# WHEEL GYMNASTICS - SOMERSAULT DISMOUNTS AND NO LANDING MAT

**Klaus Knoll[1], Falk Hildebrand[1], Volker Drenk[1] and Ines Sebesta[2]**
**[1]Institute for Applied Training Science, Leipzig, Germany**
**[2]German Gymnastics Federation, Germany**

The aim of this study was to investigate which biomechanical principles act during salto dismounts from the gymwheel and in which way the load during landing can be reduced. For this purpose a forward and a backward somersault dismount from straight-line voluntary routines were studied. The movement of the gymnast and the wheel were analyzed with a 3D photogrammetric procedure. Flight height and salto angular momentum can be increased if the take-off is improved. For example, the wheel velocity has to decelerated during the take-off to zero in order to transmit a bigger amount of energy back to the gymnast. The maximum loads while landing from approx. 2.50 m height on the hard ground can be reduced by suitable movements of the body segments. But we recommend to the I.R.V., though, to introduce landing mats in the straight-line discipline too.

**KEY WORDS:** wheel gymnastics, somersault dismount, landing

**INTRODUCTION:** Wheel gymnastics is a sport discipline which comes from Germany and which is mainly known in Europe. The voluntary straight-line routines of wheel gymnastics are ended with dismounts like jumps with twist and forward or backward somersaults. The gymnasts land in these dismounts on the hard floor - unlike the vault discipline, where the gymnasts may use a mat. Good gymnasts achieve flight heights up to 2.5 m above the ground. Although the gymnasts in these jumps bounce with high energy at the parquet floor, dismounts from the gymwheel have not yet been analyzed until now with regard to their biomechanical principles and physiological effects on the gymnasts.

**METHODS:** On the occasion of German Gymnastics Festival 2002 in Leipzig, the dismount somersaults of two elite wheel gymnasts (performance class L 9, 15 and 17 years old) were examined. Two GEN-locked and panning video cameras with the frame rate of 50 Hz recorded the motion sequences. One camera recorded the movement laterally, the other frontally (distance approx. 15 m). The cameras were about in a right angle to each other. The movement to be registered was performed in an upright plane of approx. 4 m length and 3 m height. A forward and a backward somersault dismount were selected.
The digitalization and calculation of the 3D co-ordinates of 22 body points (on the basis of a 13 segment body model) as well as two points of the wheel were done with the photogrammetric procedure SimMess (Drenk & Hildebrand, 1999). We used the values for wheel size, wheel mass, body mass of the gymnast and body point co-ordinates in a specific analysis program to determine which parameters have a deciding influence on the energetic potential of the wheel and the gymnast and on the swing action of the gymnast:
horizontal velocity of the wheel (velocity on the wheel center)
velocity of the take-off board rung (circumferential velocity of the wheel)
location and velocity of the center of gravity (CG)
total force acting at the CG with the components tangential and radial force
kinetic energy of the gymnast and the wheel.
In addition with the visualization system SimBA 2.0 (Spahr, 1999) a computer animation was designed with spatial figures, that represents the motions of the wheel and the gymnast in three dimensions and as a skeleton diagram.

**RESULTS AND DISCUSSION:** The gymnast employed the wheel to generate swing, similar to a springboard, in order to achieve big flight heights. During the last wheel turn before the dismount he accelerated it very strongly, before he jumped from the wheel against the rolling direction. During the take-off the kinetic energy of the wheel was partially transferred to the gymnast. The wheel was decelerated, the gymnast was accelerated. He used this energy in order to gain height and to perform the body rotations (somersault or twist). Due to the high velocity of the wheel during the take-off and the subsequent rotary motion, the gymnast had a relatively high kinetic energy during the dismounts. After the somersault rotation the gymnast performed against the angular momentum in order to reach a stable standing position. He extends and thus decreases the rotational velocity (see Figure 1, frame 31 and Figure 2, frame 110). He absorbed the remaining kinetic energy at the ground (Figure 1, frame 139-162 and Figure 2, frame 139-162).

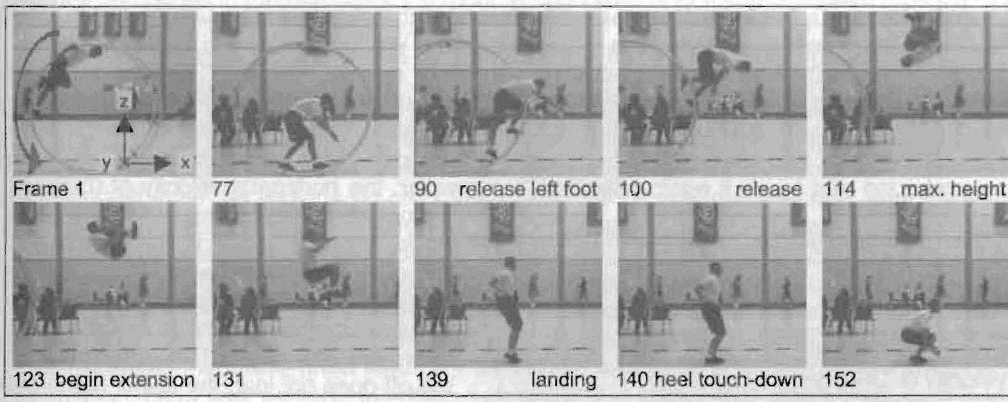


**Figure 1 Somersault dismount in straight-line voluntary routine.**

Using his body weight the gymnast put the wheel in motion, in the example of the **forward somersault dismount** from almost zero up to more than 4.50 m/s in the deepest CG position. He partially got back the energy of the wheel, when he then moved upwards. The horizontal velocity of the CG amounted to 0.35 m/s and the vertical velocity 2.65 m/s at moment he released the board rung. According to a short-term blocking with the right leg, the left knee was stretched and a vertical acceleration started in the low position of the CG. The biggest effect of the force was monitored after 0.14 s and at a knee angle from 130°. The greatest strength can be developed in this knee angle range. The right leg behaves passively, perhaps it is stabilizing or it is covering the fine adjustment.

The somersault angular momentum was produced only after the vertical impulse, when the left foot left the board rung of the wheel (frame 90 in Figure 1). Unlike floor exercise, in this respect the rolling wheel is helpful. It rolls in the opposite direction and increases the horizontal distance of the CG from the center of pressure (lever arm). It was amazing to see that no more force was applied onto the wheel already 0.2 s before the athlete left the wheel. The CG curve shows that this passive behavior of the gymnast was correct, because the small horizontal velocity of the CG of 0.35 m/s is just at the boundary of what the subject

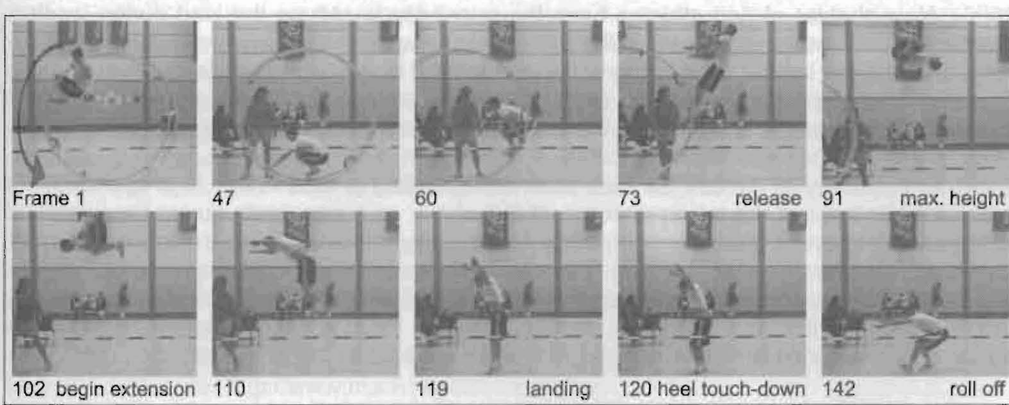


**Figure 2 Backward somersault dismount in straight-line voluntary routine.**

additionally can bear during landing - besides compensating the salto angular momentum - in order to stand in a stable position. While landing within 0.02 s the energy is reduced to about 1100 Nm, before the athlete initiates the flexion in the knee joints. Therefore, this difference must be absorbed passively by the muscle skeleton system. Within 0.04 s from touch-down on the floor to the impact of the heels about one third of impact energy is removed. The vertical velocity still amounts to -3.70 m/s. For this somersault the maximum CG height amounted to 2.13 m.

When performing a **backward somersault dismount** the gymnast released the hands from the rims already before achieving the deepest location. We found a kinetic energy at take-off of 1530 Nm and 0.02 s after touch-down on the floor of only 760 Nm. The maximum CG height at backward somersault amounted to 2.36 m. Thus, as in artistic gymnastics the backward somersaults are executed higher than the somersaults (see Table 1). The gymnast lands on the pads and immediately bends in the knee joint. After 0.02 s the heels touch the floor, rebound and touch it again after 0.16 s. However, the horizontal velocity of 0.25 m/s cannot be compensated in this way. The backward somersault is not stood, and the gymnast drops back. While staying on the pads and flexing the knees, the athlete removes two thirds of the impact energy within 0.16 s. This (unintentional) roll off does not load the spine. Since the angular momentum is not removed all at once, the impact energy is distributed within the body over a longer period resulting in smaller load peaks.

**Table 1 Comparison of somersault parameters.**

| | Somersault forward | Somersault backward |
|---|---|---|
| Horizontal release velocity of CG [m/s] | 0.35 | 0.25 |
| Vertical release velocity of CG [m/s] | 2.65 | 3.38 |
| Flight height [m] | 2.13 | 2.36 |

In order to avoid dropping back the following methodic instructions were given to the coach:

- The head that initiates all movements must not be taken into the neck too soon during take-off.
- The arms could be swung from that deep position into oblique high position while take-off.

Or as an alternative, the gymnast should extend earlier while air-borne.

The horizontal motion of the CG is almost zero. A slight velocity, namely against the wheel movement, would also have been helpful here. The earlier arm movement during the take-off would already be able to cause that. On the other hand, an earlier extension at the vertex of the flight curve looks quite spectacular, because the body seems to remain still longer in a hovering position due to the extension of the big partial masses of the feet.

The impact energy gives information on the load which a gymnast has to bear while landing. The measurement results confirmed the assumption that the load on the gymnast during landing is equivalent to approx. the 25-fold body weight (compare Brüggemann & Krahl, 2000). Nevertheless skilled athletes have the possibility to reduce the load during landing. With specific counter movements of the arms and the upper body a gymnast can slow down resp. dampen the impact. Due to the enlarged moment of inertia the precisely timed opening causes a reduction of the body's angular velocity. In addition the period during which compensation strength is acting on the body while landing can be prolonged by an active stretching of the toes towards the ground.

A further possibility to remove the load peak while landing is to land with legs apart resp. to make a lunge against the rolling direction of the wheel, as it was made during the backward somersault. However, that is incompatibly to the judging rules of the International Wheel Gymnastics Federation (I.R.V. 2003). The consequence of all these measures is that impact energy and angular momentum need not be removed immediately while striking onto the ground, because this energy then is distributed within the body and mainly to the muscles during a longer period of time. Correspondingly the load peaks become less.

**CONCLUSIONS:** When the gymnast lands on the floor and in this case comes into the safe standing position, the total impact energy passes onto his body. Indeed the modern

gymnastic hall floors are slightly elastic, however, they can presumably dampen only a very small part of this impact energy. The muscles cushion another part of this impact energy by a transformation into heat energy. The remaining part is passed onto the gymnast's supporting apparatus (tendons, ligaments and bones). There is a shock wave within the body which is directed from the feet to the spine. It takes just 4 ms from the touch-down of the feet on the floor until the heels hit the floor. That is the phase with the heaviest load during which tendons and bones in the feet suffer the most. A short time later the shock wave runs into the spine and again returns. This process can be repeated several times, but with an increased dampening. The musculature of the legs and of the trunk can never compensate that, it slows down the upper body only later.
The implemented investigations are to be continued in order to gain significant findings on the impact load. For gymnasts and trainers, conclusions can be drawn from these findings with regard to impact prevention. In future it might become a duty to make use of a mat for dismounts in case the findings do recommend that. Since only a somersault and a somersault backward were analyzed, the results are not generally representative. But the present video recordings and data make it possible to draw initial conclusions on the energy process during dismounts and on the load while landing.
We would like to draw the attention to the fact that a trained body is prepared for such loads. On the other hand not every body has good enough prerequisites to manage such maximum loads, including that these great loads are performed with several repetitions in training and competition. From floor exercise in artistic gymnastics it is known that similar maximum loads result in leg and ankle fractures caused by fatigue.
Gymnasts with pre-damages or knee problems should always use landing mats. Dampening plimsolls are recommended. It is desirable that plimsolls are developed with air-cushioned soles, but still flexible and supple. The suppleness of the soles is indispensable for movements in the gymwheel. In other sport disciplines with comparable flight heights as vaulting or horizontal bar dismounts, nobody would perform dismounts without a mat. The judging rules of the Federation Internationale de Gymnastique (F.I.G. 2002) have detailed specifications with respect to thickness and characteristics of the mats.
It remains to be hoped that the findings on ways to decrease injury risk are introduced into future judging rules of the I.R.V. From artistic gymnastics, it is known, caused by maximum loads in the execution of certain somersault take-offs in floor exercises, leg and ankle fatigue fractures may occur.
In a couple of years from now the executing of a double somersault dismount, especially a double backward somersault, appears to be possible under two conditions:
stronger take-off (the wheel velocity must be slowed down to zero by the take-off)
longer keeping of the tucked posture (shortening of the extension phase).

**REFERENCES:**

Brüggemann, G.-P. & Krahl, H. (2000). Belastungen und Risiken im weiblichen Kunstturnen (Loads and Risks in Female Gymnastics). *Schriftenreihe des Bundesinstituts für Sportwissenschaft.* Band 101. Schorndorf: Hofmann, Germany.
Drenk, V. & Hildebrand, F. (1999). Simultane Bildmessungen und Nutzung virtueller Körpermodelle (Simultaneous photogrammetry and use of virtual body models). *Zeitschrift für Angewandte Trainingswissenschaft.* 6(2), 69-86.
F.I.G. (2002). Federation Internationale de Gymnastique. Access on March 1st, 2003 under http://www.fig-gymnastics.com/.
I.R.V. (2003). International Wheel Gymnastics Federation. Access on March 1st, 2003 under http:// www.gym-wheel.com/WTB.htm.
Spahr, M. (1999). The use of a three-dimensional real-time movement analysis system in sport. *New Studies in Athletics* 14(1), 43-56.
Spahr, M. (2001). SimBA 2.0, 3D-Realtime Movement Visualisation in Sports. Access on May 2st, 2001 under http://www.martin-spahr.de/simba/.