60 METERS HURDLES STEP LENGTH ANALYSIS AT DIFFERENT COMPETITIVE LEVELS

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Abstract: The aim of this study was to examine the step length during the 60 meters hurdles races in relation to different performance levels. All the 44th Spanish Indoor Championship and the 12th IAAF World Indoor Championship (Valencia 2008) races were analyzed with a new methodology based on two-dimensional video with "Direct Lineal Transformation" algorithms used to obtain the spatial parameters of the competition area. The results of this study show that the best male group presented a lower distance in the first eight steps ($p<0.05$), a greater take-off distance (0.11 m; $p<0.001$), a lower landing distance (0.17 m; $p<0.001$) and a greater step length in the run-in phase. The best female group showed a greater recovery step (0.07 m; $p<0.01$) and a greater step length in the run-in phase. There were more statistically significant differences between the male groups than between the female groups. Therefore, it would be important to analyze the temporal parameters at different performance levels and during the Olympic distances: 110 and 100 meters hurdles.

Key Words: biomechanics, track & field, hurdles, competition analysis, length step.

I. INTRODUCTION

The 60 meters hurdles races, as well as 110/100 meters hurdles, are characterized by running between the hurdles and the clearance of them. The number of strides before the hurdles is relatively standardized as the distance between the hurdles remains fixed by the rules. However, will all the athletes organize the steps before the hurdles in the same way?

The state of the art regarding the influence on the step length on indoor or outdoor high hurdles includes studies carried out using three- (Mero & Luhtanen, 1986; McDonald & Dapena, 1991; Grimshaw, Marar, Salo, Knight & Vernon, 1995; Coh & Dolenec, 1996; Salo, Grimshaw & Marar, 1997; Coh, 2002, 2003, 2004; McDonald, 2002) and two-dimensional techniques (McLean, 1994; Kampmiller, Slamka & Vanderka, 1999) or using similar methodologies (Mann & Herman, 1985; Rash et al., 1990; Chow, 1993). The major limitations of these studies (Rash et al., 1990; McLean, 1994; Coh, 2004) are that only one or two hurdles are analyzed along the race, few athletes are examined in the race and most of the observations are performed during training conditions.

Therefore, it appears interesting to examine the competitive values within a large sample of subjects as, to our knowledge, previous attempts have been carried out with small samples which complicates the extrapolation of results. Moreover, as these studies have not always been carried in the same hurdle, but sometimes in the second (McLean, 1994; Grimshaw et al.,1995), more frequently in the third, fourth and fifth hurdle (Mero &Luhtanen, 1986; Rash et al., 1990; McDonald & Dapena, 1991; Coh, 2003, 2004) and even in the eighth and ninth hurdle (Mann & Herman, 1985; Kampmiller et al., 1999) it seems essential to determine these values across the whole race. It would be expected that the step length would be modified during the run and would be dependent on the athletes´ competitive level.

Consequently, the aim of this study was to compare all the step lengths in the 60 meters hurdles races during the 44th Spanish Indoor Championship and 12th IAAF World Indoor Championship (Valencia 2008) at different competitive levels, in both genders.

II. METHODS

Subjects

All the races were filmed during the 44th Spanish Indoor Championship and 12th IAAF World Indoor Championship (Valencia 2008). The best result of each athlete was included in the study. The trials were further divided into two groups, in both genders, according to the official times achieved during the competition.

Table I. Subjects of the study.

GENDER	LEVEL	AGE (years)	RESULT (s)
MEN (n=59)	N1 (n=30)	26.8 ± 3.6	7.71 ± 0.12 (7.46 – 7.93)
	N2 (n=29)	22.6 ± 3.9	8.39 ± 0.28 (7.97 – 8.93)
WOMEN (n=51)	N1 (n=27)	26.3 ± 3.3	8.14 ± 0.20 (7.80 – 8.46)
	N2 (n=24)	22.9 ± 4.5	9.06 ± 0.32 (8.54 – 9.72)

Race phases

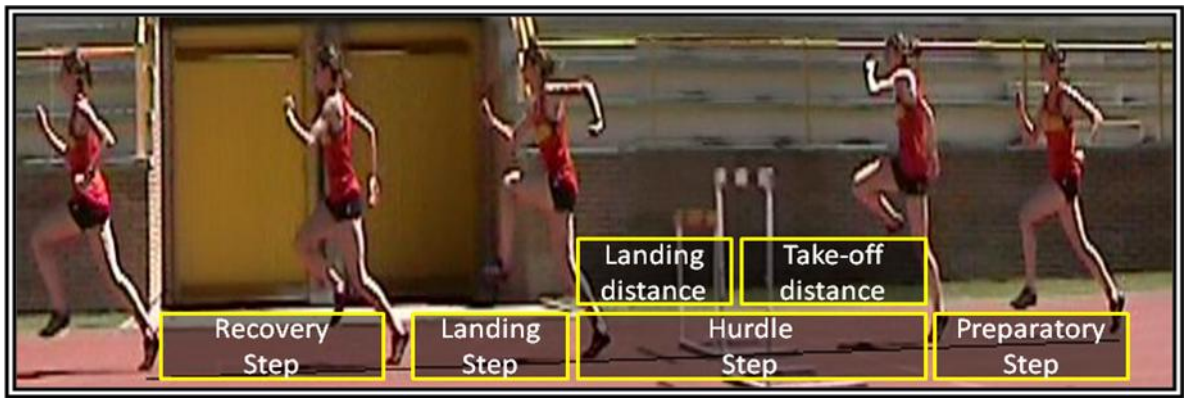
“The hurdle events include characteristic phases determined by the position and the height of the hurdles” (Brüggemann, 1990). Based on Brüggemann´s study, in the actual investigation the following model was employed:

Approach run phase: the first eight steps before the first hurdle.

Hurdle unit phase: Preparatory step, Hurdle step (take-off distance and landing distance), Landing step and Recovery step (Figure I).

Run-in phase: the strides between the last hurdle and the finish line.

Figure I. Hurdle unit phase model.



Data registration and analysis

Six fixed video camera, located at the main stand and operating at 50 Hz were used to film the races. Camera 1 recorded the first 13 m; camera 2 from meters 13 to 30; camera 3 from 30 to 47 m and camera 4 the last 13 m (47-60 m) of the race. Complementarily and in order to avoid athletes´ occlusion, cameras 5 and 6 were located with a frontal view: camera 5 filming the first 30 m (including the referees´ starting gun) and camera 6 the last 30 m.

The athletes´ foot landing and take-off points were digitized in the frames. After developing a calibration system with the lane marks, Direct Lineal Transformation algorithms (Abdel-Aziz & Karara, 1971) were used for the reconstruction of real coordinates (x,y). The validity of this method was previously assessed, with a RMS error (Root Mean Square; Allard et al., 1995) lower than 0.04 m for the step length and step width on the six cameras.

Means and standard deviation (in the case being different than 0.00 m) are reported in the text. Repeated measures analyses of variance (ANOVA) were performed to examine the differences within performance levels and gender groups. Post-hoc analyses were carried out using Bonferonni´s procedure. The alpha level of significance was set a priori at $p<0.05$.

III. RESULTS

Approach Run Phase

Mean distance in the first eight steps for males was 1.47 m, with a lower ($p<0.05$) value for level 1 (1.46 m) than level 2 (1.47 m) groups. The greater differences were detected in the fourth (0.04 m; $p<0.01$) and fifth (0.03 m; $p<0.05$) step, where the higher level athletes had a shorter length than those from level 2. The mean step length for the females was 1.40 m, without differences ($p>0.05$) between levels. The female group athletes had a 0.05 longer ($p<0.05$) first step than those from level 2, whereas this group achieved a 0.06 m longer (<0.01) sixth step (Table II).

Table II. Step length in the approach run phase. *Significant difference ($p<0.05$) between levels; ** Significant difference ($p<0.01$) between levels.

	SL1	SL2	SL3	SL4	SL5	SL6	SL7	SL8
MALE	0.62±0.01	1.17±0.01	1.37±0.01	1.49±0.01	1.67±0.01	1.71±0.01	1.89±0.01	1.81±0.01
N1	0.64±0.02	1.16±0.02	1.37±0.01	1.47±0.01**	1.65±0.01*	1.69±0.01	1.88±0.01	1.83±0.02
N2	0.60±0.02	1.18±0.02	1.38±0.01	1.51±0.01	1.68±0.01	1.72±0.01	1.91±0.01	1.79±0.02
FEMA	0.66±0.01	1.12±0.01	1.33±0.01	1.44±0.01	1.58±0.01	1.67±0.01	1.79±0.01	1.63±0.01
N1	0.68±0.02*	1.14±0.02	1.33±0.02	1.44±0.01	1.57±0.01	1.64±0.01**	1.77±0.02	1.65±0.02
N2	0.63±0.02	1.10±0.02	1.32±0.02	1.45±0.02	1.60±0.01	1.70±0.01	1.81±0.02	1.60±0.02

Hurdle Unit Phase

As it can be seen from Table III, male level 1 athletes (2.15 ± 0,02 m) presented a longest ($p<0.001$) Take-off Distance (TD) than those belonging to level 2 (2,04 ± 0,02 m), even though their Landing Distance (LD) was shorter (1.59 ± 0.03 m; $p<0.001$) than those from level 2 (1.76 ± 0.03 m). Additionally, the hurdle by hurdle analysis (Table IV) revealed that level 1 athletes had a longer Preparatory Step Length (PSL; $p<0.05$) in the second and fourth hurdle, a greater TD and LD in all hurdles ($p<0.05$-0.001), as well as a higher Landing Step Length (LSL) on the fifth hurdle

For the female group (Table III), the mean LSL of the five hurdles was longer ($p<0.01$) for level 1 (1.52 ± 0.02 m) than level 2 athletes (1.45 ± 0.02 m). In addition (Table V), the LSL was longer for level 1 athletes at the third (0.07 m; $p<0.05$), fourth (0.06 m; $p=0.064$) and fifth hurdle (0.13 m; $p<0.001$), as well as the Recovery Step Length (RSL) was greater ($p<0.05$) during the fifth hurdle in relation to level 2 athletes.

Table III. Average step length in the Hurdle Phase: Preparatory Step Length (PSL), Hurdle Step Length (HSL), Take-off Distance (TD), Landing Distance (LD), Landing Step Length (LSL) and Recovery Step Length (RSL). **Significant difference ($p<0.01$) between levels; * Significant difference (p<0.001) between levels.**

	PSL	HSL	TD	LD	LSL	RSL

MALE	1.87±0.01	3.76±0.02	2.09±0.01	1.67±0.02	1.46±0.01	2.00±0.01
N1	1.89±0.02	3.73±0.03	2.15±0.02***	1.59±0.03***	1.48±0.02	2.02±0.02
N2	1.85±0.02	3.79±0.03	2.04±0.02	1.76±0.03	1.45±0.02	1.99±0.02
FEMALE	1.75±0.01	3.23±0.02	1.92±0.02	1.30±0.03	1.48±0.01	1.95±0.01
N1	1.76±0.01	3.22±0.02	1.93±0.03	1.29±0.04	1.52±0.02**	1.94±0.01
N2	1.74±0.01	3.24±0.03	1.92±0.03	1.32±0.04	1.45±0.02	1.96±0.01

Table IV. Step Length in the five hurdles for the male groups: Preparatory Step Length (PSL), Hurdle Step Length (HSL), Take-off Distance (TD), Landing Distance (LD), Landing Step Length (LSL) and Recovery Step Length (RSL). *Significant difference (*p*<0.05) between levels; **Significant difference (*p*<0.01) between levels; * Significant difference (p<0.001) between levels.**

		PSL	HSL	TD	LD	LSL	RSL
MALE		1.87±0.01	3.76±0.02	2.09±0.01	1.67±0.02	1.46±0.01	2.00±0.01
H 1	N1	1.85±0.02	3.71±0.04	2.05±0.03*	1.65±0.04***	1.42±0.02	1.99±0.02
	N2	1.79±0.02	3.81±0.04	1.97±0.03	1.84±0.04	1.42±0.02	1.98±0.02
H 2	N1	1.91±0.02*	3.72±0.03	2.17±0.03**	1.55±0.04**	1.45±0.03	2.03±0.02
	N2	1.84±0.02	3.75±0.03	2.06±0.03	1.69±0.04	1.48±0.03	1.98±0.02
H 3	N1	1.90±0.02	3.85±0.04	2.21±0.03***	1.63±0.04***	1.49±0.02	1.99±0.02
	N2	1.93±0.02	3.95±0.04	2.06±0.03	1.88±0.04	1.42±0.02	1.97±0.02
H 4	N1	1.90±0.02*	3.69±0.03	2.13±0.02***	1.56±0.04**	1.51±0.02	2.04±0.02
	N2	1.84±0.02	3.73±0.03	2.02±0.02	1.70±0.04	1.49±0.02	2.02±0.02
H 5	N1	1.87±0.01	3.71±0.03	2.17±0.02**	1.55±0.03*	1.51±0.03	2.05±0.02*
	N2	1.85±0.02	3.74±0.03	2.08±0.02	1.66±0.03	1.44±0.03	1.98±0.02

Table V. Step Length in the five hurdles for the female groups: Preparatory Step Length (PSL), Hurdle Step Length (HSL), Take-off Distance (TD), Landing Distance (LD), Landing Step Length (LSL) and Recovery Step Length (RSL). *Significant difference (*p*<0.05) between levels; * Significant difference (p<0.001) between levels.**

		PSL	HSL	TD	LD	LSL	RSL
FEMALE		1.75±0.01	3.23±0.02	1.92±0.02	1.30±0.03	1.48±0.01	1.95±0.01
H 1	N1	1.65±0.02	3.14±0.04	1.78±0.02	1.36±0.04	1.49±0.03	1.92±0.02
	N2	1.60±0.02	3.23±0.04	1.80±0.03	1.44±0.05	1.47±0.04	1.95±0.02
H 2	N1	1.78±0.02	3.19±0.03	1.94±0.03	1.25±0.04	1.48±0.02	1.96±0.02
	N2	1.73±0.02	3.23±0.04	1.91±0.03	1.32±0.04	1.43±0.03	2.00±0.02
H 3	N1	1.78±0.02	3.35±0.03	2.04±0.03	1.32±0.04	1.54±0.02*	1.93±0.02
	N2	1.79±0.02	3.30±0.03	1.98±0.03	1.32±0.04	1.47±0.02	1.97±0.02
H 4	N1	1.78±0.02	3.19±0.03	1.93±0.03	1.26±0.04	1.52±0.02	1.96±0.02
	N2	1.80±0.02	3.21±0.03	1.94±0.03	1.28±0.04	1.46±0.02	2.00±0.02
H 5	N1	1.79±0.02	3.21±0.03	1.97±0.03	1.24±0.04	1.56±0.02***	1.94±0.02*
	N2	1.79±0.02	3.23±0.03	1.96±0.03	1.27±0.04	1.43±0.02	1.87±0.02

Run-in Phase

Mean distance in the last four steps for males was 2.02 ± 0.02 m with significant differences between groups (level 1: 2.07 ± 0.02 m *vs* level 2: 1.96 ± 0.02 m; p<0.001). As it can be seen from Table VI, level 1 athletes showed longest lengths in the four steps of this phase: SL1 (0.06 m; p=0.083), SL2 (0.07 m; p<0.05), SL3 (014 m; p<0.01) y SL4 (0.15 m; p<0.01).

In the case of the female group, the final six steps averaged 1.90 ± 0.01 m with significant differences (p<0.001) between level 1 (1.95 ± 0.02 m) and level 2 (1.84 ± 0.02 m) hurdlers. Level 1 athletes achieved longer (p<0.05-p<0.001) lengths in all the steps of this phase than level 2 athletes.

Table VI. Average step length of the run-in phase. *Significant difference (*p*<0.05) between levels; **Significant difference (*p*<0.01) between levels; * Significant difference (p<0.001) between levels.**

	SL1 (m)	SL2 (m)	SL3 (m)	SL4 (m)	SL5 (m)	SL6 (m)
MALE	1.48±0.02	2.02±0.02	2.13±0.02	2.44±0.03		
N1	1.51±0.03	2.05±0.02*	2.20±0.03**	2.52±0.04**		
N2	1.44±0.03	1.98±0.02	2.06±0.03	2.37±0.04		
FEMALE	1.50±001	1.91±0.01	1.86±0.01	1.94±0.02	1.98±0.02	2.19±0.03
N1	1.56±0.02***	1.94±0.02*	1.91±0.02***	1.98±0.02*	2.03±0.03*	2.28±0.04**
N2	1.43±0.02	1.87±0.02	1.81±0.02	1.90±0.02	1.94±0.03	2.11±0.04

IV. DISCUSSION

Approach run phase

Mean step length differences were detected within the male groups, related to the first hurdle take-off distance and due to the shorter level 1 athletes´ fourth and fifth step. The data presented in this study regarding take-off distance (level 1: 2.05 ± 0.03 m; level 2: 1.97 ± 0.03 m) is very similar to that recommended by Schmolinsky (1981) for hurdlers. In the case of the female group, mean step length and take-off distance were similar between both groups. The take off distance reported in the actual study for level 1 (1.78 ± 0.02 m) and level 2 (1.80 ± 0.03 m) athletes remains far away from that previously suggested by Hünckleke mkes (1990): 1.95 m.

Hurdle unit phase

The higher level athletes showed an improved skill which allowed them a longer take-off distance and a shorter landing distance, supporting data presented in previous studies which are essential for an efficient hurdle clearance (Coh, 2004). In relation to the female group, there were no significant differences detected regarding take-off

and landing distance. However, in 1997 Salo, Grimshaw & Marar reported that female take-off distance was dependant on the athletes´ level, probably due to the greater heterogeneity of the sample from this study. Additionally, the hurdle height differences between genders can help explaining the take-off and landing differences (Mann, 1996; McDonald, 1996). On the other hand, top-level female athletes presented a longer landing step length, which can be related to a lower horizontal velocity loss in the hurdle and achieving a better landing position.

Run-in phase

Reinforcing previous observations (McDonald, 2002) hurdle events require a special ability to run between the hurdles but also, as it can be seen in top-level athletes, a longer step length in the final run.

V. CONCLUSIONS

This study has shown the importance of step length analysis at different performance levels. More differences were observed in male than female athletes. Specially, male level 1 athletes presented a shorter distance until the first hurdle, a longer take-off distance and a lower landing distance. Female top-level athletes showed a longer landing step length. Altogether, top-class hurdles achieved a longer step length in the run-in phase. Future research is required in order to study the temporal parameters during competition and the competitive level differences in the Olympic program distances: 110 and 100 m hurdles, where major differences would be expected between groups from the fifth hurdle onward.

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