Costa-Scorse, B. A., Hopkins, W. G., Bahr, R. (2015). Evaluation of ski-binding-boot system safety using torque testing. *ASTM Special Technical Publication, STP 1582*, 163-170.

STP 1582, 2015 / available online at www.astm.org / doi: 10.1520/STP158220130158

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Evaluation of Ski-Binding-Boot System Safety Using Torque Testing

Reference

Costa-Scorse, Brenda A., Hopkins, Will G., and Bahr, Roald, "Evaluation of Ski-Binding-Boot System Safety Using Torque Testing," *Skiing Trauma and Safety: 20th Volume*, STP 1582, Robert J. Johnson, Ed., pp. 163–170, doi:10.1520/STP158220130158, ASTM International, West Conshohocken, PA 2015.[3]

ABSTRACT

This study evaluated release torque values for rental ski-binding-boot (S-B-B) systems that had one to four seasons use in a popular New Zealand commercial ski area. The proportions of S-B-B systems in classes of deviation from the reference release moment were determined according to the international equipment safety requirements from ASTM F1063-03, ASTM F1064-03, ASTM F939-06, ISO 13993: 2001, and ISO 11088-2006 (E). A randomly chosen sample of 9 % (124 skis/62 pairs) of S-B-B systems from the total ski rental fleet was tested using a Wintersteiger calibration machine. There were a high percentage of Class I deviations in the rental fleet: 50 % (2 seasons), 95 % (3 seasons), and 64 % (4 seasons). Class 1 deviations do not require corrective action; however, increased sampling is indicated. Based on the high percentage of Class I deviations the entire fleet should be inspected. Class II deviations that required immediate corrective action were found in 48 % of the S-B-B with two seasons of use. Only 8 % of the rental fleet had Class III deviations warranting removal from the rental fleet. The heel-pieces of S-B-B systems that had two or more

Manuscript received October 15, 2013; accepted for publication August 27, 2014; published online October 21, 2014.

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seasons of use were nine times more likely to be out of tolerance than those with only one season of use; however, there was only a small increase in the proportion of toe-pieces out of tolerance for older compared to newer S-B-B systems. These differences may be due to age or to different models of S-B-B systems. The policy of retiring ski rental equipment after three or four seasons of use appears to be inadequate to ensure the supply of safe equipment.

Keywords
ski-binding-boot system, torque, standards

Introduction

Ski-bindings are constructed using levers and springs. Calibration procedures ensure that the binding mechanism works effectively, and that the release value indicator is truly reflective of the torques or force required for the ski-binding to release. To accurately set-up alpine ski-binding-boot (S-B-B) systems there are trade-offs between a maximum retention setting likely to cause injury due to non-release and, conversely, a minimum retention setting likely to cause injury due to inadvertent release, and a more appropriate ski-binding release value that is easy to calculate in a busy ski hire setting [1]. It is not possible to ascertain the exact status of the S-B-B system without making torque checks using a calibration device. Currently in New Zealand there are no major ski areas using calibration machines to test their rental fleets; only two off-hill ski rental businesses use a calibration machine, and only one of these businesses pre-season tests all of their rental fleet. There are no rental outlets in New Zealand using torque wrenches. International standards produced by ASTM International and ISO [2–4] outline the necessity to use torque testing equipment to accurately determine the S-B-B system functionality. Large rental outlets in New Zealand replace ski rental equipment on a three-year to four-year cycle. There are no replacement cycle recommendations in the standards. Skiers that own skis in New Zealand have limited access to torque testing equipment. There is no national education programme for alpine skiers on the necessity to correctly setup and torque test alpine ski equipment. The exact number of countries that consistently apply international standards for setup and testing of alpine ski equipment is not known. Medicines de Montagne reported that although skiing is popular in France, understanding and adoption of equipment-related practice standards in France is limited [5].

Current research findings on equipment-related injury were provided to the national ski areas association from an epidemiological study on the magnitude of the lower limb injury problem in alpine skiing in New Zealand using Accident Compensation Commission (ACC) snow sports injury claimant data from 2000 to 2007 [6], and from a prospective study on current rental shop practices using surveys in 2008 and 2009 [6,7]. After the survey results were presented, national ski areas association members requested more evidence as to why they should purchase calibration machines or torque wrenches rather than continuing to use their present maintenance and rental fleet replacement strategies. The purpose of this study was

to provide more data to support the introduction of a uniform method of testing and maintaining alpine ski equipment.

Methods

The study involved testing alpine S-B-B systems to determine the release torque and percentage of alpine S-B-B systems that did not meet the international standard for release torque. Testing parameters were based on a 70 kg skier aged less than 50 years, 1.70 m height, type II skier ability, and a ski boot that was 314 mm in sole length that warranted a release value of 6.0 as outlined in ASTM F939-06 [8] and ISO 11088:2006 (E) [3] release value tables. The reference moment as calculated using the international standards release tables for these skier parameters were 224 Nm in My (forward lean in the heel) and 57 Nm in Mz (twist right, i.e., clockwise, and twist left, i.e., anticlockwise in the toe-piece). The in-tolerance threshold was ±15 % from the reference moment. Deviations from the tolerance threshold were Class I deviations when the S-B-B toe-piece and/or heel-piece were ±16 % to ±30 %, Class II ± 30 % to ±45 %, or Class III deviations when the S-B-B toe-piece or heel-piece test result was more than ±45 % Three trials for each S-B-B system for forward lean or twist direction were recorded. Comparisons between trials were calculated. The proportion of the S-B-B that did not meet the threshold of ±15 % was determined to not be in tolerance. Logistic regression analyses were used to determine the effect of age (seasons of use) on binding release using the third trial.

SAMPLE CHARACTERISTICS

Random sampling was conducted of the ski rental fleet at the sole rental shop at one commercial ski area. Every ski with a mounted binding had an equal chance of being included in the sample. The ski area manager stated that the total inventory was 700 pairs of skis. ASTM and ISO guidelines for random sampling are 5 % of the rental fleet. The researcher randomly selected 16 pairs of skis from year one, 16 pairs of skis from year two, and 16 pairs of skis from year three ($n = 48$ pairs). There were only 14 pairs of four year old skis in the rental fleet so all 14 pairs were tested. There were two brands of S-B-B with one season of use (Brand A and Brand B). The older rental fleet were all Brand (B) systems. A total of 62 pairs of S-B-B were tested ($n = 124$ skis).

EQUIPMENT AND PROCEDURES

The Wintersteiger calibration machine determined the force (torque) required to release the boot from the ski-binding and whether or not the ski-binding release value indicator was accurate (see **Fig. 1**). The calibration machine was moved from the resort town of Queenstown to the ski area, a distance of 18 km (11 miles). As movement can affect the accuracy of the torque testing machine, checks of the machine were made with the manufacturers' calibration device prior to commencing S-B-B testing. Five adjustments of the machine were required and conducted as per the manufacturers' manual before testing began. For reliability, rechecks of the

FIG. 1 Wintersteiger calibration machine torque testing the toe-piece in Mz twist.

machine were made with the calibration device after each set of 30 tests; no further calibration of the machine was required.

A single ski-boot from the rental fleet with one season of use and no wear and tear on the sole was used as the reference boot to test the entire rental fleet. A reference boot is a boot that is compatible with the ski-binding that has no excess wear on the heel and toe-piece and is typical of ski-boots that are in the inventory (see **Fig. 1**). The boot was checked after each test to ensure that there were no contaminants that could lead to boot/binding incompatibility.

Results

All S-B-B systems that were found to be more than 15 % from the reference moment were over tolerance (too tight). No S-B-B systems tested were under tolerance (too loose). The rental fleet inventory failed the in-season inspection as more than 20 % of the sample torque-tested had Class I deviations. Class II deviations of 48 % were found in S-B-B with two seasons of use. Of the rental fleet, 3 % with two seasons use and 5 % of the rental fleet with three seasons use had Class III deviations (see **Table 1**).

In further analysis in **Table 1**, the heel-piece of older S-B-B was nine times more likely to be out of tolerance than those after one seasons use (proportion ratio 9.4, 90 %CI 7.8 to 10.1). However, there was only a small increase in the proportion of toe-pieces out of tolerance for older compared to the newer S-B-B systems (proportion ratio 1.12, 0.92, to 1.31).

Two manufactures S-B-B systems (Brand A and Brand B) were used in the newer rental fleet with one season of use (see **Table 2**). Only Brand B systems were used in the older rental fleet that had two to four seasons of use.

TABLE 1 Proportions as percentage of SBB systems in classes of deviation from the reference release moment.

	Seasons of Use			
	One ($n = 32$)	Two ($n = 32$)	Three ($n = 32$)	Four ($n = 28$)
Heel-Piece Over				
Class I	9.5	50.0	95.0	63.6
Class II	0	47.5	0	0
Class III	0	2.5	0	0
R) Toe-Piece Over				
Class I	23.8	42.5	25	54.6
Class II	0	0	0	9.1
L) Toe-Piece Over				
Class I	81	67.5	65	90.9
Class II	4.8	0	15	4.6
Class III	0	0	5	0

Note: Classes of deviation are defined as the following changes in moment that are required to release the boot from the ski-binding. Torque test results that are more than 15 % under or over the reference release moment. Class I ± 16 % to ± 30 %, Class II ± 30 % to ± 45 %, Class III > ± 45 %.

Discussion

Ettlinger et al. [9] in a study of the functional and release characteristics of alpine skiing equipment in a case-control study of 17 967 injuries over 32 years (1972–2004) noted that "the problem, in the opinion of the authors, is not the standards, but their implementation…Skiers who shun the efforts of a well-trained mechanic in a properly equipped ski shop and instead put blind faith in their binding's release indicator are not well served." Calibration machines and torque wrenches determine release torque values and the accuracy of the release value indicator. Manual twist of the toe-piece by the ski mechanic or skier, or manual release in the heel-piece does not prove that the ski-binding release setting (DIN) is actually working at the torque level registered on the scale at the binding toe-piece and/or at the binding heel-piece. There was a high percentage of Class I deviations in the rental fleet that was tested: 50 % (2 seasons), 95 % (3 seasons), and 64 % (4 seasons). Latitude exists in tolerance from the reference moment in Class I ± 16 % to ± 30 %. Torque values in Class I are classified as a minor deviation not requiring correction. As outlined in ASTM 1064-03 [2] and ISO 13993:2001 [4] where a class I deviation of 20 % is detected, the inventory fails and the entire rental fleet should be inspected. With Class II deviations of 48 % that had two seasons of use, the reliance on retiring ski rental equipment on a three-season to four-season basis to ensure that safe equipment is supplied can be questioned. Incorrect release settings

TABLE 2 Proportions (%) of each of two brands of S-B-B systems tested that had one seasons use showing Class I and Class II deviations from the reference moment for release.

	Brand A ($n = 16$)	Brand B ($n = 16$)
Heel-piece over		
Class I	7	0
Class II	0	0
R) Toe-piece over		
Class I	0	19
Class II	4.8	0
L) Toe-piece over		
Class I	38	43
Class II	4.8	0

Note: Only Brand B were in the rental fleet for seasons two to four.

may result in S-B-B systems that are too tight or too loose. Class II deviations of ±30 % to ±45 % prompt inspection of the entire inventory, and maintenance, where maintenance does not remedy the Class II deviations correction is required during setup. The correction requires factoring the deviation into the determination of release value setting as determined by skier weight, height, boot sole length; the correction is three lines up or down from the selected reference moment. Only 8 % of the rental fleet had Class III deviation of greater than ±45 %, indicating that these skis should be removed from the inventory.

To gauge the workload implications for busy ski rental operations, one Class II S-B-B system of the tested rental fleet ($n = 124$) was manually adjusted. The ski-binding release value indicator had to be adjusted down three times to get within the permissible range resulting in a release setting on the heel-piece of 4.5. The total time for this adjustment process was 10 min. An automated machine ensures testing time would be reasonably fast; however, when equipment adjustments are needed, there will be an impact on customer clearance through the ski rental shop.

Torque testing results from the commercial ski area were compared with release torque testing paper-based records for 2009 for Browns Ski Shop in Queenstown [10]. The historical data identified that there were 790 tests with only 5.4 % ($n = 43$) Class I deviations. These data support the benefits of a long-term torque testing programme in determining maintenance and rental fleet replacement requirements. A system also needs to be set up for ski rental workers to identify S-B-B with Class II deviations. For example, Browns Ski Shop use water proof colour coded identification on the ski tip to alert the ski rental worker that the deviation needs to be factored in when setting the release value indicator; this system may not be suitable for commercial ski area rental shops.

Limitations

A possible limitation in the study is that the there was insufficient four year old stock to randomise. Another possible limitation was that there were three different ski-bindings in the Brand B rental fleet. Based on product information, there were apparently no changes to the rental ski-binding mechanism from this manufacturer over the years of purchase of the rental fleet (2005–2009), the changes to Brand B were only cosmetic. However, if there were any changes in the rental ski-binding mechanism, this might impact on the performance of the ski-binding and the findings on the effect of years of use. Regardless of the cause, the high proportion of S-B-B systems out of tolerance is an important equipment safety concern.

PRACTICAL RECOMMENDATIONS

Torque testing S-B-B using a calibration machine or torque wrench is essential to ensure that the whole mechanism is working effectively and that the release value indicator is truly reflective of the forces (torque) that are required for the skier to release from the ski-binding. Although there has been extensive work by ski researchers and standards organisations to determine the appropriate setup and maintenance of alpine skiing equipment, there appear to be disconnects with practitioners.

According to ASTM F1064-03 [2] and ISO 13993: 2001 [4] pre-season visual inspection and manual movement checks of the S-B-B system are required. This manual maneuver only tests elastic travel and recentering; it does not replace the need for torque testing. Boot inspection is also needed to determine whether the boot sole is worn and remains compatible with the ski-binding. Cleaning and servicing to remedy any issues of wear and tear including ski-edge maintenance, ski-base repairs, and waxing are paramount for performance and equipment safety. Alpine skiers who own their own equipment need to undertake the same regular routine inspection of equipment and functional torque testing as rental shops to ensure that they too are skiing on safe functional equipment that will release under the appropriate load. All skiers, whether on rental or private equipment, need to have equipment that is set up accurately for their age, weight, height, boot sole length, and skier type.

It is recommended that all rental shops apply standards of inspection and torque testing of S-B-B systems pre-season and in-season to mitigate the risk of equipment-related injuries. It is also recommended that alpine skiers who own their equipment are provided with information on correct setup, maintenance, and testing. Finally, easy access to torque testing for all skiers should be provided across New Zealand and in any other countries lacking adequate torque testing services.

ACKNOWLEDGMENTS

The writers are most grateful that Browns Ski Shop loaned their calibration equipment and provided a ski mechanic that had well-established torque testing capabilities to

assist in this study. The writers also wish to thank ski area management for their openness to this on-mountain torque testing study, and acknowledge the encouragement of Miles Davidson of Ski Areas Association New Zealand to continue the quest for research informed changes in industry practice.

Conflict of Interest: University research institute funds were used for this study, some of which were funds accrued from research grant money from the New Zealand Accident Compensation Commission and the New Zealand Mountain Safety Council. The authors declare that they were not influenced by having received research funding from these external bodies and that they have no conflict of interest.

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