Proceedings of the ASME 2017 International Mechanical Engineering Congress & Exposition
IMECE2017
November 3-9, 2017, Tampa Convection Center, Tampa, Florida, USA

**IMECE2017-71976**

# The Mechanical and Electrical Performance of a Motorized Car Seat

Kathia Coronado
Manhattan College
Riverdale, New York, USA

Veronica Valerio
Manhattan College
Riverdale, New York, USA

Caitlin Hall
Manhattan College
Riverdale, New York, USA

Dr. Parisa Saboori
Manhattan College
Riverdale, New York, USA

Dr. Graham Walker
Manhattan College
Riverdale, New York, USA

## ABSTRACT

It has been shown that outside of a car crash scenario infants and young children can be exposed to many hazardous situations if left sitting in a car seat. Researchers have tied sleeping in a car seat to hyperextension of neck muscles, oxygen deprivation, or even positional asphyxia. To address this issue the present research involved creating a three-dimensional model of the head, neck, spine, and trachea of a two-years-old toddler. These components were then assembled and a kinematic analysis was run using computer-aided engineering (CAE) software.

This analysis simulated the effects that acceleration and deceleration would have on a baby sleeping in a car seat with the head slumped forward, with particular emphasis being placed on the neck and spine of the child. This allowed the points of maximum relative acceleration to be observed when the head starts from a slouched position. This information was then used to determine the conditions that might lead to the pinching (buckling) of the trachea. Also, a stress analysis was performed to examine the stresses experienced by the disks and neck muscles, again associated with the head in the extreme sleeping position during deceleration.

Work was also done to redesign a car seat with respect to allowing the head to be repositioned should the child's head slump forward.

## INTRODUCTION

Babies and infants do not have full control of the muscles in their neck; therefore their heads often slump forward when they fall asleep. Unfortunately, this can lead to hyperextension of the neck muscles causing neck pain, but more seriously this can cause the trachea to become pinched leading to positional asphyxia.[1,2,3,4,5] This has become such a concern that the American Academy of Pediatrics recommends that "preterm infants complete a pre-discharge 'car seat challenge' observation for cardiorespiratory compromise while in a car seat[1]."

This present study has therefore been designed to examine the mechanics associated with an infant's head being in a slumped position for extended periods of time, and particularly when the child might also experience accelerations and decelerations that exist at the extreme ends of "normal" driving. Specifically, this involved developing a solid model of the neck and head of a median two years old toddler, and then exposing the model to a static and dynamic loading scenario with the head in a slumped position to obtain the resulting stresses and forces associated with the disks, neck muscles, and trachea.

These results then allowed an appropriated car seat position to be determined that would minimize biomechanical loadings, while retaining an upright position as much as possible, and providing maximal protection should a crash occur. With this information a modified car seat was designed that would recline enough to allow the child's head to roll back into an in-line position if the child fall asleep.

This was done by designing a motorized reclinable seat that would detect when the toddler falls asleep by measuring pulse rate, and then either adjusting itself or providing a message to a smart device via Bluetooth indicating that the child was asleep, thereby allowing an adult to adjust the seats orientation if desired.

## METHODS AND MATERIALS

The solid model for a toddler was constructed from spinal CT scans that were available on the internet. This allowed the C1-C7 vertebra to be modelled accurately (Fig. 1) while the disks were created by filling in the gaps between the vertebrae as needed and as realistically as possible using the CAE software, with each piece being drawn separately and later assembled prior to analysis.

The head was modelled as a simple spheroid with the location of the center of mass and second moment of inertia matching those for a two year old toddler. The neck muscles were then represented by a cylinder that encased all of the spinal elements, and finally, the trachea was modelled separately, as a stiff tube and was analyzed in a separate buckling analysis.

The FEM consisted of three parts the vertebrae, the disks between the vertebrae and the neck muscle. The vertebrae were assumed to be made of a linear elastic material (bone) with a Poisson ratio of 0.2 and a Young's Modulus of 12 GPa, while the disk was taken to be a linear elastic fibrocartilaginous joint with a Poisson ratio of 0.4 and a Young's Modulus of 90 MPa. Finally, the muscle was assumed to be composed of a collection of fibers that could only transmit tensile loads and when loaded they were assumed to be linear elastic with a Poisson ratio of 0.38 and a Young's modulus of 1 GPa.

The mesh itself was tetrahedral with an average mesh size of 5 mm for the bone, 5 mm for the disks, and 2 mm for the muscle. All connections to the various materials were assumed to be "glued" connections which could transmit both tensions and compressions. For boundary conditions the bottom of the spine (C6) and the bottom of the muscle cylinder were fixed thereby representing the child being held in place by a tight seatbelt. The top of the spine (C1) and the top of the muscle cylinder were fixed to a rigid massless disc that had a diameter equal to the outer diameter of muscle cylinder. The head was then represented as a hollow sphere that had a mass and second moment of inertia equal to that of a toddler with these numbers being taken from a CRABI dummy.

The forces from a simulation of the movement that a child would experience when the head falls forward while sleeping in a moving vehicle was used as the input into the program, with the lower portion of the spinal column being fixed because of the existence of the car seat seatbelt straps. This analysis then allowed for an understanding of where the highest stresses would be found and the associated magnitudes of all forces to allow a bucking analysis of the trachea to be performed.

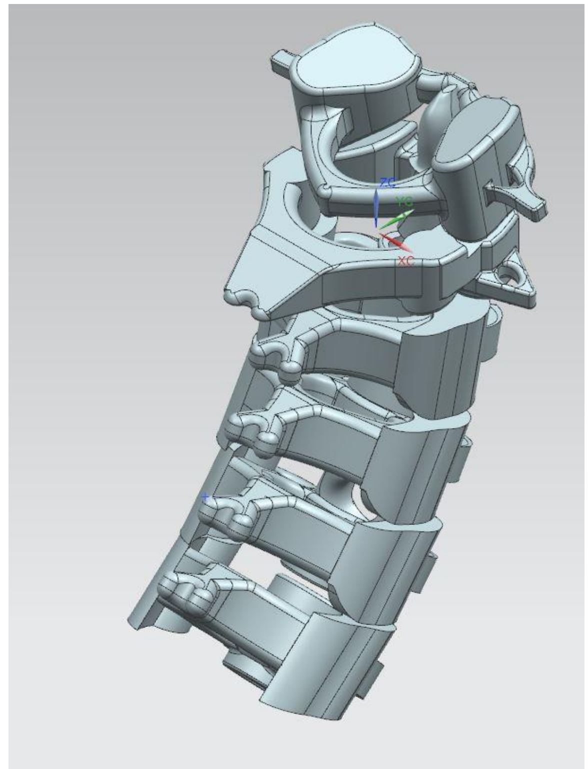

**Figure 1:** Solid Model of C1-C6

The initial analysis involved examining the stresses associated with a single vertebrae-disk-vertebrae system. In this case the bottom of the lower vertebrae was fixed while a load equivalent to the weight of the head was placed on the upper vertebrae, with a "glue" connection being used to transmit the forces from the vertebrae to the disks (Fig. 2).

As expected the results show the maximum stress occurring at the location where the disk was compressed between the disks because of the slumping of the head (Fig.3).

A further analysis was then done with muscle surrounding the vertebrae and strains were found to be close to those associated with muscle tears[6]. In addition, a recent analysis of the standalone trachea model indicates that the trachea could buckle due to a slumped head being exposed to a "normal" deceleration.

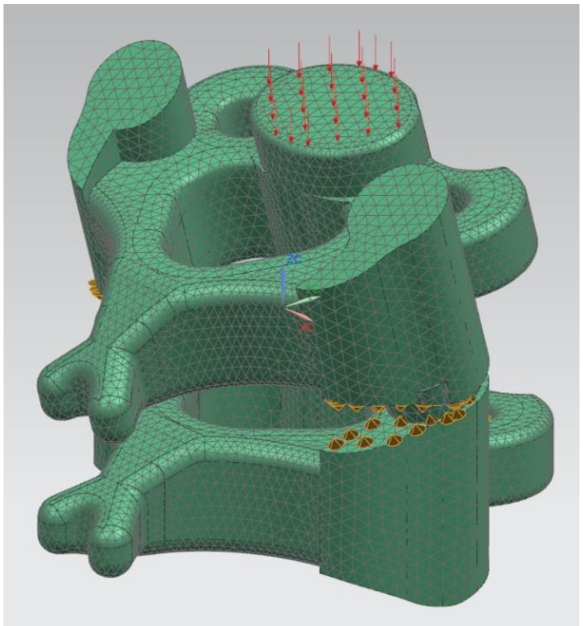

**Figure 2:** Constrains and loading on the model

## SEAT OPERATION

The next step for this study was to design an appropriated mechanism and control system to allow a car seat to adopt a more horizontal attitude. This involved designing a suitable servo motor based reclining mechanism, motor controller, pulse rate sensor, and communication system. This was done by using an Arduino® microcontroller as the master controller and Bluetooth® as the communication system that linked all of the ancillary devices, such as a smartphone, servo motor, and wrist band pulse sensor to detect when a sleeping pulse rate was present.

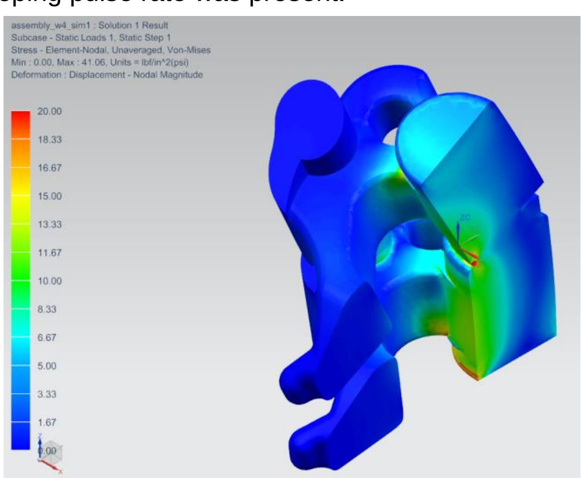

**Figure 3:** Stresses for a slumping head

A circuit using an Arduino Uno® microcontroller was built to monitor the voltage in the circuit and to control a DC motor via Bluetooth®. The user could then use an application on their smartphone to connect to the Arduino, also via Bluetooth (figure 4 shows the Arduino® circuit). The materials used for this circuit includes:

1. 1 HC 06 Bluetooth module
2. 1 DC Motor
3. 1 Potentiometer
4. 1 L293D Motor Driver
5. 1 Arduino UNO
6. 1 Breadboard

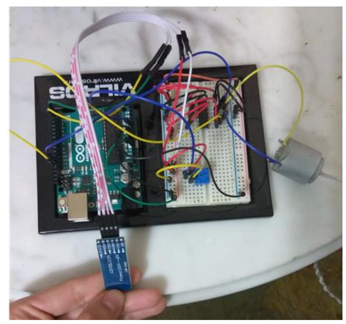

**Figure 4:** Arduino circuit for car seat

The motor driver (Fig. 5) was used to provide a bidirectional drive current of up to 600-mA at voltages from 4.5 V to 36 V. This driver was then used to control two DC motors, while the potentiometer allowed an appropriate constant motor speed to be established.

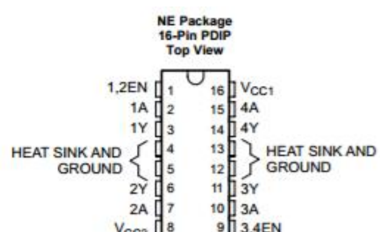


**Figure 5:** H-Bridge motor driver (Texas Instruments)[7]

The control code used to process the wrist band signals and to control the operation of the servo motors was written for the Arduino, while the App Inventor for Android® was used to write the Bluetooth® communication code. The program was very basic in that it merely triggered a signal when the value from the heart rate monitor fell below a prescribed value. This signal was then used to either level the seat or send a signal to a smart device indicating that the child was asleep.

All smart device programs were written using Android App Inventor® to provide a user friendly GUI and the code needed to run the Bluetooth® communication system. The GUI (Fig. 6) then allowed the user to activate the communication system if the "Not Connected" message was at the bottom of the screen. The user was then sent a "Sleep" message, and could either adjust the seat "manually" from the smart device or allow the seat to respond autonomously to the sleep condition.


**Figure 6:** Smartphone application designed to be used with Arduino UNO circuit.

For the purpose of simulating and testing the Arduino interface and GUI, a potentiometer was used to provide the sleep signal. If the signal fell below a preset value the application displayed the message "Baby is Sleeping ZZZZZZZ" in the black strip as shown in Figure 6. To activate the DC motor the user was then allowed to press either the "Front" or "Back" buttons to control the motion of the seat using the DC motors.

## RESULTS AND DISCUSSION

The simulation results showed that harm can come to a sleeping toddler in an upright car seat if the child's head is slumped forward and the car decelerates violently. It was found that muscles and ligaments could experience excessive strain and results have indicated that the trachea could become pinched.

The results of the design of the user-to-car seat interface proved to be successful. The Arduino® was able to effectively receive and transmit information to and from a smart phone. This included the successful detection of a child's pulse rate, and the desired seat motion when the user pressed the "Front" and "Back" buttons on the smart device. However, in a full scale design, a large DC motor will be used and the Arduino will be replaced by a simpler chip, a power amplifier, and an opto-isolator.

## REFERENCES

1. Arya, R., Williams, G., Kilonback, A., Toward, M., Griffin, M., Blair, P.S., and Fleming, P. (2016), "Is the infant car seat challenge useful? A pilot study in a simulated moving vehicle", *British Medical Journal*, v102, n2, p136.

2. Batra, E.K., Midgett, J.D., and Moon, R.Y. (2015), "Hazards Associated with Sitting and Carrying Devices for Children Two Years and Younger", *Journal of Pediatrics*, v167, n1, p183.

3. Chowdhury, R.T. (2010), *Nursery Product-Related Injuries and Deaths Among Children under Age Five*, Consumer Product Safety Commission.

4. Kassa, H., Moon, R.Y., and Colvin, J.D. (2016), "Risk Factors for Sleep-Related Infant Deaths in In-Home and Out-of-Home Settings *Early Human Development*", *Pediatrics*, v138, n5, p1

5. Tonkin, S.L., Gunn, T.R., Bennet, L., Vogel, S.A., and Gunn, A.J. (2002), "A review of the anatomy of the upper airway in early infancy and its possible relevance to SIDS", , v66, p107.

6. Noonan and Garrett (2014), "Muscle Strain Injury: Diagnosis and Treatment", *Journal of the American Academy of Orthopaedic Surgeons*, v7, n4, p262.

7. Texas Instruments (2016 January). L293X Quadruple Half-H Drivers. Retrieved from www.ti.com.