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BIOMECHANICAL CRITERIONS TO ESTIMATE ROUND-OFF TUCKED PERFORMANCE AMONG ACROBATS AGED 10-11

Biomechanical criterions to estimate round-off tucked

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Abstract
Introduction. The aim of the study was to carry out a biomechanical analysis of performing key elements of sports technique of the round-off tucked back somersault by acrobats aged 10-11. ***Material and methods***. Thirty male acrobats participated in the study. They were randomly assigned to two groups: experimental (n=15) and control (n=15). Training experiment (specially designed training program applied in the experimental group), experts' evaluation and film analysis were the methods used to evaluate effects of experiment. ***Results***. The results of the experimental group were statistically significantly better than in the control group (p<0.05). ***Conclusion.*** Training program based on teaching and improving key elements of technique may be recommended as one of the effective ways of teaching and improving the technique of selected acrobatic exercises of a coordinationally complex movement structure.

Introduction

The development of sports acrobatics and an inclusion of trampolining in the programme of the Olympic Games led to the fact that exercises, their dynamic connections as well as the whole sets are more and more difficult. Training an acrobat to become highly skilled, so that he can compete in the international arena, requires implementing new training means, forms and methods based on research results. There appears a need to make use of new technical ideas in order to perform an in-depth analysis of the structure of sports exercises to identify the most important elements of a particular movement. From the point of view of teaching a movement, information about the most characteristic and important moments in the course of a move-ment is necessary to create effective training programmes. An identification of such elements, described in literature as key elements of sports technique, ought to be an introductory stage to form such programmes [1, 2, 3, 4].

Such knowledge is indispensable from the very beginning, i.e. already at the stage of versatile preparation, since it will make it possible to select those training means which will influence the harmonious development of an acrobat as well as contribute to a direct positive transfer of a movement habit to more and more difficult exercises [5, 6]. On this basis it will be possible to form more and more complex training and competition sets as well as expect their effective performance.

Results of research [7, 8, 9, 10, 11, 12, 13] confirm that the knowledge of technical training is still not sufficient, and the range and amount of research into movement technique is not large. In a technical training of an acrobat there are many unexplained matters.

The aim of the study was to carry out a biomechanical analysis of performing key elements of sports technique of the round-off tucked back somersault by acrobats aged 10-11.

Material and methods

The study included thirty boys (body mass 39.73 ± 3.22 kg, height 148.43 ± 4.24 cm, age 10.8 ± 0.67 years) at the level of the second sports class. The following methods were used: training experiment (specially designed training program applied in the experimental group), experts' evaluation and film analysis. Technical preparation of acrobats was evaluated on the basis of experts' notes given for performing some movement tasks, i.e. particular phases as well as the whole exercise, namely the round-off tucked back somersault. The choice of exercises was determined by classification requirements of the Polish Association of Sports Acrobatics. The group of experts consisted of referees of sports acrobatics (n=5). The criteria of evaluating were in accordance with the referee rules in sports acrobatics.

To evaluate the round-off tucked back somersault a film analysis was also applied. The best performance was selected for analysis. All the best trials were recorded with two NTSC (60 Hz) video cameras and APAS 2000 (Ariel Dynamics) cinematographic analysis systems. Ten light-reflective markers were placed on different parts of the subject's body (on the right side of the body on a foot, ankle, knee, hip, wrist, elbow, shoulder, hand, and the centre of the head). Cameras were placed 6 m apart, 9 m from the front of the data acquisition region, and 1.75 m high. Calibration cube (2.0 m wide x 2.0 m high x 1.5 m deep) was placed in the field to the utilization of the athletes body measurement and to quantify error of measurement. Motion sequences were auto-digitized, transformed, and smoothed using a low pass digital filter (10 Hz). The choice to use a digital filter at 10 Hz was made to minimize any smoothing effect on raw data to thereby avoid masking any inherent system error. Accuracy of tree-dimensional linear and angular values was estimated based on the procedure described by Klein and DeHaven [14]. Composite control cube consisting of 22 reflective calibration points and 10 data points placed on the acrobat body were digitized and entered into the 3-dimensional linear transformation (DLT) module and converted to real displacements. The average error of marker position determined for all measurements was 2.88 mm (1.2%), for a subject to camera distance of 9 m. During the round-off tucked back somersault the following parameters were recorded: movement trajectories of body joints and the centre of gravity (CG), time characteristics of movement phases and joint angles. The normality of distribution and homogeneity of variances were tested with the Shapiro-Wilk test. After the verification of the prerequisite, studied variables were analyzed using the t-Student test. Probability level of $p<0.05$ was used as critical. For significant differences, Fisher *post hoc* test was used. The results were statistically analyzed using the Statistica program (StatSoft, Inc. 2005, STATISTICA – data analysis software system, version 7.1. www.statsoft.com).

Results

On the basis of a biomechanical analysis it was possible to obtain information concerning selected biomechanical factors characterize the round-off tucked back somersault performed by the acrobats from the experimental and control group.

The analysis included the values of joint angles and the time duration of particular elements of the round-off tucked back somersault. The data are presented in Table 1 and 2.

Joint angles of knee and hip were presented as the most characteristic while performing the round-off tucked back somersault by acrobats from both groups. In the starting body posture the following values were noticed in the experimental group: knee – 172.33^0 (±1.39^0), hip – 184.04^0 (±5.21^0). As for the control group, it was as follows: knee – 173.34^0 (±1.93^0); hip – 185.58^0 (±4.44^0), (Tab. 1).

Relocating – pivotal body posture, where the CG was at its highest, was performed without a proper 'tuck'. It is indicated by the obtained average values of joint angles. The following values were achieved in the experimental group: knee – 132.05^0 (±2.60^0) and hip – 55.23^0 (±8.07^0). As for the control group, the results were as follows: knee – 130.64^0 (±3.01^0) and hip – 53.15^0 (±2.36^0).

The final posture at the moment of landing was assumed by the acrobats from the experimental group with the following average angle values: knee – 117.64^0 (±3.07^0) and hip – 120.95^0 (±2,89^0). As far as the control group is concerned, it was as follows: knee – 118.80^0 (±3.17^0) and hip – 122.94^0 (±2.96^0).

Table 1. Average values of biomechanical parameters for acrobats from the experimental (EG) and control group (CG) at the beginning of the experiment

Biomechanical indexes	Key elements of sports technique of the tucked back somersault in an acrobatic exercise of the round-off – somersault									
	Starting body posture		Relocating – pivotal body posture: Assuming the 'tuck' posture		Relocating – pivotal body posture: CG at its highest		Relocating – pivotal body posture: The end of the 'tuck' posture		Final posture at the moment of landing	
	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
Time (s)	-	-	0.30 ±0.02	0.31 ±0.03	0.43 ±0.03	0.41 ±0.02	0.55 ±0.02	0.56 ±0.03	0.84 ±0.02	0.85 ±0.02
Knee angle [^{0}]	172.33 ±1.39	173.34 ±1.93	81.40 ±2.10	78.93 ±0.88	132.05 ±2.60	130.64 ±3.01	74.79 ±5.45	75.43 ±5.03	117.64 ±3.07	118.80 ±3.17
Hip angle [^{0}]	184.04 ±5.21	185.58 ±4.44	84.01 ±1.81	82.20 ±2.23	55.23 ±8.07	53.15 ±2.36	61.41 ±6.82	59.49 ±9.02	120.95 ±2.89	122.94 ±2.96

Also, a biomechanical analysis of performing key elements of sports technique in the round-off tucked back somersault was done at the end of the experiment after special training programmes had been implemented. It confirmed that the acrobats from the experimental group were better prepared technically than those from the control group (Tab. 2).

Table 2. Average values of biomechanical parameters for acrobats from the experimental (EG) and control group (CG) after the experiment

Biomechanical indexes	Key elements of sports technique of the tucked back somersault in an acrobatic exercise of the round-off – somersault									
	Starting body posture		Relocating – pivotal body posture: Assuming the 'tuck' posture		Relocating – pivotal body posture: CG at its highest		Relocating – pivotal body posture: The end of the 'tuck' posture		Final posture at the moment of landing	
	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
Time (s)	-	-	0.27 ±0.01	0.30 ±0.02	0.44 ±0.01	0.44 ±0.02	0.56 ±0.01	0.55 ±0.02	0.95 ±0.02	0.86 ±0.02
Knee angle [^{0}]	178.41 ±1.33	174.62 ±2.73	68.03 ±0.51	72.73 ±1.84	57.76 ±1.34	127.59 ±2.21	145.64 ±1.11	86.72 ±1.94	153.95 ±1.79	145.38 ±1.79
Hip angle [^{0}]	180.70 ±2.14	184.44 ±3.42	63.71 ±0.34	78.58 ±0.65	50.53 ±1.72	52.60 ±1.08	166.28 ±2.79	65.61 ±1.21	146.95 ±1.39	130.80 ±2.67

The starting body posture was assumed by the acrobats from the experimental group with the following average angle values: knee – 178.41^0 (±1.33^0) and hip – 180.70^0 (±2.14^0). The values obtained by the control group were as follows: knee – 174.62^0 (±2.73^0) and hip – 184.44^0 (±3.42^0). The presented results indicate that the experimental group acrobats performed this element assuming a stiffer body posture than the control group. While performing a relocating – pivotal body posture, where the CG was at its highest, the joint angles in the experimental group had the following values: knee – 57.76^0 (±1.34^0) and hip – 50.53^0 (±1.72^0). As for the control group, the values were as follows: knee – 127.59^0 (±2.21^0) and hip – 52.60^0 (±1.08^0). At the end of the 'tuck' posture the analysed angles in the experimental group were the following: knee – 145.64^0 (±1.11^0) and hip – 166.28^0 (±2.79^0). In the control group it was as follows: knee – 86.72^0 (±1.94^0) and hip – 65.61^0 (±1.21^0). The results confirm that while performing a relocating – pivotal body posture the acrobats from the experimental group had a better 'tuck' posture. It allowed them to perform ¾ of the body pivot during the ascending part of flight trajectory as well as 'untuck' properly in the final phase of the relocating – pivotal body posture, which the acrobats from the control group did not manage to do. The body posture at the moment of landing was characterised by the following joint angles: knee – 153.95^0 (±1.79^0) and hip – 146.95^0 (±1.39^0) in the experimental group, whereas in the control group it was as follows: knee – 145.38^0 (±1.79^0) and hip –

130.80⁰ (±2.67⁰). It enabled the acrobats from the experimental group to perform a technically better and a more stable landing than that of the control group.

At the end of the training experiment the results of the experimental group for performing three key elements of starting body posture, relocating – pivotal body posture and the final posture at the moment of landing were statistically significantly better than in the control group ($p<0.05$).

Making fewer mistakes in key elements was reflected in the mark given by experts for performing the round-off tucked back somersault. In the experimental group it was better by 9.8%, whereas in the control group only by 3.5% ($p<0.05$). The result of the experimental group was 6.0% better than that of the control group ($p<0.05$).

Discussion

Technique analysis is the term given to an analytical method that is used to understand the way in which sports skills are performed and, through this understanding, provide the basis for improved performance. It is used primarily within the teaching and coaching of sports skills and within the field of sports biomechanics, although it is equally applicable in the clinical setting [8].

The conduct of an effective process of teaching and improving technique in disciplines involving a complex structure of movements requires the application of new means, forms and sports methods based on the research results. It is necessary to have information concerning those stages of physical movement that are the most characteristic and the most important from the point of view of teaching the movement. Only if such information is available it is possible to prepare an effective training schedule of teaching and improving the technique of exercises involving a complex coordinational structure of movement.

The aim of the study was to carry out a biomechanical analysis of performing key elements of sports technique of the round-off tucked back somersault by acrobats aged 10-11.

Joint angles of knee and hip were presented as the most characteristic while performing the round-off tucked back somersault by acrobats from both groups. In the starting body posture the following values were noticed in the experimental group: knee – 172.33⁰ (±1.39⁰), hip – 184.04⁰ (±5.21⁰). As for the control group, it was as follows: knee – 173.34⁰ (±1.93⁰); hip – 185.58⁰ (±4.44⁰). After the experiment the starting body posture was assumed by the acrobats from the experimental group with the following average angle values: knee – 178.41⁰ (±1.33⁰) and hip – 180.70⁰ (±2.14⁰). The values obtained by the control group were as follows: knee – 174.62⁰ (±2.73⁰) and hip – 184.44⁰ (±3.42⁰).

The slight difference in the joint angles, especially in the starting body posture, is essential for the implementation of this key element and subsequent elements and, first of all, influences the performance of the motor task. In the opinion of many authors the starting body posture is more important than the values of the forces produced in the take off. Authors Shan et al. [15] claim that the initial body position (which is called "critical phase") determines mainly the correctness of the implementation of the motor task. Their results have been equally interesting – only 35% of the subjects were able to take into performance of exercise the recommendations of trainers for the critical phase of the exercise. Most subjects did not pay attention to the key element and focus on the activities carried out in flight and landing. They emphasized the initial body position, and although it takes the shortest time, it is the most important. The results of our study and other authors confirm that sports success, particularly in the disciplines of complex structure movements, largely depends on properly adopted systems of the body and requires special preparation of the technique [12, 16, 17, 18, 19].

On the basis of the experiment it may be stated that it is groundless to underestimate those little differences concerning the values of biomechanical indexes. Drawing on the research results of King and Yeadon [1], a bigger role in the case of exercises of complex movement structure is played by body postures, linear velocities and, first and foremost, joint angles performed at a proper time than by the maximal power used in the take-off. It confirms a dominant role of technical preparation over physical in the first years of training. Similarly, in the case of gymnastic and acrobatic exercises, Gawierdowski [20] attaches the highest importance to the body posture with and without any contact with an apparatus, exercise phases and connections between phases as well as a proper rhythm of a performance. Gervais and Dunn [21] prove that while performing the landing after a double back somersault from symmetric bars gymnasts who "feel boundaries" achieve better results. An identification of boundary positionings of a body in particular phases as well as between them may be of primary importance in creating effective training programmes.

At the end of the training experiment the results of the experimental group for performing three key elements of starting body posture, relocating – pivotal body posture and the final posture at the moment of landing were statistically significantly better than in the control group ($p<0.05$). Making fewer mistakes in key elements was reflected in the mark given by experts for performing the round-off tucked back somersault. In the experimental group it was better by 9.8%, whereas in the control group only by 3.5% ($p<0.05$). The result of the experimental group was 6.0% better than that of the control group ($p<0.05$).

The obtained results confirm that there is still a lot to be discovered in the training of acrobats as long as adequate training technologies are implemented. Paying proper attention to the correctness of sets and positionings of a body may contribute to a lesser intensification of a training process of young sportsmen and to opting for a training model which is more beneficial in a long-term preparation process [22, 23, 24, 25, 26].

Conclusions

1. As far as the technique of performing the round-off tucked back somersault is concerned, it is possible to identify key elements that determine the correctness of performing this set. These include the starting body posture – biomechanical optimal positioning of body biolinks in the final moment of a preparatory phase just before the take-off; relocating – pivotal body posture – an exercise phase that begins the moment an acrobat grabs his shanks and finishes when his hands are no longer in contact with his shanks; the final posture at the moment of landing – a phase that starts the moment the legs touch the ground and lasts until the end of amortization movements.
2. Training program based on teaching and improving key elements of technique may be recommended as one of the effective ways of teaching and improving the technique of selected acrobatic exercises of a coordinationally complex movement structure.

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