INFLUENCE OF FATIGUE IN THE SELECTED KINEMATIC PARAMETERS OF HURDLE CLEARANCE IN 400 METRE RACE - IN SEARCH OF AN ACCURATE TRAINING TEST

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The paper describes a initial study on the effects of fatigue on the selected kinematic parameters of hurdle clearance. Original test involving a hurdles race over 5 hurdles on a curve was used. The analysis concerned clearing the third hurdle in the initial and final (after the 200 m hurdles race) phase of the race. The study analyzed 15 parameters in five phases of hurdle clearance estimated using the particle swarm optimization algorithm. The material was recorded with a 100 Hz industrial camera. The results indicate that the basic parameters in the changes of a hurdling technique influenced by fatigue include: length of the hurdle clearance and landing distance past the hurdle.

KEY WORDS: hurdle clearance, 400 m hurdle races, kinematic parameters.

INTRODUCTION: Hurdling is a category of athletics events where one of the decisive elements is the technique of clearing the hurdle. Most studies in this area relate to sprint races i.e. 110 m races (Salo et al., 1997; Čoh, 2013). This is due mainly to the facilitation of a technical nature, because such races take place in a straight line which makes the implementation of research easier. Much more difficult to implement are kinematic analyses of a 400 m race because there are two significant drawbacks. The first problem concerns the fact that the 400 m hurdles race takes place on a curve making data acquisition difficult. Apart from that, which is crucial from an organizational point of view, fatigue in the second part of the distance does not allow for precise determination of which leg the athlete is going to use while jumping the hurdle (Iskra, 2013). Therefore, there is a need for reliable research in this area.
The main aim of this research was to evaluate the effects of fatigue on the level of technique of hurdle clearance in the 400 m hurdles race. It was a initial study. An innovative element of the presented research is the analysis of hurdle clearance on a curve.

MATERIAL AND METHODS: The tests were carried out on an athletics stadium. The analysis concerned a high-level athlete (his personal life record at 400 m hurdles was 50.40 s). The study specified 14 kinematic parameters, including 10 distance and 4 angular ones. The characteristics of the measured parameters, with the division into the analyzed phases, is shown in Figure 1.
The test protocol was designed to assess scientifically techniques of clearing the hurdles on a curve taking into account the conditions of training during the special preparation phase. With this assumption in mind, the test of a hurdles race designed by the authors was used. The test has been adapted to real training conditions. The basic the idea behind the development of the test was the possibility of using it during each period of training, in groups of athletes with different levels of sports performance and different stride pattern. The standard distance between hurdles (35 m) was abandoned because (1) athletes perform this form of hurdles race only in the initial training and pre-competition period and (2) clearing the hurdle during increased fatigue leads to a change of the lead leg and unpredictable shortening or lengthening of the last strides before the hurdle. The analysis of hurdle clearance technique would be (from coach's and scientific point of view) very accurate, while taking into account the uncontrolled change of the lead leg. During the test the athlete performed two attempts of hurdling. In the first attempt he cleared 5 hurdles (on a curve), then 1 minute after clearing the hurdles he ran on a flat distance of 200 m with maximum intensity. After completing the 200 m run and after a one-minute rest he made a second attempt at clearing 5 hurdles also on a curve. In both cases hurdle clearance was recorded at the third hurdle, which was located at the centre of the curve. The distance between the

hurdles was 10x the height of the competitor (Iskra, 2012). As it was demonstrated by previous analyses (Kodejs, 1987; Iskra and Walaszczyk, 2007; Iskra, 2008), an important parameter in determining the stride pattern is body height. The two sequences were recorded with an industrial camera Basler Ace acA645-100gc of 100 Hz frequency. The method of particle swarm optimization (PSO) was used in order to estimate the parameters (Kwolek et al., 2011). The details of using the PSO algorithm for parameter estimation of hurdle clearance were described in the authors' earlier works (Krzeszowski et al., 2016).

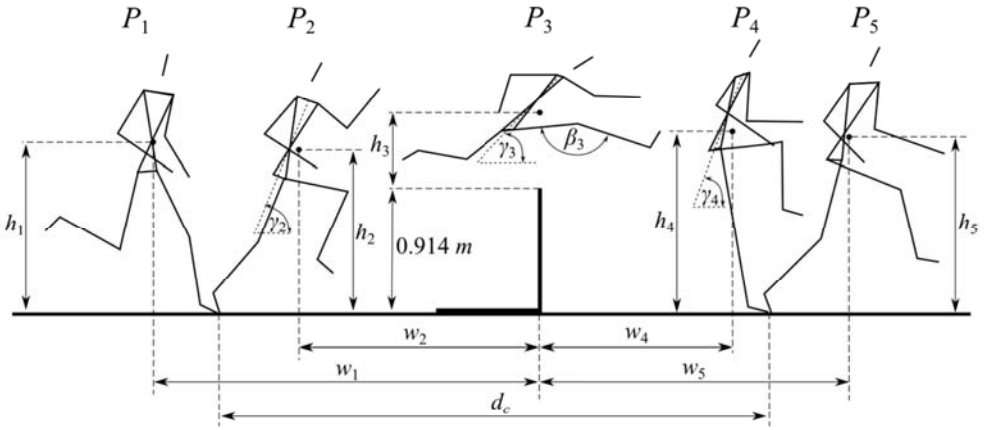

Figure 1: Selected parameters of hurdle clearance

RESULTS AND DISCUSION: The 14 kinematic parameters were analyzed, which were measured at two attempts: 1st attempt – clearing the third hurdle, 2nd attempt – clearing the third hurdle while being fatigued. Table 1 shows the measured values of parameters, and the relative difference expressed by the formula:

$$\Delta = \frac{|X_1 - X_2|}{X_1} * 100$$

where: X_1 – first attempt, X_2 – second attempt, Δ – relative difference.

Table 1
Values of parameters of hurdle clearance

Parameter	X_1	X_2	Δ [%]
Phase 1:			
h_1 - height of the centre of mass [mm]	994	991	0.3
w_1 - distance from the centre of mass to the hurdle [mm]	2791	2572	7.8
Phase 2:			
h_2 - height of the centre of mass [mm]	1023	1038	1.5
w_2 - distance from the centre of mass to the hurdle [mm]	1924	1694	12.0
γ_2 - angle of torso [deg]	61	60	1.6
Phase 3:			
h_3 - height of the centre of mass [mm]	348	356	2.3
γ_3 - angle of torso [deg]	47	48	2.1
β_3- angle of bend of lead leg [deg]	161	163	1.2
Phase 4:			
h_4 - height of the centre of mass [mm]	1038	1020	1.7
w_4 - distance from the centre of mass to the hurdle [mm]	1097	1190	8.5
γ_4 - angle of torso [deg]	61	62	1.6
Phase 5:			
h_5 - height of the centre of mass [mm]	1004	1020	1.6
w_5 - distance from the centre of mass to the hurdle [mm]	1633	1902	16.5
d_c - length of hurdle clearance [mm]	3709	3124	15.8

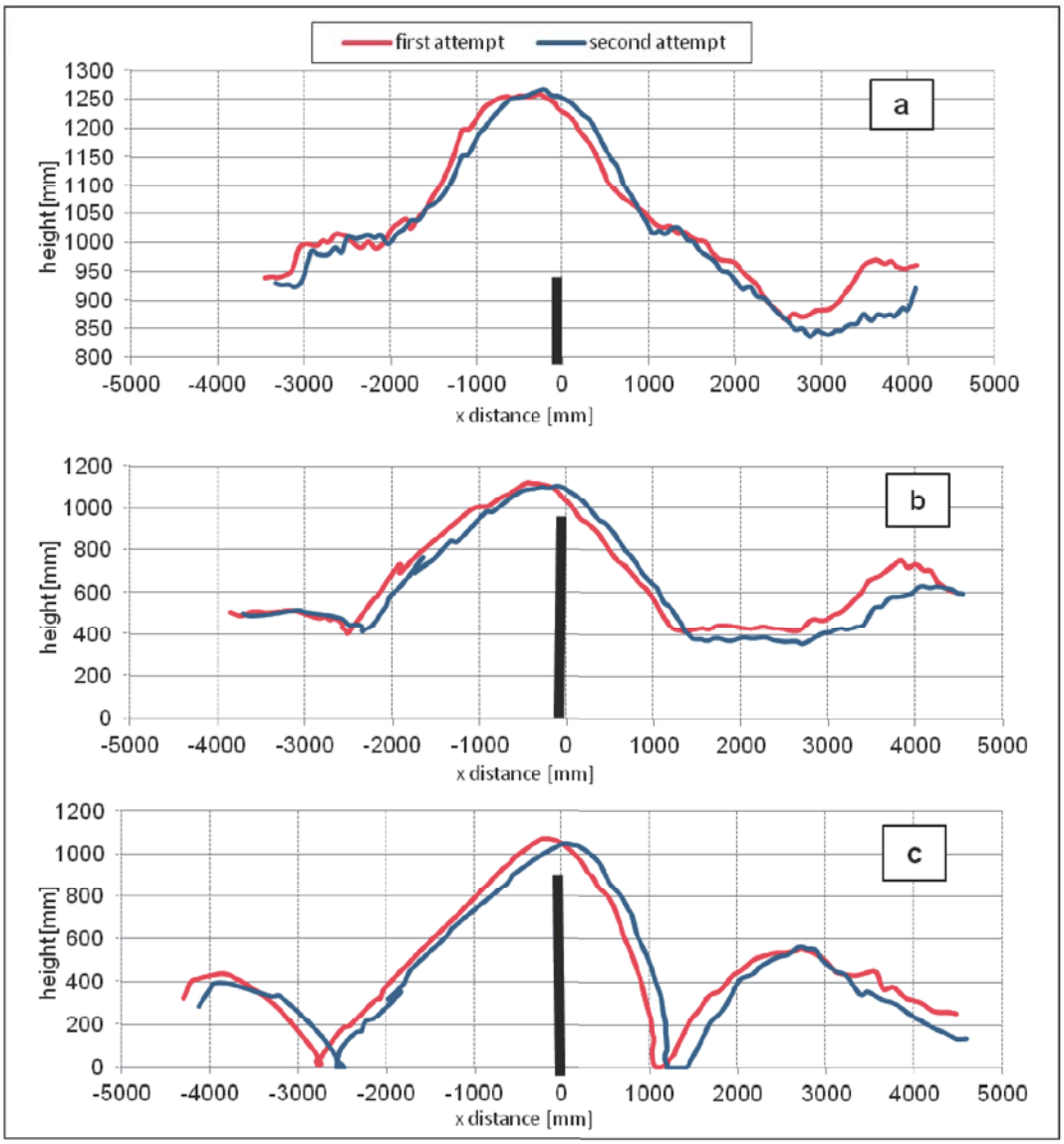

Figure 2: Movement trajectory of selected body parts of athlete in two attempts; a) center of gravity, b) knee of lead leg, c) foot of lead leg. The 0 value on x-axis represents position of hurdle.

The analysis shows that in the majority of the analyzed parameters, there were no changes over 3%. The parameters which are characterized by relatively large changes are distance parameters (distance from the centre of gravity to the hurdle), they changed from 7% to 16%. This influenced directly hurdle clearance, where the differences were recorded at the level of 16%. The length of the whole hurdle clearance (d_c) during the second attempt was shorter by up to 585 mm. It can be concluded that the basic parameters indicative of the changes in the technique of hurdling during intensified fatigue include: length of hurdle clearance (d_c) and distance from the centre of mass to the hurdle in the fifth phase (w_5). This data confirms the intuitive observations of coaches as well as a few earlier analyses concerning the impact of fatigue on technique of 400 m hurdles races (Schwirtz, et al., 1990; Guex, 2012). At the same time the changes in the kinematic structure of the movement confirm the need for special technical training: so-called "long rhythm" and endurance elements of hurdle technique (Iskra, 2013).

Additionally, in order to illustrate the kinematic characteristics of hurdle clearance, trajectories of the selected body segments of a hurdler were determined (Figure 2). The centre of mass, the knees and the feet of the lead legs were analyzed. The trajectories, which were calculated, indicate that the competitor had a very good technique, even when he was tired, because it did not influence significantly the way of clearing the hurdle. It may indicate a well settled motor habit.

CONCLUSION: The analysis undertaken allowed to observe the most important parameters characterizing hurdling technique at the moment of fatigue, taking into account the race on the curve. The research protocol has confirmed the applicability of the test during specialized sports training. During discussions with the coaches of the Polish national team it was suggested that race distance between attempts should be extended to 300 m. Changes in the hurdling technique at the final phase of the distance fully justify the use of training means related to strength endurance.
Future studies will focus on the analysis of hurdles clearance on a curve among high level competitors. In order to minimize measurement errors various methods of tracking movement will be verified. Additional cameras will be used to facilitate estimation for parameters and increase accuracy.

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