THE STRUCTURE OF GROUND REACTION FORCE IN VERTICAL COUNTER MOVEMENT JUMP AT DIFFERENT INTENSITIES

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The aim of the study was to ascertain the structure of ground reaction force CMJ (counter movement jump) at varying intensity of take-off, and further, to evaluate the mechanisms of performing final force impulse. CMJ, in three intensive varieties comprising maximal intensity, 75% intensity and 50% intensity, was conducted in a group of 44 university students. The vertical component of reaction force F(t) was analyzed in terms of force, time and track take-off parameters. Statistical analysis confirmed differences between take-offs at different intensities in the magnitude of force impulse, track and time variables of the F(t) curve. The crucial factor influencing the creation of force impulse is the range of the CG track in the preparation and acceleration phases.

KEY WORDS: structure, reaction force, counter movement jump, take-off, different intensity.

INTRODUCTION: Most of the time the realization of motion exercise is related to concrete requirements on intensity and accuracy. Optimizing force actions on account of the intended movement task is a frequent subject of discussion in the field of motor control research. Most studies (e.g. Latash, 1998; Jaric et al., 1995; Sternad & Katsumata, 2000) deal with time and space structure of an examined motion, accuracy of realization or repetitive movement frequency under specifically defined conditions (e.g. Vaverka et al., 2004). The mentioned approaches deal mostly with the motion of a bio-kinematics pair, where motion of one segment is analyzed. The complex motor movements are more difficult encompassing participation by all muscle groups and segments.
The study by Vaverka et al. (2005) focuses on the influence of verbal instructions pertaining to take-off intensity. The counter movement jump (CMJ) served as a model for analyses. The aim of the project was to determine how subjects react to instructions on performing take-off with specified intensity (maximal take-off, take-off with 50% and 75% intensity). The accuracy assessment criterion of take-off intensity was characterized by the height of jump. Analysis of results proved differences in assessment accuracy of take-off intensity; such that with increased intensity the subjective assessment became more precise (see study by Vaverka et al., 2005). In terms of biomechanics, we restricted our focus on the mechanism of performing force impulse with different take-off intensity. Our study deals with the structure of ground reaction force in vertical counter movement jump of different intensity. In terms of kinematics and kinetics of vertical jump it is obvious that the final take-off intensity (final force impulse) can be regulated by the magnitude of reaction force, timing of performed motion and the range of centre of gravity (CG) motion. Hypothetically, our assumption is that the differences in kinematic and kinetic take-off models performed with different intensity will be duly ascertained.

METHODS: The research involved participation by 44 university students in total (body height 1.81 ± 0.05 m, body weight 74.47 ± 8.23 kg), who performed CMJ without arm movement in three variants of intensity: maximal intensity, half-intensity (50%) and three-quarter-intensity (75%). For each person, a theoretical value of take-off intensity at 50% and 75% respectively, based on his/her best achieved maximal jump, was allocated and the real CMJ result was compared to the theoretical values. The number of trials, organization of measurement and results are shown in the study (Vaverka et al., 2005). The vertical component of reaction force in CMJ was recorded by AMTI force plate and analyzed using the methodology of Vaverka et al. (2005). In total, 15 variables were ascertained as corresponding to force, time and distance of CG movement indicators of CMJ performance.

Figure 1 illustrates graphic and verbal forms of the measured variables. STATISTICA 6 (basic statistical characteristics, normality of experimental data distribution, one-way analysis of variance) was used.

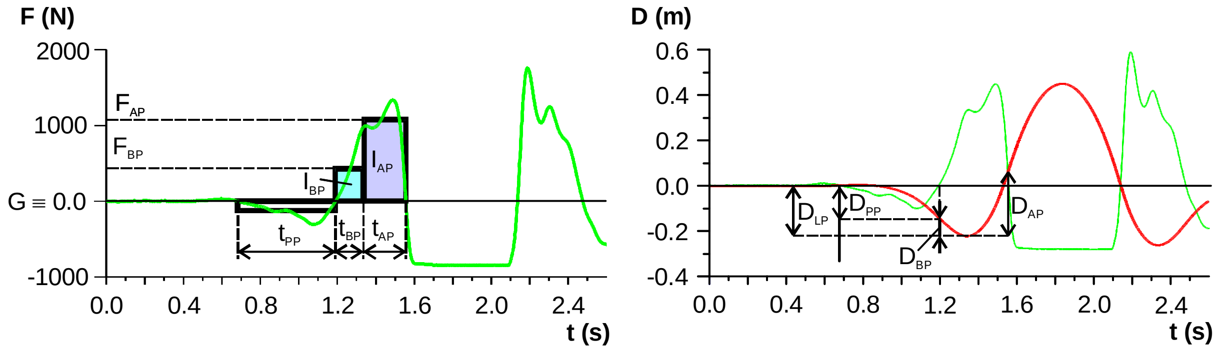

Figure 1: Graphic illustration of measured variables (HJ – final result of CMJ height of jump. *Time variables:* t_{PP} – time of preparatory phase; t_{BP} – time of braking phase; t_{AP} – time of accelerating phase. *Force variables:* F_{BP} – average force of braking phase; F_{AP} – average force of accelerating phase; I_{BP} – force impulse of braking phase; I_{AP} – force impulse of accelerating phase; I_{BPR} – relative force impulse of braking phase ($I_{BPR} = I_{BP}/G$); I_{APR} – relative force impulse of accelerating phase ($I_{APR} = I_{AP}/G$); KA – quotient of I_{BP} and I_{AP}. *Distance variables:* D_{PP} – distance of lowering CG in preparatory phase; D_{BP} – distance of lowering CG in braking phase; D_{LP} – distance of complete lowering of CG; D_{AP} – distance of CG in accelerating phase.)

RESULTS: Basic statistical characteristics and results of one-way analysis of variance are included in Table 1.

Table 1 The basic statistical characteristics and the results of one-way analysis of variance

		Intensity of the take-off								
Variable		MAX (A)		50% (B)		75% (C)			p	
		MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	A-B	A-C	B-C
HJ (cm)		40.17	5.282	27.16	5.225	32.61	5.178	**	**	**
t (s)	t_{PP}	0.50	0.13	0.43	0.12	0.46	0.12	*	–	–
	t_{BP}	0.20	0.06	0.15	0.05	0.16	0.05	**	**	–
	t_{AP}	0.27	0.05	0.19	0.05	0.20	0.05	**	**	–
F (N)	F_{BP}	421.2	169.31	416.3	130.64	450.3	161.43	–	**	–
	F_{AP}	715.2	131.96	763.2	138.58	810.2	151.96	**	–	–
I (N.s)	I_{BP}	74.43	18.251	57.89	17.710	65.45	19.795	**	–	–
	I_{BPR}	1.002	0.234	0.779	0.223	0.880	0.247	**	*	–
	I_{AP}	208.4	24.885	170.7	22.381	187.67	21.113	**	**	**
	I_{APR}	2.802	0.180	2.298	0.223	2.529	0.202	**	**	**
	I_{KA}	0.359	0.082	0.337	0.084	0.347	0.099	–	–	–
D (cm)	D_{PP}	19.61	5.74	13.27	6.03	15.10	6.38	**	**	–
	D_{BP}	13.44	3.79	8.43	3.80	9.72	4.13	**	**	–
	D_{LP}	46.13	8.39	30.70	8.60	34.43	8.29	**	**	–
	D_{AP}	33.05	8.00	21.71	9.46	24.82	10.10	**	**	–
HJD (cm)				7.081	4.030	2.483	3.160			**

HJD – difference between expected and actual value of the vertical jump height
* $p < 0.05$, ** $p < 0.01$

The anticipated statistically significant differences were confirmed among variables indicating CMJ height in different variants of the jump and acceleration impulses (I_{AP} and I_{APR}). Within the CMJ time structure, significant differences can be found only between maximum jump and both variants of lower take-off intensity. No significant difference was found between 50% and 75% intensity variants of CMJ. Within the scope of average force, no significant difference was observed between variants maximal intensity and 75% intensity, but the difference between maximal and 50% intensity of CMJ was significant. No statistically significant differences were found between 50% and 75% intensity of the take-off in all discussed time and force variables. The average models of time and force structure F(t) in three different variants of CMJ are demonstrated in Figure 2.

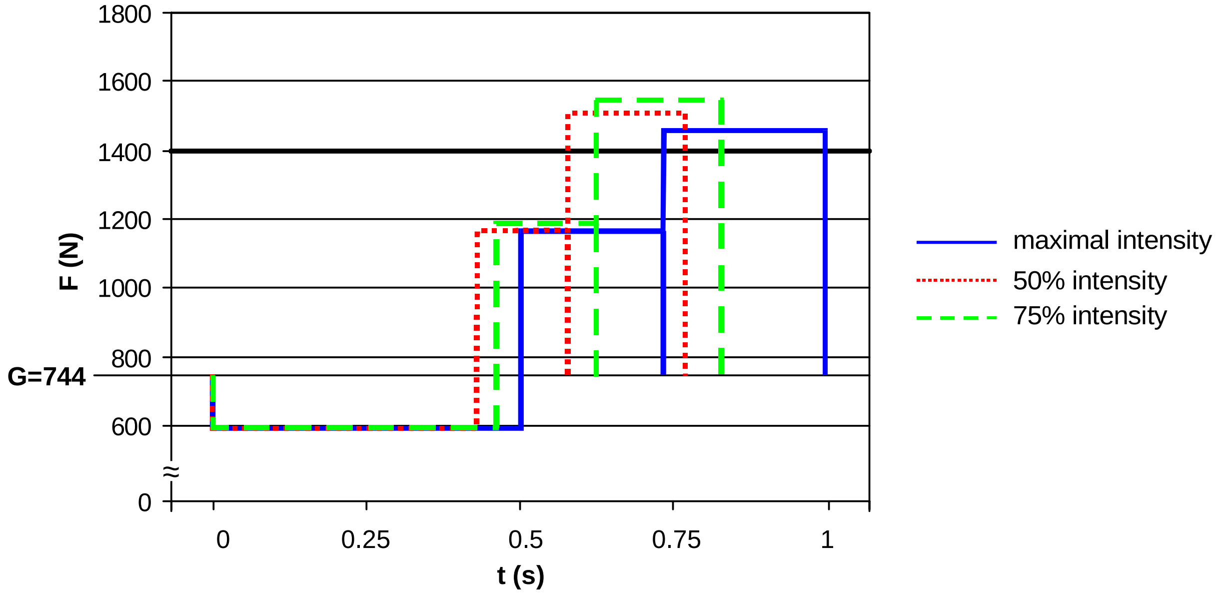

Figure 2: Model of F(t) curve for different variants of CMJ

As to the occurrence of force impulse, we found relatively small differences between I_{BP} in different variants of the jump in comparison with I_{AP} (see Table 1). An interesting indicator seems to be magnitude KA where no statistically significant differences between individual variants of the jump were ascertained. The range of CG track in the preparation phase of the jump and the braking phase of the jump shows significant statistical difference between take-off with maximal intensity and variants with 50% and 75% intensity (see Table 1). Statistically significant difference between deviation from actual value and theoretical value of the requisite jump intensity (magnitude HJD) shows that estimation of the jump with higher take-off intensity is significantly more precise than with lower take-off intensity jump.

DISCUSSION: There are several literary sources dealing with the impact of verbal instruction on the result of vertical jump with respect to various health aspects (eg. prevention of knee-joint injury in drop jump, Arampatzis, Bruggemann, & Klapsing, 2001) or in relation to estimation of the jump height with respect to some external stimulus (eg. Krol, 2004). However, no literary sources dealing with the analysis of the course of the curve F(t) in relation to the different take-off intensity were found. All verbal instructions for the group of measured subjects were aimed at take-off intensity (maximum, 50%, 75%) and not on the manner of take-off execution. The magnitude of force impulse in relation to weight of the measured subject serves as a decisive factor determining the height of the jump. As the definition of force impulse ($I = \int F(t).dt$) implies, the force impulse value can be achieved by various combinations of the magnitude of applied force and time of its realization. The track range of CG movement on which the action of the force is applied enters into the process of performing CMJ. As the figures and diagrams depicting the results of the experiments show, the maximum intensity take-off differs significantly and all other take-offs in all observed variables except for I_{KA} and the average force in the acceleration phase of take-off (F_{AP}). It means that the greatest force impulse was achieved while the action of the force was applied on the longest possible trajectory of CG for longer time together with lower average force applied in the acceleration phase of the jump. There is no statistically significant difference between F_{AP} of the maximum take-off intensity and the same magnitude at 50% intensity. On the other hand, F_{AP} of 75% take-off intensity proves to be statistically and significantly higher than at maximum take-off. The crucial indicator of differentiating intensity of take-off seems to be the range of CG movement in the preparatory, braking and acceleration phases of the jump. The achieved results indicate that the force of take-off activity is nearly the same in all variations of take-off intensity; the range of the movement in the phase of lowered CG (preparatory and braking phase) seems to be a significant factor determining the track of the centre of gravity in the acceleration phase, thus influencing the magnitude of force impulse.

CONCLUSION:

- The presented conclusions result from natural performances of CMJ by a group of motorically skilled university students where the sole instruction was different intensity of CMJ realization.
- Varying intensity of the jump is related to differences in the magnitude of force impulse and has considerable impact on the course of the vertical component of the reaction force F(t) curve, especially time and space movement of the centre of gravity. Analysis has proved that the values of average force in the acceleration phase of the jump differ minimally when different take-off intensity is applied.
- The range of track of centre of gravity movement in the preparatory and braking phases of the movement proves to be the crucial mechanism during take-off movement influencing the final force impulse. These results provide the magnitude of track of CG during movement in the take-off acceleration phase as well as the duration of action of the force during production of the final force impulse. The relationship between the braking and the acceleration force impulses was the same in all tested variants of the jump.

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