Dynamics of biomechanical indicators for 800-meter running technique in terms of competition for high-class athletes

UDC 796.422.14

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Received by the editorial office on 14.07.2024

Abstract
Objective of the study was to inquire the changes in biomechanical indicators of 800 m running technique in terms of competition for high-class athletes.
Methods and structure of the study. The analysis of changes in biomechanical indicators of 800 m running technique of highly qualified athletes at competitions were carried out. Based on high-speed video (250 fps) on straight sections of the track at four points of the distance, the characteristics of running technique (duration of phases, length and speed of running steps) of 19 participants were evaluated.
Results and conclusions. Reliably significant ($p<0,05$) changes from start to finish were revealed: a) increase in the duration of the push-off and support phases, b) decrease in the flight phase. The length and speed of the double step significantly ($p<0,05$) decrease from the middle of the distance to the finish. At the hypothesis level, it was noted that the decrease in the flight phase is largely associated with increasing fatigue, rather than with a change in running speed. A tendency towards increasing asymmetry of the running step along the distance was revealed.

Keywords: *high-class athletes, track and field athletics, middle distance runners, running technique, high-speed video, documents analysis.*

Introduction. In modern literature, much attention is paid to improving the efficiency of running technique, in particular, middle-distance running [1]. Oxygen consumption at a fixed submaximal speed, the amount of mechanical work performed by an athlete during running, the reaction of the cardiorespiratory system under load, as well as biomechanical characteristics of running technique: athlete's vertical body movement (AVBM) [3-6, 8], running stride parameters [7] are used as efficiency indicators. Analysis of the biomechanical characteristics of running technique is carried out using 3D shooting, tensometry, accelerometry and other technologies [2, 10]. Most of the listed technologies are used to study running technique in laboratory conditions during a specially organized study, less often in the training process. The amount of data on running technique, in particular, on running stride parameters, obtained during competitions is limited. At the 2017-2018 World Championships, 3D filming of the races was conducted, based on which biomechanical reports were published, including the parameters of the running stride over short distances [9]. An urgent task for finding means and methods for improving the training process of highly qualified middle-distance runners is to assess changes in the biomechanical characteristics of running technique from start to finish in competition conditions. Obtaining such data can be used to develop a methodology for assessing running technique using high-speed video filming.

Objective of the study was to inquire the changes in biomechanical indicators of 800 m running technique in terms of competition for high-class athletes.

Methods and structure of the study. *The study was conducted as part of the work on the NMO of the sports teams of the Russian Federation.* The studies were conducted on highly qualified runners, including athletes of the Russian national team. To determine the characteristics of the running stride of middle-distance runners, filming of men's 800 m races was conducted. The characteristics were calculated for 19 participants who showed results in the range from

1:47.63 to 1:54.00 min. Filming was carried out at the international competitions «Memorial of the Znamensky Brothers» (Moscow, Luzhniki Stadium, Northern Sports Center) in 2024. High-speed video cameras (250 fps) were placed opposite the running track so that the optical axes of the lenses were perpendicular to the marking lines. The races were filmed on straight sections of the running track at points along the distance located at 180, 380, 580 and 780 m from the start (filming points 1, 2, 3 and 4, respectively). The video materials were marked and digitized by one qualified operator. MaxTraq 2D software was used for processing. Track and field hurdles placed on each running track were used as scaling objects.

The durations of the phases, the length and speed of the double running step were calculated. At each of the four filming points, the durations of the support and unsupported (flight) phases were determined, as well as the smaller phases that make up the support phase: cushioning, push-off and the phase of switching between them. The durations of the phases were determined as the average value of the duration of each phase for two consecutive steps. The length of the double step was determined from the lift-off of the leg to the next lift-off of this leg from the track. When calculating the lengths, the distance between the corresponding points was found using the flat coordinates of these points. The length and speed of a double running step were calculated for the second (380 m) and fourth (780 m) points, for which the shooting scene was scaled using barriers.

A statistical analysis of the calculated indicators was performed using Statistica 64 software. To identify the reliability of differences in the average values of the studied indicators at the shooting points, Student's t-test for dependent samples was used.

Results of the study and discussion. The results are presented in Tables 1, 2 and figure 1. Each column of Table 1 contains the parameters of one of the compared pairs of survey points. 1. M.±σ in the rows of Tables 1, 2 is the mean value (s) and standard deviation at the first point from the compared pair, 2. M.±σ is the same for the second point. Traditionally, the phase structure of a running step is divided into support and flight phases. The use of high-speed photography made it possible to determine and calculate the duration of shorter phases on the support (Table 1). After the foot touches the support (in the amortiza-

Table 1. Comparative analysis of the durations of the running step phases

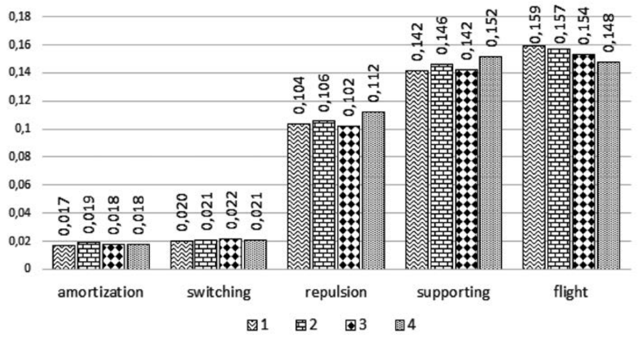
Indicators	Pairs of shooting points					
	1-2	1-3	1-4	2-3	2-4	3-4
Duration of the amortization phase (s)						
1.M.±σ	0,017±0,003	0,017±0,003	0,017±0,003	0,019±0,003	0,019±0,003	0,018±0,004
2. M.±σ	0,019±0,003	0,018±0,004	0,018±0,004	0,018±0,004	0,018±0,004	0,018±0,004
p-val	0,059	0,131	0,154	0,680	0,436	0,67
Switching phase duration (s)						
1.M.±σ	0,020±0,004	0,020±0,004	0,020±0,004	0,021±0,005	0,021±0,005	0,022±0,005
2. M.±σ	0,021±0,005	0,022±0,005	0,021±0,007	0,022±0,005	0,021±0,007	0,021±0,007
p-val	0,463	0,332	0,536	0,693	0,828	0,674
Duration of the repulsion phase (s)						
1.M.±σ	0,104±0,010	0,104±0,010	0,104±0,010	0,106±0,010	0,106±0,010	0,102±0,010
2. M.±σ	0,106±0,010	0,102±0,010	0,112±0,010	0,102±0,010	0,112±0,010	0,112±0,010
p-val	0,305	0,054	**0,009**	0,010	0,066	**0,002**
Duration of the support phase (s)						
1.M.±σ	0,142±0,010	0,142±0,010	0,142±0,010	0,146±0,008	0,146±0,008	0,142±0,009
2. M.±σ	0,146±0,008	0,142±0,009	0,152±0,008	0,142±0,009	0,152±0,008	0,152±0,008
p-val	**0,0001**	0,9271	**0,0004**	**0,00001**	**0,0190**	**0,0003**
Flight phase duration (s)						
1.M.±σ	0,159±0,009	0,159±0,009	0,159±0,009	0,157±0,009	0,157±0,009	0,154±0,010
2. M.±σ	0,157±0,009	0,154±0,010	0,148±0,012	0,154±0,010	0,148±0,012	0,148±0,012
p-val	0,1125	**0,0100**	**0,0001**	**0,0275**	**0,0005**	**0,0217**
Double step phase duration (s)						
1.M.±σ	0,605±0,026	0,605±0,026	0,605±0,026	0,604±0,025	0,604±0,025	0,562±0,097
2. M.±σ	0,604±0,025	0,562±0,097	0,570±0,099	0,562±0,097	0,570±0,099	0,570±0,099
p-val	0,7367	0,0133	0,6308	0,0008	0,7377	0,224

Table 2. Comparative analysis of the lengths and speeds of running steps (2–4)

Indicators	Double step length (m)	Double step speed (m/s)
1.M.±σ	4,248±0,159	7,047±0,237
2. M.±σ	4,020±0,239	6,677±0421
p-val	**0,00002**	**0,0007**

tion phase), the ankle and knee joints bend, the heel or the forefoot (in athletes who place their foot from the heel) move toward the support. In the switching phase, the foot does not move relative to the track, the ankle and knee joints continue to bend. In the push-off phase, the heel begins to move upward. At the end of the switching phase, extension of the knee joint begins, followed shortly thereafter by extension of the ankle joint.

As can be seen from Table 1, the duration of the first two phases on the support remains virtually unchanged during the distance (p>0,05). The duration of the push-off phase increases from the start to the finish. In most of the compared pairs, these differences are reliably significant (p≤0,01), in some cases (1–3, 2–4) they are observed at the trend level (p≤0,066). In almost all compared pairs, the duration of the support phase increases from the start to the finish (p≤0,019). The exception is the absence of significant differences in the duration of the support phase between survey points 1 and 3. It can be assumed that this exception was a consequence of the acceleration of running by most athletes on the section of the distance near point 3 (580 m from the start). Often, before the start of the final turn, athletes reorganize to take more advantageous positions before the finish.



Dynamics of the duration of the running step phases (average values, s)

As can be seen from the graph in the figure, the duration of the flight phase decreases as the distance progresses. In most cases, there are reliably significant differences (p<0,03). The absence of reliable differences in the duration of this phase at points 1 and 2 is apparently due to the fact that fatigue has not yet had an effect on the first lap of the distance.

The duration of the double step does not have reliably significant differences between the beginning (point 1) and the finish (point 4) of the distance (p=0,631), and in most other compared pairs of points. We can say that there is no tendency for this parameter to change as the distance progresses. Perhaps this is due to the multidirectional dynamics of the duration of individual phases of the running step. The reliable decrease in the duration of the double running step (p<0,05) between survey points 1–3 and 2–3, in our opinion, is due to the acceleration of running opposite survey point 3, as mentioned above.

The length and speed of the double step decrease as the distance progresses. The differences in these parameters in the middle and at the finish of the distance have reliable significant differences (p≤0,0007). When determining the lengths of steps, a difference in the length of two adjacent steps constituting a double step is observed (similarly - in other studies [10]). At the same time, there is a tendency for the difference to increase, that is, to increase the asymmetry of steps along the distance. At the end of the first lap, the differences in the length of two steps were 0,066 ± 0,059 m, at the finish – 0,098 ± 0,074 m. Despite the absence of reliable differences (p>0,05), an increase in the asymmetry of steps can characterize the athlete's fatigue at the finish of the distance. The problem of determining which parameters and to what extent change depending on the running speed, and which due to fatigue, has been solved previously [2, 4], but is still relevant, especially when running in competitive conditions. In our study, despite the tendency for the running speed to decrease during the distance (Table 2, Figure), during the finishing acceleration the running speed of some runners increased. Six of the examined athletes showed similar double step speeds in the middle of the distance (point 2 – 380 m from the start) and at the finish (point 4 – 20 m before the finish). The difference was no more than 1,5% (p=0,379). These athletes showed a reliable decrease in the duration of the flight phase (point 2 – 0,1597±0,007 s, point 4 – 0,1477±0,008 s, p=0,016). The durations of other phases of the running step in the middle and at the finish of the distance did not differ significantly (p>0,05). The duration of the flight phase changed little in the first half of the 800-meter distance (points 1-2, p=0,113). It can be assumed that the duration of the flight phase changes not due to running speed, but due to fatigue. Further research is required to confirm this hypothesis.

Conclusions. The values and dynamics of the 800 m running technique indicators of highly qualified athletes were determined based on high-speed filming under competition conditions. The indicators were identified whose changes over the distance were reliably significant (p<0.05). It was shown that from the start to the finish the duration of the push-off and support phases increases, and the flight phase decreases. The length of the steps (double step) and the speed of the double step significantly (p<0.05) decrease from the middle of the distance to the finish. A tendency towards an increase in the asymmetry of the running step over the distance was found. A hypothesis was put forward that a decrease in the flight phase is largely associated with an increase in fatigue, rather than with a change in running speed. The study demonstrated the possibility of calculating indicators for assessing the technique and fitness of middle-distance runners under competition conditions. To test the hypotheses, further experiments are required to create an instrumental methodology for assessing the technical fitness of athletes. To improve the accuracy of the measurements and simplify the processing of the obtained data, it is advisable to use 3D high-speed video filming.

References

1. Aikin V.A., Koryagina Yu.V. Begovaya ekonomichnost i osobennosti yeye povysheniya u legkoatletov-stayyerov (zarubezhnyy opyt). Nauka i sport: sovremennyye tendentsii. 2014. No. 3. Vol. 4. pp. 86-90.
2. Arakelyan E.E., Tyupa V.V., Mikhaylova O.D., Mnukhina O.N. Biomekhanika utomleniya v bege. Teoriya i praktika fizicheskoy kultury. 2010. No. 1. pp. 66-72.
3. Demidov V.A., Mavliev F.A., Nazarenko A.S., Demidova V.V. Nekotoryye aspekty otsenki effektivnosti bega. Chelovek. Sport. Meditsina. 2018. Vol. 18. No. 4. pp. 7-13.
4. Kryazhev V.D., Dorontsev A.V., Shvetsov A.V., Amelina E.N. Biomekhanicheskiye i bioenergeticheskiye kriterii tekhniki bega na sredniye i dlinnyye distantsii. Uchenyye zapiski universiteta im. P.F. Lesgafta. 2023. No. 1 (215). pp. 267-271.
5. Lysenko E.N. Prognozirovaniye fizicheskoy rabotosposobnosti i reaktsiy kardiorespiratornoy sistemy pri nagruzkakh aerobnogo kharaktera u sportsmenov vysokogo klassa. Vestnik sportivnoy nauki. 2013. No. 4. pp. 33-38.
6. Barnes K.R., Kilding A.E. Running economy: measurement, norms, and determining factors. Sports Medicine – Open.
7. Cavanagh P.R., Williams K.R. The effect of stride length variation on oxygen uptake during distance running. Med Sci Sports Exerc. 1982;14(1):30-5.
8. Cynthia R. Lee, Claire T. Farley Determinants of the center of mass trajectory in human walking and running. The Journal of Experimental Biology 201, 2935-2944 (1998).
9. Pollitt L., Walker J., Tucker C., Bissas A., (2018). Biomechanical Report for the IAAF World Championships 2017: 200 Metres Men. Birmingham, UK: International Association of Athletics Federations.
10. Rachel Mason, Liam T. Pearson, Gillian Barry, Fraser Young, Oisin Lennon, Alan Godfrey, Samuel Stuart Wearables for Running Gait Analysis: A Systematic Review Sports Medicine (2023) 53:241-268.