

The effect of ski binding position on performance and comfort in skiing

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Introduction

Turning in alpine skiing depends, among other factors, on the forces applied from the skier to the skis. These forces depend on the skier, the ski and the position of the binding on the skis. Based on this knowledge skiers train to improve technique and muscle forces applied to the ski during skiing (Veicsteinas, A., 1984; Baum et al., 1997; Raschner et al., 1997). Additionally, the ski manufacturers developed skis that allow easier and/or more controlled turning. The positioning of the ski binding has attracted less attention in these attempts to improve performance and comfort in skiing. It has been shown that gliding performance is affected by changes in the force application to the ski (Spitzenpfeil et al., 1997). It is speculated that the positioning of the ski binding has a substantial effect on both, performance and comfort, and it seems logical to quantify these possible effects. If such a relationship between the position of the ski binding and the skiing performance exists it would be advantageous to have some reliable measurement to determine the “optimal” ski binding position. Complex assessments would include actual center of pressure measurements during skiing (Schaff et al., 1997). However, these assessments are not practical in most applications. A simple functional variable for such an assessment could be quasi-static assessment of the center of pressure in defined skiing positions.

Thus, the purposes of this study were

- (a) to quantify the effect of systematically changed ski binding positions on performance and comfort of ski racers and recreational skiers and
- (b) to determine the relationship between the skiing results and the position of the center of pressure in well defined skiing positions.

The hypotheses tested in this study were:

- H1 Performance of ski racers is significantly affected when changing the position of the ski binding.
- H2 Comfort of recreational skiers is significantly affected when changing the position of the ski binding.
- H3 The results for performance and comfort are subject specific.
- H4 The results for performance are leg specific (and might be different for the right and left leg)
- H5 The center of pressure in defined skiing positions is correlated with the position of the “optimal” binding position.

Methods

The *skis* used in this study were equipped with a 12mm thick aluminum plate mounted underneath the *binding* (Atomic 614 race) in analogy to a regular riser. The neutral position of the boot-ski system was defined as the alignment of the midpoint of the sole length on the boot and the position mark on the ski (provided by the ski manufacturer). The bindings could easily be moved in two anterior positions (A = +14 mm; B = +7 mm), a neutral (C) and two posterior positions (D = -7 mm; E = -14 mm).

The **recreational test program** was performed with 11 recreational skiers (9 males and 2 females). The test subjects performed free skiing with short and long turns in each ski binding position for about 45 minutes (including lift time) with the binding positions randomly altered. Throughout the whole test the bindings were covered to avoid any optical feedback about the binding position. The subjects were allowed to make notes after each ski binding position and assessed all five randomly tested binding positions at the end of the test program with respect to their skiing characteristics, using a scale from 1 (not comfortable) to 10 (comfortable). If necessary, the test subjects could repeat runs in a given binding position. Three subjects were asked to repeat the test program for one randomly selected ski binding position to provide information about the reliability of the test procedure.

The **racing test program** was performed with 5 members of the Alberta junior racing team (4 males and 1 female). They skied through a giant slalom course and the times were measured for gates 6 (left turning) and 7 (right turning) using photocells. Each subject skied three sets of 6 trials with the test skis and two trials with their own skis. The six trials included one trial for each randomly used binding position and a repeat trial for a randomly determined binding position (to assess the reliability of the results). The bindings were covered to prevent any optical feedback to the athletes. The total course time was about 12 seconds and the time between trials was between 7 and 10 minutes. One additional junior racer was used to assess possible changes in time due to changes in snow conditions and/or fatigue, performing an identical program with his own skis and a constant binding position.

The location of the **center of pressure** was determined in the laboratory for four defined body positions for the recreational skiers and the racers, using a Kistler force platform. For the recreational skiers the location of the center of pressure was determined for the integrated skier position (left and right together), for the racers two force platforms were used to determine the center of pressure for the left and the right foot independently. Data were collected for 3 seconds at 100 Hz for the postures (1) upright standing position, barefoot, (2) upright standing position with ski boots, (3) tucked position with ski boots, (4) midpoint between maximal forward and backward leaning position with ski boots. Each position was measured 5 times. The average location of the center of pressure was calculated by averaging the middle three values. The reliability of the center of pressure measurements was determined by re-testing 7 subjects of the recreational group.

Results

The **reliability** of the subjective assessment of “comfort” by the recreational skiers was 0.97 for subject 5, 0.37 for subject 6 and 0.89 for subject 7. The reliability for the gate times in the two measured gates and for the sum of the two gate times for the racers was between 0.96 and 0.99. No significant and/or remarkable differences were found between the times for the test skis and the average times for the personal skis compared to average time. The small and not systematic changes in gate times for the extra test subject suggested that changes due to snow conditions and/or fatigue were minimal.

The reliability of the center of pressure measurements was 0.94 for the barefoot standing position (position 1), 0.93 for the ski boot standing position (position 2), 0.84 for the tucked position (position 3) and 0.63 for the midpoint between fore- and backwards position (position 4).

The **recreational skiers** were able to detect differences in binding position. Only one of the 11 recreational skiers classified “neutral” binding position as the most comfortable. Two of the 11 recreational skiers assessed the “neutral” position as the least comfortable. The +7 mm position (B) was the most comfortable binding position for 4 recreational skiers, the –7 mm position (D) was the most comfortable binding position for 5 recreational skiers. An extreme binding position was only once assessed as most comfortable. Seven of the 11 recreational skiers showed a comfort assessment with one peak, four showed a double peaked distribution (Fig. 1). The results for the recreational skiers provided support for the hypotheses H2 and H3.

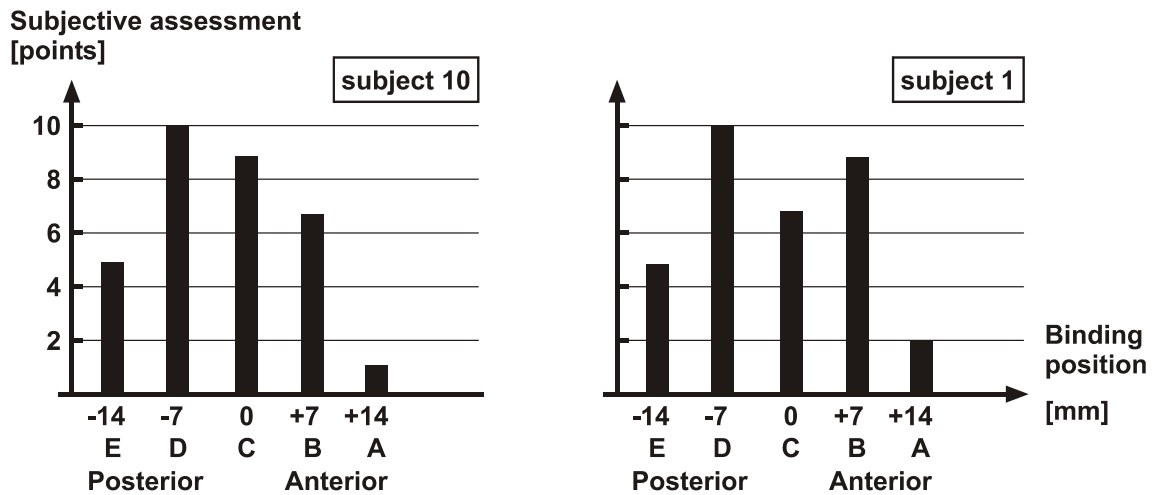


Fig. 1 Illustration of the two typical comfort assessments for the five binding positions, a single peak distribution (subject 10) and a double peak distribution (subject 1).

The individual gate times for the **racing group** were substantially influenced by the position of the binding in this study. The maximal relative differences for the mean values of three races (relative to the fastest mean time) between the various binding positions were up to 4.6% (3.1% for the left turning and 2.3% for the right turning gate for racer 1; 3.2% and 2.9% for racer 2; 3.1% and 4.6% for racer 3; 2.8% and 3.1% for racer 4; 3.7% and 0.6% for racer 5). The corresponding relative gate time differences if compared to the neutral position were up to 3.2% (3.1% and 0.7% for racer 1; 3.2% and 2.9% for racer 2; 0.8% and 2.6% for racer 3; 0.7% and 0% for racer 4; 1.7% and 0% for racer 5). The influence of changes in binding position was different for the left and the right turning gate. Racer 1 had the best average racing times for both turns with the most anterior binding position (A = +14mm). The corresponding best positions for the left and right turning gates were D (-7mm) and E (-14mm) for racer 2, D (-7mm) and A (+14mm) for racer 3, D (-7mm) and C (0mm) for racer 4 and B (+7mm) and C (0mm) for racer 5. The corresponding

relative time differences compared with the “neutral” binding position for the left and the right turning gates were up to 3.5% (3.0% and 0.7% for racer 1; 3.5% and 2.6% for racer 2; 0.6% and 2.6% for racer 3; 1.2% and 0% for racer 4; 1.6% and 0% for racer 5). Some time difference distributions (Fig. 2) were rather small (e.g. 5R), some were systematic (e.g. 1L, 2R, 3R and 4L), others were rather unsystematic (e.g. 2L, 4R and 5L). Thus, the results for the racing group provided support for the hypotheses H1, H3 and H4.

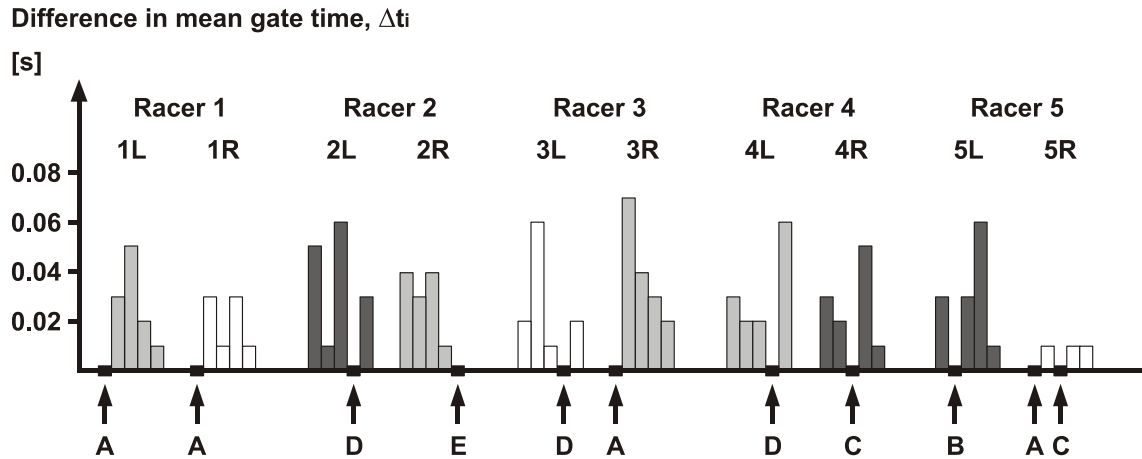


Fig. 2 Mean gate time differences with respect to the best time (in seconds) for each skier and each turn. The binding position with the best mean gate time is indicated with the corresponding letter and an arrow.

The correlation between the results of the *center of pressure* measurements in the laboratory in the four positions ([1] standing barefoot, [2] standing ski boots, [3] tucked ski boots, [4] midpoint ski boots) and the best position were 0.09, 0.47, 0.04 and -0.24 . Thus the results for the recreational and the racing groups did not support hypothesis H5.

Discussion

The results of this study showed clearly that the simple changes in the anterior-posterior positioning of the binding on the ski influenced performance and comfort in the alpine skiing tasks tested in this study. The difference in average gate times for the “best” and the “neutral” binding position were in some cases substantial (up to 3.5%). Assuming that these differences accumulate during a race the race times for skiing in the “neutral” and the “optimal” binding position might be substantially different.

The results for the recreational and the racing group showed that the “optimal” binding positions were subject and leg specific. The general comfort feeling during skiing was clearly different for many recreational skiers when changing the binding position. Additionally, the results of the gate times for the racing group showed that the “optimal” binding positions were typically different for the left and the right turning gates. Four of the five racers had different “optimal” binding positions for the left and the right turning gates. Assuming

that the left turning gates were primarily skied on the right ski and the right turning gate on the left ski an “optimal” binding position should be determined for each leg. If this is the case, only two of the 10 “leg conditions” had the best gate times with the neutral binding position. It might be that the type of race (e.g. slalom or downhill), the snow condition and other factors influence this “optimal” binding position. However, it is speculated that the major influencing factors are the subject specific characteristics of the skier (e.g. skiing technique, muscle strength, skeletal alignment, and anthropometric asymmetries). The results of this study suggest that the gains in race time can be substantial (in the seconds!) if the ski binding positions are optimized.

“Optimal” binding positions exist not only for racers but also for recreational skiers. Most recreational skiers know that they turn better to one than to the other side. This might be due to similar reasons as mentioned for the racer group, skiing technique, muscle imbalances and asymmetric skeletal alignment. The seven recreational skiers with the clear one peaked rating distribution suggest that a large majority of good skiers feel these differences clearly. The skiers with the double peaks in their comfort rating might be skiers that had strong differences in optimal binding position for the left and the right leg, don’t ski in a very controlled way, turned primarily with strong muscle efforts and little technique or skiers that were not very sensitive to external force changes.

The results for the racers and for the recreational skiers were in some cases (binding position and/or leg) systematic. The skier-leg combinations 1L, 2R and 3R, for instance, showed the worst racing times in the neutral position and the best racing times in one of the extreme binding positions. However, there were some results that did not show the same consistency. The skier-leg combination 2L, for instance, showed the fastest average gate times for the two slightly offset binding positions, B and D, and relatively slow average results for the other three binding positions, A, C and E. In general, the gate times for racer 2 were the least consistent of all racers and the results for this racer are, therefore, not conclusive. The gate times are the result of many factors, including the skiing technique, the performance in the previous gates, possible errors and recoveries and other factors. The fact that some leg binding conditions were systematic and others not and the fact that some skiers performed very reliably and others not suggests that more trials are needed for certain subjects to arrive at a systematic and conclusive result. However, the results of this study provide the justification to continue these measurements, especially for high performance skiers.

One limitation of this study was that effects of changes in binding position were only assessed for the anterior-posterior direction. It is speculated that changes in performance and/or comfort might be as substantial for changes in medio-lateral direction, the ab-adduction position of the boot and/or the plantar-dorsiflexion position of the boot.

Based on the results of this study, positioning of the ski binding seems extremely important for ski racers and expert skiers. It is, therefore, of importance to provide a method to identify this optimal position for the task at

hand. For this reason, the center of pressure measurements were performed. However, the correlations found between the quasi-static center of pressure determination in the lab and the “optimal” binding positions were small and not significant. The reasons for this result are not clear. It might be that the quasi-static variables determined are not relevant quantities for determining the optimal binding positions. However, it has been shown in pilot measurements (Schwameder et al., 2000) with a few expert skiers that the location and the movement of the center of pressure during a ski turn depends substantially on the binding position and is subject and leg specific (Fig. 3). There is no doubt that the application of force to the ski is the relevant factor for a ski turn. The differences in the illustrated example suggest that the “optimal” solution for this skier must be different for the left and the right leg. However, an appropriate method to determine this “optimal” binding position is still not available and needs further research. Extensive field measurements with expensive measuring technology might be acceptable for top racers. However, it is not visible for the general skiing population.

COP position during one turn

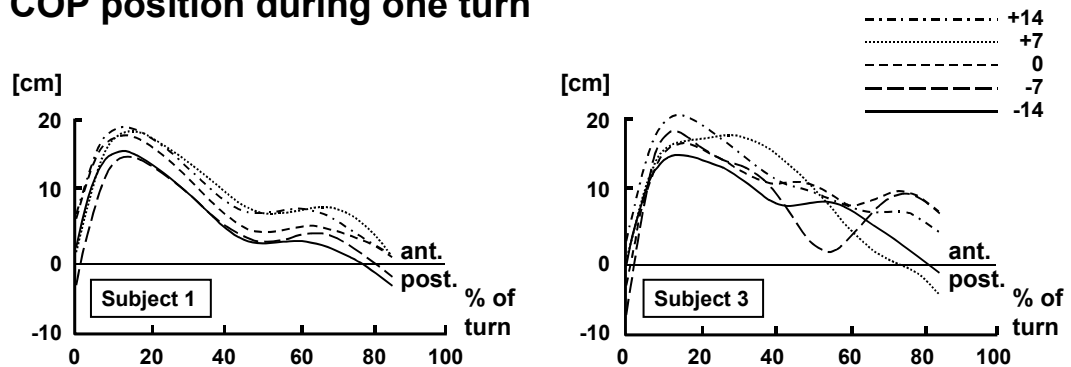


Fig.3 Illustration of the differences in the movement of the center of pressure for one leg and two different skiers during a left turn (data from pilot measurements by Schwameder et al., 2000 and von Tschärner and Schwameder, 2000).

The results of this study showed the subject and leg specific “optimal” solution for a piece of sport equipment. The results are rather similar to results with different materials used in running shoes. The change from an elastic to a viscous heel material in a running shoe changed oxygen consumption of specific runners by up to 5%. Some runners were faster with the elastic, some were faster with the viscous heel and others did not show any change for the two different materials (Nigg, accepted). As for the results of the running study, the factors determining these changes in oxygen consumption and performance are not understood. However, it seems to be important to “tune” sport equipment to the specific athlete and or the specific foot-leg system of an athlete. The differences in athletic performance in high performance sport between an untuned and an “optimally tuned” piece of equipment (such as shoe, ski, ski binding) can be substantial and might be much higher than the performance differences among the first 10 competitors.

Conclusion

The results of this study showed that the positioning of the binding on the skis is highly important with respect to comfort and/or performance. The changes in comfort and performance are subject and/or leg specific and can be substantial. The factors responsible for this effect are not known. It is speculated that skiing technique, muscle strength, skeletal alignment, sensory feedback and anthropometric asymmetries of the individual skier are prime influencing factors for comfort and performance in a given ski-binding-position situation.

References

- Mester, J. Movement regulation in alpine skiing. In: Müller, E., Schwameder, H., Kornexl, E. and Raschner, C. (eds.), Science in Skiing, Spon, London. pp 333-348, 1997.
- Nigg, B.M. The role of impact forces and movement control on the epidemiology of running injuries. *Cl. J. Sports Medicine*, (accepted).
- Raschner, C. Müller, E. and Schwameder, H. Kinematic and kinetic analysis of slalom turns as a basis for the development of specific training methods to improve strength and endurance. In: Müller, E., Schwameder, H. Kornexl, E. and Raschner, C. (eds), Science in skiing, Spon, London, pp 251-261, 1997.
- Schaff, P., Senner, V. and Kaiser, F. Pressure distribution measurements for the alpine skier – from the biomechanical high tech measurement to its application as SWINGBEEP-feedback system. In: Müller, E., Schwameder, H. Kornexl, E. and Raschner, C. (eds), Science in skiing, Spon, London, pp 159-172, 1997.
- Schwameder, H., von Tscherner, V., Stefanyshyn, D. and Nigg, B.M. Changes of the forces between the skier and the skis as a function of the ski binding position. Proceedings of the 2nd Congress on Science in Skiing, St. Christoph, Austria, pp 10-11, 2000.
- Veicsteinas, A., Ferreti, G., Margonato, V. Rosa, G. and Tagliabue, D. Energy cost and energy sources for alpine skiing in top athletes. *J. Appl. Physiol.: Respirat. Environ. Ex. Physiol.* 56(5): 1187-1190, 1984.
- von Tscherner, V. and Schwameder, H. Decomposition of experimentally determined force signals between boots and skis in alpine skiing. Proceedings of the 2nd Congress on Science in Skiing, St. Christoph, Austria, pp 12-13, 2000.

Acknowledgement

The financial and/or material support of Atomic, Blake Lowden, Calgary, Canada and the University of Calgary, Canada for this project is gratefully acknowledged.