KINETIC AND KINEMATIC CHARACTERISTICS AS THE BASIS FOR EVALUATING TAKE-OFF IN BACKWARD ACROBATIC JUMPS

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Abstract

Introduction. Some of the most important roles of coaches are organising the technical training for evaluating movement technique and indicating errors as gymnasts perform the elements of this movement. This can only be applied in individual gymnasts [2, 3], and there are gaps in our knowledge about the details of the technique of individual gymnasts. Therefore, due to the structural complexity of acrobatic elements, the evaluation of a technique should precisely locate errors indicated in specific phases of the exercise. Material and methods. In this paper, the results of the atypical back tucked somersault and counter movement jump of one of the participants are reported on. This participant was a 16-year-old female gymnast with a body mass of 51 kg and a height of 156 cm. While coaches use a subjective qualitative analysis of the sporting movement to determine what advice must be given, a sports biomechanics researcher must make use of objective quantitative data. In our study, we have used the multimodular measuring system SMART when studying the structure of the acrobatic jumps, and we conducted a complex analysis of these exercises. Results. These exercise approaches may be used to achieve important training goals. It seems logical, therefore, that physical educators, coaches, and athletes should look to biomechanics for a scientific basis for the analysis of the individual techniques used in sports. As for practical implications, we recommend that coaches and physical education educators carefully monitor the gymnast’s leg joints and avoid extension of the knee and ankle at the counter movement phase during standing acrobatic jumps.

Key words: acrobatic jumps, biomechanical analysis, case study, comprehensive methodology

Introduction

Biomechanical research on artistic gymnastics has grown substantially over the years. Artistic gymnastics has received considerable attention from investigators of biomechanics. The kinematic analysis of gymnastics provides information that can be used in two ways: scientists can learn about the nature of gymnastic movements, and a framework within which coaching analysis can be objectively interpreted is provided [1].

Some of the most important roles of coaches are organising the technical training for evaluating movement technique and indicating errors as gymnasts perform the elements of this movement. This can only be applied in individual gymnasts [2, 3]. However, most biomechanical research involves generalisation [4], which is done by averaging the temporal characteristics of the movement. Consequently, our understanding of the principles and bases of this sport, although improved, is still marginal. There are gaps in our knowledge concerning the details of the technique of individual gymnasts.

One way to get out of this situation is to use an experimental approach. Sometimes this approach takes the form of direct intervention in the activity. Such intervention may understandably meet with some resistance from the gymnast and the coach. More often, the gymnast is not aware of the ongoing experiment. The experiment is actually the way in which the biomechanist selects the data. By obtaining movement data on an individual gymnast, it may be possible to identify those elements of a technique which are associated with better performance. The movement data can indicate how personal performance may be improved. By obtaining data on the gymnast and identifying the characteristics of the better gymnasts, it may be possible to gain insight into how the training should be structured [5].

A special way to assess the efficiency of mastering a technique involved in acrobatic jumps is based on the results achieved in sport competitions (the scores given by the jury). Scoring, however, does not contain detailed information on the movement technique, nor does it indicate in which phase and to what extent the gymnast deviated from the ideal technique. Furthermore, the results of the assessment of acrobatic jumps obtained by observing gymnasts, which are often similar to scores given during competitions, are flawed, mainly due to the imperfection of visual perception [6]. Therefore, due to the
structural complexity of acrobatic elements, the evaluation of a technique should precisely locate errors indicated in specific phases of the exercise. This is possible only by means of a complex analysis of the movement [7]. In our study, we have checked the usefulness of the multimodal measuring system SMART (BTS, Italy) in studying the structure of acrobatic jumps.

Material and methods

**Materials**

Twelve healthy female artistic gymnasts participated in this investigation. The participants were a convenient sample of highly competitive national-standard female gymnasts who demonstrated proficiency in performing the skills required for the investigation. The gymnasts were informed about the nature of the study. Prior to data collection, the participants were required to sign a consent form according to human subject regulations. Parental or guardian consent was required for those younger than 18 years. The research project was approved by the Ethics Committee for Scientific Research at the Jerzy Kukuczka Academy of Physical Education in Katowice, Poland.

All subjects were tested under the same conditions in a laboratory setting. Each gymnast performed three randomised trials of four acrobatic skills (jumps): standing backward tucked somersault, standing backward piked somersault, standing backward handspring with landing in the place of take-off, and counter movement jump (CMJ). The rest periods between these acrobatic jumps lasted about 3 minutes. In this paper, the results obtained for the atypical back tucked somersault and counter movement jump of one of the participants are reported on. This participant was a 16-year-old female gymnast with a body mass of 51 kg and a height of 156 cm.

**Methods**

Using the SMART-E measuring system (BTS, Italy), a multidimensional registration of the motion was performed. The system includes six infrared cameras with a frequency of 120 Hz, synchronised with a module for wireless measurement of the electrical activity of the muscle called Pocket EMG (BTS, Italy), and a force platform. Infrared camera recordings of the performances were collected to allow access to kinematic parameters of the take-off techniques of the acrobatic jumps. The parameters could help explain the characteristics of muscle activation. The set of passive markers permitting the calculation of some chosen parameters were applied. Modelling in 3D space as well as the calculations of parameters were performed with Smart Analyzer software (BTS, Italy). The technical accuracy of the system seemed to be almost equal to the body weight of the gymnast. The cause of the acrobatic jump, the vertical component of the reaction force was almost equal to the body weight of the gymnast. The cause seemed to be the angle-time curves. Angular displacement of the ankle joint, knee joint, hip joint, and shoulder joint is shown in Figure 4.

**Results**

The comparison of EMG patterns in the set of muscles between the two acrobatic jumps (the back tucked somersault and counter movement jump) performed by the same female gymnast indicated large differences (Fig. 1). The differences in the muscle activation were especially evident for the *rectus femoris* muscle in the take-off phase and for the *rectus abdominis* muscle in the flight phase. Interesting information about the back tucked somersault and counter movement jump was also delivered by the vertical and horizontal components of the ground reaction force (Fig. 2 and 3). The vertical force in the back tucked somersault proved to be especially interesting. For a period equal to about 2/3 of the time of the take-off phase of this acrobatic jump, the vertical component of the reaction force was almost equal to the body weight of the gymnast. The cause seemed to be the angle-time curves. Angular displacement of the ankle joint, knee joint, hip joint, and shoulder joint is shown in Figure 4.

**Discussion**

Bounces (take-offs) are complex multi-degree free exercises requiring good muscle coordination. Thus, the control strategy implemented during take-off performed under certain conditions can be identified on the basis of muscle activity. Muscle activation on both sides of the lower extremity joints was evident in both acrobatic jumps (the back tucked somersault and counter movement jump). These findings suggest that biarticular muscles play a main role in adjacent joint power flow during bounces. Thus, these biarticular muscles serve as the stabilisers of the prime “mover muscles” (the stabilisers are the muscles that hold the body parts in place, and the prime movers are the muscles that move the body parts). The differences in muscle activation were especially evident for: the *anterior deltoides*...
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1 = counter movement phase; 2 = take-off phase; 3 = flight phase. The vertical dashed line shows the beginning of the take-off phase, and the solid vertical line shows the end of the take-off phase.

**Figure 1.** Root-mean-square (RMS) normalised (MVC) EMG for eight muscles during acrobatic jumps performed by the selected female gymnast.
Figure 1. Root-mean-square (RMS) normalised (MVC) EMG for eight muscles during acrobatic jumps performed by the selected female gymnast (continued).

Figure 2. Vertical component of ground reaction force in A) back tucked somersault and B) counter movement jump, performed by the selected female gymnast.
Figure 3. Horizontal component of ground reaction force in A) back tucked somersault and B) counter movement jump, performed by the selected female gymnast.

Figure 4. Joint angle patterns in A) back tucked somersault and B) counter movement jump, performed by the selected female gymnast.
muscle in the counter movement phase, the rectus femoris muscle in the take-off phase, and the rectus abdominis muscle in the flight phase.

Kinetics indicate muscle involvement in acrobatic jumps, which is characterised by the graph of the ground reaction force (Fig. 2). Two-thirds into the back somersault take-off phase (Fig. 2A), the vertical force maintains a nearly constant value equal to the gymnast's body weight. A similar force-time pattern is commonly obtained in the vertical jump (CMJ without arm swing) when the body stops in the squat. One might therefore assume that in the back somersault, the gymnast also remained motionless for a very long time – she stopped in the lowest bottom position, which should be regarded as an error. The question is whether this was indeed an error.

It turns out that at the end of the counter movement phase, when the gymnast is still bending the legs at the knee and ankle joints have changed direction, extension and plantar-flexion are changed, respectively (Fig. 4). The change in direction in the motion also took place in the shoulder joint, which undoubtedly influenced the effectiveness of the somersault. According to various authors [9, 10, 11], the height of the jump and its mechanical efficiency are considerably affected by the following: the starting position at take-off, the direction of the arm swing, and the final position of the arms during the jump. Therefore, it is not without significance which specific movements are performed by the body parts of the jumper; by averaging the kinematics, reaction forces, and muscle activation patterns, we lose the individual nature of acrobatic jumps and the main features of these movements become blurred. While coaches use a subjective qualitative analysis of the sporting movement to determine what advice must be given, the sports biomechanics researcher must make use of objective quantitative data.

Conclusions

In our study, we have used the multimodular measuring system SMART to study the structure of acrobatic jumps, and we conducted a complex analysis of these exercises. These exercise approaches may be used to achieve important training goals. It seems logical, therefore, that physical educators, coaches, and athletes should look to biomechanics for a scientific basis for the analysis of the individual techniques used in sports.

As far practical implications are concerned, we recommend that coaches and physical educators carefully monitor the gymnast's leg joints and avoid extension of the knee and ankle at the counter movement phase during standing acrobatic jumps.

Literature


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