The Effect of Impact Location on Brain Injury Risk in Boxing

S. Rudolph, D. Stark, Y. Kang, PhD

Injury Biomechanics Research Center, The Ohio State University

THE OHIO STATE UNIVERSITY

Contact Information:
- Stephen Rudolph
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- rudolph.121@osu.edu

INTRODUCTION

- Annually, there are between 1.6 and 3.8 million sports-related concussions in the United States. Additionally, athletes who participate in contact sports have up to a 20% likelihood of sustaining a concussion each season.[1]
- This high incidence of concussions is certainly existent in boxing as studies have shown that concussions account for up to 16% of the injuries in boxing.[2]
- Overall, there is a need for improvement in the understanding of concussions and the biomechanics of the head that create them as this is the first step toward improving injury prevention and developing protective equipment.
- This study aimed to investigate the effect of impact location on brain injury risk in boxing.
- A laboratory setting was used to examine how variations in impact location to an instrumented anthropomorphic test device (ATD) effects head kinematics and injury criteria values related to concussion risk: namely, Head Injury Criterion (HIC) and Brain Injury Criterion (BrIC).[3,4]

MATERIALS & METHODS

- A pneumatic ram weighing 4.5 kg was fitted with a boxing glove and used to impact an instrumented Hybrid III 50th percentile ATD head-neck mass assembly, weighing 44.6 kg, at approximately 7 m/s.
- The Hybrid III head and neck were impacted in five directions, shown in **Figure 1**, with three vertical offsets at each location, shown in **Figure 2**. Each location was impacted 3 times (n=45).
- For each test, a 6aω motion block comprised of 6 accelerometers and 3 angular rate sensors was secured at the center of gravity of the Hybrid III ATD head and used to directly measure linear acceleration and angular velocity. Angular acceleration was then calculated using rigid body mechanics.
- Linear acceleration and angular velocity data were used to calculate HIC and BrIC values using **Equations 1** and **2**, respectively.

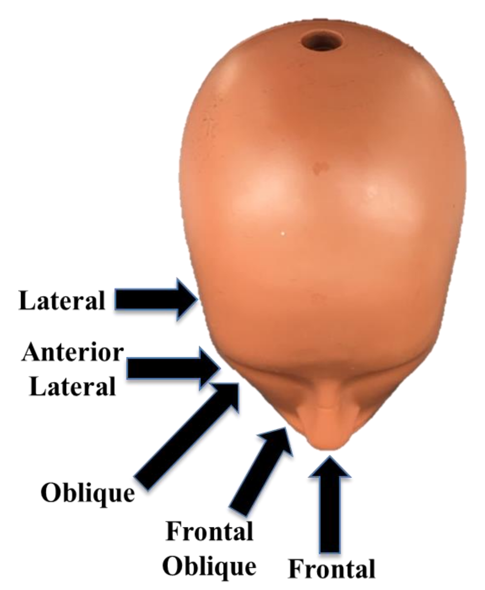

Figure 1: The 5 impact directions tested.

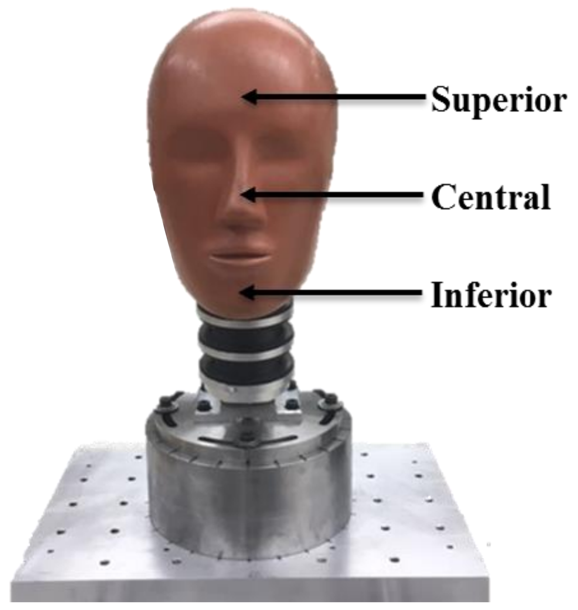

Figure 2: The 3 vertical offsets for each impact direction.

$$HIC_{15} = \left[(t_2 - t_1)\left(\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} a(t)dt\right)^{2.5}\right]_{MAX}$$

Equation 1: HIC_{15} equation. $(t_2 - t_1) \leq 15$ ms.[3]

$$BrIC = \sqrt{\left(\frac{\omega_x}{\omega_{xc}}\right)^2 + \left(\frac{\omega_y}{\omega_{yc}}\right)^2 + \left(\frac{\omega_z}{\omega_{zc}}\right)^2}$$

Equation 2: BrIC equation with critical values: ω_{xc}: 66.25 rad/sec, ω_{yc}: 56.45 rad/sec, and ω_{zc}: 42.87 rad/sec.[4]

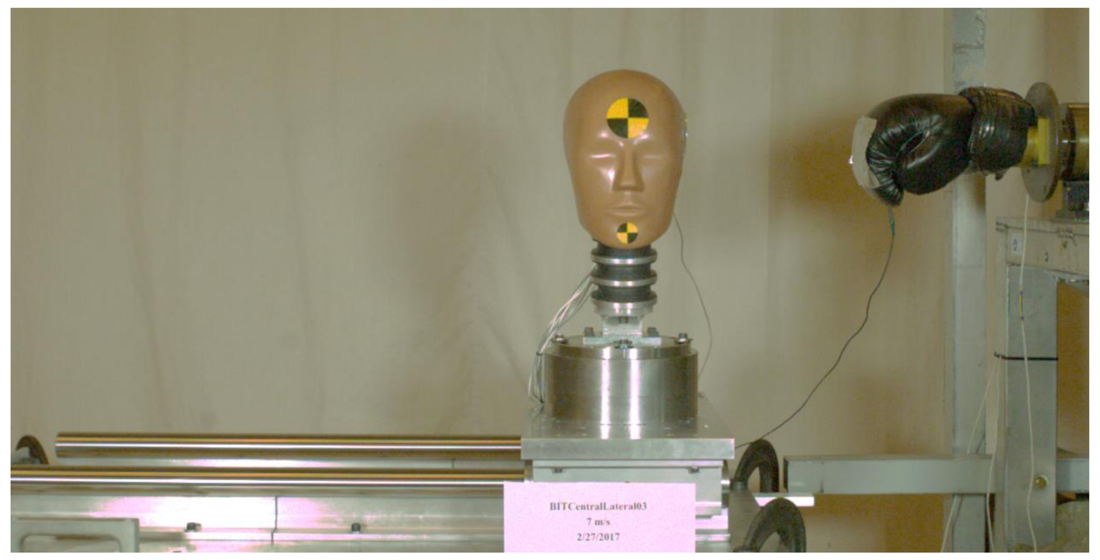

Figure 3: Test setup for a central lateral impact.

RESULTS & DISCUSSION

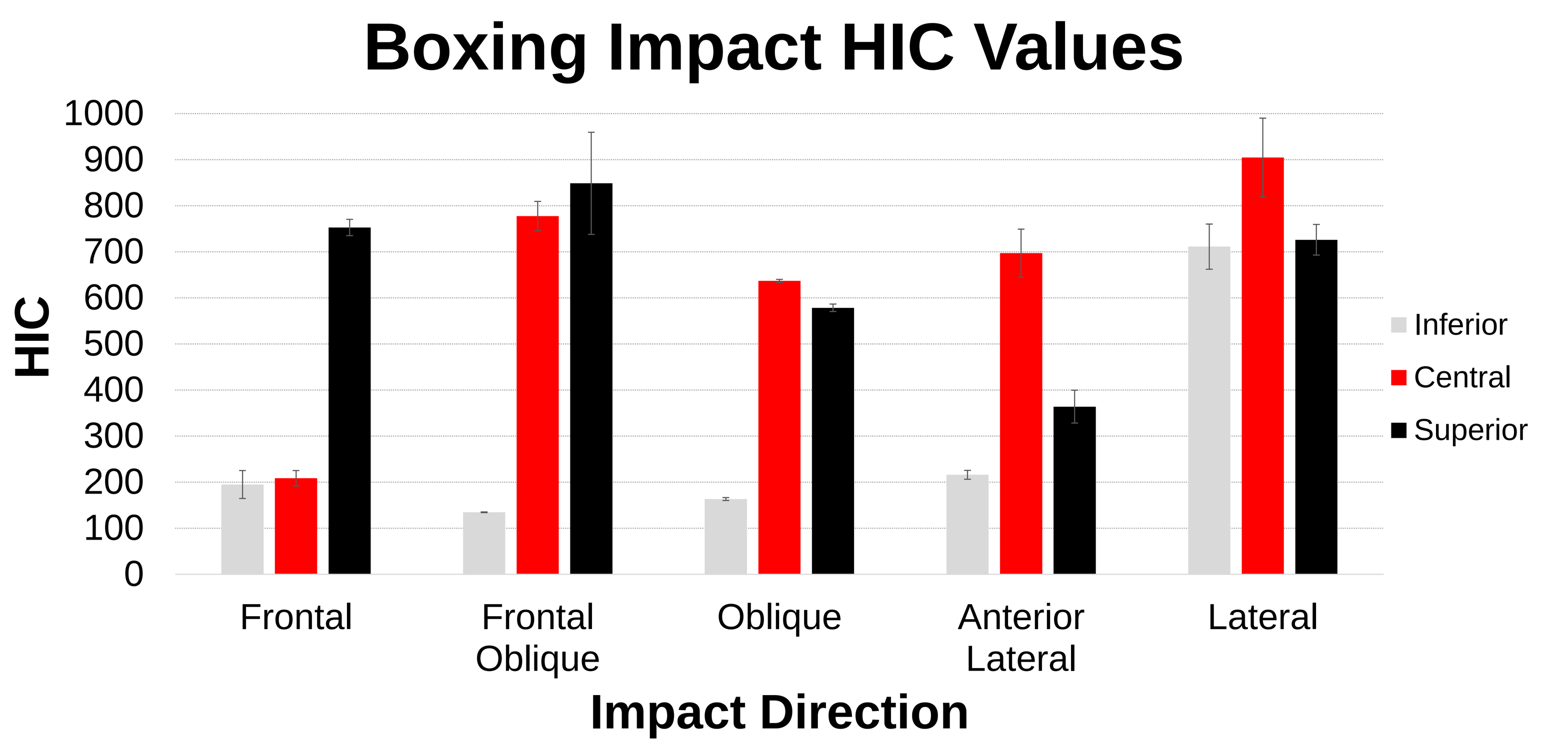

Figure 4: HIC values averaged by impact direction and vertical offset.

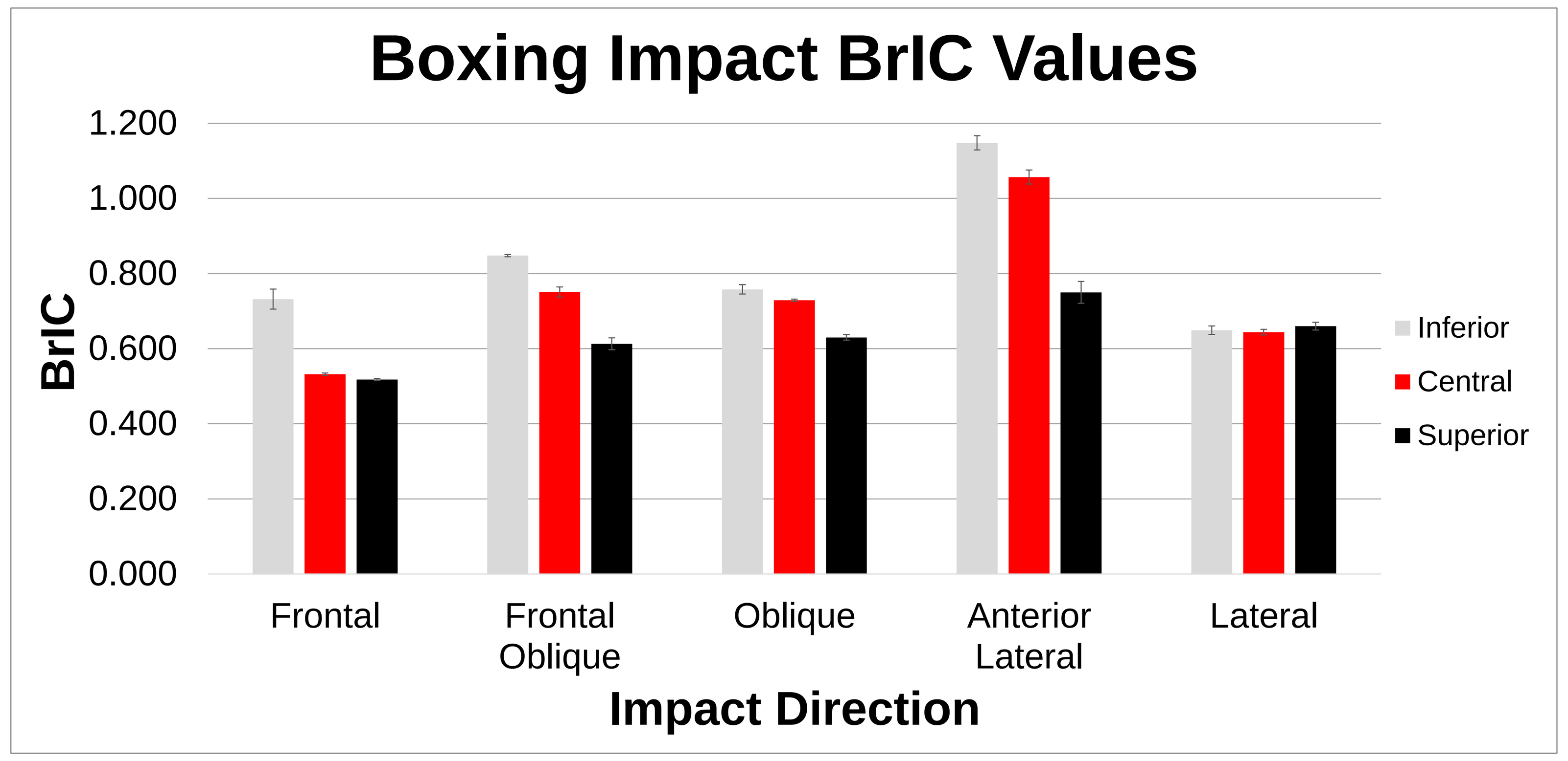

Figure 5: BrIC values averaged by impact direction and vertical offset.

Table 1: Average percent difference in HIC values between impact directions.

	Frontal	F-Obl	Oblique	Ant. Lat.
F-Obl	38.1			
Oblique	14.0	24.1		
Ant. Lateral	7.6	30.5	6.4	
Lateral	**74.9**	36.7	60.8	67.2

Table 2: Average percent difference in BrIC values between impact directions.

	Frontal	F-Obl	Oblique	Ant. Lat.
F-Obl	19.5			
Oblique	15.2	4.3		
Ant. Lateral	**53.2**	33.7	38.0	
Lateral	7.7	11.7	7.4	45.4

Table 3: Maximum percent difference in HIC and BrIC values between vertical offset locations in the same impact direction.

	HIC	BrIC
	Percent Difference	Percent Difference
Frontal	117.7	34.2
Frontal Oblique	**145.2**	32.1
Oblique	118.3	18.4
Anterior Lateral	105.3	**41.9**
Lateral	23.9	2.4

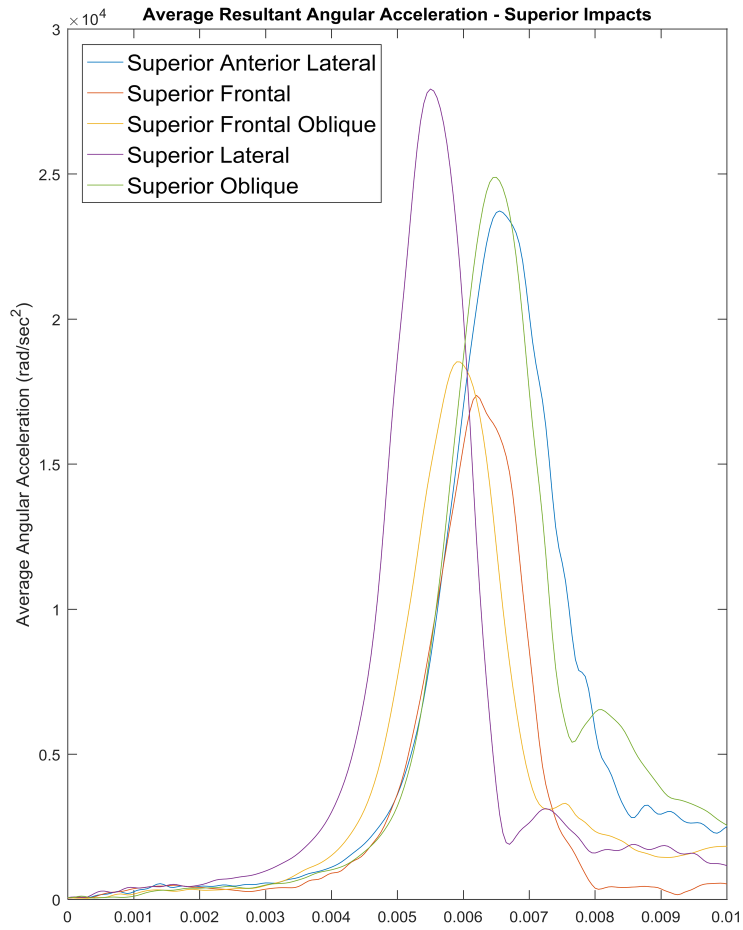

Figure 6: Average resultant angular acceleration of superior impacts.

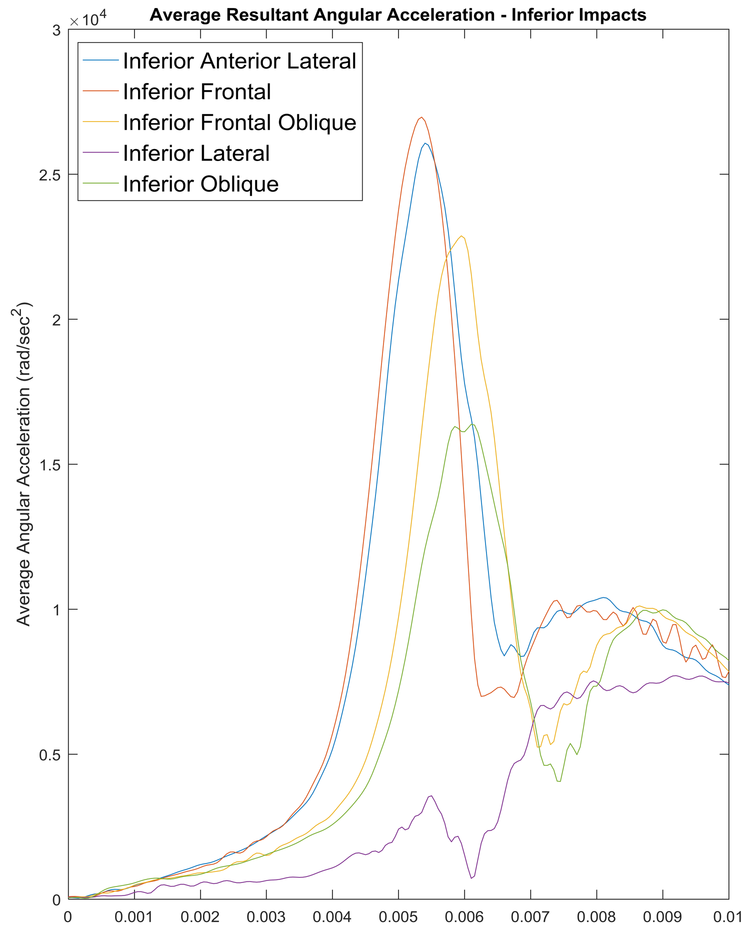

Figure 7: Average resultant angular acceleration of inferior impacts.

- For all impact directions, inferior impacts produced the smallest HIC values.
- Anterior lateral impacts produced significantly larger BrIC values in comparison to other impact directions.
- Vertical offset had the least effect in lateral impacts for both HIC and BrIC values.
- Lateral impacts had the largest average percent difference in HIC values from any impact direction.
- Anterior lateral impacts had the largest average percent difference in BrIC values from any impact direction.
- The maximum percent difference between vertical offsets was more pronounced in HIC values in comparison to BrIC values.

CONCLUSIONS

- In general, vertical offset played a large role in the impact response of 4 out of the 5 impact directions. Lateral impacts were not effected by variations in the vertical offset.
- Anterior lateral impacts produced the largest risk of brain injury according to BrIC values.
- Central lateral impacts produced the largest risk of injury according to HIC values. Interestingly, inferior impacts produced relatively low HIC values for all impact directions except the lateral impact direction.
- Overall, this study determined that both the impact direction and the vertical orientation of impact play a role in the head impact response and brain injury risk.
- Future studies will investigate how the use of boxing headgear and other glove types effect head impact response and concussion risk. Furthermore, more impact locations and velocities than the ones assessed in this study will be examined.

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