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Lactate concentration and creatine kinase activity after 110-m and 400-m hurdles races

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Abstract

Introduction. 110-m and 400-m hurdles races are based on anaerobic energy metabolism which can induce muscle fatigue and muscle fiber damage. The most common biochemical parameters used in controlling athletes' training loads and post-exercise fatigue are blood lactate (La) concentration and creatine kinase (CK) activity. Aim of Study. The aim of the study was to determine and compare runners' biochemical response after 110-m and 400-m hurdles races. The influence of warm-up before both races was taken into consideration. Material and Methods. Eight male hurdlers took part in this research. They were subjected to two test exercises: a 110-m and a 400-m hurdles race. During each test, pre-warm-up, post-warm-up, and post-exercise capillary blood from a fingertip was collected to determine the La concentration and CK activity. Furthermore, during both sprint runs the athletes' time (to the nearest 0.01 s) and heart rate (HR) were measured. Results. Each kind of exercise test increased the La concentration and CK activity. More significant changes of both biochemical parameters occurred after the 400-m race. Furthermore, after each warm-up significant increases of La and CK levels were observed. After the 400-m hurdles race higher HR values were noted (184.50 ± 8.32 compared to 177.50 ± 11.14 after the 110-m sprint). Conclusions. Both specialist warm-up and 110 and 400 meters hurdles races lead to significant changes in athletes' physiological and biochemical blood parameters. La concentration and CK activity demonstrate greater muscle fatigue and muscle fiber damage after a 400-m than a 110-m hurdles race.

KEYWORDS: anaerobic exercise, hurdling, warm-up, muscle damage, muscle fatigue.

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What is already known on this topic?
110-m and 400-m hurdles races are exercise types not exceeding 60 seconds. Therefore they are based on the anaerobic metabolism of phosphocreatine and muscle glycogen. Depletion of anaerobic energy substrates causes rapid exhaustion and muscle fiber damage. Few studies have been published so far describing the metabolic response in hurdlers. No research comparing these two sprint track events has been published so far.

Introduction

Hurdles races are held over the distances of 100-m and 110-m for women and men, respectively, and 400 meters for both sexes. Junior hurdlers run over a shorter distance of 300 meters. Sprinting engages heavily the runner's muscular system. Muscles involved in the sprinter's locomotion can be divided into nine large muscle groups. Every muscle through its work (contraction) is responsible for individual elements performed by the athlete. Within most muscle groups one-step running contractions of various types (eccentric, concentric and isometric) can be observed [1].

The short duration of a sprint race (10-60 s) and its high intensity determine the metabolic pathways that produce the energy required to cover the energy expenditure of the working muscles. Short sprinting efforts such as 60-m and 100-m flat sprints, or 100-m and 110-m hurdles, are dominated by anaerobic metabolism based primarily on the hydrolysis of phosphagens, i.e. phosphocreatine [2, 3, 4, 5]. Efforts lasting for about 60 seconds (400-m flat and 400-m hurdles) involve the anaerobic breakdown of muscle glycogen, although an increase in the rate of aerobic metabolism can also be noted [6, 7, 8, 9]. In contrast to 100-m and 110-m hurdles races, efforts lasting about one minute lead to a substantial accumulation of metabolites such as lactic acid (LA), creatinine, hydrogen ions (H^+), and they also lead to damage of muscle fibers, which is demonstrated by an increase of LDH and CPK blood levels [6, 7, 10]. In scientific literature comparative studies of metabolic effects of 100-, 200-, 400- or 800-m flat races can be found [5, 7, 9, 10, 11]. Numerous articles have focused on biomechanical aspects of the running step in hurdling [12, 13, 14]. In spite of this, no paper comparing the metabolic response in hurdlers has been found.

Material and Methods

Participants

The study sample consisted of eight well-trained athletes competing in 110- and 400-m hurdles races (age 22.75 ± 3.62 years, body height 1.82 ± 0.06 m, body mass 74.87 ± 8.15 kg, BMI 22.58 ± 1.45). In the studied group four sprinters specialized in 110-m hurdles, while the other four in 400-m hurdles. The athletes expressed their voluntary agreement to undergo exercise tests, and were given the opportunity to discontinue their participation in the experiment without providing any reason. Permission to carry out the measurements and collect blood samples was obtained under Resolution 380/15 issued by the Bioethics Committee of the Poznań University of Medical Sciences on 9 April 2015.

Procedures

Eight athletes undertook two exercise tests: a 110-m and a 400-m hurdles race. The races were held on two consecutive days of 16 and 17 April 2015, in the afternoon, from 15.00 to 17.00. Before each test all sprinters performed a standard warm-up. On the first day the 110-m hurdles race took place (hurdle height 91.4 cm, distance between hurdles – 9.14 m, and between the start line and the first hurdle – 13.72 m). On the second day the 400-m hurdles race was held (hurdle height – 83.80 cm, distance between the hurdles – 35 m, distance between the start line and the first hurdle – 45 m). The results of the races were measured to the nearest 0.01 of a second using a set of FK2000k photocells (Slandi, Poland). The sprinters' heart rate during the tests was measured using an RS400 electronic heart rate monitor (Polar, Finland).

Blood Sampling

Blood samples were collected from the runners by professional laboratory staff. All the cleaning and care rules were strictly adhered to during blood collection. Capillary blood was collected from a non-dominant fingertip, using a disposable lancet-spike Medlance® Red (HTL-Zone, Germany) with a 1.5 mm blade and 2.0 mm penetration depth. 50 ml of material was collected into a neutral (without anticoagulant) glass capillary (Vitrex, Medlab, Poland), and then deproteinized in 0.6 mol·L^{-1} of perchloric acid ($HCLO_4$). After centrifuging (4000g/10min/4°C) the supernatant was isolated for lactate determination. Moreover, 300 ml of blood was collected into a Microvette® CB 300 Z tube (Sarstedt, Germany) with a clotting activator for analysis of creatine kinase activity in separated serum.

Each day during the experiment capillary blood was collected three times, before and after warm-up, and 3 minutes directly after the race.

Biochemical Analysis

Enzymatic determination of lactate (La) concentration was based on methodology proposed by Maughan [15]. Lactate is converted to pyruvate during a reaction with the oxidized form of nicotinamide adenine dinucleotide (NAD^+) and lactate dehydrogenase (EC 1.1.1.27) in a glycine-hydrazine buffer (pH = 9.0). The activity of creatine kinase (CK) was determined with the use of commercially available reagents (Liquick Cor-CK, Cormay, Poland).

Spectrophotometric measurements were performed using a multi-mode microplate reader (Synergy 2 SIAFRT, BioTek, USA) on maximum absorption at λ = 340 nm after one hour (ambient temperature) for lactate concentration, and after 10 minutes of incubation in 37°C for CK activity, respectively.

Statistical Analyses

Statistical analysis was performed using Excel 2010 spreadsheets and the 10.0 Statistica software package (StatSoft. Inc., USA). Variables subjected to statistical analysis showed the characteristics of normal distribution during all exercise tests. These indicators were verified

Table 1. Running times and heart rate values (mean ± SD) during 110-m and 400-m hurdles races

Sprinter no.	110-m hurdles race		400-m hurdles race	
	time [s]	HR [bpm]	time [s]	HR [bpm]
1	14.51	176	61.02	187
2	15.95	176	62.58	190
3	17.01	184	63.47	179
4	16.55	158	62.57	170
5	15.58	195	63.34	195
6	15.39	186	62.84	177
7	17.27	175	62.53	189
8	16.82	170	63.21	189
mean ± SD	16.14 ± 0.94	177.50 ± 11.14	63.04 ± 1.41	184.50 ± 8.32

HR [bpm] – heart rate [beats per minute]; SD – standard deviation

using Student's t test to compare changes between the results obtained at rest, warm-up, and after the exercise test. The resulting differences in the results of individual tests were also analyzed with Student's t test. The level of significance for all analyses was set at 95% (*$p < 0.05$).

Results

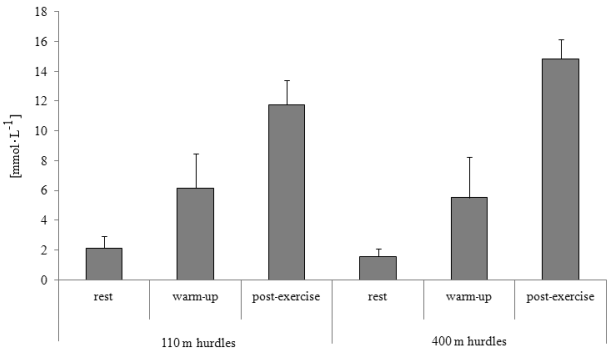
Table 1 presents the results of running and post-exercise values of heart rate (HR). A higher HR average value was recorded on the 400-m hurdles (400-m: 184.5 ± 8.32 bpm; 110-m: 177.5 ± 11.14 bpm). The running times at 110-m and 400-m ranged from 14.51 s to 17.27 s, and from 61.02 s to 63.47 s, respectively.

Figure 1 and 2 show the concentrations of blood lactate and CK activity measured on the first and the second day of testing. The La and CK resting levels were within physiological limits. The warm-up before both the 110-m and the 400-m hurdles race caused a statistically significant increase in the blood levels of La ($p < 0.01$) and CK ($p < 0.01$). Higher post-exercise concentrations of La and CK were recorded after the 400-m hurdles race (14.8 ± 1.3 mmol·L^{-1} and 419.0 ± 173.7 U·L^{-1}, respectively).

Figure 3 shows post-exercise increases in La and CK levels after both hurdles races. After the 400-m hurdles significantly higher increases in both indicators were recorded.

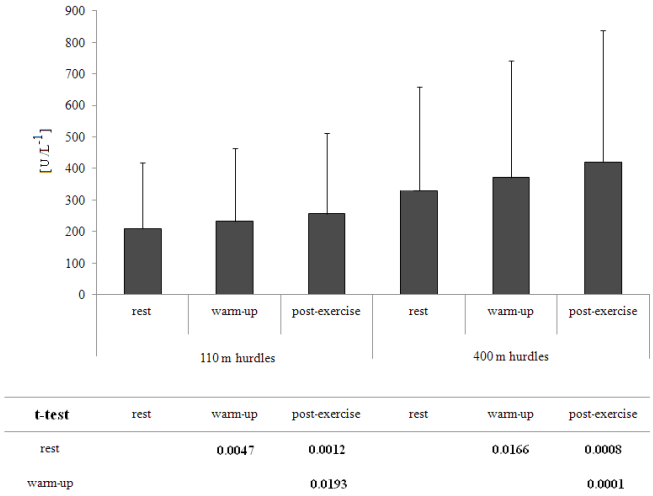
Discussion

The studied group of hurdlers was not homogeneous in terms of anthropometric parameters. The sprinters' mean body height and body mass amounted to 1.82 ± ± 0.06 m and 74.87 ± 8.15 kg (min-max differences being 0.20 m and 23.35 kg, respectively). Similar differences were also noted among the world's leading hurdlers. Caucasian athletes such as Artur Noga and Petr Svoboda are taller and heavier (196 cm, 92 kg, and 195 cm, 83 kg, respectively), while Dominik Bochenek is shorter and lighter (177 cm, 72 kg). The body height and body mass of non-Caucasian hurdlers such as Aries Merritt, Colin Ray Jackson and Liu Xiang are 188 cm and 75 kg, 182 cm and 75 kg, and 189 cm and 85 kg,



t-test	rest	warm-up	post-exercise	rest	warm-up	post-exercise
rest		0.0004	0.0000		0.0044	0.0000
warm-up			0.0003			0.0000

Figure 1. Concentration of blood lactate at rest, after warm -up and post-exercise in 110-m and 400-m hurdles races. The relations between the measurements are shown in the table below Figure 1



t-test	rest	warm-up	post-exercise	rest	warm-up	post-exercise
rest		0.0047	0.0012		0.0166	0.0008
warm-up			0.0193			0.0001

Figure 2. Blood creatine kinase activity at rest, after warm-up and post-exercise in 110-m and 400-m hurdles races. The relations between the measurements are shown in table below Figure 2

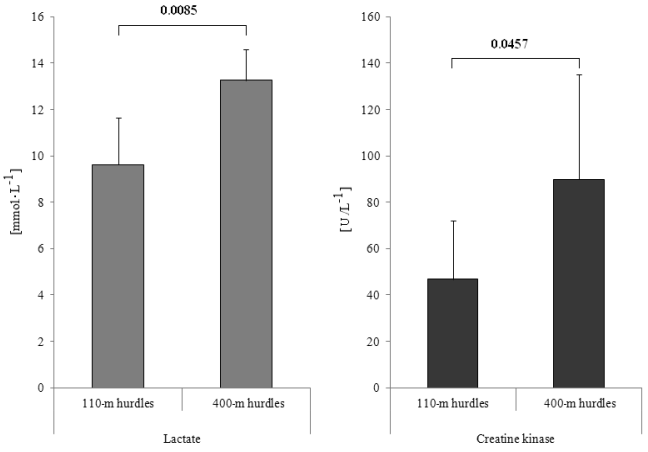


Figure 3. Comparisons between post-exercise and rest differences in blood lactate concentration and creatine kinase activity in 110-m and 400-m hurdles races

respectively [16]. The tested sprinters did not differ significantly in anthropometrical parameters from the world's elite hurdlers.

In the studied group of hurdlers the average HR values after the 110- and 400-m hurdles races amounted to 177.5 and 184.5 bpm, respectively. In Gupta et al. [17] the average HR value amounted to 176.7 bpm in an 8-person group of sprinters after a 400-m hurdles race. Higher HR values (189.9) after a 400-m hurdles race were recorded by Zouhal et al. [9]. In our study, the maximum post-exercise HR value was 195 bpm, and in Gupta et al. – 192 bpm. In both studies the hurdlers achieved similar HR values. Novak et al. [18] found that flat running at the same distances led to greater HR changes (200.1 bpm).

A biochemical index of muscle fatigue and damage used in different sports is the creatine kinase level (soccer [19], marathon [20], 400-m flat sprint [6]). In our study the post-exercise creatine kinase activity was within the reference range, i.e. from 209.3 to 329.2 $U \cdot L^{-1}$ [21]. Both exercise tests resulted in a statistically significant increase in the CK level. A higher CK activity was recorded after the 400-m hurdles race. A search of the available databases produced only a few reports on CK activity in flat sprints. Kłapcińska et al. [22] observed an increase in CK activity from 168 $U \cdot L^{-1}$ to 223 $U \cdot L^{-1}$ after a 300-m run. Similar changes in CK levels in our study were observed after the 110-m hurdles race (46.8 $U \cdot L^{-1}$), and the 400-m hurdles race (89.8 $U \cdot L^{-1}$). On the other hand, Hellsten-Westing et al. [23] found no significant differences in creatine kinase activity after a 100-m flat sprint. A significant increase in CK activity after the 110-m hurdles race may be due to the slight increase in distance and duration of the exercise and different biomechanics of the hurdler's steps. Compared to a 100-m flat sprint in a 110-m hurdles race the same muscles are loaded more heavily, which can cause a more significant increase in creatine kinase activity. Okhuwa et al. [6] in a study of 400-m sprinters found a relationship between the speed of overcoming distance and CK activity. Surprisingly, exercise-induced creatine kinase level was lower in a sprinter who overcame the distance at a higher speed. This might have been due to the fact that the lower running speed results in a longer exercise time over a given distance, and thus longer engagement of muscle fibers. It might be assumed that sprinters ran more slowly, and that their fitness level was lower in competition compared to faster athletes and their muscles response to the stronger damage of muscular fibers. No similar correlations were found in the present study.

The blood lactate level indicates the load sizes during exercise [24]. An exercise-induced higher La concentration was recorded after the 400-m hurdles race (14.8 mmol/L). In Gupta et al. [17] these values were higher but comparable (16.1 $mmol \cdot L^{-1}$). Lacour et al. [7] in a study of sprinters running a 400-m (flat) race noted a higher La level (20.1 $mmol \cdot L^{-1}$). These observations correspond with those of Zouhal et al. [9], who found that running flat over 400 m increasingly involves anaerobic glycolytic metabolism than running the same hurdles distance. In the studied group the mean

LA concentration after a 110-m rose to 11.8 mmol·L^{-1} which is higher than in sprinters running a 100-m flat race (8.51 mmol·L^{-1} [10]; 9.0 mmol·L^{-1} [5]). A study revealing changes in lactate levels after a 110-m hurdles race concerned a decathlon competition, and values ranged from 5.74 to 8.19 mmol·L^{-1} [25].

In our study, also measurements of La and CK levels after the warm-up were performed. It turned out that warm-up has a significant impact on all measured parameters. Similar changes were noted in earlier studies [9, 17]. The authors of those studies found that the warm-up carried out before a 400-m hurdles race resulted in an increase in lactate concentration to 4.0 ± 0.5 mmol·L^{-1} and 8.4 ± ±2.4 mmol·L^{-1}. In our study, the warm-up before the 400-m and 110 m races increased the lactate concentration to 5.5 ± 2.7 mmol·L^{-1} and 6.1 ± 2.3 mmol·L^{-1}, respectively. Post-warm-up La accumulation ranged from 4 to even 8 mmol·L^{-1} revealing a high intensity of this part of sprinter's preparation.

Conclusions

Both a specialist warm-up and 110-m and 400-m hurdles races lead to significant changes in physiological and biochemical blood parameters. The 400-m hurdles race is an exercise which is metabolically much heavier than the 110-m hurdles. Although the men's 110-m hurdles race is dominated by phosphagen energy metabolism, also a significant glycogen anaerobic energy metabolic process was found.

What this study adds?

The study revealed significant differences in metabolic response after both a 110-m and 400-m hurdles race. A higher concentration of lactate after the 400-meter hurdles race indicates a greater involvement of anaerobic glycolysis than after the 110 m hurdles race. A significant increase of lactate level after the 110-m hurdles sprint also shows that even in such a short sprint competition, glycogen metabolism plays a crucial role. The higher CK activity after the 400-meter hurdles race indicated a greater level of muscle fatigue and damage. This is an important sign for trainers, which should be taken into consideration in planning recovery breaks during the training process. Coaches and athletes should also take into account the impact of warm-up on energy metabolism. A warm-up which exceeds the lactate threshold leads to an increase in blood lactate concentration and fatigue. This all point to the importance of control of warm-up intensity before training sessions and competitions.

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