On-field evaluation of in-ear sensor systems for quantifying repetitive head impacts in youth soccer

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Introduction

Wearable sensor systems have the potential to quantify head kinematic responses of head impacts in soccer. However, on-field use of sensors, e.g. accelerometers, remains challenging, due to poor coupling to the head and difficulties discriminating low-severity direct head impacts from inertial loading of the head from human movements, such as jumping and landing.

Novel in-ear sensors have been designed to combat these challenges, but on-field evaluation is needed before usage in prospective studies.

Aims

The aims of this study were to test the on-field ability of a new in-ear sensor to quantify head impacts in youth soccer and to discriminate head impacts from other non-head impact accelerative events.

Methods

Six male youth soccer players (15.3±0.29 years) were instrumented with custom-moulded in-ear sensors (MV1, MVTrak, Durham, NC, USA) and completed a structured training protocol consisting of five heading and six non-heading exercise drills typical in soccer. Additionally, they completed two regular training sessions with their team.

For each nominal head impact event recorded by the MV1, peak linear acceleration (PLA), peak rotational acceleration (PRA) and peak rotational velocity (PRV) were obtained from the sensors, and classified by comparison with video recordings. Mean values ± SD were calculated for (1) all heading and (2) all non-heading events, and receiver operating characteristic (ROC) curves were constructed to determine the discriminatory capacity of the sensors. This was done separately for the structured training protocol and regular training sessions.

Sensitivity and positive predictive value were calculated in both settings according to different cut-off values identified from the ROC curve, to investigate sensor performance in settings without other verification means.

Results

Structured training protocol:
Heading events (n=431) resulted in higher average values for all three variables compared to non-heading events (n=750):

- PLA: 15.6±11.8 g vs. 4.6±1.2 g
- PRA: 10543±10854 rad/s^2 vs. 1095±823 rad/s^2
- PRV: 35.1±18.3 rad/s vs. 9.8±4.6 rad/s

ROC curve analyses revealed an area under the curve (AUC) of 0.98 for PLA, 0.99 for PRA and 0.97 for PRV.

Regular training sessions:
In total, 2039 nominal head impact events were recorded from the MV1. Of these, 15 events were confirmed to be direct head impacts (PLA=20.7±10.6 g; PRA=14541±7994 rad/s^2; PRV=43.5±16.4 rad/s), all of them due to heading the ball. The remaining 2024 were triggered by jumping, tackling, touching the sensor etc. (PLA=4.0±3.1 g; PRA=835±2541 rad/s^2; PRV=7.4±4.9 rad/s).

ROC curve analyses revealed an AUC of >0.99 for both PLA, PRA and PRV.

Table 1. MV1 sensitivity and positive predictive value for classifying accelerative events as head impacts (i.e. headers) or non-head impacts for different peak linear acceleration (g) cut-off values.

	Sensitivity (%)		Positive predictive value (%)	
Cut-off value *(g)*	Structured protocol	Regular training	Structured protocol	Regular training
>6	96	100	82	22
>7	90	93	93	37
>8	83	87	98	50
>9	73	87	100	65
>10	65	87	100	68

Conclusions

The in-ear sensor shows excellent on-field accuracy for discriminating headings from non-head impact accelerative events in youth soccer. However, there is still a need for secondary means of verification (e.g. video analysis) in real-life settings.

The kinematic values obtained for heading events were greater than expected, and should be interpreted with caution.

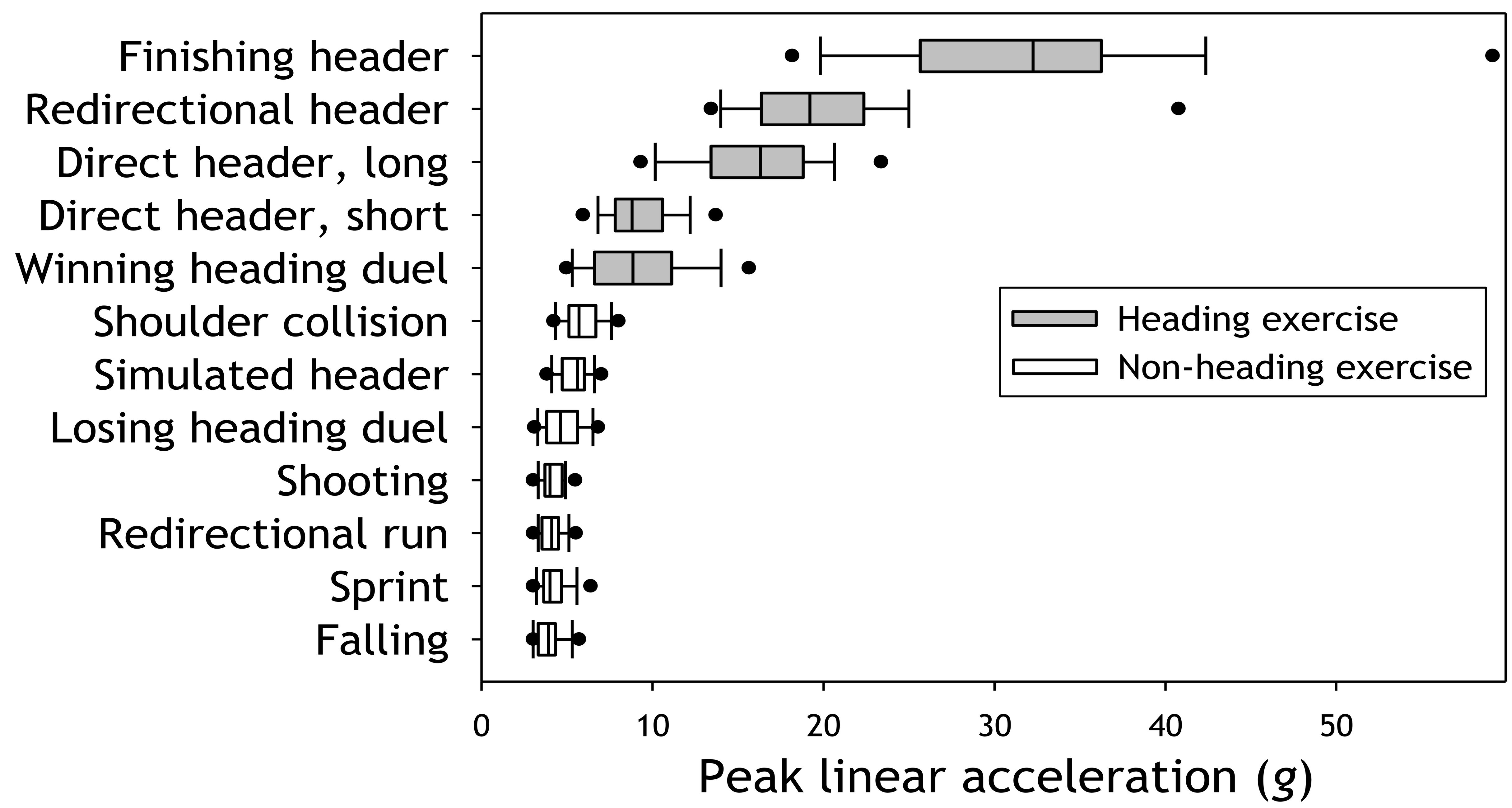

Figure 1. Box-plots showing median value and interquartile range of peak linear acceleration from MV1 for the exercises from the structured training protocol. The left and right markers are for the 5th and 95th percentile, respectively.

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