

Optimizing Automotive Seating Position to Reduce Injury Severity in Short-Statured Drivers

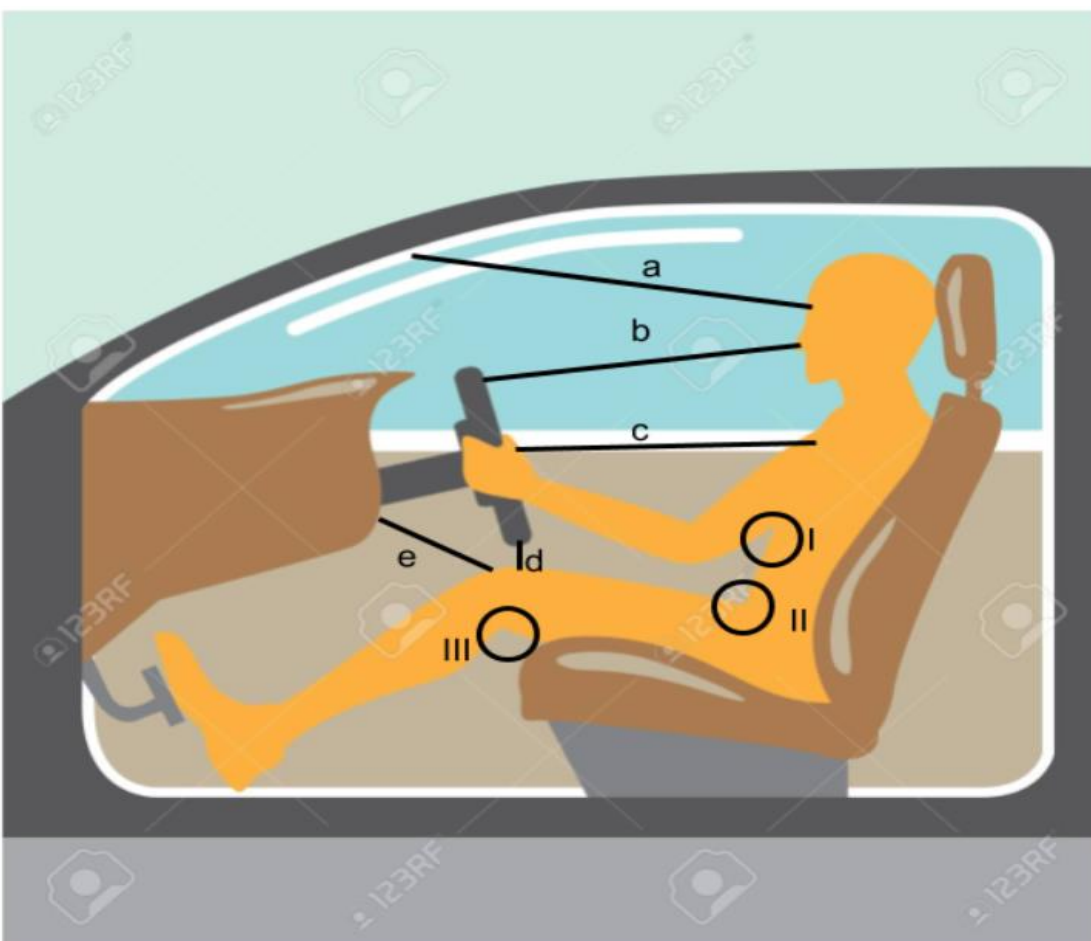
Project Goal

This project's goal is to find the optimal seating position for short-statured drivers to reduce injury severity in a frontal collision. This will be done by performing a non-linear finite element analysis simulation using LS-DYNA to determine Chest Severity Index and Head Injury Criteria scores through a range of possible seating positions for drivers of varying stature/anatomy.



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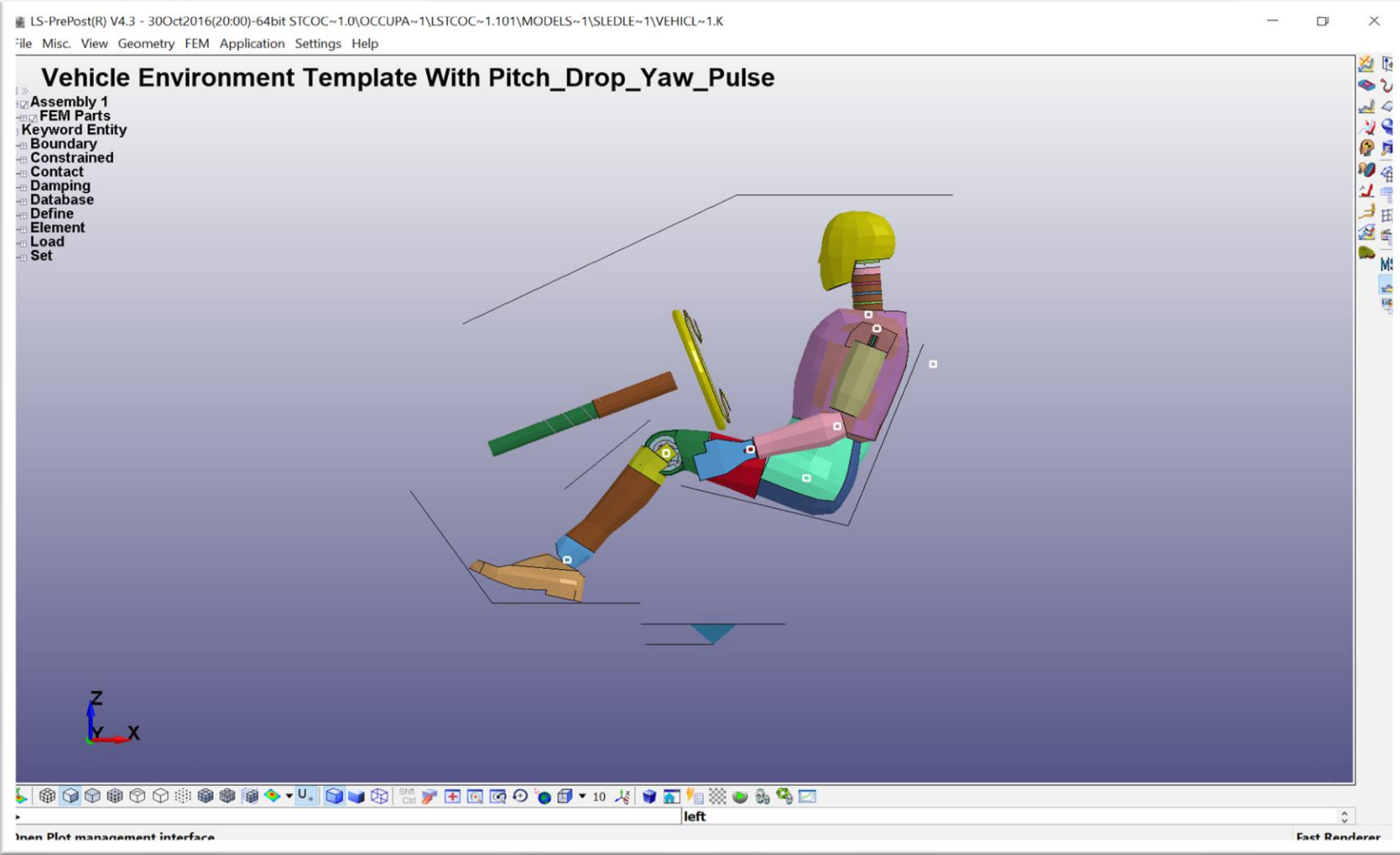
Human Measurements



Driver Seat: Relative Position Measurements Diagram: Image from "Car Side View: Person No Airbag No Seat Belt," I23RF; Measurements and Angles added by Student Researcher; 11/20/2019



Image of Driver/Data Set 2 (45th Percentile Male) in Driving Position, Taken by Student Researcher; 11/23/2019



Screen capture of Sled Model with VATD from LS-DYNA; Loaded by Student Researcher; 12/2/2019

Injury Statistics

“The Deadly Truth About a World Built for Men”, *The Guardian*

- Short-statured, out-of-position drivers have a 47% increase in likelihood of serious injury and a 17% increase in likelihood of death.
- Female crash test dummies were introduced 60 years after male dummies.
- These dummies are not anthropomorphically correct. Even today, no testing requires accurate dummies.

“The Effect of Height on Injury Outcome for Drivers of European Passenger Cars,” *Association for the Advancement of Automotive Medicine*

- Drivers up to 155 cm tall are more likely to experience serious head, pelvis, and lower extremity injury.
- While testing for the average of the population is logical, it endangers the extreme ends of the population. Simply extrapolating or adjusting data is not accurate.

“Sensitivity Analysis and Optimization for Occupant Safety in Automotive Frontal Crash Test,” *Latin American Journal of Solids & Structures*

- Airbag distance to dummy is the most important factor to determine peak head acceleration and injury. Increasing airbag distance decreases injury.

Problems Posed by Physical Crash Test Dummies

- Expensive and single-use
- Materials cannot accurately simulate human responses

Virtual Anthropomorphic Devices (VATDs)

- VATDs are in-silica versions of physical crash test dummies with increased capabilities to be used in virtual crash test simulations
- While labor-intensive to design, it is a one-time cost and are infinitely reusable
- Increased biofidelity over crash test dummies
 - Can simulate a broader group of humans
- In this project, pre-existing VATDs will be utilized and their driving position will be adjusted according to human data

Method to solve complex math/physics problems

Take a complex structure and decompose into many finite elements

- Finite elements can be solved individually and then reassembled

LS-DYNA

- Nonlinear finite element analysis simulations
- Industry standard for automotive companies in occupant safety and crash test applications
- Extensive material and element libraries and contact algorithms
- Existing open-source models

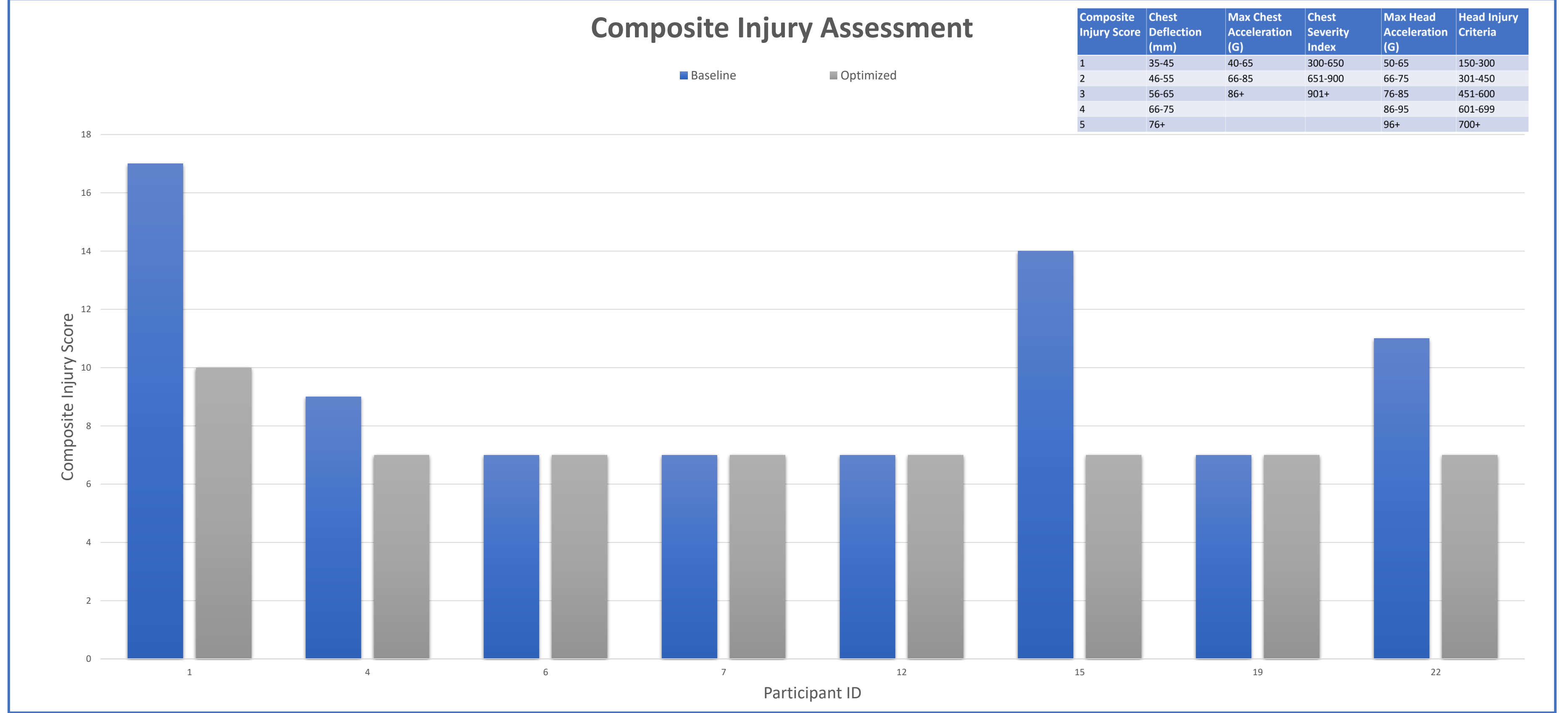


- Automobile “neutral” with a seat, seatbelt, airbag, and steering column
- Impact at 40mph
- Frontal collision
- Driver position
- Wearing seatbelt
- Airbag deployed
- For initial simulations, 50th FE Rigid Dummy
- Length and angle measurements to describe seating position according to Driver Seat: Relative Position Measurements Chart
- Use human participant data to set positioning for VATD in the crash and execute sled simulation
- Perform analysis to determine chest deflection (mm), maximum chest acceleration (G), Chest Severity Index, head acceleration (G), and Head Injury Criteria from the mathematical outputs of the simulation
- Identify subset of high-injury, short-stature occupant models
- Adjust parameters to minimize injury severity

Procedure

Simulation Data

Demographic Data				As Baselined									As Optimized						
Participant ID	Height (cm)	Sex	Age/Height Percentile	B (mm)	C (mm)	Pelvic Angle (deg)	Chest Deflection (mm)	Max Chest Acceleration (G)	Chest Severity Index	Max Head Acceleration (G)	Head Injury Criteria	Composite Injury Score	Method	Chest Deflection (mm)	Max Chest Acceleration (G)	Chest Severity Index	Max Head Acceleration (G)	Head Injury Criteria	Composite Injury Score
1	167	M	13	445	381	109	38	133	1314	119.9	893	17	B25	37	84	692	65	666	10
4	157	F	26	280	229	108	53	52	487	66.6	561	9	B4D	45	52	451	55	499	7
6	163	F	52	440	280	120	40	44	374	61.3	581	7	F25	39	42	372	60	573	7
7	158	F	26	270	260	118	41	46	360	53.2	560	7	B4D	15	45	505	61	492	7
12	163	F	57	343	292	103	42	52	479	58.7	588	7	PAM	44	38	342	56	542	7
14	170	M	23	470	406	115	51	62	723	84.0	970	13	Sim Error						
15	150	F	24	432	286	94	83	59	555	65.8	700	14	PAM	40	42	363	59	557	7
19	158	F	28	279	248	94	42	59	547	55.9	571	7	B4D	40	44	378	59	568	7
22	155	F	17	343	279	88	49	70	838	60.0	621	11	PAM	45	43	398	63	575	7



Composite Injury Score	Chest Deflection (mm)	Max Chest Acceleration (G)	Chest Severity Index	Max Head Acceleration (G)	Head Injury Criteria
1	35-45	40-65	300-650	50-65	150-300
2	46-55	66-85	651-900	66-75	301-450
3	56-65	86+	901+	76-85	451-600
4	66-75			86-95	601-699
5	76+			96+	700+

Conclusion

Drivers do not inherently know the safest position for them to drive in- they can only determine where they can reach the steering wheel and the pedals, have proper visibility, and be comfortable. There are, however, driving positions that are similarly physically realistic that are safer for the driver in a crash scenario. For example, in #15, the chest distance is the same as the baseline, but by adjusting the pelvic angle (and the head position by proxy), the injury severity decreases by 50%.

The goal of this project is to optimize automotive seating position to reduce injury severity in short-statured drivers. The first participant to go through the entire optimization process was #15, who was the overall shortest person with some of the highest severity scores across the board. By performing bracketed changes, the positioning was reasonably optimized, as across all parameters the position became 50% safer using the Composite Injury Score.

A total of 145 simulations were run, and after performing optimization simulations to the other short-statured drivers, changes to the pelvic angle, specifically a pelvic angle between 112 and 120 degrees, while keeping the head distance as close as possible to the baseline, proved to have the most significant positive change on the injury severity scores. For the drivers whose optimized positions exhibited improved injury severity scores, the overall effect was a 39% reduction.

Get more human data and complete the LS-DYNA simulations

Run simulations with 5th percentile, non-rigid dummy

Mobile app using data to help driver make informed decisions, like a “calculator”

Create sensor to alert driver of an unsafe driving position to prompt readjustment

Create system to automatically readjust seat based on safety data

Applications and Future Plans

Error Analysis

- Human Response/Personal Preference
- Human Error in Measurement Collection
- Insufficient Model Fidelity (ex. can only match 2/3 measurements)

Measurement	As seated	As baselined	As optimized
B mm	432	363	432
C mm	286	286	286
Pelvic angle deg	94	94	112

All graphs, charts, images, and graphics were created by the Student Researcher unless otherwise stated.