DOES A SKIER'S POSITION ON THE SKI AFFECT THE RESULTS OF GLIDING TESTS USED TO ASSESS SKI-SNOW FRICTION?

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Ski manufacturers and ski racers test the gliding performance of skis by standardized gliding tests on straight runs. These test procedures have the advantage that they resemble the real situation in ski racing, but they have the disadvantage that the tester might influence the test result by influencing air drag or ski-snow friction. In this study we analysed if the position of the skier on the ski, which determines the force transfer from the skier onto the ski, affects the results of gliding tests. Three professional ski testers were asked to perform five different tasks: glide with the skis as flat as possible, stabilize your motion by edging the skis, glide in neutral, in forward, or in backward leaning position. The results show that edging on the one hand stabilizes the gliding motion, on the other hand, it significantly increases gliding time. The position of the skier in direction of the ski axis did not affect the skiers' gliding times, which contradicts a common opinion of many ski racing experts.

KEY WORDS: alpine skiing, gliding, ski-snow friction.

INTRODUCTION: Ski manufacturers and ski racers test the gliding performance of skis by standardized gliding tests on straight runs. An important issue in these tests is the skier's posture since it affects the air drag acting on his body (Barelle et al., 2004). However, even in a perfect tucked position the skier has to balance his weight and react to unevenness of the slope or changing slope inclinations. If the skier wants to remain in a perfect aero-dynamical position he is left with only two types of motion for balancing his weight: He can either shift his weight in anterior-posterior direction, i.e. assume forward leaning or backward leaning positions, or he can shift his weight medio-laterally, which causes edging of the skis on the snow. In straight gliding the later can be limited to setting the skis as flat on the snow as possible or shifting weight onto the inside edges of the skis. - Loading the outside edges would increase the risk of the skis catching an edge, loading the same edges would initiate turns.
The purpose of this study was to (1) investigate how edging is accomplished during a gliding test, (2) determine the range of motion in forward- and backward-shifting, and (3) to investigate whether these movements affect the gliding times.

METHOD:

Test Design: Two test series were executed. In the first series the testers were alternately asked to "*glide with the skis as flat as possible on the snow*" (*flat skis)* or "*stabilise your motion by edging*" (*edged skis*). In the second test series they were asked to glide "*in your standard position*" (*neutral*), "*in a forward leaning position*" (*forward*) and "*in a backward leaning position*" (*backward*). The actual posture of the skiers was recorded by video. Additionally, one skier was equipped with Kistler™ force sensor plates, by which the force application point on the skis was determined. Hence, it was possible to quantify how much the skier shifted his weight relative to his skis. The impact on the gliding test was determined by measuring the gliding time.
Test Day and Test Procedure: The gliding tests were carried out on 21st April 2006 on a test run on the glacier *Rettenbachferner* of the ski resort *Sölden* in Austria. The weather conditions recorded during the test period by a meteorological station indicated nearly perfect testing conditions: wind speed fluctuated between 0.6 and 2.2 m/s with a mean wind speed of 1.3 m/s (shifting between side- and tailwind), air temperature and snow surface temperature increased slowly from -5.5° to -4.5° and -7.4° to -3.9°, respectively, and humidity decreased slightly from 60 to 56%. To limit the impact of external changing conditions it is

important that the test procedure is executed as fast as possible. This is one reason why the number of test runs was strongly limited, another reason was subject fatiguing. In our study four ski testers took part each of which performed 17 runs. Three testers executed the two test series. The two tasks of series one were alternately performed four times, the three positions of the second test series were alternately repeated three times. A fourth tester set a reference time, i.e. he always glided in his standard tucked position. On the one hand his gliding times show which fluctuations have to be generally allowed for. On the other hand deviations from his typical gliding time could indicate changing external conditions, which might derogate the significance of the gliding test's results.
Data Collection: The test run consisted of a more inclined acceleration section, in which the tester accelerates to typical downhill speeds, then passing into a flat run-out section, over which the skier glides at racing speeds (see Figure 1). The gliding performance was assessed by four light barriers L1..L4 measuring the gliding time of the acceleration section (L2 - L1) and of the whole run (L4 - L1). The test runs were recorded by video cameras V1 and V2 at the start and the end of the test run. A third camera, V3, recorded the test runs from a position perpendicular to the run allowing an approximation of the skier's joint angles.

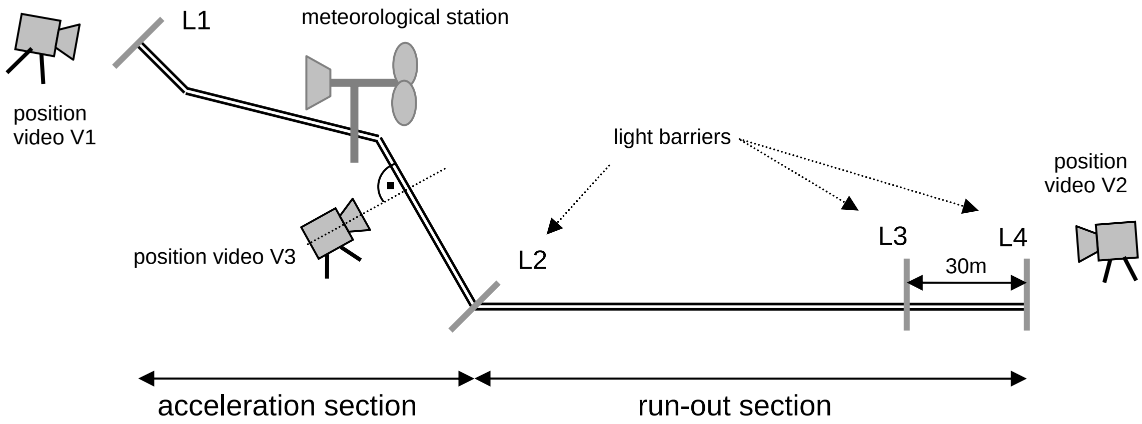

Figure 1: Setup of the test run

To quantitatively asses whether the testers could accomplish the required body postures one skier was equipped with Kistler™ force plates (www.kistler.com), which recorded the forces between bindings and skis in three dimensions at a sampling frequency of 200 Hz (Stricker et al., 2006). Video and force data were synchronised with the software Ikemaster™ (www.ike-software.com) using a jump executed by the skier just before the run as trigger. The recorded forces allowed calculating the position of the force application point (FAP) on the ski (Kröll et al., 2004). The FAP is defined as the point at which a normal force on the ski surface of equal absolute value as the measured force causes the same moment of force. The FAP is a good indicator of the position of the skier's centre of mass relative to the ski, however, it may also be affected by an external moment of force generated for example by impacts on the ski.

RESULTS AND DISCUSSION: A first impression of how the skiers accomplished the given tasks was obtained from an analysis of the video images. Figure 2 shows images from the video sequences of V1 (Fig. 2a, b) and of V3 (Fig. 2c, d, e). Comparison of the images 2a) and b) clearly shows that the skier stabilizes his motion by increasing the distance between his skis. (Note: these two pictures show the skier equipped with the Kistler™ force plates. The data acquisition system is placed in the backpack carried by the skier). The image sequence 2c), d), e) compares the postures of the tasks *backward*, *neutral*, and *forward*, respectively: *backward* and *neutral* position are almost identical, only the knee and ankle angles differ slightly. *Forward* leaning is achieved by a noticeably smaller ankle angle which modifies the skier's entire posture.

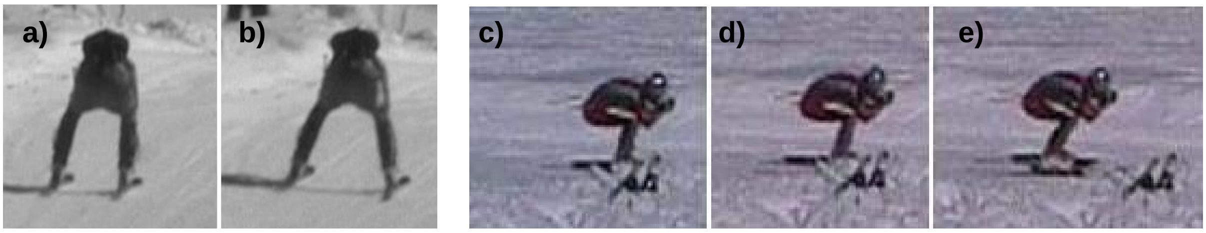

Figure 2: Images from the video sequences of the following tasks: a) ”glide with the skis as flat as possible on the snow” (*flat skis*); b) “stabilise your motion by edging” (*edged skis*); c) backward leaning position (*backward*); d) standard gliding position (*neutral*); e) forward leaning position (*forward*).

Figure 3 shows the FAP determined of two sample runs with the tasks *flat skis* (on the left) and *edged skis* (on the right). The mean value of the FAP position is indicated as a white dot, the ellipses’ radii indicate two times the standard deviation, which indicates the skier’s motion stability.

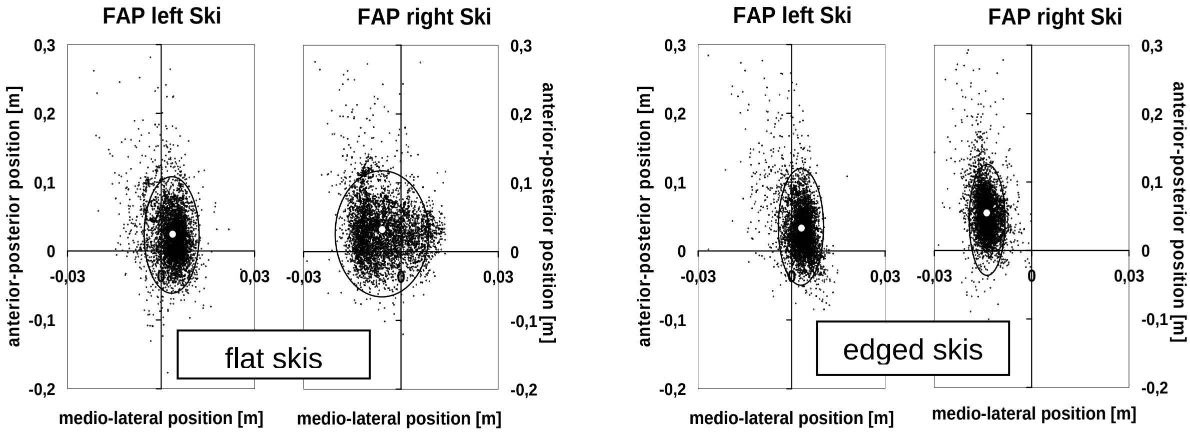

Figure 3: Position of the force application point (FAP) on the ski for the tasks *flat skis* (left) and *edged skis* (right).

Figure 4 displays the mean FAP positions and its standard deviation for all five tasks. In medio-lateral direction the FAP stays within a band of +/- 14 mm from the ski axis. Maximum values were found at the right ski during the runs with the given task of *edged skis*. The mean standard deviation of the lateral FAP position is for *edged skis* 28% (left ski) and 48% (right ski) smaller than the mean standard deviation found in all other test runs. This indicates

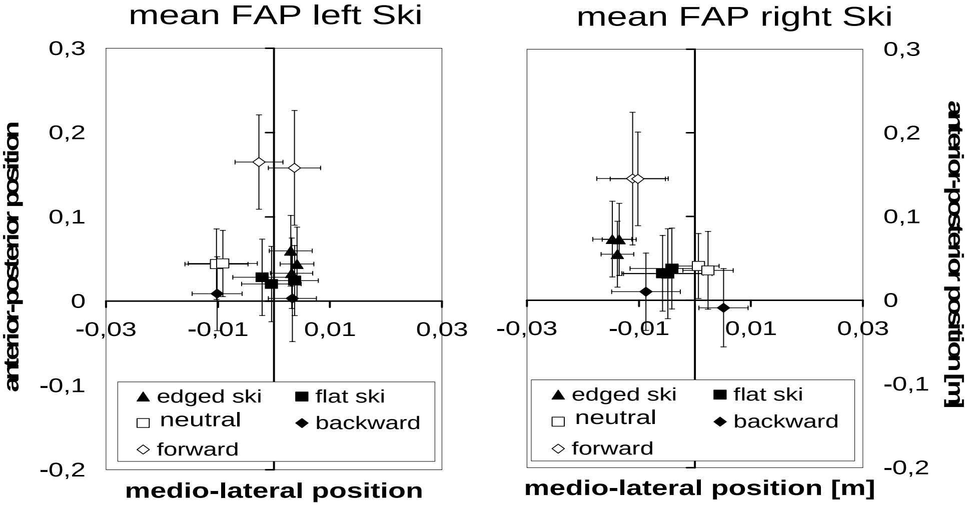

Figure 4: Mean position of the force application point (FAP) displayed for two test runs of each of the five different tasks. The error bars indicate the standard deviation.

that edging in fact increases (lateral) stability of the gliding motion. In anterior-posterior direction the fluctuations of the FAP are one order of magnitude larger. In *neutral* posture our test person's FAP was found between +3 to +7 cm measured from the ski boot centre, which is indicated on the ski. In *backward* posture the FAP shifted by 5 cm to a position between -1 to 1 cm. *Forward* posture caused a larger shift of about 10 cm to a position at 14.5 to 16.5 cm. The standard deviation in anterior-posterior direction was 4 - 5 cm, in case of forward leaning it increased to 5.5 - 8 cm.

Mean gliding times of the three testers and the reference tester are displayed in Figure 5. The gliding times of the runs of the task *edged skis* are significantly higher compared to all other test runs. Differences in the gliding time of all other tasks are not significant.

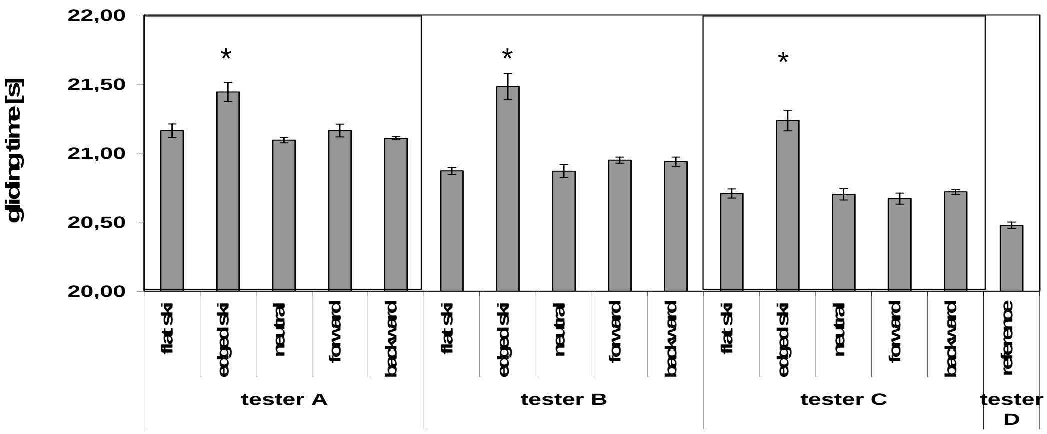

Figure 5: Gliding time results of the three testers and the reference skier.

CONCLUSION: The first aim of this study was to investigate how the skiers accomplished the given tasks:

- Edging can be accomplished by increasing the distance between the skis.
- Forward and backward leaning are accomplished by changes in the ankle and knee angles. The range of the FAP's motion was observed to be -5 cm for backward leaning and +10 cm for forward leaning. These are probably typical values – a limiting factor is the ski boot.

Secondly the effect on the gliding performance was analysed:

- Edging the skis had in fact a positive effect on the motion stability but a negative effect on the gliding time in all test runs. Obviously laterally balancing is an important skill for ski testers and ski racers.
- Forward-backward motion is executed in a much wider range, but in our study no impact on the gliding times was observed. This result contradicts a common belief of many experts in ski racing who assume that rear loading of the ski is faster than forward loading.

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