GENDER DIFFERENCES IN HEAD IMPACT ACCELERATION IN COLLEGIATE ICE HOCKEY

[1]Lindley L. Brainard, [1]Jonathan G. Beckwith, [1]Jeffrey J. Chu, [3]Joseph J. Crisco, [4]Thomas W. McAllister, [4]Ann-Christine Duhaime, [4]Arthur C. Maerlender, [5]Stefan Duma, [6]Gunnar Brolinson and [1,2]Richard M. Greenwald

[1]Simbex, Lebanon, New Hampshire, [2] Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, [3]Alpert School of Medicine of Brown University/Rhode Island Hospital, Providence, Rhode Island, [4]Dartmouth Medical School, Lebanon, New Hampshire, [5]Virginia Tech, Wake Forest Center for Injury Biomechanics, Blacksburg, Virginia, [6]Edward Via College of Osteopathic Medicine, Blacksburg, Virginia
Email: lbrainard@simbex.com, Web: http://www.simbex.com

INTRODUCTION

In 2003, the Center for Disease Control and Prevention concluded that over 1.2 million instances of sports related mild traumatic brain injury (mTBI), or concussion, are reported annually in the United States, with the actual number of injuries probably much higher due to under-reporting [1]. Athletes participating in helmeted sports at the collegiate level are frequently exposed to direct head impacts, creating a unique cohort of subjects to study the relationship between impact exposure and concussion. Epidemiological studies of collegiate athletes have suggested concussion rates for females are higher than their male counterparts [2]. There are no data available comparing head impact exposures between male and female athletes. Head Impact Telemetry (HIT) technology (Simbex, Lebanon NH) was developed to measure the location and severity of head impacts sustained during helmeted team sports without affecting play. This technology previously has been used to quantify head impacts sustained by junior level male hockey players [3] and provides an ideal method for exploring the role of gender with respect to mTBI. This study aims to quantify the differences in severity and location of head impacts experienced by male and female collegiate ice hockey players.

METHODS

On-ice head impact data from 3 NCAA Division I hockey teams (one male, two female) were collected from every practice and competition, defined as contact sessions, during the 2008-2009 season. Participating athletes wore helmets equipped with 6 single-axis accelerometers which measure and record head impacts in real-time [4]. Data collected from the helmets were post-processed to compute linear and angular acceleration of the head as well as impact location. All impacts were categorized into one of five location groups (Top, Left, Right, Back and Front). Two-sample t-tests ($\alpha = 0.05$) were conducted to assess differences by gender for impact frequency, impact location, and maximum recorded peak linear and angular acceleration.

RESULTS AND DISCUSSION

A total of 9,790 impacts were collected from 41 female and 10 male hockey players. Female and male athletes participated in 111 ± 17 and 95 ± 5 contact sessions, respectively, where the mean number of impacts sustained by female subjects during each session was significantly lower than males (1.5 ± 0.7 vs 3.2 ± 1.4, $p < 0.001$). Male

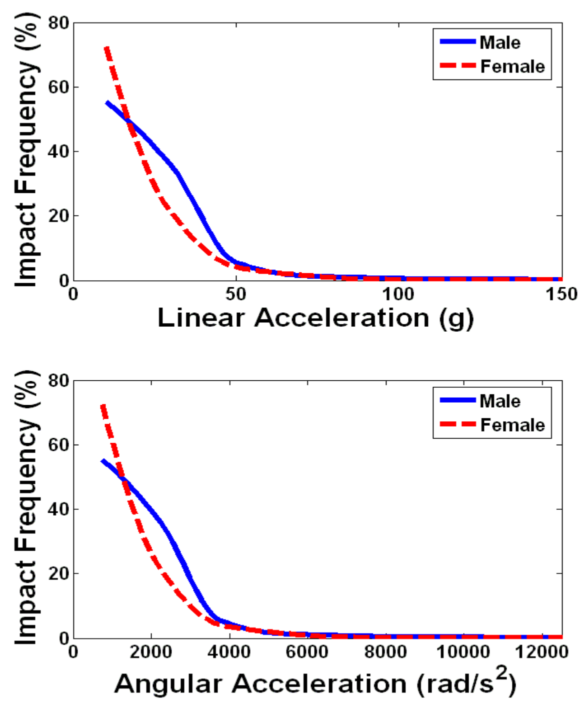

Figure 1: The frequency of more severe impacts was higher in male hockey players than in female hockey players.

hockey players had higher resultant linear and angular head accelerations than female hockey players (Figure 1). Distributions of impacts by peak linear and peak angular acceleration were not normally distributed, with 95% of all impacts less than 50g and 5,183 rad/s^2 for males, and less than 45g and 3,786 rad/s^2 for females. The top 1, 2, and 5 percentiles of all impacts, for both linear and angular acceleration, were significantly higher ($p < 0.001$) for males than females (Table 1).

Multiple t-tests were performed to compare impact locations by gender. The frequency of impacts by location was the same between male and female subjects ($p > 0.22$) for all locations except the top of the head, where males received fewer impacts than females (Figure 2). The highest percentage of impacts for both men and women occurred to the front and back of the head (Front - 32%M, 28%F; Back - 36%M, 33%F), while impacts to the Top (3%M, 9%F) were relatively infrequent, compared to the other locations.

The differences in impact frequency and magnitude between male and female hockey players could reflect differences in speed, body weight, and allowable contact in the respective games. The similarity of impact location distribution between gender may simply be a characteristic of the sport of hockey. It is important to note that these impact data do not necessarily correlate with resultant anatomic or functional tissue injury or symptomatology, which likely depends on a complex interaction between host and biomechanical factors, including brain mass and physiology.

CONCLUSIONS

Male athletes sustained higher numbers of head impacts per session with higher head acceleration than their female counterparts. The relationships among head impact biomechanical variables and the

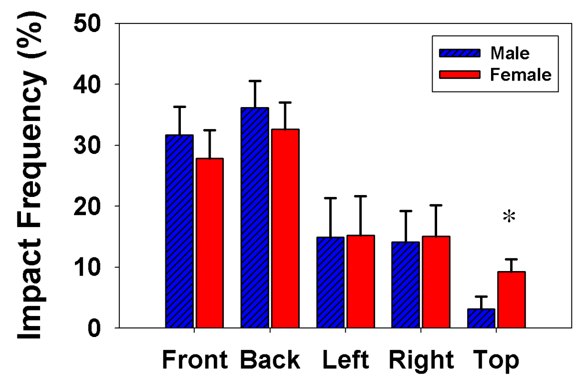

Figure 2: Frequency of head impacts by location for male and female collegiate hockey players. (* $p < 0.05$)

incidence and severity of concussions are unknown. Understanding the intrinsic and extrinsic risk factors that differentiate head impact biomechanics experienced by male and female athletes may lead to increased understanding of the mechanisms causing concussion and other long-term effects, which in turn could lead to improved standards, equipment design and guidelines for diagnosing and treating concussions on an individual basis.

REFERENCES

1. Gerbeding JL et al. *Center for Disease Control and Prevention*. 1-5, 2003.
2. Agel, J et al, *Journal of Athletic Trainers.* 42(2), 249-254, 2007.
3. Mihalik, JP et al. *Journal of Sports Engineering and Technology.* 222(Part P.), 45-52, 2008.
4. Crisco, JJ et al. *Journal of Biomechanical Engineering* 126, 849-854, 2004.

ACKNOWLEDGEMENTS

Research for this study was funded by the National Center for Medical Rehabilitation Research at the National Institute of Child Health and Human Development at the National Institutes of Health (Grant R01HD48638) and the National Operating Committee on Standards for Athletic Equipment (Grant 04-07).

Table 1: Male hockey players sustained head impacts with higher peak linear and angular acceleration than female hockey players. The top 1, 2 and 5 % of all impacts were higher for males than females (*$p < 0.001$).

	Male Hockey (Total Impacts = 3,052)				Female Hockey (Total Impacts = 6,747)			
	Linear Acc. (g)		Angular Acc. (rad/s^2)		Linear Acc. (g)		Angular Acc. (rad/s^2)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
***Top 1 %**	128±20	≥ 101	13069±1931	≥ 10250	93±22	≥ 72	8204±2193	≥ 6382
***Top 2 %**	108±26	≥ 78	11007±2556	≥ 7975	80±20	≥ 62	6928±2011	≥ 5183
***Top 5 %**	80±29	≥ 50	8373±2742	≥ 5183	63±19	≥ 45	5395±1812	≥ 3786