SIMULATION OF VIBRATIONS IN ALPINE SKIING

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INTRODUCTION: Modeling and simulation has become a significant method in biomechanical research. The cause for using models and performing simulations is the investigation of complex systems, and further more the diagnosis of objects that are not directly analyzable. Thus the model construction has on one hand the function of abstracting a real object or interaction, and on the other hand it is the concrete form of an investigation idea (Perl 1996). The advantage of this diagnostic technique is primarily to analyze the function and influence of one single parameter in a complex systems while keeping co-parameters constant. Especially in alpine ski racing, which is characterized by a great variety of situations, this method is of crucial importance.

The main component in alpine skiing technique is the control of vertical load distribution. A few studies have shown that this coordinating capability is considerably influenced by physical conditions. Primary components are obviously maximal strength, power and balance (Kornexl 1980, Müller 1987, Jeschke et al. 1994).

The mechanical explanation of these factors is on the one hand high external forces, and on the other hand oscillating ground reaction forces. In the literature there is little to be found about the influence of physical conditions on controlling vibrations in alpine skiing. The studies of Mester (1996) and Spitzenpfeil/Mester (1997), which are based on the generation of vibrations with a hydro-pulser, show the dependence of the damping technique on the frequency of the oscillation. While the subjects were able to dampen vibrations of 6 Hz, the vibrations reached an overload level at 8 Hz. The neuro-muscular system reacted by producing a co-contraction of knee extensors and flexors.

As the characteristics of vibrations on the ski slope depend on many components (e.g., dynamic behavior of the ski, structure of the snow, velocity of the skier) which cannot be kept constant in field studies and therefore do not permit a diagnosis of the influence of any one particular parameter, it is necessary to simulate these vibrations in the laboratory.

The first aim of this study was to develop a versatile useable diagnosis and training system that is able to generate vibrations that correspond to measured vibrations on the ski slope. The reasons for developing this simulation system are related to the second aim of the study, which is to investigate physiological parameters of the controlling vibrations.

METHODS: To generate vibrations in the laboratory we used a roller ski system with eccentric rolls driven by a treadmill. In view of the results of field studies (Mester 1996) and theoretical considerations we worked with a vibration frequency between 4 and 20 Hz. It must be assumed that higher vibration frequencies cannot be controlled actively (rhythmic contraction of leg extensors) for the reason of reflex times and refractory periods. The amplitude of the oscillation was between 4

and 21 mm and was based on the eccentric size of the used rolls. The application of different roll types at the rear and the shovel of the ski also made it possible to generate disharmonious vibrations.
In order to get information about the control of vibrations we designed an analysis of four single case studies. Three subjects who were involved in the study were ski teachers from the 'Federation of German Ski Instructors' and the 'German Ski Association'. One person was a recreational skier. The skiers were subjected to vibrations for about 20 sec. in an upright stance and for the same time in a crouching stance. To measure the generated vibrations and their influence on body movements, we used a one-dimensional acceleration sensor (ERNST) attached on the middle of the central axis of the ski, a goniometer (PENNY & GILES) attached to the right knee, and a video system (50 Hz). The acceleration sensor and the goniometer worked with a sampling frequency of 500 Hz. To access the vibration control abilities of the subjects we primarily used the parameter 'resultant acceleration maximum'. The later analysis of a High Speed Video (200 Hz) showed that the parameter 'amplitude of knee' angle contained an aberration due to skin vibrations that influenced the goniometer measurements. We used this parameter only for additional considerations.

RESULTS AND DISCUSSION: Depending on the used frequency and amplitude, the maximum acceleration reached +50/-40 g, the average maximum acceleration during a period of 15 sec. reached +40/-30 g. The data for acceleration measurements on the slope proved to be similar (+40/-30 g, Niessen 1996).
The signal analysis of measured ground reaction forces in the giant slalom (carved turn) showed main peaks of frequencies between 15-20 Hz (Mester 1996, Spitzenpfeil/Mester 1997). In view of the fact that the physical characteristics of generated vibrations in the laboratory correspond with diagnosed vibrations on the slope, and that furthermore the movements and motor demands are comparable, the developed system enables a ski-specific simulation of vibrations (Haas 1997).
Concerning the regulation of vibrations, notable intra-individual (upright stance/ crouching stance) and inter-individual (ski teacher/recreational skier) differences in 'resultant acceleration maximum' were detectable.

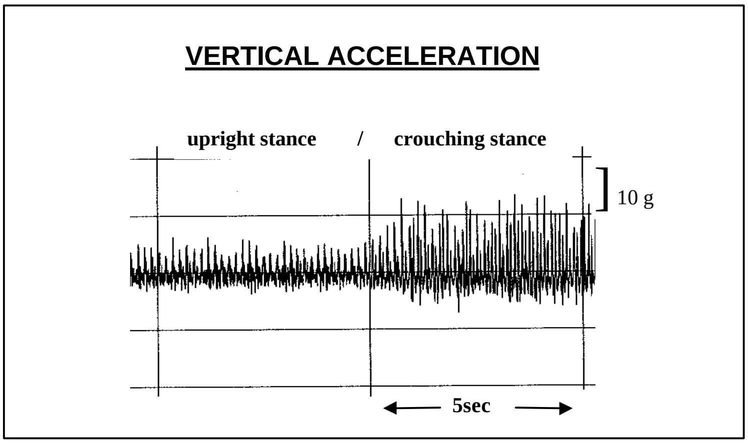

Figure 2: **Vertical acceleration in upright stance and crouching stance.**
Frequency: 5 Hz **Amplitude: 9 mm**

It became evident that the skiers preferred different positions (upright stance/ crouching stance) to damped vibrations effectively. Nearly all skiers gave preferential treatment to a specific position at all frequencies and amplitudes.
The parameter 'resultant acceleration maximum' is not only a measure of different types of vibration regulation, it also characterizes the quality of damping. The simultaneous analysis and evaluation of the video showed that high accelerations resulted from losing contact between roller ski and treadmill. In performing a carved turn on the ski slope, it is of major importance not to lose ground contact, if transverse drifting, which is connected with a reduction of velocity, is to be be avoided.
The inter-individual comparison leads to the following results: It could be shown that the ski teachers tended to have better vibration damping abilities than the recreational skiers. It must be taken into account that differences in damping are influenced by frequency and amplitude. Decisive differences were recognizable primarily at middle and higher frequencies (>7 Hz), and at higher amplitudes (>4 mm).

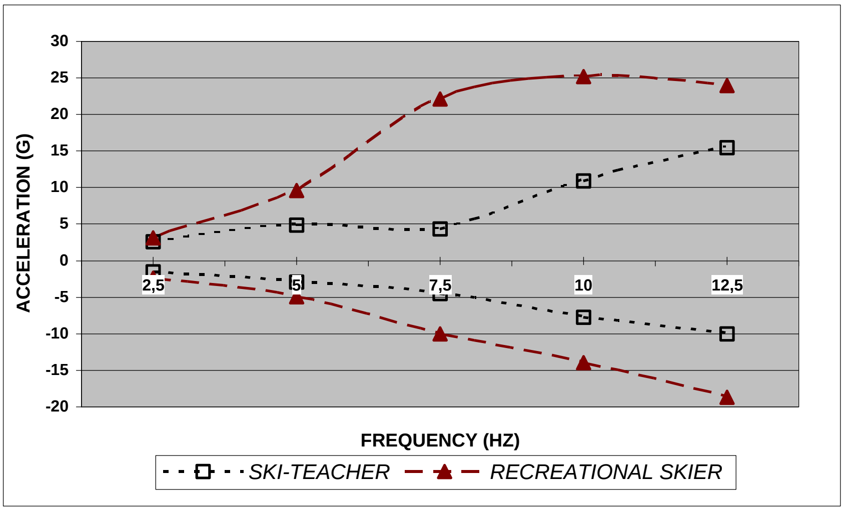

Figure 2: **Average positive and negative acceleration amplitude at different frequencies.**
Oscillation amplitude: 9 mm

We postulate that the main causes for damping vibrations effectively are on the one hand the ability to reach higher frequencies with active damping (rhythmic contraction of leg extensors), and on the other hand a more effective stiffness regulation of the tendo-muscular system, if higher frequencies are compensated in a passive way (co-contraction of knee extensors and flexors). In order to come to concrete conclusions this assumption has to be proved in an additional study.

CONCLUSION: The capability to damp vibrations effectively has to be regarded as a decisive parameter of conditional and coordinative demands in alpine skiing and ski racing. The development of the simulation system enables one to verify the physiological reactions during the process of compensating vibrations. At this point in our research we believe that there is an individual optimum of vibration control with respect to frequency and amplitude, depending on anthropometric measurements and physical conditions.

In a current study we are investigating different vibration-regulation-techniques and furthermore the connection between strength, power, balance and damping abilities. Additionally, it should be clarified which effects arise from vibration damping training in comparison to the effects of RNS training (Künnemeyer/Schmidtbleicher 1997, Weber 1997).

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