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**Full Papers**

**Wednesday, October 20, 2021**

**8:00 AM - 9:20 AM: Drugs/Alcohol/Occupant Factors**

**8:00 AM - 8:20 AM**

**The Effectiveness of Alcohol Monitoring as a Treatment for Driving-While-Intoxicated (DWI) Offenders: A Literature Review and Synthesis**

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**ABSTRACT**

**Objective**: The advent of continuous, passive, transdermal alcohol-monitoring devices and portable breath-testing devices with cameras provides a more efficient method for controlling the impaired driving of driving-under-the-influence (DUI) offenders. The objective of this study was to conduct a comprehensive literature review and synthesis of the strategies, the obstacles and the effectiveness of implementing alcohol monitoring as a component of treatment for DUI offenders. This review was designed to reveal the strengths and weaknesses of alcohol monitoring and document policies and obstacles that tend to interfere with alcohol monitoring in treatment programs for DUI offenders.

**Method:** A formalized review of the existing literature was conducted including both peer-reviewed and grey literature resources such as government reports, unpublished manuscripts, or working papers. Professional association websites were also searched in an effort to seek information on the effectiveness or ineffectiveness of alcohol monitoring as a strategy to treat DUI offenders. The review was guided by pre-defined inclusion/exclusion criteria that identified the scope and key terms to use when searching. Information was analyzed and summarized in an objective manner, using illustrations (e.g., examples that represent key findings that emerged across the documents) as appropriate.  
**Data Sources:** Articles Plus, Cochrane Library (Wiley) Medline, ISI Web of Science, ProQuest, PsycINFO, Social Services Abstracts, and WorldCat. Available subscription databases include Science Citation Index, Social Sciences Citation Index, Scopus, and others.

**Results:** The literature shows that there is evidence (promising to strong evidence) that alcohol monitoring is an effective component in treating DUI offenders and reducing recidivism rates. Alcohol ignition interlocks had the most studies (71 of the 131 articles identified in this review covered ignition interlocks) and research shows that recidivism rates can be reduced by 50 to 90 percent for offenders who install interlocks. However, ignition interlock studies are subject to sampling issues, such as participants are not randomly assigned to groups in comparison studies resulting in study groups that may not be similar. There is also evidence that alcohol monitoring is a key measure in 24/7 Sobriety Programs, in enforcing abstinence, and in overall alcohol treatment programs.  Although evidence shows that use of transdermal devices combined with contingency measurement interventions can lead to the reduction of alcohol consumption, more research is needed to also show that it can lead to reductions in DUI recidivism.   
**Conclusions:** Transdermal monitoring is generally effective in deterring offenders from drinking alcohol. Information collected through transdermal technology is generally accurate. Offenders who drink or are otherwise noncompliant are likely to be identified. Information regarding noncompliance flows quickly to the appropriate officials. Transdermal monitoring helps enforce abstinence, which in turn helps offenders quit drinking and go into a recovery stage, potentially creating long-term safety benefits for the community. Continuous transdermal monitoring is a more effective means of monitoring drinking than other techniques and technologies (e.g., self-report, periodic or random breath tests, patches, or urinalysis). There appears to be cost savings for transdermal alcohol monitoring compared to alternatives.

**8:20 AM - 8:40 AM**

**Perceived Effects of Cannabis and Changes in Driving Performance Under the Influence of Cannabis**

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**ABSTRACT**

**Objective:** The objective of this analysis was to examine how driver's perception of their state are related to performance while operating a motor vehicle.  There are reports that cannabis users will adapt their driving to compensate for the effects of cannabis.  This manuscript will explore the relationship between driver perceptions and objective measures of performance.  
**Data Source:** Data collected from eleven subjects in a study examining the effects of cannabis on driving performance.  Driving performance was collected on the miniSim, a quarter cab limited field of view non-motion simulator, approximately 2 hours after cannabis inhalation. Driving measures included standard deviation of lane position (SDLP), and speed relative to the speed limit.  Subjective effects of the effects of cannabis were collected at peak and prior to driving.  Subjective effects included visual analog scales on a scale of 100 for drug effect, high, stoned, stimulated, sedated, anxious, and restless.  
**Methods:** Data were analyzed using the SAS GLM Select procedure with subjective effect, dosing condition (placebo vs 6.9% THC), and driving event as independent measures.  The stepwise selection method was used.  
**Results:** SDLP was increased with cannabis use and differed by the type of driving environment.  Subject perception of level of high increased SDLP by 0.17 cm for every unit increase (increase of 8.7 cm for a 50 unit increase).  Subject perception of level of stimulation decreased SDLP by 0.15 cm for every unit increase (decrease of 7.8 for a 50 unit increase).  Average speed relative to the speed limit decreased with cannabis use and differed by the type of diving environment as well.  Subject perception of stoned increased average speed by 0.03 mph per every unit increase (increase of 1.6 mph for a 50 unit increase).  Subject perception of stimulated decreased average speed by 0.06 mph per every unit increase (decrease of 3.0 mph for a 50 unit increase).   
**Significance of results:** Overall, the results indicate that differences in the perceived effects of the cannabis use are reflected in changes in both lateral and longitudinal control beyond just the effect of acute use of cannabis. This points to the possibility the how driver's feel may in fact result in changes in driving behavior that could mitigate the effect of cannabis  For both lateral and longitudinal control, an increasing perception of stimulation produced positive effect on performance.  More broadly this could provide a better understanding of how different strands of cannabis products which produce different subject experiences for users could impact driving safety. Specifically those that produce a more stimulating effect may have less impact on driving while those that produce a more stoned or high feeling may have a greater negative effect on driving.

**8:40 AM - 9:00 AM**

**Trajectories of Risky Driving Among Emerging Adults with Their Mental and Psychosomatic Health Predictors in the 12th Grade**

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**ABSTRACT**

**Objective:** Cross-sectional associations of depressive and psychosomatic symptoms with risky driving and driving while impaired (DWI) after high school have been reported in young drivers. However, it remains unclear if depressive and psychosomatic health status in high school predicts risky driving and DWI after high school. This study examined prospective associations of depressive and psychosomatic symptoms in 12th grade with risky driving and DWI 4 years after high school among U.S. emerging adults.  
**Methods:** Outcome variables were W4-7 risky driving measured with the 21-item Checkpoints Self-Reported Risky Driving Scale (C-RDS) and W4-7 DWI (dichotomous variable: ≥1 day vs. 0 days in the last 30 days). Independent variables were depressive symptoms measured with a validated Pediatric Patient-Reported Outcome Measurement Information System (PROMIS) scale and psychosomatic symptoms measured with a validated psychosomatic scale including 8 symptoms (e.g., headache, stomachache, backache, feeling low in the last half-year). These independent variables were measured in W3 and W4-7 after high school. Covariates included sex, race/ethnicity, family affluence, parental education, and urbanicity. Multivariate logistic and linear regressions were conducted with complex survey features considered.  
**Data Sources:** Data were from the last year in high school (12th-Grade - Wave 3 [W3]) and years 1-4 after high school (Waves 4-7 [W4-7]) of the NEXT Generation Health Study, a nationally representative study starting with 10th grade (2009-2010).  
**Results:** W3 depressive symptoms were significantly associated with C-RDS in W4 (Beta [*β*]=0.07, *p*<.01), W5 (*β*=0.06, *p*=.04), W6 (*β*=0.07, *p*<.01) and W7 (*β*=0.04, *p*=.05) and DWI in W4 (Adjusted odds ratio [AOR]=1.03, *p*<.01) and W6 (AOR=1.02, *p*=.02) when controlling for the covariates. W3 psychosomatic symptoms were significantly associated with C-RDS (*β*=0.19, *p*<.01) and DWI (AOR=1.08, *p*<.01) only in W4 when controlling for the covariates. With further controlling for concurrent depressive and psychosomatic symptoms in W4-W7 respectively, the noted significant associations did not remain except for the association between W3 psychosomatic symptom and W4 DWI (AOR=1.08, *p*<.01). W3 depressive symptoms were highly (*p*<.01) correlated with depressive symptoms in W4 (*r*=0.52), W5 (*r*=0.44), W6 (*r*=0.45) and W7 (*r*=0.39). W3 psychosomatic symptoms were highly (*p*<.01) correlated with psychosomatic symptoms in W4 (*r*=0.64), W5 (*r*=0.60), W6 (*r*=0.55) and W7 (*r*=0.52).  
**Significance of results:** Mental and psychosomatic health in high school (12th-grade) is intimately associated with mental and psychosomatic health in early adulthood (i.e., 1-3 years after high school). Without taking into account concurrent depressive and psychosomatic status in early adulthood, 12th-grade depressive symptoms predicted risky driving in all 4 years after high school and DWI in the 1st and 3rd years after high school. Further, 12th-grade psychosomatic symptoms predicted both risky driving and DWI in the 1st year after high school. However, when concurrent depressive and psychosomatic symptoms were accounted for, most predictive associations did not remain. These findings suggest that prevention programs that incorporate screening and treatment of mental and psychosomatic health in high school may be an important opportunity to help reduce risky driving and DWI once youth graduate from high school and transition into emerging adulthood.

**9:00 AM - 9:20 AM**

**Analysis of Factors Influencing Aggressive Driver Behavior and Crash Involvement**

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**ABSTRACT**

Aggressive driving behavior is one of the major contributing factors to traffic accidents worldwide. The current study explored the influence of aggressive driving behavior on self-reported accidents of professional drivers. In the existing literature, many methodologies are used to model aggressive driving behavior based on either self-reported psychological measures or vehicle kinematics collected through naturalistic driving. This study attempted to consider both psychological and naturalistic driving data in modeling aggressive driving behavior to provide experimental validation and to model the accident probability of aggressive drivers.  
A sample of 190 have participated in a questionnaire survey and 22 of them were selected to conduct the naturalistic driving experiment.  Professional drivers are more prone to accidents as they are exposed to longer hours of driving. Therefore, this study selected 22 male professionals (who are working as full-time drivers in a transport company with a valid driving license) drivers to collect naturalistic driving data in Mumbai, India. Aggressive drivers tend to move with rapid acceleration/deceleration frequently to attain higher speeds and to overtake other vehicles therefore, this study adopted vehicle kinematics (speed, longitudinal and lateral accelerations) to identify aggressive drivers. K-means clustering algorithm was employed to cluster the drivers into aggressive and non-aggressive. When personality traits (in this case trait aggression and driving-related aggression) interacts with external stressors (experience in general while driving for instance traffic congestion and other aggressive drivers' behavior) to elicit a state of negative emotions and leads to aggressive driving behavior. Therefore, the current study used the self-reported questionnaires Aggressive Driving Scale (ADS) and the Buss-Perry Aggression Questionnaire (BPAQ) to measure the trait and driving-related aggressions of the individual drivers. Multinomial logit regression was used to model the aggressive driving behavior and to explore the association between the trait and driving-related aggressions. Binary Logistic regression was used to model the probability of accident occurrence of three driving groups based on self-reported accident history.  
The results obtained in this study showed that driver aggression was strongly associated with the odds of accident occurrence. Compared to cautious drivers, the accident probability was increased by 3.42 and 2.91 times in the case of aggressive and normal drivers, respectively.  Among the driver demographics, marital status significantly associated with the accident probability. The results showed that married driver's involvement in accident probability was decreased by 2.61 times that of un-married drivers.  The ADS and BPAQ scores were significantly higher for aggressive drivers compared to normal and cautious drivers. Multinomial logit model results showed that a higher proportion of aggressive drivers are young drivers (20-30 years) than mid-age (31-50 years) drivers. Results showed that the probability of a driver to be an aggressive driver was increased by 35% with a one-year decrement in driver's age.  
Aggressive driving behavior can be monitored to determine the accident risk and provide feedback to the driver through advanced driver assistance systems (ADAS). Further investigation of aggressive driving behavior needed to enhance the traffic safety regulations and to improve policy implications for safety management related to driving behavior.

**Wednesday, October 20, 2021**

**9:50 AM - 11:00 AM: Drugs/Alcohol/Occupant Factors**

**9:50 AM - 10:10 AM**

**A Survey of Distracted Driving and Electronic Device Use Among App-Based and Taxi Drivers**

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**ABSTRACT**

**Introduction:** Studies have indicated that electronic devices (ED) such as smartphones are a source of distracted driving (DD), causing visual, cognitive and manual distraction. Most research has focused on commercial drivers and not small passenger-carrying vehicle drivers, such as taxi and app-based drivers.  While sharing the challenges commercial drivers face, taxi and app-based drivers have other unique demands on their attention including heavy reliance on ED and more circumstances for distracted driving, including direct interaction with passengers and ED use while driving. The purpose of this study was to identify, characterize and compare attitudes, beliefs, behaviors and other factors related to DD among taxi and app-based drivers.  
**Data Sources:** An anonymous survey was developed, pilot tested and distributed to participants online through social media and in-person at locations in San Diego frequented by drivers from October 2016 to January 2017. Inclusion criteria to participate in the survey were: 1) age 21 and older; 2) own and use smartphone for work 3) drive a vehicle at least one day a week to transport people for income; and 4) US resident. The survey collected information on 1) demographics, 2) ED use, 3) attitudes toward ED use while driving, and 4) citations and collisions.  
**Methods:** Chi-square or Fisher's exact test was used to assess the difference between sociodemographic, ED use, ED use attitudes, and citation and crash history by driver type. Prevalence ratios were assessed for differences in ED use and ED use attitudes by driver type using Poisson regression models with robust error variance and a log link function. The final models adjusted for age, sex, level of experience, education and English fluency. All analyses were performed using SAS version 9.4.  
**Results:** Of the 177 drivers that met eligibility criteria, 131 reported driving for app-based services and 44 identified as taxi drivers. All but one driver reported at least one type of DD while the car was in motion. Compared to taxi drivers, app-based drivers were more likely to be female, native English speaking, and have fewer than 3 years of experience. App-based drivers were also more likely to use a smartphone while driving (adjusted prevalence ratio (APR): 1.42, 95% Confidence Interval (CI): 1.07-1.88), and more likely to report that while driving it is safe or very safe to accept a call (APR: 1.73, CI: 1.09-2.76), receive/respond to a passenger request (APR: 3.40, CI: 1.38-8.37), or process a payment (APR: 5.39, CI: 1.30-22.33). Taxi drivers were more likely to either receive a citation for ED use (31.8 v 7.6%, p<0.001), or be in a collision while using ED (29.6 v 4.6%, p<0.001).  Almost all drivers who received a citation or who were involved in a crash reported becoming somewhat or significantly more cautious about using ED while driving.  
**Significance of Results:** Drivers in the small passenger-carrying transportation industry engage in DD, frequently due to occupational demands. Given the known increased crash risk with DD, effective policies and interventions for app-based and taxi drivers are needed.

**10:10 AM - 10:30 AM**

**Facilitating Research on Racial and Ethnic Disparities and Inequities in Transportation: Application and Evaluation of the Bayesian Improved Surname Geocoding (BISG) Algorithm**

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**ABSTRACT**

**Objective**: Emerging evidence indicates there are racial/ethnic inequities in transportation. For instance, there is a wide and growing racial/ethnic disparity in driver fatality rates,1 and Black children are twice as likely as White children to be killed in a crash.2 However, race/ethnicity data are not captured in many states' traffic databases, which substantially limits our ability to comprehensively understand sources of transportation inequities. We conducted a methodological study to determine the extent to which integration of licensing and crash data with other state-level data sources and innovative imputation methods can facilitate critical research on racial/ethnic inequities in transportation outcomes.  
**Data Sources:** We integrated 15 years of New Jersey licensing and crash data with several statewide databases, including hospital discharge and vital records data, via probabilistic linkage. The final NJ Safety and Health Outcomes (NJ-SHO) warehouse includes ~88M records for 22.3M individuals from 2004-2018.3 Reported race/ethnicity data are available in hospital and vital records data but not in licensing or crash data.  
**Methods:** We explored two methods for identifying licensed drivers' race/ethnicity in the NJ-SHO (n=10,294,063). First, we utilized reported race/ethnicity from statewide databases integrated with licensing and crash data. Second, we utilized a validated algorithm, Bayesian Improved Surname Geocoding (BISG), to impute race/ethnicity.4,5 BISG combines information on last names with US Census block group of residential addresses to estimate a posterior probability of membership in each of six mutually exclusive racial/ethnic categories (Table 1). The sum of the six probabilities generated by the BISG algorithm equals 1; individuals are not assigned a specific race/ethnicity value. To further validate use of the BISG algorithm, we evaluated the concordance between reported values and BISG probability distributions using an area under the receiving operating curve (AUC) within each race/ethnicity category. A higher AUC value indicates better correlation between reported race/ethnicity and higher BISG probability for that category; an AUC between 0.8 and 0.9 is generally considered excellent concordance and more than 0.9 outstanding.6 Overall AUC was calculated by weighting each AUC value by the population count in each reported category.  
**Results:** Hospital and/or vital statistics data included reported race/ethnicity for 62.1% of all licensed drivers, while BISG calculated race/ethnicity probabilities for 97.4%. Table 1 depicts concordance of BISG-imputed and reported race/ethnicity for drivers who have both values (n= 6,337,886, 61.6%). Concordance was greater than 0.85 for White, Hispanic, Black, and Asian/Pacific Islander drivers, indicating that BISG has excellent to outstanding agreement with reported race/ethnicity among these groups. BISG classified more drivers as White (68.0% vs. 66.1%), while the report method classified more drivers as Hispanic (16.4% vs.13.5%). The overall AUC was 0.889.  
In this paper, we will also conduct analyses to explore concordance by driver's age and sex, and will demonstrate the utility of this approach by comparing population-based crash rates among racial/ethnic groups.  
**Significance of Results**: Findings of excellent concordance between reported race/ethnicity and BISG probabilities demonstrates the utility of this innovative approach in enabling research on transportation inequities, even in states that do not collect race/ethnicity on license and/or crash records.

**10:30 AM - 10:50 AM**

**Understanding Clinician Strategies for Assessing Driving Fitness: An Initiative to Improve Provider-Patient Discussions about Safe Driving**

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**ABSTRACT**

**Research Objective:** Clinicians are in a critical position (and often legally mandated) to identify patients with impairments that may impact their driving ability and counsel them on appropriate next steps. Prior studies have revealed that provider-patient discussions about driving occur relatively infrequently and that clinician recommendations about when patients can resume driving vary substantially. This research aimed to document current practices and attitudes pertaining to driver fitness assessments among neurosurgery and neurology providers, with the overall purpose of informing quality improvement efforts.  
**Methods and Data Sources:** This project collected baseline data on driver assessment and reporting practices through a cross-sectional, anonymous survey. Multiple choice and open response questions collected data on 1) frequency of discussions about driving, 2) comfort discussing driving with patients, 3) criteria used to assess patient driving fitness, 4) driver rehabilitation program training and referral practices, and 5) Pennsylvania Department of Transportation (PennDOT) reporting. Physicians (attendings, fellows, and residents) and advanced practice providers in the departments of neurology and neurosurgery at a large teaching hospital were invited to participate.  
**Results:** Survey respondents (50 total) primarily consisted of attending physicians and nurse practitioners (86%), with few trainees (8%). Responses revealed that although most providers had high levels of perceived responsibility for counseling patients about driving, a minority regularly discussed driving with patients (19% in the inpatient setting and 49% in the outpatient setting). About half (54%) had ever filed a report about a patient with the PennDOT, and only a third (34%) had referred a patient to a driver rehabilitation program within the past year. Frequency of discussions about driving, PennDOT reports, and driver rehabilitation referrals were not found to differ by provider type (pinpatient discussions =.74, poutpatient discussions=.59, pPennDOT reporting =.48, pdriver rehab referrals=.11). Likelihood of PennDOT reporting was, however, found to be associated with provider knowledge of Pennsylvania unsafe driver reporting laws (p=<.001); 20 out of the 22 respondents who had never filed a report with PennDOT reported that they did not feel confident they would know how to file a report. It is also notable to mention that, of the providers who had filed a PennDOT report, 74% cited seizures as the reason for their most recent report.  
When asked about resources that would help them feel more comfortable discussing driving safety and driving restrictions with patients, providers most frequently suggested the following: 1) Handouts for patients containing information about driving guidelines (11 respondents); 2) protocols for reporting patients to DOTs in surrounding states (6 respondents), and 3) information about local driver rehabilitation programs (5 respondents).  
**Significance of results**: This study revealed room for improvement and simple, practical actions that could be taken to improve driver screening, counseling, and reporting practices. The three main strategies supported by providers were: (1) standardized driving guidelines for review with patients; (2) protocols for DOT reporting; and (3) procedures for referring patients to driver rehabilitation services. Future studies would need to: (1) examine the generalizability of these results and (2) evaluate improvements gained from implementing these strategies.

**Wednesday, October 20, 2021**

**2:00 PM - 3:20 PM: Biomechanics**

**2:00 PM - 2:20 PM**

**Injury Risk Function for the Lumbar Spine in Combined Compression and Flexion**

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**ABSTRACT**

**Research Question / Objective:** Lumbar spine injuries in motor vehicle crashes may be increasing. Future automated driving systems (ADS) have been suggested to enable novel occupant postures. One posture, increased occupant recline, may subject the lumbar spine to higher combined axial compression and forward flexion than those typically experienced in frontal crashes, resulting in the potential for more frequent and severe injuries. Our objective was to develop a lumbar spine injury risk function (IRF) that best fits results from compression-flexion tests.  
**Methods:** Censored (none, left, and right) force and moment failure data from 40 three-vertebrae lumbar spine segments tested in combined compression-flexion were leveraged. Univariate linear regressions were performed to identify covariates from specimen factors: age, sex, segment level (upper/lower), and vertebral body cross-sectional area, length, and width. The geometric similitude assumption was assessed through comparing scaled vs. unscaled failure data.  
Four IRF formulations were investigated. Initially, both failure moment and failure force were used as separate single predictor variables. Next, failure forces and moments were normalized by the average failure force and moment to consider a unitless linear combination of these predictors (e.g., Nij). Finally, a mechanics-based approach was considered, in which the lumbar spine was modeled as a curved beam subjected to a combination of stresses from the axial compression and bending moment. The mechanics-based model was optimized using a tuning factor to produce the IRF with best predictive fit to the data since the appropriate relative contributions of force and moment to failure were unknown. All formulations were fit using Weibull survival models, and goodness-of-fit was assessed via log-likelihood and Akaike information criterion (AIC).  
**Data Sources:** Data from experiments performed at UVA were utilized for the IRF.  
**Results:** There were eighteen uncensored, nineteen right-censored, and three left-censored data points. Age, sex, cross-sectional area, length, and width significantly affected failure moment (all p<0.011). However, cross-sectional area, length, and width were geometrically similar when comparing scale factors, so cross-sectional area was the sole geometrical parameter chosen as a covariate. After controlling for geometrical effects by scaling to cross-sectional area, failure moment remained significantly higher in males than females (p=0.0094). Therefore, age, sex, and cross-sectional area were the covariates of interest. Evaluating the variations in potential IRF formulations by goodness-of-fit showed the mechanics-based approach provided the IRF that yielded the best fit to the experimental data.   
**Significance of Results:** The proposed IRF represents the first for combined compression-flexion loading of the lumbar spine, including covariates of age, sex, and geometric size of the vertebra. The statistical approach allowed for a quantitative assessment to determine the appropriate covariates. While several formulations were considered, the mechanics-based approach produced the best fit to the experimental data and its formulation is supported by the mechanics principle suggesting axial compressive stresses from different sources can be superimposed to produce injurious loading. The proposed IRF may be used to predict lumbar spine injury risk in frontal crashes, which has the potential to direct vehicle safety research toward reducing lumbar fractures in future vehicles.

**Wednesday, October 20, 2021**

**3:50 PM - 4:40 PM: Biomechanics**

**3:20 PM - 3:40 PM**

**Deflection-based Parametric Survival Analysis Side-impact Chest Injury Risk Curves AIS 2015**

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**ABSTRACT**

**Research Objective:** Reanalyze lateral post mortem human surrogate (PMHS) sled test chestband data to calculate updated deflection measures and, combined with injury outcomes, to construct lateral thoracic injury risk curves (IRCs) using parametric statistical survival modeling (PSSM) based on the thorax level independent deflections.  
**Methods**: Chestband contour and injury data were gathered from previous PMHS sled tests.  Briefly, three chestbands were wrapped around the thorax's circumference at the level of rib four, xiphoid process, and rib ten.  The PMHS was seated on a bench-seat with horizontal tubing to support the back and head.  Tests were conducted on a rigid and padded (10 cm Ethafoam LC 200) loadwall.  Posttest radiographs were obtained, and an autopsy was performed.  The original data was coded using the AIS 1990-98 update and were reclassified using AIS 2015 for the current study.  Chestband signals were combined with pre-test specimen measurements to calculate the chest deflection contour time-history.  Deflections were determined using updated processing techniques.  The maximum value was determined by calculating the change in length of every point on the impacted side contour using the thorax's midpoint as the origin.  
The greater peak deflection of upper and middle chestbands was the response variable, and specimen mass was a covariate in the PSSM.  AIS 2+ IRCs were developed by considering outcomes AIS≥ 2  as injured ( AIS ≤1  as non-injured).  All injury data were uncensored, while the non-injured data were right-censored.  Three specimen mass-based IRCs were determined: The first corresponded to the average mass of the PMHS ensemble, the second to the 5th percentile female mass (50 kg), and the third to the 50th percentile male mass (75 kg).   
**Data Sources**: Data were obtained from the NHTSA biomechanics database.  
**Results**: Seventeen PMHS were used in the current study.  All tests were conducted at 6.7 m/s, with a flat loadwall.  The average mass was 65 ± 12 kg.  Five of the specimens were right-censored, and twelve were uncensored.  Mass was a significant covariate, and the Weibull distribution was used for the 65 kg (PMHS), 50 kg (5th), and 75 kg (50th) IRCs.  For the 65 kg IRC, The 5% injury risk corresponds to a deflection of 60 mm, and the 50% risk was 76 mm.  The 50 kg and 75 kg IRCs 5% injury risks were 48 and 69 mm, and the 50% injury risks were 61 and 88 mm.  
**Significance of Results**: These tests were previously analyzed using a binary regression statistical model, while the current study used parametric survival analysis techniques, recommended by ISO for developing injury criteria.  While the former method has a long history of usage, it cannot accommodate data censoring.  Using the PSSM, lateral thorax IRCs for AIS 2+ injuries were developed for the 65, 50, and 75 kg occupant.  As all injuries were rescored using the latest AIS 2015 scale and IRCs were developed using the ISO recommendations, the present set of mass-based IRCs represents an advancement of previous IRCs and may be used to better assess injuries nearside impact environments.

**3:40 PM - 4:00 PM**

**Effect of Body Size and Enhanced Helmet Systems on Injury Risk for Motorsport Drivers**

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**ABSTRACT**

**Research Question / Objective:** Computational modeling is a useful tool for simulating representative motorsport impacts and studying driver injury risk. Previous studies have used computational modeling to analyze the probability of injury in specific regions of a 50th percentile male driver. However, modern motorsports drivers represent a range of size and sex. Additionally, motorsport helmets can be outfitted with external attachments, or enhanced helmet systems (EHS), whose effect is unknown relative to head and neck kinematics. The current study expands on previous work by incorporating a 5th percentile female and 95th percentile male human body model (HBM) into a motorsports environment to determine correlations between injury metrics and factors such as PDOF, resultant ΔV occupant size, and EHS.  
**Methods:** The Global Human Body Models Consortium (GHBMC) simplified occupant models (v2.1) were settled into a motorsport environment. This included the 5th percentile female (F05-OS, 53 kg), 50th percentile male (M50-OS, 78 kg), and 95th percentile male (M95-OS, 102 kg) (Figure 1), which provide a representative range of the size and sex of drivers seen in motorsports associations such as NASCAR. Fifty representative impacts were simulated in triplicate (for three distinct helmet configurations: baseline, visor, and visor with camera) resulting in 450 total simulations. A paired t-test (α = 0.05) was performed to study the effect of helmet configuration on 10 head and neck injury metrics without adjusting for the other variables of the study. A mixed-effects model (α = 0.05) with unstructured covariance matrix was also utilized to correlate the effect between five independent variables (resultant ΔV, body size, helmet configuration, impact quadrant, and steering wheel position) and a selection of 25 biomechanical metrics. All simulations were conducted using LS-Dyna R.9.1.  
**Data Sources:** On-track chassis acceleration crash data was used to model simulated crash pulses.  
**Results:** Risk estimates from the M50-OS with baseline helmet were used as reference values to determine the effect of body size and helmet configuration. The paired t-test found significance for helmet configuration in select head-neck metrics, but the relative increase in these metrics was not meaningful in terms of increased injury risk. Within the mixed-effects model, no significance was found between helmet configuration and injury metric values. Overall, the greatest effect was found from resultant ΔV, body size, and impact quadrant. The greatest mean difference relative to the M50-O model in head linear acceleration was found in the F05-OS (-6.41 g), while the M95-OS showed an increase (+5.26 g) (Figure 2). Lateral impacts showed the greatest effect on neck tension, however, reported Nij and neck tension values correlated to minimal injury risk (maximum values: 0.18 & 1.2 kN respectively). Trends from the mixed-effects model indicate that the occupant size and PDOF significantly influenced observed biomechanical metrics (Figure 2).  
**Significance of results:** Parametric studies provide an avenue to identify potential injury modes, and assist in the development of standards relative to personal protective equipment. The study suggests the use of modeling as an efficient means to generate data to provide rulemaking guidance to governing bodies in motorsports.

**4:00 PM - 4:10 PM**

**Brain Injury Severity Due to Direct Head Contact from Near Side Motor Vehicle Collisions**

**Author:** Rachel Tanczos, *rltanczos@ucdavis.edu*

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**ABSTRACT**

**Research Question / Objective:** This investigation aimed to analyze real world crash data to generate injury severity risk curves for brain injuries caused by direct head impacts in near side motor vehicle collisions.

**Methods:** Custom MATLAB© scripts identified near side collisions using the vehicle's most severe general area of damage, principal direction of force (PDOF), and occupant seat position. The dataset was restricted to vehicles with a change in velocity indicated to be reasonably generated by the database technician (DVCONF = 1). Occupants that were involved in a rollover, not between 16 and 65 years of age, or in a vehicle other than a passenger car were excluded. To further reduce crash condition variability, vehicles involved in more complex crash sequences (ACCSEQDV > 3) and occupants with injury sources located anterior or posterior to a typical sitting position were removed from the data set.

Brain injured occupants were identified using the Abbreviated Injury Scale (AIS) codes for concussions and internal organ injuries of the head. Injuries due to head impact were selected for using the database's direct contact variable (DIRINJ = 1). To validate impact, the attributed injury source was required to have been identified with certain or probable confidence (SOUCON = 1 or 2). For a shared condition of head impact, the occupants considered to be not brain injured were required to have some other type of direct contact head injury satisfying this same criterion.

For risk curve generation, stepwise logistic regressions were performed with combinations of various predictors: lateral change in velocity, longitudinal change in velocity, shoulder belt use, injury source type, and PDOF directionality.

Starting models consisted of a linear term for each predictor and one term for each product of predictor pairs. Eq. (1) shows this type of model with two predictor inputs of 𝑥1 and 𝑥2. Terms resulting in chi squared p-values greater than 0.05 were removed.

      𝑙𝑜𝑔𝑖𝑡(𝑀𝐴𝐼𝑆) ~ 1 + 𝑥1 + 𝑥2+ 𝑥1𝑥2                                                                       (1)  
**Data Sources:** Data was collected from the National Automotive Sample System Crashworthiness Data System's (NASS-CDS) publicly available database for the years 2001 to 2015. 129 brain injured and 121 non brain occupants met the filtering criteria.

**Results:** Lateral change in velocity (DVLAT) was the only significant predictor of brain injury risk. The dataset included DVLAT's ranging from 5 km/hr to 84 km/hr. DVLAT values for 50% risk were 28.4 km/hr (MAIS0 and MAIS1+), 32.6 km/hr (MAIS2+), and 45.8 km/hr (MAIS3+). Model accuracies, sensitivities, and specificities were all 70% and above except for the MAIS2+ and MAIS3+ sensitivities (61% and 45%, respectively).

**Significance of results:** The presented methodology determined the significance of potential injury predictors and generated injury risk curves from detailed filtering of real-world crashes. Of the preliminary predictors tested in this investigation, only DVLAT was found to be significant. Future work will expand data sources to a wider year range and explore other potential risk predictors to further improve model performance. Through simple modification, this filtering and analysis method can also be extended to other injury and collision types.

**Thursday, October 21, 2021**

**8:30 AM - 10:00 AM: Pre-/Post-Crash Research**

**8:30 AM - 8:50 AM**

**Quantitative Characterization of AEB Pulses Across the Modern Fleet.**

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**ABSTRACT**

**Research Question:** Variations in Automatic Emergency Braking (AEB) pulses among different vehicles result in increased motion of the occupant, which can significantly displace them from the ideal occupant position such that when a crash occurs their protection may be compromised (Graci et al. 2019; Osth et al. 2013). Quantifying these variations across the modern fleet is crucial to understand the loading environment vehicle occupants are exposed to - across all age passengers. The specific aim of this study was to categorize the AEB pulses in modern vehicles based on acceleration pulse features such as deceleration magnitude, jerk, ramp time, and time of deceleration.  
**Methods:** The total of 2279 AEB vehicle tests were extracted from the Insurance Institute for Highway Safety (IIHS) database and analyzed. The following pulse characteristics were extracted: jerk (g/s), ramp time (s), maximum deceleration (g). Occurrence of target contact was also considered.  A subset of tests in which the tested vehicle did not contact the foam target (n=1666) were analyzed further, with the following additional variables extracted: time of deceleration (s), steady-state acceleration (g) and duration (s). Other non-pulse related features were also considered for both total and subset analyses: initial test speed (20 and 40 kph), vehicle curb weight (lbs), vehicle model year. Using a machine learning algorithm (K-mean clustering), distinct categories of pulses were identified. One-way ANOVAs for continuous variables and X2 for categorical features were used to assess differences between clusters (p<=0.05).  
**Data Sources:** Insurance Institute for Highway Safety (IIHS) test database 2013-2019.  
**Results:** Using the entirety of the AEB vehicle tests (n=2279), a total of 3 distinct clusters were identified. The three clusters showed significantly different jerk, ramp time, and maximum deceleration (p<0.001). Target contact in AEB tests decreased in more recent vehicle model year AEB tests (rate of contact 66% in 2014 vs 1.7 % in 2019). Using the subset of tests in which there was no contact between the tested vehicle and the foam target (n=1666) and thus, steady-state variables and time of deceleration could be incorporated, 4 categories of pulses were identified and statistically significant differences were shown across all features. In both analyses, ramp time and jerk increased with vehicle model year.  
**Significance:** These results show that AEB technology improved from model year 2013 to 2019 in obstacle detection as less contact occurred with the foam target in more recent model year vehicles. The identification of AEB pulse clusters is important in order to describe distinct approaches to achieving AEB and to be able reproduce representative AEB pulses in the laboratory and understand the influences of those pulses on occupants' motion.

**8:50 AM - 9:10 AM**

**In-Depth Analysis of Crash Contributing Factors and Potential ADAS Interventions Among Risky Drivers Using the SHRP 2 Naturalistic Driving Study**

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**ABSTRACT**

**Research Question/Objective:** Motor vehicle crashes continue to be a significant problem in the United States and worldwide, particularly for young and older drivers who exhibited elevated crash risk. Advanced driver assistance systems (ADAS) have the potential to reduce the incidence and severity of these crashes.  In order to optimize these systems for real-world crash scenarios, an in-depth understanding of driver-specific errors and environmental hazards in naturalistic crash environments must be understood.  The Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS) provides extensive data on real-world crashes, offering a unique opportunity to identify factors contributing to crashes and potential ADAS interventions in a naturalistic setting.  The objectives of this study were to quantify crash causation factors among risky drivers using naturalistic crash data, identify potential ADAS interventions, and make recommendations to optimize ADAS for real-world crash scenarios.  
**Methods:** A subset of the SHRP2 NDS consisting of 369 at-fault crashes among three risky driving groups - teens (16-19 yrs), young adults (20-24 yrs), and older adults (70+ yrs) - and a baseline driving group -adults (35-54 yrs) - were reviewed to identify crash causation factors and potential ADAS interventions by two independent coders.  Causation factors were classified according to National Motor Vehicle Crash Causation Survey (NMVCCS) pre-crash assessment field categories.  A critical causation factor, defined as the primary cause of the crash, was identified for each crash.  Discrepancies were reconciled by the study team.  For SHRP2 crashes labeled as *most severe* according to the SHRP2 crash severity classification, case reviews with industry experts were conducted to identify recommendations for ADAS improvements.  Critical causation factors were compared across risky driving groups using chi-square statistics in SPSS Statistics 21.0.   
**Data Sources:** Subset of the SHRP2 NDS consisting of crash events among teen, young adult, adult, and older drivers.  
**Results:** Similar to NMVCCS, driver error was the critical factor in 94% of all crashes.  Recognition error (56%), including inadequate surveillance and internal distraction, was the most common driver error sub-type (Figure 1).  Teens and young adults exhibited greater decision errors compared to older adults (p<0.01).  Older adults exhibited greater performance errors (p<0.05) compared to teen and young adult drivers.  Automatic emergency braking (AEB) had the greatest potential to prevent crashes (Figure 2), being applicable to 48% of SHRP2 crashes.  This was followed by Vehicle-to-Vehicle (V2V) technology (38%) and driver monitoring (24%).  ADAS recommendations for more complex crashes included (1) implementing adaptive FCW, AEB, high-speed warning, and curve-speed warning to account for road surface conditions in poor weather (2) ensuring AEB detection of non-standard road objects, (3) V2V alerting drivers to cross-traffic, (4) V2I alerting to the presence of pedestrians in crosswalks, and (5) optimizing lane departure warning for end-departures and pedal confusion.   
**Significance of Results:** These data provide traffic safety stakeholders with comprehensive crash causation factors as well as recommendations for ADAS improvements based on naturalistic crashes.  These data can be used to optimize ADAS for driver-specific errors and help develop more robust vehicle test procedures.

**Thursday, October 21, 2021**

**2:10 PM - 3:50 PM: Vulnerable Populations**

**2:00 PM - 2:20 PM**

**Development of a Concise Injury Prediction Model for Pediatric Patients Involved in an MVC**

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**ABSTRACT**

**Objective:** Transporting severely injured pediatric patients to a trauma center has been shown to decrease mortality. However, prehospital determination of which patients are severely injured can be difficult.  An optimal decision support tool for emergency medical services (EMS) providers would be both as parsimonious as possible and highly accurate for predicting injury severity.  The study objective was to determine the minimum data required to accurately predict severe injury and develop a reduced variable set model.  
  
**Methods:** We developed a baseline model for predicting severe injury in pediatric patients using the following predictors: age, female sex, seat row, restraint use, principal direction of force (PDOF), total change in velocity (delta-V), single vs. multiple collisions, and non-rollover vs. rollover.  Occupant ages were grouped as 0-4, 5-9, 10-14, and 15-18 years.  PDOFs were based on quadrant and classified as frontal, rear, near-side, and far-side.  Restraint use was represented with two binary variables: 1) no restraint use; 2) optimal restraint based on age/size-specific recommendations.  The outcome of interest was severe injury (injury severity score (ISS) ≥16).  Accuracy was measured by the mean and 95% CI of the receiver operator curve (ROC) area under the curve (AUC) from ten-fold cross-validation.  We repeated this procedure for every combination of variables (all subsets regression).  The importance of each variable was determined using Bayesian Model Averaging (BMA).  The mean AUC of the highest performing model for each number of variables was also recorded.  These results were compared to the baseline model using a two-sample T-test to assess for a statistically significant difference (p<0.05).  A reduced variable set model was derived using this information.   
**Data Sources:** Data were combined from the National Automotive Sampling System (NASS) 2000-2015 and Crash Injury Surveillance System (CISS) 2017-2018.  Only occupants aged 0-18 years were included.  Cases were excluded if there was missing data regarding age, delta-V, PDOF, proper restraint, or ISS.  These criteria resulted in 13,421 pediatric occupants for analysis.   
**Results:** The baseline model using all thirteen variables performed well (AUC of 0.90 [95% CI: 0.86-0.94]).  The six most important variables using BMA were delta-V, no restraint use, near-side collision, multiple collisions, optimal restraint use, and rollover (Figure 1).  Deterioration of accuracy was not seen until the models were reduced to less than five variables. No statistically significant decrease in accuracy was seen until there were less than three variables in the model (Figure 2).  A reduced variable set model developed using the top three variables (delta-V, no restraint use, and near-side collision) had an AUC of 0.89 (95% CI: 0.85-0.93), nearly equivalent to the baseline model.  In the models that did not include delta-V, the highest AUC achieved was 0.75 [95% CI: 0.68-0.81] from a seven-variable model.     
**Significance of Results:** These findings indicate that a very succinct model could be effective for accurately predicting severely injured pediatric patients in the prehospital triage context. However, in order to realize the pragmatic implementation of such a model, there remains a critical need to develop systems that readily facilitate delta-V data collection in real-time.

**2:20 PM - 2:40 PM**

**Effect of Pedestrian Physique Differences on Head Injury Prediction in Car-to-Pedestrian Accidents Using Deep Learning**

**Author:** Shouhei Kunitomi, *kunitomi.syouhei@gmail.com*

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**ABSTRACT**

**Research Question / Objective:** Advanced automatic collision notification (AACN) systems predict the occupant injury severity in car-to-car accidents using information collected by event data recorders. To apply AACN to pedestrians, we propose a new injury prediction algorithm using pedestrian collision images and deep learning for head injury prediction.  
Our previous works have focused only on the AM50, so the effects of pedestrian physique differences on injury prediction using deep learning have not been studied. There is general consensus that pedestrian physique differences may significantly impact the occurrence and severity of injuries. Moreover, pedestrian physiques change the range and sizes of pedestrians in collision images that simulate dash-cams, thereby affecting injury prediction accuracy.  
 The aim of this study is to identify the effects of pedestrian physique differences on head injury prediction by deep learning in car-to-pedestrian incidents.  
**Methods:** In this study, based on the prediction results of trained models that have learned the relationships between pedestrian collision images and head injury criterion (HIC) from simulations, we identified the effects of pedestrian physiques on head injury prediction accuracies using deep learning (Figure 1).  
Simulations were performed using a vehicle finite element (FE) model and MADYMO pedestrian models (AM50, AF05, 6YO). The vehicle FE model was developed and validated by 12 impact tests at the component and full-scale levels. The initial gaits for the pedestrian models were obtained from volunteer experiments to reproduce 420 pre-crash reactions using 32 angles for the 13 joints of the pedestrian model. Furthermore, by factoring the pedestrian models (3 types), pedestrian directions (2 each), impact positions (3 each), and vehicle velocities (6 levels) with the pre-crash parameters, a total of 45,360 car-to-pedestrian impact simulation cases were obtained.  
After simulation, image datasets were created by labeling the pedestrian collision images with HIC and dividing into training and test data based on model type. Next, deep learning was conducted with the training dataset to obtain trained models. Finally, the effects of pedestrian physique differences on head injury predictions were investigated via the accuracy of each trained model for test data.  
**Data Sources:**  MADYMO simulation results, Euro NCAP TB024, and literature.  
**Results:**  In head injury prediction with deep learning, AF05 showed the highest prediction accuracy (93.25%), followed by AM50 (90.60%) and 6YO (88.29%). These results show the high performance of deep-learning methods in head injury predictions not only in adult men but also children and small women. Furthermore, our results demonstrate that pedestrian physique differences affect injury prediction accuracies. Based on analyses of the image datasets and collision behaviors of each pedestrian model, we conclude that differences in the head contact area and amount of pedestrian information in the image affect the deep-learning prediction results (Figure 2).  
**Significance of results:**  The large-scale simulations comprehensively reproduce car-to-pedestrian impacts and clarify the effects of pedestrian physique differences on head injury predictions using deep learning.

**2:40 PM - 3:00 PM**

**Rear-Seated Pediatric Occupant Head Kinematics and Kinetics in Small Overlap Frontal Crashes: Restraint Characteristics and Occupant Interaction**

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**ABSTRACT**

**Research Question/Objective**: Advances in front-seated occupant protection have not been realized for rear-seated occupants in crash impacts. Studies have reported rear-seated occupants sustaining severe injuries due to belt loading where front-seated occupant survived. One particular impact that has received recent attention is the small overlap crash, which accounts for 26% of severe frontal crashes, and has a high likelihood of injury to both the driver and passengers. Prior studies have shown that the small overlap injury risk in the rear seat is comparable to that in the front seat, with head injuries being commonly reported. These can be exacerbated due to interaction with an adjacently seated occupant. Therefore, the aim of this study was to explore the responses of adjacently rear-seated pediatric occupants under different vehicle restraint characteristics, child seats, and seating positions in small overlap crashes.  
**Methods:** The PIPER 6YO and THUMS 5th percentile (representing a 12YO) finite element (FE) human body models were positioned in the rear seat of a 2015 Toyota Camry FE model with a side-curtain airbag. The PIPER was seated on a lowback and a highback booster, whereas the THUMS was seated on the vehicle seat directly. The occupants were seated in two positions: 1) THUMS in the left outboard seat and PIPER in the center, and 2) PIPER in the left outboard seat and THUMS in the center.  
A standard 3-point lap-shoulder belt system was modeled to restrain the occupants. The left outboard restraint included a retractor, pretensioner, and a load-limiter, while the center seat restraint was modeled with and without a pretensioner and load-limiter. Two load-limits were tested: 4kN and 2kN. The load-limits used for the left outboard and center seat were same across conditions. The vehicle environment was subjected to a driver-side and a passenger-side small offset (25% overlap) frontal barrier impact at 40MPH.  
**Data Sources**: 32 conditions were simulated in LS-DYNA R10.1.0 (LSTC, CA). Kinematics and kinetics were extracted and compared as per SAEJ211 metrics.  
**Results**: For the driver-side small overlap crash, the PIPER's head contacted either the THUMS, the child seat, or its own limbs in 7/16 cases. Contact with the THUMS resulted in greater head acceleration (107G-129G) than other simulated cases (47G-95G). In both seating position-1 and 2 with the retractor/pretensioner/4kN-load-limiter, forward head excursions for the PIPER and THUMS were lower than other simulated restraint conditions. Lateral head excursions were similar across all simulated restraint conditions for both occupants.  
For the passenger-side small overlap crash, the shoulder belt slipped off the PIPER in 5/16 cases and the THUMS in 4/16 cases. Again, in both seating position-1 and 2 with the retractor/pretensioner/4kN-load-limiter, both forward and lateral head excursion for the PIPER and THUMS were mostly lower than other simulated restraint conditions.  
The study is limited by restraint parameters, crash impact directions, and simulation environment validation with physical test data.  
**Significance of Results**: The data can aid in the future development of vehicle rear-seat injury mitigation technologies and restraints, booster designs, and anthropomorphic test devices (ATDs).

**3:00 PM - 3:20 PM**

**Evaluation of Static Belt Fit and Belt Torso Contact for Children on Belt-Positioning Booster Seats**

**Author:** Gretchen Baker, *gretchen.baker@osumc.edu*

**Co-Authors:** Julie Mansfield, *julie.mansfield@osumc.edu*, Randee Hunter, *randee.hunter@osumc.edu*, John Bolte, *john.bolte@osumc.edu*

**ABSTRACT**

**Research Question/Objective:** Previous studies have indicated that gap between the seatbelt and torso (less belt torso contact) for children on belt-positioning booster seats (BPBs) may lead to less torso engagement and increased likelihood of shoulder belt slip-off during evasive vehicle maneuvers, potentially increasing injury risk during crash. However, current BPB belt fit measures do not quantify belt gap and may not be able to fully discriminate between designs which provide good vs. poor dynamic outcomes. The goal of this study is to evaluate novel metrics of belt fit (namely, belt gap characteristics) in addition to conventional measures of seatbelt fit for BPB-seated child volunteers. This study ultimately seeks to enhance understanding of optimal belt fit.  
**Methods:** Ten BPBs (representing various manufacturers and belt routing schemes) and three seatbelt anchor positions were investigated. A cohort of 50 volunteers (4-14 years, 18.8-52.6 kgs, 108-161 cm) were recruited and each evaluated on six unique combinations of BPB and seatbelt anchor position on a vehicle rear seat in a laboratory setting (total trials n=300). A 3D coordinate measurement system quantified positions of anatomic, seatbelt, BPB, and vehicle reference points. Novel belt fit metrics (percent belt torso contact, gap location, gap size, and gap length) were calculated using 3D positions of anatomic and seatbelt landmarks. Conventional belt fit metrics were computed, as in previous studies, to quantify the belt position on the shoulder and pelvis. ANOVA and univariate linear regressions were utilized to investigate variation in belt fit and belt gap due to BPB, seatbelt anchor positions, and anthropometry.  
**Data Sources:** Images of children in each BPB, 3D positions of anatomic, seatbelt, and vehicle reference points, and qualitative assessment of belt fit by a certified child passenger safety technician for each trial (n=300).  
**Results:** BPBs produced significantly different belt fit and belt gap outcomes, while seatbelt anchor location did not. Gap size and length were significantly different between BPB designs. BPBs with design features that directly routed the shoulder belt more forward on the buckle side (Figure 1) produced the largest (2.8±1.4 cm) and longest (10.6±6.7 cm) gap on average while BPBs that pulled the belt less forward or did not directly route the belt (Figure 2) produced the smallest (0.4±0.9 cm) and shortest (1.4±3.1 cm) gap on average. Belt gap outcomes were not strongly associated with conventional belt fit metrics, indicating that evaluation of belt gap may provide additional insight when attempting to discriminate between BPBs which provide good vs. poor seat belt engagement during vehicle maneuvers and crashes.  
**Significance of Results:** This is the first study to evaluate belt gap size, length, and position for BPB-seated children. Results from this study suggest that belt fit and belt gap are influenced by BPB design, particularly shoulder belt routing features on the buckle side, and may have implications for belt engagement during dynamic events. Results from this study provide essential initial conditions for future evaluation of the kinematic and belt interaction outcomes for BPB-seated occupants during crashes.

**Thursday, October 21, 2021**

**4:00 PM - 5:00 PM: Vulnerable Populations**

**4:00 PM - 4:20 PM**

**Evaluation of LATCH vs. Non-LATCH Installations for Boosters in Frontal Impacts**

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**ABSTRACT**

**Research Question / Objective:** The objective was to understand how the use or non-use of the Lower Anchors and Tethers for Children (LATCH) system affects the performance of booster seats during frontal impacts.  
**Methods:** Four high-back booster models and two backless booster models were tested in frontal impacts using the FMVSS 213 pulse (approximately 30 mph and 25 g). A production vehicle seat buck was attached to the sled. Each booster model was installed two different ways: using the LATCH system ("LATCH" installation) and without using the LATCH system ("non-LATCH" installation). All installations used a 3-point seat belt with retractor in emergency locking mode (ELR) to restrain a Hybrid III 6-year-old anthropomorphic test device (ATD). The retractor, belt webbing, buckle, vehicle seat cushion, and booster were replaced after each test. Some conditions were tested twice to establish repeatability. ATD and booster responses were compared between LATCH and non-LATCH tests.  
**Data Sources:** Kinetic and kinematic data from eighteen sled tests using six different booster seat models installed on a production vehicle seat.  
**Results:** The forward movement of the booster was less during LATCH installations compared to non-LATCH installations (average of 7.2 vs. 14.6 cm, respectively). Forward movement of the ATD head was similar between LATCH and non-LATCH tests and ranged from 31.3 cm to 42.3 cm, measured from initial position. HIC36 values trended slightly higher for LATCH installations compared to non-LATCH installations (average of 633 vs. 562, respectively). Chest resultant accelerations ranged from 48.3 g to 72.8 g and did not show trends with respect to installation method. For the backless boosters, chest deflections trended higher for LATCH installations compared to non-LATCH installations (average of 4.2 vs. 3.5 cm, respectively). For high-back boosters, chest deflection was similar between installation conditions. Pelvis angular velocities about the y-axis were higher for LATCH installations than non-LATCH installations, in both positive and negative directions. Shoulder belt loads ranged from 4.6 kN to 6.8 kN and did not show trends with respect to installation method. Instances of ATD submarining were not observed in these tests.  
**Significance of results:** LATCH installations are optional on most booster seats on the US market. There is currently little data available to inform consumers and safety advocates about the potential benefits vs. detriments of using LATCH for boosters. One previous study found evidence of the ATD occupant de-coupling from the booster and submarining under the lap belt when a LATCH installation was utilized, while other studies from Europe have cited minimal differences in performance between installation conditions. The current study adds more insight about the role of booster installation conditions across different booster types. Since most boosters are tested only on the FMVSS 213 bench using clamped seat belts, this study offers more realistic information about booster performance on production vehicle seats with seat belt retractors for LATCH and non-LATCH installations.

**4:20 PM - 4:40 PM**

**The Rider Behaviour Questionnaire as a Predictor of Motorcycle Taxi Crashes in Cartagena (Colombia)**

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**ABSTRACT**

**Objective:** The study aims to identify the association between behavioural factors and near-crashes, crashes, traffic violations, and at-fault crashes, with demographic, exposure, and operational variables of motorcycle taxi drivers through the Motorcycle Rider Behaviour Questionnaire (MRBQ).   
**Methods:**  This study was a cross-sectional survey of motorcycle taxi riders in Cartagena, one of the capital cities with more traffic crashes and motorcyclists dedicated to informal transportation in Colombia. The MRBQ was adapted to the sociocultural context and contained 45 items. The survey was carried out between February 2019 and May 2019. Motorcycle taxi drivers were randomly selected and invited to participate in the study from 27 informal stations identified in areas with high mobility convergence. The questionnaire collected demographic (gender, age, marital status, education), riding (engine-cylinder, maintenance, and riding experience) and operating conditions (property, daily income, and passengers transported), history of crashes, and traffic fines. The structure of the MRBQ items used a factorial analysis (principal components with varimax rotation). Comparisons were developed with the Chi-square test of Kruskal-Wallis and Mann-Whitney. Finally, four logistic regression models were used to analyse the association between behavioural factors and aspects of demographic, operating conditions, and riding with near-crashes, crashes, traffic fines, and at-fault crashes.   
**Results:**Four hundred and thirty-eight motorcyclists taxi drivers (male = 99.5%; mean = 33.5 years) participated in the questionnaire. The average riding experience was 9.9 years. The average hours of riding per week were 61.3. The exploratory factor analysis extracted 5 elements as stunts (intentional sensation-seeking behaviours or manoeuvres), speed violations (deliberate or intentional acts), traffic errors (unintentional mistakes), control errors (conscious or unconscious failures), and safety (protection elements) that explained 42% of the variance. The Cronbach's alpha reliability coefficients were over 0.75. The most-reported factors were control errors (M: 3.24, SD: 0.51), safety (M: 2.74, SD: 1.05), and traffic errors (M: 2.30, SD: 0.70). Stunts were the least reported factor (M: 1.72, SD: 0.60). The score of stunts and speed violations were higher for the motorcycles in low-quality conditions. The score of stunts presented significant differences with fewer years of riding experience. The increase in the hours riding per week showed significant differences with stunts, speed violations, and traffic errors. Finally, riding experiences, traffic errors, control errors, and safety were significant predictors of crashes and near-crashes. Stunts were the strongest predictor of traffic fines. Speed violations were the strongest predictor at-fault crashes.   
**Conclusions:** This is a study applied to identify behavioural aspects of motorcycle taxi drivers in South America, where studies are very limited. The research is a pioneer in the behavioural analysis of motorcyclist road safety in Colombia through the MRBQ instrument. The adaptation of the instrument to the context was an effective mechanism and useful for understanding the behaviour, exposure, and operating conditions of economic activity of motorcycle taxi drivers, and its relationship with collisions and infractions. The study recommends some practical implications for the well-being of motorcyclists and road safety.

**4:40 PM - 5:00 PM**

**Motorcycle Autonomous Emergency Braking (MAEB) Employed as Enhanced Braking: Estimating the Potential for Injury Reduction Using Real-World Crash Modeling**

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**ABSTRACT**

**Research Question/Objective:** Recent field-tests on Motorcycle Autonomous Emergency Braking system (MAEB) showed that higher levels of deceleration to improve its effectiveness were feasible. However, the potential of MAEB in mitigating rider injuries is still not well understood, particularly in scenarios where the efficacy of standard MAEB is limited because the rider is manually braking. Therefore, the purpose of this study was first, to assess the injury mitigation potential of MAEB and second, to test MAEB as an enhanced braking system applied in circumstances where the rider is manually braking before a crash.

**Methods:** Real-world motorcycle injury crashes that occurred in Australia were reconstructed using a 2D model. The intervention of MAEB was applied in the simulations to test both MAEB standard and new strategies for MAEB intervention working as enhanced braking system (Fig. 1). The effects of MAEB in mitigating crashes were separated by crash configuration and evaluated based on the modelled reductions in impact speed and injury risk, employing injury risk functions published in the literature.

**Data Sources:** Data was sourced from previously investigated motorcycle injury crashes that occurred on public roads in Australia (Allen et al., 2016).

**Results:** About half of cases in the crash database (53%) were assessed as possibly applicable for MAEB, of which a subset of 33 cases were selected for reconstruction. After modelling was applied, MAEB was found to be applicable in 30 cases (91%). The overall Impact Speed Reduction (ISR) among the 30 cases averaged 5.0 km/h (Fig. 2), and relative injury reduction was 7.2% for MAIS2+ and 15.5% for fatal injuries. For cases without rider manual braking (n=16), the mean ISR due to standard MAEB was 7.1 km/h (Fig 2), and relative injury risk reduction ranged from 10% for MAIS2+ to 22% for fatal injuries. In the 14 cases with manual braking, the MAEB modelled as enhanced braking led to an average ISR ranging from 5.3 to 7.3 km/h (Fig. 2), depending on the mode of MAEB intervention. This resulted in an injury risk reduction ranging from 9 to 12% for MAIS2+ and from 16 to 21% for fatal injuries (depending on the mode of MAEB intervention).

**Significance of results:** This study estimated the potential benefits of the highest levels of intervention for MAEB field-tested to date. New strategies for MAEB intervention as enhanced braking were tested using crash reconstruction of real-world crashes. Results showed MAEB could mitigate motorcycle crashes and reduce injury risks for motorcyclists. An improvement in the potential of MAEB was also found for MAEB as enhanced braking in cases where riders were manually braking before the crash. This highlights the requirement to perform new field-based tests to assess the feasibility of MAEB deployed as enhanced braking system.

**Friday, October 22, 2021**

**10:15 AM - 11:55 AM: Automated Systems/AV Seating/Biomechanics**

**10:15 AM - 10:35 AM**

**Differential Benefit of LIDAR and Current Sensor Systems in Pedestrian Automated Emergency Braking Systems**

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**ABSTRACT**

**Research Question / Objective:** In active safety development, there is a delicate balance between the benefit from high performance sensors and the associated cost for these more capable sensors. Current Pedestrian Automatic Emergency Braking (PAEB) systems use a combination of radar and cameras to detect pedestrians and apply heavy braking to prevent or mitigate an impending collision. However, these current sensor systems have a restricted field-of-view (FOV) which may not detect all pedestrians. LiDAR has a wider field of view that may substantially improve detection, but it is more expensive. The objective of this study is to determine the influence of field-of-view and range on the effectiveness of PAEB systems.  
**Data Sources:** This study utilized vehicle-pedestrian crashes from Pedestrian Crash Data Study (PCDS). PCDS was collected from 1989-1993 and contains 549 vehicle-pedestrian crashes. Each case contains detailed pedestrian injury information, reconstructed impact speeds, non-digitized crash scene diagrams, and vehicle damage reports.  
**Methods:** To supplement the PCDS data, we manually collected vehicle and pedestrian trajectory locations from the crash scene diagrams and used an assumed velocity profile to estimate the time and velocity at each vehicle and pedestrian location. Counterfactual simulations of vehicle-pedestrian crashes were conducted to determine how PAEB could reduce or avoid crashes with pedestrians. As we did not have vehicle kinematic data, we assumed two potential vehicle velocity profiles for each case, a late/hard and early/weak braking driver model. The pedestrian was assumed to travel at a constant speed based on the age, gender, and group size and take no evasive actions. The simulations were conducted using a variety of field-of-views and ranges in order to represent both commercial LiDAR and radar systems. The sensor systems were assumed to always detect the pedestrian regardless of weather, pedestrian size, and pedestrian clothing. We simulated sensors with 24° - 360° FOV and 40 m - 250 m range. We also varied PAEB system activation time-to-collision and computational latency to capture a range of potential PAEB system parameters.  
**Results:** The most robust sensor, 360° FOV and 250 m range, could avoid up to 97% of crashes compared to 81% for a sensor with a 24° FOV and 40 m range. Avoidance capability increased with the time-to-collision of the PAEB activation and decreased with the computational latency. As FOV and range of the sensor decreased, effectiveness decreased. Range had little effect on system performance. Increasing the range of a 24° FOV system from 40 m to 160 m only increased avoidance by 2%. FOV had a greater effect on avoidance capability with the LiDAR systems performing about 13% better than the radar systems regardless of range.  
**Significance of results:** These results are significant because they elucidate the effect of FOV and range on system effectiveness and are the first of their kind using the U.S. data from PCDS. This information could be useful in active safety deployment to determine potential benefits of sensors and provide manufactures with information that may aid in the development of more effective and affordable PAEB systems.

**10:35 AM - 10:55 AM**

**US Vehicle Occupancy Trends Relevant to Future Automated Vehicles and Mobility Services**

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**ABSTRACT**

Identifying current occupant travel patterns can inform decision-making regarding the design, regulation, and occupant protection systems needed for automated vehicle systems and mobility services. Two travel datasets were analyzed to quantify travel patterns: the 2017 National Household Travel Survey (NHTS), which provides data on household trips logged for a 24-hour period, and the 2011-2015 National Automotive Sampling System-General Estimates System (NASS-GES), which contains data sampled from police-reported crashes. Analysis identified trends with driver age and gender, occupant age and gender, time of day, day of week, trip purpose, trip duration, vehicle type, as well as occupant role as solo driver, driver of others, single passenger, or multiple passenger.

In NHTS, the median trip duration is 15 minutes; only 10% of trips last longer than 40 minutes. Trip duration does not vary with occupant role or vehicle type. Variations with trip time of day and day of week show a unimodal pattern for weekends, as well as weekday trips for those age 55 years and older and non-solo occupants aged 18-29 years. Other occupant groups have a bimodal weekday travel pattern with peak trips corresponding to morning and evening rush hours.

In GES, approximately half of occupants are solo drivers. Female drivers age 55 and older travel alone 60% of the time, and drivers under 18 and female drivers age 30-54 drive alone on less than 45% of trips. Approximately 13% of occupants are single passengers, while 16% travel with a driver and at least one other passenger. About 16% of occupants are front passengers.

This analysis of vehicle occupancy provides insights on what ridership of future automated vehicles and expanded ride-hailing services may look like. Because half of occupants are solo drivers, only 16% are multiple passengers, and median trip length is just15 minutes, proposed alternative seating arrangements intended to promote comfort and passenger interaction may not be justified given the challenges in designing effective occupant protection systems for these scenarios.

**10:55 AM - 11:15 AM**

**A Holistic Assessment of Injury Risk in Planar Crashes with Application for Autonomous Vehicles**

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**ABSTRACT**

**Research Question** Automated driving systems (ADS) are actively being designed and deployed throughout the driving fleet. These vehicles are being built to safely navigate roadways, which includes executing proper roadmanship and responding accordingly when other actors take surprising actions. A key piece to the ADS design and evaluation process is the assessment of potential injury severity when crashes are not prevented. To do so, the ADS vehicle design process should consider and assess injury risk for the various speeds, directions of force, and objects contacted, while potentially accounting for occupant characteristics. Current regression models in the literature are bespoke analyses involving targeted PDOFs and occupant positions. The novelty of the proposed model are continuous, parametric injury risk surfaces (at varying severity thresholds) that encompass the full spectrum of available field data. This model can serve to provide insight to potential outcomes of counterfactual simulations as well as provide insights into injury risk and crashworthiness considerations for all vehicles.

**Methods** We used field data and logit models to estimate injury risk at the maximum AIS 3+ and 5+ levels for all occupants traveling in passenger vehicles model years 2002 or newer which were less than 10 years old at the time of the crash. The logit models included covariates delta-V, principal direction of force, subject vehicle type, partner/object type and vehicle model year, as well as occupant restraint usage, age, male/female, and seating position. Occupants involved in fires or roll-overs or seated in a non-standard seating position (such as in someone's lap or in the bed of a pick-up) were excluded. Interactions and injury severity prediction between a vehicle and vulnerable road users (i.e. pedestrian, bicyclist, powered two wheeler) were not considered in this analysis.

**Data Sources** We used years 2001-2015 of the National Automotive Sampling System, Crashworthiness Data System (NASS-CDS) and years 2017-2018 of the Crash Investigation Sampling System (CISS). All analyses accounted for survey design and weighting.

**Results** We present statistical models suitable to predict injury in all non-rollover crashes at the maximum AIS 3+ and 5+ levels, and we show that these models can be made to perform similarly to similar single scenario (e.g. Frontal) crash models. We further discuss challenges with imputing missing field data which are specific to this problem, and we discuss handling of covariates that may not be known at the time of the crash.

**Significance of Results** Collision severity assessment is a vital component of the ADS design process. A novel injury risk function was developed that provides a means for assessing vehicle occupant injury risk across the spectrum of foreseeable collisions. This model provides a methodology that can be applied in the ADS industry for safety benefits estimation and in simulated and real-world driving events evaluation.

**11:15 AM - 11:35 AM**

**Effect of Various Restraint Configurations on Submarining Occurrence Across Varied Seat Configurations in Autonomous Driving System Environment.**

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**ABSTRACT**

**Research question/objective:** Self-driving technology will bring novelty in vehicle interior design and allow for wide variety of occupant seating choices. Previous studies have shown that the increased risk of submarining exhibited by reclined occupants cannot be fully mitigated by changes in the seat configuration alone. This study aims to investigate the effects of additional restraint countermeasures on submarining risk and injury prediction metrics for reclined occupants in frontal crashes.  
**Methods:** Vehicle environment frontal crash Finite Element (FE) simulations were performed with the two simplified Global Human Body Model Consortium (GHBMC) occupant models: small female and midsize male. The baseline occupant restraints consisted of a frontal airbag, a seatback-integrated 3-point belt with a lap belt anchor pre-tensioner, and a retractor-mounted pre-tensioner and load limiter. Based on submarining threshold identified in previous studies, three baseline configurations were chosen for the male and female models. For each baseline case three restraint system modifications were evaluated. The modifications consisted of the introduction of a pelvis restraint cushion airbag, the use of a knee airbag and the modification of the of the passenger airbag location. All simulations were performed using the USNCAP 56 km/h frontal crash pulse (without vehicle deformation). Occupant kinematic data was extracted from each simulation to investigate how changes in the restraint system configuration affects submarining across all eighteen simulated cases.  
**Data Sources:** Eighteen sled FE frontal crash simulations with GHBMC occupant models.  
Results: Overall, none of the investigated cases proposed modification to the restraints prevented submarining occurrence, however each of the restraint modification reduced the pelvis excursion over the baseline scenario. The presence of the pelvic restraint cushion airbag showed the highest reduction in pelvis forward excursion for the female occupant model. The presence of the knee airbag and the modified location of the passenger airbag also contributed to reductions in excursion to a smaller degree. For the male surrogate, the knee airbag showed the highest reduction in pelvis forward excursion. The other restraint systems reduced pelvis excursion in a lesser degree. The presence of the pelvic restraint cushion led to a reduction in the lumbar spine shear force.  
**Significance of Results:** Submarining may be a major challenge to overcome for reclined occupants in autonomous driving systems. This study shows that implementing a PRC airbag in the seat may be a promising concept that could help in restraining occupants in recline scenarios and potentially in combinations with other preventive systems could prevent submarining.