TAKE-OFF STRUCTURE AND TOUCH DOWN LOADS DURING LANDING IN SELECTED RHYTHMIC SPORT GYMNASTICS JUMPS

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INTRODUCTION: Jumps can be found in various sport disciplines, and the technique of execution depends on the specifics of the event. In the case of rhythmic sport gymnastics, jumps as well as turns, elements of flexibility and balance in connection with the use of equipment are some of the elements assessed in competition. Each jump must have a form defined in the rules. A long flight phase makes possible the execution of the desired form of a jump.

Rhythmic sport gymnastics is one of the sports disciplines with early specialization, which means that girls start training when they are five years old. The specific character of this discipline consists in repeating elements of technique, which means that dozens of jumps are done landing on one or two legs during each training session. Counting the number of repetitions, the number of practice sessions in a week and multiplying by the number of weeks in the year - in the case of the youngest girls - we get about six thousand repetitions. Cumulating loads while landing and the specific structures of children's bones are the cause of repetitive strain injury, especially to the knee and ankle joints. Research on the structure of take-offs in jumps is referred to for factors that contribute to achieving maximum length and height of jump (Aura & Viitasalo, 1989; Dowling & Vamos, 1993; Janiak, Eliasz & Gajewski, 1997), but few works deal with the landing phase and the resulting loads on the movement system.

Investigations point to the importance of co-ordination, specifically of the movement of the upper extremities in the take-off phase, which may depend on the synchronization of the movements of the lower and upper extremities and trunk (Aragon-Vargas & Gross, 1997). Some authors have found that the arm swing improved the jump height (Shetty & Etnyre, 1989), increased the downward load on the legs (Amin & Bober, 1989), and enhanced the impulse generated by the lower extremities by lengthening the time of force application (Harman et al.,1990). However, in the cited papers the authors did not consider the influence of arm swinging on load parameters during the landing phase.

The aim of this paper is to define the value of the reaction force which must be absorbed during the landing phase and to investigate the share of the upper extremities in damping touch down loads in jumps with different difficulty levels.

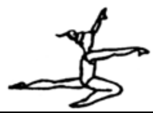
METHODS AND PROCEDURES: The competitors (N=20) of rhythmic sport gymnastics took part in the research.

Table1. Characteristics of subjects

Number	Age [years] Min. – max.	years of practice min. – max	Body mass $\bar{x} \pm$ SD
20	8-16	2 – 10	36.39 $\pm$ 10.54

The experiment consisted in making - from both legs - six jumps according to the illustration and description of their form in Table 2.
The jumps denoted J_1, J_3, J_5 were done without arm swing, which was achieved by putting a 3 cm wide rubber band on freely hanging upper extremities (at the height of the elbow joints) and trunk. The jumps denoted J_2, J_4, J_6 were done with symmetrical arm swing, face up. Selection of a jump for further analysis was based on earlier results of experiments in which the difficulty level was estimated using biomechanical criteria (Rutkowska-Kucharska & Sikora, 1996). The selected jumps differed in the level of difficulty, but all competitors, independently of years of practice, performed them correctly.

Table 2. The name and form of selected jumps

Symbol of jump	Name of jump	Form of jump
J_1	Vertical jump arms down	
J_2	Vertical jump arm swing	
J_3	Stag leap arms down	
J_4	Stag leap arm swing	
J_5	Stag ring leap arms down	
J_6	Stag ring leap arm swing	

The measurement of kinetic parameters of jumps was done on a dynamographic force platform (Kistler), and data were analyzed using the Bioware program. The height of jumps (h_1, h_2, h_3, h_4, h_5, h_6) was calculated from the registered courses of the center of mass and reaction force. Moreover, for each jump the following quantities were estimated: maximum force of unload (F_1), reaction force of take-off (F_2), reaction force of landing (F_3), unloading time (t_1), time from overloading to F_2

(t_2), time from F_2 to the end of take-off (t_3) and time from start of touch down to F_3 (t_4).
Statistical analysis was done using the Statistica program. Jumps were done from a static, upright position with the arms down. Each subject was instructed to perform three repetitions of each jump, and the execution with the best height was taken for statistical analysis.
RESULTS AND DISCUSSION: The value of the reaction force of landing (F_3) in five investigated jumps exceeded the value of 900 N, which is three times the body mass of the girls. In contrast, the reaction force of landing (F_3) in the stag ring leap with arm swing was lower (776 N). The highest value of F_3 was noticed in the vertical jump with arm swing (J_2), thus in the jump whose technique is the easiest. For jumps with multiple structures, higher values of reaction force (F_3) were noticed in jumps without arm swing than in those done with movement of the arms. For vertical jumps this relationship was the opposite.

Table 3. Mean values and SD of height of jump and reaction force of landing (F_3) for different jumps.

Type of jump		Height of jump [cm] $\bar{x}$ ± SD	F_3 [N] $\bar{x}$ ± SD
Vertical jump	J_1	23.3 ± 2.4	989.63 ± 545,52
	J_2	27.3 ± 3.4 *	993.04 ± 438.81
Stag leap	J_3	18.7 ± 2.8	997.04 ± 330.09
	J_4	20.7± 4.1 *	945.02 ± 398.16
Stag ring leap	J_5	18.3 ± 2.5	976.76 ± 466.31
	J_6	21.9 ± 4.1*	776.17 ± 246.88*

*significant at 0.05

The next part of the analysis was to find the relationship between the reaction force of landing and parameters characterizing the phase of take-off, body mass and height of jumps. The peak of reaction force related significantly to body mass only in jumps without swinging the arms (except the stag leap). Moreover, in the vertical jump it was found that the peak of the reaction force of landing (F_3) depends on the force of unloading (in jumps without arm swing). The reaction force associated with the landing phase was found to be significantly related to the values of unloading time (t_1), time from overloading to reaction force of take-off (t_2), and time from reaction force of take-off to the end of take-off (t_3).
The arm swing caused a statistically significant increase in height in all kinds of jumps, and the increase in height was greater for vertical jumps than for horizontal jumps. Lower results in the height of jumps (J_3, J_5) in comparison with the same jumps with an arm swing (J_4, J_6) indicate an important role of arm movement in the phase of take-off. But lower results in the height of complicated jumps and their SD values (J_3, J_4, J_5, J_6) in comparison with vertical jumps indicate a relationship between the co-ordination of the arms and other parts of the body and the height of jumps. In the case of multiple jumps, a statistically significant decrease in the reaction force of landing in the jump with arm swing (J_6) indicates that the arm swing plays a important role in decreasing loads during the landing phase. This information is especially important in the case of jumps with one leg landing.

Table 4. Correlation coefficients of the take-off parameters, body mass and height of jumps with reaction force of landing

Type of jump	Parameters of take-off and correlation coefficient
J_1	F_1 (0.54*), M (0.57*), H (0.47*)
J_2	H (0.43*)
J_3	t_2 (0.58*), M (0.49*), H (0.65*)
J_4	t_2 (0.50), M(0.47*)
J_5	t_1 (0.45*), t_3, M (0.48*), H (0.47*)
J_6	t_1 (0.45*), t_2 (0.59*)

F_1 -force of unload, t_1-unloading time, t_2-time from overloading to force of take-off, t_3 -time from max. force of take-off to the end of take-off, M-body mass, H-height of jump
*significant at 0.05

CONCLUSIONS:

1. The reaction force during the phase of landing is three times the body mass.
2. The arm swing in the vertical jump doesn't decrease the value of the force needed to dampen shocks during the landing phase.
3. The arm swing in multiple jumps decreases loads on the movement system in the landing phase.
4. The degree of loading during the landing phase of multiple jumps depends on temporal parameters of the take-off.

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