DETERMINANTS OF THE MAXIMAL MECHANICAL POWER DEVELOPED DURING THE COUNTERMOVEMENT JUMP

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INTRODUCTION

The vertical jump test described by Sargent in 1821 (Matthews, 1958) has been till now utilized to estimate a jumping ability or maximal mechanical power. Biomechanical aspects of different kinds of vertical jumps (CMJ, SJ or DJ) have been widely reported (Komi and Bosco, 1978; Van Soest et al., 1985; Aura and Viitasalo, 1989; Dowling and Vamos, 1993). It is well known that a countermovement (a preparatory movement in a direction opposite to the goal direction) increases performance in explosive movements (Bosco and Komi, 1980; Bobbert et al., 1995). Bartosiewicz et al. (1990) demonstrated that the height of a jump did not depend on the countermovement depth in the CMJ performed by the same subject. The maximal power, however, was reported as a linear function of the countermovement depth. Dependency of maximal power upon the knee angle was also reported by Harley and Doust (1994). Therefore, it can be stated that the height of a jump characterizes the jumping ability of a subject, when maximal power depends mostly on the take-off technique applied. Dowling and Vamos (1993) showed that the height of a jump and the maximal power divided on body weight were significantly correlated. Considering the above statements, one can suppose that the maximal power value may be determined by height of jump, countermovement depth and body mass. The purpose of the present study was to identify the influence of these variables on mechanical power developed during the positive take-off phase in female and male groups.

METHODS

Two groups of untrained students (56 females and 38 males) participated in the present study. Body mass and height in the female group ranged between 19 and 23 years, 44.4 and 72.0 kg (58.7±7.1), 1.57 and 1.88 m (1.672±0.059), respectively. The same parameters in the male group ranged between 19 and 24 years, 61.3 and 92.5 kg (74.4±8.6), 1.68 and 1.95 m (1.801±0.071), respectively. The subjects took part in a CMJ jumping test consisting of 3 jumps performed on the Kistler force plate with a one-minute interval in between. The tested persons were asked to achieve a maximal height of jump. The results of the highest jump were selected for each subject for further calculations. The preamplified signal of the ground reaction force (vertical component) was digitized at a sampling frequency of 250 Hz using a 12 bit A/D converter and stored in the computer memory. Specially designed software was employed to calculate the mechanical parameters of a jump. Two courses: the vertical coordinate of the body mass center and the mechanical power were taken into consideration. The following parameters were extracted for statistical analysis: the height of jump (H), the lowering of the body mass center before take off (L) and the maximal mechanical power (P_{max}) developed during take off. Additionally, body mass (m_b) was included into calculations. The multiple regression was used to estimate the contribution of the selected jump and body dimensional parameters to the maximal value of jumping power. A normality of distributions required by the applied statistical method were examined using. the Shapiro-Wilk test. The value of the S-W p greater than 0.20 was considered as confirming normality.

RESULTS

The normality of all considered variables (see S-W p value in Tab.1.), except the body mass in the male group, was confirmed. Statistically significant differences were found between average values of all parameters except L in female and male groups.

Tab.1. Descriptive statistics for the parameters in female (a) and male (b) groups.

a)

	Mean	SD	Min	Max	S-W p
P_{max} [W]	1395	289	886	2179	0.168
H [m]	0.350	0.045	0.24	0.47	0.995
L [m]	0.246	0.050	0.15	0.37	0.205
m_b [kg]	58.7	7.1	44.4	72.0	0.205

b)

	Mean	SD	Min	Max	S-W p
P_{max} [W]	2535	547	1438	3748	0.722
H [m]	0.494	0.052	0.41	0.62	0.348
L [m]	0.307	0.082	0.13	0.51	0.336
m_b [kg]	74.5	8.6	61.3	92.5	0.046*

Tab.2 Correlation tables for female (a) and male (b) groups ($p<0.05$).

a)

	P_{max}	H	L	m_b
P_{max}	1.00	**0.67***	**-0.40***	0.13
H	**0.67***	1.00	0.11	-0.21
L	**-0.40***	0.11	1.00	0.18
m_b	0.13	-0.21	0.18	1.00

b)

	P_{max}	H	L	m_b
P_{max}	1.00	**0.42***	**-0.61***	**0.35***
H	**0.42***	1.00	0.05	-0.26
L	**-0.61***	0.05	1.00	0.13
m_b	**0.35***	-0.26	0.13	1.00

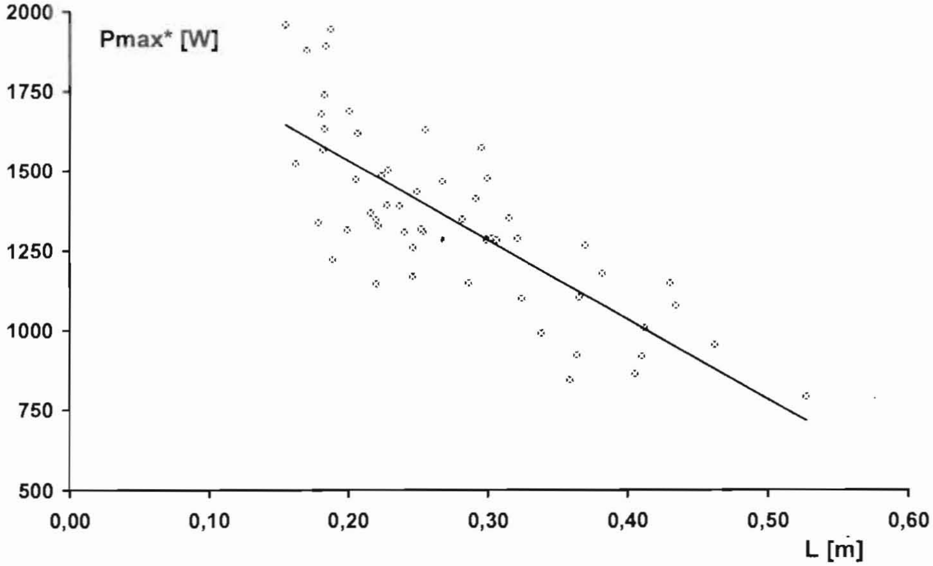
In both female and male groups a multiple regression procedure (the forward stepwise method) selected all the independent variables: the height of a jump (H), the lowering of the body mass center (L) and the body mass (m_b). In both cases highly significant regression was obtained (see Fig.1). The values of F amounted $F_{3,52}=78.3$ and $F_{3,34}=95.0$, ($p<0.001$) for the female and male groups, respectively. The following equations described the P_{max} dependencies upon H, L and m_b in both groups:

for females: $P_{max} = 5270 * H - 3260 * L + 16.5 * m_b - 610$,

for males: $P_{max} = 6400 * H - 4740 * L + 37.7 * m_b - 1972$.

The standard errors of the estimations were 127 and 187 W, respectively (9,1% and 7,4% of average P_{max}). The obtained models explained 80.8% and 88.4% of the P_{max} variance for females and males, respectively. The contributions of H, L and m_b to the P_{max} variance were estimated as follows (Dolittle method): 54%, 22%, 5% in female group and 25%, 20%, 43% in male group.

a)



b)

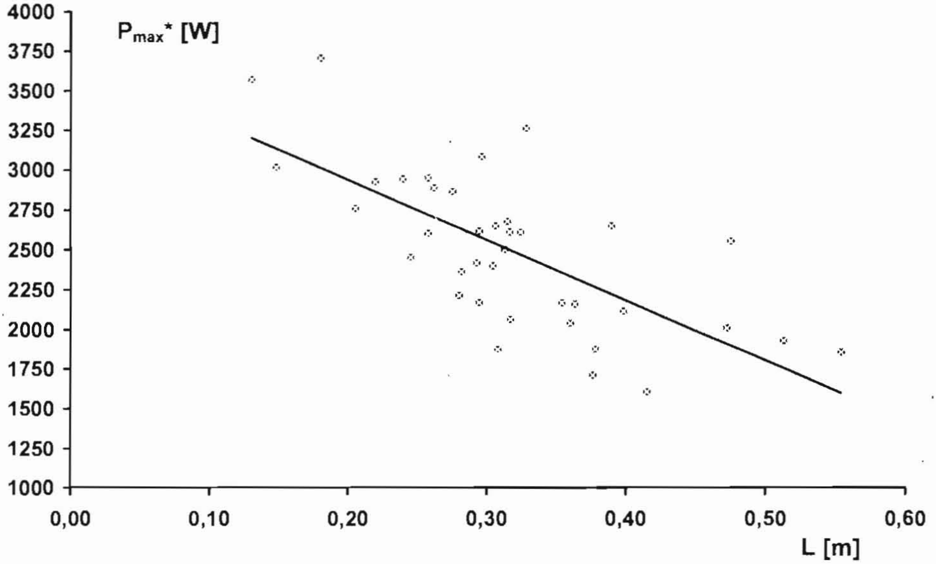


Fig. 1. The relationship between maximal power and countermovement depth with height of jump controlled for female (a) and male (b) groups .

The maximal power was found to be significantly correlated with the height of jump. This was in line with the existing literature (Dowling and Vamos, 1993). Obvious differences between jump parameters measured in females and males have been reported previously (Komi and Bosco, 1978.). A new fact shown in this study is a different contribution of the tested variables to the P_{max} value in the both groups. Although, the countermovement depth explained about 20% of P_{max}, similarly in both groups, the height of a jump had a greater contribution to the P_{max} for females than males (54% vs. 25%, respectively), oppositely than the body mass (5% vs. 45%, respectively). Rather small influence of the body mass on P_{max} in the female group could be thought of the result of a greater interindividual difference in the fat percent in the female group.

CONCLUSIONS

The present results delivered the evidence that the maximal mechanical power developed during the positive phase of a take-off could be sufficiently explained by the three independent variables: the height of a jump, the lowering of the center of the body mass in negative phase (countermovement depth) and the body mass. The considered variables explained more than 80% of the P_{max} variance. This means that when knowing the body mass and two simple geometrical parameters characterizing a jump performance one can estimate a maximal mechanical power with a standard error less then 10%. This seems to be especially interesting for testing and training purposes.

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