COMPARISON OF THE FORCE-TIME STRUCTURE OF THE VERTICAL JUMP BETWEEN MEN AND WOMEN

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INTRODUCTION

Take-offs are very frequent movement actions concerning a wide variety of sport and human activities. The vertical jump has very often been used as a suitable model for the solution of many problems in sport pedagogy, effectiveness of the training process, quality of muscle performance, coordination of movement etc. (Bobbert & Schenau, 1988; Hudson & Owen, 1985, Komi & Bosco, 1978; Sanders et al. 1993, and others). The vertical jump can be defined as a complex series of ballistic multijoint actions where the muscles around the hip, knee, and ankle joint collectively operate to produce patterns of movement (Rodano et al., 1996). The arm activity contributes to the final reaction force acting upon the centre of mass positively in the range of about 13 percent of the peak total vertical momentum (Lees & Barton, 1996). The course of the force-time curve of the counter-movement vertical jump with the swing of the arms (CMJ) is characterized by one or two peak shapes, the pattern is very individual and it can be considered as total information about the sum of partial moments of body segments contributing to the final vertical momentum (Vaverka, 1980). Differences between men and women (gender differences) in take-off activities are well known in sport as well as in some research studies (e.g., Asmussen & Bonde-Petersen, 1974; Komi & Bosco, 1978; Hudson & Owen, 1985; Rodano et al., 1996; Tant et al., 1996). But the comparison of the course of the movement by the CMJ has not yet been described in more detail.

The main goal of this study was to focus on the following problems:

1. The stability (reproducibility) of the movement during the CMJ
2. The inter-individual variability of the structure of the CMJ
3. Differences in the structure of the CMJ between the men and women

We expect the existence of significant differences between men and women in the final results of the CMJ as well as in the CMJ structure of movement.

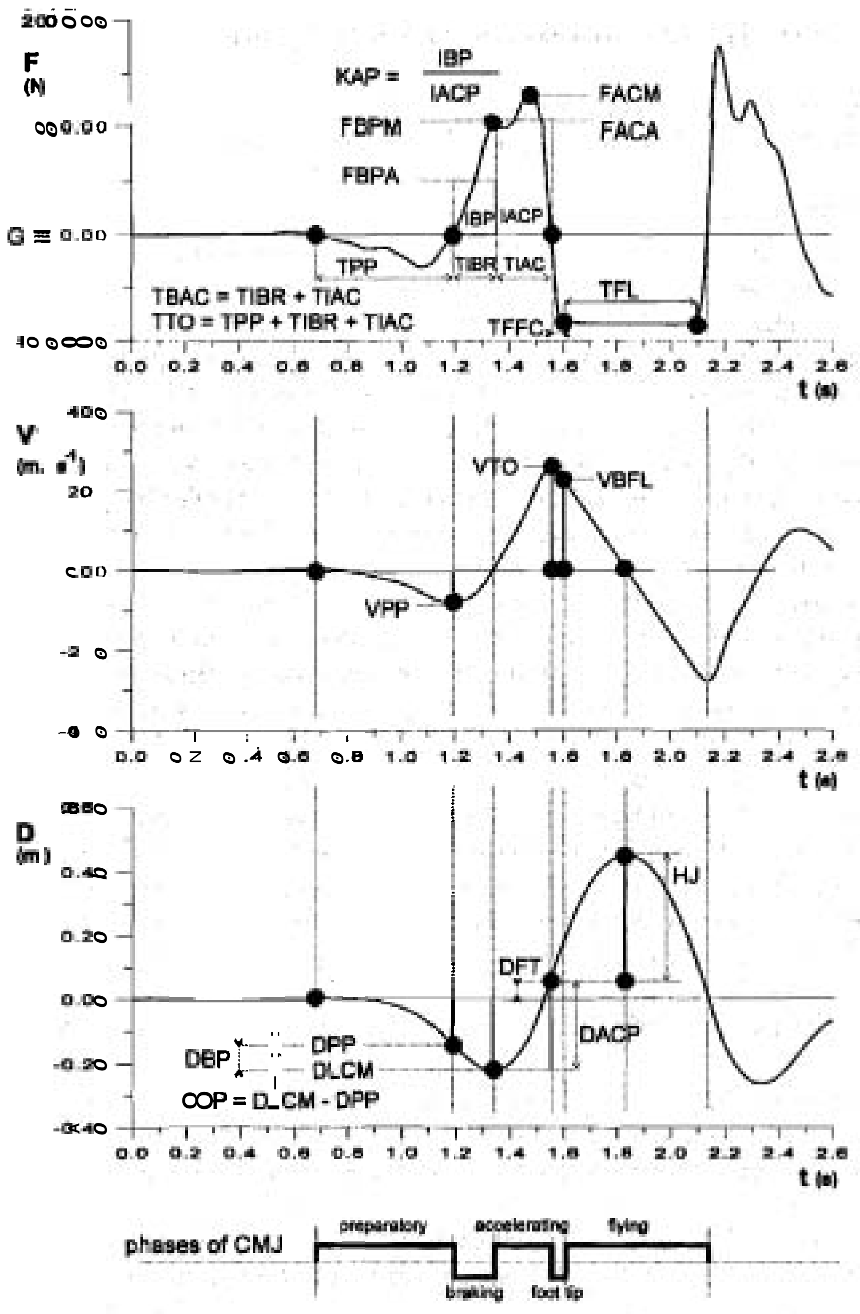

Figure 1. Graphical expression of measured variables.

METHODS

The CMJ was at the centre of our interest. Two groups of students of physical education (men, n = 54, body height = 178.40 (6.12 cm, body mass = 79.00 (6.36 kg; women, n = 47, body height = 168.48 (6.20 cm, body mass = 59.72 (6.44 kg) were the subjects of the research. They performed two CMJ on a KISTLER platform. The reaction force **Fz(t)** was analyzed on an ON-LINE system by using our own software which derived the velocity-time and distance-time functions from the **Fz(t)** component (sampling frequency 1 kHz). Twenty-three biomechanical variables describing the structure of CMJ from the point of view of time, force, velocity, and distance of the centre of mass (CM) of the human body in defined phases during the jump (preparatory, braking - eccentric, accelerating - concentric, and flying phase) were computed in the real-time. Graphic expression of all measured variables is given in Figure 1. Data were elaborated by statistical procedures based on the STATGRAPHICS package (basic statistical characteristics, t-test, correlation analysis).

RESULTS

All statistical characteristics of measured data are given in Table 1. The mean and standard deviation describe basic information about the inter-individual variability of variables by gender categories.

Table 1

Counter-movement vertical jump. Difference between men and women, coefficients of stability-reproducibility

Variable	Men		Women		|d|	T-test	Men	Women
	Mean	SD	Mean	SD			r_s	r_s
TPP	0.418	0.140	0.314	0.072	0.104	4.599**	.735	.500
DPP	0.162	0.056	0.120	0.029	0.042	4.619**	.781	.749
TIBR	0.142	0.054	0.134	0.029	0.008	0.910	.449	.659
DBP	0.090	0.033	0.085	0.025	0.011	1.782	.669	.818
VPP	1.077	0.262	1.018	0.223	0.059	1.204	.742	.742
FBPM	950.6	197.6	793.0	220.3	157.6	3.789**	.781	.869
FBPA	566.4	146.9	480.8	143.1	85.60	2.957**	.764	.845
IBP	75.95	18.85	61.90	15.24	14.05	4.078**	.740	.907
DLCM	0.258	0.077	0.205	0.049	0.053	4.002**	.776	.831
TIAC	0.246	0.045	0.224	0.044	0.02	2.508*	.867	.853
TBAC	0.388	0.088	0.358	0.070	0.030	1.902	.693	.830
DACP	0.383	0.067	0.307	0.056	0.076	6.118**	.912	.874
VTO	2.97	0.167	2.54	0.166	0.430	12.979**	.924	.940
FACM	1124.4	184.3	863.5	217.62	260.9	6.520**	.849	.759

Variable	Men		Women		|d|	T-test	Men	Women
	Mean	**SD**	**Mean**	**SD**			r_{tt}	r_{tt}
FACA	**877.7**	**171.1**	**711.1**	**146.46**	**166.6**	5.219**	.879	.855
IACP	**209.9**	**22.69**	**154.9**	**20.73**	**55.00**	12.642**	.979	.978
DFT	**0.126**	**0.046**	**0.102**	0.035	0.024	2.862**	.530	.813
TTO	**0.806**	**0.184**	**0.671**	0.123	0.135	4.246**	.792	.445
TFFC	**0.018**	**0.002**	**0.020**	0.003	0.002	-3.897**	.561	.858
VBFL	**2.879**	**0.171**	**2.439**	0.173	0.440	12.830**	.917	.948
TFL	**0.603**	**0.037**	**0.512**	0.038	0.091	12.059**	.893	.844
HJ	**0.451**	**0.507**	**0.330**	0.043	0.121	12.829**	.927	.947
KAP	**0.363**	**0.086**	**0.399**	0.083	0.036	-2.148*	.700	.871

* t < .05 ** t < .01

Units of measure:
T - time (s), D - distance (m), V - velocity (m.s-1), F - force (N), I - force impuls (Ns), HJ - height of jump (m), **KAP = IBP / IACP**

The coefficients of stability - reproducibility expressed by the correlation coefficient between the 1st and 2nd jump have been found in the range of r_{tt} = .45 to .98. We have seen the most stability (r_{tt} = .80 - .98) in the variables of the final results of the jump (VTO, VBFL, TFL, HJ) and the parameters of the acceleration phase of the take-off (TIAC, DACP, FACM, FACA, IACP). The stability of the other variables is relatively high (r_{tt} = .70 - .80) with the exception of the time of braking impulse (TIBR, r_{tt} = .45, resp. .66) for both men and women. The women are less stable during the time of the preparatory phase (TPP) and the total time of the take-off (TTO). Lower level of stability was found in the set of men in the variables of the distance of the foot-tip (to the tip-toe position) (DFT, r_{tt} = .53) and the time of the falling of the force-time curve TFFC (r_{tt} = .56).

The differences between men and women were statistically significant (see Table 1). The men and women were different in all of the above final variables of the jump -jumping performance (VTO, VBFL, TFL, and HJ). We have found exceptions in the variables of the time of braking phase (TIBR), distance of the braking phase (DBP), the velocity of the center of mass at the end of the preparatory phase (VPP), and the total time of the braking and acceleration phase (TBAC) in which the gender differences were not significant. The men differ from the women in the structure of the CMJ in the longer time of some take-off phases (TPP - time of preparatory phase, TIAC - time of acceleration impulse, TTO - total time of the take-off), the extent of the center of mass movement in the preparatory phase

(DPP) , total lowering of the center of mass (DLCM), distance of the acceleration phase (DACP), and distance of the foot-tip (DFT). Evident differences between observed sets of men and women have been found in the values of force variables (FBPM, FBPA, FACM, FACA) and in the impulses of braking and acceleration phase (IBP, IACP).

DISCUSSION

The differences in jumping performance between men and women are well in agreement with the literature findings (Gajevski et al., 1996; Hudson & Owen, 1985; Komi & Bosco, 1978; Nelson & Martin, 1985). A high level of stability was found in the force variables in the acceleration phase. It seems that a lower level of stability was found in the movement in the preparatory phase at the beginning of lowering the center of mass and also in this phase no statistical differences between men and women were found (TIBR, DBR, VPP). The gender differences in the time, force, and distance variables of the CMJ structure are probably related to the differences between men and women in the body dimensions and the force capacity.

CONCLUSIONS

1. A high stability - reproducibility of the movement structure of the CMJ was found for both sets of men and women above all for the jumping performance, force, time, and distance variables of the acceleration phase of the take-off (r_{tt} = .80 - .97). A lower level of stability (r_{tt} = .45 - .66) was found in the preparatory phase of the take-off.

2. The gender differences in the structure of the CMJ have been found for most variables except for the time, distance, and velocity variables of the preparatory phase of the take-off.

3. The research has confirmed the usefulness of the ON-LINE system of analysis of the $F_z(t)$ to gain information about the take-off in the real-time of the experiment.

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