NORGES IDRETTSHØGSKOLE

Evaluation of an in-ear sensor system for quantifying repetitive head impacts in youth soccer

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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 e.g. poor coupling of the device to the head.

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

Aim

The aim of this study was to test the validity of an in-ear sensor for quantifying head impacts in youth soccer.

Methods

Phase 1 (laboratory testing):
The in-ear sensor (MV1, MVTrak, Durham, NC, USA) was mounted to a Hybrid III headform (HIII) and impacted with a linear impactor or soccer ball. Peak linear acceleration (PLA), peak rotational acceleration (PRA) and peak rotational velocity (PRV) were obtained from both systems; random and systematic error of the in-ear sensor were calculated using HIII as reference.

Phases 2 and 3 (on-field testing):
Six youth soccer players (15.3±0.29 years) were instrumented with custom-moulded in-ear sensors and completed a structured training protocol including heading and non-heading exercises (phase 2). The same six players also completed two regular training sessions with their team (phase 3).

For each accelerative event recorded by the sensor, PLA, PRA and PRV outputs were compared to video recordings. Receiver operating characteristic curves were used to determine the sensor's discriminatory capacity; this was done separately for phases 2 and 3.

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

Results

Phase 1 (laboratory testing):
A total of 112 impacts were recorded (HIII PLA range: 9-144 g). The random error was 11% for PLA, 20% for PRA and 5% for PRV; the systematic error was 11%, 19% and 5%, respectively.

Phase 2 (controlled on-field testing):
Heading events (n=431; PLA=15.6±11.8 g) resulted in higher average values than non-heading events (n=750; PLA= 4.6±1.2 g). ROC curve analyses revealed an area under the curve (AUC) of 0.98 for PLA, 0.99 for PRA and 0.97 for PRV.

Phase 3 (real-life on-field testing):
Out of the 2039 accelerative events recorded from the MV1, 15 events were confirmed to be direct head impacts (PLA=20.7±10.6 g),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.

Cut-off value *(g)*	Sensitivity (%)		Positive predictive value (%)	
	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 sensor displayed considerable random error and overestimated head impact exposure substantially in laboratory settings.

On-field accuracy for discriminating headings from other accelerative events was excellent, but secondary means of verifying events (e.g. video analysis) are still necessary in real-life settings due to poor positive predictive value.

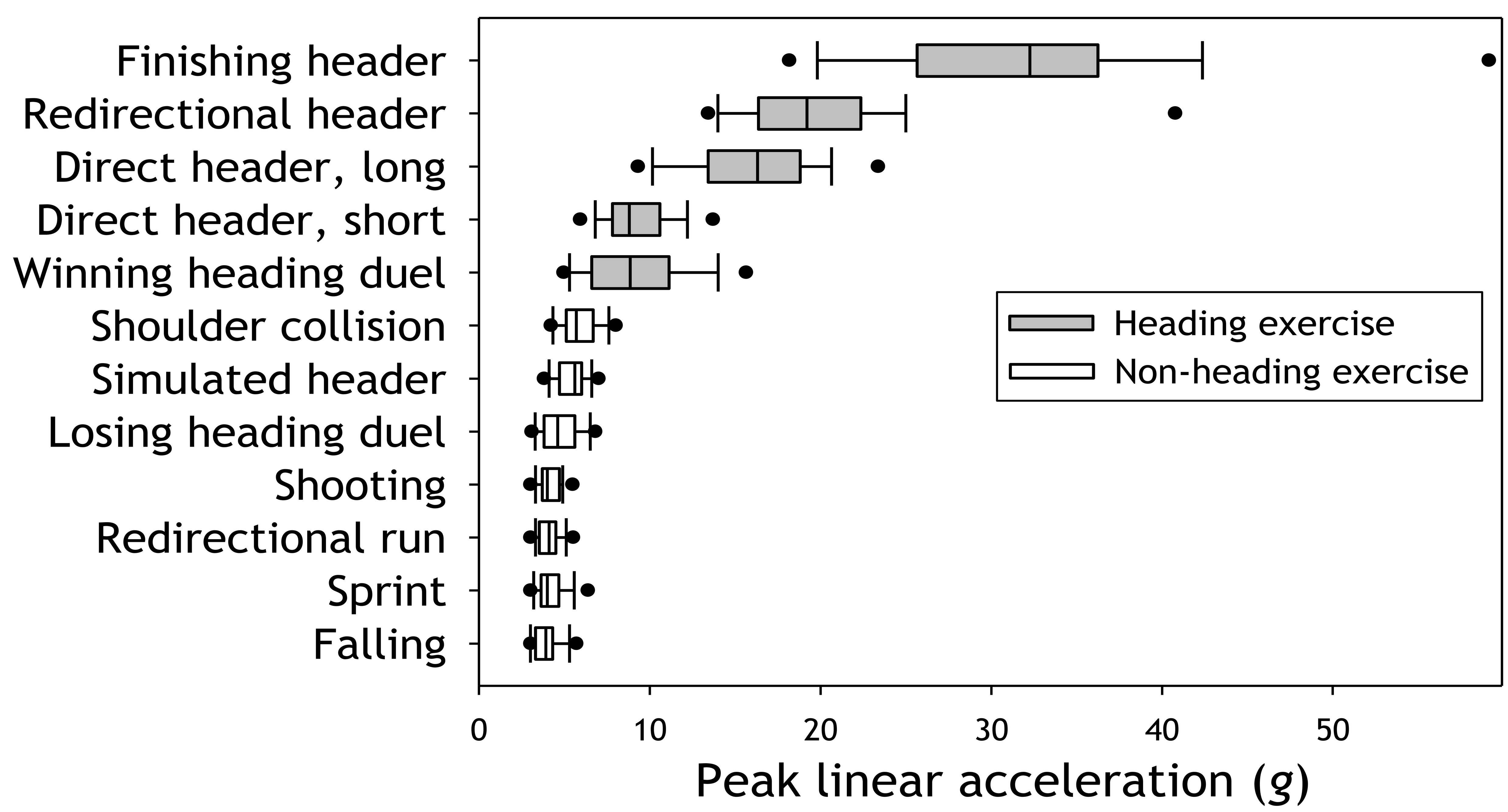

Figure 1. Box-plots showing median value and interquartile range of peak linear acceleration from MV1 for the exercises from the structured training protocol. The left and right markers are for the 5th and 95th percentile, respectively.

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