ORIGINAL ARTICLE

The effect of stride frequency, stride length, and stride time on sprint patterns

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ABSTRACT

The research has been done to explain the complex interrelation of three important parameters of the sprinters-stride frequency, stride length, and step time-in the case of a national athlete HTY during the 100 meters sprint. Stride length refers to the distance covered in one complete step, while stride frequency is defined as the number of steps one makes in a unit of time. Previous studies have shown that both these two variables are related in a complex way. Usually, if one increases, the other decreases because of biomechanical limitation. This paper is a quantitative description, and performance variables of HTY were analysed through video analysis software namely, Kinovea. The results showed that HTY finished the race with 13.24 seconds and an average of 172.85 cm stride length with a total of 57 steps. Variabilities in speed during successive intervals, such as the peak from the 10-20-meter interval, were analysed. The results show that literature supports stride frequency and length significantly influence sprint performance. More precisely, it is proven that there is room for improvement in the specific strengthening exercises by the fact that the measured stride time differs between legs. Fine-tuning in the relationship between stride frequency and length is the most important in enhancing sprint performance. The study gives some useful suggestions for coaches and athletes in the modification of their training strategies, thereby improving the overall efficiency in sprinting.
Keywords: Biomechanics, Stride frequency, Stride length, Step time, Sprint patterns.

Cite this article as:
Ridwan, M., Rizki, A. Z., Dinata, V. C., Ayubi, N., & Kubaeva, S. (2026). The effect of stride frequency, stride length, and stride time on sprint patterns. *Journal of Human Sport and Exercise, 21*(3), 891-900. https://doi.org/10.55860/sv4nd178

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Submitted for publication February 13, 2026.
Accepted for publication March 16, 2026.
Published May 07, 2026.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/sv4nd178

INTRODUCTION

Step frequency, step length, and step time are important components that affect the performance of the sprinter (Miyashiro et al., 2019). Understanding how these elements interact can provide insights into optimizing sprint techniques (Yan, 2024). Stride length refers to the distance travelled in a complete step, whereas step frequency is the number of steps taken per unit of time (Hiraga et al., 1994). Various researches indicate a complex interaction of step length with step frequency. Because of the biomechanical constraint, generally, an increase in one would result in the reduction of another, such that if an athlete increases his stride, the frequencies reduce, or vice versa (Niay et al., 2019; Sobarna et al., 2023). This inverse relationship requires a careful training strategy focused on achieving optimal ratios, as excessive focus on improving one component without considering the other can lead to decreased performance (Arora & Doshi, 2021). Therefore, trainers and trainers must design a training regimen that harmoniously enhances both attributes (Wang et al., 2023).

Specific biomechanical aspects, including hip flexion and muscle coordination, significantly affect stride characteristics as well as overall sprint performance (Krebs et al., 1998). Optimal hip flexion allows for the development of more effective thrust force, while good muscle coordination supports a smooth transition of lower limb motion during the ground contact and swing phases. For example, superior muscle coordination is required to achieve high stride frequencies, which ultimately improves sprint performance holistically (Majumdar & Robergs, 2011). In addition, research shows that strength training has more effect on increased stride length than frequency, indicating that different training modalities can produce varying impacts on these biomechanical parameters (Schubert et al., 2014).

It was important for the performance pattern of the sprinter that this relationship among step frequency, length, and step time is complexly interrelated. It will also clearly be an added tool to help both the athletes develop their technique and help the coaches design effective training programs related to each one's needs. And as sprints continue to change with every development in the knowledge of sports sciences, ongoing research on these factors shall be relevant for optimizing athletic performance.

METHODS

This study uses a single-subject research design with a descriptive quantitative approach to analyse the 100-meter sprint of national athletes with the initials HTY. The variables measured included step frequency (stride frequency, steps per second), step length (stride length, cm), step time (step time, seconds), travel time per interval, and speed (m/s).

Participants

The subject of the study was one female national athlete with the initials HTY with a height of 154 cm and a weight of 52.7 kg. The selection of subjects used purposive sampling techniques based on their status as a national athlete in the 100-meter sprint, thus meeting the criteria for the biomechanical analysis of single running performance. No exercise interventions were provided in this study; Data are completely taken from one time of the subject's maximum running performance for the purpose of biomechanical descriptive analysis. This approach allows for pure observation of stride frequency, stride length, and step time patterns without the influence of external variables.

Data collection procedure

The 100-meter running video was recorded using a high-quality digital camera with a minimum specification of 60 fps and 1080p resolution. The camera is positioned side-by-side (profile view) at waist height as well as 10-15 meters away from the subject to minimize perspective distortion and ensure the accuracy of biomechanical measurements. Data collection was carried out on standard athletic tracks with 10-meter interval markers (0-10 m, 10-20 m, up to 100 m). Subjects warmed up standard before the maximum run from the start blocks or standing start positions, with video recording starting 2-3 seconds before the start and ending after crossing the finish line.

Video analysis with Kinovea

The video is imported into the Kinovea software (version 0.9 or later, free download from kinovea.org) for detailed biomechanical analysis. This process allows for precise measurement of running motion variables through the tracking and automatic measurement features available in the software. The first step is to calibrate the scale by drawing a line of known distance (e.g., 1 meter between lines of trajectory), then calibrate using the "*Linear scale*" tool to convert units of pixels to meters or cm. Furthermore, step identification is done by playing the video frame-by-frame at a slow-motion speed of 0.1x; Mark the initial right/left foot contact with the ground as a "*touchdown*" using the Trajectory Tool or Auto Marker, where one stride is defined from the same foot touchdown to the next touchdown.

Variable measurements

Measurement of biomechanical variables is carried out systematically using the Kinovea feature. The length of the stride is calculated as the horizontal distance between two consecutive touchdowns on the same leg as the line tool, while the step time is measured as the time interval (seconds) between consecutive touchdowns (left-right or right-left) based on an automatic timestamp. The frequency of the stride is obtained by the formula 1/average step time per stride or the number of strides divided by the total interval time, while the travel time and speed per 10-meter interval are calculated using the stopwatch tool with the formula speed = distance/time. Data were extracted for each individual stride (57 stride total) and summarized per 10-meter segment for performance pattern analysis. The accuracy of the measurement is improved through repetition at least twice per variable with the taking of mean values, thereby minimizing observation errors and providing reliable descriptive data for the evaluation of HTY running techniques.

Data analysis

The data is processed using descriptive statistics to produce relevant central tendency and dispersion measures, including means, minimum values, as well as maximum values of stride length and step time. In addition, the total steps (57 steps) were calculated, along with analysis of performance change patterns through graphical visualization that showed the relationship of distance travelled to step time, stride length, and speed per interval.

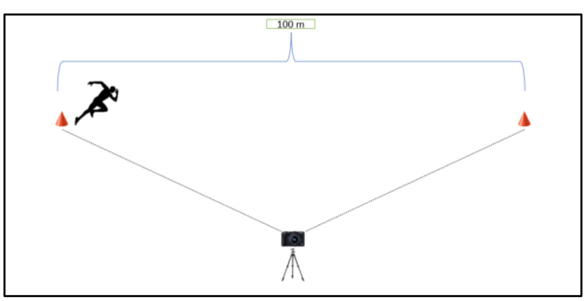

Figure 1. Running motion video capture mechanism.

No inferential test was carried out considering that the single-subject research design is quantitative descriptive. Validation of results is carried out by qualitatively comparing findings against the established biomechanical literature of sprint running, thus ensuring that the interpretation of the data is in line with applicable scientific principles.

RESULTS

The results of the study were obtained from taking videos directly and then video analysis was carried out using Kinovea software. The following are the results of the movement analysis of HTY athletes.

Table 1. Based on the results of the analysis of stride frequency, stride length, and stride time in HTY athletes.

Motion analysis						
Interval (meter)	Stride frequency	Stride length (cm)	Step time (seconds)	Travel time (seconds)	Speed (m/s)	Time records
0-10	1	100	0.32	2.16	4.62	13.24
	2	65.14	0.24			
	3	112.12	0.24			
	4	97.27	0.24			
	5	129.08	0.2			
	6	128.25	0.24			
	7	132.46	0.2			
	8	147.65	0.24			
	9	161.26	0.24			
10-20	10	153.77	0.2	1.08	9.25	
	11	176.84	0.24			
	12	178.93	0.2			
	13	180.53	0.24			
	14	183.25	0.2			
20-30	15	188.72	0.24	1.36	7.35	
	16	184.81	0.2			
	17	199.22	0.24			
	18	189.87	0.24			
	19	194.34	0.24			
	20	187.08	0.2			
30-40	21	195.78	0.24	1.16	8.62	
	22	198.87	0.24			
	23	200.21	0.24			
	24	200.3	0.2			
	25	189.56	0.24			
40-50	26	198.84	0.24	1.36	7.35	
	27	202.08	0.24			
	28	192.52	0.2			
	29	195.04	0.24			
	30	184.74	0.24			
	31	182.92	0.2			
50-60	32	178.37	0.2	1.12	8.92	
	33	175.87	0.24			
	34	172.12	0.24			
	35	173.93	0.24			
	36	173.25	0.2			

60-70	37	189.01	0.28	1.2	8.33
	38	173.17	0.2		
	39	179.25	0.28		
	40	169.22	0.2		
	41	188.98	0.24		
70-80	42	185.03	0.24	1.48	6.75
	43	187.17	0.28		
	44	179.03	0.24		
	45	185.68	0.24		
	46	177.07	0.24		
	47	183.06	0.24		
80-90	48	183.06	0.24	1.24	8.06
	49	188.61	0.28		
	50	166.6	0.2		
	51	183.86	0.28		
	52	169.7	0.24		
90-100	53	175.49	0.24	1.24	8.06
	54	169.5	0.24		
	55	170.12	0.28		
	56	170.9	0.24		
	57	172.89	0.24		

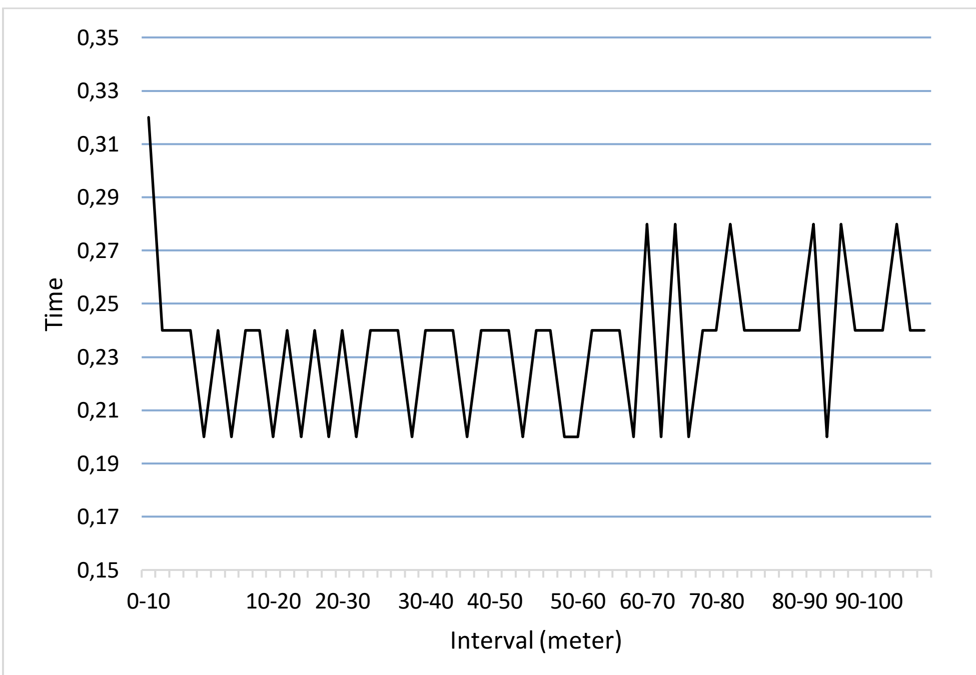

Figure 2. Distance movement against HTY athlete's step time.

In Figure 2, it is shown that HTY runners get a number of 57 steps and the time per step at meters 0-10 decreases in step time, then at 10-70 meters the step time is stable. At 70 – 100 there is a steady increase in step time.

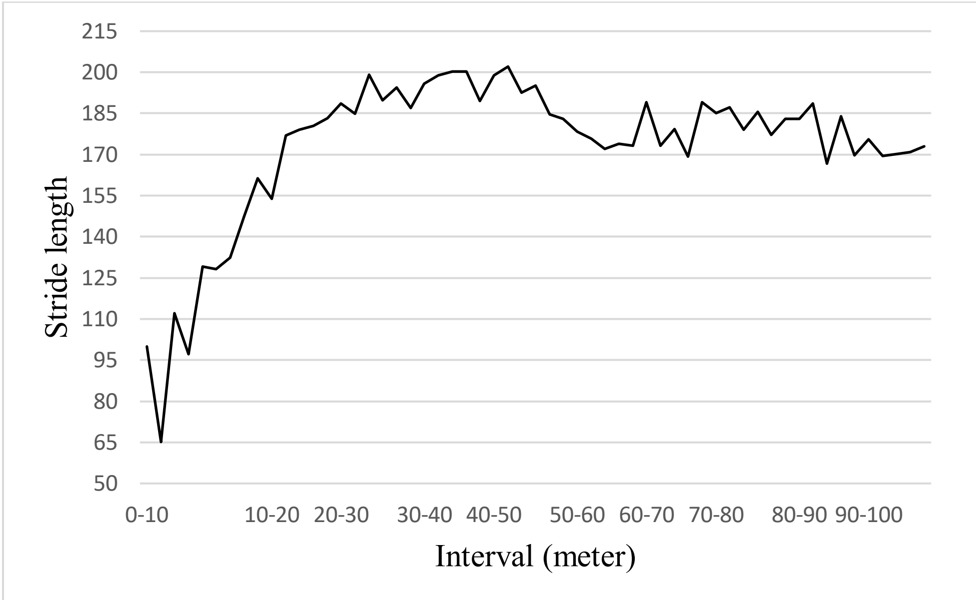

Figure 3. Distance movement graph against stride length of HTY athletes.

In Figure 3, it is shown that HTY runners get a number of 57 steps and the stride length per step at 0-3 meters decreases in stride length, then at 4-50 meters the stride length increases steadily. At 50 – 100 there is an irregular change in stride length.

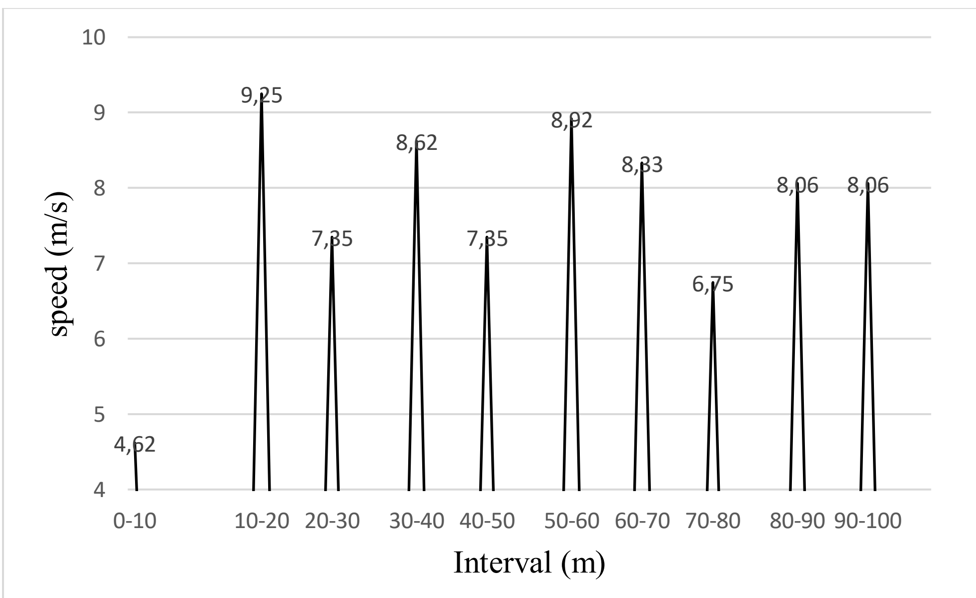

Figure 4. Speed per 10 meters.

In Figure 4, it is the speed per 100 meters. At 0-10 meters it gets a speed of 4.62 m/s, then it increases at 10-20 meters with an increase in speed of 9.25 m/s, at the 20-30 meters it decreases at 7.35 m/s, at the 30-40 meters it increases the speed at 8.62 m/s, at the 40-50 meters it decreases again at 7.35 m/s, at the 50-60 meters it increases the speed at 8.29 m/s, at the 60th-70th meter there was a decrease in speed at 8.33

m/s, the decrease in speed again at 70-80 meters at 6.75 m/s, then at the 80-90th meter it increased at 8.06 m/s and stabilized until the 100th meter.

DISCUSSION

Based on the results of the research that has been obtained, HTY athletes have performed a 100-meter running movement with a record time of 13.24 seconds with a total of 57 steps, average stride length or stride length of 172.8489 cm, minimum stride length or stride length 65.14 cm, maximum stride length or stride length 202.08 cm, average stride time 0.2351 seconds, minimum stride time 0.20 seconds, maximum stride time 0.32 sec. At a speed per 10 meters that experienced an unstable decline and increase. The top speed is located at 10-20 meters. With these results, based on the results of the movement analysis obtained, namely side length and stride frequency have a great influence on the speed and time record obtained by the runner. The results of this study are in line with the theory from (Al Ardha et al., 2022) in their research, namely the analysis of running kinematics in the world's female sprinters at the 2022 Tokyo Olympics that stride frequency can determine the time record of runners. Stride frequency and stride frequency are closely related to stride length. Supported by the theory from (Sugiura et al., 2021) that the sprinters to press the foot to the ground as quickly as possible to increase the frequency of the step and prevent too long steps. Supported by the theory of (de Ruiter et al., 2014) trained runners choose a near-optimal step frequency for energy expenditure and heart rate can be used to set the optimal step frequency. Research from (Paruzel-dyja et al., 2006) revealed that stride frequency determines the results achieved by elite female sprinters, while stride length is the most important step parameter for sprinters and the greater the mass and height, the more stride length is taken and the lower the stride frequency of the runner. In the research (Batra et al., 2021) stated that the ability to produce energy quickly has the potential to directly affect sprint performance through changes in stride length and stride frequency. So it can be said that the lower the more steps and the shorter the steps, the better.

The right foot and left foot are not balanced with evidence that the stride time of HTY athletes on the right foot takes a long time when compared to the left foot. So that the strongest leg of HTY athletes is the right foot. This is in line with research from (Sudhakar et al., 2018) Short-distance runners should have a balance between the right foot and the left foot to support performance when running. It is also supported by research from (Wessbecher & Ahn, 2019) that runners who have balanced legs will support movement when running. Supported again by (Karamanidis & Arampatzis, 2007) that the best time of a runner is supported by a balanced right foot and left foot. So HTY athletes need to add strength training on the right leg so that the balance of the right and left legs is good.

In anthropometry, HTY athletes have a height of 154 cm, and a body weight of 52.7 kg. so that the results of the time records obtained by HTY athletes are influenced by their anthropometry. This is supported by research from (Maćkała & Mero, 2013) researching the world's best athlete, Usain Bolt at the 2008 Beijing Olympics with anthropometric results from Usain Bolt being 196 cm tall and weighing 90 kg resulting in a time of 9.69 seconds. The time record supports the running performance of the Usain Bolt with his best time. With the height of the high Usain Bolt will support the range of stride frequency and the number of stride lengths. So anthropometry will greatly affect the time record when running.

CONCLUSSION

The anthropometry possessed by HTY athletes cannot be a problem that needs to be fixed because the age of HTY athletes is not in the growth period. So that the time record that is felt to be less than HTY athletes that needs to be emphasized is technique when running. This is because the stride length and stride frequency of HTY athletes which totalled 57 steps and the average stride length was 172.84 cm. There needs to be a good combination of stride length and stride frequency to get the best time record. This ability needs to be combined with longer strides, allowing him to achieve very high running speeds. Therefore, it is worth noting that the main focus should be on the optimal interaction between stride frequency and stride length. This data can be important for practitioners to identify possible weaknesses and refine training methods for sprinters and other athletes whose performance depends on movement speed initiation. HTY athletes can use the results of movement analysis in this study to improve their performance.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Mochamad Ridwan contributed to conceptualisation, investigation, writing original draft, writing review & editing, and supervision. Ainun Zulfikar Rizki contributed to conceptualisation, formal analysis, and writing original draft. Vega Candra Dinata contributed to methodology, investigation, and writing review & editing. Novadri Ayubi contributed to methodology, data curation, and writing review & editing. Shoira Kubaeva contributed to formal analysis, data curation, writing review & editing, and supervision. All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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