SKI GLIDING TECHNIQUE ON A QUASI STATIC LABORATORY DEVICE - COMPARISON WITH THE SITUATION "ON SNOW" AND POSSIBILITIES OF PERFORMANCE ENHANCEMENT

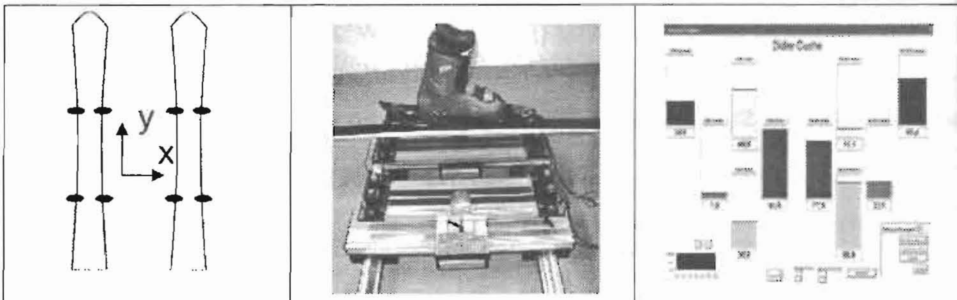
Josef Kröll, Gerhard Stricker, Klaus Mayrhofer, Hermann Schwameder, and Erich Müller
Christian Doppler Laboratory, "Biomechanics in Skiing",
Department of Sports Science, University of Salzburg, Austria

The purpose of this paper is to introduce possibilities for the enhancement of the gliding performance in alpine ski racing using a specific gliding device. This device is used in our laboratory for evaluating and adjusting ski equipment on the one hand, and to give specific feedback on the athletes gliding technique on the other hand. Two independent studies will be presented to show transfer effects from the lab situation to the situation on snow. The first study examines the correlation between the force distribution while gliding on the device and gliding on snow (n=6 female elite skiers). Study two (experimental group n= 8; control group n=8) describes the changes of the force distribution on the device and the gliding time in a field test after 9 weeks of specific dry land training. The results of study 1 shows that the correlation between the situations is not as high as expected. The results from study 2 (significant change of force distribution on the device) show that we can quantify some relevant coordinative parameters of the gliding movement. One could conclude that performance diagnostics on the device is not sufficient to describe the complete gliding abilities of athletes. On the other hand athletes can use the device for specific coordination training, especially as it offers various options for feedback.

KEY WORDS: alpine skiing, gliding technique, performance diagnostics, feedback training.

INTRODUCTION: The gliding technique plays an important role in elite alpine ski racing and can be demonstrated by the following example: If HK (member of the Austrian national team) had been 0.14 s faster (separated in 5 different races) he would have become a double world champion and moreover, the owner of three more medals. The optimisation of gliding performance can be achieved regarding different aspects. Aerodynamics, snow resistance, material aspects, force distribution and the coordinative control of the athletes are the limiting factors of efficient gliding. In cooperation with a ski company a standardised device (ski gliding tester, SGT) has been developed in order to analyse the influence of different ski boot and binding setups on the force distribution (Raschner et al. 2000). Additionally, the device offers the possibility to enhance the specific coordinative abilities of athletes. High level gliding technique is characterised by a balanced force distribution in the frontal and in the sagittal plane in order to potentially maximise gliding velocity. The specific coordinative abilities also help to avoid dangerous situations by "catching the edge" (Spitzenpfeil et al. 1997). After a series of set up diagnostics and training sessions, a positive transfer to the competition technique could be observed. Furthermore, the best gliders in several groups had also the best results on the SGT. In some cases, however, improvements on the SGT did not lead to performance enhancement on snow. The static imitation most likely differs more from the situation on snow than expected. Two independent studies should help to find similarities and differences between gliding on the SGT and on snow.

METHODS:
Ski gliding tester (SGT): The force distribution is measured using 4 strain gauge sensors mounted under each ski at a sampling rate of 200Hz (Fig.1A). The marked center on the ski boot is used to adjust the athlete correctly in the center position of the SGT. By adding the signal of specific sensors the distribution regarding different aspects (left and right side, inside to outside edge etc.) can be determined. The construction allows an individual adjustment in both horizontal directions (x and y) by a nearly frictionless gliding construction (Fig.1B). For specific purposes the position of the skis can be fixed in both axes.

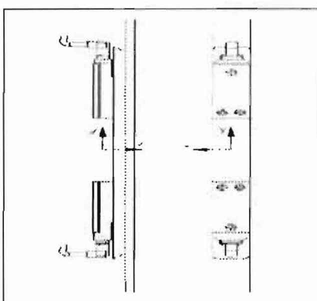


A Position of sensors | **B** Ski Gliding Tester | **C** Report example

Figure 1

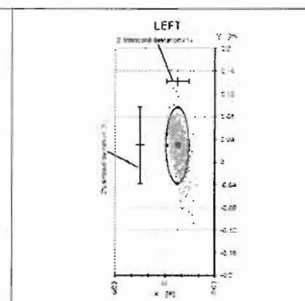
Figure 1C shows the bar charts of the force distribution on the SGT representing: forces left vs. right, inside vs. outside edge of both skis, forward vs. backward of both skis. The software allows for using the system in different measurement modes. For testing and modifying the material components the mean and standard deviation of a defined time window (e.g. 8 sec.) are determined and stored in a database. In order to find the optimal gliding position or just to exercise on the device one can get either online or time delayed feedback after a trial via "bar - movie".

6 component dynamometer by Kistler: For the analysis of the movement regulation during gliding on snow 4 special force plates (mounted between the bindings and skis) were used to measure the ground reaction forces in three dimensions (Fig. 2A). Each plate is equipped with three sensors. Each of them can measures the forces in all three dimensions. The sensors are based on the piezo-crystal technology. The sampling rate again was 200Hz.



$$x = \frac{\sum_{i=1}^{6} F_{z,i} \cdot x_i + \sum_{i=1}^{4} F_{x,i} \cdot |z_i|}{\sum_{i=1}^{6} F_{z,i}}$$

$$y = \frac{\sum_{i=1}^{6} F_{z,i} \cdot y_i + \sum_{i=1}^{4} F_{y,i} \cdot |z_i|}{\sum_{i=1}^{6} F_{z,i}}$$



A Binding force plate | **B** Calculation of displacement | **C** x – y displacement

Figure 2

The same distributions as on the SGT (Fig. 1C) can be calculated with the 4 dynamometers. The dynamic situation on snow causes movement regulations. The amount of this regulation can be quantified by the x-y displacement of the application point of force (Fig. 2B). The diagram in Figure 2C shows the application point of force during one specific run, represented by the mean in x- and y-direction. The ellipse represents the average variation. The length of the ellipses axes are calculated by mean ± 2 SD, both, in x- and y direction. The simultaneous measurements on both devices (SGT and binding force plates) yielded a correlation of the three calculated distributions higher than r=0.97.

Transfer of gliding on snow to the laboratory situation on SGT (Study 1): 6 female racers took part in this study. The racers had no experience and no feedback training prior to this study. On the first day of testing subjects had to complete 5 trials with 10 s each without any feedback. The purpose was to imitate the individual gliding technique as good as possible. After finding a balanced position the subject gave a sign to start with data collection. All subjects used the same skis, boots and poles as on the following tests on snow. The second part of the study took place on a 150 m, relatively flat, gliding run. Again 5 runs were performed. 5 s from each run were used for the analysis. In both situations the means of trial 2, 3 and 4 were calculated. Afterwards the correlation coefficients for the items 'inside edge', 'forefoot' and 'overall forces' for both legs were determined ($p < 0.05$).

Effect of specific training on gliding performance on snow and on the SGT (Study 2): 16 racers (FIS level) were divided into an experimental and a control group. The gliding time on snow and the force distribution on the SGT were measured prior and after a specific training intervention (pre- and post tests). The field tests took place on a 200 m gliding run. Every had to perform 5 runs. The best and the worst run were not considered for further analysis. In one test session 4 subjects performed the runs with 4 different pairs of skis. Considering the different skis and changing snow conditions 2 professional ski testers performed several runs between the runs of the subjects. The running times of the subjects were consecutively calculated relative to the running times of the professional testers. On the SGT the athletes performed 5 trials, 15 s each. Again, the best and worst trials were not included in the analysis. Absolute differences to the optimal values (overall forces and inside edge 50%; forefoot 55%) were added. After the pre-test the experimental group performed a specific coordination training over 9 weeks. The subjects exercised 3-4 times a week. Each training session lasted for about 40 minutes and included primarily specific training of balance and coordinative strengthening in a standard gym hall. Paired sample t-tests were performed to analyse the difference between pre- and post tests ($p < 0.05$).

RESULTS:

Study 1: Table 1 shows the results of the calculated correlations between the SGT and gliding on snow. It couldn't be identified any correlation in the different items.

Table 1 Correlation between SGT and gliding on snow.

	inside edge	forefoot	overall forces
left	.362	.458	.514
right	.677	.281	.514

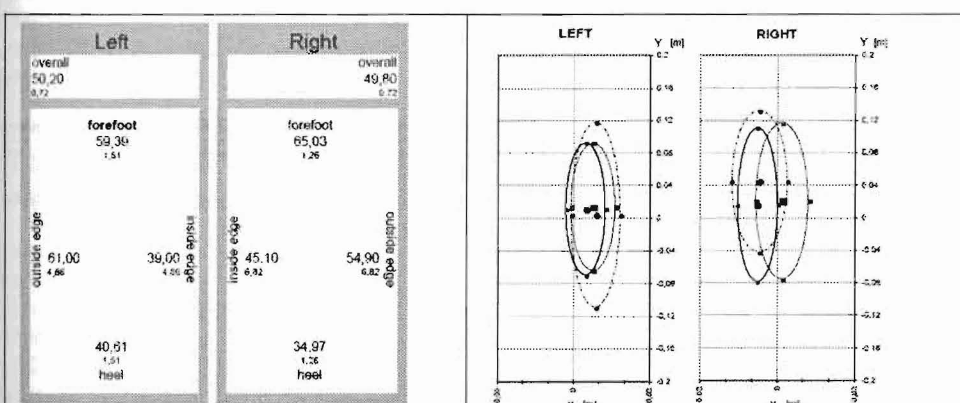


Figure 3: Average force distribution on the SGT (left) and ellipse of average variation of three runs on skis (right) for one subject.

Figure 3 shows the results for one selected subject in both situations. On the left side the means and standard deviations (small letters) of all trials are shown. The standard deviation was - in comparison to other subjects - relatively low, so this pattern on the SGT is very stable. The overall forces are well balanced with low standard deviations. The distribution between forefoot and heel is ideal on a level of 55% to 45% (experience of service men and coaches). This athlete shows too high forces on the forefoot (59.4% left and 65.0% right) on the SGT. While gliding on snow the mean displacement of the application point of force in anterior-posterior (y) direction (center of ellipse in Fig 3. - right) is not that pronounced in anterior direction compared with the SGT. The distribution between the inside and outside edge shows a dominance on the outside edges on the SGT (Fig. 3 left). On snow, however, the application point of forces is shifted towards the inside edges (Fig. 3 right). The dominant loading on the inside edges on snow is not a specific pattern of this particular athlete. This was observed in all other subjects too. These results on snow did not correspond with the distributions on the SGT causing the low correlations determined.

Study 2: The results of the statistic analyses show a significant change of the performance on the SGT after a nine week specific dry land training for the experimental group (p=0.022). For the control group no changes of performance during this period (p=0.378) could be observed. On snow, however, no statistically significant changes regarding gliding time was found in both groups (experimental group p=0.099, control group p=0.470). An interesting detail was detected by looking at the results individually. The three slowest gliders of the experimental group had a substantial enhancement in gliding time after the 9 week training period. The overall correlation (n=32; including pre- and post-tests for both groups) between the results on the SGT and the gliding time on snow was similar to the results of study 1 (r=0.28; p=0.122).

DISCUSSION AND CONCLUSION: The low and not significant correlations in both studies indicate that the transfer from the results on the SGT to the situation on snow is generally overestimated. Consequently, the modifications of the equipment not necessarily cause an enhancement of the gliding performance on snow, although measurements on the SGT would have lead to such an expectation. This might be caused by the static position on the SGT. Further developments of the ski gliding tester, including simple simulations of the dynamic situation on snow, will be necessary. On the other hand changes of specific coordinative abilities can be measured on the SGT indicated by the results of study 2. As a conclusion one should focus more on this field of application. That could be done by training on the device (feedback training), but also by new test assignments and training procedures. This includes not only the achievement of the optimal distribution along a defined time. The athlete should also be forced to balance dynamic tasks in testing and training (e.g. swaying between 40% and 60% relative loading at 0.5 Hz over 10 s in the different items). The first experiments with these forms of training leads to very good expectations to enhance gliding abilities of elite ski races.

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