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Development of a method for measuring quasi-static stiffness of snowboard wrist protectors

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Abstract

In snowboarding, the wrist is the most common injury site, as snowboarders often put their arms out to cushion a fall. This can result in a compressive load through the carpals coupled with wrist hyperextension, leading to sprains or fractures. Wrist protectors are worn by snowboarders in an effort to reduce injury risk, by decreasing impact forces and limiting wrist hyperextension during falls. However, there is no international standard or universally-accepted performance specification that these products should conform to, resulting in an inability to judge which design elements offer the most protection. EN 14120:2003 prescribes requirements that roller sports wrist protectors should meet, and has been identified as a starting point for developing a snowboarding-specific standard. This paper critiques the EN 14120:2003 test protocol and goes on to present a mechanical test for assessing the ability of snowboard wrist protectors to resist extension of the hand under an applied load. A bespoke rig incorporating the hand/arm surrogate from EN 14120:2003 was mounted to a uniaxial test machine, and wrist protectors were strapped to the surrogate at a set tightness (tight, moderate, loose). Linear displacement of the uniaxial test machine was transferred to angular displacement of the hand via a galvanised steel cable passing through a low friction pulley. Linear displacement was set to 200 mm/min and force was measured at the load cell until 80 N was reached. The test, presented here, found that the ability of the protectors to limit hand extension was dependent on how tightly they were fitted to the surrogate; therefore, strap tightness must be accounted for during further wrist protector safety assessments. This test provides a repeatable way to characterise the ability of snowboarding wrist protectors to limit wrist extension.

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Keywords: injury prevention; mechanical testing; snowboarding; wrist

1. Introduction

The upper extremity is the most common injury site in snowboarders, representing 35 to 45% of all snowboarding injuries [1]. Falls are the most common injury mechanism in snowboarding and account for 69 to 93% of all injuries [2]. In moments of instability, snowboarders attempt to cushion their fall by putting their arms out which can result in a load being applied to the outstretched hand. The load is transmitted along the upper extremity as an axial compression force and moment, often resulting in wrist hyperextension leading to wrist sprains or fractures [3,4]. Wrist protectors have been adopted as a preventative measure to reduce injury risk and different designs are available.

There is conflicting evidence regarding the effectiveness of snowboard wrist protectors, some studies show them to reduce risk of injury by attenuating impact forces in the wrist and limiting hyperextension during falls [1,5]. Whilst others argue that protectors transfer the load to another body region increasing the risk of injuries to the elbow or shoulder [6,7]. To date, there is no international standard that these products should conform to, or even a universally-accepted performance specification, making it hard to determine which designs offer the most protection. A repeatable method of characterizing snowboard wrist protectors is required to help identify products which reduce injury risks. The specific injury mechanisms of wrist fractures in

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snowboard fall scenarios is not well understood, however, mainly due to the complexity of the wrist joint and limited availability of cadavers for testing.

Some researchers state that snowboard wrist protectors should attenuate impact forces, absorb or shunt the impact energy away from the wrist and prevent hyperextension [8,9]. Whilst Maurel et al. [10] argue that there is no real literature basis for whether or not the prevention of hyperextension reduces the risk of fracture. A common approach to protector design is to include features intended to limit hyperextension, such as rigid splints on the palm and dorsal sides of the wrist. It is, therefore, deemed important to be able to assess the ability of protectors to resist wrist extension under an applied load. This paper presents a mechanical test for assessing the ability of snowboard wrist protectors to resist wrist extension.

1.1. EN 14120:2003 bending test

The international standard EN 14120:2003 [11], prescribes requirements that roller sports wrist protectors should meet. The standard includes a bending test to determine protector stiffness when fitted to a simplified hand and forearm surrogate. Schmitt et al. [12] deemed this test to be a suitable starting point for characterizing snowboard wrist protectors. It is unclear, however, how the size of the hand corresponds with published anthropometric data [e.g. 13] and three dimensions are missing from the drawing provided in the standard (a, b and c in Figure 1a). There are also a number of issues with the test protocol and setup as outlined below.

Protectors are deemed sufficiently stiff if the hand angle is between 35 to 55° when a 3 Nm torque is applied. Figure 1b illustrates the test setup, where angles greater than 45° cannot actually be reached as the load applicator would no longer be in contact with the hand. The suitability of transferring test parameters from a roller sports context to snowboarding is also questionable. For example, during an on-slope study measuring wrist moment and hyperextension, Greenwald et al. [14] observed extension angles 76.8 ± 15.8° (mean and standard deviation) at wrist moments of 15.9 ± 20.7 Nm in snowboard falls which didn't result in injury. These values are significantly higher than those currently used in the roller sports standard implying that higher thresholds might be more appropriate for snowboarders. The protocol also fails to state how tightly protectors should be strapped to the surrogate and the rate at which the load should be applied, which could lead to inconsistent results between operators.

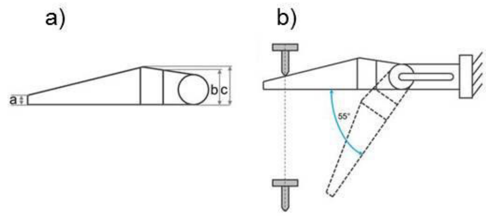

Fig. 1. a) Missing hand dimensions (a, b, c) and b) Schematic of EN 14120:2003 bending test (adapted from European Committee for Standardization, 2003)

This paper uses the surrogate from EN 14120:2003 and presents a method which is more appropriate for testing snowboard wrist protectors. A uniaxial testing machine (Instron 3367, fitted with a 5 kN load cell) and bespoke rig was used to apply an angular displacement to the hand while measuring load. The results for three protector designs are presented to demonstrate the method.

2. Methods

2.1. Test Setup

The experimental procedure is based on the approach described in EN 14120:2003, with modifications to the setup and testing protocol. The hand and forearm sections of the surrogate were made from plastic using additive manufacturing, based on the dimensions specified in EN 14120:2003 for range C users (>50kg). Assumptions were made for the three hand dimensions missing from the standard (a = 15 mm, b = 38 mm, c = 40 mm (Figure 1a)), based on approximations from the other dimensions. Figure 2a shows the test setup, which converted linear displacement of the uniaxial test machine to angular displacement of the hand. In contrast to Schmitt et al. [12] where angles were only obtained for torques of 3 and 16 Nm, the new setup enables load to be measured across a range of hand angles.

The rig consists of a low friction pulley and a mounting fixture to hold the forearm of the surrogate in a vertical position. The rig was mounted to the Instron machine via the flexure fixture and positioned with a galvanized steel cable (diameter 1.9mm) running vertically from the load cell through the pulley. The cable was connected to the load cell at one end via a cable lock (Rize Enterprises, USA) and the distal end of the hand via a karabiner at the other. Through vertical displacement of the load cell, a torque was applied around the wrist joint pulling the hand backwards. A tensile test of the cable resulted in a strain of <0.01 at 80 N (maximum load in the protector tests), confirming extension of the cable did not influence the results of the protector test.