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Key sports technical elements in the phase structure of moves connecting acrobatic exercises performed on a beam

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By T. Niznikowski, Jozef Pilsudski Academy of Physical Education in Warsaw, Poland, and J. Sadowski, Department of Physical Education and Sport in Biala Podlaska, Poland

Summary by James Major, Davis Diamonds Gymnastics

Introduction

Balance beam routines are the women's gymnastics event that requires precise, but graceful movements, and control of body posture. Modern routines on a beam are, in fact, floor exercises on a narrow support, including very complex acrobatic jumps. Analyses of gymnasts' performances in competitions suggest that most technical errors executing salto skills onto a beam are made during the take-off or landing.

Postural landmarks are used in a method for analyzing techniques and key technical elements. A key element is a signal point (posture) during a movement, controlling optimal actions in the phase structure of the skill. Body postures and positions in the structure of competition skills control the biomechanics of previous and subsequent motions: the previous element (posture) contains the properties (speed-strength, spatial-temporal, tempo-rhythmical, etc.) of the subsequent one. When there is an optimum ratio of elements, the athlete performs the skill or the connection of skills with slight motor rearrangements, without accumulating technical errors.

The multitude of acrobatic skills performed on a beam (landings, transitions, connections) increases the importance of technically correct body positions, held for an optimal amount of time, for effective take-off, rotation, and stable landing. Successful biomechanical analysis of gymnastic and acrobatic skills, and the development of modern training programs, will reveal significant reserves of training and performance. The purpose of this study was

1. to identify the kinematic structure of the key technique indices of the acrobatic skill round-off, tucked back salto connection performed on a beam and,

2. then to identify key technical elements in the phase structure of the skills.
3. To study the kinematic structure of the key technique indices of the connection of acrobatic skills round-off, tucked back salto performed on a beam;
4. to single out key technical elements in the phase structure of the skills and connections.

Methods

Professors T. Niznikowski, PhD. and J. Sadowski, PhD. investigated the phase structure of a round-off, tucked back salto on a balance beam. Their study involved sixteen skilled and highly skilled female gymnasts of an average age of 20 years old. Data was collected with high-speed, three dimension video and analyzed with motion analysis software. Key technical elements were identified in the phases of the acrobatic skills and connections. The phase of the main motor actions (salto) and final one (landing) were highlighted. The phase structure of the studied skills and connections was assumed to be a cause-and-effect, structural-functional integrity. In addition, the indices of the elements in each phase were identified:

- launching posture (**LP**), finishing the round-off: almost vertical, stable, body posture in a narrow stance, and legs apart, on tiptoe, with arms forwards-and-upwards, for an efficient upward-backward take-off;
- multiplication of body postures (**MP**) “tucked”: active, successively alternating, instant, fixed salto phases creating an integrated action, the phase of the main motor actions;
- concluding body posture (**CP**): the final motor action phase, landing to a stop on the beam.

Results

The phase structure of a round-off, tucked back salto executed on a beam was identified and then studied by biomechanical analysis. Figure 1. shows the kinematic structure and the trajectory of the body center of mass (COM) movement (stable landing on the beam). Biomechanical analysis of the skills and connections gave the outline of the structure of the round-off and the launching posture (LP) of the body. LP is a biomechanically stable, vertical position of the gymnast’s body at the end of the round-off onto the beam, creating efficient conditions for a take-off, directed upward-backward into the main (salto) phase. In the next phase of main motor actions the key element is multiplying body postures (MP) “salto tuck shape”. Multiplying body postures into a “tuck shape” is a process of successive alternating body shapes to create the dynamic and integrated tucked back salto that is the skill. In the final phase, the key technique element is the finishing posture (CP): a landing that meets requirements and recommendations for gymnastics technique.

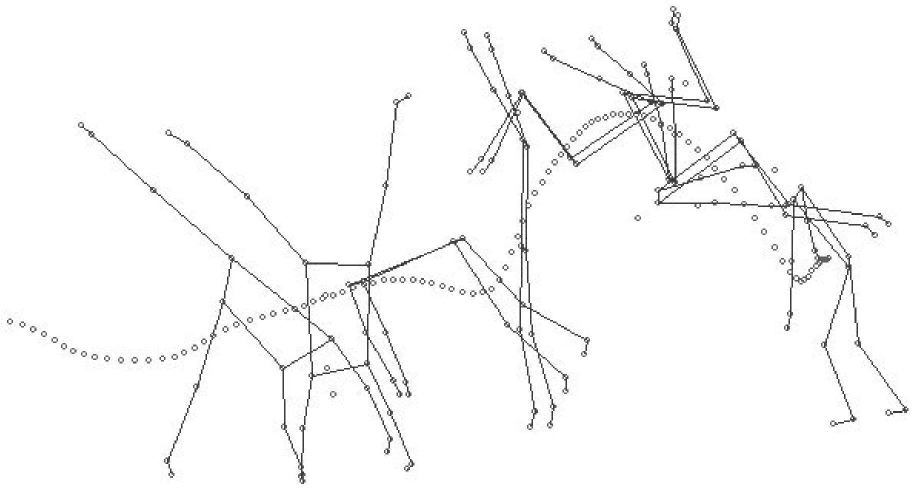

Fig. 1. Kinematic structure and path of the body center of mass (COM[1]) during performance of the round-off, tucked back salto connection on a beam.

Preparatory Phase: Biomechanical analysis identifies the LP as the key element of the final actions of the round-off preceding the tucked back salto performed at elapsed time 0.08 sec. The LP of the body is slightly in front of vertical (thigh-trunk angle equals 171.67°), the arms have moved forward and upward, on toes, in a narrow stance, with legs apart, one leg in front of the other (Fig.2).

[1] The COM position and path through space is marked with a °.

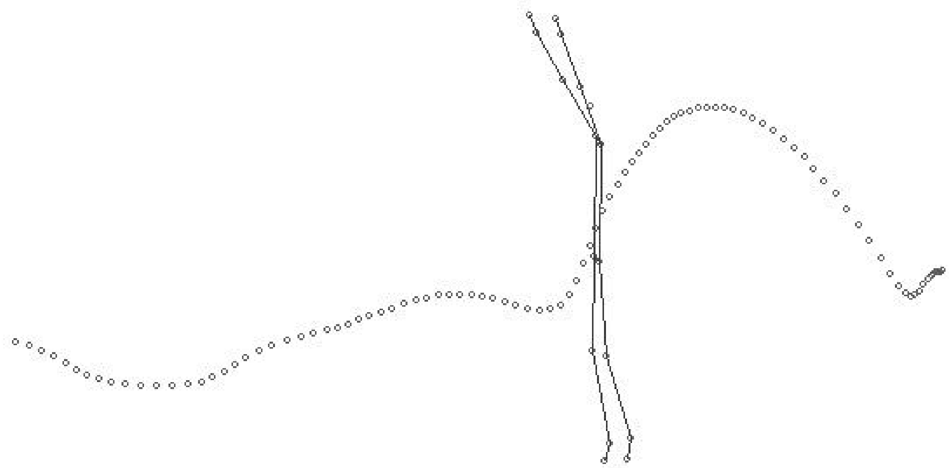

Fig. 2. LP (launching posture) during the final actions of the round-off in the skills and connections round-off, tucked back salto, performed on a beam (at elapsed time 0.08 sec.).

Executing a round-off, tucked back salto on a beam (at elapsed time 0.08 sec) (Fig. 3.), the take-off to the salto is preceded by the final phase of the round-off (snap down of the feet onto the beam). This phase is characterized by high velocities of the limbs: the velocity of the ankle joints was 3.09 m/s[2], that of the knee joint 3.00 m/s, hip joint 2.99 m/s, shoulder joint 3.75 m/s, elbow 5.99 m/s, and wrist 8.49 m/s at 0.08 sec. elapsed time. There was insufficient coordination between the velocity curves during the brief foot contact with the beam during LP before taking off. This was due to feet landing on the beam with increasing velocity during the snap down phase of the round-off, thus leading to some "dispersion of velocity curves". The subjects were highly skilled female gymnasts, so we attribute these peculiarities in executing the take-off postures to individual styles. This dispersion is an opportunity to further improve the performance of the launching posture (LP), a significant, key, technical element. Note in particular, the different velocities of shoulder and wrist joints, respectively 3.75 m/s and 8.49 m/s.

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[2] m/s is the abbreviation for meters per second, or a velocity of a little over 3 feet per second.

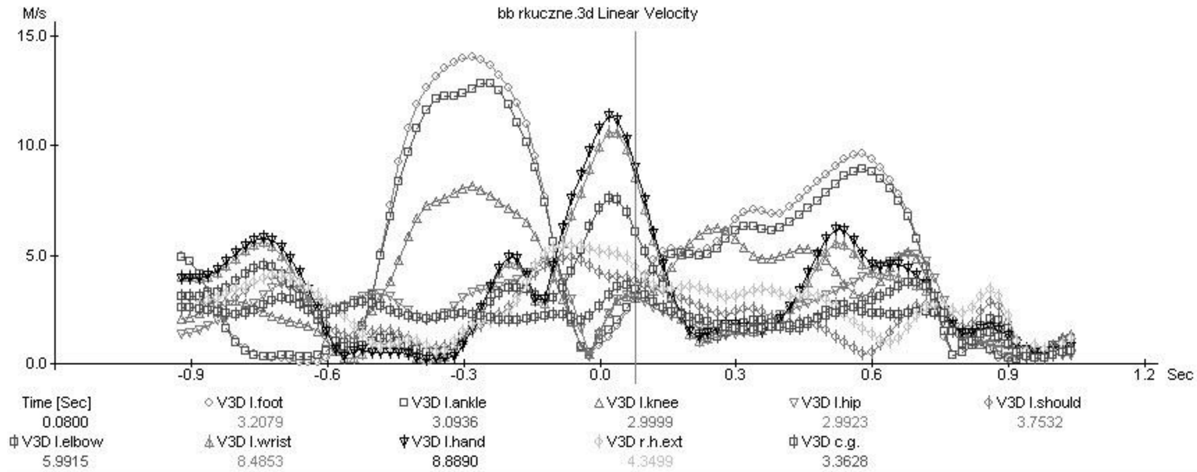

Fig. 3. Trajectories of the three dimension resultant velocities of ankle, knee, hip, shoulder, elbow, and wrist joint displacements, as well as gymnast COM, during the brief body launching posture in the final phase of round-off during performance of the skills and connections: round-off, tucked back salto on a beam[3]. Note: c.g. – general center of mass.

"Tucking" during a tucked back salto (at elapsed time 0.28 sec) is the phase of multiple body postures (MP). The gymnast is in the process of tucking; the thigh-trunk angle equals 101.03° (Fig. 4).

[3] In this and the following graphs, the elapsed time of 0.0 was placed at the approximate end of the round-off. Elapsed times with a minus sign are before the end of the round-off and with a positive sign are after the round-off.

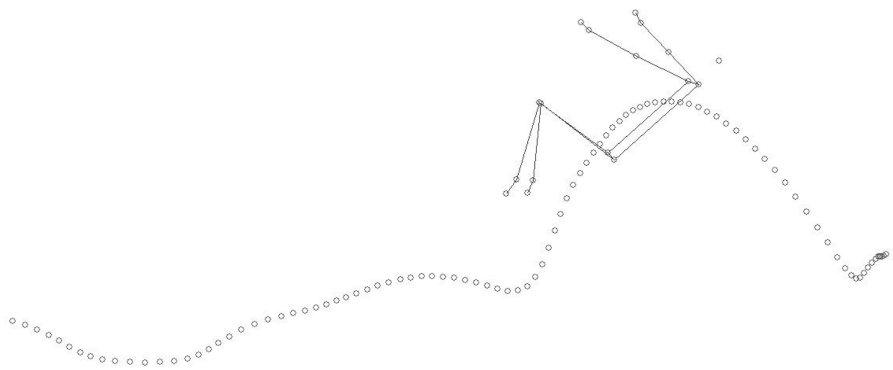

Fig. 4. MP: one of a multiple “tucked” body shapes connecting the acrobatic skills round-off, tucked back salto performed on a beam (at elapsed time 0.28 sec).

Figure 5. shows the trajectories of resultant three -dimension velocities of ankle, knee, hip, shoulder, elbow, and wrist joints motions, as well as athlete body COM, during the phase of the main motor actions: multiple tucked body postures during salto performance connecting the round-off, tucked back salto on a beam. The trajectories of the three dimension resultant velocities show cause-and-effect dependencies as energy is transferred from the previous motions (postures) to the subsequent ones. For instance, higher velocities of the ankle and knee joint motions are recorded during the ascending part of the salto trajectory, which increases rotation around the transverse axis.

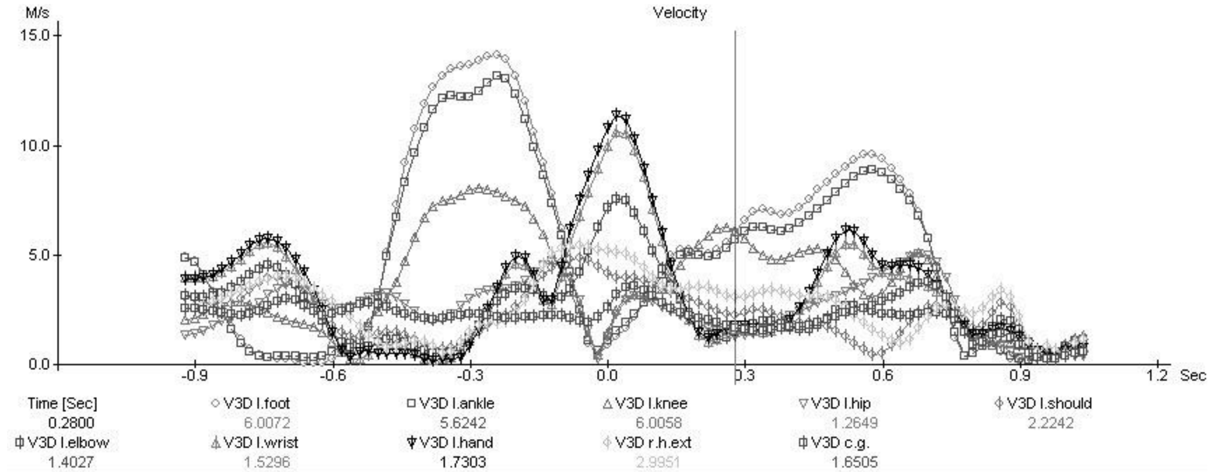

Fig. 5. Trajectories of three dimension resultant velocities of ankle, knee, hip, shoulder, elbow, and wrist joint motion, as well as gymnast COM, during the phase of main motor actions: MP of body during performance of the skills and connections round-off, tucked back salto on a beam (at elapsed time 0.28 sec).

Velocity of ankle joints increased by 5.62 m/s between 0.08 sec and 0.28 sec, whereas in knee, hip and shoulder joints by 6.01 m/s, 1.26 m/s and 2.22 m/s, respectively. Velocity slowed in elbow and wrist joints by 1.40 m/s and 1.53 m/s, respectively. The velocity of body COM displacement was 1.65 m/s. During the rest of MP (Fig. 6.), the gymnast performs half a salto during the ascending segment of salto flight trajectory within round-off, salto structure (at elapsed time 0.44 sec.); thigh-trunk angle is 62.19°.

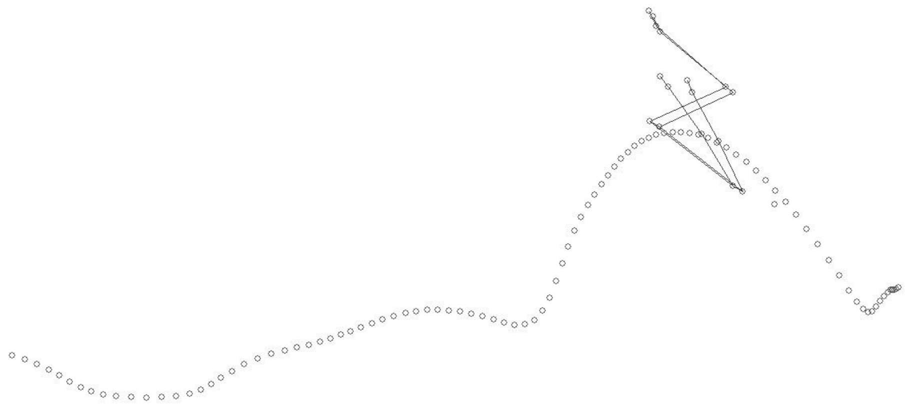

Fig. 6. Phase of main motor actions: MP, key technique element tucked body during a round-off, tucked back salto on a beam (at elapsed time 0.44 sec.).

By the time that half of a salto has been completed, the gymnast is tightly tucked (Fig. 6.), the velocity of ankle and knee joints has increased, which will prepare execution of the phase of concluding motor actions that prepare the landing. The trajectories of resulting velocities characterize the displacement of the ankle, knee, hip, shoulder, elbow, and wrist joints, as well as the athlete's COM during the body MP phase of main actions (at elapsed time 0.44 sec.) (Fig. 7.).

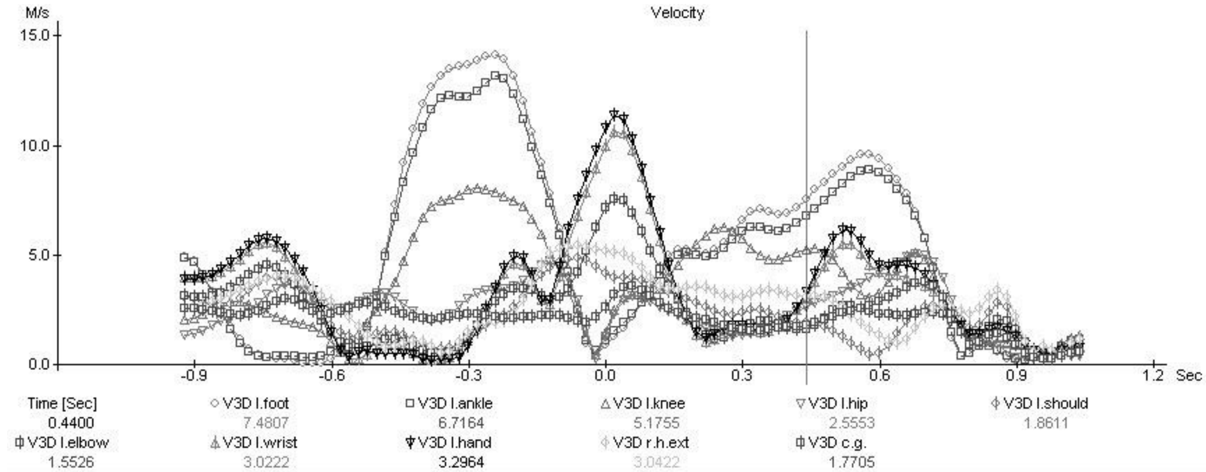

Fig. 7. Trajectories of resultant three dimension velocities of ankle, knee, hip, shoulder, elbow and wrist joints, as well as athlete body COM, during the MP phase of main motor actions (at elapsed time 0.44 sec).

As illustrated in Fig. 7., the velocity of the ankle joint at elapsed time 0.44 sec. is 6.72 m/s, that of knee joint 5.18 m/s, that of hip joint 2.56 m/s, that of shoulder joint 1.86 m/s, that of elbow joint 1.55 m/s, and that of wrist joint 3.02 m/s. The velocity of the gymnast COM at elapsed time 0.44 sec is 1.77 m/s.

Phase of the final motor actions: at elapsed time 0.62 sec. the gymnast prepares to execute the landing, the key technical element of the concluding posture (CP). This preparation for landing is characterized by descending flight trajectory, joint angles (thigh-trunk angle 91.22°) (Fig. 8.). The three dimension resultant velocities of ankle, knee, hip, shoulder, elbow, wrist joint motion, and athlete body COM are presented in Fig. 9. (at elapsed time 0.62 sec).

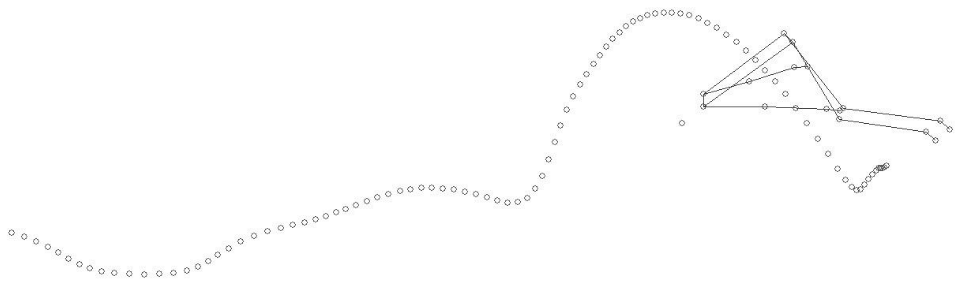

Fig. 8. Phase of the final motor actions during performance of the skills and connections round-off, tucked back salto on a beam (at elapsed time 0.62 sec).

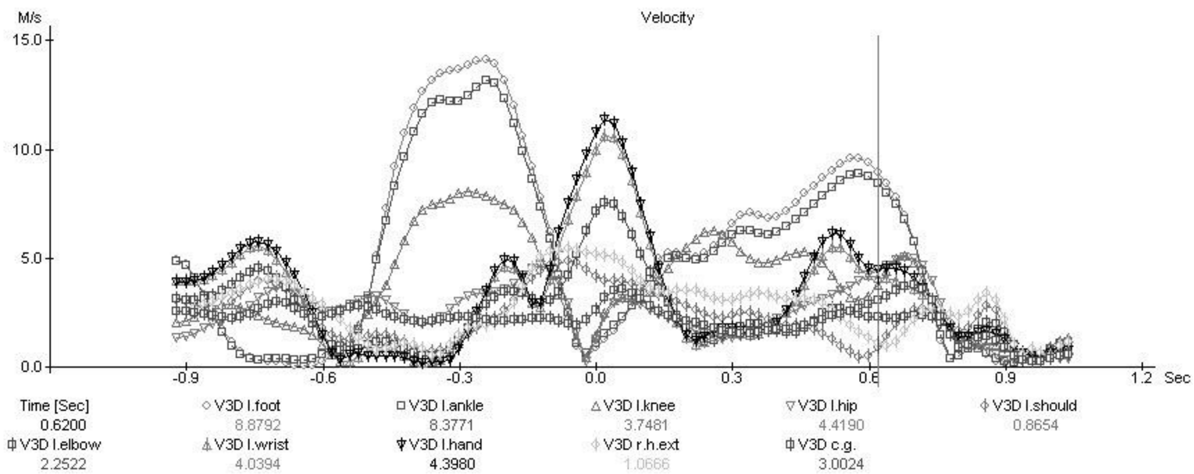

Fig. 9. Trajectories of three dimension resultant velocities of ankle, knee, hip, shoulder, elbow, and wrist joint motion, as well as gymnast COM, during the CP phase of the final motor actions at elapsed time 0.62 sec. Velocities of the ankle, knee, hip, shoulder, elbow, and wrist joints are 8.38 m/s, 3.75 m/s, 4.42 m/s, 0.87 m/s, 2.25 m/s, and 4.04 m/s, respectively. Velocity of the gymnast COM is 3.00 m/s.

Figure 10. shows CP during the phase of the final motor actions: stable landing on the beam (at elapsed time 1.04 sec). Thigh-trunk angle is equal to 153.31°. Biomechanical analysis and pedagogical observations show that the gymnast has an elastic, stable interaction with the beam during the CP: semi-tuck stride posture, with one leg in front of the other, and body slightly bent forward, arms in front-downward.

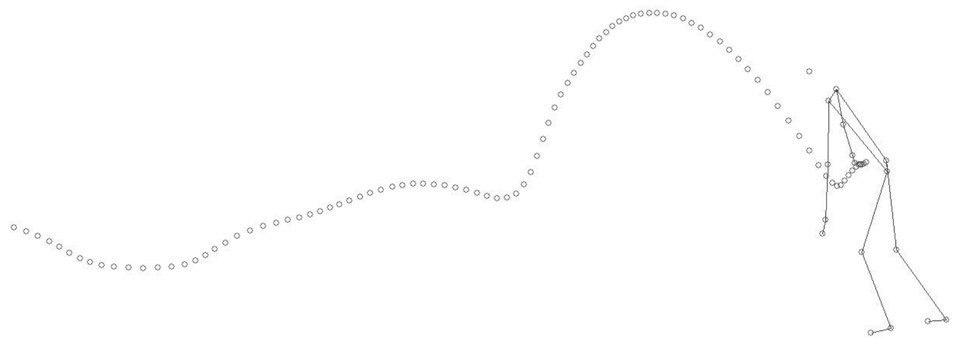

Fig. 10. Phase of the final motor actions (CP): landing after performance of the skills and connections round-off, tucked back salto onto a beam (at elapsed time 1.04 sec).

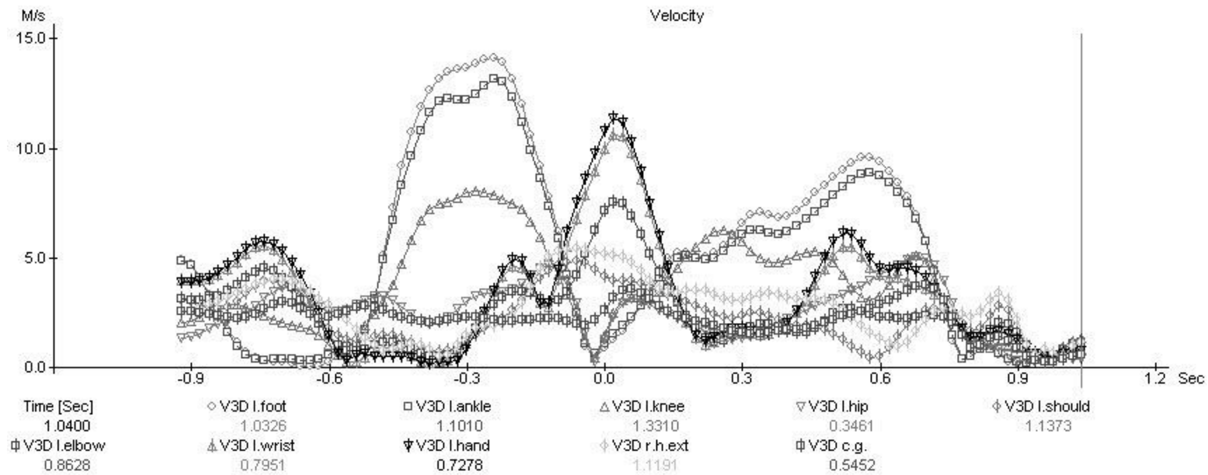

Fig. 11. Trajectories of three dimension resultant velocities of ankle, knee, hip, shoulder, elbow, and wrist joint motion, as well as gymnast COM, during the phase of the final motor actions: CP during performance of round-off, tucked back salto onto a beam (at elapsed time 1.04 sec).

Figure 11. shows the trajectories of three dimension resultant velocities of body part motions during performance of the skill connection round-off, tucked back salto onto a beam. Velocities of the ankle (at elapsed time of 1.04 sec), knee, hip, shoulder, elbow, and wrist joints are 1.33 m/s, 0.35 m/s, 1.14 m/s, 0.86 m/s, and 0.8 m/s, respectively. Body COM is moving at 5.81 m/s. Body posture on the beam is characterized by the key element of sports technique: CP, i.e., landing posture of semi-tuck position with body semi-bent forward, one leg in front of the other, arms in

front-downward on the beam. The three dimension resultant velocities of joints and COM confirm the controlled motor actions during a stable landing. They have “bunched up” at elapsed time 1.04 sec.

Discussion

Review of scientific and methodical literature, and practical experience, indicates the importance of the posture and position of the athlete’s body for studying and teaching the technique of gymnastic and acrobatic skills. The method of postural landmarks and their key elements is recommended for studying the technique of skills in artistic gymnastics. This is a method of biomechanical study of skills by analyzing previous and subsequent body postures and positions, and their multiples, in the phase structure of the executed skill in order to identify the key technical elements. The present study suggests that the conceptual essence of the method of postural motion landmarks is that each previous posture in skills performed should positively impact the biomechanics of the subsequent skill, carry the properties enabling skill performance without unnecessary motor rearrangements, and so avoid the accumulation of technical faults during the skill performance process. The key technical elements play a positive role in the skill learning process because they provide the basis for building the didactic construction for the formation of skills and abilities of motor actions in the phase structure of the skill. In this respect, the method of postural motion landmarks underlies practical methodology of biomechanical and didactic improvement of technical preparation and technical fitness in sports events with complex, coordinated structure of movements by implementing the indices of key technical elements in the phase structure of exercises (skill connections, transition from one motor action to the subsequent one within the exercise, transition to the next element in composition, firm stand – stable landing on the beam).

Biomechanical studies and training experiments confirm the expediency of using the method of postural motion landmarks as a means of analysis and assessment of technical elements, as well as for the development of didactic technologies of training skills of different coordination complexity. In addition to the results obtained in gymnastics events, positive results were also achieved in track and field. For example, studies recommend using the postural method for training track and field running technique. The authors distinguish between three postures: posture while running, attacking, and landing after clearing the hurdle; in high jumps – postures running, take-off, and passing over the bar; in long jumps – posture running (during run-up and “scissor” flight), taking-off in stride, and landing. The authors emphasize practicing the body posture and reproducing postures.

Conclusions

1. The key technical elements of the round-off, back tucked salto performed on a beam were identified with the method of postural motion landmarks. The key technical element is posture, functioning as a signal point in a connection. The signal points (postures) in the examined skills and connections are: launching posture (LP) of the body (biomechanically rational body posture on the beam for an efficient salto take-off), multiplying postures (MP) of the body (successive, alternating, fixed postures creating an integrated action), concluding posture (CP) of the body, landing to a stop.
2. The biomechanical structure of the key technical elements of the skills and connection round-off, tucked back salto performed on a beam is characterized by individual biomechanical indices of executing the take-off posture, multiples of body postures, and concluding body posture: joint angles, the velocities of ankle, knee, hip, shoulder, elbow, wrist joints and body COM; body postures, body positions on the beam and in support-free environment; timing of the phases during the skill performance.
3. Indices of key sports technique elements in the phase structure of skills undergo development and improvement based on using exemple training programs to enhance motion control quality, while accounting for individual levels of fitness, specifics and difficulty of skills.

References

A complete list of references is available in the original online article.