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KEY COMPONENTS OF ACROBATIC JUMP

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Abstract. The purpose of the study was to conduct biomechanical analysis of basic acrobatic jump – tuck back salto after round-off and to determine the key elements of sport technique in phase structure of tuck back salto which allow the athlete to execute acrobatic jump without technical errors and to demonstrate the high mastery. One 60 Hz (JVC GR-DVL 9800 NTSC) camera and APAS 2000 (Ariel Dynamics) cinematographic analysis systems were used to analyze acrobatic jump. 7 highly skilled acrobats-jumpers (body mass 66.57±1.95 kg, height 170.25±2.04 cm, age 18.42±1.2 years) attended to this project. Three key components were indicated in tucked back salto: lunching posture of body, “tuck” posture and its multiplication, and final posture. Then they were subsequently included in training process. All body positions were characterized by joint angles and velocities (vertical, horizontal and resultant). An important information about key elements of tuck back salto has been obtained during analysis of the velocities. The establishment of the key components of acrobatic jump, in their biomechanical analysis and in utilization of obtained results during training and educational process is the reason for further increase of exercise complexity and improvement of acrobats mastery. ***(Biol.Sport 22:385-395, 2005)***

Key words: Technique – Tumbling - Tuck back salto

Introduction

Recent results of acrobat jumpers at World Championships and World Cups (2000-2003) demonstrate high complexity of acrobatic jumps and high mastery of athletes. The salto composition of athlete S.S. (Poland) includes the following complex acrobatic jumps: round-off - tempo salto - double salto backward stretched - tempo salto - tempo salto - tempo salto - tempo salto - triple-back somersault tucked. The pirouette composition of athlete A.K. (Russia): round-off - tempo salto - double salto backward stretched, each with 360° turn - tempo salto -

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tempo salto - tempo salto - tempo salto - salto with 1440° turn [2].

Athletes demonstrate stability in execution of complex jumps, good “school” of motions, individual style of sports techniques the most characteristic peculiarities of which are the precise postures and body positions which change dynamically during the phases of acrobatic jump. High level of complexity and high mastery are demonstrated by leading athletes who are, as rule, winners, prize-winners and participants of the major international tournaments and championships of those countries in which sports acrobatics is highly developed. However, analysis of phase structure of executed acrobatic jumps (both basic and competitive of various complexity) shows rather significant and even gross technical errors in exercises of many athletes. This is especially peculiar to the phase of preparatory actions of executed salto and that of concluding actions [2,5,6,7].

During the phase of preparatory actions for salto execution these technical errors include: flexed knee joints, flexed hip joints, extremely inclined to vertical line or beyond its body position during support before taking-off in salto [4,7]. Technical errors committed during the phase of preparatory actions prevent athlete from assuming technically correct body position while flying up to and thus do not allow to execute sufficient push-flying up to, so that to reach an ascending part of flight trajectory (high, high-far). While performing the jump with technical errors the subsequent motions are executed “stracossied’, that is “under oneself” or with “falling onto the back” which decreases height of flight, velocity of body rotation and significantly distorts exercise techniques. Technical errors prevent the athlete from qualitative execution of the major actions during flight - the salto proper [6,8,9].

At the phase of concluding actions the most typical technical errors (being the consequence of preparatory actions performed with technical errors) are: the lacking untucking, which prevents trunk extension for "gliding" in the space before landing, insufficiently or excessively turned salto at the moment of landing, landing in low squat position [7]. Technical errors in concluding actions decrease the quality of stable landings as well as transition to another acrobatic jump [4,5].

In order to reveal the causes of technical errors commited by athletes during performance of acrobatic jumps we have studied tuck back salto executed after round-off in combination round-off –tuck back salto by highly skilled athletes.

Objective

The aim of the study was to determine the key components of sports techniques in the phase structure of tuck back salto which allow the athlete execute acrobatic jump without technical errors and to demonstrate the high mastery.

Materials and Methods

One 60 Hz (JVC GR-DVL 9800 NTSC) camera and APAS 2000 (Ariel Dynamics Inc.) cinematographic analysis systems were used to analyze tuck back salto after round-off acrobatic jump. Reflective markers (n=17) on the subject were positioned. All marker positions were tracked and reconstructed using the APAS system. Video camera was placed in key position, 90 degrees to the plane of the path tumble. Dimensions of known factors on the field and various other measured objects in the field of view were used for the calibration points. The video pictures were grabbed and the files were stored in Audio Video Interlace format (AVI). The data coordinate endpoints were then smoothed using a second order low-pass Butterworth digital filter with a 10 Hz cutoff frequency. The 17 data points digitized were (left and right) foot, ankle, knee, hip, foot, wrist, elbow, shoulder, hand, and center of the head. Composite control cube consisting of 8 points and 17 data points were digitized and entered into the 2 dimensional linear transformation (DLT) module and converted to real displacements. The real coordinate endpoints were smoothed using a 10 Hz cutoff frequency in a low-pass digital filter.

Joint angles during tuck back salto performance, velocity of body segments (horizontal, vertical and resultant) and their trajectories, time of execution of acrobatic jump phases were studied. 7 highly skilled acrobats-jumpers (body mass 66.57 ± 1.95 kg, height 170.25 ± 2.04 cm, age 18.42 ± 1.2 years) attended to this project. All examined people were acknowledged with measurement form and agreed to join the research. The studies were conducted on standard acrobatic path (type PTS 2000). Mean score ($\bar{x}$ ± SD) of judges of international class (n=5) for tuck back salto performance by seven acrobats was 9.700 ± 0.090 points. Element-by-element analysis of the phases was made. During the phase of preparatory actions the indices characterizing the body postures and positions were analyzed (from courbette round-off to the beginning of taking-off to fly up to salto). During the phase of major actions the indices of athlete's movements (assuming tucked position, body rotations and untucking) were subjected to analysis. At the phase of concluding actions the indices of body "gliding" in extended position after backward salto untucking before and during leg contact with support were analyzed.

Results and Discussion

Analysis of the indices of the tuck back salto after round-off execution has allowed to outline three key components of sports techniques: launching body posture (LP), multiplication of postures (MP), final posture (FP), (Fig. 1).

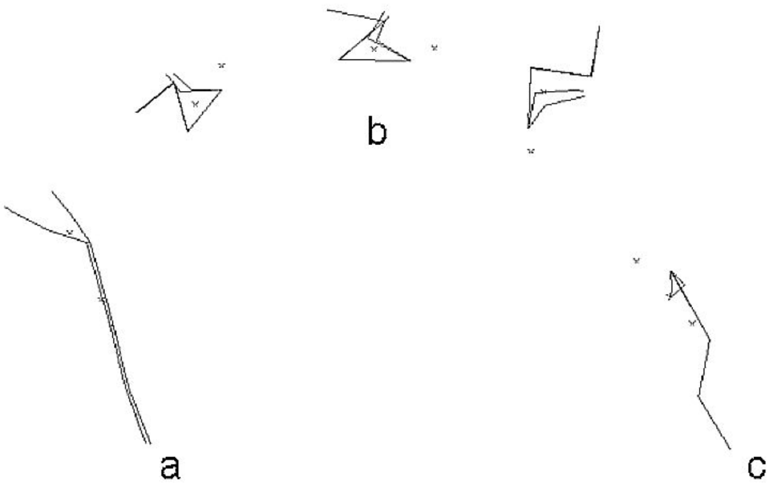

Fig. 1
Key components of tuck back salto after round-off performed by A.V. champion of Poland in acrobatic jumps; a- launching posture of body (LP), b-"tuck" posture and its multiplication (MP), c- final posture (FP)

Launching posture (LP) is outlined at the phase of preparatory actions. It is characterized by technically correct position of body segments on the support for efficient fly up to salto. Individually LP of every athlete is characterized by different position within coordinate system, however all of them are within taking-off sector restricted 7°÷5° before and 5° after vertical line. Athletes assume elastically stiff body position on the support in on tiptoe stand elevated up and forward. Joint angles of LP are equal to: shank-thigh 177.72±0.5°; thigh-trunk 178.01±0.73°; trunk-shoulder 149.71±1.51°; shoulder-forearm 155.00±3.82°. During taking-off the above indices are equal to: 179.00 ± 0.48°, 179.80±0.50°, 155.19±0.95°, 163.20±1.70°. During the phase of major actions of tuck backward salto the key element of sports techniques is the "tuck" posture and it's multiplication. MP determines the contents of athlete's movements during the major phase of tuck back salto after round-off. Tightness of tucking, velocity of rotation, height of flight and timeliness of untucking characterizes level of special technical fitness of acrobats. MP is characterized by the following joint angles of the body: shank-thigh 53.70±1.66°; thigh-trunk 48.15±1.01°; trunk-shoulder 29.00±0.90°; shoulder-forearm 115.55±1.70°.

Final body posture is significant key element of sports techniques of the final phase of tuck back salto after round-off allowing to execute acrobatic jump to stop or to create effective conditions for transition to another jump. As regards touchdown the athletes perform half squat (angle shank-thigh –147.03± 1.33°) with forward half bending (angle thigh-trunk 161.40 ± 1.78°), hands forward-up; forward-sideward (angles: trunk-shoulder 108.10± 1.40° shoulder-forearm 160.50±2.70°).

Minor error of mean arithmetical value of joint angles has been obtained which is indicative of the density of indices obtained during analysis of biomechanical characteristics of key elements of tuck back salto sports techniques and thus, of similar techniques of jump execution by seven highly skilled acrobats.

Of great scientific and practical interest is the analysis of the indices of individual execution of tuck back salto by each athlete.

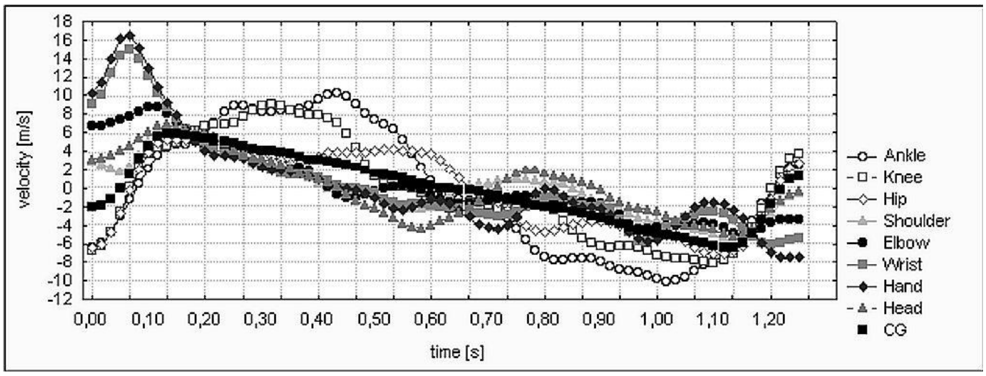

Fig. 2
Kinematical diagrams of vertical velocities for athlete's joint angles displacement during execution of tuck back salto after round-off. Performer – A.V., champion of Poland in acrobatic jumps

Launching posture of athlete A.V. (height 172 cm, body mass 72 kg, age 21 years), champion of Poland in acrobatic jumps, executing tuck back salto after round-off is characterized by following joint angles: shank-thigh 178°; thigh-trunk

174°; trunk-shoulder 146°; shoulder-forearm 170°. Body position in LP - 5° before vertical line. We consider such position of LP as technically correct providing more favorable indices of athlete's joint angles during taking-off: shank-thigh 180°; thigh-trunk 180°; trunk-shoulder 152°; shoulder-forearm 165°. Extended elastically stiff body position has been recorded during support and taking-off in 0.02 s. Such LP position also indicates sufficient special technical fitness of athlete [1,3]. The above may be confirmed by kinematical diagrams of body links velocities (vertical) in LP (Fig. 2). During taking-off velocity of ankle constitutes 5.06 m s^{-1}, knee 6.28 m s^{-1}, hip 5.33 m s^{-1}, shoulder 5.84 m s^{-1}, elbow 5.45 m s^{-1}, CG 5.60 m s^{-1}. It appears that cooperation of the velocity of the body links and their combined actions have allowed to optimize subsequent actions of athlete and efficiently enter an ascending part of trajectory of tuck back salto flight at the expence of correctly executed from the point of view of techniques, launching posture.

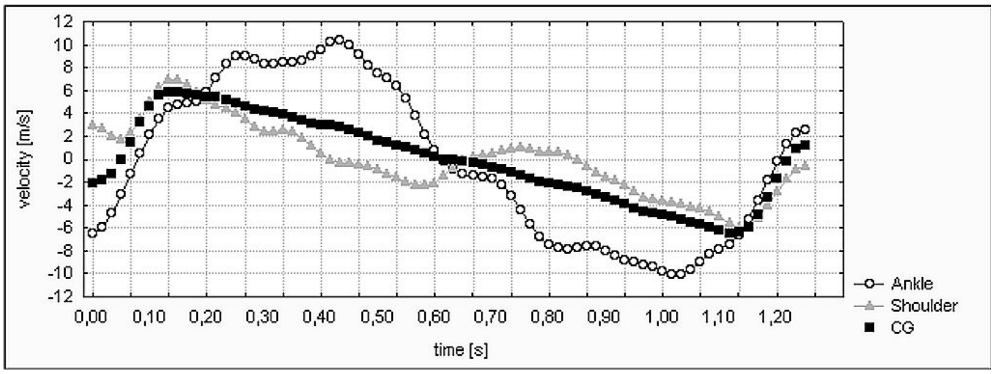

Fig. 3
Kinematical diagrams of velocities (vertical) of athlete's joint angles displacement (CG, shoulder, ankle) during execution of tuck back salto after round-off. Performer – A.V., champion of Poland in acrobatic jumps

During the phase of major actions athlete executes salto rotation trying to fix close "tuck" posture. Joint angles during close tuck have the following characteristics: shank-thigh 60°, thigh-trunk 46°, trunk-shoulder 32°, shoulder-forearm 127°. At achieving CG of the highest point of flight (in 0.45 s) the following velocities (vertical) of joints are observed: ankle 0.25 m·s^{-1}, knee 2.04 m·s^{-1}, thigh 3.08 m·s^{-1}, shoulder 1.48 m·s^{-1}, elbow 1.31 m·s^{-1}, hand 1.36 m·s^{-1}, CG 0.02 m·s^{-1} (Fig. 3). In fact, only the velocities of the ankle and thigh were of positive sign, whereas velocities with negative sign characterized the other body links. The above may be indicative of the body transition to descending part of flight trajectory. At the highest point of flight the athlete begins untucking at the expense of establishing greater angle between thigh and trunk, whereas the angle between trunk and shoulder decreases to 11° (classical style of salto untucking by trampoliners, when extended body is "hanging" during the flight ("glides") and right angles are pressing to the trunk). During untucking the thigh and the shoulder still have the positive velocity (vertical) of body rotation equal to 0.15 $m \cdot s^{-1}$ and 0.19 $m \cdot s^{-1}$, respectively, whereas the other body segments - low negative velocity in the range of 0.34 $m \cdot s^{-1}$ ÷ 1.69 $m \cdot s^{-1}$, and only the hand has higher velocity 3.18 $m \cdot s^{-1}$ (Fig. 3).

During landing FP of athlete is characterized by the following joint angles: shank-thigh 145°, thigh-trunk 165°, trunk-shoulder 110°, shoulder-forearm 170°. Peculiar style of landing of athlete A.V. is manifested in efficient leg shock-absorbing actions in combination with some balancing actions of arms.

Table 1
Biomechanical indices of velocities (resultant) for athlete's body segments displacement during execution of tuck back salto. Performer – A.V., champion of Poland in acrobatic jumps

	Key components of technique						
	Launching posture	Takeoff	Tucking phase	The highest position of CG	Untucking phase	Landing	Touchdown
Time of execution (s)	0.00	0.02	0.37	0.45	0.50	0.98	1.07
Foot (m/s)	4.86	5.06	9.60	7.92	7.88	5.47	1.22
Knee (m/s)	5.58	6.52	5.53	4.60	4.54	5.88	3.59
Hip (m/s)	5.48	5.56	4.37	5.50	4.92	6.66	3.41
Shoulder (m/s)	7.92	7.65	2.02	1.93	2.53	6.80	0.97
Elbow (m/s)	7.86	7.16	2.56	2.63	1.78	6.36	3.64
Hand (m/s)	8.05	6.71	7.56	5.69	3.43	5.05	8.26
CG (m/s)	6.26	6.11	2.57	2.47	1.96	6.40	1.45

An important information about key components of tuck back salto has been obtained during analysis of the velocities (resultant) of athlete A.V. body segments. Table 1 and Fig. 4 contain biomechanical indices and kinematical diagrams of the velocity (resultant) of body joints displacement during execution of tucked back salto. Analysis of findings demonstrates that despite variety and different direction of velocities (resultant) of body segments movements one may judge about cause and effect character of functioning key elements of tuck back salto sports techniques. In order to confirm the abovementioned let us outline the velocities (resultant) of movement of CG, shoulder and foot. Assumption of LP by athlete is realized with the velocity of CG 6.26 $m \cdot s^{-1}$ (shoulder 7.92 $m \cdot s^{-1}$, ankle 4.86 $m \cdot s^{-1}$), (Fig. 5). During taking-off CG velocity is 6.11 $m \cdot s^{-1}$ (shoulder 7.65 $m \cdot s^{-1}$, ankle 5.06 $m \cdot s^{-1}$). During tucking velocity of CG is 2.57 $m \cdot s^{-1}$ (that of shoulder 2.02 $m \cdot s^{-1}$, whereas the velocity of foot reaches 9.60 $m \cdot s^{-1}$). Elevation of CG to the highest point of flight has decreased the velocity of CG to 2.47 $m \cdot s^{-1}$ (shoulder 1.93 $m \cdot s^{-1}$, velocity of ankle is high – 7.92 $m \cdot s^{-1}$).

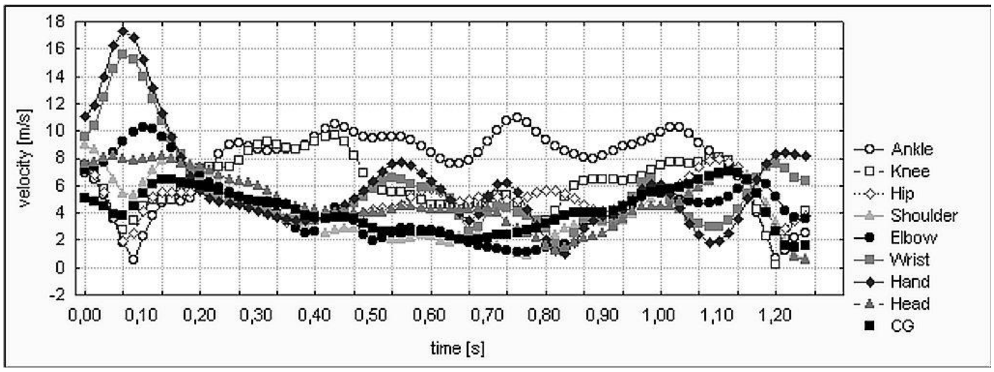

Fig. 4
Kinematical diagrams of velocities (resultant) of athlete's joint angles displacement during execution of tuck back salto after round-off. Performer – A.V., champion of Poland in acrobatic jumps

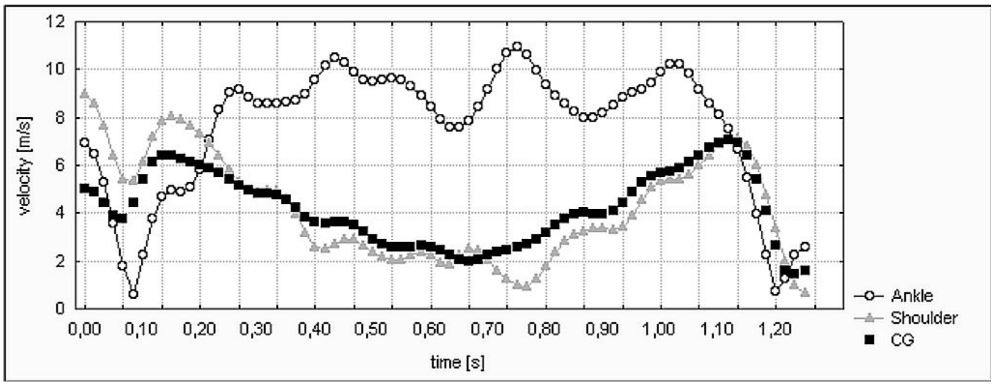

Fig. 5
Kinematical diagrams of velocities (resultant) of athlete's joint angles displacement (CG – center of gravity, shoulder, ankle) during execution of tuck back salto after round-off. Performer – A.V., champion of Poland in acrobatic jumps

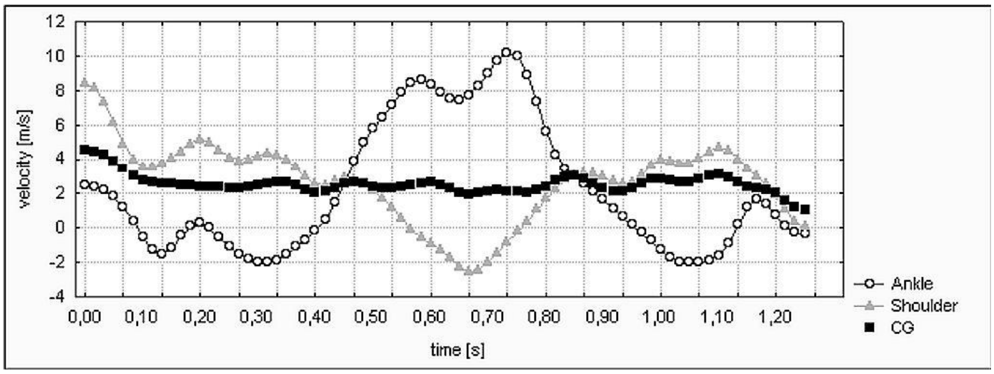

Fig. 6
Kinematical diagrams of velocities (horizontal) of athlete's joint angles displacement (CG, shoulder, ankle) during execution of tuck back salto after round-off. Performer – A.V., champion of Poland in acrobatic jumps

Body untucking has resulted in further decrease of CG velocity 1.96 $m\cdot s^{-1}$ (shoulder 2.53 $m\cdot s^{-1}$, foot 7.88 $m\cdot s^{-1}$). Before contact with support CG has rapidly increased velocity to 6.40 $m\cdot s^{-1}$ (shoulder 6.80 $m\cdot s^{-1}$, ankle 5.47 $m\cdot s^{-1}$). During contact with support velocities of body segments constituted 1.45 $m\cdot s^{-1}$, 0.97 $m\cdot s^{-1}$, 1.22 $m\cdot s^{-1}$, respectively. Velocities (horizontal) of body joints during contact with support are equal to: CG 1.17 $m\cdot s^{-1}$, shoulder 0.36 $m\cdot s^{-1}$, ankle 0.26 $m\cdot s^{-1}$ (Fig. 6). This is indicative of the fact that FP is stable and the landing is performed in accordance with the demands of sports techniques and biomechanics [1,4,7].

Conclusion

Key components of tuck back salto after round-off have been outlined and studied. During the phase of preparatory actions the launching posture of the body has been outlined. It is individual for each athlete (n=7) and is located within coordinate system 7°÷5° before and 5° after vertical line. It is characterized by biomechanical rational, elastically stiff body position during support in on tiptoe stand, creates prerequisites for cooperation of the velocities of CG and body segments, contributes to body braking from backward movement and allows athlete to begin an efficient execution of the main phase of acrobatic jump, that is to "twist" the body up, multiplicating “tuck” posture which allows to execute the body rotation on ascending part of flight trajectory (height of CG elevation 1.38 cm, distance of jump 2.35 cm, time 0.98 s). Multiplication of “tuck” posture determines the contents of motions in the major phase of back salto. Tightness of tuck, velocity of rotation, height and distance of flight, timeliness of untucking characterizes the level of special technical fitness of acrobats. In the phase of tuck back salto concluding actions the key element of sports techniques, i.e., final posture - landing to stop or to transition to execution of another jump of the composition has been outlined. It looks like that in establishment of the key components of acrobatic jump sports techniques, in their biomechanical analysis and in utilization of obtained results during training and educational process is the reason for further increase of exercise complexity and improvement of acrobats mastery.

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