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Optimisation of performance through kinematic analysis of the different phases of the 100 metres

By Krzysztof Maćkala

ABSTRACT

The aim of this study was to investigate the variability of stride length and stride frequency between athletes of different performance levels in the 100m and then verify the influence of these kinematic parameters on the phases of the race and technical efficiency. Data from a group of 8 average male sprinters (mean performance 11.18) and the men's 100m finalists in 1991 IAAF World Championships in Athletics were compared. Based on statistical analysis of the kinematic parameters, the author identifies different phase structures for the races of the two groups. The results suggest that stride length contributes much more to the velocity curve of the 100m than stride frequency, which can no longer be considered the most important performance-determining factor in either average- or high- level performers.

AUTHOR

Krzysztof Maćkala, Ph.D., currently works a Lecturer in the Department of Track and Field at the University School of Physical Education in Wroclaw, Poland. He has been a sprints and hurdles coach for more than 15 years and has worked with athletes in Poland, Canada and at University of Montana in the USA.

Introduction

The importance of stride length and stride frequency to the velocity curve of the 100 metres is well documented in the sport science literature (MURASE et al., 1976; VOLKOV and LAPIN, 1979; MANN AND HERMAN, 1985; BRÜGGEMANN and SUSANKA, 1988; MORAVEC et al., 1988; BRÜGGEMANN and GLAD, 1990; GAJER et al., 1999; FERRO et al., 2001). However, it is not clear how these kinematic parameters affect the different phases of a sprint race. Little is known about how sprinters manipulate their stride patterns during the phases of acceleration, maximum velocity, and deceleration to reach optimal efficiency. Moreover, there is

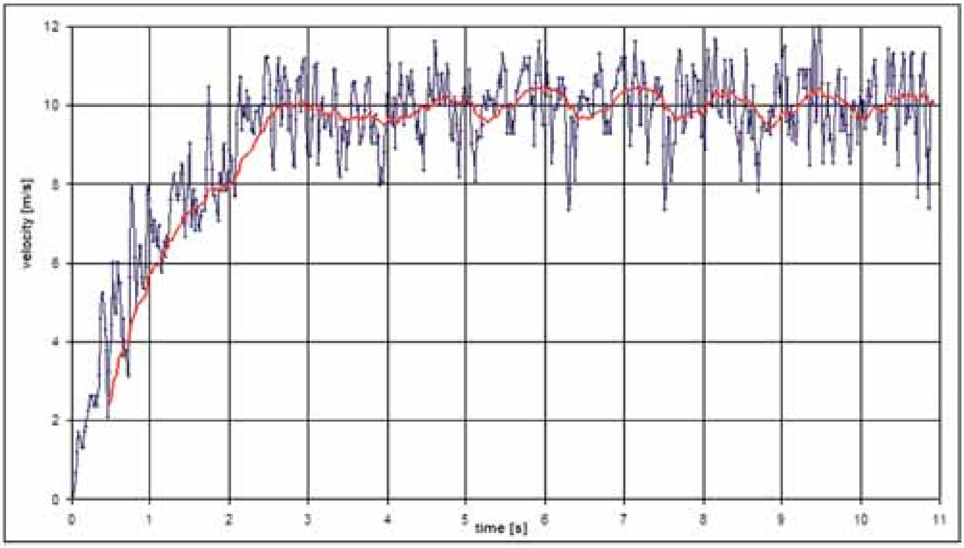

Figure 1: Example of velocity curve (instantaneous speed) based on time measurement (0.02 sec intervals) for an average sprinter (10.78) (MAĆKALA, 2004)

the question as to whether the phase structure of the 100 metres is the same for athletes of different levels of performance.

This is an important theme for research as information in this area will promote the understanding of the biomechanics of sprinting and provide a basis for developing training protocols that are specifically designed for individual athletes.

The purpose of this study was to determine the relevance of the variability of the main kinematic parameters between athletes of different performance levels in the 100 metres and then verify their influence on the phases of the race and technical efficiency.

Data obtained for a group of “average” sprinters was collected and compared with published data for elite sprinters to understand the relationships between stride length and frequency, and then running velocity, and to determine the phase structure for each group. To draw conclusions and make recommendations it was necessary to observe the changes in velocity and estimate the proportionate effects of stride length and stride frequency by measuring both variables and computing their influence using appropriate statistics.

Methods

Eight male sprinters (average values: age = 21.3 years, height = 179.9cm, weight = 74kg, 100m performance = 11.18 with best result = 10.78sec) make up Group A. From their performance level, these sprinters can be considered national- or average-level performers.

The data for the analysis of Group A were obtained from recordings of eight individual time trials made with 10 video cameras (operating at 50 frames/sec). The cameras were synchronised with the starter’s gun. The cameras were placed perpendicular to the running direction on special tripods at 10m intervals along the track. Markers were placed at each 10m section to allow interval times to be calculated by counting the

Table1: Mean of selected parameters for 10m sections of the finalists in the men's 100 metres at the 1991 IAAF World Championships in Athletics (Data from AE, ITO and SUZUKI, 1992)

Place	Name	Variables	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
1	Lewis (USA)	Stride Frequency	3.83	4.81	4.45	4.41	4.66	4.86	4.76	4.45	4.34	4.53
		Stride length	1.39	1.92	2.44	2.55	2.56	2.42	2.50	2.71	2.65	2.57
		Time	1.88	2.96	3.88	4.77	5.61	6.46	7.30	8.13	9.00	9.86
		Velocity	5.31	9.26	10.87	11.24	11.90	11.76	11.90	12.05	11.49	11.63
2	Burrell (USA)	Stride Frequency	3.59	4.81	4.61	4.43	4.41	4.50	4.57	4.50	4.34	4.23
		Stride length	1.52	1.96	2.38	2.57	2.61	2.58	2.52	2.64	2.59	2.71
		Time	1.83	2.89	3.80	4.68	5.55	6.41	7.28	8.12	9.01	9.88
		Velocity	5.46	9.43	10.99	11.36	11.49	11.63	11.49	11.90	11.24	11.49
3	Mitchell (USA)	Stride Frequency	4.28	4.96	4.61	4.70	4.92	4.94	4.74	4.60	4.67	4.61
		Stride length	1.30	1.88	2.33	2.42	2.34	2.33	2.46	2.53	2.43	2.44
		Time	1.80	2.87	3.80	4.68	5.55	6.42	7.28	8.14	9.04	9.92
		Velocity	5.56	9.35	10.75	11.36	11.49	11.49	11.63	11.63	11.36	11.24
4	Christie (GBR)	Stride Frequency	3.89	4.95	4.65	4.48	4.54	4.72	4.84	4.75	4.44	4.20
		Stride length	1.39	1.91	2.34	2.51	2.59	2.46	2.40	2.48	2.50	2.71
		Time	1.85	2.91	3.83	4.72	5.57	6.43	7.29	8.14	9.04	9.92
		Velocity	5.41	9.43	10.87	11.24	11.76	11.63	11.63	11.76	11.11	11.36
5	Fredericks (NAM)	Stride Frequency	4.31	4.36	4.61	4.59	4.91	5.02	4.96	4.80	4.66	4.37
		Stride length	1.25	1.94	2.36	2.39	2.34	2.29	2.35	2.45	2.41	250
		Time	1.86	2.92	3.84	4.73	5.60	6.47	7.33	8.18	9.07	9.95
		Velocity	5.38	9.43	10.87	11.24	11.49	11.49	11.63	11.76	11.24	11.36
6	Steward (JAM)	Stride Frequency	3.37	5.02	4.85	4.79	4.90	4.97	4.83	4.55	4.58	4.73
		Stride length	1.43	1.86	2.27	2.35	2.38	2.31	2.35	2.52	2.43	2.35
		Time	1.81	2.88	3.79	4.68	5.54	6.41	7.29	8.16	9.06	9.96
		Velocity	5.52	9.35	10.99	11.24	11.63	11.49	11.36	11.49	11.11	11.11
7	da Silva (BRA)	Stride Frequency	3.96	4.91	4.49	4.27	4.36	4.61	4.73	4.69	4.36	4.16
		Stride length	1.32	1.92	2.40	2.63	2.60	2.44	2.35	2.45	2.55	2.57
		Time	1.91	2.97	3.90	4.79	5.67	6.56	7.5	8.32	9.22	10.12
		Velocity	5.24	9.43	10.75	11.24	11.36	11.24	11.24	11.49	11.11	11.11
8	Surin (CAN)	Stride Frequency	3.98	4.32	4.52	4.49	4.67	4.75	4.54	4.23	4.21	4.27
		Stride length	1.34	1.94	2.41	2.48	2.41	2.34	2.50	2.72	2.61	2.55
		Time	1.88	2.95	3.87	4.77	5.66	6.56	7.44	8.31	9.22	10.14
		Velocity	5.31	9.20	10.87	11.11	11.24	11.11	11.36	11.49	10.99	10.87

frames in the video. For each athlete, the number of strides was counted and length of each stride measured in order to calculate the average stride length and stride frequency for each section. The methodology was similar (less three cameras) to that applied during finals of the 100 metres at the 1997 IAAF World Championships in Athletics in Athens (BRÜGGEMANN, KOSZEWSKI and MÜLLER, 1999). The instantaneous running velocity of the sprinters was calculated from the video by measuring the displacement of the centre of mass for each 0.02sec (see Figure 1). Kinematics analysis was performed using the SIMI Motion Biomechanical Computer Program.

Table 2: Comparison of the mean values for selected parameters of 10m sections and phase breakdown in the 100 metres for average sprinters (Group A) (MAĆKALA, 2004)

	Group A (n=8)								
Phase	Distance [m]	Average Time [s]	Total	Average velocity [m/s]	X	Stride length [cm]	X	Stride frequency [Hz]	X
1	0-10 10-20	1.850 1.077	2.927	5.41 9.29	7.35	147.8 211.4	179.6	3.670 4.400	4.035
2	20-30 30-40	1.067 1.045	2.112	9.38 9.58	9.48	219.2 218.9	219.0	4.244 4.374	4.309
3	40-50 50-60	1.037 1.037	2.074	9.65 9.66	9.65	223.5 226.5	225.0	4.321 4.266	4.293
4	60-70 70-80	1.052 1.055	2.107	9.51 9.49	9.50	224.9 223.8	224.3	4.242 4.246	4.244
5	80-90 90-100	1.067 1.075	2.142	9.38 9.34	9.36	224.8 232.6	227.0	4.177 4.070	4.123

Table 3: Comparison of the mean values for selected parameters of 10m sections and phase breakdown in the 100 metres for elite sprinters (Group B) (data from AE, ITO and SUZUKI, 1992)

	Group B (n=8)								
Phase	Distance [m]	Average Time [s]	Total	Average velocity [m/s]	X	Stride length [cm]	X	Stride frequency [Hz]	X
1	0-10 10-20	1.82 1.07	2.89	5.39 9.38	7.38	137.0 192.0	164.0	3.85 4.77	4.31
2	20-30 30-40	0.92 0.89	1.81	10.87 11.25	11.06	237.0 249.0	243.0	4.60 4.52	4.56
3	40-50	0.866	0.87	11.55	11.55	248.0	248.0	4.67	4.67
4	50-60	0.871	0.87	11.48	11.48	240.0	240.0	4.80	4.80
5	60-70	0.867	8.87	11.53	11.53	243.0	243.0	4.75	4.75
6	70-80	0.85	0.85	11.70	11.70	256.0	256.0	4.57	4.57
7	80-90 90-100	0.89 0.887	1.78	11.21 11.24	11.22	252.0 255.0	253.5	4.44 4.40	4.421

Group B comprised the eight finalists in the men's 100 metres at the 1991 IAAF World Championships in Athletics in Tokyo. From their performance level, these sprinters are clearly international or elite-level performers. The raw data for the race (see Table 1) was obtained from AE, ITO and SUZUKI (1992) and then processed by the author.

Results and discussion

The results of the study show that differences in the temporal development of stride length and stride frequency are evident for the sprinters in both groups. The two parameters are characterised in most cases by high variability over the course of the race. This can be seen particularly well when the distance is divided into 10m sections and analysed. Analysis of the changes in these parameters and comparison to the running velocity also reveals that the phase structure for the 100 metres is more complex than the standard three-phase model of acceleration, maximum velocity and deceleration (DICK, 1987; RADFORD, 1990; GAJER, 1999; BRÜGGEMANN and SUSANKA, 1988) and differs between sprinters depending on the performance level. Table 2 shows the relevant data and a five-phase structure for Group A and Table 3 shows the same data and a seven-phase structure for Group B.

Acceleration phases

In the first 20m of the race, both groups showed a dynamic increase in running velocity (up to 9.29m/s for Group A and 9.38m/s for Group B) that was the result of intensive increases to both stride length and stride frequency. In the second 10m, the mean velocity of Group A increased about 70% or 3.88m/s^{-1} over the first 10m, the stride frequency increased about 20% to 4.40 strides per second (Hz) and the stride length increased about 43% to reach a value of 211.4cm. In this section, the mean velocity of Group B increased 3.99m/s^{-1} (74%) and the stride length increased 40% to 192cm.

In both groups, the rate of the increase in stride frequency was fairly constant over the 20m (slightly greater in first 10m, slightly less in second 10m). This finding confirms KORCHEMNY (1985) and ATWATER (1982), where stride frequency was on average 4.20Hz over the first three strides and then increased to 4.48HZ at the end of 40m (increase of 0.28Hz). In the present study, the Group A sprinters reached a stride rate equal 4.08Hz in the first three strides.

In general terms, no differences were found between dynamics of the acceleration in the two groups in the first two 10m sections and for both the stride frequency was the main kinematic variable that had an impact on the increase of running velocity. For both groups this 20m could be called the "Initial Acceleration" Phase.

Over the two 10m sections between 20 and 40m, acceleration continued; the mean velocity for Group A was 2.13m/s^{-1} (29%) greater than the first 20m while group B's mean velocity increased by 3.68m/s^{-1} (49 %). In contrast with the first 20m, the acceleration here was the result of a distinct increase in stride length, which for Group A was as much as 48.2% (compared to the increase in mean stride frequency of 6.8%). Overall, Group A increased its stride length more than 90% from 117cm (average of first step) to 229cm (average of last step at 40m) (author's data). By end of this phase, the mean stride length for Group B reached a value of 249cm, (48%) of the maximum average value achieved in the race. Similar results have been found previously: in RADFORD's 1990 study, stride length increased by over 100% by 45m of the race (from 109cm to 244cm). The significant change to the stride length in this phase is apparently due to the increased overall velocity, which enables the sprinter to cover more space during the air-borne phases of the strides (SCHMOLINSKY, 1993).

For both groups, the different dynamics of the kinematic parameters in the 20-40m segment warrant its distinction from the first phase and it could be called the "Extended Acceleration" Phase.

Mid-race phases – Group A

The differences in the dynamics of the kinematic parameters between the two groups for the segments between 40m and 80m are significant enough that two different phase structures can be identified.

For Group A, the two 10m sections between 40m and 60m are when the peak velocity was obtained and thus can be called the "Maximum Velocity" Phase. This phase is crucial to the final time. In this part of the race, the running velocity increased but at a slower rate (increase 1.7%) compared to the previous phase. This increase was mainly due to a 2.7% increase in stride length, as stride frequency remained almost constant (increase 0.004Hz).

The two 10m sections between 60 and 80m might also be considered to be part of the Maximum Velocity Phase for this group. However, there was, in fact, a slight decrease in average velocity of 0.15m/s^{-1} (1.5%) from the previous 10m to an end phase velocity of 9.50m/s^{-1}, caused by decreases in stride length and stride frequency of 0.3% and 0.15% respectively. In other words, in this phase the sprinters are not at their maximum velocity but are holding quite close to it. To distinguish the two phases this 20m can be called the "Velocity Maintenance" Phase.

Mid-race phases – Group B

For Group B it was found that acceleration continued even more strongly in the 40-50m segment than for Group A. Both the stride length and stride frequency increased (2% and 2.41% respectively) compared to the previous phase and a peak velocity of 11.55m/s^{-1} was reached. However, this was not the maximum velocity for the race. Moreover, the maximum values for both stride length and stride frequency were achieved at later points in the race. Therefore, in the elite sprinters this 10m segment is a third phase of the race, different from the third phase we see in Group A, and can be called the "Initial Peak Velocity" Phase.

The changes to the development of the kinematic variables in the 50-60m segment for Group B warrant the identification of a fourth phase. Here, the stride rate continued to increase by 2.8% over the previous phase to 4.8Hz (the highest 10m average in the race) but the stride length decreased about 3.2%. By 60m, the velocity had dropped marginally (0.07m/s^{-1} or 0.6%). In the next 10m segment the kinematic development was the opposite. Here, the stride length increased 1.2% and stride frequency dropped 1.1% with the effect that the velocity increases 0.05m/s^{-1} back up to 11.53m/s^{-1}, more or less the same as it was at the end of the 40-50m segment. In other words, we can see that there are two phases in which there are significant (and opposite) changes to the kinematic variables and small variations in the velocity at different moments but essentially no change to the average velocity. Therefore, for the elite sprinters we can identify two phases that can be called "Velocity Regulating I" (50-60m) and Velocity Regulating II" (60-70m).

After the velocity regulating phases, the Group B sprinters reached their "Maximum Velocity" Phase between 70m and 80m", where a top value of 11.70m/s^{-1} was achieved. The average velocity for this segment was 1.5% greater than the previous phase. Note that when these sprinters reached their initial velocity peak between 40m and 50m it was the result of increases in both stride length and stride frequency whereas here we see the stride frequency has decreased to 4.57Hz (compared to 4.67Hz in the 40-50m segment and even higher in the velocity regulating phases where the maximum values were achieved) while the stride length has increased significantly (13cm or 5.3% over the previous phase) to the maximum mean value for the race.

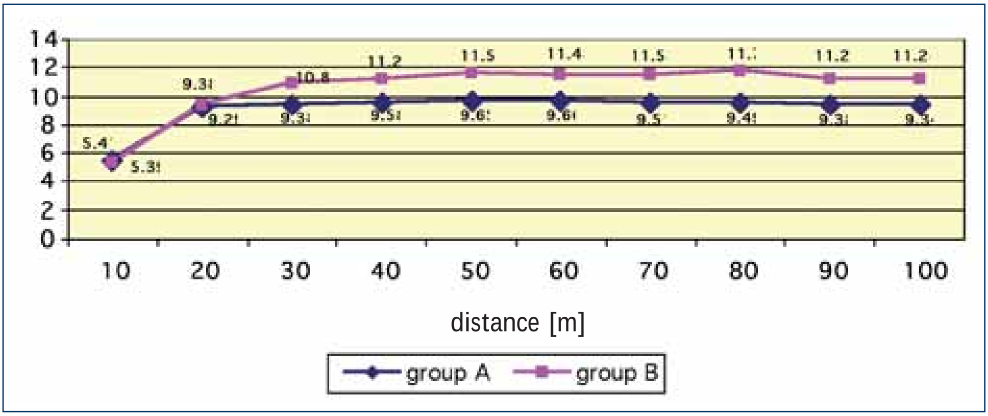

Figure 2: Comparison of the velocity curves of average sprinters (Group A) and elite sprinters (Group B) by 10m interval over the course of the 100 metres

Table 4: Differentials of interval time, stride length and stride frequency for average sprinters (Group A) during selected phases of the 100 metres (MAĆKALA, 2004; MAĆKALA and KOWALSKI, 2005)

Descriptive statistic	Group A (distance in m) 0-20	20-40	40-60	60-80	90	100
Value of change in velocity (m/s)	7.35	(+) 2.13	(+) 0.16	(-) 0.15	(-) 0.12	(-) 0.04
Share of change in velocity (%)	-	(+) 29	(+) 2.0	(-) 1.5	(-) 1.5	(-) 0.43
Value of change in stride length (cm)	179.6	(+) 39.4	(+) 6.0	(-) 0.7	(+) 0.5	(+) 4.4
Share of change in stride length (%)	-	(+) 21.9	(+) 2.7	(-) 0.3	(+) 0.2	(+) 1.95
Value of change in stride frequency (Hz)	4.035	(+)0.274	(-) 0.016	(-) 0.049	(-) 0.067	(-) 0.11
Share of change in stride frequency (%)	-	(+) 6.8	(-) 0.37	(-) 0.15	(-) 0.6	(-) 2.6

*(+) increase, (-) decrease, * time measured from camera*

Table 5: Differentials of interval time, stride length and stride frequency for elite sprinters (Group B) during selected phases of the 100 metres (calculated by the author using data from AE, ITO and SUZUKI, 1992)

Descriptive statistic	Group B (distance in m) 0-20	20-40	40-50	50-60	60-70	70-80	80-100
Value of change in velocity (m/s)	9.38	(+)3.68	(+)0.49	(-)0.07	(+)0.05	(+)0.17	(-)0.48
Share of change in velocity (%)	-	(+) 18	(+) 4.4	(-) 0.6	(+) 0.4	(+) 1.5	(-) 4.1
Value of change in stride length (cm)	164	(+) 79	(+) 5	(-) 8	(+) 3	(+) 13	(-)2.5
Share of change in stride length (%)	-	(+)48.1	(+) 2	(-) 3.2	(+) 1.2	(+) 5.3	(-)0.98
Value of change in stride frequency (Hz)	4.31	(+)0.25	(+)0.11	(+)0.13	(-) 0.5	(-)0.18	(-)0.15
Share of change in stride frequency (%)	-	(+) 5.8	(+)2.41	(+) 2.8	(-) 1.1	(-) 3.8	(-) 3.3

(+) increase, (-) decrease

Deceleration

As stated above, between 60m and 80m the sprinters from Group A slowed from their maximum velocity due to slight decreases in both stride frequency and stride length. This trend continued in the last two 10m sections, which can be called the “Deceleration” Phase: at 90m, the velocity had dropped about 1.3% (0.12m/s^{-1}) and in the last 10m it continued to decrease by 0.43% (0.04m/s^{-1}). In contrast to the previous phase, the slowing in this part of the race was mainly the result of a significant decrease in stride frequency as the mean stride length actually showed an increase in value.

Group B also slowed in the last 20m of the race. There was a significant decrease in the mean velocity of about 0.48m/s^{-1} (4% compared with the 70-80m section). This was due to a significant 3.3% decrease in stride frequency and a 1% decrease in stride length. However, if we focus on the last 10m of the race we see that the velocity was slightly higher (11.24 m/s^{-1}) and the stride length increased slightly over the 80-90m section. While this can be called the “Deceleration” Phase, it should be pointed out that there are also similarities to the kinematic dynamics of the Velocity Maintenance Phase (Phase 4) in the Group A sprinters.

Running velocity is the product of stride length and stride frequency ($v = l \times f$). Accordingly, an increase in mean velocity (v) and, thereby, a decrease the running time (t) for a given distance, can only result from changes to these two parameters: an increase of stride length (with a decrease of number of strides and their frequency) or inversely a decrease of stride length (with an increase in stride rate. On the basis of this general definition of the running speed, BALLEREICH (1976), five logical possibilities exist for improving performance in the sprint events:

1. $V+ \Delta V = (L + \Delta L) \cdot f$ where ($f \sim$ constant)
2. $V+ \Delta V = L \cdot (f + \Delta f)$ where ($L \sim$ constant)
3. $V+ \Delta V = (L + \Delta L) \cdot (f + \Delta f)$
4. $V+ \Delta V = (L + \Delta L) \cdot (f - \Delta f)$;
   $[(L + \Delta L) \cdot (f - \Delta f) > L \cdot f]$
5. $V+ \Delta V = (L - \Delta L) \cdot (f + \Delta f)$;
   $[(L - \Delta L) \cdot (f + \Delta f) > L \cdot f]$

The data in Table 6 illustrates that velocity increased in 8 of the 13 analysed phases (in 1, 2, 3 for Group A and in 1, 2, 3, 5, 6 for Group

Table 6: Comparison of the velocity curve for selected phases of the 100 metres due to individual changes of stride length and stride rate

Phase	Distance [m]	Group A	Group B	Distance [m]	Phase
1	0-10 10-20	$V + \Delta V = (L + \Delta L) - (f + \Delta f)$	$V + \Delta V = (L + \Delta L) - (f + \Delta f)$	0-10 10-20	1
2	20-30 30-40	$V + \Delta V = (L + \Delta L) - (f + \Delta f)$	$V + \Delta V = (L + \Delta L) - (f + \Delta f)$	20-30 30-40	2
3	40-50 50-60	$V + \Delta V = (L + \Delta L) - (f - \Delta f)$	$V + \Delta V = (L + \Delta L) - (f + \Delta f)$	40-50	3
4	60-70 70-80	$V - \Delta V = (L - \Delta L) - (f - \Delta f)$	$V - \Delta V = (L - \Delta L) - (f + \Delta f)$	50-60	4
5	80-90 90-100	$V - \Delta V = (L + \Delta L) - (f - \Delta f)$ $V - \Delta V = (L - \Delta L) - (f - \Delta f)$	$V + \Delta V = (L + \Delta L) - (f - \Delta f)$	60-70	5
			$V + \Delta V = (L + \Delta L) - (f - \Delta f)$	70-80	6
			$V - \Delta V = (L - \Delta L) - (f - \Delta f)$	80-90 90-100	7

B). This is 61.5% of the total number of investigated phases. In the majority of the phases (62.5 % of all cases) the running velocity increased due to increases of both kinematic parameters $V + \Delta V = (L + \Delta L) - (f + \Delta f)$. In three cases, increased stride length significantly dominates over increase stride frequency as the cause of the increased velocity, however, in two cases these were inversely related. In three cases, the increase in running velocity took place with an increase of one variable and a drop of the second (twice the increased stride length was dominant and once the increased stride rate was dominant).

A decrease in running velocity took place in five phases (three in Group A and two in Group B). Additionally, two investigated phases showed only an increase of stride length $V - \Delta V = (L + \Delta L) - (f - \Delta f)$ and in two cases, the increase in stride rate was dominant over an increase in stride length. In one phase, a decrease in velocity was due to a drop of both parameters. This took place in Phase 4 for the average sprinters and Phase 7 for elite sprinters.

Conclusion

According to this investigation, the velocity curve of the 100 metres illustrates that changes in velocity over the course of the race must be analysed via the change of velocity in each phase (section). The course of the velocity curve (increase or decrease of velocity) is very important for training applications, practical understanding of running form, evaluation of the technique of a single stride, optimal diagnosis of sprinting ability and developing effective race strategies. Achieving the most effective velocity curve depends on the optimal dynamics of the various phases due to changes of the main kinematic parameters: stride length and stride frequency. Consequently, this set of variables can be used as a tool for identification of the phases in the race structure of the 100m for elite sprinters:

Phase 1	Initial Acceleration (0-20m)
Phase 2	Extended Acceleration (20-40m), often called second acceleration phase
Phase 3	Initial Peak Velocity (40-50 m)
Phase 4	Velocity Regulation I (50-60m)
Phase 5	Velocity Regulation II (60-70m)
Phase 6	Maximum Velocity (70-80m)
Phase 7	Deceleration (80-100m)

Data from the study demonstrates that stride length contributes much more to the velocity curve of the 100 metres than stride frequency. It seems that stride frequency can no longer be considered the most important performance-determining factor in the 100 metres in either average- or high- level performers.

Furthermore, this study found that excessive acceleration with excessively high stride frequency in the first 10m of the initial acceleration phase (over 90% of its maximum), had a negative impact on the optimal relationship with stride length. This also affected the overall development of velocity to a certain degree (Phase 4 in elite sprinters and Phases 4 and 5 in average sprinters). This statement is confirmed by earlier studies (GAJER et al., 1999; SHEN, 2000). This problem is much more evident in average sprinters (Group A). According to the relative analysis, this study indicates that to improve performance it is necessary to control the stride frequency and increase the stride length while accelerating in the first 10-20m section of the race.

Recommendation

The length of the stride, particularly maintenance of its optimal length for the longest possible distance, is the key element for technical efficiency and performance optimisation in the 100 metres. The increase in stride length must be directly proportional with the decrease of stride frequency, especially at the beginning of the race – the initial acceleration phase.

Please send all correspondence to:
Dr Krzysztof Maćkala
krzysztof.mackala@awf.wroc.pl

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