustained until the final few meters. Others say the best plan is to maximize velocity early on, and then try to keep the speed drop to a minimum for the rest of the race. (Van Ingen Schenau, et al., 1994)

The results of the present study of contemporary elite 400 m performances support the latter position.

Tables (1,2) show that max velocity is achieved from the 2nd 100 m split and then drops down for the rest of the race. Figures (1,2) clearly show this trend in rounds (heats, semifinal andfinal)An important observation from this study is that men consistently share faster relative 1st100 m split times than women, as a percentage of their PB.On the other hand, performance is hindered by starting time loss if the starting race speed is set too slowly.

The highest speed average came in the 100m in all three rounds for men (9.65±0.19) in the heats, (9.77±0.20) in the semi-finals, and (9.79±0.15) in the final, while it came (8.45±0.21) in the heats, (8.59±0.13) in the semi-finals, and (9.01±0.34) in the final for women, which indicates that the highest speed averages came in the 100m in the second, regardless of the round, whether for men or women.

Singh & Mandal (2003) discovered evidence of a second, mid-race acceleration phase for 12 women (in the 50 m split from 300 m to 350 m) and 12 men (250 m to 300 m) 400 m athletes, which seems to be a unique finding. The results of pacing in the first 200 meters are suggested by this mid-race re-acceleration.and serves as a warning about the dangers of inadequate race pacing. If you begin at a slowerpace, you may retain your energy for the latter parts of the race; however, any surge at the end is too late to overtake those athletes who began more quickly and established a lead that cannot be overcome. (Fukuba & Whipp, 1999)

The results of the tables (3,4,5,6) Figures (3,4,5,6,7,8) showed thatit is clear that the analysis of split time lead topacingstrategies revealed a clear tendency for elite athletes to adopt a positive split strategy, especially in the men and women 400m races. The 1st100 meters for the 400m men were typically run at or near maximum speed,then (2nd100m) appeared the fast stage in the race for men and women followed by a slight deceleration in the final 200 meters.The 4th100 meters was marked by the most significant deceleration, as athletes reached the limits of their anaerobic capacity, with lactate accumulation becoming a major factor. It could be brought on by the effects of exhaustion and physiological reactions.

In order to prevent central control from intervening too soon, slower athletes must run for longer periods of time. The results from this study shows that slower athletes must use a smaller proportion of their PB than faster athletes. It would seem that an athlete's capability to sustain race pace is directly related to their maximal velocity and the percentage of it they apply.

A significant degree of mental toughness is required of elite 400-meter athletes, especially when they are faced with the discomfort and exhaustion brought up by lactic buildup. Top performers frequently cited mental methods like concentrating on keeping form or utilizing visualization to overcome weariness. To stay focused and control perceived effort, some athletes claimed to use tactical clues, such as visualizing their rivals or particular race milestones.(Ae, 1982; Chapman, 1982; Fu-dong, 2011; GRGIĆ et al., 2019; Grgić et al., 2019; Hanon et al., 2010; Ji, 2003; Mastalerz et al., 2024; Willis et al., 2013).

In general, men’s races tended to feature more strong starts and stronger finishes, leading to larger positive splits. Women’s races, while still featuring a significant level of fatigue in the final 100 meters, showed more variability in pacing, with some athletes demonstrating a more even distribution of effort. This difference may be attributed to physiological and biomechanical factors, as well as differing tactical approaches.(Adeniji, 2019; Bc & Ad, 1980; Bridgman, 2015; Casado et al., 2021; Elliott & Roberts, 1980; Gironimo et al., n.d.; Kunz & Kaufmann, 1981; Wen, 2001).

It was clear that there were no differences between the heats, semi-finals and finals in the running strategies and reaction time, but there was an improvement in the time for the same athlete. The goal in the qualifying rounds and semi-finals is only to qualify for the final round, although it was noted that the athletes in the first, second, fourth and fifth places had performed better during the semi-finals,this may be due to trying to qualify for the finals of the race, and it also appeared in the women's race, except for the first and seventh place athletes.

CONCLUSION:

Competitors in the 400m event must maintain their top speed while demonstrating endurance through the demanding phase of the short-distance race. The best athletic performance results from pacing strategies that respond to both athletes' physical characteristics and their chosen tactics. Top-level athletes achieve higher performance in 400m races by initiating their races with maximum speed and maintaining that pace throughout

the duration. Examining physiological markers like lactate profiling and heart rate variability can enhance future studies focused on pacing strategies. By examining physiological and tactical as well as psychological aspects of 400m performance athletes can improve their training and mental preparation resulting in superior race-day strategies for important competitions.

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REFERENCES:

1. Adeniji, O. (2019). *BIOMECHANICAL PERFORMANCE ANALYSIS IN ATHLETICS AT THE COLLEGIATE LEVEL* (Vol. 37, p. 65).
2. Ae, C. (1982). *Hierarchy of changes induced by fatigue in sprinting.* (Vol. 7, p. 116).
3. Bc, E., & Ad, R. (1980). *A biomechanical evaluation of the role of fatigue in middle-distance running.* (Vol. 5, pp. 203–207).
4. Bridgman, C. (2015). *Biomechanical evaluation of distance running during training and competition*.
5. Casado, A., Renfree, A., Jaenes-Sánchez, J. C., Cuadrado-Peñafiel, V., & Jiménez-Reyes, P. (2021). Differentiating Endurance-and Speed-Adapted Types of Elite and World Class Milers According to Biomechanical, Pacing and Perceptual Responses during a Sprint Interval Session. In *International Journal of Environmental Research and Public Health* (Vol. 18). https://doi.org/10.3390/ijerph18052448
6. Chapman, A. E. (1982). Hierarchy of changes induced by fatigue in sprinting. In *Canadian journal of applied sport sciences. Journal canadien des sciences appliquees au sport: Vol. 7 2* (pp. 116–122).
7. Duffield, R., Dawson, B., & Goodman, C. (2005a). Energy system contribution to 400-metre and 800-metre track running. In *Journal of Sports Sciences* (Vol. 23, pp. 299–307). https://doi.org/10.1080/02640410410001730043
8. Duffield, R., Dawson, B., & Goodman, C. (2005b). Energy system contribution to 1500- and 3000-metre track running. In *Journal of Sports Sciences* (Vol. 23, pp. 1002–1993). https://doi.org/10.1080/02640410400021963
9. Elliott, B., & Roberts, A. (1980). A biomechanical evaluation of the role of fatigue in middle-distance running. In *Canadian journal of applied sport sciences. Journal canadien des sciences appliquees au sport: Vol. 5 4* (pp. 203–207).
10. Fukuba, Y., & Whipp, B. J. (1999). A metabolic limit on the ability to make up for lost time in endurance events. *Journal of Applied Physiology*, 87(2), 853861.
11. DOI: 10.1152/jappl.1999.87.2.853
12. Fu-dong, X. (2011). *Analysis on the Speed Control of Optimum Stage of Men's 400m Running*.
13. Gironimo, G. Di, CAPORASO, T., & Lanzotti, A. (n.d.). Development of biomechanical-based analysis tools for the evaluation of infringements and performance in race-walking. *Fedoa.Unina.It*. http://www.fedoa.unina.it/12521/2/Caporaso_Teodorico_XXXI.pdf
14. GRGIĆ, D., BABIC, V., & BLAŽEVIĆ, I. (2019). RUNNING DYNAMICS IN MALE 400M SPRINT EVENT. *Series IX Sciences of Human Kinetics*, *12(61)*(2), 41–48. https://doi.org/10.31926/but.shk.2019.12.61.2.37
15. Grgić, D., Babić, V., & Blažević, I. (2019). *RUNNING DYNAMICS IN MALE 400M SPRINT EVENT* (pp. 41–48). https://doi.org/10.31926/but.shk.2019.12.61.2.37
16. Hanon, C., Leprêtre, P., Bishop, D., & Thomas, C. (2010). Oxygen uptake and blood metabolic responses to a 400-m run. In *European Journal of Applied Physiology* (Vol. 109, pp. 233–240). https://doi.org/10.1007/s00421-009-1339-4
17. Iwańska, D., Tabor, P., Grabowska, O., & Mastalerz, A. (2021). The symmetry of fatigue of lower limb muscles in 400 m run based on electromyography signals. *Symmetry*, *13*(9). https://doi.org/10.3390/sym13091698
18. Ji, Z. (2003). *The poly-analysis of the male's 400 meters running competition*.
19. Kunz, H., & Kaufmann, D. (1981). Biomechanical analysis of sprinting: decathletes versus champions. In *British Journal of Sports Medicine* (Vol. 15, pp. 177–181). https://doi.org/10.1136/bjsm.15.3.177
20. Li-bo, C. (2004). Characteristic Analysis of the Speed of 400m for World Elite Women Runners. In *Journal of Shandong Physical Education Institute*.
21. Lin, L. (2002). Studies of the Interrelationship between the Result of Woman's 400 Meters Race and the Sectional of 50 Meters. In *Journal of Liaocheng Teachers University*.
22. Martín-Acero, R., Rodríguez, F. A., & Codina-Trenzano, A. (2021). *A Model for Individual Pacing Strategies in the 400 Metres*.https://api.semanticscholar.org/CorpusID:245536865
23. Mastalerz, A., Johne, M., Mróz, A., Bojarczuk, A., Šťastný, P., Petr, M., Kolinger, D., Pisz, A., Vostatková, P., & Maculewicz, E. (2024). Changes of Anaerobic Power and Lactate Concentration following Intense

Glycolytic Efforts in Elite and Sub-Elite 400-meter Sprinters. In *Journal of Human Kinetics* (Vol. 91, pp. 165–174).https://doi.org/10.5114/jhk/186074
24. Ming, Y. (2006). Analysis on the Characteristics of Speed Distribution of World Elite Male 400m Runners. *Sport Science Research*.
25. https://api.semanticscholar.org/CorpusID:113252387
26. Ramadan, S. M. (2014). *Theories & Applications, the International Edition Comparative Analysis on Speed Distribution of Women 400m Finalist Athletes in the World Athletics and Olympic Championships* (Vol. 4, Issue 2).
27. Ramadan, S. M. (2020). *Comparative Analysis on Speed Distribution of Women 400m Finalist Athletes in the World Athletics and Olympic Championships.*
28. https://doi.org/10.21608/jass.2014.84787
29. Singh, A., & Mandal, S. K. (2003). Velocity curves of competitive male and female sprinters at inter-university level. *Research Bi-Annual for Movement* 19(2), 30-37.
30. Van Ingen Schenau, G. J., de Koning, J. J., & de Groot, G. (1994). Optimisation of sprinting performance in running, cycling and speed skating, *Sports Medicine*, 17(4), 259-275.DOI: 10.2165/00007256-199417040-00006
31. Wen, R. (2001). *A Biomechanical Study on the Elite Man's 200m-running in the world*.
32. Willis, R., Burkett, B., & Sayers, M. G. L. (2013). 400 Metre Race Pace Strategies: How your 200 Metre Personal Best Influences your Performance Options. In *Journal of Fitness Research* (Vol. 1, pp. 40–49).
33. world Athletics. (n.d.). *https://worldathletics.org/*.
34. Xiao-ping, Z. (2004). *On the Characteristics of the Performance Model of Elite 400 m Men Athletes in the World*. https://api.semanticscholar.org/CorpusID:131228516
35. Yao-xin, H. (2003). Analysis of Speed Characteristics of World Outstanding Athletes in Men's 400 m Race. *Journal of Shandong Physical Education Institute*. https://api.semanticscholar.org/CorpusID:147722092
36. Yong, D. (2008). Comparative study on the sectional fastest speed and utilization rate of elite men 400m runners. *Journal of Shandong Institute of Physical Education and Sports*. https://api.semanticscholar.org/CorpusID:167416909
37. Yu, L. (2007). *Multiple Analysis on Speed Distribution of World Elite Women 400m Athletes*.