Determination of wrist biomechanics during snowboard falls as a precondition for the development of a harmonized international standard for wrist protectors in snowboarding

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Introduction and Aim

Snowboarding is associated with a relatively high injury risk and the incidence of snowboarding-related trauma seems to be increasing [1]. The most frequently injured body region is the upper extremity which comprises 35% to 45% of all snowboard related injuries [2]. Especially among 9–19-year olds, there is evidence that snowboarding injury rates are among the highest of all sports [3]. Among snowboarders, the wrist represents the most frequently injured body region and accounts for 19–28 % of all injuries [1]. The most common injury mechanism is described as a compressive load applied to a hyperextended wrist when falling onto outstretched arms (**Fig. 1**). However, little is known about the actual loading on the hands, wrist and forearm during such snowboard falls. To collect actual field data on forces and moments generated on the hand and wrist, an instrumented ski glove capable of recording *in-situ* kinematics and forces applied to the hand during falls occurring while participating in snowboarding was designed, validated, and used in a pilot study on-slope. One goal of the research is to inform efforts to develop appropriate laboratory test methods and standards for the evaluation of wrist protection that is based on actual injury mechanisms and conditions that occur on the slopes.

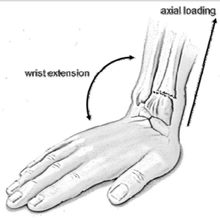


Fig. 1: Injury mechanism of a radial fracture attributable to compressive (axial) load applied to a hyperextended wrist at impact

Material and Method

An instrumented snowboarding glove was designed to measure flexion/extension of the wrist in the sagittal plane, as well as forces and moments imparted to the hands and wrist joint of snowboarders while practicing their sport. Flexible Bend Sensors were used to record wrist flexion/extension angle and force sensing to record forces on the palm of the hand and fingers (**Fig. 2 and 3**). Prior to on-slope testing, a series of laboratory validation tests were performed to evaluate the instrumented glove's measurement accuracy as well as use function. Drop tests were conducted by fitting the instrumented glove prototypes to a previously instrumented artificial arm/force plate test apparatus [4] (**Fig. 5**).

Fig. 2: Sensor layout for a miniature DAQ system: (left) force sensing resistors (FSRs) and (right) bend sensors on a ski glove insert.

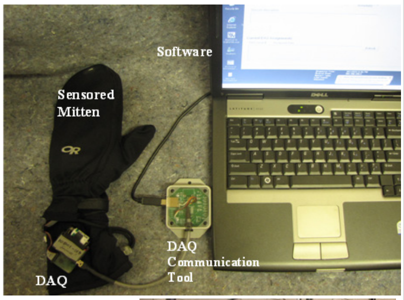


Fig. 3: Instrumented glove with communication board and PC application (DAQ: data acquisition)

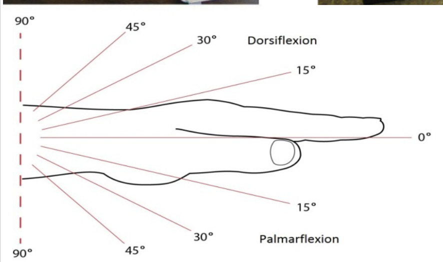


Fig. 4: Wrist angle definitions. Neutral wrist position is defined as 0°. Wrist were computed from the bend sensors and reported to 0.1°. The 15° increments shown are for reference only

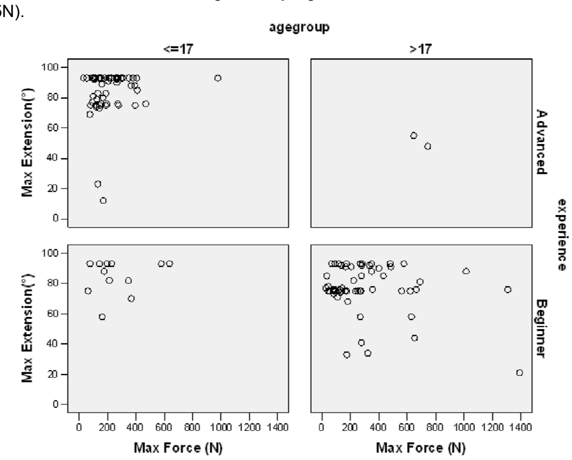
Fig. 5: Drop-test apparatus utilizing an instrumented, anatomically correct arm and force plate

A convenience sample of 20 snowboarder volunteers (♀=3;♂=17), aged between 11-45 years, was recruited randomly at Whaleback Mountain (Enfield, NH, USA), Dartmouth Skiway (Lyme, NH, USA), and Okemo Resort (Ludlow, VT, USA) to wear instrumented gloves while snowboarding. Data analysis included identification of fall type (fall/hand drag, leading/trailing), direction of fall, peak wrist extension angle (**Fig. 4**), peak impact force, and peak wrist extension moment in total and as a function of age group and experience level.

Results

A total of 128 events of hand impacts with the snow surface were identified from video and/or sensor data for analysis (**Tab. 1**). No injuries were recorded. There were statistically significant differences in maximum force (**Fig. 6**) and maximum extension moment as a function of age group. Adults had significantly higher maximum force (313 vs. 222N) and maximum extension moments (16 vs. 11Nm) compared to young adults. Average maximum wrist extension at impact was 84° and 76° for young adults and adults, respectively (**Fig. 6**). There were no statistically significant differences in maximum force or maximum wrist extension moment as a function of experience level and fall type (leading/trailing). Backward falls resulted in significantly higher maximum force than forward falls (313 vs. 225N).

Fig. 6: Maximum force [N] vs. maximum wrist extension angle [°] as a function of age group and experience level for all falls (n=128)



	Experience Level	# of Subjects	# of Falls	Max Force [N]	Max Extension Moment [N m]	Max Wrist Extension [°]	Mean Body Mass [kg]
Young Adults (≤17)	Beginner	1	12	266 ± 184	10.8 ± 6.9	84 ± 11	52 (52-52)
	Advanced	10	55	213 ± 148	10.7 ± 11.8	84 ± 15	52 (34-69)
	Total	11	67	222 ± 155	10.8 ± 11.0	84 ± 14	52 (34-69)
Adults (>17)	Beginner	7	59	301 ± 284	15.9 ± 20.7	77 ± 15	73 (52-93)
	Advanced	2	2	695 ± 69	35.5 ± 0.7	51 ± 5	76 (69-82)
	Total	9	61	313 ± 289	16.5 ± 20.7	76 ± 16	74 (52 -82)
Total	Beginner	8	71	295 ± 269	15.0 ± 19.2	78 ± 15	70 (52-93)
	Advanced	12	57	230 ± 171	11.6 ± 12.5	83 ± 16	55 (34-82)
	Total	20	128	266 ± 232	13.5 ± 16.6	80 ± 15	62 (34-93)

Tab.1: Number of falls recorded and mean ± standard deviation for wrist forces and wrist angles for subjects as a function of age and self-reported snowboarding experience level (The values in brackets in "Mean body mass" column represent the range of participant body mass for reference purposes only)

Conclusion

Instrumented gloves were developed and used for on-slope testing of wrist forces and wrist angles. On slope testing provides an opportunity to study real-life fall situations. This pilot study presents for the first time on-slope data of fall-related impact measures, which can be compared to existing and future laboratory experimental data [5]. Backward falls in beginners represented the highest loading conditions. Most falls resulted in significant wrist extension near terminal extension, which might have implications on the likelihood of wrist fracture in snowboarding, even though no injuries were reported in this study. There were significant differences in wrist biomechanics as a function of age, but these findings must be viewed with caution because of the limited sample size and the fact of arbitrarily selected 17 years as the cutoff for young adults. This cutoff at 17 years was chosen based on published suggestions that all school-age children should be required to wear wrist protectors for snowboarding [6]. These results have implications for education of riders and for beginners in particular, with respect to falling technique and landing on the hands in the backward position. Finally, these data will be valuable in the development of wrist protector standards and products [1].

References

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