COMPARATIVE BIOMECHANICAL ANALYSIS OF 110 m HURDLES OF IGOR KOVÁČ AND PETER NEDELICKÝ

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PRIMERJALNA BIOMEHANIČNA ANALIZA TEKA NA 110 M OVIRE IGORJA KOVAČA IN PETRA NEDELICKYJA

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Abstract

The biomechanical characteristics of two athletes' technique in 100m hurdles were analysed, trying to find the parameters leading to the difference in their running results. The measurements were performed in the final race of the IAAF-II meeting Slovnaft '97 in Bratislava. The subjects were I.K. with a personal best of 13.13 s and P.N. with 13.97 s. They were filmed with a S-VHS camera at 50 Hz on the 8^{th} hurdle. The film was analysed with the BAF 2D video analysis system, the time, space and velocity parameters were obtained and joint moments of the knees and hips computed.

The competitors realise the support phase before and after the hurdle in different ways. The position of C.G. before the hurdle is lower for I.K., he has a longer breaking and acceleration phase. However, differences are mostly in the kinematics after the hurdle. I.K. goes to touch-down with a higher C.G. position. His elastic stiffness is more developed because of quicker deceleration of C.G. lowering during the first part of the support phase after the hurdle. Also, during take-off, the position of C.G. of I.K. is higher. This leads to I.K.'s higher velocity with shorter support and acceleration phases.

Keywords: hurdle clearance, braking and acceleration phase, kinematic structure, takeoff and landing

Izvleček

V delu so bile analizirane biomehanične značilnosti tehnike prehoda ovire dveh tekmovalcev v teku na 110 m ovire, z namenom ugotoviti kateri parametri pripeljejo do razlike v njunem tekmovalnem rezultatu. Meritve so bile opravljene v finalu IAAF-II mitinga Slovnaft '97 v Bratislavi. Subjekta sta bila I.K. z najboljšim časom 13.13 s in P.N. s 13.97 s. Posneta sta bila s 50 Hz S-VHS kamero na osmi oviri. Posnetki so bili analizirani z BAF 2D video sistemom, dobljeni so bili časovni, prostorski in hitrostni parametri ter izračunani momenti v kolenih in bokih.

Tekmovalca izvajata podporno fazo pred in po oviri na različen način. Položaj težišča telesa I.K. pred oviro je nižji, ta tekmovalec ima tudi daljšo zaviralno in pospeševalno fazo. Vendar je največ razlik v kinematiki po oviri. I.K. ima višji položaj težišča telesa ob pristanku. Njegova elastična togost je bolj razvita, kar se vidi iz hitrejše deceleracije pri spuščanju težišča telesa v prvem delu podporne faze po oviri. Ta tekmovalec ima tudi višji položaj težišča telesa pri odrivu. Vse navedeno pripelje do večje hitrosti in krajše podporne in pospeševalne faze pri I.K..

Ključne besede: prehod ovire, zaviralna faza, pospeševalna faza, kinematična struktura, odriv, pristanek

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INTRODUCTION

110 m hurdles has a extraordinary demands to the hurdler from the point of view of sprint speed, explosive strength, special co-ordination and rhythm. Their characteristics are clearly shown in the parameters of the technique economy. A lot of authors have been already interested – in hurdling technique. The biomechanical models defined by time, spatial and velocity parameters are presented in the contributions of the following authors: Oros (1980), Schlüter (1981), Kollath (1983), Kampmiller – Koštial (1987), McDonald – Dapena (1991), LaFortune (1991), Hommel Vernon (1991), McLean (1994), Milerová a kol. (1996), Čoh (1997). They coincide that hurdling inevitable needs to minimise the velocity loss during the takeoff phase and mainly by the landing phase at the moment of touchdown. As base parameters for the technique economy evaluation in these phases are usually used the angle of takeoff and landing angle at the moment of touchdown. Individual analysis of the technique and rhythm of the hurdling are done by Glad Brüggemann (1990), Mero – Luhtanen (1991), Dapena (1991), Arnold (1993), Hommel (1995), Iskra (1995) on the sample of the world best hurdlers. They refer to claims of creation of the individual models of the hurdling technique. At the same time they analysed insufficiency each individuals from the point of view of rational generalised model.

The object of our research was the hurdle clearance with support phases before and after the hurdle. In particular the landing phase and following support phase after the hurdle clearance are significantly different from sprint support phase and takeoff preparation phase of jumping events. The main aim of the movement during both support phases of the hurdling before and after the hurdle clearance is to maintain the velocity as much as possible.

METHODS

The measurement was performed on the final race of 110 m hurdles during IAAF II meeting Slovnaft '97 in Bratislava. Sample was made by I.K.with personal best (P.B.) 13.13 s and 13.48 s performance during analysed race. The second member of the sample was P.N. with personal best 13.97 s and 14.09 s performance during analysed race. The movement for analysis was filmed by S-VHS camera with frequency of 50 Hz on the 8 the hurdle. Record movement has bee analysed by two dimensional (2D) video analysis system BAF. By the 2D analysis we have obtained the time, spatial and velocity parameters. Also resultant and total joint moments of knees and hips were calculated. We were going out of contributions, which have been done by Carol (1991) and Sanders (1996). We assume that resultant force of C.G. (centre of gravity) is based on the principle of action and reaction and therefore compensated by the force with equal value and opposite direction in the support place. The reaction force can by divided to horizontal and vertical parts. It is a basis for the creation of the force moments in the joints of lower extremities. The addition of these moments equals the resultant joint moments (RJM). During the lash phases following forces affect to the segments of unsupported leg: centrifugal force evoked by angular velocity, inertial force excited by angular acceleration and forces effected by gravity of each segment. These forces are included in total joint moment (TJM) of unsupported lash leg. To eliminate the random errors we applicate to the entry data the method of cascade gliding averages (Kendal,1976).

RESULTS

The trajectory of C.G. and the curve of vertical and horizontal velocity are presented on the figure 1 and 2. Table 1 contains the high of C.G. in selected positions. I.K. has a wider angle of activity during support phase before hurdle an about 9°. P.N. presents a higher position of C.G. (P.N.'s 106.4 cm vs. I.K.'s 103.4 cm) during the first part of support phase before takeoff to the hurd-

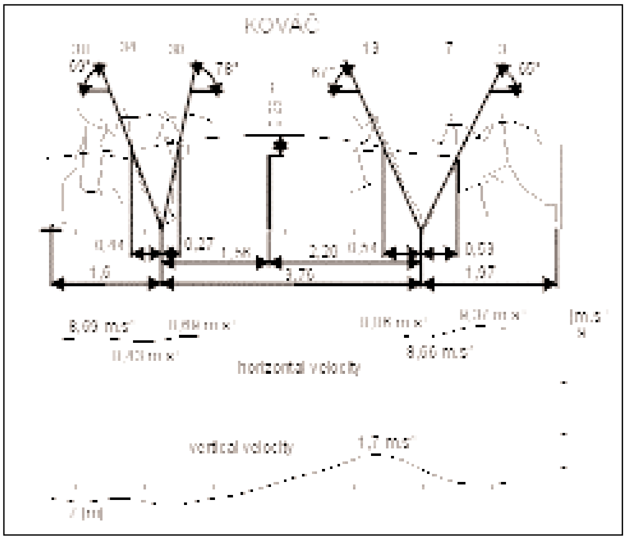

Figure 1

Tab.1 High of C.G. in the choice positions during the hurdle clearance

		I.K.		P.N.
	Position	High (cm)	Position	High (cm)
Start of takeoff	7	103.4	10	106.4
End of takeoff	13	115.6	15	119.3
	14	119.6	16	123.4
Start of touchdown	30	123.1	35	119.4
	31	120.2	36	115.5
End of touchdown	34	114.7	40	107.9
	35	113.5	41	106.7

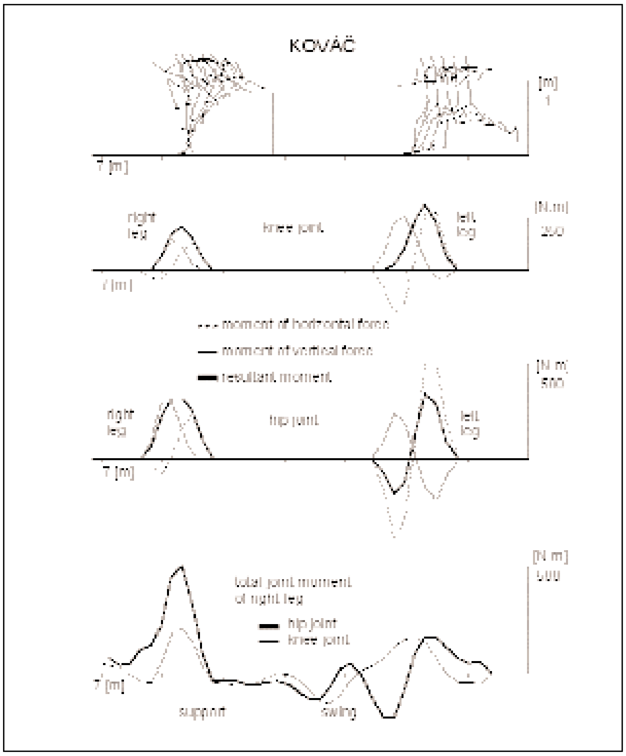

Figure 2

le. It results to the keener angle in the moment of touchdown (65° vs. 67°) and the longer breaking phase (53 cm vs. 47 cm). This activity is going to higher decreasing of horizontal velocity for I.K. an about 0.7 $m.s^{-1}$ while as for P.N. it is only 0.56 $m.s^{-1}$. The takeoff angle is for I.K. 67° and for P.N. 74°. It corespondates with longer acceleration phase of I.K. (54 cm) than P.N.'s (34 cm). It makes a higher increasing of horizontal velocity (0.20 $m.s^{-1}$ vs. 0.19 $m.s^{-1}$). The value of vertical velocity after the takeoff is in spite of different solution of the movement structure almost the same (1.70 $m.s^{-1}$ vs.1.73 $m.s^{-1}$).

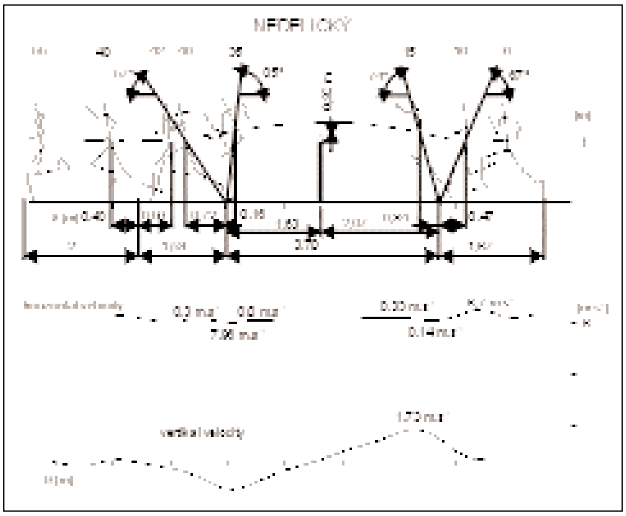

Figure 3

The stride length over the hurdle (so called »clearance phase«) is very similar 376 cm for I.K. and 370 cm for P.N. The highest position of C.G. over the hurdle is 29 cm vs. 30 cm. Despite of higher position of C.G. over the hurdle P.N. slightly strikes the hurdle as it is visible at figure 4. We find out also the differences between the hurdlers in distances of the takeoff positions 220 cm for I.K. vs. 207 cm for P.N. The deviations are also found by distances from instep to the hurdle during the moment of touchdown (so called »landing distance«) 156 cm vs. 163 cm. Owing to different takeoff angles has I.K. less value of vertical velocity of C.G. in the moment of touchdown 1.16 $m.s^{-1}$ vs. 1.71 $m.s^{-1}$. We can affirm that I.K. at the moment of touchdown falls down more slowly than P.N. It entails to the less value of vertical force and resultant joint moments of knee and hip. The high of C.G. positions at the moment of touchdown after the hurdle is in table I. For I.K. it is in 30th position and high of C.G. in this moment is 123.1 cm and for P.N. it is in 35th position with high of C.G. 119.4 cm. That is probably caused by different length of lower extremities, higher position of ankle, knee and hip joints. (We do not have any antropometric parameters.) It is possible that I.K. is able to deviate the axis of hips in frontal plane more than P.N., but this phenomena is unidentified from the sagital plane view, which was used for 2D analysis. Landing angle at the moment of touchdown after the hurdle is for I.K. 78° vs. P.N. 85°, so that breaking phase is by I.K. an about 9 cm longer

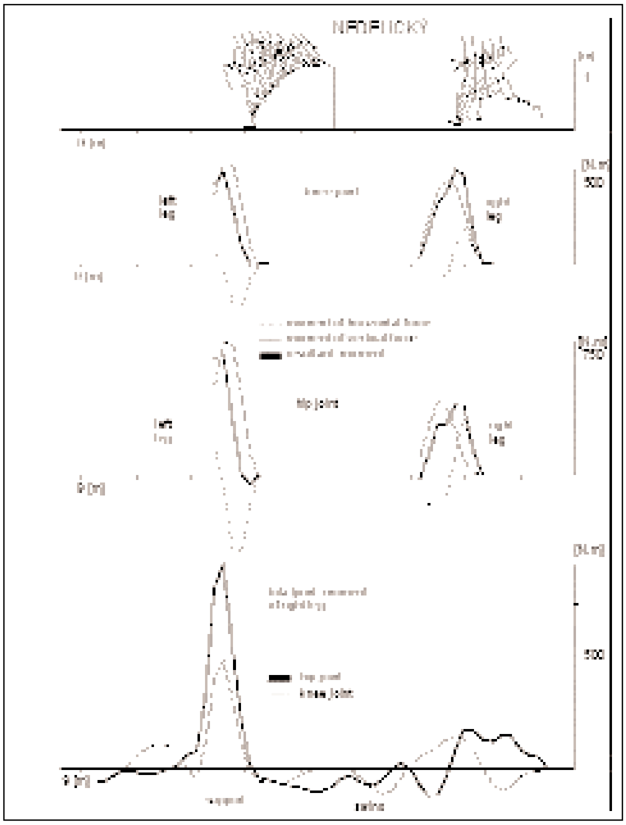

Figure 4

than P.N. s (27 cm vs. 16 cm), also I.K.'s decreasing of horizontal velocity is larger than P.N. s (0.26 $m.s^{-1}$ vs 0.04 $m.s^{-1}$) The length of C.G. s trajectory during the support phase has I.K. shorter than P.N. (44 cm vs. 72 cm) and takeoff angle is for I.K. 69° vs. P.N.'s 57°. This kinematics parameters also exert the influence upon increasing the horizontal velocity (I.K.'s 0.26 $m.s^{-1}$ vs. P.N.'s 0.34 $m.s^{-1}$).

Figure 3 and 4 presents the kinograms of landing phases up to the touchdowns before and after the hurdle. I.K. use the active way of touchdown that is characterised by negative horizontal velocity of instep after the hurdle clearance tightly to touchdown. On the other hand P.N. has more active touchdown before the hurdle. As for landing phase we observe by P.N. wider range and dynamics of vertical velocity. It corespondates with larger maximal values of vertical force of C.G. and RJM of knee. The flight parabola is more fluent by I.K., all of kinematic and dynamic parameters confirm this statement, because the vertical part of the movement are smaller.

Different situation sets in RJMs. We can analysed only the RJM of lash (lead) leg. This movement is going through the sagital plane, which is perpendicular to axis of recording. During the support phase after the hurdle is lashing movement limited so that RJMS. I.K. best specifies the movement in this plane has relatively smaller values of RJM during this support phase. It causes by smaller range and dynamics of C.G. movement. During unsupported phase of hurdling clearance (flight parabola) are vertical and horizontal forces equal to zero. We neglect aerodynamics resistance. The character of the movement progression is determined by centrifugal force which is evoked by angular velocity, inertial force excited by angular acceleration and forces effected to the gravity of the lower extremities segments.

P.N. achieves high values of total joint moments (TJM) in both observed joints during the support phase after the hurdle. Especially TJM of hip is an about 40 % higher than by I. K. (1 000 N.m vs. 600 N.m). The C. G. of P. N. is during breaking phase after the hurdle falling down more than by I.K. It results to the sharper angle of takeoff (57° for P.N.) and longer acceleration phase (72cm), which presents the branch of vertical force activity. P.N. falls down at the moment of touchdown more aggressively from the point of view of the high value of vertical force and longer branch of this force. It results to the higher RJM of hip. P.N. achieves RJM and about 700 N.m and I.K. only 400 N.m. The difference between TJM and RJM is for P.N. 300 N.m and for I.K. 200 N.m. The differences are evoked especially by the effect of inertial force during the angular acceleration of lash leg. P.N. has longer acceleration phase which inevitable reflects to the longer trajectory of leg pulling. It has influence upon growing the TJM. So that this growing is caused by lash work of takeoff leg in the end of support phase. Owing to this results we are able to affirm that the economy of landing is much more effective by I.K.

Well, following facts of P.N. limit the chance of the stride frequency and velocity increasing. So that P.N. achieves during the landing phase after the hurdle larger lowering of C.G., harder touchdown, longer acceleration phases, sharper takeoff angle and higher value of TJM of hip. He has to move his takeoff leg from longer distance and must exert more effort to achieve a optimal structure of the movement.

I.K. achieves during hurdle clearance higher moment of the forces of hip and knee joints. Higher horizontal velocity, higher intensity of lash movement and shorter time of the movement execution by lower extremities is characterised for I.K. As for P.N.'s TJMs, there is opposite tendency. Both support phases before and after the hurdle take 0.6 s by P.N. and 0.54 s by I.K. The movement execution takes more time and therefore P.N. needn't exert so much effort for lashing work of legs.

CONCLUSIONS

Both of competitors realise the support phases before and after the hurdle by different ways. C.G. position before the hurdle is lower by I.K. so that he presents longer breaking but also acceleration phase. Total lost of horizontal velocity before the hurdle is higher by I.K. (0.51 $m.s^{-1}$ vs. 0.37 $m.s^{-1}$). Differences are above all in kinematics after the hurdle. I.K. is going to touchdown with higher position of C.G. His elastic stiffness is more developed because of higher intensity of deceleration of C.G. lowering during the first part of support phase after the hurdle. Also during the takeoff moment is C.G. position of I.K. higher than P.N. These facts exert the influence upon I.K.'s higher velocity with shorter support phases and shorter acceleration phases than P.N.'s. The P.N.'s landing angle in the moment of touchdown after the hurdle is 85°. His C.G. is during this moment directly over the instep of support leg, which evokes very short trajectory of deceleration. Further part of P.N.'s support phase is characterised by higher intensity of the C.G.'s lowering. We suppose that it prolongs the time of contact and acceleration phase. The question is: how does it work in the following phases of the hurdling'? The changes of horizontal velocity during support phase after the hurdle is zero by I.K. and by P.N. +0.3 $m.s^{-1}$. Horizontal velocity during the clearance phase together with both support phases decreases by I.K. an about 0.68 $m.s^{-1}$ vs. P.N.'s 0.4 $m.s^{-1}$ In spite of following better performance both of competitors during the '97 season, we set great store by next recommendations for hurdling clearance phase.

1. By larger angle of touchdown before the hurdle can I.K. achieve shorter breaking phase. As for the landing phase after the hurdle we approve the same method: to increase the angle of touchdown with fixing C.G. on the same or higher position so that the lost of velocity can by lower.
2. For P.N. we recommend more aggressive attack to the hurdle, sharper angle of takeoff connected with shorter stride length before the hurdle, takeoff place should be more distant to the hurdle. In spite of the touchdown after the hurdle seems to be effective, the position of the C.G. needs to be higher. It could decrease the values of vertical forces and makes the support phase-to be lighter. We also recommend prolonging the length of the first stride after the hurdle.

Based on these results we are able to affirm that the way of kinematic structure execution during both support phases can exert the dominant influence upon resultant efficiency of the movement over and tightly after the hurdle.

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