Ice hockey boards: how to assess the biomechanical loading of a player upon impact?

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I. INTRODUCTION

Ice hockey is a sport in which injuries occur frequently, with injuries sustained through board contact accounting for approximately 20–40% of all injuries sustained [1-3]. There are indications that improved ice hockey boards could significantly reduce injury risk, by virtue of a design that reduces the biomechanical loading of a player at impact [4-6]. Today, ice hockey board systems consist of the actual board element and a transparent shielding. While some requirements regarding the geometry are defined, performance criteria related to an impact of a player or standardised impact tests currently do not exist. One option to investigate the impact dynamics of a board is the performance of pendulum tests [e.g. 7]. Such tests determine the displacement of a board system, as well as its stiffness and energy absorption characteristics. However, it remains unclear to what extent these parameters are linked to the injury risk. Therefore, a test series was conducted using crash test dummies.

II. METHODS

Six commercially available board systems were tested in a laboratory setting. We tested all systems with synthetic shielding, plus two with glass shielding, i.e. a total of eight configurations were used. Three elements of each system were mounted in a straight configuration; all impacts were performed on the element in the centre. The boards were instrumented with two displacement sensors: one at 1 m above ground (board area), and another at 1.4 m above ground (shielding area). Additionally, an accelerometer was mounted 1 m above ground. All tests were recorded by high-speed cameras.

Pendulum impact testing

The pendulum tests were performed in line with the procedure described in [7]. A pendulum of 60 kg impacted the systems at 1.0 m (board area) and 1.4 m (shielding area) above ground. Impact velocities were chosen at $v1=3.37$ m/s, as in [6], and $v2=4.76$ m/s. Outcomes of these tests included measurements of the displacement (at 1.0 m and at 1.4 m), the stiffness of the boards, the effective mass, the rebound velocity and the overall energy absorption.

Crash test dummy testing

For these tests, an ES-2 dummy (Humanetics®, Plymouth, USA) was used with standard instrumentation. The dummy was positioned on a sled, which was accelerated and then stopped shortly before the board (Fig. 1), at which point the dummy was released, impacting the board at a velocity of 4.76 m/s. Two dummy positions were used: an upright position, representing a standing player impacting the board (e.g. resulting from a body check); and a forward inclined position. For some tests, the dummy was equipped with personal protective equipment, as is usually worn in ice hockey games. In addition to recording the displacement of the board, the biomechanical loadings were also determined in terms of head acceleration and head injury criterion (HIC), shoulder forces, compression of the ribs, viscous criterion (VC), abdominal force, acceleration/forces/moments of the lower spine, acceleration of the pelvis and the pubic symphysis force.

III. INITIAL FINDINGS

As expected, the pendulum tests resulted in repeatable results. The displacement of the boards, as determined by the pendulum tests, was comparable to the displacement obtained in tests using the dummy in the upright position (i.e. covering board and shielding). Thus a pendulum mass of 60 kg and the effective mass

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Fig. 1. Dummy impact on an ice hockey board with the dummy in the upright position (top) and in the forward inclined position (bottom).

of the impacting dummy seem to correspond well. The dummy experiments allowed us to record the biomechanical loading of different body regions. Comparing the results with threshold values commonly used in the automotive environment (e.g. HIC=1000, VC=1.0) showed that basically all values were well below these criteria. However, despite similar displacement of the board, different board designs clearly resulted in different biomechanical loading. There was no correlation between measurements such as the HIC and the board displacement.

IV. DISCUSSION

Pendulum impact tests are a straightforward and fairly simple method in impact testing, but the insight gained from such tests is limited. Displacement of ice hockey boards is often presented as a measure to characterise the flexibility of a design, implying that a larger displacement is related to a lower injury risk. In contrast, performing impact tests with a crash test dummy reveals that even boards that exhibit a larger displacement than other products do not necessarily result in a lower biomechanical loading. From a methodological perspective, it was shown in this study that the application of dynamic testing using crash test dummies results in relevant additional information that cannot be retrieved by pendulum tests. Based on the dummy experiments, the performance of different board systems can be assessed and rated. Such a procedure seems appropriate in the context of a performance standard for ice hockey boards, to ensure a certain impact performance and to encourage designs that reduce the injury risk of an impacting player. However, the evaluation of the dummy experiments based on threshold values from the automotive environment can be questioned as these values are more related to life-threatening injury. More adequate reference values should be considered for the assessment of sports-related injury. Likewise, the impact conditions used here are subject to discussion. Generally, however, the sole use of pendulum impact tests seems too limited to capture all relevant parameters to assess the injury risk due to impacts to a board.

V. REFERENCES

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