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Article

An Analytical Study of the Velocity Curve of Indian National Level and World Class 1500m Runners

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Abstract: The 1500-meter race, also known as the metric mile, is one of the most prestigious middle-distance track events in athletics. It is contested in both men's and women's competition, and requires a combination of speed, endurance, and strategic pacing. Middle-distance events like 1500 m typically exhibit varied pacing profiles. Studies shown that 1500 m races often follow a parabolic or J-shaped pattern. The race is characterized by moderate opening laps, slowing mid-race, and a strong finish. Despite these general trends, training environment, altitude exposure and gender can also significantly influence velocity curve. Present study aims to fill these knowledge gaps by comparing velocity curve of Indian and foreign male athletes. The study involves exploration of velocity curve differences between Indian and foreign 1500-m runners. To acquire this, a design based on comparative observation was employed, examining split times from World Athletics and Olympic Games as world class runners and 80th All India Inter University Athletics Championships for India national level runners. The methods of the study include data sourcing by identifying the pacing profiles and statistical procedures. The findings of the study bring about some significant conclusions on the velocity pattern of Indian and foreign 1500-m runners. The intuitions developed from the findings of the study targets to contribute to the deeper understanding of performance characteristics of 1500-m run and can help in training and adopting perfect race strategies especially for Indian national level 1500-m male runners

Keywords: 1500-meter race, Velocity curve, Pacing strategy, Middle-distance running, Performance analysis

1. Introduction

The 1500-meter race is unique in that it is longer than a sprint, but shorter than a distance race. Running 1500-m race is a test of both endurance and speed and demands maintaining of a fast and sustainable pace for 3 and ¾ laps around a 400-m track. A 1500-m race requires a balance of speed and endurance and it is called a perfect race (Athletics, 2019).

The race typically starts with a fast and aggressive pace, with runners jostling for position and attempting to establish themselves in the lead pack (International Association of Athletics Federations (IAAF), 2019). The middle

portion of the race is very important, which is characterised by a strategic and tactical approach for the athletes who attempting to conserve their energy and like to have a strong finish. The final lap of 1500-m race is a very exciting and acute for the runners who push themselves to the limit to sprint to the finish line (Haugen et al., 2021). 1500-m race is a middle-distance running events and it has served as long as a yardstick of an athletes' aerobic capacity, speed, tactical efficiency and physiological competence (Casado et al., 2020). As track and field continues to develop with the progression in sport science including sports nutrition, sports biomechanics and sports training methodologies, analysing of running performance has become a serious aspect of competitive assessment (Llanos-Lagos et al., 2024). Running pace is one of the most vital parameters for evaluating performance in middle distance events. Running pace is not only an indication of an athlete's physical habituation but it also indicates their race strategy and psychological stamina (Billat et al., 2009) An increasing curiosity has arisen in the relative performance analysis of athletes from different training backgrounds, geographical conditions and cultural environment in recent decades. In addition to that the dynamics of national level and world class in running pace also open up a path for an accompanying analysis in understanding the variation in pace strategies and endurance efficiency across the same distances of Indian national level and world class athletes across the same race distance (Viveiros et al., 2015).

This study emphasized on a comprehensive analysis of the running pace of Indian national level and world class middle-distance runners in the 1500-meters race. (Casado et al., 2021). By examining velocity curve uniformity, variations across race segments and comparing average paces between Indian national level and world class athletes, this research aims to recognize patterns, strengths, and areas of excellence (Casado et al., 2021). The findings will contribute to improved training frameworks, improved race tactics, and more targeted athlete improvement programs for Indian national level middle-distance runners(Mondal, 2023). The study begins by contextualizing the significance of velocity curve in middle-distance running, followed by a review of appropriate literature, objectives, and the foundation for selecting the proportional framework of athletes. Through a scientific and statistical approach, the study tried to improve the understanding of how running pace of world class 1500-m runners influences competitive victory and what differentiates them in comparison to Indian national level 1500-m runners.

2. Material and Method (Data Acquisition)

The subjects include elite male athletes specializing in the 1500m events. Data were obtained from international competitions, like World Athletics Championships, Olympics games. Ten male athletes of Indian national level and world class runners were selected and they have contested authorized 1500-m races. Data with respect to Indian national level male athlete, authors visited the venue of the 80th Association of Indian Universities (AIU) All India Inter University Athletics (Men & Women) Championship 2020 at the Alva's Education Foundation, Moodubidire, Mangalore organized under the Rajiv Gandhi University of Health Sciences, Bangalore, Karnataka, India. With formal consent of the Organizing Secretary of the championship, four numbers of high-definition cameras were positioned in each 100 meters of the 400-meter standard track. 4 numbers of indicators are also placed inside the running track for accurate footage and timings. Cameras are handled by the authors and other experienced assistants. Cameras which were placed in the curved were aligned to the centre of the track. Cameras which were placed in straight are perpendicular to the running direction. Cameras are placed horizontally with front angle at a distance of 5 meter from the outer lane of the 400-meter standard running track. Cameras were placed at the height of 1.20m from ground and 2m away from the inner border of the track. On gun fire from the starter for starting of the 1,500-meters male and female race, investigator and others assistants on the cameras for video footage and timings separately. Free access software 'Shotcut' was used to evaluate accurate timings of the athletes from the self-captured video footage. Data pertaining to the world class 1500-m runners were sourced from the widely accessible data in the World Athletics website (Dr Brian Hanley and Dr Athanassios Bissas, 2018). An official request application was sent to the President of the World Athletics previously known as International Association of Athletic Federation (IAAF). Consequently, an official Data Feed License Contract was signed between the corresponding author and Chief Executive Officer (CEO) of the World Athletics with its Head Offices at 6-8 Quai Antoine 1er, 98007 Monaco. As per Data Feed License Contract, data with respect to the 1500- meter male runners of the IAAF World Championships and Olympic Games was downloaded from the World Athletics website. (Das & Mandal, 2021). A cross-sectional study design was employed to analyse the data of Indian national level and world class 1500-m runners

3. Analysis and Results

The average zonal velocities are the criterion of the present study which was measured by employing the following equations-

$\bar{\upsilon}$=d/t Here, $\bar{\upsilon}$=average velocity, d=displacement i.e. 100-m zone and t = time elapsed by the athletes to run the 100-m zone

Statistical analysis was carried out by JASP software(Darjee & Sahai, 2026).

Zone	Group	No. of Subjects	Mean	Std. Deviation	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Shapiro-Wilk	P-value of Shapiro-Wilk	Minimum	Maximum
1st 100-M	WC	10	6.713	0.124	-0.677	0.687	-0.157	1.334	0.938	0.535	6.477	6.859
	IND	10	6.541	0.03	-1.706	0.687	2.544	1.334	0.791	0.011	6.472	6.57
2nd 100-M	WC	10	6.212	0.053	0.423	0.687	0.044	1.334	0.96	0.783	6.139	6.313
	IND	10	6.525	0.033	-0.041	0.687	-2.14	1.334	0.846	0.052	6.485	6.566
3rd 100-M	WC	10	6.209	0.046	-2.334	0.687	6.68	1.334	0.722	0.002	6.086	6.258
	IND	10	6.549	0.053	-0.156	0.687	-1.515	1.334	0.909	0.272	6.481	6.618
4th 100-M	WC	10	6.81	0.168	0.455	0.687	-0.932	1.334	0.946	0.616	6.601	7.097
	IND	10	6.494	0.077	0.268	0.687	-0.934	1.334	0.934	0.489	6.386	6.609
5th 100-M	WC	10	6.712	0.257	0.673	0.687	-0.298	1.334	0.933	0.477	6.382	7.174
	IND	10	6.402	0.073	-0.406	0.687	-0.652	1.334	0.951	0.676	6.27	6.494
6th 100-M	WC	10	7.031	0.09	0.824	0.687	-0.742	1.334	0.876	0.117	6.93	7.194
	IND	10	6.445	0.191	-2.143	0.687	5.107	1.334	0.757	0.004	5.959	6.605
7th 100-M	WC	10	7.16	0.107	0.711	0.687	-0.303	1.334	0.873	0.109	7.057	7.369
	IND	10	6.268	0.061	-0.237	0.687	-0.841	1.334	0.947	0.638	6.161	6.345
8th 100-M	WC	10	7.072	0.146	-0.289	0.687	-1.188	1.334	0.923	0.383	6.821	7.252
	IND	10	6.153	0.081	-0.44	0.687	-0.665	1.334	0.952	0.694	6.006	6.258
9th 100-M	WC	10	7.188	0.069	1.237	0.687	0.578	1.334	0.84	0.044	7.123	7.331
	IND	10	6.084	0.087	-1.487	0.687	0.809	1.334	0.744	0.003	5.921	6.161
10th 100-M	WC	10	7.138	0.11	0.442	0.687	-1.045	1.334	0.851	0.06	6.974	7.294
	IND	10	6.114	0.089	1.351	0.687	0.996	1.334	0.835	0.038	6.035	6.301
11th 100-M	WC	10	7.2	0.132	0.365	0.687	-1.494	1.334	0.902	0.228	7.022	7.407
	IND	10	6.085	0.098	0.182	0.687	-1.648	1.334	0.912	0.297	5.963	6.227
12th 100-M	WC	10	7.212	0.044	1.82	0.687	4.634	1.334	0.82	0.025	7.163	7.321
	IND	10	6.109	0.174	1.134	0.687	0.928	1.334	0.881	0.133	5.931	6.477
	WC	10	7.461	0.08	-0.658	0.687	-1.082	1.334	0.888	0.159	7.337	7.559

13th 100-M	IND	10	6.304	0.151	-0.268	0.687	-1.802	1.334	0.862	0.081	6.068	6.472
14th 100-M	WC	10	7.384	0.189	-1.15	0.687	2.226	1.334	0.915	0.316	6.959	7.651
	IND	10	6.294	0.247	0.023	0.687	-1.309	1.334	0.947	0.636	5.931	6.636
15th 100-M	WC	10	7.284	0.374	-0.842	0.687	2.173	1.334	0.927	0.418	6.468	7.868
	IND	10	6.301	0.238	-0.003	0.687	-0.237	1.334	0.967	0.866	5.889	6.658

Table-1 Descriptive Statistics of 100-M Zone of 1500-M Race (m/s)

Note: WC= World Class and IND= Indian National Level

Table-1 revealed that, across all 15 zones, world class 1500-m runners consistently faster with lower mean times in every 100-m segment of 1500-meter race. The Indian national level 1500-m runners are slower in every zone with higher mean times. The IND male runners have their mean times approximately 0.2-1.1 seconds slower per 100-m segment of 1500-m race. This indicates that the WC male runners maintain a higher speed and better pace distribution. The gap of IND and WC male 1500-m runners increases especially in the middle and late race zones. In the early race of 1st to 5th zone of 100-m segment, WC runners start strong with times between 6.20-6.81 seconds. Whereas in the 1st to 5th zone of 100-m segment, the IND runners start slower with times in between 6.40-6.55 m/seconds. In the middle from 6th to 10th zone of 100-m segment WC male runner's timings rises slightly to 7.03-7.19 m/s. The IND runners stay in between 6.08- 6.45 m/s. But since IND runners' earlier baseline was slower, the difference remains ~1 second. From the above we can say that the WC runners demonstrate a controlled increase in speed and they have a better lactate tolerance. The IND runners show a small variability but they remain consistently slower. In the final 1500-m race zones from 11th to 15th 100-m segment, the WC runners reach a peak speed in the last 400-m i.e. 7.20-7.46 m/seconds. Whereas, the IND runners remain at a constant speed at 6.08-6.30 m/seconds. This indicates less finishing kick on part of the IND male runners of 1500-m race. Overall, the WC male runners finish the 1500-m race significantly stronger. They show superiority in speed endurance, tactical finishing sprint and an aerobic-anaerobic transition.

The standard deviation (SD) of WC runners ranges from 0.044 to 0.374. The WC runners show a greater variability in later zones especially 15th zone, where SD is 0.374. The SD of WC runners indicate stronger finishing strategies, where some WC runners' runs with sprint and other were fading. The standard deviation (SD) of IND runners ranges from 0.03 to 0.247, the IND runners show more consistent with less speed. The lower SD of IND runners show that they run more uniformly but with less aggressive pacing. As the sample size of the present study was 10 numbers i.e. n=10, Shapiro-Wilk Test is the best choice for establishing the normality of the data.

For 1500-meter WC male runners, 1st zone ($p = 0.535$), 2nd zone ($p = 0.783$), 4th zone ($p = 0.616$), 5th zone ($p = 0.477$), 7th zone ($p = 0.109$), 8th zone ($p = 0.383$) 10th zone ($p = 0.060$, 11th zone ($p = 0.228$), 13th zone ($p = 0.159$), 14th zone ($p = 0.316$), 15th zone ($p = 0.418$) reveals $p > 0.05$, means data are normally distributed for these zones. Meanwhile p-value of Shapiro-Wilk for 3rd zone ($p = 0.002$), 9th zone ($p = 0.044$) and 12th zone ($p = 0.025$) reveals $p < 0.05$, means data are not normally distributed. In all data sets Skewness and Kurtosis were found to be normal. (Hair & Hair, 2010) defined normal data as having skewness between -2 and +2 and kurtosis between -7 and +7. For zone number 3rd, 9th and 12th skewness is -2.334, 1.237 and -0.842 respectively, whereas kurtosis for zone number 3rd, 9th and 12th are 6.68, 0.578 and 4.634 respectively. This means data for these three zones are also normally distributed.

For 1500-meter IND male runners, 2nd zone ($p = 0.052$), 3rd zone ($p = 0.272$), 4th zone ($p = 0.489$), 5th zone ($p = 0.676$), 7th zone ($p = 0.638$), 8th zone ($p = 0.694$), 11th zone ($p = 0.297$), 12th zone ($p = 0.133$), 13th zone ($p = 0.081$), 14th zone ($p = 0.636$), 15th zone ($p = 0.866$) reveals $p > 0.05$, means data are normally distributed for these zones. Meanwhile p-value of Shapiro-Wilk for 1st zone ($p = 0.011$), 6th zone ($p = 0.004$), 9th zone ($p = 0.003$) and 10th zone ($p = 0.038$) means data are not normally distributed. However as mentioned above skewness < 2 and kurtosis < 7 are established to be normally distributed. For zone number 1st, 6th, 9th and 10th zone is -1.706, -2.143, -1.487 and 1.351 respectively. This means that the data for these zones are also normally distributed. Shapiro–Wilk analysis showed that most 100-meter segment data for both WC and IND 1500-m male runners followed a normal distribution ($p > 0.05$). WC runners exhibited normality in a greater number of segments compared to IND runners. This indicates more consistent pacing and fewer performance outliers. Several early and mid-race segments for IND runners showed significant deviations from normality ($p < 0.05$). This indicates an irregular pacing and larger fluctuations in

performance. The WC runners having their quality with faster initial speed, better acceleration between the zones. WC runners also have a strong mid-race pace control and they had superior finishing kick i.e. in zone number 13th to 15th. They have higher aerobic power and anaerobic capacity. The WC runners also exhibited better tactical distribution effort. The IND male runners in 1500-meter race revealed that they are more rhythm-based running but showed less aggressiveness. The IND male runners in 1500-meter race are slower in across all 15 numbers of zones. The IND male runners are also revealed limited late race acceleration and lower maximal sprint capacity in the last 300 to 400 meters.

Table:2. Independent Samples T-Test of 100-M Zone of 1500-Meter Male Runners

Zone	t	df	p	Mean Difference	SE Difference
1st Zone 100-M	4.27	18	< .001[a]	0.172	0.04
2nd Zone 100-M	-15.961	18	< .001	-0.313	0.02
3rd Zone 100-M	-15.334	18	< .001	-0.34	0.022
4th Zone 100-M	5.407	18	< .001[a]	0.315	0.058
5th Zone 100-M	3.678	18	.002[a]	0.31	0.084
6th Zone 100-M	8.792	18	< .001	0.586	0.067
7th Zone 100-M	22.834	18	< .001[a]	0.891	0.039
8th Zone 100-M	17.368	18	< .001[a]	0.919	0.053
9th Zone 100-M	31.339	18	< .001	1.104	0.035
10th Zone-100-M	22.893	18	< .001	1.024	0.045
11th Zone 100-M	21.427	18	< .001	1.115	0.052
12th Zone 100-M	19.428	18	< .001[a]	1.102	0.057
13th Zone 100-M	21.447	18	< .001[a]	1.156	0.054
14th Zone 100-M	11.087	18	< .001	1.09	0.098
15th Zone 100-M	7.01	18	< .001	0.983	0.14

Note. Student's t-test.

[a] Brown-Forsythe test is significant ($p < .05$), suggesting a violation of the equal variance assumption

The results of table number-2 indicated statistically significant differences between the WC and IND male 1500-m runners across all zones, with all p-values falling below the .001 level. The mean differences illustrate the magnitude and direction of performance variations between WC and IND male runners in each 100-meter segment. These findings highlight consistent and substantial disparities in segmental race pacing across the 1500-meter event. All p-values are below the conventional significance level ($p < .05$). In most cases far below .001, which indicates that the running times between the WC and IND male runners are differed significantly in every 100-meter segment of the race. The positive t-value for the zone number 1,4,5,6,7,8,9,10,11,12,13,14 and 15 revealed a positive mean difference in comparison to the IND runners. The negative t-value for the zone number 2 and 3 revealed a negative mean difference in comparison to the WC male runners of the 1500-meter race. The largest differences appear in the middle and later zones from 7–13, where mean differences exceed 0.85 m/seconds and in some cases exceed 1.10 m/seconds. This suggests that WC runners outperformed substantially than the IND runners as the race progressed. Cells marked with [a] indicate that the Brown–Forsythe test was significant ($p < .05$). This means the assumption of equal variances was violated for these zones of 1, 4,5, 7,8 12 and 13. In such cases, the t-test results were interpreted using the Welch correction, which adjusts the t-test to account for unequal variances and provides a more accurate significance value.

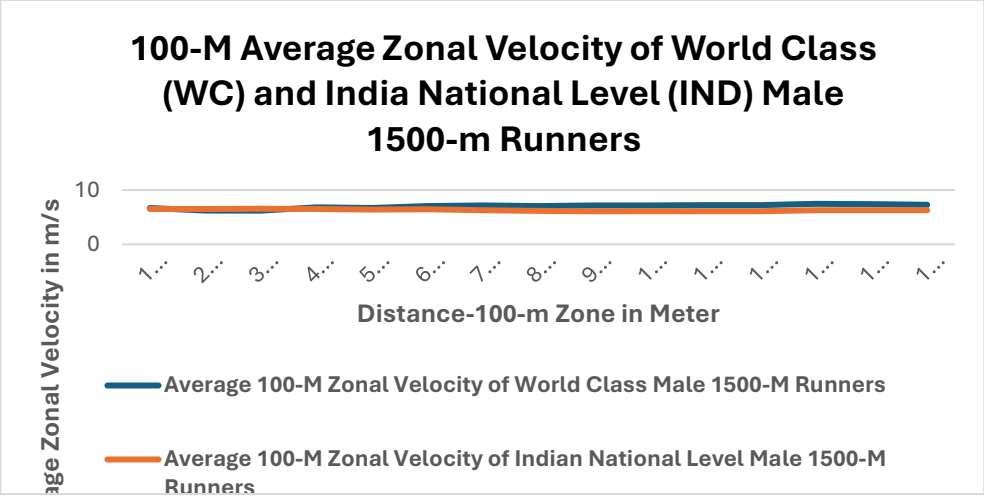

Figure:1. Graphical Representation of 100-M Zonal Velocity of WC and IND 1500-M Male Runners.

The graph illustrates the average running velocity in meters per second recorded in each 100-meter segment of the 1500-meter race for WC and IND male runners. The x-axis represents the sequential 100-meter zones from 100-M to 1500-M, while the y-axis shows the corresponding average zonal velocity.

The graph revealed that across almost all 100-meter segments, the WC runners represented by blue line remains above the IND runners represented by orange line (Singh & Mandal, 2003). This shows that WC male runners consistently ran at a higher speed throughout the race. In the first 100–200 meters, both IND and WC runners begin with similar velocities, indicating a comparable initial acceleration or race-start strategy(Das & Mandal, 2023). However, after approximately the 300-M mark, WC runners show a slight increase and stabilization of velocity, maintaining speeds between 6.5 and 7.5 m/s for most of the race. And these revealed a stronger aerobic capacity, superior pacing strategy and greater speed maintenance ability on the part of WC runners. The velocity of IND runners gradually declines after the early stages and remains consistently lower than that of WC runners. IND male runners are hovering around 6.0–6.3 m/s for most zones.

4. Discussion

The WC 1500-m male runners have a declining pace up to 200-m, then a steady pace up to 400-m and thereafter gradual increase of pace till the end of the race. The IND 1500-m runners showed a uniform pacing pattern from the beginning of the race till to the end. The WC male runners keep their anaerobic storage for a fast finish. Their race strategy is set to have a slower start, gradual pace hike and final kick, which enable them to keep anaerobic energy reserve to be utilised for the end spurt of the race. On the contrary, the IND 1500-m male runners uniformly distribute the race pace throughout the race, which may be the indication of poor energy reserve both aerobic and anaerobic and strategically incompetency which is build up through well planned energy reserve. The results suggested a consistent and statistically significant performance difference between WC and IND male 1500-meter. The early segments show some variability with IND runners outperforming in zone numbers 2 and 3. In the middle and later segments showed substantially higher performance by WC runners, which was indicated by large t-values and substantial mean differences. The analysis also demonstrates that the independent samples t-test assumptions were met in most segments. And wherever assumptions were violated, the appropriate Brown–Forsythe correction was applied.

5. Conclusion

When running pace of 1500-m male World Class 1500-m runners based on their each 100-m average velocity, they exhibit a fluctuation in zonal velocities to progressively higher amplitude. Indian National Level 1500-m male runners follow an even pace strategy in running a 1500-m race. It is recommended that a proper training methods like interval training, tempo run and speed drills should be implemented for the Indian national level 1500-m runners to improve their overall running pace.

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