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## Mechanical performance determinants in women's vs men's pole-vault

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**KEYWORDS** Pole vault; energy; performance; run-up

### 1. Introduction

Since its first world record in 1992 and its official introduction in 1999 at the 7th IAAF World Championships, the women's pole vault event has been little studied. First data showed that, similarly to men, the run-up velocity could be considered as one of the main performance factors (Grabner 2004; McGinnis 2004). It has also been shown that performance in women's pole vault was mainly explained by the energy of the athlete at the take-off and by the energy gain due to the work done by the athlete during the pole support phase (Grabner 2004; Schade et al. 2004). Although a higher angular momentum during the pole support phase has been found for women in comparison with men (Schade et al. 2004), the specificity of the women's pole vault biomechanics with regard to the men remains an open question and is it not reasonable to consider that women's performance are built similarly to men (Frère et al. 2010). This is all the more the case as the performance level in the women's pole vault is still increasing. Therefore, the aim of this study was to determine for both women and men the relative influence of several take-off and pole support mechanical variables on the pole vault performance.

### 2. Methods

#### 2.1. Participants

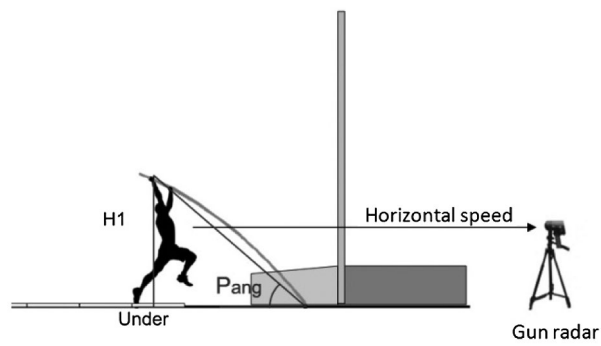
All measurements were collected during the *All Star Perche 2017* meeting. In order to obtain a large panel of performances, three levels of contest in each sex were investigated: national young athletes (, national elite athletes and world class athletes. Best vault of 31 men ( $73.9 \pm 9.2$  kg;  $180.2 \pm 6.2$  cm) and 31 women ( $59.6 \pm 6.3$  kg;  $169.1 \pm 4.7$  cm) were analyzed.

#### 2.2. Mechanical parameters

During the whole competition time, a 20-m Optojump Next system (Microgate, Bolzano, Italy) was placed along the runway, starting at 2.2 m from zero position (planting box). This configuration allowed measurement of contact time ( $t_c$ , in s), aerial time ( $t_a$ , in s), step rate (SR, in Step/s), step length (SL, in m), and length asymmetry index (AssI, in %). AssI was calculated dividing average of length step from carriage pole side by free side. To track athlete speed during the run-up, a Radar gun Stalker Pro II (Stalker Ltd, Plano, United states) was placed behind the landing mat in the run-up direction at a 1.4 m height. This data flow (46.875 Hz) was integrated into MookyStalker software (Matsport, Saint-Ismier, France) and synchronized with Optojump Next, to obtain the take-off speed (Spd, in m/s) at last  $t_c$ . In addition, high frequency camera (100 Hz) captured the take-off position in the sagittal plane (i.e. when the pole is in contact with the planting box and the foot of the athlete still on the floor) in order to obtain following values (Kinovea 0.8.15 software): grip height (Grip, in m), height of superior hand (H1, in m), distance between both hands (DH, in m), pole angle (Pang, in degree) and the position of orthogonal projection of superior hand on the floor relative to the foot (Under, in m), see Figure 1. After take-off, the maximal reduction of the pole chord ( $\Delta P$ , in m) and the maximal pelvis height were calculated. In addition, we calculated a conversion index (ConvI) dividing  $\Delta P$  by Spd.

#### 2.3. Statistical analysis

The distribution of each variable was examined with the Shapiro-Wilk normality test. Homogeneity of variance was verified by a Levene test. The performance considered for this statistical analysis was the maximal height



**Figure 1.** Illustration of measurement configuration.

achieved by the pelvis for each athlete. First following parameters were assessed using a multiple linear regression model (stepwise backward elimination procedure); Height, Weight, Spd, SR, SL, tc, ta, AssI, Grip, H1, DH, Under, Pang, deltaP, ConvI. In the backward procedure, variables with  $F$  value  $<4$  were removed from the model. We assessed the relative influence of all above described mechanical parameters (independent variables) to predict the performance (dependent variable) for each sex.

### 3. Results and discussion

For both sex, the stepwise multiple regression model links maximal pelvis height achieved to different parameters. This provides qualitative information about the implication of each parameter in performance. Regarding men, maximal pelvis height is mainly explained by speed at take-off (74.4%), then H1 (4.97%), ConvI (4.29%), and Under (2.44%). For women, performance is driven by two main parameters; Spd (58.4%) and ConvI (36.9%) whereas others were inconsequential (Table 1).

### 4. Conclusions

Performance parameters in pole vault appear very different between women and men. As previously described, the take-off speed remains the main performance factor for both men and women (Adamczewski and Perl 1997; McGinnis 1997, 2004). Nevertheless, our results showed that speed is more important for men than women (74.4 vs. 36.9%). Women performance is also largely affected

**Table 1.** Coefficient of determination ( $r^2$ , stepwise multiple regression model) and illustration of relationship between parameter and performance.

	Para.	$R^2$	%
<i>Men</i>			
1	Spd	0.744	74.4
2	H1	0.836	4.97
3	ConvI	0.787	4.29
4	Under	0.861	2.44
<i>Women</i>			
1	Spd	0.953	58.4
2	ConvI	0.607	36.9
3	AssI	0.963	0.96
4	SR	0.969	0.63

Notes: All parameter under rank 4 were excluded from the model.

by ability to transform speed into pole flexion to convert energy. Our results corroborated former findings (Grabner 2004; Schade et al. 2004) and confirmed the specificity of women pole vault technique with major importance of energy stored at maximal pole bending. This study also suggests that women could improve massively their performance with adapted strength program to obtain more benefits from their run or working on different technical strategy to improve pole flexion.

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