C34 Increased Risk of Submarining and Lower Extremity Injuries Associated With Obesity in Frontal Impacts

Christopher J. Furbish, BSc, Biodynamics Engineering, Inc., 3720 East La Salle Street, Phoenix, AZ 85040; Parris Ward, JD, Biodynamics Engineering, Inc., 17383 West Sunset Boulevard, Suite A300, Pacific Palisades, CA 90272; and Hrire Der Avanessian, PhD, Biodynamics Engineering, Inc., 2831 Montrose Avenue #5, La Crescenta, CA 91214*

After attending this presentation, attendees will be familiar with various risk factors associated with restraint effectiveness relative to body mass index (BMI), primarily for lower extremity injuries in frontal impacts.

This presentation will impact the forensic science community by aiding in better understanding occupant kinematics and restraint effectiveness during frontal impacts.

Between 1960 and 2004, the CDC reports that the obesity rate in the United States more than doubled from 13.3 to 32.1 percent for adults aged 20 to 74. Should the current trend continue to the year 2015, some models predict that the obesity rate will reach 41 percent, with as many as 75 percent of U.S. adults being overweight. After attending this presentation, attendees will be familiar with various risk factors associated with restraint effectiveness relative to body mass index (BMI). Multiple volunteers of various body sizes were placed in the driver's seat of a 2003 SUV and measurements of the seat belt and body- to-vehicle interior distances were recorded. These measurements revealed trends indicating an increased risk for submarining and lower extremity injuries for occupants with higher BMI ratings involved in a frontal impact.

Previous studies addressing obesity and injury severity for various body regions and crash conditions have revealed some contradicting conclusions. For example, a 2003 study found that the overweight occupant has a decreased risk of abdominal injury compared to both lean and obese occupants. However, a 2008 study concluded that overweight occupants (but not obese occupants) are at risk of suffering more severe injuries than an occupant with a normal BMI. The majority of these studies were based on statistical epidemiological analyses of data reported in various databases, such as CIREN, NASS-CDS, etc. This study addresses the expected kinematics of occupants with various BMI ratings based on the seat and restraint geometries, while keeping the vehicle and assumed impact configuration constant. Based on these expected kinematic differences, the potential injury patterns and risks were determined.

The male and female adult volunteers used in this study were of various ages with BMI's ranging from 20 to 45. A BMI greater than or equal to 30 is generally considered to be obese. Each volunteer was placed in the driver's seat of the SUV and asked to adjust the seat fore/aft position and seat back recline angle into the most comfortable driving position. Multiple measurements of the lap belt were taken relative to the left and right anterior superior iliac spine (ASIS) locations of the pelvis. Knee-to-dash, abdomen-to-steering wheel, and sternum-to- steering wheel distances were recorded. Additionally, the positioning of the seat bottom, seat back, and lap belt relative to the occupant compartment were documented.

Based on the recorded data, various trends were found as a function of BMI. As BMI increased, the average seat back angle relative to horizontal decreased. In other words, the higher the BMI the more likely the occupant would ride in a more reclined position. The distances in the longitudinal (x-axis) and vertical (z-axis) directions between the ASIS and the most forward portion of the lap belt both increased as BMI increased. Additionally, the length of the lap belt from the floor anchor to the latch plate increased with an increase in BMI. The data presented demonstrates how these trends predispose an occupant with a higher BMI to greater risk of lower extremity injuries and/or submarining injuries. For occupants of higher BMI, the longer lap belt length and its increased distance from the bony pelvis due to additional soft tissue would allow for a greater amount of lower extremity forward excursion during a frontal impact. The more reclined seat back position, as well as the increased height of the forward-most portion of the lap belt, would place a high-BMI occupant at greater risk of submarining as the direction of force from the lap belt shifts up toward the abdominal structures with a higher probability of overriding the pelvis. Additionally, vehicles equipped with load-limiting energy activating webbing loops in the lap belt further increase the likelihood of submarining and resultant lower extremity injury.

Mathematical dynamic models (MADYMO) simulations were conducted to demonstrate some of the expected differences between the occupant kinematics for occupants in the normal, overweight, and obese BMI ranges. Additionally, a real world case study with an occupant sustaining both lower extremity and submarining injuries was analyzed to demonstrate the potential outcome of these risk factors.

Body Mass Index (BMI), Restraint Effectiveness, MADYMO