Analysis of Take-off Phase of Somersaults with Twisting along the Longitudinal Body Axis

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***Abstract*—**The contribution deals with problem of take-off phase of back somersault with twisting with various numbers of twists along longitudinal body axis. The aim was to evaluate the changes in angles during transition phase from back handspring to back somersault using 3D kinematic analysis of the somersaults. We used Simi Motion System for the 3D kinematic analysis of the observed gymnastic element performed by Czech Republic female representative and 2008 Summer Olympic Games participant. The results showed that the higher the number of twists, the smaller the touchdown angle in which the gymnasts lands on the pad in the beginning of take-off phase. In back somersault with one twist (180°) the average angle is 54°, in 1080° back somersault the average angle is 45.9°. These results may help to improve technical training of sports gymnasts.

***Keywords*—**back somersault with twisting, biomechanical analysis, take-off

I. Introduction

IN modern period of professional gymnastics the saltos backwards stretched are being more and more often included in the gymnastic compositions. The saltos backwards stretched are specific for turns along more body axes simultaneously. They are gymnastic skills of higher level of difficulty B, C, D, E according to number of turns performed. Female competitors try to include the most difficult shapes in the end of their compositions which last around 70 s. Perfect performance of these gymnastic skills requires outstanding level of fitness and coordination abilities. Merest mistake during take-off phase manifests during the touchdown phase which plays a great role in the evaluation. One of the problems being solved by handlers are the changes in angles during take-off phase depending on number of turns in saltos backwards stretched along the longitudinal body axis. This is the reason we conducted a detailed analysis of transition phase from back handspring to back somersault.

Unfortunately, there is a lack of expert studies analyzing the gymnastic movement structures in detail. Borms, et al. [1] analyzed the full twist back somersault from kinematic point of view. He focused on movements responsible for the rotations of body, mainly the movements of arms. Van Gheluwe et al. [2] was in his study finding out which principle gymnasts use in twists in back somersaults – the two-axes theory (sometimes called the “cat” rotation) and the “hula” theory (based on gyroscopical effect). Frohlich [3] worked on different possibilities of putting body in turning along different body axes during the flight phase and the knowledge applied on specific movements in sports gymnastics. George [4] explained general biomechanical rules of twists useful in sports gymnastics. From contemporary authors there is Pascal [5] who in his article deals with general physical principles of turns of human body during gymnastic skills. He explains how twists are created, how they can be regulated or stopped or whether the simultaneous twists along different body axes may influence each other. Sands, et al. [6] in his case study dealt with twists in certain gymnastic elements. He described the performance characteristics of the quadruple twisting somersault and compared the quadruple twist to the triple twist. Another author dealing with twisting is McCharles [7] who, mainly from didactic point of view, states parameters according to which we can decide in which direction the gymnast is going to perform twisting in better way.

Physical principles taking part in realization of salto backwards stretched with multiple turns are according to Kristofic [8]: forward speed gained during run-up, moment action of lower extremities in turn-off phase and the principle of inertia which provide rotations, regulations of angular velocity of rotation by change in moment of inertia, formation of secondary rotation on principle of gyroscopic effect and Coriolis effect. During run-up phase, hurdle, round-off and back handspring body gains the kinetic energy. During the take-off phase there is a decrease in angle between segments of lower extremities, take-off leg muscles are stretching and part of the kinetic energy is transformed into static energy of elasticity of leg muscles. This form of mechanical energy is then by contraction of take-off leg muscles transformed back into kinetic energy which is in its maximum during the take-off phase. Perfect performance of take-off phase influencing following flight phase is crucial for faultless performance of the whole gymnastic skill. The aim of the take-off phase is to transform the horizontal velocity gained during the acrobatic series into inclined direction resulting in upward movement of gymnast’s body under optimal take-off angle. This transformation of vectors of velocity depends on “straighting” of legs under certain angle. This guarantees the maximum height and optimal body twisting along transverse body axis for given number of twists.

Maximum height enables execution of maximum number of turns along the longitudinal body axis during flight phase and optimal angular velocity of somersault twist is a condition for perfect execution of touchdown phase. The initiation of turn along transverse body axis takes place during a microphase in

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take-off phase completion when take-off force goes in front of the centre of gravity. Thanks to this, a moment of rotation is created and body turns along the transverse body axis which goes through the centre of gravity. During the flight phase gymnast creates secondary rotation along longitudinal body axis by asymmetrical movements of arms on principle of gyroscopic effect and Coriolis effect.

Very important part is touchdown phase when gymnast reaches the pad again. If the performance of previous flight phase has optimal time-space characteristics and gymnast does not have problems with under or over-turning of salto, her body is in this last phase pushed down by inertia forces. By eccentric activity of leg muscles she transforms kinetic energy of her body into different forms of energies and gives her body into static position.

II. Methods

It is a case study focused on analysis of salto bachwards stretched with various number of turns. The tested person was a female Czech Republic representative in sports gymnastics, Kristyna Palesova, who took part in the summer Olympic Games 2008 in Beijing. The analyzed movement structures are part of her composition on floor exercises.

We conducted the measurements in the gymnasium on flexible acrobatic floor with touchdown to soft foam hole on strengthen landing area. We analyzed the salto backwards stretched with ½ turn, 1/1 turn, 3/2 turn, 2/1 turn, 5/2 turn, 3/1 turn. The saltos were preceded by following acrobatic series: run-up, hurdle, round-off, back handspring. The gymnast performed each type of salto three times. We thus analyzed 18 saltos backwards stretched with different number of turns.

We provided the detailed analysis using Simi Motion system. We used 2 high frequency synchronized digital cameras Simi motion Version 7 to record the videos. The recorded data was directly sent to software of the same trade mark. Afterwards we processed the data in the software. Using 13 retroflective spheres we marked anatomical areas on the gymnast's body (right/left ankle, right/left knee, right/left hip, right/left shoulder, right/left elbow, right/left wrist and head).

III. Results

We found out that that there are changes in angles during the take-off phase depending on number of turns in salto backwards stretched performed after round-off and back handspring.

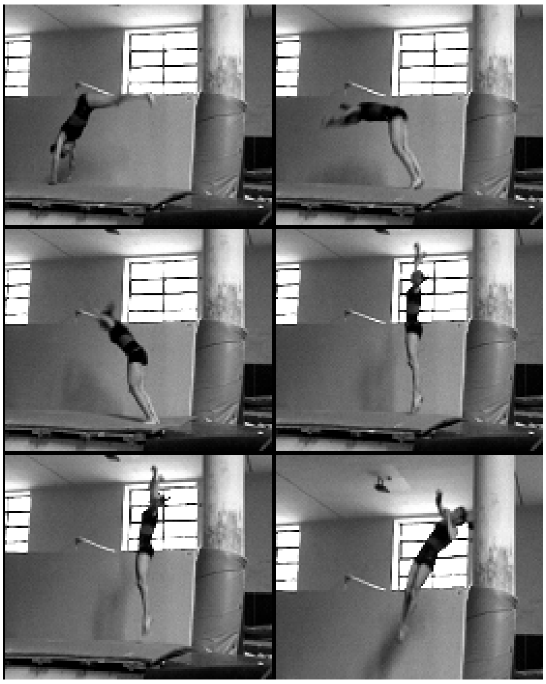

Fig. 1 Kinogram of rebound and take-off phase before salto backwars stretched with 1/1 turn

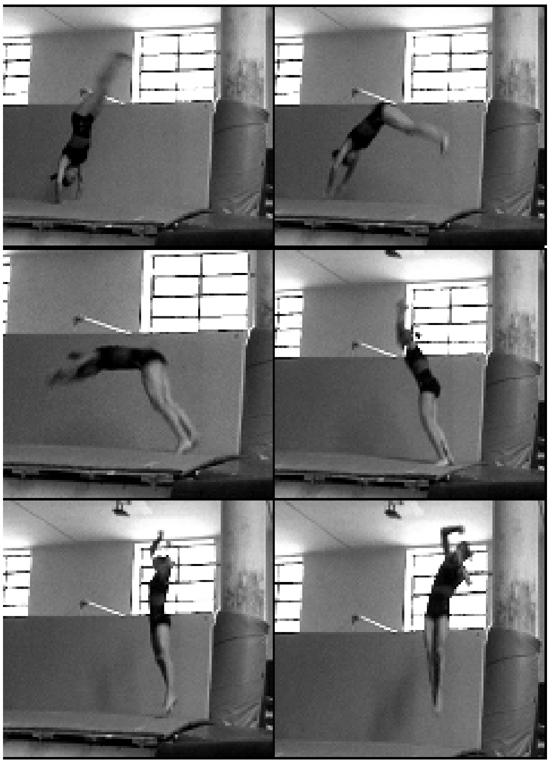

Fig. 2 Kinogram of rebound and take-off phase before salto backwars stretched with 3/1 turn

Fig. 1 shows a kinogram of rebound and take-off phase in salto backwars stretched with 1/1 turn, figure no. 2 shows the same salto with 3/1 turn. We can detect differences between positions of different body parts during the microphases just by simple observation and comparison of these two kinographs. The exact numeral data prove and quantify the differences.

We needed to synchronize the recordings in order to be able to compare individual attempts. The unifying moment was the lowest speed of the centre of gravity during the take-off phase. In this moment we measured the angle under which the gymnast lands on the pad at the beginning of new phase. We evaluated the angle between the pad and left leg point and left hip point (angle α). We monitored take-off velocity of the centre of gravity at the moment of take-off phase completion and maximum height which the centre of gravity reached. Out of 18 recorded saltos we evaluated only 16, as one salto with ½ turn and one with 5/2 turn was not performed correctly according to professional evaluation. Table no. 1 and figure no. 3 show the evaluated data.

TABLE I
RESULTS OF MEASUREMENTS OF INDIVIDUAL SALTO BACKWARDS STRETCHED WITH DIFFERENT NUMBER OF TURNS

Number of turns	α [°]	*v* [m/s]	*h* [m]
1. attempt 180°	55,464	4,443	1,684
2. attempt 180°	52,659	4,351	1,696
average 180°	**54,062**	**4,397**	**1,69**
1. attempt 360°	54,88	4,45	1,66
2. attempt 360°	51,443	4,452	1,662
3. attempt 360°	49,325	4,521	1,687
average 360°	**51,883**	**4,474**	**1,67**
1. attempt 540°	50,178	4,596	1,614
2. attempt 540°	53,121	4,451	1,644
3. attempt 540°	51,706	4,574	1,622
average 540°	**51,668**	**4,54**	**1,627**
1. attempt 720°	50,15	4,572	1,649
2. attempt 720°	51,542	4,487	1,663
3. attempt 720°	50,014	4,546	1,678
average 720°	**50,569**	**4,535**	**1,663**
1. attempt 900°	48,489	4,481	1,675
2. attempt 900°	45,184	4,659	1,666
3. attempt 900°	48,727	4,392	1,647
average 900°	**47,467**	**4,511**	**1,663**
1. attempt 1080°	46,243	4,562	1,675
2. attempt 1080°	45,539	4,639	1,692
average 1080°	**45,891**	**4,601**	**1,684**

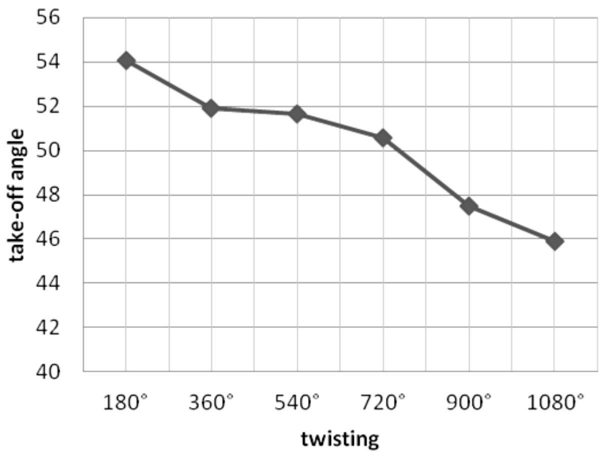

Fig. 3 Results of measurements of individual salto backwards stretched with different number of turns

We found out that the gymnast needs to adjust the angle α so that she does not under-turn or over-turn the salto. With increase in number of turns the gymnast lands on the pad under smaller angle. While in salto backwards stretched with ½ turn the average value of angle α was 54.1° (fig. 4),in salto with 1/1/ turn the average value of angle α 51.9° , the average angle decreased to 51.7° in salto with 3/2 turn and to 50.6° in salto with 2/1 turn. More significant difference was in salto with 5/2 and 3/1 turn when the angle α was 47.5° and 45.9° (fig. 5).

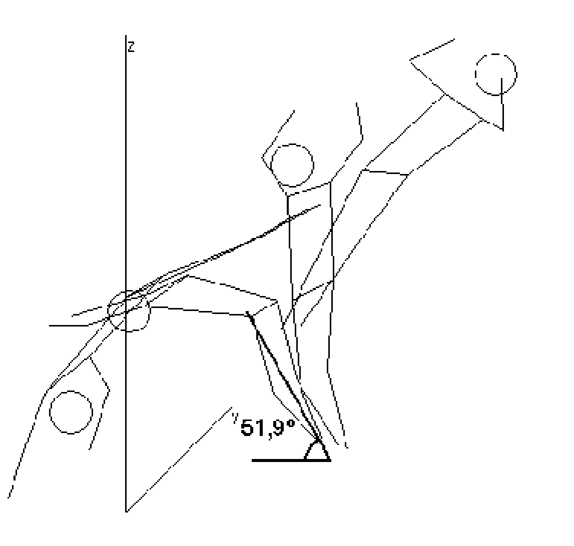

Fig. 4 Take-off phase in salto backwards stretched with 1/1 turn

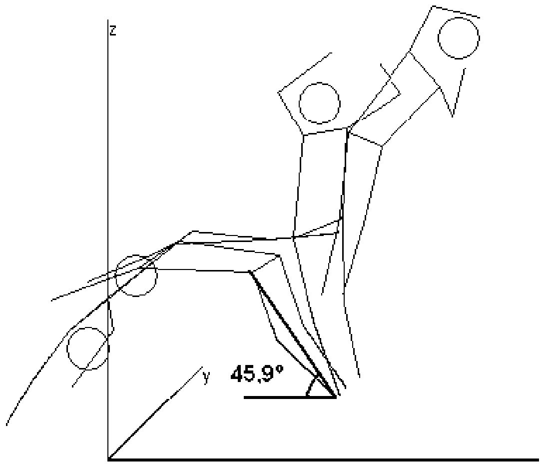

Fig. 5 Take-off phase in salto backwards stretched with 3/1 turn

With increasing number of turns there is increase in take-off velocity. In salto with ½ turn the velocity was 4.4 $m \cdot s^{-1}$, while in salto with 3/1 turn the take-off velocity increased to 4.6 $m \cdot s^{-1}$. The maximum height of hips was in all attempts between 1.6 m and 1.7 m.

IV. Discussion

The evaluated data prove our assumption dealing with angle characteristics in the beginning of take-off phase in salto backwards stretched with different number of turns. As we did not find any literature dealing with this problem, we cannot compare our results to results of another study. From the theory and the results follows that trajectory of centre of body is fully determined by parameters at the moment of take-off phase completion which are take-off velocity, take-off angle and height of centre of gravity at that moment. Sands at al. (2008) in his study showed that take-off angle in triple twisting back somersaults is smaller than in quadruple-twist back somersault. It is important to realize that these parameters result from preceding phases. Influence of parameters of touchdown phase on flight phase are clarified mainly in connection to long jump and high jump in athletics [9],[10] where reaching the maximum length or height is limiting factor for performance. Our results also show that depending on requirements of flight phase or number of turns in flight phase touchdown angle changes as well. If this angle is smaller, gymnast is able to transfer the horizontal velocity into vertical in better way. The run-up velocity and changes of this velocity determine crucial parameters in take-off phase completion.

V. Conclusion

In professional gymnastics, technical perfection is a limiting factor of perfect mastering of structures with the highest level of difficulty. Sometimes just small differences that cannot be notices at first sight may strongly influence performance of certain gymnastic skill. Also in our case, when the gymnast only felt the changes in technique, the kinematic analyses revealed certain differences in performance of salto backwards stretched with different number of turns which we were able to quantify much better. We found out that there are changes in take-off angles which strongly influence faultless execution of analyzed movement structures. After theoretical analysis there is another phase which is an interpretation of the results and their transformation to training practice. Here it depends on the handler's personality who has to sum up the whole analysis into, sometimes, only one sentence. In our case we may recommend these examples of interpretations (e.g. for salto backwards stretched with 5/2 turns and more): execute longer back handspring, faster take-off from arms, not omitting the rebound. In order to generalize the conclusion, we would have to analyze bigger number of gymnasts. Nevertheless we think that our analysis contributed to improvement in technical preparation of sports gymnasts and has its scientific value.

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