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Dynamic loads in some movement structures in acrobatics. A preliminary study

LECHOSŁAW B. DWORAK

Chair of Biomechanics, University School of Physical Education (USPE) in Poznań,
60-775 Poznań, Park Wilsona, Poland.
Chair of Bionics, Academy of Fine Arts in Poznań, 60-967 Poznań, ul. Marcinkowskiego 29, Poland.

MAŁGORZATA TWARDOWSKA

Laboratory of Biomechanics, USPE in Poznań, Division in Gorzów Wielkopolski,
66-400 Gorzów Wielkopolski, ul. Estkowskiego 13, Poland.

TADEUSZ WOJTKOWIAK

Chair of Gymnastics, USPE in Poznań

KRZYSZTOF KMIECIK, JACEK MĄCZYŃSKI

Chair of Biomechanics, University School of Physical Education (USPE) in Poznań,
60-775 Poznań, Park Wilsona, Poland.

The aim of the paper was identification of force–time characteristics of ground reaction forces exerted during take-off and landing phases in the six typical acrobatic elements. The tests of a pilot study character were carried out on two professional athletes aged 17 and 18. The levels of such parameters characterizing dynamic loads and overloads of examined movement structures as: maximal and average values of vertical ground reaction forces, total time of support phases, time necessary for generation of maximal force, force buildup indexes as well as force impulses were calculated. The results obtained suggest that dynamic overloads are serious and of traumatic character.

Key words: dynamic overloads, ground reaction forces, acrobatics, take-off, landing

1. Formulation of the problem, the objective of this paper

A significant growth of interest in active approach to sports and recreation being observed in many countries in recent years has provoked a response from the specialists in various fields of science, industry, trade and sports [4]. Statistics shows that back in 1961 less than 24% of American adult population regularly practised physical exercise. Similar tendencies were still observed in 1961. However, as early as in 1977 approximately 47% of Americans participated in active recreation [2], [10]. One can notice that similar trends are popular also in Europe, and recently in Poland. Some examples of these transformations can be itemized as follows: recreation centers – fitness clubs, waterparks designed in the form of architecturally attractive complexes that offer various types of sports-recreational activities with the use of the most modern equipment. These tendencies became most significantly visible in the example of fitness, defined as *conscious influence through movement on human physical, psychical and emotional health* [1]. They have been documented in several printed books and periodicals published in recent years in Poland, as well as in television programs aimed at popularizing a specific lifestyle with extensive physical activity.

Active participation in sports and recreation has caused many problems of medical nature, among which the problems of static and dynamic overloads as well as injuries often accompanying this activity are worth recognizing.

The understanding of the mechanisms of overloads, sometimes causing injuries, is crucial to organizing physical activity reasonably [4].

It seems that dynamic overloads being produced during movement are bigger and more dangerous than static ones, especially during sudden impacts with force that may exceed the resistance of healthy bones and muscles [7], [9], [12].

The problem of impact overloads appears to be particularly important in young training individuals (juvenile and junior age categories) still in their progressive phase of ontogenetic development [5]. These overloads, accumulated during the training process, may constitute a significant traumatogenic element [4], [11].

There is of no doubt that such movement tasks as jumping, which are inherent elements of gymnastic sports, produce great dynamic overloads, which in consequence have an adverse influence upon the motoric system of a young sportsman who still grows.

The purpose of this paper was to identify and interpret the time–force characteristics of ground reactions occurring during selected movement tasks undertaken by sports acrobatics. These movements comprise bouncing and landing elements.

2. Material and method

The research was conducted on two sportsmen, the members of the sports acrobatics division of academic club (AZS), USPE in Poznań, specializing in acrobatic track jumps, representing the 1st sports class. The characteristic of the subjects is presented in table 1.

Two research methods, similar to these of DWORAK et al. [7], have been used: piezoelectric dynamometry in order to record the ground reaction force and video recording for recording and analysing initial quality of technical movement correctness. Ground reaction forces were measured with KISTLER type platform linked to an IBM PC type computer via an amplifier and an A/C converter. The components R_z, R_y and R_x were measured during the contact of a foot or a hand with the platform [3]. Due to relatively low (in all acrobatic elements analyzed) values of the horizontal (R_y) and cross (R_x) components of the ground reaction force, the results obtained are based on the characteristic of the vertical component (R_z) only.

Table 1. General characteristic of the subjects

Subjects	Sex	Age [years]	*H* [cm]	*m* [kg]	Training period [years]
1	F	17	155	52	8
2	M	18	167	63	9

F – female, *M* – male, *H* – body height, *m* – body mass.

Video recording was used to select one (the best) of three recorded measurements of each movement task. Then the selected values were subjected to further analyzes. The choice was made by a coach.

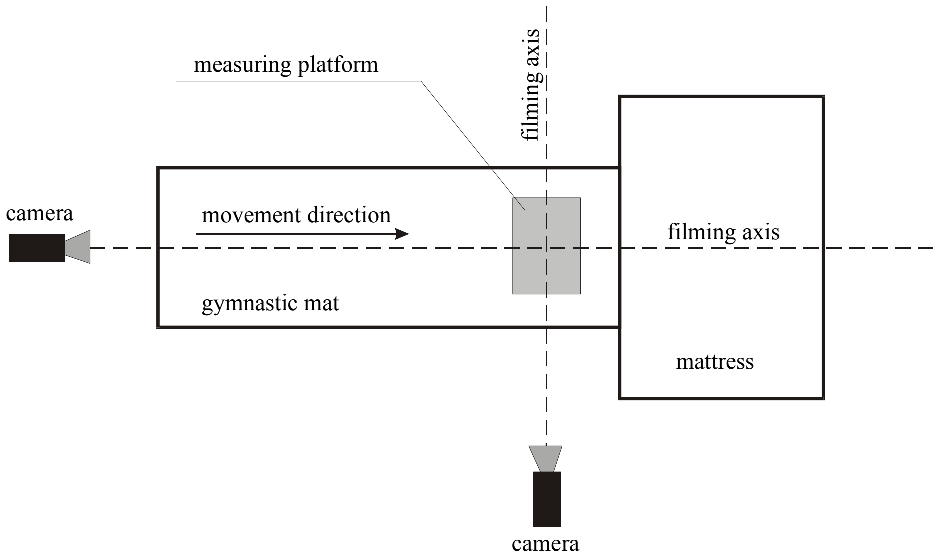


Fig. 1. Diagram of the testing ground

The subjects were barefoot when performing the tests over a specially constructed track resembling a typical gymnastic mat. Figure 1 shows the diagram of the testing ground. The following elements were analyzed: handspring forward (HH bouncing), handspring backward (HH bouncing, LL landing), back somersault (LL landing), LL bouncing after round off, front somersault (LL bouncing). HH and LL symbols stand for hands and legs, respectively.

The tests were conducted in the laboratory of the Chair of Biomechanics of USPE in Poznań.

3. Test results and discussion

The curve representing the vertical ground reaction force (R_z) versus time during the bouncing and landing phases of the dynamic tasks performed was used for determining the following parameters:

T [ms] – the total time of the contact of feet or hands with the ground during bouncing or landing,

$T_{\max}$ [ms] – the time necessary for achieving the maximum force R_z,

$R_{z\max}$ [BW] – the maximum vertical ground reaction force during the impact phase,

$<R_z>$ [BW] – an average value of ground reaction force during the impact phase,

$$< R_z > = \frac{1}{T}\int_0^T R_z(t)dt\,, \tag{1}$$

I_z [BW/s] – the force build-up index R_z during the impact phase,

$$I_z = \frac{R_{z\max}}{T_{\max}}\,, \tag{2}$$

P_z [Ns] – the force impulse achieved during the contact with ground

$$P_z = \frac{1}{T}\int_0^T R_z(t)dt\,. \tag{3}$$

Table 2. Values of selected parameters in chosen acrobatic jumps of the sportswoman

Type of exercise	T [ms]	$T_{\max}$ [ms]	$R_{z\max}$ [BW]	$<R_z>$ [BW]	I_z [BW/s]	P_z [Ns]
Handspring forward, HH bouncing	220	65	1.56	0.68	23.9	77
Handspring backward, HH bouncing	390	40	3.12	0.84	77.9	167
Handspring backward, LL landing	165	35	10.79	2.43	308.4	204
Back somersault, LL landing	315	30	11.56	2.11	385.1	339
LL bouncing after round off	165	40	10.31	2.70	257.6	227
Front somersault, LL bouncing	165	35	11.60	2.56	331.5	215

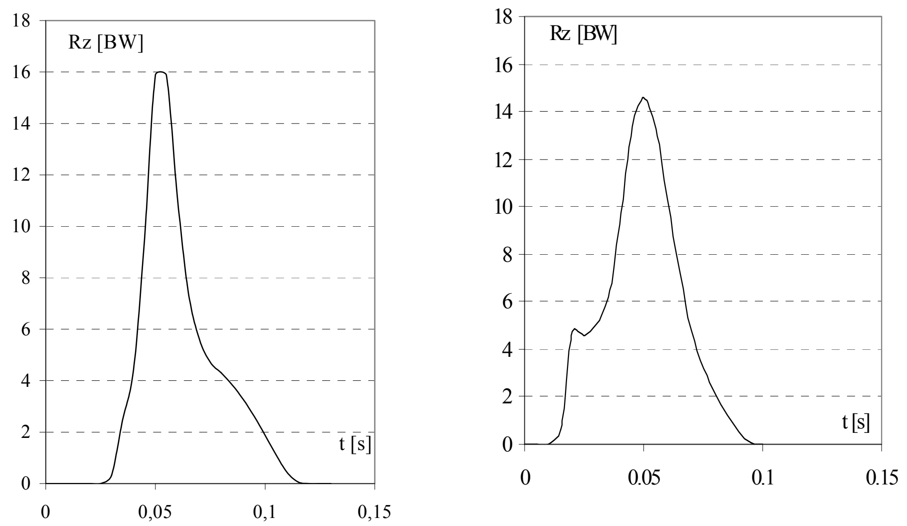
$\bar{x}$	237	41	8.16	1.89	230.7	205

$\bar{x}$ – average value.

The values of the parameters calculated for the subjects under examination have been presented in tables 2 and 3. The parameters related to force have been standardized due to the body weight. This means that these values have been divided by weight and expressed in BW (body weight) units.

Table 3. Values of selected parameters in chosen acrobatic jumps of the sportsman

Type of exercise	T [ms]	T_{max} [ms]	R_{zmax} [BW]	$\langle R_z \rangle$ [BW]	I_z [BW/s]	P_z [Ns]
Handspring forward, HH bouncing	200	40	3.06	1.06	76.5	131
Handspring backward, HH bouncing	225	35	3.83	1.20	109.4	167
Handspring backward, LL landing	165	30	10.30	2.68	343.2	273
Back somersault, LL landing	195	30	12.93	3.09	430.8	373
LL bouncing after round off	165	40	14.61	3.07	365.2	314
Front somersault, LL bouncing	165	25	15.87	2.88	634.9	393
$\bar{x}$	186	33	10.61	2.33	326.7	276



a) b)

Fig. 2. The vertical ground reaction force versus time during the LL bouncing phase: a) for a front somersault, b) after round off. Subject 2, m = 63 kg

Figure 2 shows the curve representing the vertical ground reaction force component (R_z) versus time (t) of two gymnastic elements. The parameter $R_{z\ max}$ describing the extreme values of ground reaction force is accepted as the global overload index [6]. These overloads are transmitted by a skeletal system to the ankle–

tibia joint, knee joints and the lumbar vertebrae [5]. Hence, they may constitute a traumatogenic factor, especially in the case of imperfect movement technique and inadequate motoric and physical preparation.

An average time scale over which the objects achieved the maximum values of vertical forces ($T_{\max}$) approached 18% for both sportsmen – in relation to the total time of the contact of foot with ground (T). One should notice that these time intervals last only a few dozens of milliseconds, confirming the percussive character of this bouncing/landing microphase.

The characteristic of the parameters of movement tasks, including HH bouncing (such elements as handspring forward and backward) is especially interesting. One may notice definitely lower values of $R_{z\max}$ that are equal to 1.56 and 3.12 BW for the female subject and 3.06 and 3.83 for the male subject, which constitutes, respectively, approximately 21% and 25% of $R_{z\max}$ of the remaining acrobatic elements. Similar dependence may be observed for the values of I_z and P_z, and reverse dependence – for the parameter T [ms]. Presumably, these differences are due to the distinct functions fulfilled by the upper and the lower limbs, and smaller accommodative capabilities of upper limbs to bear the locomotory (driving) function. A prolonged amortization phase is related to the eccentric activity of relatively weaker muscular groups, which in such situations counteract the gravitation force.

In all elements, where a dancer bounces and lands on lower limbs, the force $R_{z\max}$ exceeds more than a dozen times the value of body weight of subjects (10.30–15.87 BW). This value is higher than that obtained in dancer tests by DWORAK et al. [7]. It should be stressed once more that the changes in these values have a percussive character of short duration, which decreases the possibility of exercising a correct (safe) technique of positioning feet or hands during their contact with ground. The scale of these loads may also be estimated comparing the loads in locomotive movements obtained by us and by DWORAK et al. [5]. The characteristics of vertical reaction force for walking and running are presented in table 4.

Table 4. Maximum values of vertical ground reaction force (GRF) in standard walk and run [5]

Type of locomotion	Velocity V [m/s]	Force $R_{z\max}$ [BW]
Walk	1.59	1.1
Run	3.81	2.53

4. Summary

On the basis of the pilot tests conducted, an analysis of force–time parameters of a few gymnastic elements (bouncing and landing) typical of sports acrobatics was carried out. In the light of the results obtained, one can say that these tasks suffer from huge dynamic overloads, which exceed several times the body weight of the subjects.

The highest values of force are related to these elements where a dancer bounces or lands on lower limbs.

Without any doubt, one should pay special attention to these tasks in which bouncing/landing is carried out by upper limbs. Although in this case the force values are lower (compared with lower limbs), they are significant and equivalent, e.g., to the values of lower limbs in their locomotive function such as running.

The results of the tests illustrate the seriousness of the problem. They also encourage the authors to propose a large-scale and more complex research project, whose realization will allow a more detailed study of the matter.

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