Performance Evaluation of Wrist Guards Under Dynamic Testing

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Introduction:
Snowboarding, both as an outdoor sport and cultural trend, has grown tremendously over the past three decades. As a result, the number of trauma related injuries and emergency room visits has risen significantly. According to the literature, more than 50% of upper extremity injuries involve the wrist. The primary mechanism of injury is a backwards fall onto outstretched hands, resulting in hyperextension of the wrist. Thus, protective gear in the form of wrist guards has evolved as a means of decreasing the frequency of wrist injury.

Clinical and cadaveric studies have supported the use of wrist guards for snowboarding. With the lack of standardization, however, there exists large variation in design and application among commercially available wrist guards. Furthermore, there is a need for mechanical and biomechanical data to assess the performance of such devices. Previous studies have evaluated the performance of wrist guards under impact loading. Though impact data may be useful, it is our opinion that wrist guards undergo low load fatigue followed by occasional impact loading. Thus, the slow loading of wrist guards serves as a clinically relevant model for the determination of both fatigue and failure when impact conditions arise. Therefore, the purpose of this study was to evaluate the fatigue performance of commercially available wrist guards.

Materials and Methods:
Three (3) commercially available wrist guard designs (Figure 1: A, B, C) were selected for evaluation. These included ProTec IPS wrist guard, Santa Fe, CA (N=5), Burton RED Impact wrist guard, Truckee, CA (N=5) and Flexmeter wrist guard, NY, NY (N=5).

A fixture was constructed using PCV pipe as a support for the wrist guard. In addition a stop block was employed in order to provide a rigid anchor point as experienced during normal functional use. A moment arm was generated by placing the wrist guard at an XXmm distance from the central loading axis. Finally, a circumventing circular clamp was used to secure the wrist guard to the support pipe. All guards were positioned so as to align the exit hole of the thumb with the distal end of the support pipe. The circular clamp was located at this point as well.

The fatigue testing regimen consisted of sinusoidal loading between -25N and -100N for 500 cycles at 0.5 Hz. Load and displacement data was collected at 50-cycle intervals. The total deflection at each 50-cycle interval was computed for each screw guard type and subsequently averaged for a given cycle interval. The resulting average deflection at each interval was then subjected to a non-linear regression to compute mean deflection versus the number of cycles applied for each guard design. Statistical comparisons between designs were performed with a 1 way ANOVA using a Tukey post-hoc analysis.

Results:
All design types resulted in a fitted curve of the form seen in Figure 3, where the Plateau is the Independent Variable (Y) value at infinite cycle number (i.e. the asymptote); K is the rate constant, expressed in reciprocal of the X axis units (Cycles-1) and is related to the rate at which the deformation changes over the number of cycles; Half-life is in the units of the X axis and is computed as ln(2)/K and represents the point at which a 50% change in the deformation value has occurred; and Span is the difference between Y0 and Plateau, or the change in deformation over the course of the fatigue test.

In Figure 4A, the results of continuous cyclic loading are presented. The plot of deflection change versus cycle number illustrates the variation in the mechanical performance of these devices over the life span of use. All data sets resulted in r2 values for the fitting in excess of 0.95. From the fitting parameters, the half life comparison (Figure 4B) did not yield a statistically significant difference. That is, all of the wrist guards collapsed to the 50% maximum deformation over the same number of cycles. However, if one considers the Plateau (or settling) values to which the wrist guards sustained the resistance to loading, all wrist guards were statistically different from each other (Figure 4C).

Discussion:
Injuries of the wrist are common among snowboarders. Protective devices such as wrist guards have been shown to decrease the prevalence of injury to the upper extremity. Currently, there are no FDA requirements for the testing or manufacturing of wrist guards; thus, commercially available products are highly variable. Design, application, and cost of wrist guards differ greatly among models. In addition, the lack of research makes it difficult to assess degree of protection under both low load and impact conditions.

This study evaluates three different commercially available wrist guards under slow load fatigue compression. For all wrist guards tested, the data demonstrates a direct relationship between number of cycles and change in deflection. Plateau comparison reveals a significant change in deformation for all three wrist guards. ProTec guards demonstrated the greatest change in deformation followed by Flexmeter guards. Burton RED Impact wrist guards were least likely to deform over the course of slow load fatigue testing. Clinically, this may suggest that wrist guards lose a certain degree of protective functionality under normal activity conditions. This could potentially increase the risk of injury to the upper extremity under impact loading. Further biomechanical testing employing impact testing to compare new and slowly fatigued wrist guards may elucidate which wrist guard design is most effective in preventing injuries to the upper extremity.