Laboratory evaluation of in-ear sensor systems for quantifying head impact exposure in contact sports

Sandmo SB, Andersen TE, McIntosh AS, Koerte IK, Bahr R

Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, 0806 Oslo, NORWAY

Introduction

Wearable sensor systems may be useful for quantifying head impact exposure in athletes. However, the development of valid head-mounted sensors for non-helmeted sports such as soccer has proven difficult due to poor coupling of the device to the head.

Aim

The aim of this study was to test the validity of a new in-ear sensor for quantifying head impacts in contact sports.

Methods

The in-ear sensor MV1 (MVTrak, Durham, NC, USA) was assessed in a laboratory setting by mounting it in the ear region of a Hybrid III (HIII) head and neck assembly. The HIII was instrumented with a triaxial linear accelerometer and triaxial angular velocity sensor array; angular acceleration was derived from angular velocity. HIII-measured impact characteristics were considered reference values. The HIII was impacted with either a linear impactor or a football at five different locations and a range of speeds. Peak resultant values for linear acceleration (PLA), rotational acceleration (PRA) and rotational velocity (PRV) were obtained for each impact from both systems. To estimate the accuracy of the MV1 sensor, its method error ($^{SDmean\ diff/\sqrt{2}}/_{combined\ means/2}$*100) was calculated as an expression of the random error and mean difference ($^{meandiff}/_{meanHIII}$*100) as an expression of the systematic error.

Figure 1. Mounting of the MV1, testing both an in-ear (left) and a flat mounting configuration (middle). Shown to the right is an example of a setup for right frontal impacts with a padded impactor striking from a 45 degree angle.

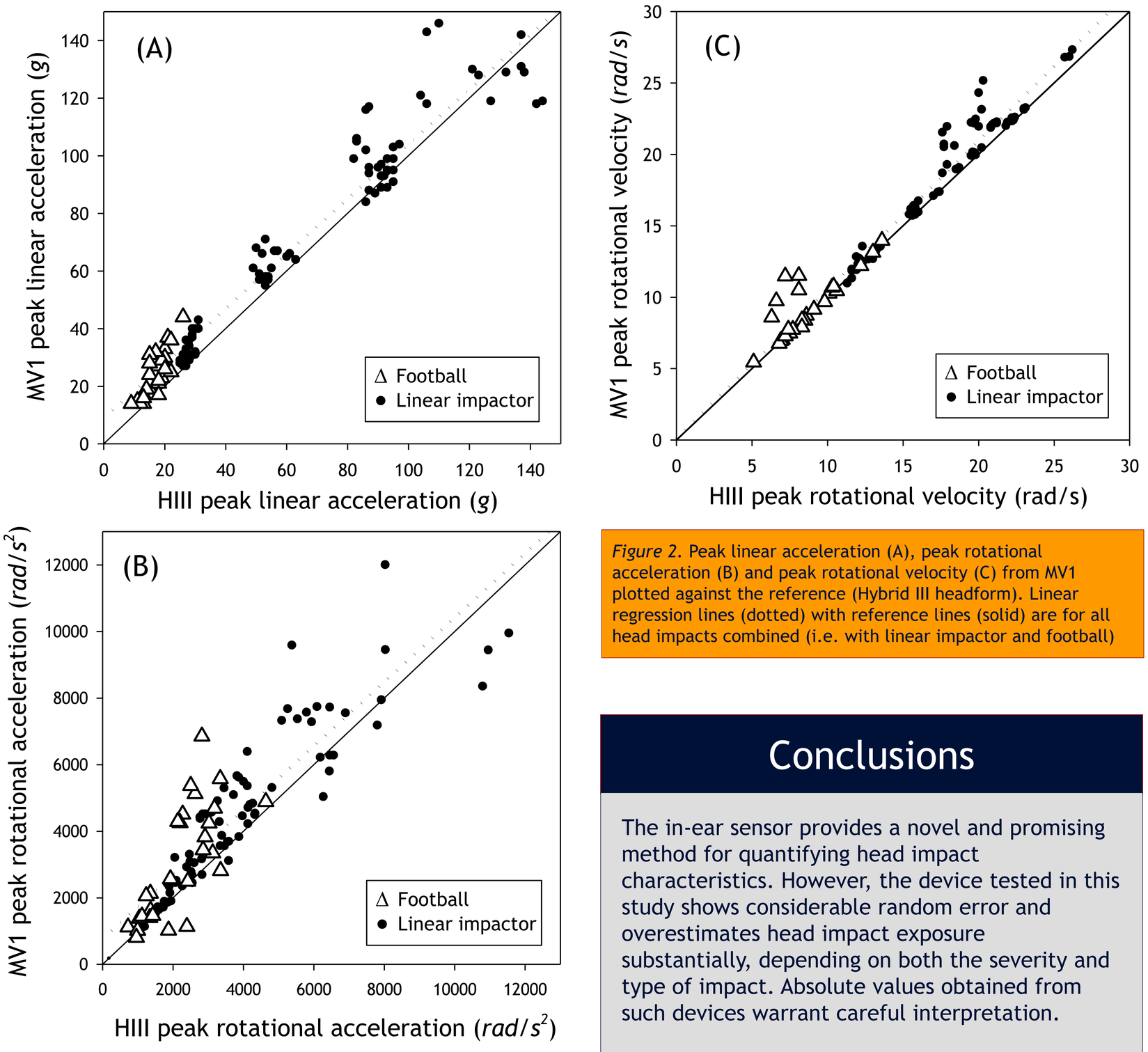

Figure 2. Peak linear acceleration (A), peak rotational acceleration (B) and peak rotational velocity (C) from MV1 plotted against the reference (Hybrid III headform). Linear regression lines (dotted) with reference lines (solid) are for all head impacts combined (i.e. with linear impactor and football)

Results

A total of 112 impacts were recorded (HIII PLA range: 9-144g). The random error for all impacts was 11% for PLA, 20% for PRA and 5% for PRV. The systematic error was 11% for PLA, 19% for PRA and 5% for PRV. The random error was higher for football impacts (n=29) than for the linear impactor (n=83):

- PLA: 18% vs. 10%
- PRA: 33% vs. 18%
- PRV: 10% vs. 5%

The same pattern was seen for the systematic error:

- PLA: 45% vs. 8%
- PRA 39% vs. 15%
- PRV 7% vs. 4%

The greatest error for all peak values was for right frontal impacts with the football, with a systematic error of 67% for PLA.

Conclusions

The in-ear sensor provides a novel and promising method for quantifying head impact characteristics. However, the device tested in this study shows considerable random error and overestimates head impact exposure substantially, depending on both the severity and type of impact. Absolute values obtained from such devices warrant careful interpretation.

References

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