SUBDMSION OF SKIING TURNS USING GROUND REACTION FORCES

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INTRODUCTION

In downhill skiing, the description of the turning technique is often based on a subdivision into functional phases. For that, various subdivisions are used For example, skiing turns are described based on an initiation phase and a steering phase (e.g. Kaufmann, 1989; Miiller, 1991), or based on preperation, initiation, steering, and completion phases (e.g. Gamma, 1982; United States Ski Team, 1977). Additionally, the main actions described for certain phases differ considerably.

Ground reaction forces have been used to define the functional phases of many sport activities, e.g. running (Slocum and James, 1968). Force measurements in alpine skiing using transducers mounted between the ski and ski boot have been described by several investigators for selected skiing movements (e.g. Nishiwaki et al., 1956; Moser, 1957; Fukuoka, 1971; Hull and Mote, 1978; Müller, 1991; Nachbauer and Rauch, 1991). However, no attempt has been made to subdivide skiing turns into functional phases using the recorded forces. Thus, the purpose of this study was to subdivide the movement of a skier during turns by means of the forces between the skis and the ski boots and to illustrate the ability of the proposed phase structure to provide a functional description of the ski racing technique.

METHOD

Two gate combinations representing typical standard combinations for slalom and giant slalom were set on a slope with an inclination of about 21 degrees. A sample of 42 elite male,' alpine ski racers were recruited from the Austrian, Jugoslavian, Bulgarian, and USA ski teams. The skiers had to race each course two times as fast as possible. All subjects used the same skis. Each ski was equipped with four one-dimensional strain gauge sensors, which were placed between the ski and ski boot under the outside and inside of the forefoot and rearfoot. The reaction forces acting perpendicular to the top surface of the ski were measured and transmitted telemetrically. All subjects were filmed with a Locam camera at 50 Hz from a front view. The filming was synchronized with the force data collection by setting time marks on the film perforation and on the magnetic tape where the force data was stored. The filming was used to relate the measured forces to the position of the skis relatively to the gates.

For the analysis the eight sensors were grouped according to left and right ski and to the inside and outside edge of each ski. The forces measured by each group of sensors provided the reaction force for the right and left skis and the inside and outside edges of each ski. The subdivision of the turns into phases was determined from an examination of the force/time curve of the outside ski. In order to check the functionality of the phase structure, the phase duration of slalom and giant slalom turns were compared as well as the one of slower and faster turns in slalom. For both, slalom and giant slalom, 42 turns were analysed. The grouping of the slalom turns in a slow and fast group was established according to the running time in the analysed gate combination. The running time was determined by the film frequency. The slow and fast groups consisted of 30 turns each. Group means were calculated for the phase duration and statistically analysed. Wilcoxon tests were conducted to determine significant differences between the group means. The null-hypothesiswas rejected with an alpha level lower than 0.05.

RESULTS

Phase structure. According to the force/time curve of the outside ski, racing turns may be divided into four phases: load transfer phase, unloading phase, load build-up phase, and loaded phase (Fig. 1)..

Load transfer phase. This phase begins with the transfer of the load from the preceding outside ski to the new outside ski. The phase starts when the reaction force of the outside ski reaches 200 N. During this phase the reaction force increases mainly on the outside edge of the outside ski. The load transfer phase ends when the reaction force of the new outside ski reaches a local maximum.

Unloading phase. After the load transfer phase the reaction force of the outside ski decreases. The unloading phase ends when the reaction force of the outside ski reaches a local minimum. During this phase the skier is unloading from the outside edge of the outside ski in preparation to transfer the load to the inside edge of the outside ski.

Load build-up phase. After the unloading the reaction force of the inside edge of the outside ski increases. The reaction force levels off and the end of the phase is defined as the beginning of the plateau of the reaction force of the outside ski.

Loaded phase. A relatively constant force is applied in the loaded phase. This phase ends when the reaction force of the outside ski begins to decrease abruptly.

The .phases can further he combined to another functional description of a turn. The movements of the skier during the load transfer and the unloading phases initiate the turn. The movements during the load-build up and the loaded phases carve the skis through the turn.

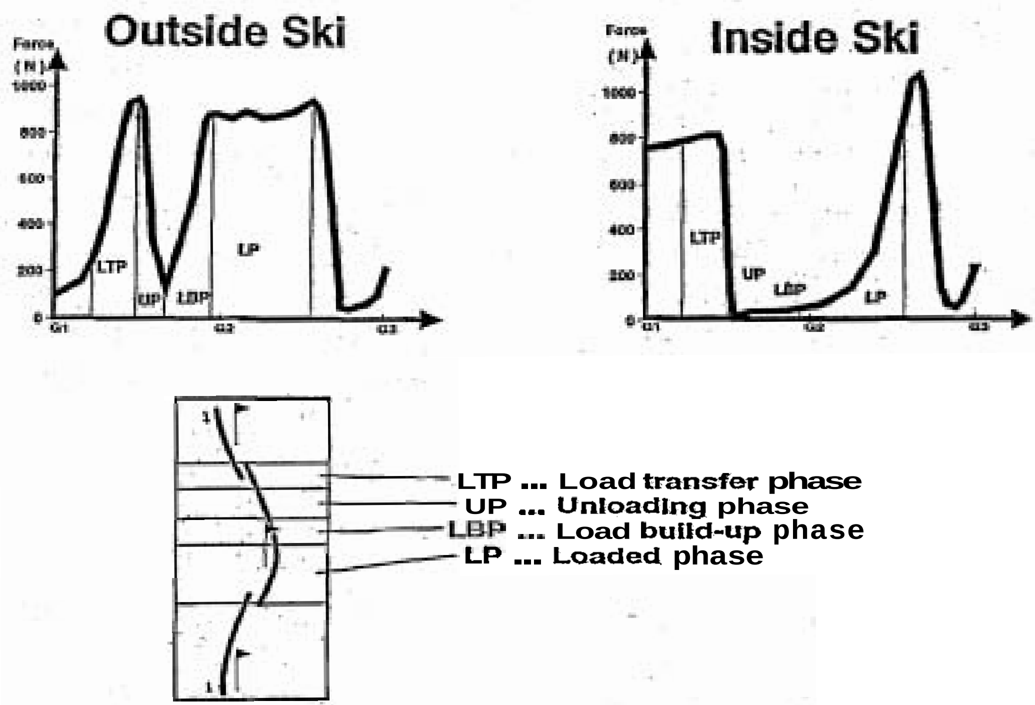

Fig. 1: Phase structure

Comparison of giant slalom turns with slalom turns. The duration of the load transfer and unloading phases was about the same for giant slalom and slalom turns, i.e. the time needed far the turn initiation was about the *same*. The load build-up and loaded phases lasted significantly longer for giant slalom than for slalom turns. There were no differences in the loading and unloading actions. The differences in the magnitude of the reaction forces were unimportant.

Comparison of fast turns with slow turns in slalom. The unloading phase of the faster turns lasted significantly longer than the one of the slower turns. The loaded phase of the faster turns was significantlyshorter than the one of the slower turns. There were no significant differences in the duration of the load transfer and load build-up phases.

CONCLUSIONS

From the results of this work it may be concluded that ground reaction forces are useful for subdividing skiing turns into functional phases. The proposed phase structure has the ability to characterize the turning technique of elite ski racers as shown when comparing slalom with giant slalom turns and turns of different quality in slalom. The comparison provides interesting facts for the racing technique. It can be assumed that by applying the phase structure to ski training the skiing technique may be improved. It would need further investigations to find out if the proposed subdivision can be applied to recreational skiing as well.

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