TRAINING EFFECTS OF RAPID ROTATIONS IN A "SOMERSAULT SIMULATOR"

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The purpose of the present study was to analyze training effects in a new training device. State-of-the-art analyses in diving and gymnastics showed an increasing of angular velocity in somersault rotations. Subjects of different ages and performance levels took part in several experiments with the "somersault simulator". The investigation was divided in two parts. The differences between the movement in the training device and real situation of competition were analyzed. In the "somersault simulator" the athletes reached an angular velocity of approximately 700 deg/s. This is similar to a 2 ½ somersault in diving or a double somersault in gymnastics. The experiments demonstrated that with the use of the simulator, the athletes significantly improved the level of vestibular adaptation and visual perception by performing rapid somersault rotations.

KEY WORDS: somersault, visual perception, vestibular load, diving, gymnastics

INTRODUCTION: The angular velocity of somersault rotations has grown up in the last years. Using state-of-the-art analyses on increasing the angular velocity in rapid somersault rotations in gymnastics and diving, the highest level of this parameter was found to be with the 4½ somersault forwards tucked in diving (approximately 1300 deg/s). The same levels were also found in the handspring and double somersault forwards tucked in gymnastics (approximately 1200 deg/s). This rapid somersault rotation places high demands on the individual's visual control and motor coordination.

Figure 1 - 4½ somersaults forwards tucked.

In diving competitions, the 4½ somersault forwards tucked (Figure 1) was seldom performed. Evidently, this dive with high-speed rotation is one with a high degree of difficulty. However, in gymnastics, many athletes have demonstrated the handspring and double somersault forwards tucked on the vaulting horse at the World Championships in the last few years (Figure 2). Not only is the rapid somersault rotation a highly difficult move in gymnastics, but also the visual orientation and the motor control is very complicated in the rapid backward somersault rotation in diving.

In the present study, using state-of-the-art analyses it has been possible to demonstrate that there are some dives and gymnastic elements with angular velocity higher than 1000 deg/s (table 1). These movements have been identified for use in testing new training methods.

In the scientific literature, air-borne human rotational movements represent a complicated problem involving theoretical mechanics. Many studies have been presented during recent years, by Yeadon (1990) and Hildebrand (1997) and other authors, in order to gain new insight into mechanical principles. In these studies, the athlete was considered to be a multi-link system of rigid bodies.

Studies on the increase of the angular velocity of somersault rotations in gymnastics and diving in the last few years has been mainly concerned with examining the increase in angular momentum. As a result, bio-mechanical analyses were directed towards the production of

Figure 2 - Handspring and double somersault forwards tucked on the vaulting horse.

a higher level of angular momentum, not only with the preparatory elements but also the take-off (Miller, Hennig & Pizzimenti, 1989; 1990; Brüggemann, 1994; Knoll, 1996; Murtaugh & Miller, 1998).
The scientific problem of the coordination, especially on the subject of motor control at rapid somersault rotations, was often neglected (Krug & Witt, 1996).

Table 1 Diving and Gymnastic Elements with Angular Velocity Higher Than 1000 deg/s

Diving	Gymnastics
Forward 4½ somersaults	Vaulting Horse
Back 3½ somersaults	Handspring and double somersault forwards
Reverse 3½ somersaults	Tsukahara with somersault backwards
Inward 3½ somersaults	Floor Exercise
Arm-stand forward triple somersault	Triple somersault backwards
Arm-stand backward triple somersault	

It seems that only among diving coaches was there any discussion on the subject of teaching for spotting in back and reverse somersaults (De Mers, 1983a, 1983b). In the laboratory Stangl and Gollhofer (1998) investigated athletes in several kinds of sports concerning the spatial-dynamic precision of the vestibulo-ocular reflex. The athletes were trained to suppress this reflex in all of three rotational directions. However, the angular velocity in this experiment was relatively slow (100 deg/s). The level of angular velocity at somersault rotations is ten times higher than in this laboratory study. In order to achieve more realistic conditions of somersault rotations a training device ("somersault simulator") was developed in the Institute for Applied Training Science. In this study, the training effects of rapid air-borne rotations in the "somersault simulator" were investigated.

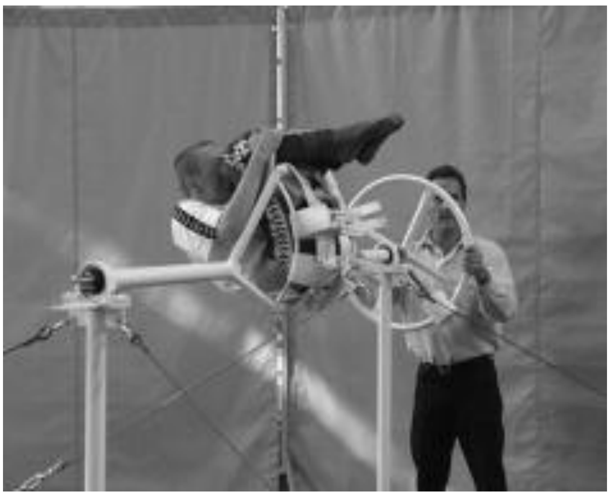

Figure 3 - Athlete in the "somersault simulator."

METHODS: The athletes were fastened into the training device ”somersault simulator” with the seatbelt. With the help of the wheel, the coach set the athlete in motion with the ”somersault simulator”. Using the training device during the rotation, the athletes were able to perform tucked, piked, or stretched positions. On the axle of the training device, a speedometer was set up to measure the angular velocity. The number of rotations and the angular acceleration were calculated with the computer. The diode lamp was used to test the visual orientation and perception. The video camera (synchronized with the speedometer) was placed in a position that was rectangular to the movement plane. The force plate was integrated in this computer-aided measurement system for posturographic tests. This test was used before and after the rotational load. The athletes had to perform as quickly as possible on the platform for the post-test. This paper focused on several investigations:

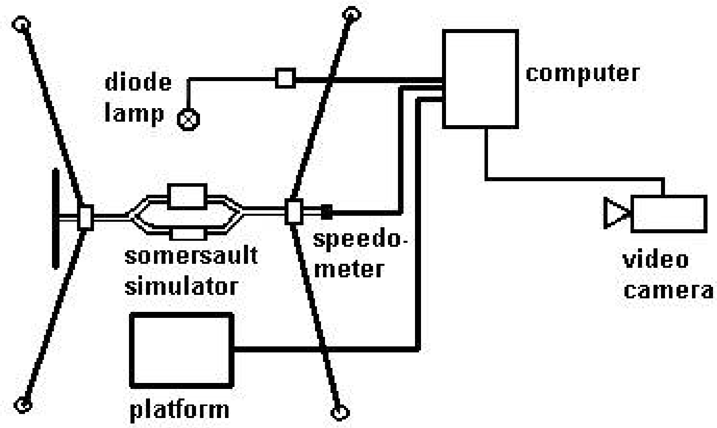

Figure 4 - Schematic of the “somersault

1. Comparison between the somersault in the simulator and in the competition:

The videometric data recording was used and the angular velocity was calculated, relating to trunk and head. Additionally, the load on the vestibular apparatus was estimated with following parameter:

Centrifugal force	$F_Z = m * \omega^2 * r$	[N]	(1)
Centrifugal acceleration	$a_Z = \omega^2 * r$	[deg/s^2]	(2)
Coriolis force	$F_C = 2 * m * v_r * \omega$	[N]	(3)

2. Analyses of the visual perception and motor control:
   6 female and male divers (13-15 years old) trained over 6 weeks in 12 sessions made up of different rotational movements (2x 1 ½; 2x 2 ½; 2x 3 ½ somersault backwards) with orientation tasks. After the orientation tasks the subjects had to perform 15 somersaults backwards. The training effects were analyzed, with a pre-test versus post-test design. For statistical analyses we applied the software package SPSS 8.0.

RESULTS AND DISCUSSION: The rotational load in competitions with two dives was analyzed. The characteristic parameters are shown in Table 2.

Table 2 Parameter for Rotational Load in Diving

Dive	max. Angular Velocity [deg/s]	Centrifugal Force (on the head) [N]	Centrifugal Acceleration (on the head) [m/s^2]	Coriolis Force [N]	max. Acceleration (on the head) [g]
Armstand Triple Somersault bw tucked	900	360	90	101	9.2
Back 3 ½ Somersault tucked	1080	437	109	103	11.1

In the ”somersault simulator” the angular velocity was approximately 700 deg/s. This measurement corresponds to dives with 2 ½ somersaults and double somersaults in gymnastics. The training device is particularly well suited for age-group training. Additionally, the investigation demonstrated the high load on the vestibular apparatus using rapid somersault rotations.
The advantage of the ”somersault simulator” is that the athletes train with a significantly higher number of rotations in relationship to real training situations. For that reason, the adaptation of the vestibular apparatus can be useful in training.
The analyses of the visual perception and motor control illustrated several interesting facts. Divers use a spotting-technique for visual perception in rapid somersault rotations. This was identified with rhythmical head movements during the somersault. The characteristics are as follows:
First, the head is moved before spotting in direction of rotation.
Following that, the head is counter-rotated to the trunk for spotting.
In the experiment with the young divers the following results were obtained:
The training with visual perception of the diode lamp produced significant improvements within the 6 weeks ($p = 0.05$). In the training sessions, a randomized flash (but each time in the same angle) of the diode lamp was used. At the end of the experiment, the recognition rate of the flash was very high. Obviously, in a relatively short interval the visual perception is trainable in the ”somersault simulator”. However, there are differences of the head movement in real somersaults and in the training device. In the ”somersault simulator” the head movement was performed with a wider amplitude. From this, it can be assumed that in the training device the athletes performed the somersaults without anxiety. Simultaneous psychological analyses demonstrated the advantage of the ”somersault simulator”.

CONCLUSIONS: The ”somersault simulator” is very helpful for special training sessions to extend the training duration for somersault rotations. The training device is particularly well suited for age-group athletes. One aspect, the training load of rotational movements potentially could be better organized and evaluated. The computer-aided simulator makes new training methods possible. The improvement of performance in the simulator was transferred into the competition.

REFERENCES:
Brüggemann, G.P. (1994). Biomechanics of Gymnastic Techniques. In *Sport Science Review.* **3**(2), 79-120.
De Mers, G.E. (1983a). Utilizing visual reference points in springboard diving - 1. Article. *Swimming World. - Los Angeles.* **24**, 38-41.
De Mers, G.E. (1983b). Teaching spotting in back and reverse somersaulting dives - 2. article. *Swimming World.- Los Angeles.* **24**, 46-48.
Hildebrand, F. (1997). *Eine biomechanische Analyse der Drehbewegungen des mensch-lichen Körpers*. Aachen: Meyer & Meyer.
Knoll, K. (1996). Analyses of acrobatic tumbling exercises on floor and balance beam. In Abrantes, J.M.C.S. (Ed.). (1996). *Proceedings XIV International Symposium on Biomechanics in Sports*, June 25-29, Madeira.
Krug, J., & Witt, M. (1996). Motor learning and muscular requests for rapid air-borne rotations of athletes. In Abrantes, J.M.C.S. (Ed.). *Proceedings XIV International Symposium on Bio-mechanics in Sports*, June 25-29, Madeira.
Miller, D.I., Hennig, E. & Pizzimenti, M.A. (1989). Kinetic and kinematic characteristics of 10-m platform performances of elite divers: I. Back takeoffs. In *Int. Journal of Sport Biomechanics*. **5**, 1, 60-88.
Murtaugh, K., & Miller, D. I. (1998). The Golden Armstand. North American Congress on Biomechanics 1998. http://www.asb-biomech.org/NACOB98/122/index.html.
Stangl, W., & Gollhofer, A. (1998). Räumlich-dynamische Präzision des vestibulo-okulären Reflexes im Sport. In *Bundesinstitut für Sportwissenschaft (Hrsg.)*. BISp Jahrbuch 1997. S. 119-127, Köln.

Yeadon, M.R. (1990). The simulation of aerial movement. In *Journal of Biomechanics*. I. The determination of orientation angles from film data. 23(1990a) pp. 59-66, II. A mathematical inertia model of the human body. (1990b) pp. 67-74, III. The determination of the angular momentum of the human body. (1990c) pp. 75-83.

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