HEAD ACCELERATION EVENTS USING INSTRUMENTED MOUTHGUARDS IN FEMALE RINGETTE PLAYERS

Kenzie B. Friesen[1], Emily Hemming[1], Chris Dennison[2], Reed Ferber[1], Carolyn Emery[1].

[1]University of Calgary, Calgary, Alberta, Canada. [2]University of Victoria, Victoria, British Columbia, Canada.

Ringette is a contact sport which prompts high rates of head contacts and concussion, some of the highest reported rates in youth sport. Biomechanical forces at the head can cause concussion injury, therefore examination of head acceleration events and head biomechanics during ringette is useful to understand injury risk and mechanism. The purpose of this study was to describe head acceleration events (HAEs) in female youth ringette players and examine head biomechanics during video-verified head acceleration events. Instrumented mouthguards were worn by 8 players and 36 video-verified HAEs were accumulated from in-game exposure. Results indicate athletes sustain HAEs from both direct and indirect head contacts. Mann Whitney U tests reveal no significant differences in biomechanics between direct and indirect HAEs. Most direct head impacts were related to mechanism of head-head contacts or head contact with the boards and typically involved impact high on the head. Indirect HAEs were usually due to whiplash or stabilization. Data also show most HAEs result from deliberate physical contacts initiated by non-ring carriers. Future work with greater data accumulation and verification of head acceleration events can inform coaches and players on the risks of head injury associated with specific mechanisms.

KEYWORDS: ADOLESCENT, BIOMECHANICS, CONTACT SPORT, CONCUSSION, INJURY

INTRODUCTION: Concussion injuries are traumatic brain injuries induced by biomechanical forces that result from either direct or indirect contacts to the head (McCrory et al., 2017). While concussions typically resolve spontaneously within one week, concussions can have detrimental and long-lasting symptoms (McCrory et al., 2017). As a result, concussion prevention is important, especially among vulnerable populations, including youth. Ringette is a popular sport in Canada and players regularly accrue high rates of head contact and suspected injury (Heming et al., 2022). Varsity ringette players sustain approximately 18 head contacts/100 team minutes – about a 68% higher rate of total head contacts than during female ice hockey (Heming et al., 2022). Given the high rates of contact and potential for concussion in ringette, injury epidemiology research has used video analysis to investigate injury risk and mechanisms in ringette. While video analysis is useful, it does not fully describe the observed impacts, which limits our understanding of injury. Wearable technology can uniquely assess head biomechanics in response to forces applied to the head or body. Measurement of biomechanical forces sustained by athletes in response to an impact or other event can provide further evidence for injury risk and mechanisms to ideally inform safe practice and policy.

Specifically instrumented mouthguards (iMGs), are a useful tool for in-game tracking of player biomechanics to assess injury propensity in realistic contexts. iMGs are inertial measuring units which measure head biomechanics when worn. iMGs have been used in combat sports, various football types, rugby, ice hockey, lacrosse, soccer, and water polo (Le Flao, Siegmund, & Borotkanics, 2022). Ringette player head acceleration events (HAEs) in response to stimuli have yet to be studied with use of iMGs despite the high injury risk present in ringette. Therefore, the objectives of this study were to 1) describe angular and linear velocity and acceleration of HAEs with iMGs in female youth ringette players, 2) compare direct vs. indirect HAEs, and 3) examine mechanism of contact associated with HAEs via video verification.

METHODS: Eight female U16 youth ringette players (ages 15.1 ± 0.5 years) agreed to participate and parental consent and player assent was obtained. Ringette players wore iMGs during a portion of their 2021-2022 ringette season; although there was a high rate of attrition given mouthguard use is not mandatory. Instrumented boil-and-bite mouthguards from Prevent

Biometrics® were used to measure head biomechanics during HAEs. The iMGs fit with triaxial accelerometers and gyroscopes measure linear and angular velocity and acceleration. Also, an embedded proximity sensor ensures data were gathered only while the iMG was tightly coupled with the upper dentition of the athlete. Data were gathered when a 5g threshold trigger was surpassed on any individual accelerometer (Le Flao, 2022). The iMGs gathered data at 3.2 kHz for a 50 ms frame (10ms pre-trigger and 40ms post-trigger). Biomechanics were extracted for assessment including peak resultant linear acceleration, peak resultant angular acceleration, peak resultant linear velocity, and peak resultant angular velocity. Prevent Biometrics® iMGs are validated for use during on-field measurements and show an on-field positive predictive value of 81.6% during active play time in football (Jones et al., 2022; Kieffer et al., 2020; Liu et al., 2020; Tooby et al., 2022).

Ringette games were recorded with a standard video camera (Panasonic HD 1080p) and loaded into Dartfish Version 10.0 video-analysis software. Mouthguard data were date and time stamped and synced according to a world clock shown on video to match HAEs measured with the iMGs with on-ice characteristics recorded via video. HAEs were first coded by one trained researcher to examine the validity of the HAE based on video. Valid HAEs needed to occur on camera and with evidence of an inciting event to cause a HAE. The coder then used video to determine if the HAE was direct (contact occurred straight to the head) or indirect (non-direct to the head). Finally, for direct HAEs, video analysis confirmed what object provided the impact and head location of the impact was also video verified. For indirect HAEs, video determined type of HAE response: whiplash (forward/backward movement relative to the shoulders), rotation (whiplash type movement but in the transverse plane relative to the shoulders), stabilizing (very little/no visible movement of the head on camera), and/or jarring (short-duration movement where the head visibly moves but returns to its original position).

All head acceleration events were coded by one researcher with excellent reliability (≥ 90%) in deciphering ringette game and contact events. With use of Dartfish's custom tagging panel, the trained analyzer coded variables of interest from video including: period of play (1-2), who initiated the contact that resulted in the HAE (team with possession of the ring or the team without possession of the ring), location on the ice of the HAE (zones 1-4), whether the contact was deliberate or not, intensity of contacts made by the trunk (levels 1-5), contact type (contact occurred by trunk, limb, or stick), if contact was by the ring carrier or not, and if contact was from opponent or not. Physical contact definitions (Malenfant et al., 2012) and ice locations were based on prior work (Heming et al., 2022).

RESULTS and DISCUSSION: A total of 66 HAEs were recorded with the iMGs above a 5 g single-axis accelerometer threshold. After video-verification, several HAEs were considered false positives. Four HAEs were duplicates, seven occurred during a camera malfunction and could not be video-verified, six occurred before or after game play, five occurred off camera, four were not able to be found due to time-syncing issues, and four were shown on camera but not considered HAE as no head acceleration was observed and there was no inciting event. The five off-camera HAEs were considered false positives as video followed the play of action. However, it could be that the five off-camera HAEs could be true, but not directly related to the ringette play at hand. As a result, 36 video-verified HAEs were included in the analysis and considered true positive HAEs. A frequency analysis of HAE type and mechanism was completed (Table 1). Mean, standard deviation, and confidence intervals were calculated for peak variables of peak linear and angular velocity and acceleration (Table 2). Mann Whitney U tests were conducted to compare direct and indirect HAEs biomechanics and no statistically significant differences were found (p>.05).

Table 1: Frequency and proportion of video-verified head acceleration events (n = 36).

Head Acceleration Events (HAEs) Descriptors	Frequency (%)	Proportion
Direct HAEs	42%	15/36
Contact from:		
Head	33%	5/15
Shoulder	7%	1/15
Elbow	7%	1/15

Ice	13%	2/15
Implement (stick or ring)	7%	1/15
Boards	27%	4/15
Head Location		
High	80%	12/15
Low	20%	3/15
Indirect HAEs	58%	21/36
Whiplash	5%	1/21
Rotation	10%	2/21
Stabilizing	67%	14/21
Jarring	19%	4/21
Period of Play		
1	44%	16/36
2	56%	20/36
Player Who Initiated the Contact		
Player With Ring	17%	6/36
Player Without Ring	83%	30/36
Location on the Ice		
Along the side boards	28%	10/36
Open ice	42%	15/36
Behind net	17%	6/36
In front of net	14%	5/36
Intentionality		
Deliberate	78%	28/36
Non-deliberate	22%	8/36
Intensity of Trunk Contacts (n = 28)		
1	0%	0/28
2	21%	6/28
3	39%	11/28
4	39%	11/28
5	0%	0/28
Contact type		
Trunk	78%	28/36
Limb	14%	5/36
Stick	8%	3/36
Contact by:		
Ring carrier	83%	30/36
Not ring carrier	17%	6/36
Contact from:		
Opponent	97%	35/36
Same team	3%	1/36

Notes: Intentionality; Deliberate: purposeful intent to contact another player, Non-deliberate: accidental contact. Intensity of trunk contact level descriptions; Level 1: very light contact between two stationary players; Level 2: light contact between two players moving in the same relative direction; Level 3: moderate contact between two players moving in the same relative direction; Level 4: heavy contact, with one player forcefully exerting one's body into the opposing player, usually moving in the opposite direction; Level 5: Excessive, deliberate contact from one player with the intention beyond impeding the progress of the opponent, moving in the opposite direction. Contact Type; refers to the object that made contact with the player who experienced the HAE. Contact by; refers to whether the contact was on the player with the ring or not.

Table 2. Mean ± standard deviation (Confidence Intervals) for direct and indirect head acceleration events (HAEs).

	PLV (m/s)	PAV (rad/s)	PLA (g)	PAA (rad/s2)
Direct HAEs (n=15)	0.8 ± 0.4 (0.6 – 1.0)	5.7 ± 3.9 (3.6 – 7.9)	11.4 ± 5.8 (8.2 – 14.6)	760 ± 441 (516 – 1005)
Indirect HAEs (n=21)	0.1 ± 0.2 (0.6 - 0.9)	5.4 ± 3.6 (3.7 – 7.0)	8.7 ± 3.3 (8.2 – 11.4)	521 ± 368 (353 – 688)

Note: PLV, peak linear velocity; PAV, peak angular velocity; PLA, peak linear acceleration; PAA, peak angular acceleration.

iMGs synced with video analysis can provide evidence of mechanism of HAEs that occur within female ringette players. Considering the high rate of concussion and physical contacts associated with ringette (Heming et al., 2022), understanding of head biomechanics and risk of concussion is necessary. Exploration of data reveals HAEs are from both direct and indirect head contacts with no significant differences shown in biomechanics between direct and indirect HAEs. Of note, there appears to be a wider confidence interval for those HAEs that are direct to the head, indicative of the greater variety of what direct head impacts might encompass. Frequency analysis shows that most direct head impacts were related to mechanism of head-head contacts or contact with the boards and typically involved impact high on the head. Indirect HAEs were usually due to whiplash or stabilization. Data also shows that most contacts involve the ring carrier while players whose team was without the ring initiated most HAEs, potentially indicative of the more physical style of play among those players who were eager to get the ring back. Opponents also provided most of the contacts as opposed to players from the same team. In terms of HAE on ice location, data shows HAEs often occurred near the boards or in open ice areas versus near the net; therefore, it can be assumed that these locations pose a higher risk of head injury. Majority of HAEs were due to deliberate contacts and trunk contacts included intensities largely in the 3-4 out of 5 range. The higher range intensity of contacts recorded by the iMG is likely due to the minimum 5g threshold requirement for the iMG to register a HAE. Limitations exist and should be acknowledged. Most HAEs came from a few players who were most keen on wearing the mouthguards despite their elective use. Therefore, it could be that the habits of the players wearing the mouthguards influenced the results. Given mouthguards are not mandatory for this sport and age group, many players opted not to wear the iMGs during the season resulting in a low number of recorded HAEs. Due to lower numbers, this is an exploratory analysis and more data is needed to run thorough statistical analyses. Further, the study population being youth limits the generalizability of this data to other more experienced/elite levels of play. More research is needed to adequately inform players, coaches, and clinicians regarding the mechanisms and rates of concussion in youth ringette.

CONCLUSION: HAEs measured via iMGs and verified with video reveal the specific situations in which players might accrue a head injury. Data shows most HAEs result from deliberate contacts initiated by non-ring carriers. Future work with greater data accumulation and verification of HAEs can inform coaches and players on the risks of head injury associated with specific mechanisms.

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