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The relationship between chosen kinematic parameters of the aerial cartwheel on the balance beam during skill learning

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background: The purpose of this study was to determine a relationship between the chosen parameters of aerial cartwheel on the balance beam during learning the skill of this element.

Material and methods: Four national level junior female gymnasts participated in this study. The trials of the aerial cartwheel were filmed, and the best technically performed trial was chosen for analysis.

Results: A statistically significant relationship was found between the duration of the flight phase and the length between foot at the starting position (-0.675) and the height of the body's center of gravity (-0.626), respectively. Statistically significant positive correlations were also found between the knee angle at landing and the duration of the phase on one leg at landing (0.639). A strong positive correlation was also found between the length of the aerial cartwheel and the height of the body's center of gravity (0.677), and a negative one with the duration of the flight phase (-0.533) and the duration of the phase on one leg at the landing (-0.805).

Conclusions: Using basic biomechanical principles, the gymnast can perform movements with less effort. A coach can identify mistakes more quickly and provide their gymnasts with more effective advice.

Key words: artistic gymnastics, acrobatic elements, sport biomechanics.

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INTRODUCTION

During complex, highly valued elements, gymnast's body is moving by mechanisms associated with the regulations of displacement of a body in place. Keeping the balance of the body is crucial because of the characteristics of the balance beam. Small body compensatory movements are necessary to maintain balance and bring the center of gravity of the body above the support. If they are followed up by additional movements to prevent the fall off the balance beam, they will be penalized by the judges.

Technical training on all apparatus, especially on the balance beam, is better if based on biomechanical principles for the performance of elements, but also if it follows a methodical system of rules, established on scientific analysis. These aspects lead to the formation of stable and precise technical skills, without failures or accidents, by developing own resources of physical potential [1]. Technical training in gymnastics, especially in juniors should be based on biomechanical recommendations by applying the quantitative analysis of video-technical training. So, the learning technique based on biomechanical analyses can help in early detection of mistakes. The detailed knowledge of kinematic and dynamic characteristics of aerial cartwheel allows intervention of specialists in sports training. The objective conducting of the training process can thus contribute to the rapid evolution towards higher requirements, and the detection of potential that can help harness the increasing difficulty of execution and the transition to a high technical group for the athletes who display such unexplored reserves [1].

In conformity to the international regulations [2], the routine on the beam must include a mount, elements of different structural groups (acrobatic, gymnastic, mixed elements) and elements near the balance beam. The whole combination must be characterized by dynamism, changes of rhythm and continuity. The end of the exercise (the dismount) must be consistent with the difficulty of the whole and with the specific requirements of the competition [3]. Aerial cartwheel is a usually performed acrobatic element. This element is D value [2] and, because a gymnast is landing on one foot, it is very good for connections values and is also a requirement for forward or sideward gymnastics elements.

Free aerial cartwheel requires explosive power of the knee extensor muscle, static strength of the knee extensors and flexors, especially during the flight phase. Because of the complexity of exercise, this requires a high level of coordination, a speed of movement of individual body parts and balance. In addition to physical preparation, a gymnast who performs the aerial cartwheel must have a satisfactory level of psychological ability. Specifically, it is important to use strength preparation for the elements which are learned in order to improve intramuscular coordination and make the performance much easier [4].

Performance in artistic gymnastics happens very fast, so human eye cannot see mistakes that are occurring in the aerial phase. All phases of acrobatic movements (contact, aerial, and landing or phases) are interrelated [5]. Therefore, biomechanical analysis will help to resolve the mistakes in the performance. To understand some biomechanical requirements on the apparatus will help coaches to develop safe and effective training programs based on scientific information [6]. Another issue involves injuries that can be prevented by regular preparatory and methodical exercises. A different technique may prevent musculoskeletal overload and reduce the potential of injuries [7].

Fig. 1. Performance of aerial cartwheel

The aim of this investigation was to determine a relationship between the chosen parameters of aerial cartwheel on the balance beam during skill learning of this element. The second aim was to point out the most important problems in learning this element.

MATERIAL AND METHODS

Four national level junior female gymnasts (mean ± SD height: 1.64 ±0.08 m, body mass: 59.0 ±6.9 kg) were selected for the study and gave written informed consent. The experimental protocols were approved by the University's Research Ethics Committee. During the collection session, each gymnast performed ten successful aerial cartwheels on the balance beam (10 trials for each gymnast).

The trials of the aerial cartwheel were recorded during training, and the best technically performed trial was chosen for the analysis. Cartwheels were recorded with Casio FX Camera at speed of 300 frames per second. The camera was positioned lateral to the direction of the balance beam performance and 5 meters from the edge. Parameters were calculated using software for 2D Kinematic Analysis "Kinovea" 0.8.25.

The parameters used for analyses were: SPOS – the length between feet at starting position (in cm), LFSP – the length between feet at the beginning (in cm), DBF – the duration of phase on both feet (in seconds), HCG – the height of the center of gravity (in cm), DFP – the duration of the flight phase (in seconds), DFOL – the duration of the phase on one leg at the landing (in seconds), ATO – the angle of take-off (in degrees), AOL – the knee angle at the landing, AOKL – the angle of landing between torso and knee of the first leg (in degrees), LOAC – the length of the aerial cartwheel (in degrees).

Data analyses were conducted using SPSS 16. We used inferential statistics (the Pearson Product Moment Correlation) to determine the correlation between the variables at a 95% level of significance ($p < 0.05$).

RESULTS

The correlation coefficients between biomechanical parameters of the aerial cartwheel are presented in Table 1. A statistically significant negative relationship was found between duration of the flight phase and the length between feet at the starting position (-0.675, $p < 0.05$) and the height of the body's center of gravity (-0.626, $p < 0.05$). A negative correlation was found between the knee angle of the front foot and the length between the feet at the starting position.

Table 1. Correlations between chosen kinematic parameters of aerial cartwheel, at the level of statistical significance $p < 0.05$

Var.	SPOS	LFSP	DBF	HCG	DFP	DFOL	ATO	AOL	AOKL
LFSP	0.077								
DBF	0.064	-0.269							
HCG	0.008	0.355	0.120						
DFP	-0.024	-0.675**	0.272	-0.626**					
DFOL	-0.521*	-0.102	0.091	-0.241	0.294				
ATO	-0.132	-0.627**	0.365	-0.413	0.401	0.093			
AOL	-0.279	0.243	0.148	0.150	-0.252	0.639**	0.186		
AOKL	-0.078	0.054	-0.199	-0.302	-0.046	-0.123	0.154	0.015	
LOAC	0.488	0.187	0.027	0.677**	-0.533*	-0.805**	-0.263	-0.359	-0.201

Legend: SPOS - the length between feet at the starting position, LFSP - the length between feet at the beginning, DBF - the duration of the phase on both feet, HCG - the height of the center of gravity, DFP - the duration of the flight phase, DFOL - the duration of the phase on one leg at the landing, ATO - the angle of take-off, AOL – the knee angle at the landing, AOKL - the angle of landing between the torso and the knee of the first leg, LOAC - the length of the aerial cartwheel.

Statistically significant positive correlations were found between the knee angle at landing and the duration of the phase on one leg at the landing (0.639, $p < 0.05$). A strong positive correlation was also found between the length of the aerial cartwheel and the height of the body's center of gravity (0.677, $p < 0.05$), and a negative one with the duration of the flight phase (-0.533, $p < 0.05$), and the duration of the phase on one leg at the landing (-0.805, $p < 0.05$).

DISCUSSION

The purpose of this study was to the determine a relationship between parameters of aerial cartwheel on the balance beam during the learning process and also to point out the most important problems in learning this element. We investigated aerial cartwheels with successful performance during the learning process of this gymnastic skill. A successful aerial cartwheel can also have certain errors in technique that can result in greater deductions during competition when this skill is performed in the exercise and in different combinations with other elements. Connections of two or more elements bring connections values, and aerial cartwheel is very often part of those connections because it is a D value [2] element. D value [2] means that this element is worth 0.4 points which counts for difficulty values of the routine. Poor performance of aerial cartwheel causes mistakes in connections and inability to connect with other elements, which will result in judges' deductions. These facts can help coaches' in the learning process in order to improve aerial performance of their gymnasts and use the proper technique. The determined correlations between chosen parameters indicate important factors of proper performance. Results have shown that the aerial cartwheel should be performed in place without moving away, actually swinging under the center of gravity, and thus keeping the height for performance. If the gymnast makes a poor kick with a leg and also with arms, the performance will be worse, and landing will be lower and far. Likewise, the results indicate that elements need to be performed very quickly.

The aerial cartwheel falls into the category of complex acrobatic exercises, which are often performed in the balance beam routine, especially in connection with elements that start from one leg. In addition to fine motor and psychological preparation, the coach's training and experience is very important. His knowledge of techniques involves elements, methods of teaching, knowledge to remove the mistakes, knowledge and experience for assisting and keeping, represent perhaps even the most important components in the training process. Different gymnasts are differently built and have a different strength and flexibility. These factors have a significant effect in determining the most effective techniques for each individual gymnast. To learn these very important gymnastic elements, it is necessary to start skill acquisition with selected gymnasts at the age of 8 to 9 years old and finish it by 12 to 13 years of age.

In accordance with the mechanical laws, the take-off characteristics (arm swing, leg impulse and velocity of backward displacement) determine both the angular momentum, the trajectory of the center of mass (COM) and the total flight time of a gymnast during an acrobatic aerial flight [8, 9, 10, 11]. Gittoes et al. [12] note that discrepancies in spatial orientation during an aerial phase in gymnastics may need to be compensated for at the beginning of landing. While their study deals with dismounts, a similar situation may occur during any aerial movement in acrobatic elements on a balance beam. There is the inability to control the body's angles in the aerial cartwheel during the flight phase, and like in other elements, this fact can be a factor that will result in failed landing. To avoid falling off the beam, the gymnast may attempt to rotate the arms quickly in the direction of the fall with the possibility that the rest of the body will stop or reverse its unwanted rotation [13].

In the training process, each phase should be given an important place because it is connected to one another, and because of this error in one of the phases causes the error in the next phase. The most common errors that occur when doing an aerial cartwheel are: moving the center of gravity back at the take-off lowers the body's center of gravity during the flight and causes problems at the landing; an error in the movement occurs when the angle of the hip joint in at take-off is 90º or greater, which causes a small speed during rotation; when gymnasts have not performed blocking with arms in a position when the body is approximately vertical, this will influence the required transferring momentum, length and duration of the aerial cartwheel; the angle of the hip joint are less than 180º in the flight phase, i.e., a bent posture influences the placing the foot away from the center of gravity of the body.

There is a lack of studies investigating inaccurate gymnastic elements on the beam in order to improve gymnasts' performance and to reduce score deductions. Hars et al. [14] examined reaction forces during support phases of back walkovers. However, only good performances, from the judges' point of view, were examined. Most other studies focused on balance beam dismounts [6, 12, 15, 16, 17, 18, 19], but there is lack of investigations of acrobatic elements on the balance beam.

CONCLUSIONS

The coach and the athlete should strive towards efficiency. Efficient movement in gymnastics can be described as a movement that gives maximum results with minimum effort. Using basic biomechanical principles, gymnast can perform movements with less effort. Additionally, this result can help in eliminating mistakes, because each mistake into the steps of element will result with next mistakes that are connected. A coach can identify mistakes more quickly and provide more effective advice to their gymnasts.

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