World Para Nordic Skiing – VI Classification Research Report

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Author Notes:
[1]Marieke Creese now works for the International Paralympic Committee (IPC). However, the research presented here was completed while Marieke was working at the University of Waterloo before she joined the IPC.
[2]The research presented here was completed during Dimitrije Lazarovski's tenure as Head of World Para Snow Sport, International Paralympic Committee.

Note from FIS:
This research project was initiated by World Para Nordic Skiing in 2015 and completed in 2020 while the sport was under the governance of the IPC. Since the completion of the project the IPC has transferred the governance of Para Cross-Country Skiing to the International Ski and Snowboard Federation ("FIS") and Para biathlon to the International Biathlon Union ("IBU"). While the governance of Para Biathlon belongs to the IBU, Para Biathlon is managed jointly by FIS and the IBU through a joint Steering Committee.

All references made in this report to World Para Nordic Skiing now applies to the disciplines of Para Cross Country and Para Biathlon (together Para Nordic), and therefore approval is being sought from the FIS Council, after reaching the IPC and IBU for their approval and acknowledgment respectively, for the outcomes of the research to be implemented into the FIS Para Nordic Classification Rules and Regulations.

World Para Nordic Skiing – VI Classification Research Report

Introduction

The School of Optometry & Vision Science at the University of Waterloo, Canada conducted the *VI Para Nordic Classification Research Project* to develop an evidence-based, sport-specific classification system for Para Nordic Skiing. This report provides a summary of the key findings of the research and recommendations that have be made after discussion of the research findings at the World Para Nordic Skiing (WPNS) – Classification Research for Athletes with Vision Impairment meeting (April 2019).

This report and its recommendations are organised under 4 key research questions as follows:

1. **What tests of vision function should be included in classification for Para Nordic Skiing?**
2. **What are the minimum impairment criteria for vision impairments in Para Nordic Skiing?**
3. **What are the most appropriate competition classes for Para Nordic Skiing?**
4. **What impact do blindfolds have on Para Nordic Skiing performance in skiers in the B1 class?**

Vision Impairment Classification Research Summary

The initial research studies were developed in consultation with the Head of World Para Snow Sports, the respective Heads of Classification for both Para Nordic and Para Alpine Skiing, the IPC Medical & Scientific Department and the IPC Classification Research and Development Centre for Athletes with Vision Impairment (Free University Amsterdam). The general study methodology developed through these consultations was designed so that it could work for both Para Nordic and Para Alpine skiing.

During the first preliminary study that took place during the 2015-2016 season, researchers collected feedback from Para Nordic athletes, coaches, and team members about the current concerns / issues with VI classification in Para Nordic Skiing and the research priorities that needed to be addressed. This additional feedback was incorporated into the final studies conducted in the 2016-2017 and 2017-2018 seasons.

The major priority areas identified in the observations and expert consultation were:

- The current classification system did not account for the dynamic nature of the sports;
- The current classification system did not account for the wide variety of vision impairments that athletes had;
- An ideal classification system would include tests to mimic the dynamic nature of the sports and would account for the wide array of vision impairments in the sport.

These priority areas guided the researchers in the development of all of the experimental studies that were conducted. The experimental studies that were conducted are briefly summarised below.

- **Vision Impairment-Performance Relationship Studies:** The first study was conducted in the 2015-2016 season at the Para Nordic World Cup in Finsterau, Germany, and the second was conducted at the 2017 Para Nordic World Championships in Finsterau, Germany. 32 skiers of various skill levels took part in the first study and 20 World Championship eligible skiers took part in the second study. An additional 6 skiers of similar calibre (i.e. from a performance perspective would be eligible to compete at the World Championship level) were recruited during the 2017-2018 season at the Para Nordic World Cup in Oberried, Germany as part of the second study. Data collected from these studies was used to answer the following research questions:
    - **1. What tests of vision function should be included in classification for Para Nordic Skiing?**
    - **3. What are the most appropriate competition classes for Para Nordic Skiing?**

- **Simulation Studies:** In a study conducted at the 2018 Para Nordic World Cup in Oberried, Germany, sighted skiers were asked to ski a short race course with a number of different simulated vision impairments. A wide range of visual acuity + contrast sensitivity impairments and visual field impairments were simulated to <u>determine the minimum level of visual impairment that decreased skiing performance.</u> Data from this study was used to answer the following question:

2. What are the minimum impairment criteria for vision impairments in Para Nordic Skiing?

- **Blindfold Comparison Studies:** In a study conducted at the 2018 Para Nordic World Cup in Oberried, Germany, B1 skiers were asked to ski a short race course with and without their blindfolds. Data from this study was used to answer the following question:

4. What impact do blindfolds have on Para Nordic Skiing performance in skiers in the B1 class?

Visual Function Measures

Measures of static visual acuity, dynamic visual acuity, low contrast visual acuity, contrast sensitivity, motion perception, visual field extent, colour vision, glare sensitivity, glare recovery, and light sensitivity were used in some, or all of the experimental studies described above. As some of these measures may not be familiar to you we have described each of the vision function tests below.

- **<u>Visual Acuity (Static, Dynamic, Low Contrast)</u>**

  Visual acuity measurements are based on the angular size a target subtends at the eye, or the minimum angle of resolution (MAR; Figure 1). For all of the study we conducted, we used visual acuity charts that measure visual acuity in logMAR [$\log_{10}$(MAR)], and a smaller logMAR number means better visual acuity. For example, 0.0 logMAR = 20/20 (normal vision), while 1.0 logMAR = 20/200 logMAR (low vision). It is important to note that the logMAR visual acuity scale is not a linear scale and a change of 0.1 logMAR is equivalent to a 25% change in the physical target size. The change in target size is proportional to the size of the letter (i.e. change in letter size between lines is bigger for larger letters).

  - **Static visual acuity** is a measure of how well an individual resolves high contrast, stationary (not moving) details. Static visual acuity was measured with both eyes open using the same standardised visual acuity charts that are currently used in classification. For data analysis purposes, 'Light Perception (LP)' visual acuity was recorded as 3.8 logMAR and 'No Light Perception (NLP)' visual acuity was recorded as 4.2 logMAR. These values were chosen based on previous low vision research.

  - **Dynamic visual acuity** is a measure of how well an individual resolves details from a high contrast, randomly moving object. Dynamic visual acuity was measured with both eyes open using a computerised visual acuity chart.

  - **Low contrast visual acuity** is a measure of how well an individual resolves low contrast (light grey on a white background) stationary details. Low contrast visual acuity was measured with both eyes open using a computerised visual acuity chart.

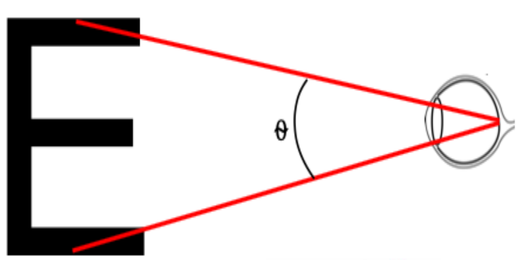

Figure 1 – Demonstration of visual angle (angular size a visual acuity target subtends on the retina)

- **Contrast Sensitivity**
  Contrast sensitivity measures how well someone resolves low contrast, stationary targets. In contrast sensitivity testing, all the targets (letters) are the same size, but the target contrast incrementally changes from black to very light grey. Contrast sensitivity can be measured with printed paper charts or computerised charts, and is reported in units of logCS.

- **Motion Perception**
  Motion perception tests measure how well someone is able to detect motion direction. In these tasks an array of moving dots was presented on a computer screen. Some dots will move in the same direction (signal) and some dots will move randomly (noise). The ratio of signal to noise dots is varied, and observers are asked to indicate the direction of the signal dots. The Motion Perception Threshold is calculated as the smallest percent (%) of signal dots needed to correctly identify the motion direction. In these studies, we used to motion directions: 1) translational motion that moved up or down on the screen, and 2) radial motion that appeared to move in or out of the screen (towards or away from the observer).

- **Visual Field Extent**
  Visual fields were measured under binocular conditions using a hand-held arc perimeter, which is a visual field instrument used for research but not for classification. The hand-held arc perimeter is a valuable tool for this type of research because it is portable and fits inside a suitcase.

  Arc perimeters are a type of kinetic visual field measurement where targets are moved from areas of non-seeing into areas of seeing along the principle meridians of the visual field. The arc rotates through 360 degrees to allow for measurement along any meridian of interest (Figure 2).

  Arc perimeters do not quantify subtle visual field loss well (as would be important in managing progressive visual field loss in glaucoma for example), but they are reasonably accurate for measuring absolute visual field loss (areas of seeing or not seeing) when used by a trained examiner. The figure to the right shows a type of hand-held arc perimeter, including the different targets that can be used to measure visual field; for research purposes the largest and brightest target was used for all measurements.[1]

  For research purposes, visual field areas (degrees^2) were calculated based on participant's actual measured visual field extents. Analyses were conducted based on visual field areas and then equivalent visual field radii (degrees) were determined for classification.

  In addition, visual field measurements were converted to a visual field score based on a modified AMA scoring grid[2] (Figure 3) to determine the visual field extent in percent. One point is given for each dot on the scoring grid that falls in the measurable visual field. The maximum possible score is 60. A full (normal) visual field will have a score of 60 or a visual field extent of 100%. If a visual score was 30 (out of 60) than the visual field extent would be 50%.

[1] Image from: The College of Optometrists, UK. Permiters: Assessing the visual field. https://www.college-optometrists.org/the-college/museum/online-exhibitions/virtual-ophthalmic-instrument-gallery/perimeters.html
[2] Mann DL, Ravensbergen RHJC (2019). *Protocol for AMA-Style Analysis of Visual Field*.

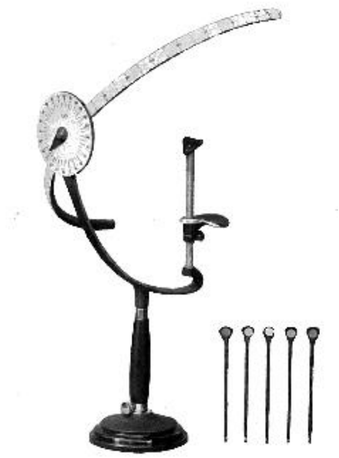

Figure 2 Hand-held arc perimeter for the measurement of visual field

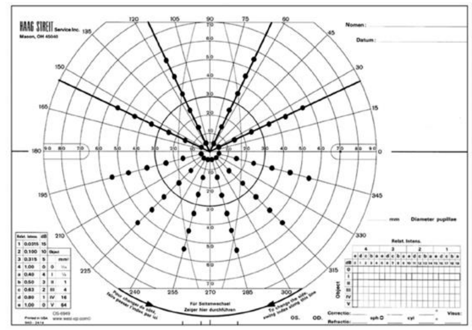

Figure 3 Modified AMA 6E Scoring Grid on a Goldman visual field scoring grid

- **<u>Colour Vision</u>**
  Colour vision was assessed using a large D-15 test, which requires individuals to sort colours in order (Figure 4). The pattern of errors made is assessed to determine if, and what type of, colour vision defect is present. Additionally, the errors made can be scored to come up with a colour vision error score. The colour vision error score was used in this research.

Figure 4: D-15 Colour Vision Test[3]

- **<u>Glare Sensitivity</u>**
  Glare sensitivity was measured by introducing a bright, binocular glare source in the line of sight, and measuring static visual acuity in the presence of the glare source. Static visual acuity in the presence of glare was compared to the baseline static visual acuity (no glare) to determine glare sensitivity in logMAR units using the following formula:

$$[\text{Static Visual Acuity}_{\text{GLARE}} – \text{Static Visual Acuity}_{\text{BASELINE}}] = \text{Glare Sensitivity}$$

- **<u>Glare Recovery</u>**
  Glare recovery was measured by re-testing static visual acuity 1 minute after the glare source was removed. Static visual acuity measured after the glare source was removed was compared to the baseline static visual acuity (no glare) to determine glare recovery in logMAR units using the following formula:

$$[\text{Static Visual Acuity}_{\text{POST-GLARE}} – \text{Static Visual Acuity}_{\text{BASELINE}}] = \text{Glare Recovery}$$

  Positive logMAR values for Glare Sensitivity and Glare Recovery indicated that visual acuity decreased (got worse) compared to baseline; negative logMAR values for Glare Sensitivity and Glare Recovery indicated that visual acuity increased (got better) compared to baseline.

- **<u>Light Sensitivity</u>**
  Light sensitivity was measured by increasing the surrounding light levels from 395 lux (standard clinical lighting) to approximately 1900 lux (similar to being outdoors on a moderately sunny day; this is the highest

[3] Image from: https://www.eyecareconcepts.com.au/blog/archives/02-2018

light level we could generate using artificial lights indoors) and measuring static visual acuity in the increased light level. Static visual acuity in the presence of the bright light was compared to the baseline static visual acuity (clinical lighting) to determine light sensitivity in logMAR units using the following formula:

$$[\text{Static Visual Acuity}_{LIGHT} - \text{Static Visual Acuity}_{BASELINE}] = \text{Light Sensitivity}$$

Positive logMAR values for Light Sensitivity indicated that visual acuity decreased (got worse) compared to baseline; negative logMAR values for Light Sensitivity indicated that visual acuity increased (got better) compared to baseline.

Skiing Performance

In the vision impairment-performance relationship studies, skiers' performance was quantified using race points, which were calculated based on a modified version of the WPNS scoring system. In these studies, race points were calculated as per the WPNS rules (i.e. Points were calculated for each athlete as the average of their best 5 skiing World Para Nordic Skiing Points (WPNS) in the 2016-2017 and 2017-2018 seasons). The race points used for research purposes were recalculated using **raw time instead of the factored time that is used in WPNS competitions**, to ensure that the performance metric was independent of the current VI classification system. The modified version of WPNS race-points ("Raw-WPNS") was chosen for this analysis, as it allowed researchers to normalize data to the specific conditions on a course on any given day, as well as between genders, and it gave a measure of consistency of performance over time. Looking at performance across seasons helps prevent erroneous conclusions based on any one skier having a particularly bad result in a specific race due to weather conditions or other extraneous factors.

In the minimum-impairment criteria and blindfold studies, **raw time** was used as the performance metric for all analyses.

Informed Consent

All the studies conducted (2015-2016 and 2016-2017) were approved by a University of Waterloo Research Ethics Board and complied with the Declaration of Helsinki. All athletes participating in the studies conducted provided informed consent prior to participation.

Vision Impairment-Performance Relationship Studies – Part 1: Athlete Evaluation

The two studies conducted below (2015-2016 study and 2016-2017 study) enabled us to determine **what measures of visual function should be included in athlete evaluations.**

2015-2016 Study

32 athletes, ages 12-48 years (20 male, 12 female) from 9 nations participated in this study. In this preliminary study we measured static visual acuity, contrast sensitivity, dynamic visual acuity (a visual acuity task with randomly moving letters), low contrast static visual acuity, colour vision, glare sensitivity, and glare recovery. All vision tests were measured with both eyes open (binocularly), except for glare sensitivity and glare recovery, which were measured with each eye individually because the glare test could only be used on one eye at a time.

None of the visual functions assessed were found to be significant predictors of Para Nordic Skiing performance, however the data suggested that glare sensitivity (in the best eye) and static visual acuity had the potential to be predictive of Para Nordic skiing performance.

In this preliminary study we were unable to measure contrast sensitivity on all skiers with the tests we had available to us, and glare testing could only be done on one eye at a time. Therefore, it was hard to determine if the lack of relationship between the vision functions and skiing performance was a real finding or an artefact due to not being able to measure all tests on each subject. Furthermore, the skiers who participated in this study had a wide range of skiing experience ranging from youth athletes in development programs to athletes who had competed in multiple Paralympic games. With such a wide skill level in the study population, it was impossible to determine if the differences in performance were related to vision or skill. Visual field testing and motion perception testing were also not included because we did not have validated portable tests of these vision functions available to us at the time of testing.

However, despite these limitations, it was determined that **colour vision was not an important factor in skiing performance**. It was also decided that **low contrast static acuity did not add any additional information** about visual function that was not already measured using the static visual acuity and contrast sensitivity tests. Subsequently, the colour vision and low contrast visual acuity tests were removed from the test battery and replaced with a binocular visual field test and two tests of motion perception.

<u>2016-2017 Study</u>

To address the limitations of the 2015-2016 study, the research team returned in the 2016-2017 and 2017-2018 seasons to test athletes who were of a sufficient standard to be eligible to compete at the World Championships, which would help ensure a minimum disparity in athlete skill level. Static visual acuity and dynamic visual acuity were re-measured using the same tests as in 2015-2016. New tests were used to measure contrast sensitivity, glare sensitivity, glare recovery, light sensitivity, visual field extent, and motion perception. All testing was done with both eyes open. More details about skier's training experience (skier's age, age started skiing, total lifetime years of training, total lifetime training hours, number of races competed in), and age of impairment onset were collected.

Data for this study was collected at two events: 1) the 2017 World Para Nordic World Championships in Finsterau, Germany, and 2) the 2018 World Para Nordic World Cup in Oberried, Germany. 26 athletes, ages 18-43 years (18 male, 8 female) from 13 nations participated in this study. Raw-WPNS points were calculated from races in the 2016-2017 and 2017-2018 seasons only.

Skiing more races and having a larger visual field were significantly associated with better skiing performance. **There were near-significant trends towards training more and having a lower (better) static visual acuity being associated with better skiing performance also** (Figure 5).

A multivariable regression analysis statistical model was then used to look at whether or not skiing performance could be predicted based on any of the individual visual functions measured. In this model, **the total lifetime hours of training was the only variable found to be a significant predictor of Para Nordic Skiing performance. The number of races completed across the two seasons also approached significance**.

It is important to note that in both the 2015-2016 and 2016-2017 studies, static visual acuity was found to be highly correlated with dynamic visual acuity, low contrast visual acuity, and contrast sensitivity. This means that an athletes performance on a static visual acuity test is representative of performance on all of these visual function tests.

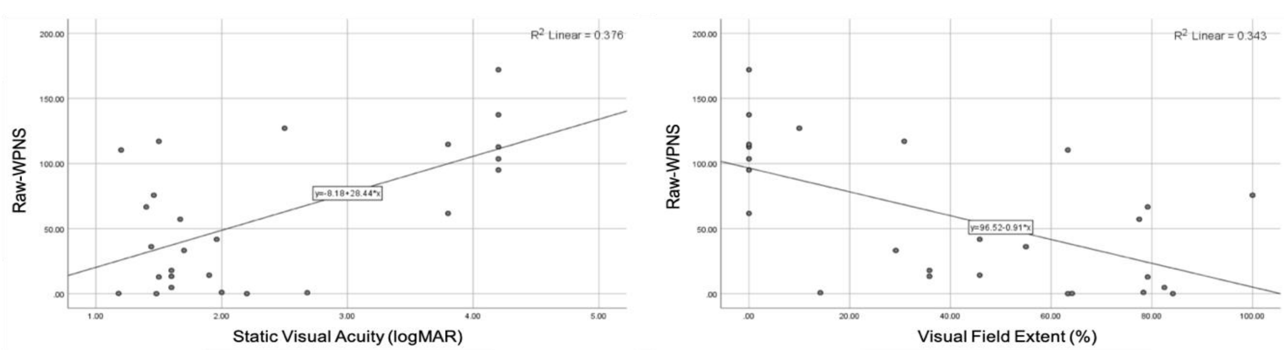

Figure 5: Each dot in the left and right panels indicates one skier's data. <u>Left Panel</u> - This panel demonstrates the correlation between static visual acuity and Raw-WPNS points, and shows that Raw-WPNS points are lower (better) when static visual acuity

is lower (better). Right Panel - This panel demonstrates the correlation between visual field extent and Raw-WPNS points. In this panel, it can be seen that Raw-WPNS points are lower when the visual field extent is larger.

Simulation Studies – Minimum Impairment Criteria

In order to determine the **minimum impairment criteria** for Para Nordic skiing, we recruited sighted, experienced Nordic skiers (coaches, guides, team members (i.e. physiotherapists), and ski club members) at the 2018 Para Nordic World Cup in Oberried, Germany. 22 skiers (16 male, 6 female) from 11 nations participated in this study. All skiers were asked to ski a short (400-500m) race course while wearing either clear goggles to simulate habitual (or normal) vision or simulated vision impairment goggles of different levels of vision impairment. The racecourses were not the same for all skiers, however all of the racecourses included at least one corner and some downhill, uphill, and flat terrain. To account for the fact that the racecourses were not the same for all skiers, baseline (no impairment, clear goggle) data was taken for each athlete on each course, and researchers calculated how much the simulated impairments changed the skier's times from baseline. Researchers then compared how much skier's times changed from baseline rather than each skier's raw times with each of the different simulated impairments.

The simulated vision impairment goggles either impaired visual acuity and contrast sensitivity simultaneously (because it is impossible to impair one without affecting the other) or decreased the binocular (both eyes) peripheral visual field. Skiers completed a total of 18 skiing trials in the study, and were asked to try and maintain a consistent, challenging (70-80%) pace across the trials. The first and last trial for every skier was completed with clear goggles. The middle 16 trials consisted of the 14 simulated vision impairments and two additional clear goggle trials to monitor fatigue across the trials. Apart from the first and last trials, the goggles that skiers wore for each trial were randomly assigned. Time to complete each run was measured.

No difference in race time was found across the four clear goggle trials in the skiers, which indicated that skiers could maintain a consistent pace, and that fatigue was not a factor that needed to be accounted for. There was no systematic order effect either (i.e. skiers did not get progressively slower or faster from trial 1 to trial 18) due to fatigue or learning the course.

To determine the impact of the simulated vision impairments on performance, the average trial time for the four clear goggle conditions was calculated for each skier. The difference from average baseline for each individual simulated vision impairment trial time was then calculated. All trial time difference data were then normalised to allow for comparison between participants. Only the visual acuity and visual field results will be presented here, because contrast sensitivity was not a recommended test for athlete inclusion.

Visual Acuity

Eight different levels of visual acuity impairments were simulated from approximately 0.1logMAR to 1.5logMAR in 0.2logMAR intervals (Figure 6).

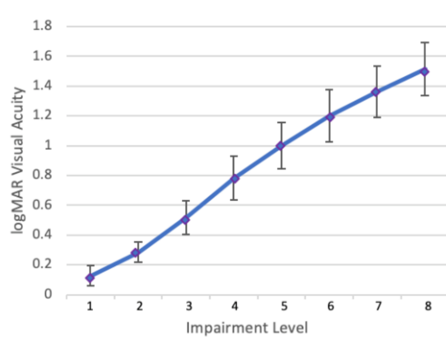

Figure 6: Average simulated visual acuities (logMAR) for all skiers in the study for each simulated visual acuity impairment level. Error bars indicate the variability (standard deviation) of the data between skiers.

The difference from baseline times (Figure 7, Left panel) gradually increased with each level of impairment, which means skiers got slower with each reduction in their visual acuity. Skiing performance decreased significantly from baseline at 0.99logMAR (Impairment Level 5), however skiing performance in some athletes changed before this impairment level, and in other athletes skiing performance did not decrease until after this level. Additionally, the statistically significant difference in performance at Impairment Level 5, was consistent with approximately a 3 second decrease in skiing performance. In recognition that statistical significance may not equate to sport significance, the investigators used additional statistical analysis methods called "receiver operator characteristics, or ROC analysis", "Youden's J" and "decision trees" to identify the optimal visual acuity minimum impairment criteria.

ROC analysis determines the sensitivity and specificity of each possible cut-off point. Both sensitivity and specificity are measured on a scale of 0 to 1. On this scale, scores closer to 1 are better. A minimum impairment criterion with good *sensitivity* would include as many skiers as possible who are performing worse than expected (i.e. assumed to have a genuine impairment). However, if the minimum impairment criterion is set too low, it will have poor *specificity*, which means skiers without genuine impairments may also be included. A minimum impairment criterion with a high *specificity*, but poor *sensitivity* would end up excluding people from competition who have genuine impairments. To find a balance between sensitivity and specificity for the minimum impairment criteria, Youden's J analysis was used, because Youden's J optimises both sensitivity and specificity.

Decision tree analyses start with the whole data set and then split it into two groups that are the most similar or homogeneous. The splitting continues as long as different groups can be clearly defined in the data. For the purposes of the research done here, the decision tree created separated the skiers' performances into 'expected' (same as no impairment) or 'below-expected' (worse than no impairment) groups.

Figure 7 below (Right panel) shows the sensitivity and specificity for different possible minimum impairment criteria for visual acuity. Youden's J analysis found that a cut-off value of **0.81 logMAR** was ideal (sensitivity = 0.88, specificity =0.71).

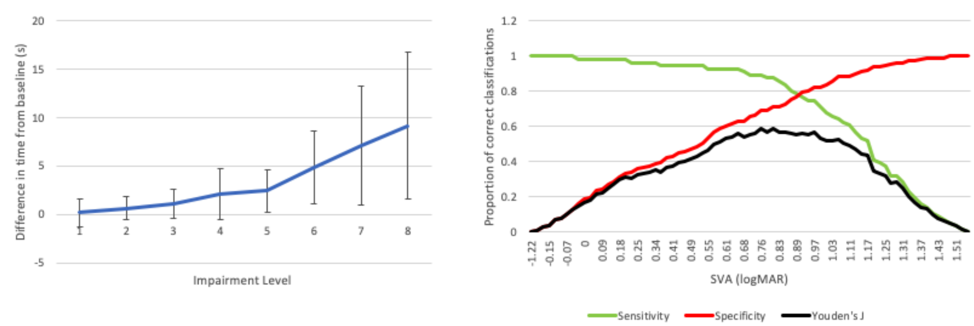

Figure 7: Left Panel – Average difference in time from baseline for each impairment level, for all skiers. Error bars indicate the variability (standard deviation) of the data between skiers. Right Panel – Minimum impairment criteria for visual acuity. Sensitivity (green line), specificity (red line), and Youden's J (black line – the 'optimal' combination of sensitivity and specificity) for each possible visual acuity criterion.

Visual Field

Six different levels of visual field impairments were simulated as shown in Figure 8. Skier's visual field extents were restricted from approximately 96% (13000 degrees^2) to 32% (1267 degrees^2) in approximately 13% intervals.

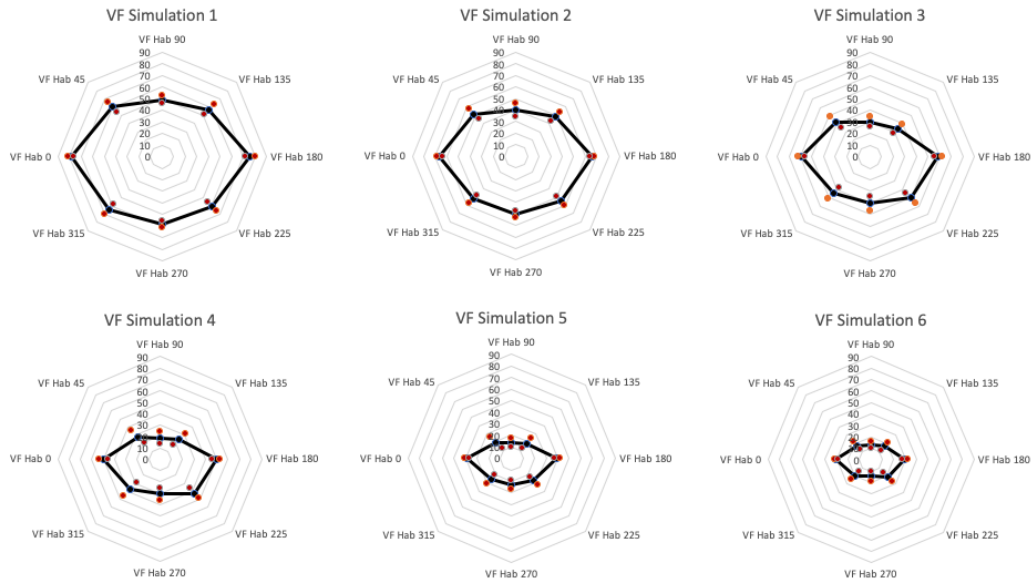

Figure 8: Average simulated visual field extent (%) and visual field traces for all skiers in the study for each simulated visual field impairment level. Red dots bars indicate the variability (standard deviation) of the data between skiers.

The difference from baseline times (Figure 9, Right panel) gradually increase with each level of impairment, which means skiers got slower with each reduction in their visual field extent. Skiing performance decreased significantly from baseline at visual field area 2229.3 degrees^2 (40.6% visual field extent; Impairment Level 5), however skiing performance in some athletes changed before this impairment level, and in other athletes skiing performance did not decrease until after this level. Therefore, receiver operator characteristics analysis was performed to identify the optimal visual field extent minimum impairment criteria.

Figure 9 (Right panel) shows the sensitivity and specificity for different possible minimum impairment criteria for visual field. To find a balance between sensitivity and specificity for the minimum impairment criteria, Youden's J analysis was used. Youden's J at the intersection of the sensitivity and specificity curves was 0.584 (sensitivity = 0.75, specificity = 0.76) and corresponded to an equivalent VF of 30° radius (44.1%; area = 2753.8 degrees^2).

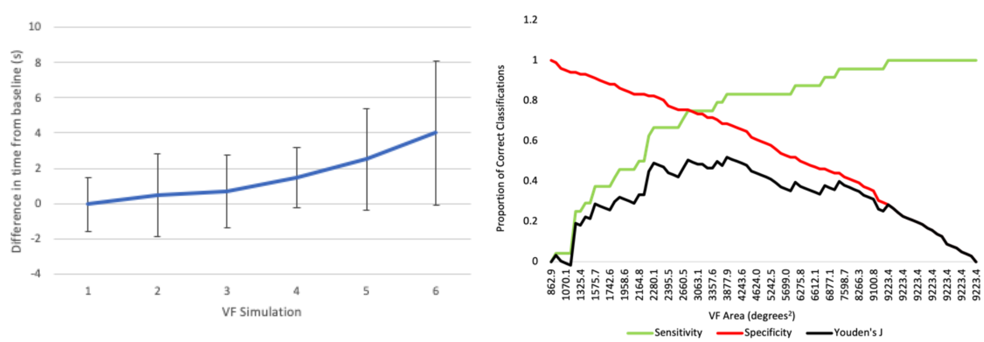

Figure 9: Left Panel – Average difference in time from baseline for each impairment level, for all skiers. Error bars indicate the variability (standard deviation) of the data between skiers. Right Panel – Minimum impairment criteria for visual field extent. Sensitivity (green line), specificity (red line), and Youden's J (black line – the 'optimal' combination of sensitivity and specificity) for each possible visual acuity criterion.

Interestingly, when a decision tree analysis was conducted on the simulation study data to determine what factors best predicted below expected performance, static visual acuity of >0.97 logMAR was the strongest predictor of poorer performance. When static visual acuity was ≤0.97 logMAR, the next best predictor of poor performance was a visual field area ≤2280.1 degrees^2 (27° radius; 38.3%). Youden's J at the intersection of the sensitivity and specificity curves for area = 2280.1 degrees^2 was 0.491 (sensitivity = 0.67, specificity = 0.82).

As sensitivity and specificity were more balanced at the intersection point of the ROC curves, a visual field cut-off of ≤30 degrees radius was recommended for the sport.

Consideration of both the ROC curves and the decision tree analysis suggests that a static visual acuity between 0.81logMAR and 0.97logMAR negatively impacts skiing performance and confirms that a visual field extent ≤30 degrees radius negatively impacts skiing performance in the non-adapted form of the sport.

Vision Impairment-Performance Relationship Studies – Part 2: Sport classes

In addition to allowing us to determine what tests should be included in athlete evaluation, data from the 2016-2017 study could also be used to determine the **most appropriate Sport Classes for Para Nordic Skiing.**

To examine the relationship between visual impairment and performance for the determination of sport classes, we used a hierarchical clustering analysis to determine if there were unique groups within the population of skiers that performed differently. Comparison of the unique groups could shed further insight into whether or not these groups had different visual abilities, as well as what aspects of vision are most important for Nordic skiing. All vision and experience variables were included in this cluster analysis, in order to account for other factors that may affect skiing performance.

Raw-WPNS performance points were used as an outcome measure in this analysis, which identified 3 distinct groups that performed significantly different (Figure 10, Left panel). For comparison purposes, Raw-WPNS points for each athlete in their current competition class (B1, B2, B3) are also included in Figure 10 (Right panel).

Raw-WPNS points, **the number of races completed across the two seasons**, **static visual acuity**, and **visual field extent** were found to be significantly different between the clusters. There was also a trend towards a difference in dynamic visual acuity between clusters. Contrast sensitivity, motion perception (translational or radial), glare sensitivity, and glare recovery were not different between groups.

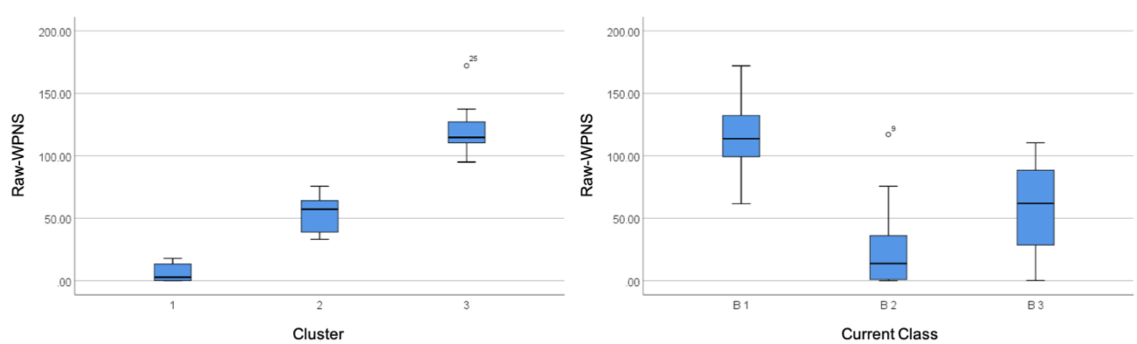

Figure 10: Left Panel – Raw-WPNS points for each unique cluster identified by the hierarchical cluster analysis. Right Panel – Raw-WPNS points for each current competition class (B1, B2, B3) for the same athletes included in the hierarchical cluster analysis.

It is important to note that there are a significant number of athletes (8 of the 26 athletes or 31% of the athletes) within the data that did not have measurable visual acuity (only light perception or no-light perception). When the distribution of athletes with light perception (LP) or no-light perception (NLP) vision are compared, there are more of these athletes in Cluster 3 (67%) compared to Clusters 1 (0%) and 2 (14%). In Cluster 1 there are no skiers without measurable static visual acuity, and in Cluster 2 there is only one skier without measurable static visual acuity.

Comparison of static visual acuity between clusters demonstrates that there was a trend towards static visual acuity being different between Clusters 1 and 3 and Clusters 2 and 3. Static visual acuity was not different between Clusters 1 and 2 (Figure 11, Left panel).

Comparison of visual field extent between clusters demonstrates that Cluster 3 had a significantly smaller visual field extent than either Cluster 1 or 2, and there was no difference in visual field extent between Clusters 1 and 2. There were also many more skiers with light perception (LP) or no-light perception (NLP) vision in Cluster 3 compared to Clusters 1 and 2 (Figure 11, Right panel).

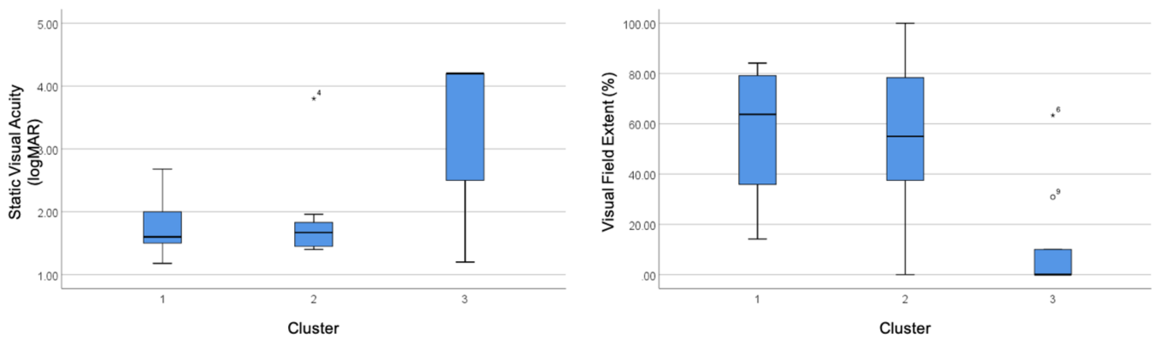

Figure 11: Left Panel – Static visual acuity distribution for each of the three clusters (the boxes represent the first to third quartiles, the band in the box represents the median value, and the error bars indicate minimum and maximum data for each cluster). Right Panel – Visual field extent distribution for each of the three clusters (the boxes represent the first to third quartiles, the band in the box represents the median value, error bars indicate minimum and maximum data for each cluster).

Finally, a decision tree analysis was used to determine what factors would best predict expected and below expected performances in the skiers studied, and where the splits between groups might be. Expected performance was defined as the average Raw-WPNS points score in Cluster 1, which had the best performance. Below expected performance was defined as any performance that exceeded the 99% confidence interval around Cluster 1's Raw-WPNS Score, which meant that below expected performance was equal to a Raw-WPNS score of 24.53 or greater.

The decision tree indicated that the most significant predictor of athlete's performance was the number of races they competed in; athletes who competed in more races were more likely to perform better, which is not an unexpected finding. The second most significant predictor of below expected performance (in athletes with fewer races only) was having a visual field extent ≤33.3%.

Static visual acuity did not show up as a significant predictor of performance in the decision tree analysis (except in athletes with ≤14.5 races and visual field extents >33.3%), however it was still a significant variable in the cluster analysis.

Two Sport Classes for Para Nordic Skiing were originally proposed in 2020. The Sport Classes were as follows:

NS12: Binocular static visual acuity of 0.9 to 2.4 logMAR OR visual field extent ≤30 degrees radius.

NS11: Binocular static visual acuity of 2.5 logMAR or worse (including visual acuities of light perception or no light perception). All skiers in this proposed class would have had to wear blindfolds at all times on the field of play.

However, in recognition of important feedback from the discussion of the research recommendations at the sport forum, STC meetings, and with the Coaches' Advisory Group, a revised Sport Classes proposal has been developed. The rational and new proposal are detailed below.

Performance of B2 skiers with poor static visual acuity

At the conclusion of the World Para Nordic Skiing – Classification Research Feedback meetings, researchers recognised there were significant concerns raised about combining the B2 skiers with poor static visual acuity with the skiers who had light perception (LP) or no light perception vision (NLP), even though the rules would be changed so that all athletes in this class would be required to wear blindfolds on the field of play.

The strongest arguments against this proposal were:

- It could potentially disadvantage athletes with the most severe impairments (i.e. athletes with NLP vision)
- It would require that more athletes in the sport, not fewer wear blindfolds to compete which will 1) create logistical challenges for rule enforcement, especially on longer distance races where the entire course cannot be monitored by technical officials, and 2) mean some athletes would need to be made more impaired to compete, which is counter to ethos of the Paralympic movement.

In the original research project, researchers were able to recruit skiers with static visual acuities ranging from 1.18 to 2.68 logMAR, in addition to skiers with LP (light perception) and NLP (no light perception) vision (Figure 12). Of the skiers recruited in the original research project, 17 skiers had static visual acuities between 1.18 to 2.20 logMAR, two skiers had visual acuities between 2.30 to 2.68 logMAR, and 7 skiers had visual acuities of LP or NLP vision. While this research had a good distribution of athletes with all levels of static visual acuity participating, there were only 2 athletes who participated that would be considered to be B2 skiers with poor static visual acuity (often referred to as 'low B2 athletes' in the sport).

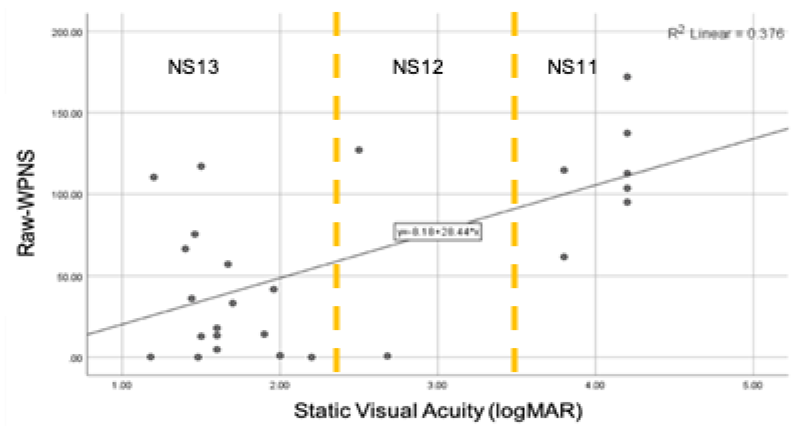

Figure 12: Each dot in the graph indicates one skier's data. This panel demonstrates the correlation between static visual acuity and Raw-WPNS points and shows that Raw-WPNS points are lower (better) when static visual acuity is lower (better). The orange lines drawn on the graph ***approximately*** *estimate where the borders between the three new proposed classes would fall. Skiers in the leftmost group on the graph would be in the NS13 class, skiers in the middle group would be in the NS12 class, and skiers in the rightmost group would be in the NS11 class.*

Based on the data collected in this study, the current B2 skiers with poor visual acuity (2.30 logMAR acuity or worse) do not appear to perform differently than skiers currently classed as B2 (with better acuity) or B3, and the current B2 skiers with poor visual acuity do appear to perform better than skiers with LP or NLP vision.

The results of this study would suggest that B2 skiers with poor static visual acuity could potentially compete in the same class as B2 skiers with better visual acuity, B3 skiers, and the NE skiers, **however**, what we cannot tell from this study is if there were only a few B2 skiers with poor static visual acuity competing at the World Championship level because they were not competitive, or if they were simply unavailable to participate in the research. In consideration of feedback received during the consultation process, that B2 athletes with poor static visual acuity often do not appear to be able to compete with B2 athletes with better static visual acuity, **the researchers would recommend that for the time being, skiers that are currently classed as B2 with poor static visual acuity compete in a new class with skiers that are currently classed as B1 with measurable static visual acuities (better than LP**

vision). Going forward, additional data will need to be collected to determine if these athletes should remain in their own separate sport class or not.

The data collected in this study with elite (World Championship eligible level skiers) would suggest that static visual acuity is a better determinant of skiing class than visual field extent. That being said, visual field extent is still important in determining eligibility to compete in the sport. Therefore, the researchers recommend that visual field extent remain as an eligibility criteria determinant. Once athletes are determined to meet the eligibility criteria for competition, they should be classified into sport classes based on their binocular static visual acuities.

Blindfold Comparison Studies

Currently, there is no evidence available on the effect blindfolds have on skiing performance in individuals with severe vision impairments. It is possible that athletes with some amount of vision or light perception might have an advantage over athletes with no light perception. However, it is also possible that an athlete's limited remaining vision is not helpful, and could actually impair their performance by distracting the athlete from the auditory information provided by their guide. Therefore, the purpose of this study was to investigate the impact of blindfolds on Para Nordic skiing performance in Para Nordic skiers classified as B1.

Four B1 skiers from two nations were recruited for this study during the 2018 Para Nordic World Cup in Oberried, Germany. Each skier's visual acuity was measured, and the skiers were each asked to ski a short (approximately 400-500m) Nordic ski course four times. Skiers skied with their own guide at all times. On two of the trials, skiers wore their blindfolds (Condition A), and on the remaining two trials, skiers did not wear their blindfolds (Condition B). The order of the blindfold / no blindfold conditions (ABBA or BAAB) were randomised between skiers. Skier's time to complete each trial was recorded, and trial times were compared between the two conditions. Skiers were also asked how they felt about skiing with and without the blindfolds.

Three skiers had no light perception vision and one skier had measurable static visual acuity. There was no difference in time between the ski runs completed with and without the blindfolds (Figure 12). One of the participants preferred to ski with the blindfold, one preferred skiing without the blindfold, and two participants had no preference for either blindfold condition. The skier who preferred to ski with the blindfold was the skier with the measurable static visual acuity.

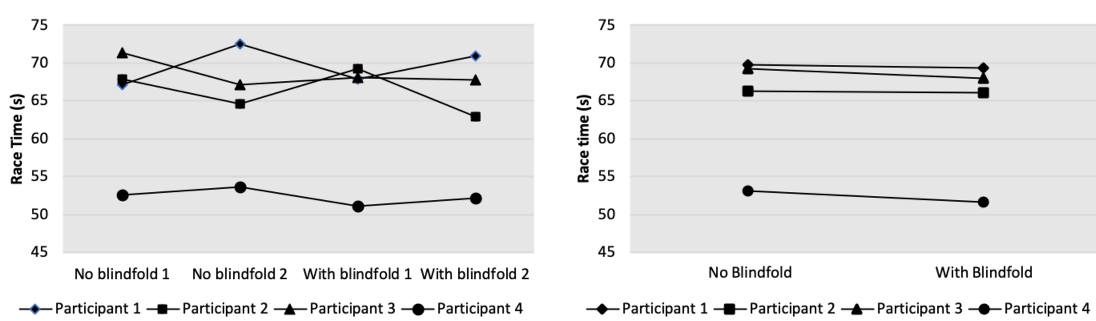

Figure 12:Left Panel – Each data point represents one raw-race time measure for each skier on each condition. Each individual skier is represented by a different symbol. Right Panel – Overall average race time for each skier in each condition (No blindfold, With blindfold). Each individual skier is represented by a different symbol.

Final Recommendations – proposals for classification rules changes to World Para Nordic Skiing Classification Rules and Regulations, Appendix 2

The recommendations are presented below.

1. **What tests of vision function should be included in classification for Para Nordic Skiing?**

   Tests of binocular static visual acuity and binocular visual field be used for classification.

   An individual's binocular static visual acuity and binocular visual field level were associated with Para Nordic Skiing performance.

   Total lifetime hours of training and number of races competed in were also important factors in Para Nordic Skiing performance.

   In addition and following recommendation of earlier expert meetings and the IPC Position Statement of the Sport Specific Classification of Athletes with a Vision Impairment (IPC Handbook, Section 2, Chapter 4.6), visual acuity and visual field will be measured with binocular focus. The measurements of vision will be completed with both eyes together, since this more appropriately reflects how an athlete uses their vision in Para Nordic Skiing.

2. **What are the minimum impairment criteria proposed for vision impairments in Para Nordic Skiing?**

   The minimum impairment criteria for visual acuity are proposed to be set at 0.9 logMAR. If an athlete has a visual acuity better than 0.9 logMAR, they may be eligible to compete if their visual field extent is less than or equal to 30 degrees radius.

3. **What are the proposed competition classes for Para Nordic Skiing?**

   Three Sport Classes for Para Nordic Skiing are proposed. The Sport Classes are as follows:

   - **NS13: Binocular static visual acuity of 0.9 to 2.2 logMAR OR binocular visual field extent ≤30 degrees radius**
   - **NS12: Binocular static visual acuity of 2.3 to 3.5 logMAR**
   - **NS11: Binocular static visual acuity of light perception or no light perception vision only**

   The final names of the classes are at the final discretion of WPNS.

4. **What impact do blindfolds have on Para Nordic Skiing performance in skiers in the B1 class?**

   Blindfolds are recommended to be optional for all skiers.

Future Opportunities and Implementation

While the full translation of research into classification practice has not been explored in this report, it is recommended any change is adequately considered, well planned and clearly communicated. Additionally, any system that is implemented should be monitored through the collection of data over time to measure the success and plan for any future change.