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EFFECT OF AGE ON HIGH JUMP TAKEOFF BIOMECHANICS

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The aim of the study was to analyse the differences in critical features of high jump take-off in different ages. 3D photogrammetry was used to analyse the best jump of the participants of 3 Spanish Indoor Championships (2009) (13-15 y, 17-18 y, and 18-34 y). The variables measured were horizontal velocity of the centre of mass (CM) at touchdown (VH0), knee angle at touchdown (K0), leg angle at touchdown (L0); height of the CM at touchdown (H0); and take-off angle (TOA). The three groups were compared with ANOVA and each variable was correlated with the maximum CM height. Statistical differences were found in VH0 and H0, but not in the variables directly related to the take-off technique. It is concluded that younger athletes use similar techniques than older ones. This might be a wrong strategy, as they should adapt it to their maturity limitations.

KEY WORDS: athletics, kinematics, photogrammetry, sports technique.

INTRODUCTION: High jump is a modality that requires a high amount of strength, velocity and technique. Several authors have stated that the take-off is the most important phase (Brüggemann & Arampatzis, 1997; Dapena, 2006), and is influenced by a great amount of variables (Dapena & Chung, 1988). Nevertheless only a few have shown to be critical features, for example horizontal speed, knee angle, leg angle at the beginning of touchdown, and CM height in the braking phase (Alexander, 1990; Conrad & Ritzdorf, 1988; Dapena, McDonald, & Cappaert, 1990; Greig & Yeadon, 2000). Despite the fact that these variables are assumed to be important in adult athletes, there is no information about them in younger ones. The younger athletes are not expected to have similar levels of strength than the adults, and so their optimal technique could be quite different. From the coaches' point of view, it is important to know the characteristics of their athletes and how they perform.
The purpose of this study was to describe the characteristics of the takeoff's critical features in the best Spanish national jumpers in three age groups, and correlate them with the performance variable.

METHODS: Three Spanish Athletics Indoor Championships were analysed. Thirty seven male high jumpers participated in the study (13-15 y, n=11; 17-18 y, n=13; 18-34 y, n=13). Table 1 shows a description of each group of participants.

Table 1
Descriptive statistics of the participants

	13-15 y (n=11)	17-18 y (n=13)	18-34 y (n=13)
Age (y)			
Mean ± SD	14.18 ± 0.75	17.69 ± 0.48	25.38 ± 5.67
Range	13 – 15	17 – 18	18 – 34
Height (m)			
Mean ± SD	1.70 ± 0.04	1.80 ± 0.04	1.89 ± 0.05
Range	1.60 – 1.76	1.74 – 1.86	1.80 – 1.98
Result (m)			
Mean ± SD	1.70 ± 0.06	1.95 ± 0.11	2.10 ± 0.09
Range	1.60 – 1.78	1.82 – 2.27	2.00 – 2.24

Three digital cameras operating at 50 Hz (Nolan & Patritti, 2008), shutter speed of 1/1000 s, were placed around the bar at about 30 m (figure 1). The focal length was increased to maximize the reference frame's size and increase the distance per pixel (maximum of 1.5 cm/pixel). The reference frame used was a prism of 10 m wide x 5 m deep x 2.92 m height. For each championship the reference frame was digitized 5 times. The mean reconstruction error was 8.9 mm. A common human model of 22 points and 14 segments was used (Alcaraz et al., 2008). The de Leva (1996) inertial parameters were used to calculate the subjects' CM. All videos were manually digitized tracking each point during the entire sequence as recommended by Bahamonde & Stevens (2006). The videos were digitized with Kwon 3D software (Visol Inc., Korea). The coordinates were reconstructed with the DLT algorithm and a low pass 2nd order Butterworth filter with a cut-off frequency of 6 Hz was applied.

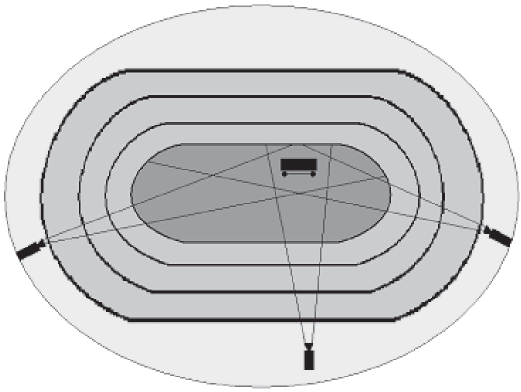

Figure 1: position of the three digital cameras around the jumping area.

The calculated variables corresponding to the take-off phases were: horizontal velocity of the CM at touchdown (VH0); knee angle at touchdown (K0); leg angle at touchdown, measured from hip to heel with respect to the vertical (L0); height of the CM at touchdown (H0); and takeoff angle (TOA), the angle of the CM velocity with respect to the horizontal. We also calculated de maximum height achieved by the CM as the performance variable. We can classify these variables as related to the strength maturation (VH0 and TOA), related to the technique (K0 and L0) and related to the anthropometry (H0).
Mean and standard deviations were calculated for every group of age. Kolmogorov-Smirnov test was applied to verify the normal distribution. ANOVA with Tukey test was used for post hoc inter group comparisons. Every variable was correlated with the performance using Spearman correlation. The statistical significance was set at α=0.05.

RESULTS: Descriptive statistics of the calculated variables in each group are shown in Table 2. Only two variables show statistically significant differences between the groups: VH0 and H0 which increase with the age. L0 shows a tendency to rise, but this is not statistically significant.

Table 2
Mean and standard deviation for the three groups of age

Variable	13-15 y	17-18 y	18-34 y
VH0 (m/s)	5.71 ± 0.59	**6.41 ± 0.29 ***	**6.69 ± 0.25 ***
K0 (°)	153.81 ± 7.15	152.30 ± 4.38	154.30 ± 7.25
L0 (°)	29.36 ± 5.50	31.53 ± 4.33	33.23 ± 3.00
H0 (m)	0.86 ± 0.03	0.87 ± 0.06	**0.93 ± 0.04 *** †
TOA (°)	45 ± 3.40	46.30 ± 3.11	46.38 ± 4.09

* Different from 13-15 year group (p<0.05).
† Different from 17-18 year group (p<0.05).

Table 3 shows the correlations between the measured variables and the performance one (maximum height achieved by the CM). There is only one significant correlation with the CM angle at take-off in the older group.

Table 3
Spearman's correlations with the performance (maximum centre of mass height)

Variable	13-15 y	17-18 y	18-34 y
VH0 (m/s)	0.360	0.474	0.490
K0 (°)	0.465	0.024	0.025
L0 (°)	0.313	0.323	0.385
H0 (m)	-0.389	-0.149	-0.237
TOA (°)	-0.071	0.382	**0.622***

VH0- horizontal velocity of the CM at touchdown; K0- Knee angle at touchdown; L0- leg angle at touchdown, measured from hip to heel respect to the vertical; H0- height of the CM at touchdown; TOA- take-off angle, the angle of the CM velocity respect to the horizontal
* $p<0.05$.

DISCUSSION: The purpose of this study was to assess the critical features of the high jump's take-off and analyse their differences in different ages. A combination of maturation and years of training (physical and technical improvements) result in an improvement in the height jumped when growing older. In the present study we compared take-off variables related to the strength maturation, technique, and anthropometry. The variable VH0, related to the strength maturation, tended to increase significantly in the older groups. We also found an increasing trend in the anthropometry related variable (H0) statistically different in the older group. Several authors have stated the importance of speed on the initial part of the take-off (Alexander, 1990; Dapena et al., 1990; Dapena & Chung, 1988; Greig & Yeadon, 2000). In our study we did not find correlations between the VH0 and the maximum height. Actually the only significant correlation found was with TOA. This could be due to the different nature of our study with respect to other studies. According to Dapena et al. (1990), the relationships would not be similar when analysing multiple jumps by a single athlete or one single jump by many athletes. In this study we analysed 11 or 13 athletes per group together and the behaviour could vary considerably from the first to the last ones. Anyway, the lack of correlations with the performance variable could be due to the existence of third variables moderating the relationships or because of the low level of the adult championship during that season (the champion jumped 2.24 m).
We did not find statistical differences in the technique related variables (K0 and L0). This may be interpreted as meaning that the main reasons why the athletes in this study jump higher when they grow older are mainly due to maturation and growth rather than changes in technique. It is possible that the optimum technique in the younger jumpers need to be adjusted to their maturational and anthropometric constraints. Training the technique following the adult criteria would be an error. This highlights the necessity of conducting studies analysing the critical features of the younger athletes.

CONCLUSION: The results show that the main differences between the groups of ages in the take-off phase are related with maturational and anthropometric variables rather than technique ones. As the maturational and anthropometric constraints can affect the optimal technique, it is recommended to conduct technique analysis adjusted to the age group.

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