Kinematic analysis of intermittent sprints of elite soccer players

by

*Robert Góralczyk[1], Kazimierz Mikolajec[1], Stanislaw Poprzecki[2],
Adam Zajac[3], Wladyslaw Szyngiera[1], Zbigniew Waskiewicz[1]*

*Authors evaluated kinematic characteristics of running velocities during
intermittent 10 x 30 m sprints. Authors also attempted to determine if
there are any significant change in human organism homeostasis after
10x30m intermittent sprints and if the maximal and temporary velocities
evaluated continuously are different after consecutive repetitions of
maximal sprints. The experiment was conducted on 19 male Polish first
division soccer players aged 24,4 ± 3,5 years. The mean body height and
mass were equal respectively 178,5±7,9 cm and 76, 5± 5,7 kg. The speed
abilities were evaluated with the use of the laser diode system LDM300C-
Sport (Laser Device Measurement from Jenoptik in Jena). The testing
protocol included 10x30 m sprints with 20 s recovery periods. According
to laser measuring system the data of whole distance were recorded:
velocity (1, 5, 10, 15, 20 and 30 m), maximal velocity in each sprint
(Vmax) and distance at which maximal velocity SVmax [m] was obtained.
Obtained experimental data and theoretical overview allowed to conclude
that repeated 30 m sprints with short rest intervals significantly disturbed
body homeostasis. The maximal velocity decreases with each sprint
reaching lowest level in 10th repetition and the changes of mean velocities
at chosen distances in consecutive sprints decreases but the course of
changes have an unjustified character*

Keywords: *soccer players, maximal sprints*

[1] Academy of Physical Education, Department of Team Sports, 40-035 Katowice, Mikolowska
  72A, waskie@awf.katowice.pl
[2] Department of Biochemistry, stan@awf.katowice.pl
[3] Department of Sport Training, adamzaj@ awf.katowice.pl

Introduction

For many years, training scientists and biomechanical researchers have studied the issue of optimal sprint performance. First investigations on sprint performance were conducted by MAREY back in 1894. Later on, physiological explanations were furnished and phase- and motion-related patterns were developed which split the sprint run down into four different sections: a reaction, an acceleration, a maximum sprint and a sprint endurance section (Turck-Noack 1996). Interesting is the human metabolism during intermittent sprints. Many works regarding this subject (Gaitanos et al. 1993) seem comprehensive. The exercise protocol consisted of ten 6-s maximal sprints with 30 s of recovery between each sprint. Needle biopsy samples were taken from the vastus lateralis muscle before and after the first sprint and 10 s before and immediately after the tenth sprint. The energy required to sustain mean power output that was generated over the first 6-s sprint was provided by an equal contribution from phosphocreatine (PCr) degradation and anaerobic glycolysis. Indeed, within the first 6-s bout of maximal exercise PCr concentration had fallen by 57% and muscle LA concentration had increased to 28.6 mmol/kg dry weight, confirming significant glycolytic activity. However, in the tenth sprint there was no change in muscle lactate concentration even though mean power output was reduced only to 73% of that generated in the first sprint. Authors suggested that, during the last sprint, power output was supported by energy that was mainly derived from PCr degradation and an increased aerobic metabolism.

Linossier et al. (1993) determined that 7-weeks sprint training induced an improvement both in peak power performances (by 25%) and in the total work (by 16%). Before sprint training, the velocity reached with no load (v0) was related to resting muscle phosphocreatine (PCr) stores. Training-induced changes in v0 were observed only when these PCr stores were lowered. This pointed to a possible limiting role of low PCr concentrations in the ability to reach high velocity. The improvement in performances was linked to an increase in the energy production from anaerobic glycolysis. This phenomenon was explained by the increase in lactate production measured after a training session associated with the 20% higher activity of both phosphofructokinase and lactate dehydrogenase.

The sexual dimorphism was evaluated by Yanagiya et al. (2003). Subjects performed ten 5-s maximal sprint runs with an interval of 10s between each sprint. The boys showed significantly higher mean mechanical power (MP)

than the girls in all sprints. However, when MP was expressed as the ratio to total volume of muscles located in the right lower limb, estimated using a bioelectrical impedance analysis, significant gender effect was limited to the values at the 1st and 2nd sprints. The decline of MP over the ten sprints, expressed as a relative value to that at the 1st sprint, was greater in boys than in girls. However, no significant difference between the boys and girls was found in relative difference between MP values at the 3rd and 10th sprints, where the gender difference in relative at every sprint was insignificant.

Also the relation between anthropometric traits and sprint abilities was examined. Coh et al. (2001) measured morphological characteristics of sprinters with a test battery of 17 measures. The kinematic variables (stride frequency and length, duration of contact and flight phases) were obtained from a flying 20 m run and a 20 m run with a low start, with the use of a contact carpet. Results showed that elite sprinters do not differ significantly in morphological characteristics. However, statistically significant differences were obtained in starting acceleration and maximal velocity. The most important kinematic parameters for generating differences between elite sprinters are contact time and stride frequency. Similar results were obtained by Kukolj et al. (1999) who stated that most of the standard anthropometric, strength and power tests could be poor predictors of sprinting performance.

Johnson and Buckley (2001) to assess the role of the lower limb joints in generating velocity in the mid-acceleration phase of sprinting evaluated muscle power patterns of the hip, knee and ankle. The results showed a proximal-to-distal timing in the generation of peak extensor power during stance at the hip, the knee and then the ankle, with the plantar flexors producing the greatest peak power. Apart from a moderate power generation peak towards toe-off, knee power was negligible despite a large extensor moment throughout stance. The role of the knee thus appears to be one of maintaining the center of mass height and enabling the power generated at the hip to be transferred to the ankle. Although sprint performance undoubtedly involves muscle power, the stiffness of the leg also determines sprint performance while running at maximal velocity. Results that include both of these characteristics have not been directly obtained in previous studies on human runners. Chelly and Denis (2001) therefore studied the link between leg power, leg stiffness, and sprint performance. The treadmill forward leg power was correlated with both initial acceleration and maximal running velocity during track sprinting. Leg stiffness calculated from hopping was significantly correlated with maximal velocity but not with acceleration. Authors stated that high leg stiffness might be needed for high running speed. The ability to produce a stiff rebound during maximal

running velocity could be explored by measuring the stiffness of a rebound during a vertical jump.

The existing experimental data related to running velocities (temporary and maximal) as well as the effect of multiple repetitions of sprints is rather scarce. Therefore authors decided to evaluate kinematic characteristics of running velocities during intermittent 10 x 30 m sprints. Such a movement is often present in team sports, especially in soccer, where short time maximal work intensity is interspersed with partial recovery periods. In order to evaluate the changes in kinematical and biochemical variables after intermittent exercises following research questions were formulated:

1. Are there any significant changes in human organism homeostasis after 10x30m intermittent sprints of 10x30 m with partial recovery intervals?
2. Are maximal and temporary velocities evaluated continuously different after consecutive repetitions of maximal sprints?

Material and methods

The experiment was conducted on 19 male Polish first division soccer players aged 24,4 ± 3,5 years. Mean body height and mass were respectively 178,5±7,9 cm and 76, 5± 5,7 kg. The measurements were performed on July 2003 at the initial phase of 2003/2004 season, 4 weeks before the first game of the season. Consent for participation was obtained from all subjects after they were informed of the purpose and nature of the study. The speed abilities were evaluated with the use of the laser diode system LDM300C-Sport (Laser Device Measurement from Jenoptik in Jena), which breaks new ground for kinematic analysis of one-dimensional acceleration phases in various branches/disciplines of sport. It provides on-line recording of the required distance-versus-time and velocity-versus-time relationship and of selected individual kinematic motion parameters, making these immediately available to coaches and sportsmen alike. Laser sensor device by contrast to ultrasonic techniques (PRATT et al. 1991, SANDERSON et al. 1991) no receiver or transmitter hardware needs to be attached to the sportsman or the instrument for being carried along. Compared to video or film analytical procedures, the overall requirements to accomplish measurement are considerably reduced, except for the fact that only one athlete can be mapped at a time.

In principle, the LDM 300 C Sport is similar to a binocular field glass, but integrating the four main components of sighting channel, laser emission channel, laser reception channel and display unit (fig. 1). A hair cross with centered ring is provided in the sighting channel to facilitate aiming at the

target area of the object to be measured (fig. 2-3). No reflectors are required. Motion sequences can be recorded over a time about 50 s for distances up to 400 m with a sampling frequency of 50 Hz in non-reflector mode. A recording and evaluation program specifically developed for practical sports applications allows measurement to be triggered from the LDM300C Sport or the PC. A very helpful option is "Marks". It allows the user to call up a desired partial time or velocity reading from a recorded velocity diagram, for example, the 5 m time value in long jumping immediately before take off or the 10 m-interval times in sprint events. The results are available on the PC screen in various evaluation modes immediately after measurement (fig.4).
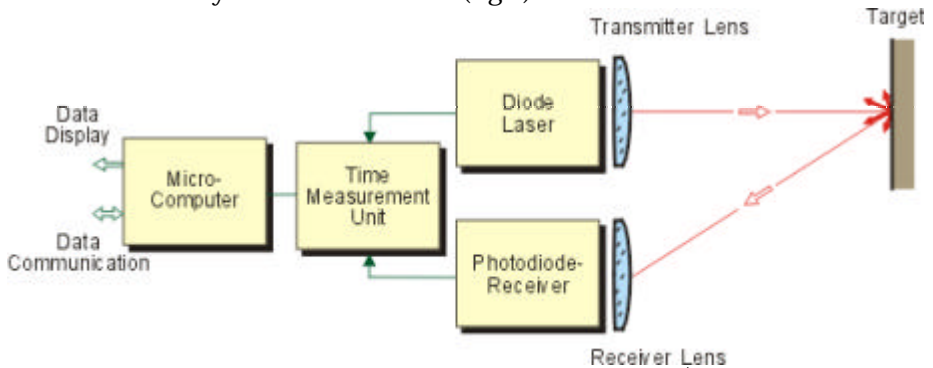

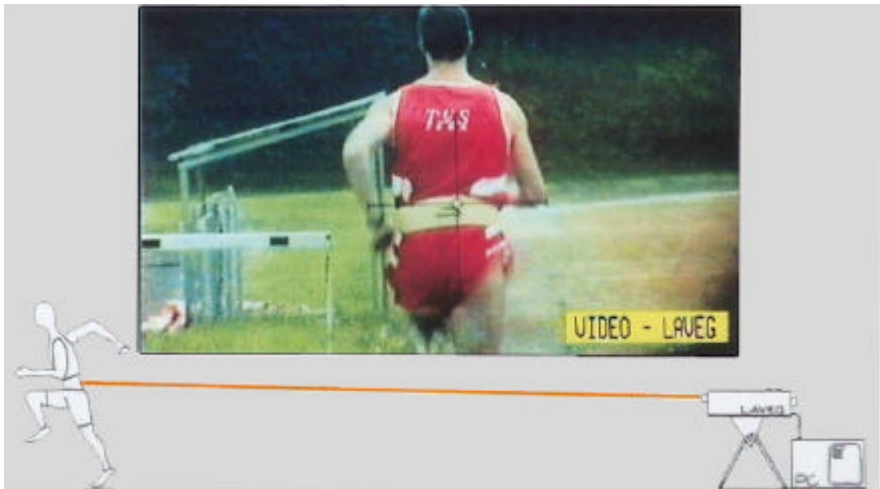**Fig. 1** The scheme of measuring system of LDM300C Sport[*]

Fig. 2 Aiming at the sprinter and target monitoring via sighting cross

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[*] All illustration in this section are reproduced from Jenoptik®, Jena, Germany materials.
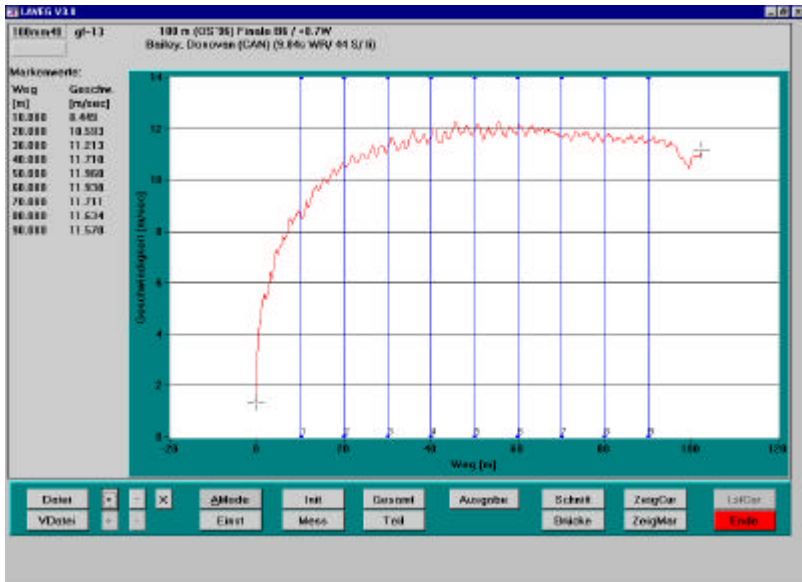
Fig. 3 Measuring set-up

Fig. 4 Evaluation screen immediately after measurement

The testing protocol included 10x30 m sprints with 20 s recovery periods. During this time athletes were obliged to jog or march to starting point to perform consecutive sprint. The starting position was high and athletes chose the position of body. Each distance from LDM300C to athletes was measured so there was no obligatory start and finish line. Only suggested line of started was marked at the floor.

According to laser measuring system the data of whole distance are available (fig. 4). The following data was used in further analysis:

1. velocity at 1, 5, 10, 15, 20 and 30 m [m/s],
2. maximal velocity in each sprint Vmax [m/s],
3. distance of obtained maximal velocity SVmax [m].

Before and 4 min. after last sprint the blood sample from the fingertips were taken in order to evaluate LA concentration and acid-base equilibrium (HCO_3^- and BE). LA concentration measurements were carried out enzymatically using commercial kits (Boehringer Diagnostica, Mannhaim).

Blood HCO_3^- and BE levels were measured using the 168pH Blood-Gas Analyzer (Ciba-Corning).

The significance of differences in the level of speed variables was calculated with the use of ANOVA with repeated measures and linear regression analysis. To determine individual differences Tukey HSD (Honest Significance Difference) post-hoc tests were used.

Results

The first stage of data analysis was focused on velocities, which were registered continuously during each 30 m sprint. The results are presented in tab. 1 and extracted for each meter of distance. However it is generally not usual in data presentation but authors decided that it might be helpful in some comparatory studies. The graphical data of chosen distances are presented in fig. 5 and 6. Fig. 5 presents the differences between 1st and 10th sprint at every meter of distance. Statistically significant differences (p≤0,05) were registered on 9, 10, 15, and 17-19 and from 22 to 29th m. The lack of significance at other distance resulted mainly from large individual variances of tested subjects.

In fig. 6 authors pr esented ANOVA results at chosen distance of the 30 m run. The mean velocity at 1st m (fig. 6a) of distance differed significantly in light of ANOVA (F= 1,712 p=0,089), especially between 1st and 8th sprint (p=0,048).

Table 1 The mean velocities at chosen distances registered in ten consecutive sprints

Dist.	Consecutive sprints									
	1	2	3	4	5	6	7	8	9	10
1 m	3,70	3,62	3,63	3,63	3,63	3,51	3,54	3,38	3,52	3,49
2 m	4,69	4,62	4,64	4,73	4,46	4,47	4,56	4,52	4,42	4,54
3 m	5,27	5,29	5,25	5,14	5,19	5,11	5,10	5,05	5,11	5,01
4 m	5,68	5,70	5,63	5,68	5,67	5,75	5,71	5,56	5,49	5,65
5 m	6,20	6,10	5,92	6,03	6,03	6,11	6,18	6,06	5,88	5,84
6 m	6,60	6,47	6,78	6,53	6,49	6,54	6,31	6,51	6,40	6,44
7 m	7,03	6,73	6,54	6,61	6,58	6,81	6,66	6,53	6,61	6,70
8 m	6,82	6,84	6,75	6,88	6,89	6,48	6,63	6,75	6,53	6,74
9 m	7,47	7,31	7,28	7,12	7,09	7,06	7,18	7,23	6,98	7,03
10 m	7,65	7,48	7,18	7,12	7,26	7,28	7,33	7,09	7,29	7,15
11 m	7,34	7,25	7,40	7,86	7,38	7,21	7,23	7,22	7,24	7,20
12 m	7,96	7,76	7,61	7,76	7,57	7,64	7,65	7,74	7,46	7,52
13 m	7,96	7,88	7,95	7,49	7,69	7,49	7,56	7,50	7,65	7,70
14 m	8,02	7,90	8,00	8,00	7,68	7,92	8,01	7,72	7,68	7,72
15 m	8,55	7,92	7,69	7,98	8,01	7,92	7,71	7,80	7,75	7,60
16 m	8,16	8,26	8,10	7,84	7,89	7,87	7,71	7,69	7,79	7,93
17 m	8,49	8,18	8,51	8,25	8,24	8,16	8,36	8,05	8,03	8,01
18 m	8,33	8,16	7,79	8,09	8,09	7,91	7,70	7,77	7,79	7,79
19 m	8,55	8,47	8,42	8,26	8,10	8,43	8,24	8,08	8,12	8,06
20 m	8,42	8,44	8,13	8,21	8,31	8,11	8,06	8,13	8,04	8,12
21 m	8,44	8,29	8,42	8,29	8,29	8,29	8,16	8,15	8,04	8,06
22 m	8,75	8,33	8,29	8,45	8,22	8,21	8,31	8,24	8,06	8,13
23 m	8,68	8,46	8,49	8,38	8,38	8,27	8,18	8,19	8,20	8,21
24 m	8,70	8,55	8,42	8,37	8,32	8,34	8,32	8,23	8,06	8,23
25 m	8,66	8,29	8,42	8,40	8,30	8,31	8,28	8,08	8,14	8,18
26 m	8,81	8,47	8,42	8,53	8,37	8,27	8,22	8,45	8,15	8,19
27 m	8,91	8,54	8,48	8,20	8,29	8,31	8,10	8,20	8,23	8,21
28 m	8,68	8,63	8,43	8,34	8,33	8,34	8,37	8,19	8,03	8,22
29 m	8,63	8,53	8,31	8,34	8,20	8,29	8,15	8,12	8,03	8,11
30 m	8,40	8,48	8,36	8,34	8,23	8,21	8,09	7,96	8,19	8,07

Second measuring point was extracted from the continuous registration at 5th m (fig. 6b). However the general analysis of variance was insignificant (F=1,067 p=0,389), specific course of changes may be observed. At 10th and 15th m the changes of the level of velocities analyzed in regard to repetitions differed significantly (F=2,320 p=0,017 and F=6,540 p=0,0001 respectively).
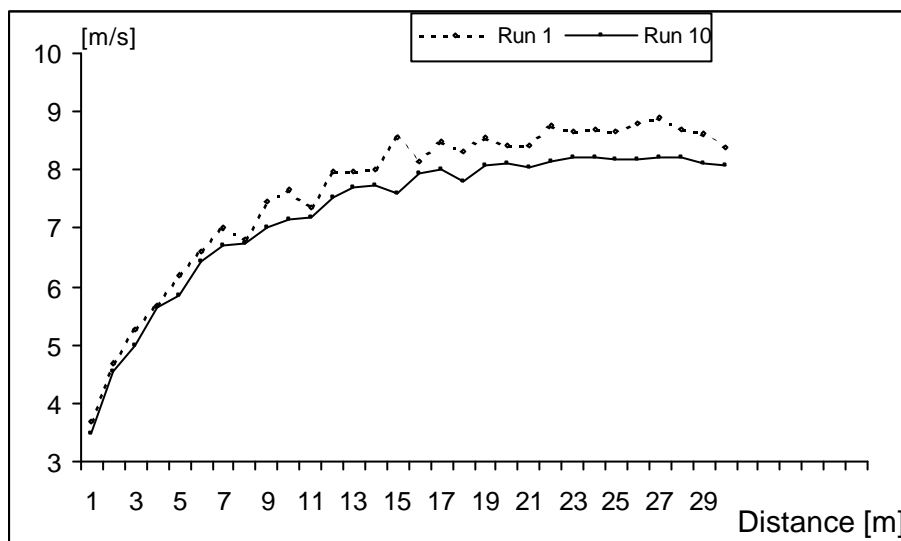
Fig. 5 The mean velocities at chosen distances registered in 1st and 10th sprint

Similar situation was registered at last two measuring points i.e. 20th (F=2,880 p=0,003) and 30th m (F=1,950 p=0,047). Tukey post-hoc tests showed that significant differences were observed between 1st and 4th (p=0,029) and 1st and 8th sprint (p=0,017) in case of 10th m. Interesting results were obtained at 15th m where post-hoc test was significant between 1st and all other repetitions of sprint. At 20th m only differences between 2nd and 7th (p=0,048) and 9th (p=0,033) were statistically significant.

The second stage of data analysis concerned changes in the level of mean values of maximal running velocity, which was obtained from the linear curve of whole distance registration. Mean levels of this variable are presented on fig. 7 linear regression line and individual dispersions.

The regression analysis showed that changes of the level of analyzed variable were statistically significant (F=72,844, p<0,0001). As it was expected, mean maximal velocity showed significant decrement with the lowest value registered in the last repetition.
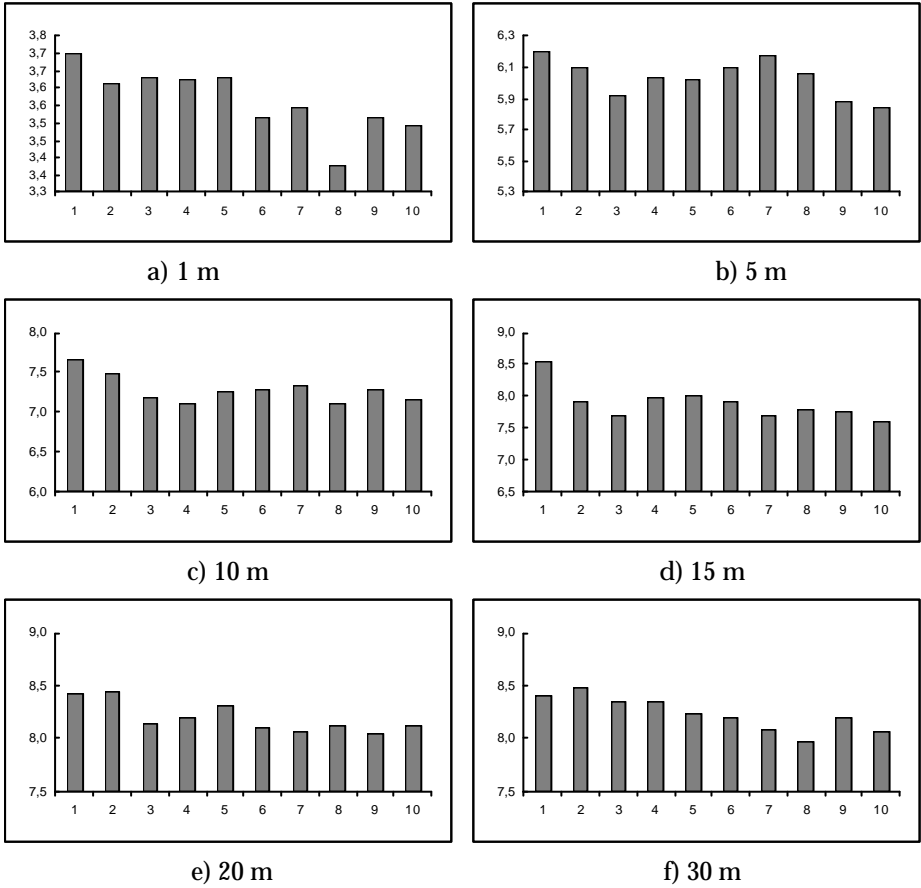
a) 1 m   b) 5 m

c) 10 m   d) 15 m

e) 20 m   f) 30 m

Fig. 6 The mean velocities at chosen distances in consecutive sprints

Table 2 The biochemical variables describing changes in homeostasis as a result of 10 x 30 m sprints

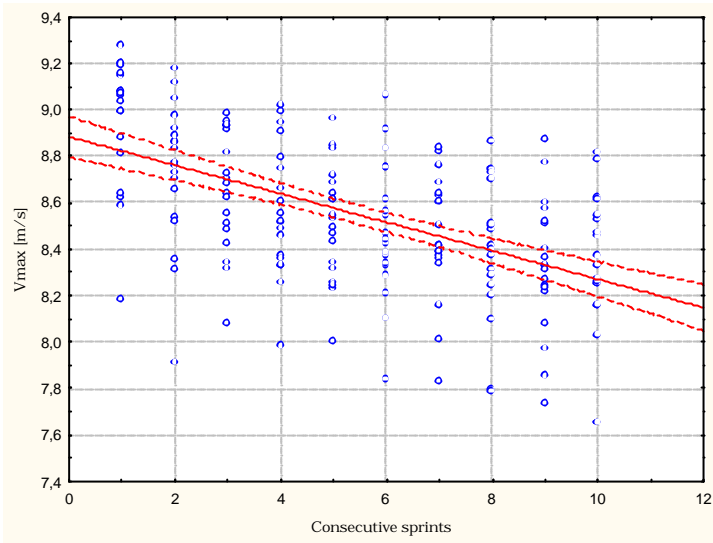| Variables	$\overline{X}$	SD	Abs.	[%]	F	P
LA rest	1,825	0,323	-8,499	565,775	275,917	0,000001
LA 4'	10,324	2,130				
pH rest	7,393	0,015	0,183	3,470	91,300	0,000001
pH 4'	7,210	0,076				
BE rest	0,500	0,945	15,284	-2956,840	295,699	0,000001
BE (B) 4'	-14,784	3,593				

Fig. 7 The mean values and individual dispersions of maximal velocities in consecutive sprints
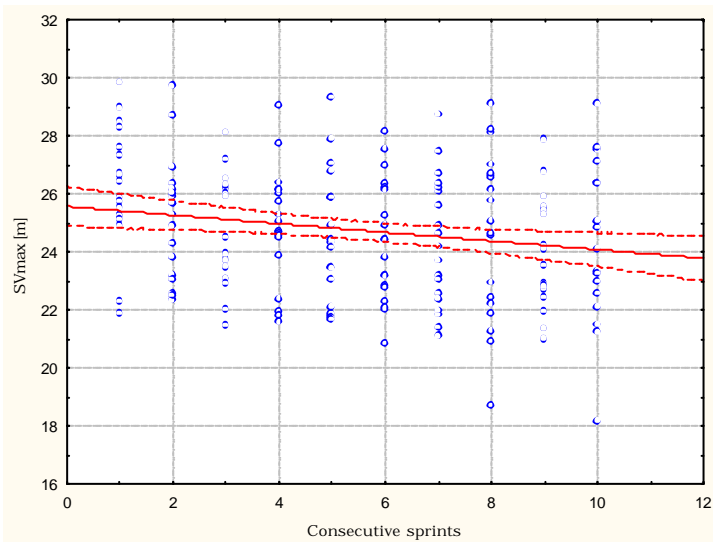

Fig. 8 The mean values and individual dispersions of distance of maximal velocity obtainment in consecutive sprints

Second variable registered in order to describe maximal running velocities was the distance at which this value was registered. In comparison to Vmax the changes in SVmax (fig. 8) were relatively smaller however still statistically significant (F=7,108 p=0,008).

As it was expected the changes in LA concentration, pH and base excess from rest values to post-exercise ones were extremely significant. The obtained values and significance showed beyond any doubts that performed exercise was extremely fatiguing.

Discussion

As it was mentioned the relative comparatory experimental data related to velocities in repeated sprints is scarce, so authors focused on experiments at least similar to presented above. Balsom et al. (1992) tested subjects at 15 x 40m sprints, on three occasions, with rest periods of either 120 s (R120), 60 s (R60) or 30 s (R30) between each sprint. The performance data indicated that running speed over the last 10 m of each sprint decreased in all three protocols performance during the initial acceleration period was only affected with the shortest rest periods. Post-exercise blood lactate concentration was not significantly different in R120 and R60, but a higher concentration was found in R30 (17.2±0,7 mmol/l-1). Evidence of adenine nucleotide degradation was provided by plasma hypoxanthine and uric acid concentrations, elevated post-exercise in all three protocols. Post-exercise uric acid concentration was not significantly affected by recovery duration. The results seem to be similar, however greater values of LA concentration probably resulted from greater number of repetitions and longer running distance. The work of Balsom et al. (1992) confirms that in order to disturb the kinematical performance of athletes the recovery periods should not be longer than 30 s.

Hamilton et al. (1991) compared physiological responses to maximal intermittent exercise: differences between endurance-trained runners and team sports athletes. They completed a standardized multiple sprint test on a non-motorized treadmill consisting of ten 6-s all-out sprints with 30-s recovery periods. Team sports athletes tended to produce a higher peak power output and higher peak speed, but had a greater decrement in mean power output than endurance-trained runners. Blood lactate after the test was higher for the team sports athletes, but the decrease in pH was similar for both groups. The average increase in oxygen uptake above pre-exercise levels during the sprint test was greater for endurance-trained athletes than for the team sports athletes, corresponding to an average oxygen uptake per sprint (6-s sprint and 24 s of

subsequent recovery) of 67.5 +/- 2.9% and 63.0 +/- 4.5% VO2 max respectively. Thus, the greater decrement in performance for the team sports athletes may be related to higher glycolytic rates as reflected by higher lactate concentrations and to their lower oxygen uptake during the course of the 10 sprints.

Berthoin et al. (2001) attempted to predict sprint kinematic parameters from anaerobic field tests in physical education students with the use of similar procedure to presented in this work method. During the first 10 s of the sprint, the position of the runners was "continuously" measured with a laser telemeter. Maximal acceleration (Amax), maximal velocity (Vmax), and time to reach Vmax (tVmax) were derived from position data. In addition, the subjects performed anaerobic tests. The highest significant correlations were calculated between Amax and V0 and counter movement jump and Vmax and standing long jump. The tVmax was uncorrelated to other tests. Therefore results fail to identify one anaerobic test that specifically explains one sprint kinematic parameter.

The relationship between maximal oxygen uptake and repeated sprint performance indices is worthy of focusing. Aziz et al (2000) used a treadmill run test to exhaustion to determine maximal oxygen uptake and 8x40 m sprints either on the field or running track to determine repeated sprint ability performance. Maximal oxygen uptake was not correlated with the fastest 40 m sprint time but was moderately correlated with total sprint time. Since the shared variance between maximal oxygen uptake and total sprint time was only 12%, further improvement of aerobic fitness will only marginally contribute to repeated sprint performance of the team sports athletes. It remains possible that a high level of aerobic fitness enhances other aspects of match play in games like soccer and hockey.

Conclusions

Obtained experimental data and theoretical overview allowed to formulate following conclusions:

1. Repeated 30 m sprints with short rest intervals significantly disturbed body homeostasis.
2. Maximal velocity decreases with each sprint, acquiring lowest level in 10th repetition.
3. Changes of mean velocities at chosen distances in consecutive sprints decreases but the course of changes have an unjustified character

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