THE ANALYSIS OF THE TAKE OFF DYNAMICS IN THE TRAINING EXERCISES OF HIGH JUMPERS

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The purpose of this paper is to identify the time-force characteristics of the take-off dynamics in six standard training exercises of high jumpers, in order to define which conform best to the take-off characteristics of the high jump. The analysis of similarities of the characteristics was based on the flow of the ground reaction forces vertical component, which produced several parameters describing the dynamics of take-off. KISTLER force plate was used.

KEY WORDS: high jump, training exercises, take-off dynamics, ground reaction forces

INTRODUCTION: High jump is characterized by considerable level of take-off dynamics, defined by the time flow of ground reaction forces (GRF).
Former research shows that a high rank jumper at the beginning of the landing phase during the take-off to high jump (during the eccentric phase of muscle work related to amortization) produces vertical ground reaction force, able to reach the level of 9.0 BW within a very short time of ca 65-85 ms, and in the take-off phase proper (during the concentric phase) the level of 3.5-5.5 BW, in the time of 90-115 ms: Aura (1989), Bosco (1975), Brüggemann (1994), Dworak (1996). The duration of the entire take-off phase oscillates between 120 and 220 ms. These authors state also that during jumping and special, take-off phase improvement exercises, the vertical ground reaction force oscillates between 3.5-5.0 BW, and the time of contact of the foot with the ground averages 177-278 ms. These values indicate serious loads and dynamic overloads that occur in the high jump discipline.
The purpose of this paper is to identify the time-force characteristics of take-off dynamics in six standard training exercises of high jumpers, in order to define which conform best to the take-off characteristics of the high jump.

METHODS:

List of used symbols

LR [m] – life record	BJ [m] – best jump
Rw_1 [BW] – VGRFmax in eccentric phase	Rw_2 [BW] - VGRFmax in concentric phase
R_1 [N] - VGRF max in eccentric phase	R_2 [N] - VGRF max in concentric phase
I_1 [N/ms] - build up index for R_1	I_2 [N/ms] - build up index for R_2
Iw_1 [BW/ms] - build up index for Rw_1	Iw_2 [BW/ms] - build up index for Rw_2
t_o [ms] - take off time	HJ [m] – high jump.

The research was carried out over a group of 7 high jumpers. Their basic somatic and sports characteristics are presented in table 1.
One should note that the subjects differed considerably in age, sports results (best jumps: 1.75-2.25m), weight and competition experience, at similar tallness.
In order to measure the time flow of take-off force components in high jump with medium run up, jumping and weight training exercises, the researchers used a triaxial piezoelectric KISTLER force plate (9261A type) coupled with an IBM-PC computer by a 12-bit / 16 channel analogue AMBEX card. The method was described in detail in Dworak et al (1996).
The measurements of high jump take-off dynamics were taken indoors, on a force plate covered with a tartan carpet. During a simulated competition, the competitors wore spikes. All jumps and other exercises were filmed with a video camera for later evaluation.

Table 1 Somatic and sports characteristics of subjects.

Values	Life record [m]	Age [years]	Body weight [N]	Height [m]	Competition experience [years]
$\bar{x}$	2.00	23	703	1.86	6
V [%]	7.8	31.0	8.8	1.7	52.2

$\bar{x}$ – average value, V [%]– variance coefficient.

The measurement of take-off dynamics of six training exercises were carried out in the lab. The competitors, wearing their sports shoes, after a standard warm up, were examined usually in two measurement sessions, performing their usual training exercises: depth jump (DJ), barbell step ups (BSU), barbell both leg toe hops (BBLTH), barbell squat jumps (BSJ), standing barbell calf raise (SBCR), barbell half squat (BHS). The purpose was to produce the most dynamic take-off in each exercise series. The bar weight was increased in steps of 10 kg, to the maximum possible level the competitors could carry out the exercise properly. In the depth jump exercise, the depth was increased insteps of 0.20 m, to the maximum level permitting a dynamic take-off.

RESULTS AND DISCUSSION: The results, in form of arithmetical means of values ($\bar{x}$) and variance coefficients (V) of vertical ground reaction force are presented in tables 2-6 and Figure 1.

Table 2 Average values of take-off parameters in the best jump (BJ) of subjects.

	LR [m]	BJ [m]	Rw_1 [BW]	R_1 [N]	Rw_2 [BW]	R_2 [N]	I_1 [N/ms]	Iw_1 [BW/ms]	I_2 [N/ms]	Iw_2 [BW/ms]	t_o [ms]
$\bar{x}$	2.00	1.81	4.88	3410	4.33	3038	197.8	0.278	28.17	0.040	198
V[%]	7.8	6.7	13.6	10.3	18.6	18.6	62.4	58.0	57.0	54.9	17.0

Tables 3-6 present values of take-off parameters, where the highest ground reaction force was recorded in the "concentric" phase of the take-off.

Table 3 Values of take-off parameters in the depth jump exercise (DJ).

	HDJ [m]	R_1 [N]	Rw_1 [BW]	R_2 [N]	Rw_2 [BW]	t_o [ms]	I_1 [N/ms]	I_2 [N/ms]	Iw_1 [BW/ms]	Iw_2 [BW/ms]
$\bar{x}$	0.49	4885	6.97	4273	6.04	226	180.54	79.68	0.245	0.114
V [%]	22.0	34.2	34.1	35.6	30.4	15.8	70.8	126.2	81.8	121.8

HDJ – hight of depth jump.

Table 4 Values of take-off parameters in the BSU and BSJ exercises.

	Bar weight [kg]	R_1 [N]	Rw_1 [BW]	R_2 [N]	Rw_2 [BW]	t_o [ms]	I_1 [N/ms]	I_2 [N/ms]	Iw_1 [BW/ms]	Iw_2 [BW/ms]	t_{lot} [ms]
BSU $\bar{x}$	34.3	1257	1.79	1295	1.85	622	9.02	2.69	0.013	0.004	306
V [%]	23.0	52.8	52.7	28.2	27.2	26.6	54.4	14.9	54.0	19.3	46.1
BSJ $\bar{x}$	35.7	3371	4.83	3107	4.45	424.3	34.04	57.99	0.048	0.088	404
V [%]	35.6	15.6	19.2	20.7	24.2	30.5	35.1	110.4	31.7	115.1	17.6

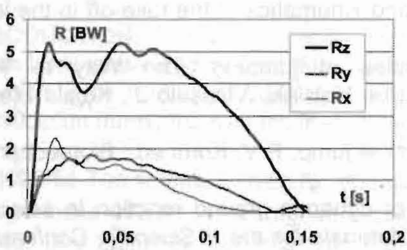
Table 5 Values of take-off parameters in the BBLTH exercise.

	Bar Weight [kg]	R_1 [N]	Rw_1 [BW]	t_o [ms]	I_1 [N/ms]	Iw_1 [BW/ms]	t_{lot} [ms]
$\bar{x}$	32.9	5135	7.30	248	52.82	0.075	388
V [%]	33.9	21.5	21.1	36.6	40.7	41.4	28.0

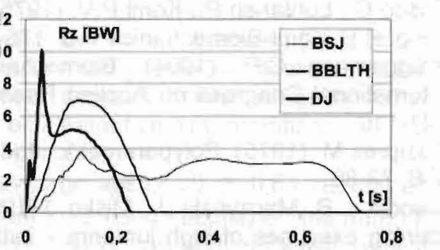
Table 6 Values of take-off parameters in the SBCR and BHS exercises.

	Bar weight [kg]	R_1 [N]	Rw_1 [BW]	R_2 [N]	Rw_2 [BW]	t_o [ms]	I_1 [N/ms]	I_2 [N/ms]	Iw_1 [BW/ms]	Iw_2 [BW/ms]
SBCR $\bar{x}$	142.9	3625	5.11	3377	4.76	921	14.94	16.261	0.021	0.025
V [%]	12.6	35.2	31.5	25.7	19.5	37.3	43.9	169.1	42.1	180.0
BHS $\bar{x}$	150	3478	4.94	3489	4.93	1189	13.21	10.22	0.019	0.015
V [%]	12.8	19.8	19.2	23.2	17.8	32.6	21.5	74.4	18.0	73.4

A.



B.



C.

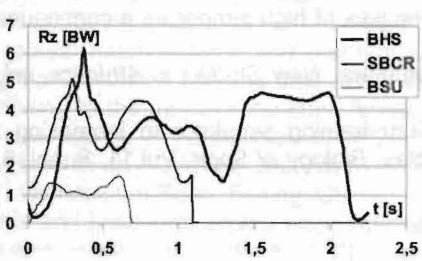


Figure 1 Typical VGRF flows in the examined exercises.
A. High jump.
B. Power exercises: BSJ, BBLTH, DJ.
C. Power exercises: BHS, SBCR, BSU.
Legend on the drawings.

Summarizing the results one may notice that:
a. the average values of VGRF in the high jump equaled respectively Rw_1= 4.88 BW, Rw_2=4.33 BW, at t_o = 198 ms;
b. maximum values of VGRF were recorded in the BBLTH exercises, equaling Rw_1 = 7.30 at t_o = 248 ms (at bar weight equaling 32.9 kg), and DJ – at the level of Rw_1 = 6.97 BW and Rw_2= 6.04 BW at t_o = 226 ms.
c. minimal values of VGRF were recorded in the Rw_1 = 1.79 BW and Rw_2 = 1.85 BW, at t_o=622 ms.
d. in reference to the height of the high jump a noticeable correlation occurred between HJ and Iw_2 ($r = 0.929^{XX}$; for $\alpha = 0.01$).
The results are partially equal to those of Aura & Viitasalo (1989), Bosco et al(1975), Regini & Sozański (1993), Trzaskoma (1994).

CONCLUSION: Analyzing the training of high jumpers one may calculate that during one year of technical training they produce ca 3400 jumps with short and long run up, and that

during the jumping training they execute ca 8500 take-offs. During the preparation phase, realizing specialized exercises, during one training session the jumper lifts 4-5 and even more tons (the bar), and the average number of jumps and weighted jumps equals 100-200 per training unit (Regini & Sozański, 1993).
The results of the research let us formulate the following statements:
1. Depth jump exercise shows the highest level of conformance to the characteristics of take-off dynamics in high jump. It perfectly shapes the take-off both in the "amortization" phase and "active" take-off. Later in sequence are: barbell squat jumps (BSJ) and barbell both leg toe hops (BBLTH).
2. Among all the 6 analyzed exercises, the lowest conformance to the characteristics of take-off dynamics occurs in step ups – BSU.
3. Take-off and landing in the high jump and the training exercises generate extreme loads of tissue structures, often possessing a traumatogenic character. An essential part of such training, that would minimize loads, overloads and related risks are: biomechanical knowledge, safety and ergonomics of training – including proper footwear, and correct technique of exercise execution.

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