Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 34 (2012) 391 – 396

Procedia Engineering

www.elsevier.com/locate/procedia

9th Conference of the International Sports Engineering Association (ISEA)

# Variation of Nordic Classic Ski Characteristics from Norwegian national team athletes

Felix Breitschädel[a]*

[a]*Centre for Sports Facilities and Technology (SIAT) at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

Accepted 02 March 2012

**Abstract**

In cross country skiing the technical equipment of an athlete constitutes a substantial part of the total performance. Thus, the focus of this study was (1) to determine if different Norwegian national athletes select Classic skis with similar characteristics and (2) to describe the key parameters for the two ski categories (*warm* and *cold*). Classic cross country skis (205 pairs) from the Norwegian men's and women's national ski teams were tested under lab conditions. Clear differences between various factors (camber height at the balance point, stiffness, length of contact zone and opening characteristics) were found. Lower camber height for *cold* skis and higher ones for *warm* skis can be explained by the wax routines and their necessities. The nominal contact zones for both men's and women's skis from the *warm* category are shorter than corresponding contact zones from skis of the *cold* category.



*Keywords:* Cross country skiing; classic technique; ski characteristics

## 1. Introduction

In cross country skiing the technical equipment of an athlete constitutes a substantial part of the total performance. A major effect of the ski span characteristics on the gliding results was already reported by Ekström in the early 1980's [1]. In the Classic technique not only the gliding performance is important. Sufficient grip during the kick phase is essential to achieve good results. Each year world class athletes spend a large amount of time together with their ski technicians to find the best possible skis. Therefore

* Corresponding author. Tel.: +47-944-39-202; fax: +47-735-970-21.
*E-mail address*: felix.breitschaedel@ntnu.no.


doi:10.1016/j.proeng.2012.04.067

the ski span characteristics of both the glide and kick phase are of interest. The knowledge about ski span characteristics, bending stiffness and pressure distribution, has been of great interest in previous years. A detailed procedure to measure the span curve and bending stiffness were given by Bäckström et al. [2]. In an earlier study skating skis were analysed [3].

The primary interest of this study was (1) to determine if different Norwegian national athletes select Classic skis with similar characteristics and (2) to describe the key parameters for each ski category.

## 2. Methods

Classic cross country skis (205 pairs) from the Norwegian men's and women's national ski teams were tested under lab conditions. The study considered skis from seasons 2009 – 2011 from four different brands. (Table 1)

Camber characteristics were measured with a SkiSelectorTM (Vendolocus Development AB, Bromma, Sweden) measurement device. The SkiSelectorTM device consisted of a rigid aluminium frame with a steel plate on top where a ski was placed. The span curve was obtained by use of a height measuring sensor that travelled along the ski and measured the spacing between the ski base and the steel plate. The sampling rate of the height measuring sensor was 200 Hz, which resulted in a longitudinal resolution of about 1 mm. The data was smoothed and interpolated by a LOESS filter in MS Excel. Out of the span curve data, parameters like stiffness, camber height at the balance point (HBP), and the net contact length were calculated. According to the usage of the skis, two categories were defined: *cold* and *warm*. The transition between the two categories was blurred. Skis for the *cold* category were in general chosen for new or partly transformed snow with low snow humidity and snow temperatures below -3°C. *Warm* skis were defined as skis for soft tracks with wet snow conditions and transformed snow grains.

Camber height values below 0.05 mm were defined as contact, and each ski was loaded with half and full body weight (HBW and FBW) of the skier. The change of camber height at the balance point (CHBP) when loaded from 0.5 to 1 times the BW was defined as camber response (in mm). The stiffness, $k$ (N/mm), was defined as the load which was necessary to press the ski down to a spacing of 0.2 mm. The load for the stiffness measurement was applied 80 mm behind the balance point and the camber height was measured at the same position. For the ski tip and tail opening characteristics, two points, one in front of and one behind the balance point at a camber height of 0.05 and 0.3 mm were chosen to represent the ski tip and tail opening characteristics, respectively. The length of the skis varied from 190 to 210 cm, depending on the height and weight of the skier. The results (distance from BP to the position with 0.3 mm camber height) are presented as fractions of the total ski length.

For the statistical analysis of the results, the SPSS Statistics programme (SPSS for Windows, Rel. 19.0.0. 2010. Chicago: SPSS Inc.) was used. The averages or differences of means from parameters of interest were compared from both temperature categories and brands. The standard deviation is denoted in brackets if not stated differently. The two-sided level of significance, $P$, was then calculated. The level of significance was set to $P \leq 0.05$ and highly significant was defined as $P \leq 0.01$.

## 3. Results

### *3.1. Men and women*

The fourteen tested male skiers had an average weight of 77.1 kg (± 4.2 kg) which was 18.5 kg heavier than the average of the nine female skiers. When considering the stiffness, both men and women chose very similar skis for cold conditions. It took 66 % and 67 % of the BW for men and women, respectively, to press the skis down to a spacing of 0.2 mm (Fig. 1b). A bigger difference could be seen for the *warm*

skis, where the women used stiffer skis that required 77 % of their BW on average to press the skis down to a spacing of 0.2 mm, while the men used on average 5 % less. The women's skis also showed a greater variation in stiffness (± 21 %).

Table 1. Number of included Classic ski pairs in this study from the Norwegian ski team

| Gender | Athletes | *Cold* | *Warm* | Brand A | Brand B | Brand C | Brand D | Total |
|---|---|---|---|---|---|---|---|---|
| Female | 9 | 51 | 42 | | 48 | 45 | | 93 |
| Male | 14 | 67 | 45 | 25 | 51 | 9 | 27 | 112 |
| Total | 23 | 118 | 87 | 25 | 105 | 56 | 30 | 205 |

### *3.2. Camber height*

The camber height measured at the balance point showed similar results for the two groups. There was no significant difference of the CHBP between men and women in either temperature category. Men's *warm* skis showed the highest camber height when loaded with either half or full bodyweight (HBW & FBW) with 1.63 and 0.56 mm, respectively (Fig. 1a). They also had the highest camber response with 1.07 mm, just slightly higher (0.01 mm) than the women's *warm* skis. A significant difference could be seen between the mean CHBP for men's *cold* and *warm* skis. Women's *cold* and *warm* skis got compressed about 4 % more, and they also had lower camber heights when loaded with FBW. A slight difference could be seen at the height and position of the peak camber height (Fig. 1c). Women's skis had their peak camber point 9.2 and 6.4 mm further in front of the balance point even if the women had shorter skis on average.

### *3.3. Camber length*

Men's skis, with an average length of 206 cm, are 8 cm longer than the average women's skis, although their camber lengths are very similar. The maximum difference was 2.1 % for *cold* skis. Both men's and women's *cold* skis had a significantly shorter camber length with 69.7 and 70.0 cm, respectively. *Warm* skis had between 5.2 % (74.0 cm; women) and 8.1 % (74.4 cm; men) longer camber length.

### *3.4. Nominal contact area*

The nominal contact area (herein shortened to *contact area*) between the skis and the flat rigid beam of the measurement device showed variations. The *contact area* increased in all sub groups when the load changed from HBW to FBW. It was interesting to see that the contact area for the men's skis increased less than for the women's skis. The *contact area* at the back part of the ski increased by 35.9 % and 39.4 % for men's *cold* and *warm* skis, respectively, whereas, it increased by 54.7 % and 63.8 % for the women's skis, respectively. The front contact area also revealed a positive but smaller change with 16.5 % (men, *cold*) to 22.8 % (men, *warm*).

There was a significant mean difference between the *contact area* of men's and women's *cold* skis loaded with HBW as well as at FBW loaded for the front *contact area*. Besides having absolutely shorter *contact areas*, women's skis also had relatively shorter contact zones in comparison to the mean ski length.

A continuous trend showed that *warm* skis have smaller *contact areas* for both men's and women's skis. The difference was significant for the front *contact area* at HBW and FBW with a difference of -21.5 % and -17.2 % (men). Women's *warm* ski's showed a decrease of -14.5 % and -13.8 % for the different loads.

### *3.5. Opening characteristics*

The length of the skis varied from 190 to 210 cm, depending on the height and weight of the skier. The results (distance from BP to the position with 0.3 mm camber height) are presented as fractions of the total ski length ( areas, women's skis also had relatively shorter contact zones in comparison to the mean ski length. ). A clear trend was revealed for all groups. *Cold* skis for men and women always showed a longer distance to the opening, both at the front and at the back part of the ski. By increasing the load from HBW to FBW, the opening tended to move between 0.7 to 1.0 % closer towards the balance point, except for men's *warm* skis where the first contact moved 2 % further away.

Table 2. Position of the opening (0.3 mm) of the ski tip and tale distance from the balance point relative to ski length. All results shown are the average ± standard deviation. Men = M and Women = W

| Avg. ± SD (%) | M - *cold* | M - *warm* | W - *cold* | W - *warm* |
|---|---|---|---|---|
| HBW front | 38.3 ± 3.5 | 33.4 ± 9.7 | 36.3 ± 3.8 | 34.4 ± 4.1 |
| FBW front | 37.6 ± 4.0 | 35.3 ± 3.8 | 35.6 ± 4.3 | 33.3 ± 4.3 |
| HBW back | -38.3 ± 3.8 | -33.4 ± 4.5 | -36.3 ± 4.3 | -34.4 ± 4.9 |
| FBW back | -37.6 ± 4.5 | -35.3 ± 4.1 | -35.6 ± 4.8 | -33.3 ± 5.1 |

### *3.6. Analyses in respect to the ski brands*

Brands B and C were the only two ski brands used by the Norwegian women's team. From the men's team four brands (A – D) were included in this study. Brands B and C contributed 75 % of the analysed skis (Table 1).

### *3.7. Camber height at balance point*

The same uniform trend with higher CHBP could be seen for all *warm* ski brands (Fig. 2a). Women and men who used Brand B selected skis with almost identical CHBP. Men had just 0.01 mm higher

Table 3. Detailed results divided by the four ski brands. CA = Contact Area; *(% of ski length)

| Ski brand | A | | B | | | | C | | | | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | Men | | Men | | Women | | Men | | Women | | Men | |
| Temperature category | *cold* | *warm* | *cold* | *warm* | *cold* | *warm* | *cold* | *warm* | *cold* | *warm* | *cold* | *warm* |
| CHBP - HBW (mm) | 1.33 | 1.83 | 1.32 | 1.52 | 1.31 | 1.51 | 1.44 | 1.91 | 1.45 | 1.55 | 1.40 | 1.53 |
| CHBP - FBW (mm) | 0.43 | 0.55 | 0.47 | 0.52 | 0.47 | 0.52 | 0.39 | 0.70 | 0.39 | 0.40 | 0.54 | 0.61 |
| Stiffness (% of BW) | 64.3 | 76.6 | 65.4 | 72.7 | 67.6 | 74.3 | 66.5 | 68.0 | 66.4 | 80.8 | 68.6 | 66.7 |
| Camber length - FBW (%)* | 44.7 | 50.3 | 47.0 | 47.4 | 44.1 | 46.8 | 42.4 | 51.5 | 43.6 | 48.1 | 40.5 | 42.8 |
| CA front- FBW (%)* | 13.9 | 9.7 | 13.7 | 11.0 | 10.7 | 8.9 | 12.0 | 10.3 | 14.3 | 13.0 | 16.6 | 15.1 |
| CA back- FBW (%)* | 19.0 | 18.1 | 20.1 | 16.9 | 18.5 | 17.1 | 17.4 | 13.7 | 17.0 | 16.2 | 18.2 | 18.7 |

camber height for both categories. The camber response was highest for *warm* skis of all brands. It was on average 0.16 mm more for *cold* skis. No significant differences could be seen, although the *warm* skis from Brands A (men) and C (men) showed especially high values.

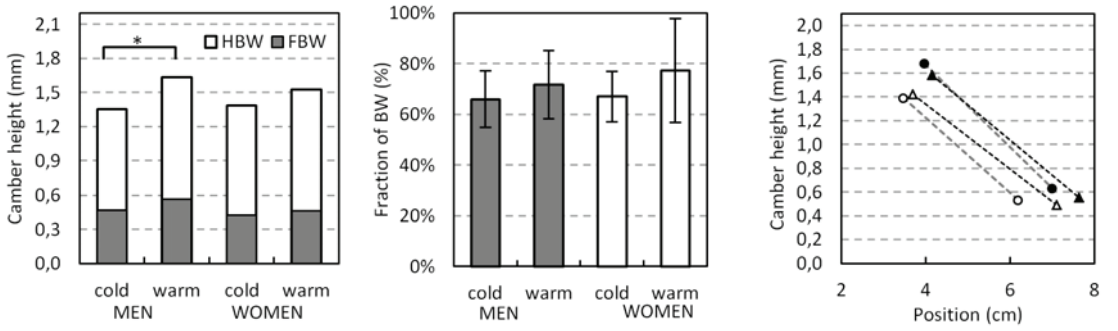


Fig. 1. (a) Average camber height, measured at balance point loaded with half and full weight for both temperature categories and gender. (b) Average relative stiffness ± standard deviation for both temperatures and gender. Fraction of bodyweight to compress the ski down to 0.2 mm camber height. (c) Average movement of the peak camber height when loaded with half and full body weight. Open symbols = *cold*; filled Open symbols = *cold*; filled symbols = *warm* temperature category; circle = men; triangle = women). Significantly different between conditions at $*P \leq 0.05$

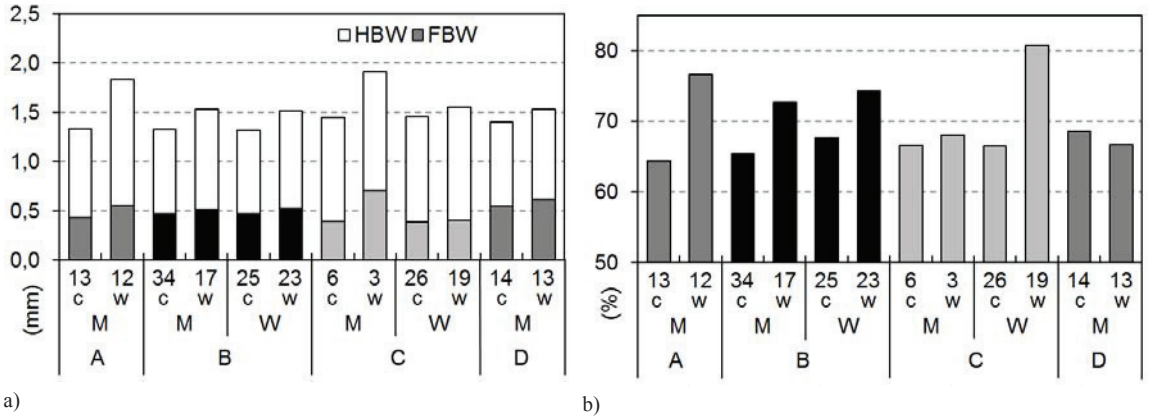


Fig. 2. a) Camber Height at the balance point for all four ski brands (A – D), both gender groups (M, W) and temperature categories (*cold* and *warm*). b) Average load which is necessary to compress the ski down to 0.2 mm camber height as fraction of the skier's body weight

### *3.8. Stiffness*

Brand D reversed the stiffness characteristic between *cold* and *warm* skis. *Warm* Brand D skis tended to be 1.9 % softer than *cold* skis from the same brand (Fig. 2b). Clearly all other *warm* skis required on average more load to be compressed to 0.2 mm. There are two significant differences between *cold* and *warm* skis from Brands A (men) and C (women).

### *3.9. Contact area*

The Brand D skis represented another exception regarding contact area loaded with FBW. They showed increasing contact area at the back part of the ski whereas all other brands showed decreasing contact area for the *warm* ski models. Brand D also had the longest contact zone at the front part for both the *cold* and *warm* skis with 17 and 15 % of total length. Their span length was also shortest with 40.5 % and 42.8 % of the total length. Brands A (*warm*) and C (*warm*), which had the highest CHBP, also revealed the longest span length with 50.3 % and 51.5 %, respectively. A detailed summary of the results is shown in Table 3.

## 4. Discussion

Skis for *cold* and *warm* conditions are designed for different snow and waxing conditions. A lower mean camber height for *cold* skis reveals the expected results. Hard waxes in the kick zone are usually applied in thin layers and uniformly rubbed by cork into the base. The application of klister wax for warmer conditions requires higher camber constructions in order to avoid increased ski drag due to a thicker wax layer. Shorter contact areas and an earlier ski tip opening can also be seen on skating skis for the same track and snow conditions [3].

Ski properties are considered to be the most important factor which contributes to the total performance on cross country skiing by many ski technicians. Especially in Classic technique, the right balance between low kinetic friction in the glide zone and high static friction in the kick zone, are essential to reach a high level of performance. Parameters, like ski base texture and material, as well as wax products, enhance the performance another step. These parameters have not been considered in this study. Dynamic ski characteristics, as well as pressure distribution between skis and snow surface, should be considered in future studies.

## Acknowledgements

I would like to thank the Norwegian Olympic Committee (Olympiatoppen) and the Norwegian Ski team for their cooperation and support during this study.

## References

[1] Ekström H. Biomechanical Research applied to skiing, 1980, Linköping University: Linköping.
[2] Bäckström M, Dahlen L, Tinnsten M, Essential Ski Characteristics for Cross-Country Skis Performance (P251), in The Engineering of Sport 7-2008, Springer Paris. p. 543-49.
[3] Breitschädel F. Variation of Cross Country Ski Characteristics. in Int. Conference of Science and Skiing. 2010. St. Christoph am Arlberg - Austria: Meyer & Meyer Sport, in press.