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Identification of Step-Length and Step-Frequency : Determining Factors of 100m Sprinting Performance At Junior Level Athlete

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Abstract

This study aims to identify the variability of stride length and stride frequency of junior-level 100 m sprinters with different performance levels and to verify the kinematics parameters of the phases of sprinting. Data were collected from a sample of 9 junior sprinter athletes determined by purposeful sampling. The analysis results show that the average number of steps for 100 m is 52.8. For the variable stride length, the average is 1.88 m. The step frequency variable shows an average of 4.77 steps/second (max step frequency). During the acceleration phase, the average stride frequency is 4.48 steps/second. The score in the last phase, i.e., the sprinters must maintain their velocity until the end of the race from a distance of 60 – 100 m, shows an average rate of 4.07 steps/second. The average sprinting time of the sprinters is 11.74 seconds, and the average speed of the sprinters is 8.54 ms-1, with a top speed of 8.95 ms-1 and the lowest speed of 7.99 ms-1. Based on the analysis of kinematic parameters, the different phase structures. The results show that stride length significantly contributes to the 100 m sprint performance than stride frequency, which is no longer considered the most critical determinant of performance at junior-level athletes.

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INTRODUCTION

The 100m sprint number can be divided into three phases: block start with acceleration, maximum speed, and deceleration (Ae et al., 1992; Shen, 2000; Wibowo et al., 2017). The duration and more in-depth details of each phase depend primarily on the level of a sprinter's ability (Smirniotou et al., 2008; Maćkała & Mero, 2013; Coh & Mackala, 2013). The acceleration phase can be further divided into several sub-phases, including initial acceleration (0-12 m) characterized by a constant increase in stride length and major acceleration (12-35 m) (Maćkała et al.,2015). When the acceleration phase has an optimal sprinting velocity, the sprinter can no longer maintain the maximum velocity, and the deceleration phase will last for a long time. Elite sprinters gain a maximum speed between 50 m and 70 m on average (Gajer et al., 1999; Čoh., 2019) and can maintain it for another 20 m, although it is scarce to maintain it for 30 m. Therefore, the third transitional subphase (35–60 m) occurs only at the elite runner level. This condition lasts until the sprinter reaches its maximum running speed level. In this phase, the sprinter reaches maximum stride length, stride frequency, and maximum velocity. Decelerations are only marked in the last 10 m of 100 m sprinting (Maćkała & Mero, 2013; Maćkała et al.,2015). At the start of a sprint, the ability to generate high concentric forces is primarily used to generate high speed during the sprint acceleration phase (Bissas & Havenetidis, 2008)

There is a relationship between stride length and stride frequency to maximize sprinting velocity in each phase carried out by athletes from different sports (Akira et al., 2007; Maćkała & Mero, 2013; Salo et al., 2011; Gleadhill & Nagahara, 2021) and even by untrained athletes (Babić et al., 2011; Chatzilazaridis et al., 2012) which has not been widely studied. Therefore, comparing the stride frequency and length characteristics of each phase expressed to sprint performance would be interesting. It is also essential to determine the relationship between the kinematic variables of various acceleration phases and the overall 100 m sprint performance among sprinters of different sprinting abilities. Furthermore, this comparison will provide information regarding the efficiency of the acceleration phase. The study's results are expected to provide a general concept of the interaction between stride length and stride frequency during the 100 m sprint for the overall sprint performance and its phases. Some studies have claimed that stride length is the most significant variable in maximal speed development (Salo et al., 2011). Other studies stated that the important variable is stride frequency (Mero et al., 1992). The new problem of most current research concerns the analysis of the interaction between stride length and stride frequency to maximize sprint speed at various sprint phases (Maćkała & Mero, 2013).

The importance of stride length and stride frequency on the 100-meter sprint speed curve is well documented in various research on sprints (Gajer et al., 1999; Majumdar & Robergs, 2011; Gleadhill & Nagahara, 2021). However, it is not yet clear how these kinematic parameters affect the different phases of the 100 m sprint. Not much is known about how sprinters adjust their stride pattern during the acceleration, maximum speed, and deceleration phases to achieve optimal sprinting efficiency. An important issue is related to whether the structure of the phases is the same for each 100 m sprint with different sprint performance levels. This issue is an essential theme for study because this information will provide an understanding of sprinting biomechanics and the basis for developing training protocols explicitly designed for sprint athletes. This study aimed to identify the prominent kinematics parameter variability among 100 m junior sprinters with different performance levels and technical quality. The data obtained were collected and compared to understand the relationship between stride length and stride frequency, then sprinting speed. In order to describe the sprinting performance, it was necessary to observe changes in speed and estimate the proportional effect of stride length and stride frequency by measuring the two variables.

METHODS

Participants

The subjects of this study consisted of 9 male junior sprint athletes from West Java (mean: age = 17.3 years, height = 173.9 cm, weight = 57kg, best result = 11.17 seconds) chosen purposively. These data show that the performance level of the sprinters can be considered junior-level sprinters. Data collection was carried out at an international standard synthetic track stadium.

Instrument and Procedure

Data were obtained from three trial recordings of each individual using 3 video cameras. A starter gun synchronized the camera. The markers, the calibration poles, with a length of 1 m (reference point), were placed horizontally in each 10 m section which was used as a reference to quantify the stride length on the computer. For each sprinter, the number of steps was counted, and the length of each step was measured to calculate the average stride length. The stride frequency for each sprint was calculated from the computer by measuring the displacement of 100 m sprinters divided by the time taken. The tools used consisted of a Sony ZR 70 MC type video camera, with a speed of 25 fps and a shutter speed of 1/1000 sec, placed perpendicularly 20 m from the subject plane of motion, thus providing a more accurate two dimension analytical view. Data analysis used Dartfish 2.5 professional software version 2.4.15.3.

These variables, among others, could be identified in several phases of sprinting: stride length, step frequency, sprinting speed, and travel time of each phase. In this study, the factor that remarkably determined the quality of the analysis results was highly dependent on the quality of the biomechanics knowledge possessed by the researcher.

RESULT & DISCUSSION

Measurement of stride length and stride frequency

Sprint mechanics analysis explains the analysis of sprint techniques, including stride length, stride frequency, sprinting speed, and arm and leg motion (Gleadhill & Nagahara, 2021). Therefore, it is necessary to know the stride length data and frequency first. In another section, technical analysis of film data taken from the field will be presented. Observation of the image would lead to identifying errors and compatibility

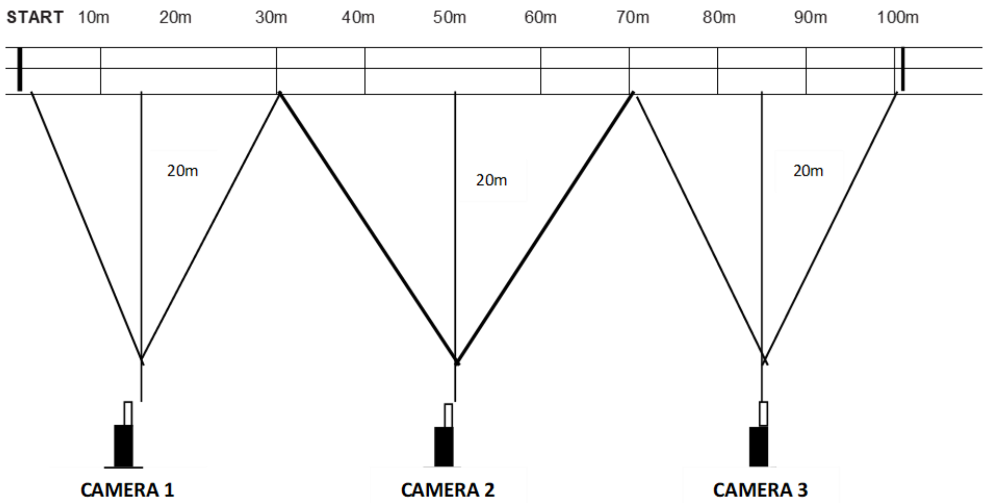

Figure 1. Camera Setting Configuration

To obtain accurate film data retrieval, the camera was set in a stationary position using a panning technique and a tripod. The camera was placed as far as possible (minimizing perspective error). The plane of motion was perpendicular to the camera's optical axis. Several kinematic variables were determined for each sprinter, which can be identified with the computer software used to determine the sprint performance.

among the subject image, the model image, and the coaching point of the sprint analysis taken from the IAAF. The followings are data on the length and frequency of steps determined from the measurement results in the field. Measurements were made mainly when the sprinter was in three phases, namely the acceleration phase (0 – 30 m), the maximum speed phase (30 – 60 m), and the speed maintenance phase (60 – 100 m). However, an analysis of changes in stride length and frequency was also carried out for every 10 m distance.

largest number for this step frequency was 4.63 steps/sec, while the smallest number was 4.30 steps/sec. During the acceleration phase, a sprinter's acceleration

Table 1. Stride length and stride frequency at a certain distance

	S1	S2	S3	S4	S5	S6	S7	S8	S9	Distance
Stride frequency (max)	4,30	4,30	4,63	4,62	4,56	4,31	4,38	4,48	4,14	30-60m
Stride frequency (min)	3,91	4,11	4,44	3,86	4,16	4,56	4,04	4,31	4,81	0-30m
Stride frequency	3,69	4,16	4,16	4,41	4,34	3,99	3,72	3,60	4,98	60-100m
Stride length (mean)	2,25	2,10	2,02	2,06	2,02	1,83	1,98	1,98	1,73	0-100m
No. of stride	44	47	49	48	49	54	50	50	57	

Table 2. Parameters of 100 m sprint time

N	Time (sec)	Distance (m) 10	20	30	40	50	60	70	80	90	100	Speed (m-1)
S1	Time	2,01	3,05	4,05	5,15	6,20	7,07	8,12	9,15	10,23	11,17	8,95
	Interval	2,01	1,04	1,00	1,10	1,05	0,87	1,05	1,03	1,08	0,94	
S2	Time	2,10	3,17	4,13	5,18	6,25	7,15	8,23	9,27	10,32	11,23	8,90
	Interval	2,10	1,07	0,96	1,05	1,07	0,90	1,08	1,04	1,05	0,91	
S3	Time	2,03	3,07	4,09	5,17	6,23	7,11	8,14	9,14	10,25	11,17	8,95
	Interval	2,03	1,04	1,02	1,08	1,06	0,88	1,03	1,00	1,11	0,92	
S4	Time	2,12	3,10	4,14	5,17	6,15	7,17	8,25	9,30	10,34	11,25	8,89
	Interval	2,12	0,98	1,04	1,03	0,98	1,02	1,08	1,05	1,04	0,91	
S5	Time	2,10	3,05	4,08	5,15	6,12	7,15	8,27	9,35	10,40	11,29	8,86
	Interval	2,10	0,95	1,03	1,07	0,97	1,03	1,12	1,08	1,05	0,89	
S6	Time	2,25	3,15	4,16	5,20	6,24	7,29	8,50	10,15	11,26	12,30	8,13
	Interval	2,25	0,90	1,01	1,04	1,04	1,05	1,21	1,65	1,11	1,04	
S7	Time	2,27	3,20	4,22	5,10	6,10	7,41	8,87	10,01	11,12	12,51	7,99
	Interval	2,27	0,93	1,03	0,88	1,00	1,31	1,36	1,14	1,11	1,39	
S8	Time	2,24	3,14	4,17	5,10	6,22	7,29	8,78	10,15	11,27	12,29	8,14
	Interval	2,24	0,90	1,03	0,93	1,12	1,07	1,49	1,37	1,12	1,02	
S9	Time	2,20	3,12	4,15	5,09	6,01	7,26	8,89	10,03	11,10	12,49	8,01
	Interval	2,20	0,92	1,03	0,94	0,92	1,25	1,63	1,14	1,07	1,39	
Mean											11,74	8,54

Table 1 shows that each subject's stride length and frequency varied. The average number of steps for a 100 m run was 47.7 steps. The largest number of steps was 49, while the smallest was 44. The average stride length variable was 2.09 m. The largest stride length was 2.25 m, while the smallest was 2.02 m. The average number of step frequency variables was 4.48 steps/sec (stride frequency max) achieved when the runner was at a 30-60 m distance (Maximum velocity). The when sprinting at a 0 – 30 m distance, the average stride frequency was 4.09 steps/sec. The largest gain was 4.44 steps/sec, while the smallest gain was 3.86 steps/sec. In the last phase, where sprinters must maintain their speed (speed maintenance phase) to the end of the race from a 60 – 100 m distance, the average number was 4.15 steps/sec. The largest gain was 4.41 steps/sec, while the smallest gain was 3.69 steps/sec.

Table 2 describes the travel time and time interval data for every 10 m and 100 m distance and the calculation of the average speed value taken by the subject. The data in Table 2 show the changes in time produced by each runner for every 10 m distance during a 100 m sprint. The sprinter data show that the consistent time interval was not too large. The average time the sprinter reached during the acceleration phase (0-30 m) was 4.09 sec. The largest gain was 4.14 s, while the smallest was 4.05 s. The average time achieved during the second phase, when the runner runs at a maximum speed (30-60 m), was 7.13 seconds, with the largest gain of 7.17 seconds and the smallest gain of 7.07 seconds. Overall, the sprinter's average time to cover a 100 m distance was 11.22 sec, the highest score was 11.29 sec, and the smallest score was 11.17 sec.

stride frequency to the 100 m sprint performance.

Acceleration Phase

At the first 20 m distance, the group of subjects showed a varied increase in sprinting speed (up to 10.42 ms-1) as the result of an intensive increase in stride length and stride frequency. In the second 10 m distance segment, the average speed increased by 80% or 5.75 ms-1 from the first 10 m segment. The stride frequency increased by 5.1% to 4.11 steps per second and the stride length increased by 1,27% to reach a 175.7 cm gain. The increase in stride frequency was constant over a 20 m distance. This finding is in line with previous studies where the average step frequency is 4.20 steps per second during the first three steps and then

Table 3. Comparison of the average score of certain parameters for each 10m distance and phases in 100m

Phase	Distance (m)	Average Time (sec)	Total	Average Speed (m/sec)	X	Stride Length (cm)	X	Stride Frequency (step/sec)	X
1	0-10 10-20	2,14 0,96	3,10	4,67 10,42	7,54	173,5 175,7	174,6	3,91 4,11	4,01
2	20-30 30-40	1,01 1,04	2,05	9,90 9,62	9,76	182,4 182,6	182,5	4,44 3,86	4,15
3	40-50 50-60	1,05 1,01	2,06	9,52 9.90	9,71	192,3 194,6	193,45	4,30 4,48	4,39
4	60-70 70-80	1,21 1,16	2,37	8,26 8,62	8,44	198,75 197,56	198,16	4,41 4,34	4,38
5	80-90 90-100	1,01 1,05	2,06	9,90 9,52	9,71	198,75 199,65	199,2	4,16 4,04	4,10

Furthermore, Table 3 compares the average score of certain parameters for each 10 m distance segment produced by each sprinter for each phase during a 100 m sprint. The data in Table 3 show that the difference in the temporal development of stride length and stride frequency is clearly visible in all sprinters. Parameters are characterized by a lot of variability during the sprint run. This picture can be seen clearly when the running distance is divided into 10 m sections. The analysis results of other studies on parameter changes and comparisons of running speed show that the phase structure for 100 meters is more complex than the standard three-phase acceleration model, maximum speed, and deceleration (Gajer et al., 1999)

The next discussion focuses on the analysis of the acceleration phase, maximum speed, and deceleration as the contribution identification of stride length and

increases to 4.48 steps until the end of the 40 m distance (an increase of 0.28 steps/second) (Korchemny, 1985; Krzysztof & Mero, 2013; Maćkała & Kowalski, 2015). In this study, the sprinters achieved a stride frequency of 4.11 in their first three strides.

In this study, the sprinter achieved the same stride speed of 4.08 steps per second in the first three strides. In general, there was no dynamic difference in the sprinter's acceleration during the first two 10 m distances. Both step frequencies were the main kinematic variables that had an impact on increasing sprinting speed. For a 20 m distance, it can be referred to as the initial acceleration phase. During two 10 m sections, between 20 m and 40 m, acceleration continued; the average speed was 2.22 ms-1, (29%) greater than the first 20 m. Unlike the first 20 m, the acceleration here was the result of the increased stride length.

Overall, the sprinter increased the stride length by more than 80% from 173 cm (first stride average) to 210 cm (last stride average at 40 m). Similar results had been found previously in Radford's 1990 study, where stride length increased by more than 100% at a 45 m distance (from 109 cm to 244 cm). The significant change in stride length in this phase appeared to be due to an increase in overall speed, which allowed the sprinter to cover more space during the stride phase when hovering in the air (Aki, 1993). The different variability of the kinematic parameters at a 20 – 40 m distance determined the difference from the first phase, and it could be considered as the acceleration extension phase (extended acceleration phase).

The varying differences in kinematic parameters between subjects for distance segments between 40 m and 80 m were significant, and two distinct phase structures could be identified. For the subject group, the two 10 m sections, between 40 m and 60 m, became the sections when the peak velocity was obtained. Thus it was called the maximum velocity phase. This phase was crucial, especially for the last time. In this phase, the sprinting speed increased, but slower (increase by 1.5%), compared to the previous phase. This increase was mainly due to a 2.5% increase in stride length, as the stride frequency was almost constant. Two 10 m sections, between 60 m and 80 m, might also be considered as part of the maximum velocity phase for this subject group. However, in reality, there was a slight decrease in the average velocity by 0.14 ms-1 (1.3%) from the previous 10 m to the final phase velocity (9.40 ms-1), which was caused by the decrease in stride length and stride frequency, respectively 0.3% and 0.15%. In other words, in this phase, the sprinters were not at their maximum speed but were quite close to this phase. Distinguishing these two 20 m phases was named the velocity maintenance phase..

Deceleration phase

As stated above, between 60 m and 80 m, runners slowed down from their maximum speed due to a slight decrease in stride frequency and stride length. It continued in the last two 10 m sections, called the deceleration phase. At a 90 m distance, the speed decreased by about 1.3% (0.11 ms-1). In the last 10 m, it continued to decrease by 0.42% (0 .03 ms-1). In contrast to the previous phase, the slowdown in this phase was mainly due to a significant decrease in stride frequency, as the average stride length actually showed an increase in its value. As we know, running speed is the product of stride length and stride frequency (v = l x f). Thus, an increase in average speed (v) and a decrease in running time (t) for a given distance can only result from changes in these two parameters: an increase in stride length (with a decrease in the number of steps and their frequency) or inversely the decrease in stride length (with increasing stride speed). The decrease in running speed occurred in five phases. Moreover, the two phases showed only an increase in stride length. In two cases, an increase in stride frequency was more dominant than an increase in stride length. In one phase, the decrease in speed was caused by a decrease in both parameters.

CONCLUSION

The results of this study indicate that the speed dynamics of 100-meter sprinting describing changes in speed during a sprint must be analyzed through speed changes in each phase. The description of increasing or decreasing speed is vital for training, practical understanding of sprinting performance, evaluation of each step technique, optimal diagnosis of sprint ability, and development of an effective race strategy. Effective speed depends on the optimal change of the various phases caused by changes in the main kinematic parameters, namely stride length, and stride frequency. The stride length, especially the maintenance of its optimal length for the longest distance, is a crucial element for technical efficiency and optimization of performance in the 100-meter sprint. The increase in stride length must be directly proportional to the decrease in stride frequency, especially in the initial acceleration phase. Since sprint speed is a function of stride length and frequency, it is important to find the optimal balance (ratio) between these two factors and not try to manipulate any of the variables as they are bound intentionally.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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