DYNAMIC OVERLOADS IN SELECTED GYMNASTIC EXERCISES

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The purpose of this study is to identify force and time characteristics of ground reaction forces produced in selected movement exercises of gymnastics that contain elements of take-off and landing. The study was conducted over four athletes, two of sports acrobatics (17 and 18 yo) and two of artistic gymnastics (10 and 11 yo). The vertical ground reaction forces recorded in time were used to calculate maximum force values and characteristic times, and permitted an evaluation of the degree of dynamic overloads. The results of the tests show high levels of dynamic overloads, which may have traumatogenic character.

KEY WORDS: take-off landing dynamics, force plates, sport acrobatics, artistic gymnastics

INTRODUCTION: The athletes who practice gymnastic sports similarly to e.g. professional dancers (ballet) generate significant forces, which may many times exceed body weight (Dworak et al., 1996, 2005a,b). The overload character of these forces, most often related to the dynamics of take-off and landing, together with very short times of these movement exercises, and accumulated in course of long-term training, is a frequent cause of injuries that mostly concern lower extremities (specially feet, as well as ankle and knee joints) (Brüggemann 1994, 2005, Caine et al. 1989, Dworak et al. 1996, Kolt et al. 1999, Lowry et al. 1982, Lundon et al. 1999, Mc Auley et al. 1987, Milan 1994, Schwellnus et al. 1990).
That is why the problem of impact overloads seems specially important in case of actively training young individuals (youngster and junior age categories) in their progressive phase of the ontogenetic development (Dworak et al. 1996, Devita et al. 1992).
The purpose of this study is to identify time and force characteristics of ground reaction forces produced in selected movement exercises of gymnastic sports (sports acrobatics, artistic gymnastics) that contain elements of take-off and landing.

MATERIAL AND METHOD: The empirical tests covered four 1st sports grade athletes: two of the sports acrobatics section, specializing in jumps on the acrobatic track and two artistic gymnasts. The characteristics of the study is presented in table 1.

Table 1 General characteristics of the tested subjects

Subjects	Sex	Age [years]	H [cm]	m [kg]	Sports discipline	Training period [years]
K.S.	F	17	155	52	SA	8
D.R.	M	18	167	63	SA	9
S.B.	F	11	139	27.7	AG	4
S.J.	F	10	132	24.9	AG	3

Explanation of symbols: F - female, M - male, H - body height, m - body mass,
AS - sport acrobatics, GA - acrobatic gymnastics.

The study applied piezoelectric dynamometry to record and analyze the vertical component of the ground reaction force. The method has been described in detail in the works of Dworak et al. (2005a). The tests were conducted in a biomechanical laboratory. The acrobats executed their movement tasks barefoot, on a specially constructed track equivalent to a typical gymnastic mat. Artistic gymnasts executed their tests in gymnastic footwear. The KISTLER platform was covered with fitted carpet (resembling the surface used

during training). The authors analyzed elements of exercises performed by acrobats and gymnasts (tab. 2 and 3).

RESULTS AND DISCUSSION: Values of the parameters calculated for the tested subjects are presented in tables 2-3 respectively. Parameters relating to force were standardized due to the body weight. It means that their values were divided by weight and expressed in BW (body weight) units. Figure 1 shows the time curve representing the vertical ground reaction force component (Rz) of two gymnastic elements.

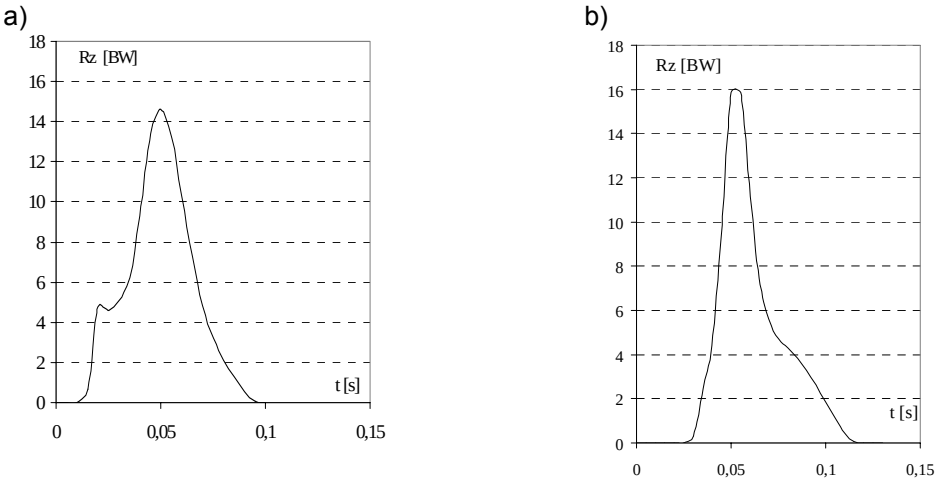

Figure 1: Time course of the vertical ground reaction force during the LL bouncing phase a) for a front somersault, b) after round off. Subject D.R., m=63 kg

Table2: Values of selected biomechanical parameters in chosen acrobatic jumps of the female athlete K.S. and male athlete D.R.

Type of exercise	Subject K.S.			Subject D.R.		
	T [ms]	T_{max} [ms]	Rz_{max} [BW]	T [ms]	T_{max} [ms]	Rz_{max} [BW]
Handspring forward, HH bouncing	220	65	1.56	200	40	3.06
Handspring backward, HH bouncing	390	40	3.12	225	35	3.83
Handspring backward, LL landing	165	35	10.79	165	30	10.30
Back somersault, LL landing	315	30	11.56	195	30	12.93
LL bouncing after round off	165	40	10.31	165	40	14.61
Front somersault, LL bouncing	165	35	11.60	165	25	15.87
$\overline{x}$	237	41	8.16	186	33	10.61

Explanation of symbols: HH- hands; LL- legs; T[ms]- total contact time of feet or hands with the ground during bouncing or landing; Tmax [ms]- time for achieving maximum force Rz; Rzmax [BW]- maximum vertical ground reaction force during the impact phase; – mean values

The Rz_{max} parameter describing extreme values of the ground reaction force assumes the role of global overload index, Dworak et al. (1996, 2005a). These overloads are transmitted through the skeletal system and affect specially talocrural joints, knee joints and the lumbar spine. Therefore they may constitute a traumatogenic factor for the body, specially when accompanied by poor movement technique and poor motoric preparation (attention should be paid to the young, still developing organisms of the young athletes).
The average of the time ranges of the exercises, during which the subjects gained maximum values of vertical forces (T_{max}) is approx. 18% for both sports acrobats and approx. 20% for artistic gymnasts in relation to the total time of feet or hands ground contact (T). One should notice that these time periods last only tens of milliseconds proving the percussive (impact) character of this take-off/landing microphase.

In movement tasks, where the take off was executed from HH (such element as handspring forward and handspring backward) one can observe significantly lower values of Rz_{max} equaling 21% for the female athlete and 25% for the male athlete in relation to the remaining acrobatic elements. Reverse dependency can be observed when analyzing the T [ms] parameter. These differences may be the result of different functions of upper and lower extremities, as well as smaller adaptation capabilities of upper extremities to the propulsory role. The prolonged amortization phase is related to the eccentric function of relatively weaker muscle groups, which in this situation oppose the gravity force acting on the tested subject. The overloads that occur in case of these tasks are smaller (from those of the lower extremities), however, due to the function of the upper extremities, they are relatively large, comparable to the values of lower extremities in such locomotion as running.
In all acrobatic elements where take off or landing was executed by the lower extremities, Rz_{max} force exceeds ten times the body weight value of the tested subjects (10.30 – 15.87 BW). The course of these values has an impact, momentary character, which decreases the possibility of monitoring proper (safe) foot and/or hand alignment during ground contact.

Table3: Values of selected biomechanical parameters in chosen elements of artistic gymnastics of the female athlete S.B. and S.J.

Type of exercise	**Subject S.B.**			**Subject S.J.**		
	T [ms]	**T_{max} [ms]**	**Rz_{max} [BW]**	**T [ms]**	**T_{max} [ms]**	**Rz_{max} [BW]**
Split jump - take off	208	29	3.90	290	35	3.85
Split jump - landing	585	46	6.68	234	51	4.88
Stag jump - take off	206	34	3.54	245	32	5.11
Stag jump - landing	590	54	5.77	260	85	4.18
“Turkish” - take off	328	51	3.22	412	122	3.81
“Turkish” - landing	528	56	6.10	528	14	3.53
Stag jump - take off	326	194	3.25	318	196	3.47
Stag jump - landing	321	61	5.75	402	89	3.11
$\overline{x}$	386.5	65.6	4.77	336.1	78	3.99

The results gained by artistic gymnasts are also characterized by high values of vertical ground reaction force, indicating significant load on the osteoarticular system of very young (10 and 11 yo) athletes. The average value of Rz_{max} for both female athletes equals 4.77 and 3.99 BW respectively. The highest values occurred during the landing phase of the split jump amounting to 6.68 BW (athlete S.B). The analyzed movement tasks of the gymnasts are visually characterized by great lightness and grace. From the point of view of a potential observer, they do not portray the danger resulting from the level of forces acting on the bodies of the athletes. This may lead in consequence to overload of the tissue structures of the extremities.

CONCLUSIONS: This pilot study resulted in formulation of the characteristic of force and time parameters in several gymnastic elements (take off and landing) that are typical for sports acrobatics and artistic gymnastics. In view of the obtained results, one may observe that these exercises bear very large dynamic loads, which many times exceed the body weight of the tested subjects. The largest values of the force characteristics concern elements where the take off or landing occurred with the use of the lower extremities.
One should also pay attention to loads occurring in those exercises, where take off or landing is executed by upper extremities. Although the values are lower (from those obtained in lower extremities), however due to the function of the upper extremities, they are relatively large, comparable to the values of lower extremities in such locomotion as running.
Taking into account young age of the gymnasts, whose skeletal development process is not yet complete, and the level of forces that act on their bodies during the execution of basic

elements of percussive (impact) character (often on hard surface), one may say about an alarming phenomenon leading to traumatism of the lower extremities and the spine (Brüggemann 2005, Dworak et al.1996, Sand 2000, Seegmiller 2003).
The results of this study demonstrate the significance of the problem. They encouraged the authors to propose a more extensive research project, that would allow to broaden the investigation.

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