Objective: The goal of this study was to investigate head impacts, neuropsychological performance and cerebral blood flow in intercollegiate boxing and its impact regarding head injury assessment in combat environments. If significant correlations were found between measures, recommendations for increasing efficiency of head impact assessment in combat environments might be made. Method: Participants-31 intercollegiate male boxers mean age 20.74 yrs., height 70.14 in., weight 164.32 lbs., & experience 1.5 yrs. Assessments occurred before and after two full-effort 2 minute sparring rounds. The Impact Headgear system tracked location/number of head impacts, translational acceleration, & rotational forces. The ImPACT test and Automated Neuropsychological Assessment Metrics (ANAM) measured neuropsychological performance and the Brain Acoustic Monitor (BAM) measured cerebral blood flow. Sparring bouts were videotaped to validate head impacts. Results: Impact Headgear recorded an average of 26.81 impacts per boxer, most of which were below the 25% probability for brain injury. The ImPACT test showed a decrease in verbal memory (p<.05), delayed memory (p<.01) and improved reaction time (p<.01). The ANAM showed a decrease in delayed memory (p<.01) and improved reaction time (p<.01). BAM detected no significant changes and no significant correlations were found between the BAM and the neuropsychological measures. Conclusion: In the current sample, head impacts were below threshold to cause brain disturbance detectable through BAM; however, consistent with research in amateur boxing, mild decline in memory function was detected. Research with a larger sample across greater impacts is recommended to further investigate the efficacy of the BAM.
**15. SUBJECT TERMS** Mild Traumatic Brain Injury (MTBI), Concussion, Head Impact, Head Injury, Head Acceleration, MTBI Diagnostics, Cognitive Testing, Brain Acoustic Monitoring, Boxing, Neuropsychology

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Standard Form 298 (Rev. 8-98)
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FINAL REPORT

AN INVESTIGATION OF HEAD ACCELEROMETRY, COGNITIVE FUNCTION, AND BRAIN BLOOD FLOW DURING INTERCOLLEGIATE BOXING AND ITS IMPACT REGARDING HEAD INJURY ASSESSMENT IN COMBAT

SEPTEMBER 6, 2010

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Prepared for:
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UNCLASSIFIED
An Investigation of Head Accelerometry, Cognitive Function, and Brain Blood Flow during Intercollegiate Boxing and its Impact Regarding Head Injury Assessment in Combat

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OBJECTIVE
The goal of the study was to investigate head impacts, neuropsychological performance and cerebral blood flow in intercollegiate boxers to increase understanding about consequences of head impacts in this population. Also, if significant correlations were found between measures, recommendations for increasing efficiency of head impact assessment in combat environments could be considered.

INTRODUCTION
Relatively little is known about the biomechanics of these mild injuries and their cognitive and neuropsychological sequelae.

In addition to its known occurrence in sports, mild traumatic brain injury (mTBI) is a signature wound of the current military conflicts in Iraq and Afghanistan with 15-28% of military personnel sustaining such injuries (Hoge et al., 2008; Cike, 2005). With increased demand for accurate measures in theater, it has become clear that conventional assessment in this setting can be challenging, thereby compromising test results. With this comes potential attendant risk of secondary injury.

Collegiate boxing provides an opportunity to study the effect of mTBI on central nervous system structure and function (Stojsh, et al., 2008) and to evaluate the validity of neuropsychological measures in the rapid assessment of head injuries.

METHOD
28 male boxers were assessed before and after two-2 min., 100% effort, sparring rounds with an opponent in the same weight class & ability.

Age: 20.21 (SD=1.77) yrs.  Ht: 70.14 (SD=2.97) in. Wt.: 164.32 (SD=23.04) lbs.  Boxing experience: 1.50 (SD=1.40; range 0-5) yrs.

Head Impact Monitoring:
Instrumented Boxing Headgear (IBH; Simbex, Inc.) is a wireless system which records number/location of impacts & strength/type of head acceleration. All bouts were videotaped to validate head impact data.

Brain Acoustic Monitoring (BAM):
BAM is an indirect measure of cerebral blood flow which uses a sensor attached to the forehead to detect sound waves generated by arterial blood flow. It has been validated in a brain injured population.

Neuropsychological Assessments:
ANAM™ TBI: Automated Neuropsychological Assessment Metrics-v.4 TBI Battery
ImPACT®: Immediate Post- concussion Assessment and Cognitive Testing v.5; computerized

RESULTS

Type of Acceleration

<table>
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<tr>
<th>Peak Lin Acc (g)</th>
<th>5.60</th>
<th>122.50</th>
<th>23.01</th>
<th>14.50</th>
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<tr>
<td>Peak Rot Accfred(2)</td>
<td>344.30</td>
<td>10124.60</td>
<td>1721.35</td>
<td>1024.49</td>
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<tr>
<td>NIC-15*</td>
<td>0.30</td>
<td>486.00</td>
<td>21.46</td>
<td>44.90</td>
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Impact Location

| Front | 34.73 | 22.30 (1.05) | 1632.82 (50.20) | 18.25 (1.78) |
| Back | 24.48 | 24.40 (1.12) | 1898.21 (98.30) | 25.71 (3.65) |
| Left | 97 | 23.67 (1.75) | 1756.22 (101.07) | 24.07 (5.58) |
| Right | 235 | 27.39 | 23.09 (1.04) | 1715.20 (64.42) | 22.28 (3.06) |
| Top | 18 | 2.10 | 17.37 (1.63) | 1457.02 (128.46) | 8.81 (1.77) |

| Trans Acl (g) | 0.20 | 1.67 | 0.50 | 15.00 |
| Rot Acl (red2) | 0.30 | 4.83 | 0.50 | 15.00 |

ImpACT Composite Score

| Pre-bout Mean (SD) | 902 (0.72) | .893 (1.11) | 2.48** |
| Visual Memory | .843 (1.05) | .795 (1.07) | 1.91 |
| Processing Speed | 43.47 (6.984) | 44.79 (6.284) | -.141 |
| Reaction Time | .540 (.061) | .505 (.051) | 4.20*** |
| Impulse Control | 7.570 (5.392) | 7.210 (5.593) | 0.556 |
| Memory Acquisition (correct) | .926 (0051) | .913 (0.066) | 1.094 |

SUMMARY
• 99.2% of impacts < Head Injury-Criterion of 250 for probable mild TBI
• Pre to post changes in neuropsychological measures:
  ImPACT: decreased verbal & delayed memory; decreased reaction time
  ANAM: increased vigor; decreased learning & recall of number-symbol pairs; decreased math reaction time
• No statistically significant changes were found in BAM and neuropsychological measures.

DISCUSSION
Consistent with research in amateur boxing (Stojsh, et al., 2008), mild decline in memory function was detected following head impacts in collegiate boxers; however, no significant change in cerebral blood flow indicative of mTBI was detectable through BAM.

REFERENCES

Corresponding author: michelle.butter@usafa.edu. Funding for this project was provided in part by USAF/SGR award to the U.S. Air Force Academy Human Performance Lab & an IR07 USAF/AMC/TATRC/AMMED Advanced Medical Technology Initiative (AMIT) award to Dr. Kristin Heaton (Proposal 42006011195) & a. The views expressed here are those of the authors and do not reflect the official policy of the Dept. of the Air Force, Army or Dept. of Defense.