ANGULAR MOMENTUM IN JUMPS WITH ROTATIONS ON THE LONGITUDINAL AXIS IN FIGURE SKATING - 3D-ANALYSES AND COMPUTER SIMULATION

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INTRODUCTION

In analyses of athletic technique in figure skating primarily jumps with three or four rotations about the longitudinal axis are considered.
The quality of these jumps is essentially influenced by vertical momentum and angular momentum. While vertical momentum can be obtained without any problem from flight parameters the calculation of angular momentum does represent a much more complicated problem.

The task is to optimise vertical and angular momentum and to answer the question why the longitudinal axis is tilted during flight. This is important since a slightly tilted position of this axis can cause a fall in figure skating.
Analyses of falls are therefore mostly concentrated on the identification of reasons for this tilted position during flight already during take-off. Therefore an exclusive 3D monitoring is insufficient for recommendations on sports techniques, but additional 3D calculations (e.g. calculation and three-dimensional presentation of angular momentum) have to be performed.

METHODS

A PEAK5 Motion Measurement System (PEAK Performance Technologies) was used to perform a three-dimensional analysis of the triple jump (triple Axel).

A procedure for a three-dimensional presentation of angular momentum as vector is presented. Using this procedure reasons for falls are determined and general orientations for sport technical models can be characterised. Another procedure offers the opportunity to quantify the partial contribution of individual parts of the body producing angular momentum.

To determine the efficient use of the produced angular momentum 3D computer simulation is applied

To compute the angular momentum and angular velocity we composed a non-rigid human body with 15 rigid segments, connected by 13 joints. The inertial parameters of each segment are computed assuming rigid segments as inclined elliptically cone-stumps. Eulers' theorem allows us to define the angular velocity of such a human body as motion of the principal axes of inertia about its centre of mass.

RESULTS

1. The influence of the angle between longitudinal axis and direction of angular momentum on an efficient use of the produced angular momentum is determined as a result of computer simulation (table 1):

Table 1: Results of the computer simulation of a triple jump in figure skating with the same angular momentum and different angle between longitudinal axis and angular momentum

angle (deg)	angular velocity (rad/s)	rotation
0	33,2	3,00
10	32,6	2,95
20	31,3	2,85
30	29,6	2,60

This result shows that an angle of 30° between longitudinal axis and direction of angular momentum produces no complete rotation and finally often causes a fall in this jump.

2. Jumps in figure skating have a good stability if the longitudinal axis has only an insignificant tilt in the landing-position. The direction of the angular momentum determines the position of the body during flight and landing. Therefore the produced angular momentum has to be almost perpendicular during take-off.

Analyses of different triple Axel prove this fact. The procedure for three-dimensional analysis in figure skating is the following:

Figure 1: Kinegram of a triple Axel in figure skating

Initially we performed a three-dimensional analysis for this jump with a PEAK5 Motion Measurement System (Figure 2) and developed mathematical model illustrating the longitudinal axis, the body movement and also the angular momentum (direction and amount) (figure 3).

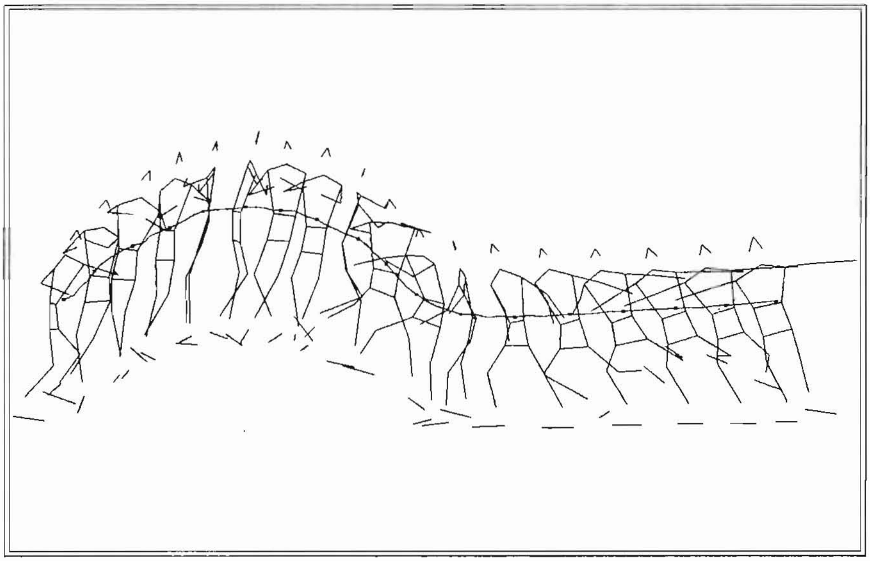

Figure 2: Three-dimensional co-ordinates (PEAK Performance) including centre of mass for the same jump

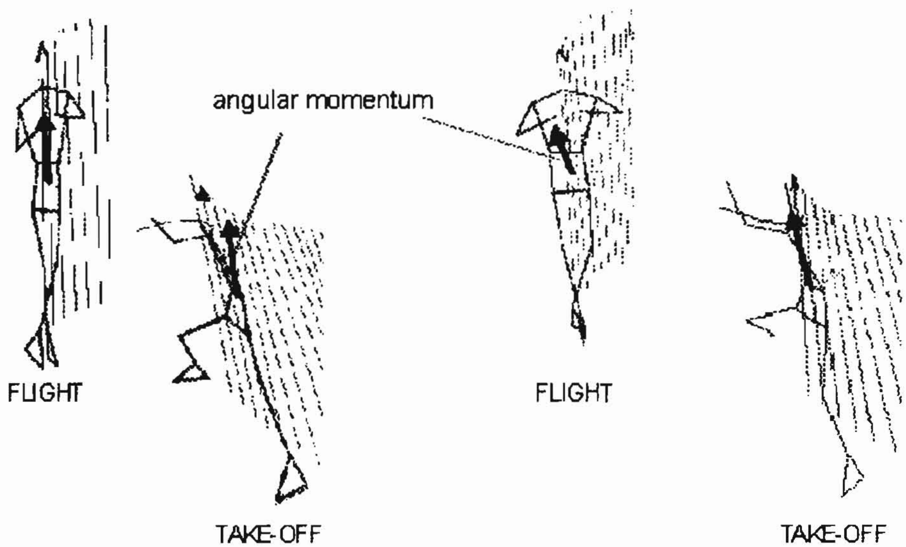

Figure 3: Illustration of total angular momentum, longitudinal axis and the body position during take-off and flight. On the left hand side a very good triple Axel (the same as above) is presented, on the right hand side another jump with sudden fall.

Not only the relationship between angular momentum and longitudinal axes determines a good flight and landing, but also the general direction of angular momentum.

CONCLUSIONS

We study practical applications in sports to present conclusions for the training of sports technique. We give recommendations for individual solutions concerning sports technique res. present general models to optimise sports technique of the most complicated technical elements. Using the example of the triple Axel, the most complicated triple jump in figure skating, we present opportunities for an interpretation of our results in sports practice.

In another procedure we can illustrate contribution of the individual parts an the body on the production of total angular momentum. Thus we present special information on different reasons for tilting the longitudinal axis to coaches and skaters.

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