RUNNING APPROACH VELOCITY AND ENERGY TRANSFORMATION IN DIFFICULT VAULTS IN GYMNASTICS

Jürgen Krug, Klaus Knoll, Universität Leipzig, Germany
Thomas Köthe, Hans-Dieter Zocher,
Olympiastützpunkt Magdeburg/Halle, Magdeburg, Germany

INTRODUCTION: Many investigations in gymnastics have focused on vaults on the horse. Brüggemann (1994) reviewed the literature on the biomechanics of gymnastics. He discussed several studies of biomechanical aspects in vaulting. In addition, some scientific reports (for example 1989, 1994, 1997) promoted by the International Gymnastics Federation (FIG) presented important facts. Evidently the running approach velocity is the most important phase of energy production in gymnastic vaults. The take-off from the springboard and the push-off from the vaulting horse are phases of energy transformation. Difficult vaults in gymnastics can be characterized by a high and long second flight phase. In this phase rapid airborne rotations are performed. These difficult saltos demand an appropriate level of energy and angular momentum. However, a complete investigation including running approach and all the phases in vaulting has not been available up until now.
In the scientific project carried out on the occasion of the 1997 Gymnastics World Championships in Lausanne (Switzerland), new aspects of difficult vaults were analyzed. The study was concentrated on the progression of the running approach up to stepping onto the springboard and the progression of energy during take-off. Moreover, the angular momentum of the take-off and the first flight phase were analyzed, and the proportion of the angular momentum from the first to the second flight phase was compared.

METHODS: A measuring system was used with two 50 Hz video cameras connected by genlock and a high speed video system (500 Hz). Additionally, the running approach velocity was measured with a laser velocity system. This setup

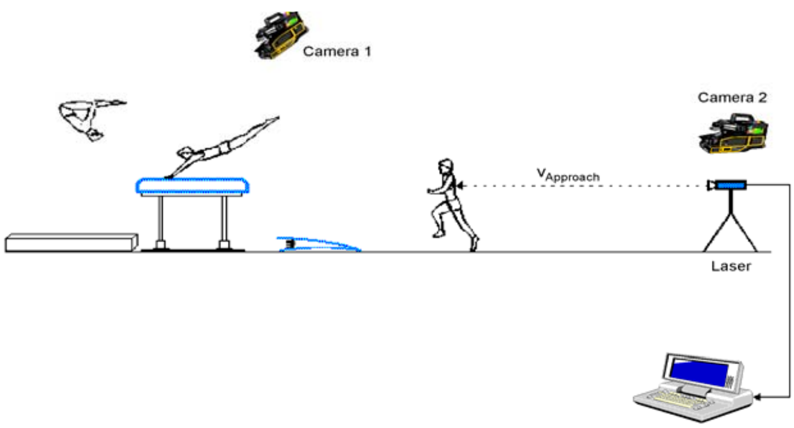

Fig. 1: Measuring System for horse vault

was used at the 1997 World Gymnastics Championships in Lausanne (Figure 1).
The calibration frame was positioned in four locations: on the two electronic light barriers in front of the horse on the springboard and behind the horse on the mat.
The energy was calculated with the 3D procedure of Hildebrand (1985). The kinetic energy, E_{kin}, for a multi-body system (e.g., Zatsiorsky, Aruin & Seluanow, 1984) is defined as:

$$E_{kin} = \frac{1}{2} M v_S^2 + \frac{1}{2} \sum_i m_i v_{S_i rel}^2 + \frac{1}{2} \sum_i \omega_i \theta_i^{S_i} \omega_i + \frac{1}{2} \omega \ \theta^S \omega$$

The angular momentum was also calculated with the procedure of Hildebrand (1985). In the case of motion without turns around the longitudinal axis we used the procedure of Hay et al. (1977).
The gymnasts (132 female and 163 male) were recorded by the measuring system. The official questionnaires of the FIG were filled out by 264 gymnasts, including age, weight and height. Unfortunately, these data were not all exact. Therefore relativized body measurements were used.

RESULTS: About 300 running approach velocities for different vaults were analyzed. The highest speed was 8.9 m/s in the men's competition and 7.9 m/s in the women's competition.

Table 1: Number (n) and mean values (M) of vaulting groups

	Difficult handsprings		Vaults with ½ turn in first flight phase		Yurchenko	
	N	M	n	M	n	M
Men	44	8.19	47	7.86	26	7.35
Women	66	7.30	10	7.28	84	6.98

Figure 2 shows the raw data progression and the smoothed curve.
Divided into three groups for men's and women's vaults (score ≥ 9.4) the statistical differences were calculated. A one-way analysis of variance yielded significant differences between the groups (except for the women's group 1 and 2).

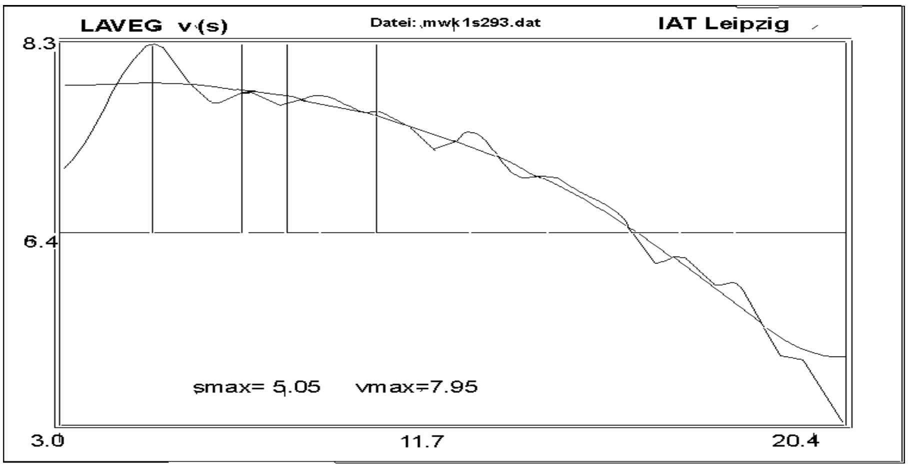

Figure 2: Curves of the fastest male (handspring vault) and female (Yurchenko) gymnast

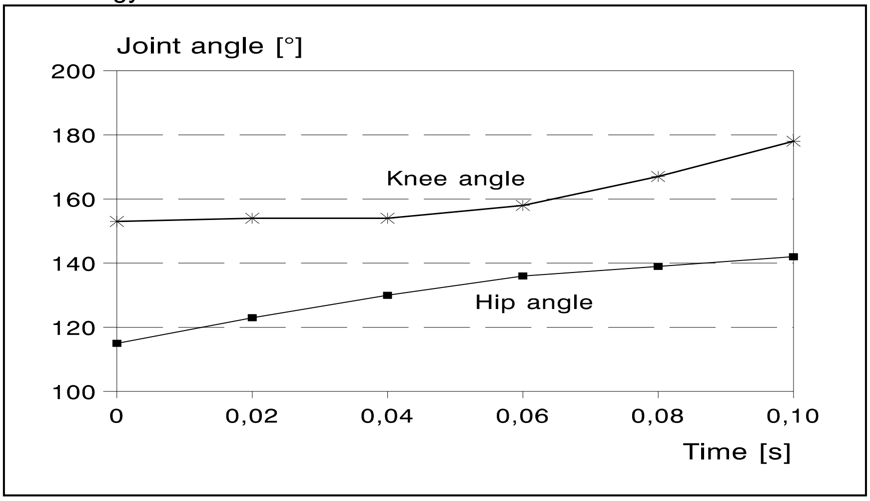

Figure 3: The take-off on the elastic springboard

The progression of hip and knee angle certified that the motion on the springboard is more a tension-shortening cycle than a stretch-shortening cycle.

The curves of the translational and rotational energy are very clear. Figure 4 certified that the energy production in the running phase is very important.

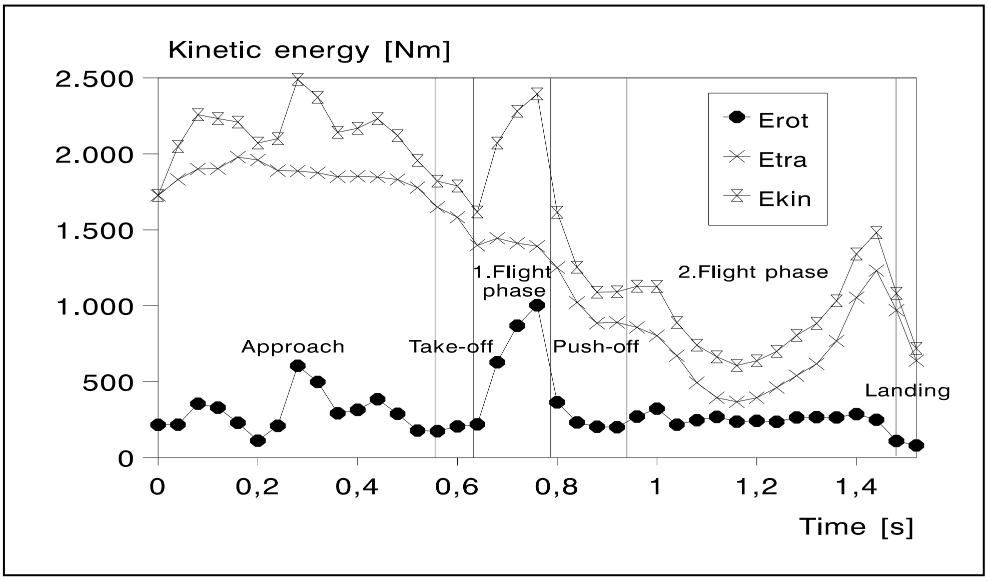

Figure 4: Curves of translational and rotational energy

The angular momentum is a decisive parameter for difficult vaults. The analysis proves that the highest level of this parameter is in the first flight phase. In the push-off phase the angular momentum is decreased (Figure 5). Indications of an increase in former investigations can not be certified. Obviously, in top level performance in the push-off the angular momentum has to decrease in order to reach a great height in the second flight phase.

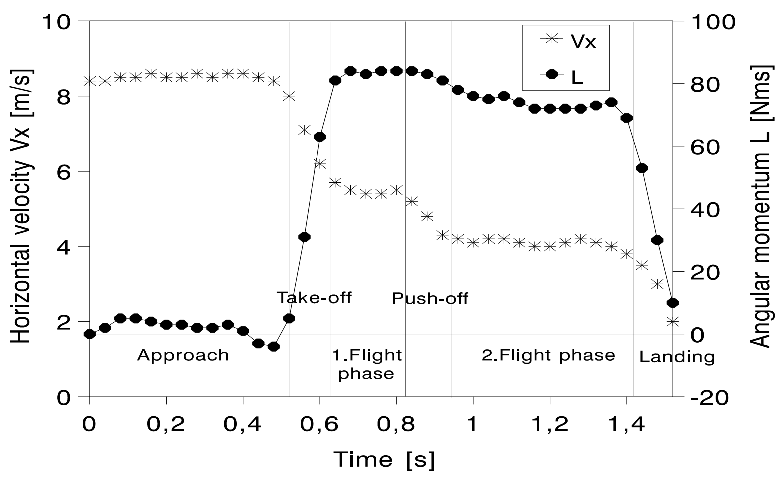

Figure 5: Curves of horizontal velocity and angular momentum

CONCLUSIONS: The investigations during the 1997 World Gymnastics Championships prove that the greatest difficulties also demand the highest levels of running approach velocity. The first flight phase is very low, but with a high level of angular momentum. The transformation index of the energy and angular momentum from the first flight phase to the second flight phase proves that both parameters have decreased. The measuring system is qualified for field settings in competitions. The oscillation of the velocity in the running approach should also be clarified in future investigations. The position for the calculation of the maximum running velocity is also suggested for electronic light barriers.

The extensive databases make it possible to recommend training programs for the FIG. Along with that, recommendations were made for the new point code. This code will be valid after the 2000 Olympic Games.

REFERENCES:

Brüggemann, G.-P. (1994). Biomechanics of Gymnastics Techniques. *Sport Science Review* **3**(2), 79-120.

Hay, J. G., Wilson, B. D., Dapena, J., Woodworth, G. G. (1977). A Computational Technique to Determine the Angular Momentum of a Human Body. *Journal of Biomechanics* **10**, 269-277.

Hildebrand, F. (1985). Eine biomechanische Analyse der Drehbewegungen des menschlichen Körpers. Habilitation. Leipzig.

Komi, P. V. (1992). Stretch-Shortening Cycle. In P. V. Komi (Ed.), *The Encyclopaedia of Sports Medicine. Vol. III: Strength and Power in Sport* (pp. 169-179). Oxford: Blackwell Scientific.

Krug, J., Noble, L. (1997). Application for Participation in the 1997-98 ISBS Gymnastics Project.

Zatsiorsky, V. M., Aruin, A. S., Selujanow, W. N. (1984). Biomechanik des menschlichen Bewegungsapparates. Berlin: Sportverlag.