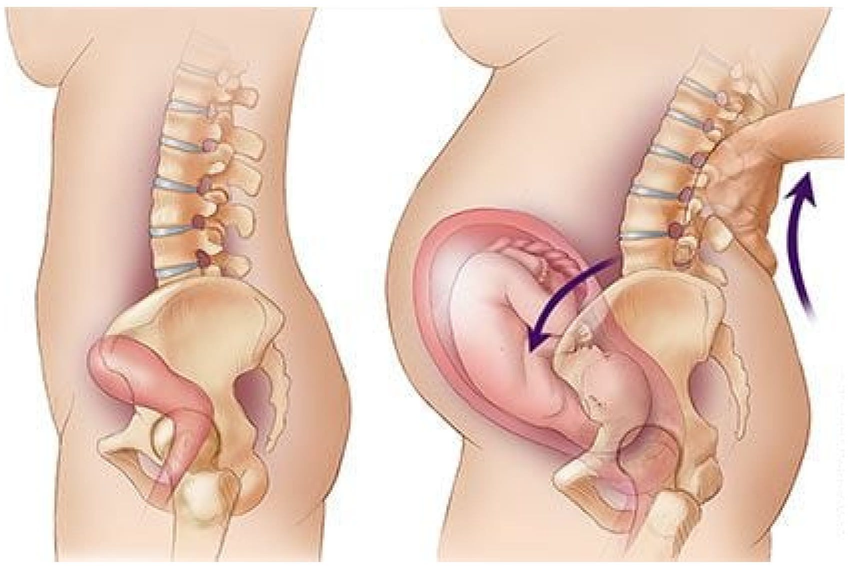
A Comparison of Lower Back Pain Biomechanics Through Different Gestation Stages



INTRO TO BIOMECHANICS

Wilmary Figuero, Jahnavi Shah, Sharanya Datta, Leah Kaup, Anjali Viswanathan

Statement of Purpose

We intend to analyze the effects of different stages in pregnancy on back pain. Lower back pain is most common in the early stages of pregnancy, but it can evolve as women are further along in the process. By analyzing the changing postural effect of pregnancy, we hope to find how back pain evolves and whether there are methods of mitigating or alleviating those effects.

Significance

Pregnancy-related lower back pain is abundantly common, occurring in about 20% - 90% of pregnancies (Katonis et al., 2011). It is important to analyze it because it can have chronic effects on expectant mothers. With a fetus growing and expanding uterus, there can be increased pressure placed on the lower back–leading to decreased quality of life, sleep disturbances, reduced mobility, and overall discomfort. This discomfort and inability to carry out daily activities not only affects the mother's health but can also affect the fetal health. Since a pregnant woman’s physical and emotional well-being is highly dependent on the management of lower back pain, it becomes imperative to make this analysis a priority in maternal care. The analysis should be made based on the distinct stages of gestation, because in the second and third trimesters the center of gravity shifts, increasing strain on the lower back and pelvis. This analysis can also be important to recommend specific exercises, ergonomic adjustments, or the development of support devices that can alleviate the discomfort caused by lower back pain.

Background

Biomechanical changes through pregnancy can alter muscular and skeletal alignments resulting in increased back pain and fall risks. Spinal curves, gait patterns, and balance are all features that alter along different stages of pregnancy. They all in combination result in postural changes which can lead to pelvic girdle pain, hip pain, leg problems, carpal tunnel, urinary incontinence, and of course lower back pain (The Biomechanics of Pregnancy, 2023). While abundantly common, these pains affect women differently and can also kick in at different stages. The prevalence is highest during the third trimester, between the fifth and seventh month, which aligns with when the postural change and body weight rise. Severe cases of pregnancy-related lower back pain have also been associated with disability, reduced quality of life, and postpartum depression.

Lower back pain in pregnancies is usually defined as pain occurring between the 12th rib and the gluteal folds/pubic symphysis (Low Back Pain and Pregnancy, 2023). This pain mainly affects the lumbar region, which is composed of five different vertebrae that are meant to withstand increased weight, maintain stability, and provide support. The lumbar region is connected by an intricate web of ligaments that provide additional stability and keep the intervertebral discs in position. The region is supported by lower back muscles, pelvic muscles, and abdominal muscles.

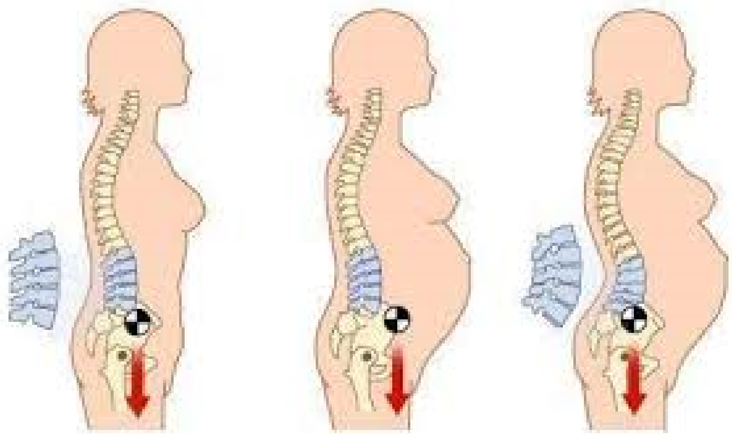


Figure 1: Changes in the Spine through Pregnancy

The spine is significantly affected throughout pregnancy and can undergo many changes. For example, a person's center of mass migrates anteriorly through a pregnancy which results in a lack of positional adjustment in the lumbar curve (Catena et al., 2019). The force of gravity also deviates from the hip, resulting in decreased upper body stability and the generation of a larger moment at the hip. In reaction to this, pregnant women develop a sway-back posture - the upper body moves posterior to the lower body which causes an increased tone between the head and neck muscles, allowing the head to shift anteriorly. The trunk movement accounts for the center of gravity shifting posteriorly which the head shift makes up for. This anteriorly shifted center of gravity also affects balance, as stated, resulting in an increased risk of falling.

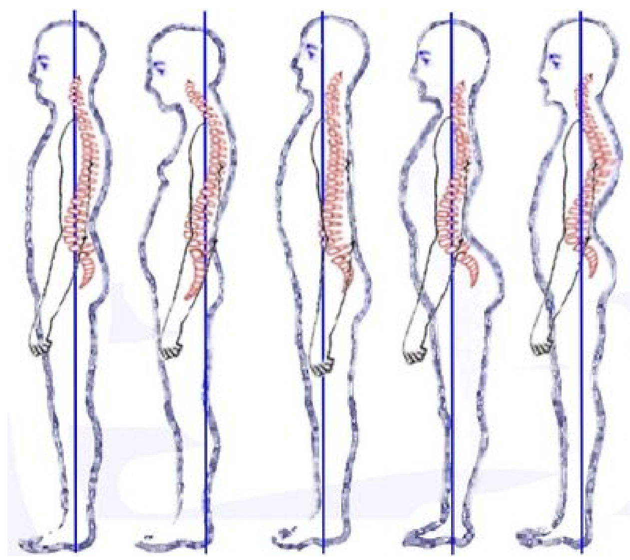


Figure 2: Sway Back Posture

Other studies show that while back pain is significantly increased in pregnant women, there may not be a significant correlation just with spinal changes. As pregnancy develops to its further stages, there is increased movement of the center of pressure and increased stability indexes. These indicate that postural control is reduced in pregnancy. Trunk range of motion, hip flexion, and extension are reduced, along with decreased stride length, decreased gait velocity, and increased step width (Conder, 2019). All these factors when combined change the overall posture of pregnant women, often resulting in increased lower back pain.

Methods

The goal of our project is to analyze the biomechanical changes through pregnancy and determine how they contribute to increased back pain/discomfort. To do this, we constructed a free-body diagram of the spinal column, indicating major forces of consideration. However, before we began our analysis, a few assumptions needed to be made to simplify the complexity of our calculations. We assumed the first trimester to be equivalent to non-pregnancy as the center of mass and degree of curvature of the thoracic and lumbar spinal regions do not change significantly (Yoo et al., 2015). Also, in order to obtain the most accurate curvature angles we assumed the spine to be straight with angles only between the thorax and lumbar regions, that there were also no reaction forces between the disks of the vertebrae, the location of the sacroiliac joint does not shift during pregnancy, and that the distance between the back and the sacroiliac joint can be approximated to 4 inches or 0.1m. Overall, the most important assumption was that to not consider any of the internal reactions and forces that arise from the shifting of the organs and the pressure placed on the abdominal cavity by the growing fetus.

	Non-Pregnant Women	Pregnant Women in Second Trimester	Pregnant Women in Third Trimester
Thoracic Curvature (degrees)	10.6 ± 2.9	10.7 ± 2.1	11.5 ± 2.4
Lumbar Curvature (degrees)	7.3 ± 1.3[3]	9.0 ± 1.7	1.0 ± 1.9

Figure 4: Changes in Spine Curvature: spinal curvature changes between each trimester incorporating one of our assumptions that non-pregnant women are regarded to be in the first trimester. Angle values were obtained from (Yoo et al., 2015)

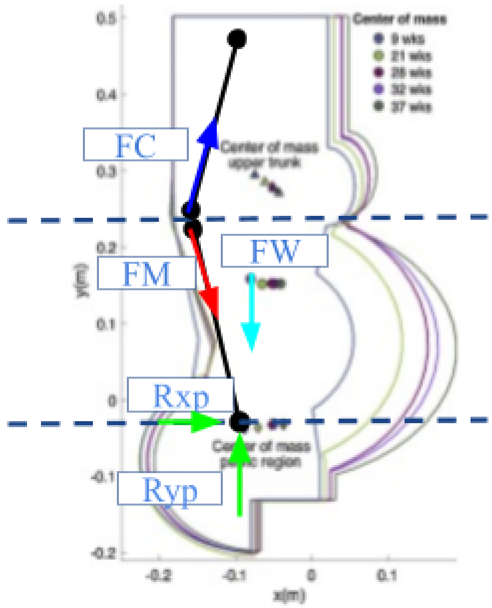


Figure 4: Force Diagram of Spinal Biomechanics: Force Fc represents a compressive force acting at the center of the vertebrae along the thoracic spinal region. Fm represents the muscle forces acting along the spine specifically along the lumbar spinal region. Muscles included in this consideration are spinalis muscles as well as the erector spinae muscles. RxP and RyP represent the reaction forces that occur at the sacroiliac joint and FW symbolizes the weight of the individual at its full body center of mass location. Fm is attached vertically at 0.24 m and the sacroiliac joint is located at 0.08 m horizontally and 0.02 m vertically (0.08, 0.02).

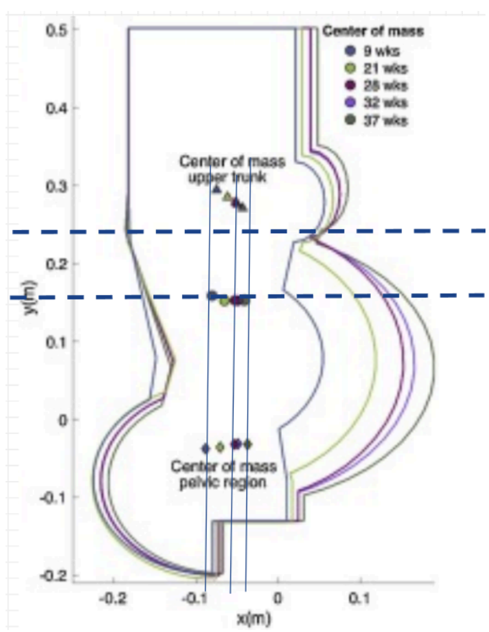


Figure 5: Center of Mass Approximations: The first dashed line, at approximately 0.25 m, represents the location from which our cut was taken to construct our free body diagrams and respective equations. The second dashed line, at approximately 0.175 m, represents the locations of the body's center of mass as it shifts throughout pregnancy. We shifted our x-axis to begin at 0 m instead of -0.2m for simplicity. Locations of center of mass are as follows: 9 weeks (0.20, 0.175) m, 25 weeks (0.25, 0.175) m, and 37 weeks (0.27, 0.175) m.

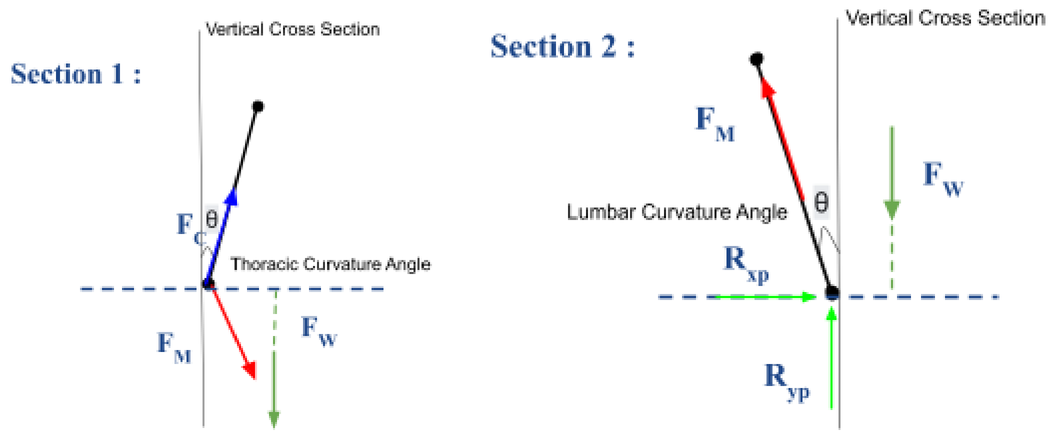


Figure 6: Sectioned Free Body Diagrams

Non-Pregnancy Static Equilibrium Conditions (taken at 9 weeks) (COM = 0.20):

<u>(Section 1)</u>

Sum of Fx:

$0 = F_c \sin(10.6)+F_m \sin(7.3)$

$F_c \sin 10.6 = -F_m \sin 7.3$

Sum of Fy:

$0 = -F_w+F_c \cos 10.6 -F_m \cos 7.3$

Moment about curvature:

$M_c = -(COM*F_w)$

<u>(Section 2)</u>

Sum of Fy:

$0 = -F_w+F_m \cos(7.3)+R_{yp}$

Sum of Fx

$0 = -F_m \sin(7.3)+R_{xp}$

Moment about Sacroiliac joint:

M_p:

$$0 = F_m*\cos(7.3)*(0.1)- F_m*\sin(7.3)*(0.24+0.02) -F_w*(COM-0.08)$$

Second Trimester Static Equilibrium Conditions (taken at 25 weeks) (COM = 0.25):

(Section 1)
Sum of Fx:
$0 = F_c\sin(10.7)+F_m\sin(9.0)$
$F_c\sin10.7 = -F_m\sin9.0$
Sum of Fy:
$0 = -F_w+F_c \cos 10.7 -F_m\cos9.0$
Moment about curvature:
$M_c= -(COM*F_w)$

(Section 2)
Sum of Fy:
$0 = -F_w+F_m\cos(9.0)+R_{yp}$
Sum of Fx
$0 = -F_m\sin(9.0)+R_{xp}$
Moment about Sacroiliac joint:
M_p:
$0 = F_m*\cos(9.0)*(0.1)- F_m*\sin(9.0)*(0.24+0.02)$
$-F_w*(COM-0.08)$

Third Trimester Static Equilibrium Conditions (taken at 37 weeks) (COM = 0.27):
(Section 1)
Sum of Fx:
$0 = F_c\sin(11.5)+F_m\sin(1.0)$
$F_c\sin11.5 = -F_m\sin1.0$
Sum of Fy:
$0 = -F_w+F_c \cos 11.5 -F_m\cos1.0$
Moment about curvature:
$M_c= -(COM*F_w)$

(Section 2)
Sum of Fy:
$0 = -F_w+F_m\cos(1.0)+R_{yp}$
Sum of Fx
$0 = -F_m\sin(1.0)+R_{xp}$
Moment about Sacroiliac joint:
M_p:
$0 = F_m*\cos(1.0)*(0.1)- F_m*\sin(1.0)*(0.24+0.02)$
$-F_w*(COM-0.08)$

Results

Figure 5: Forces(N) and Moments(N*m) as a function of Weight (N) for Non-Pregnant Women.

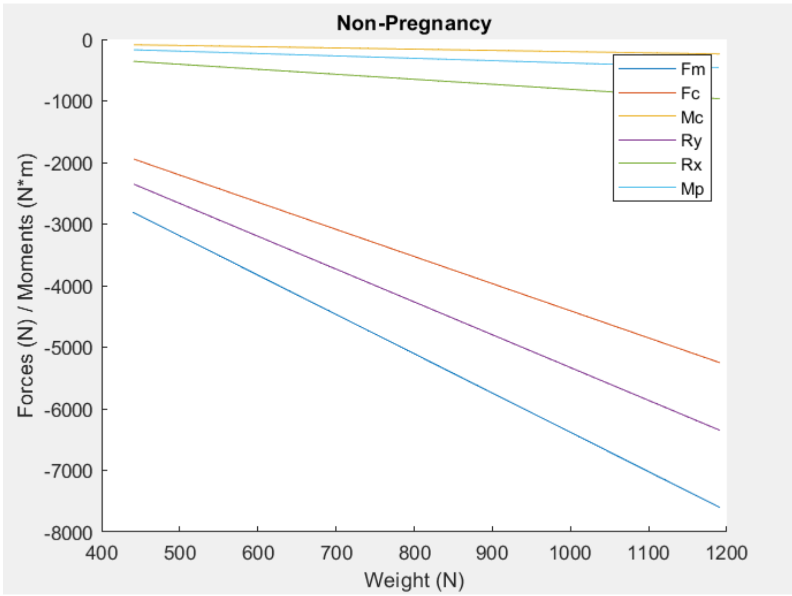


Figure 6: Forces(N) and Moments(N*m) as a function of Weight (N) in the Second Trimester for Women

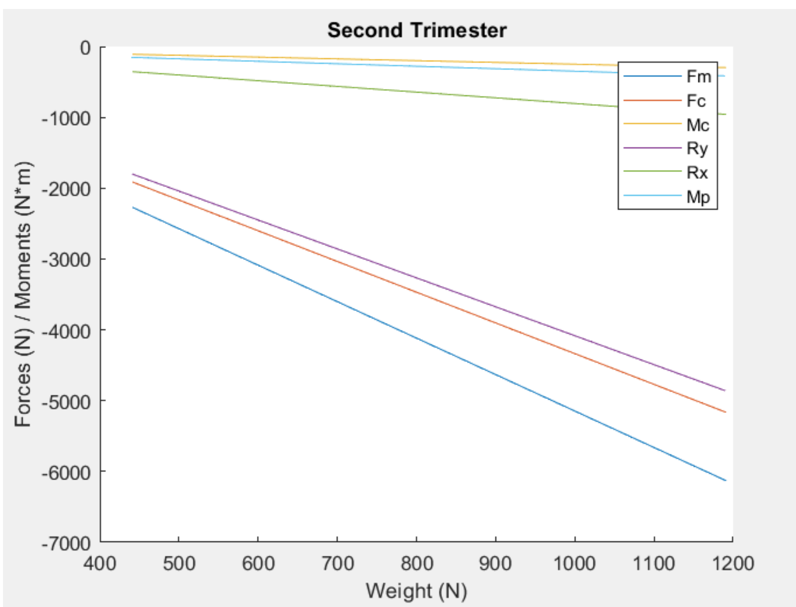


Figure 7: Forces(N) and Moments(N*m) as a function of Weight (N) in the Third Trimester for Women

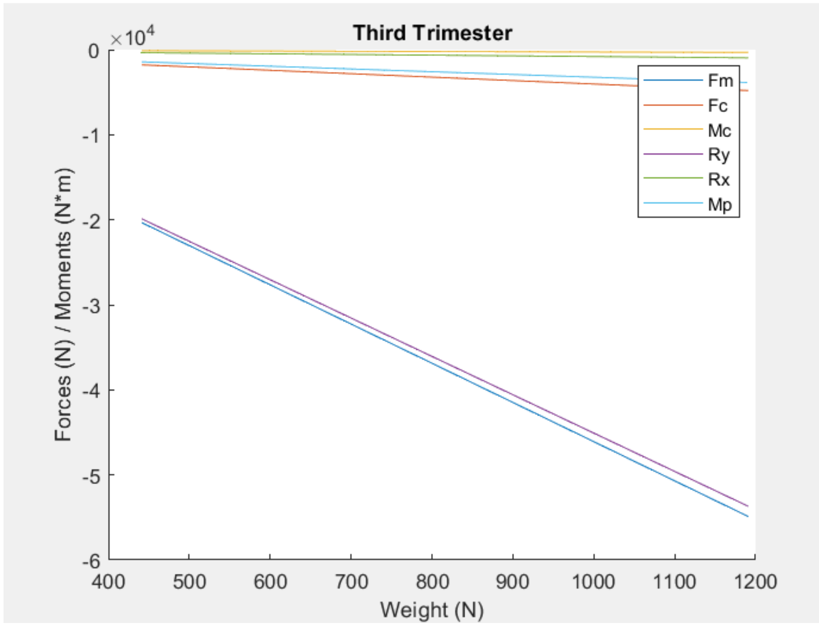
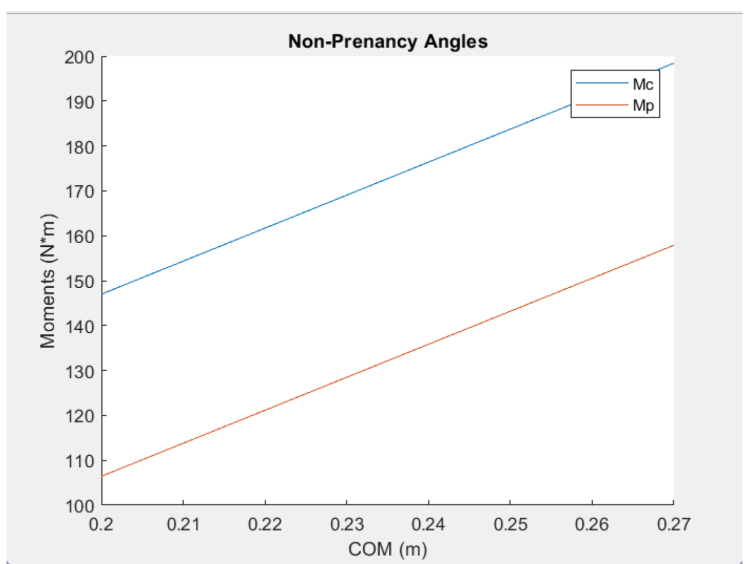


Figure 5,6,7: The Center of mass is varied along with the degree of curvature of lumbar and thoracic regions with respect to each trimester.

Figure 8: Fixed Weight- 75 kg and fixed thoracic and lumbar angle with varying center of Mass.

Non-Pregnant	

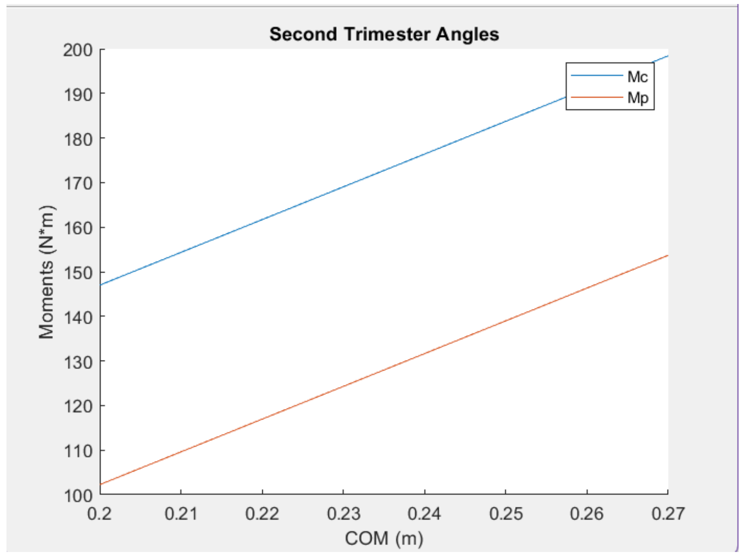
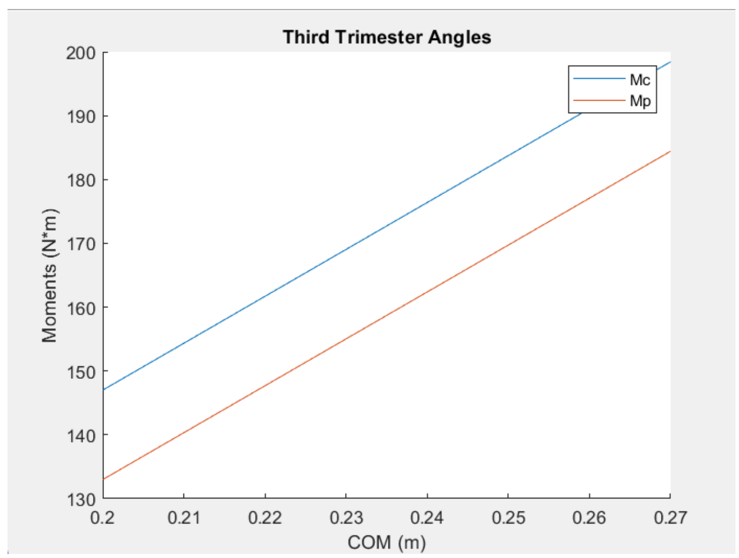
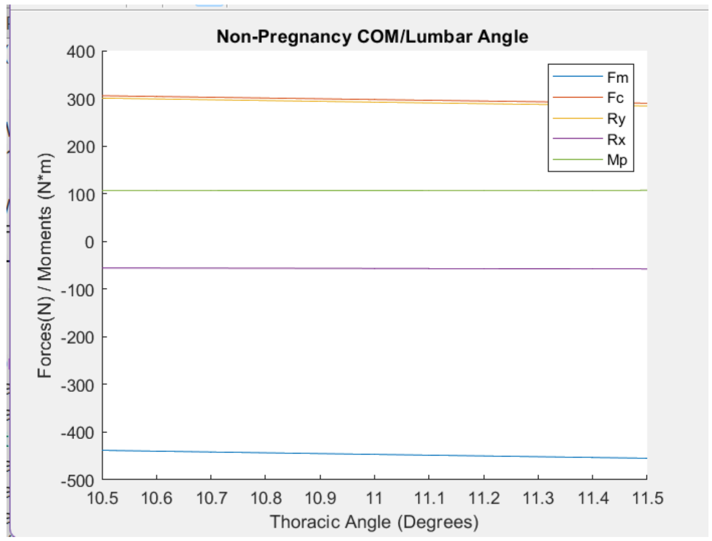
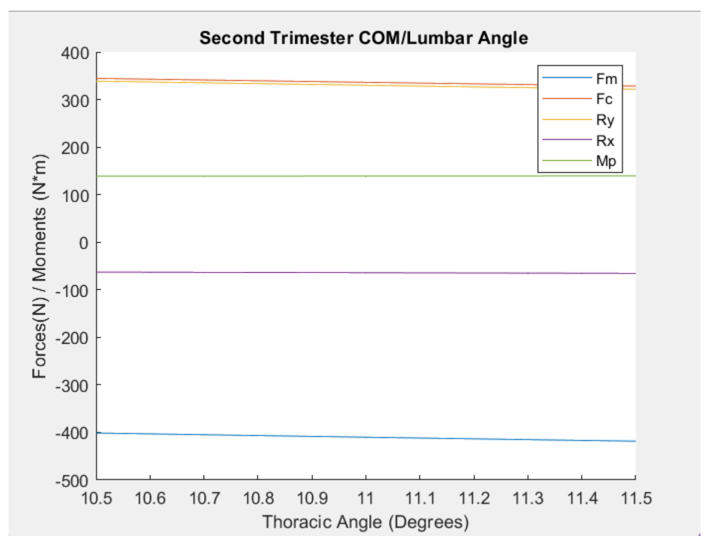
Second Trimester	
Third Trimester	

Figure 9: Fixed weight- 75 kg and fixed Center of Mass with thoracic angle variance

Non-Pregnant	
Second Trimester	

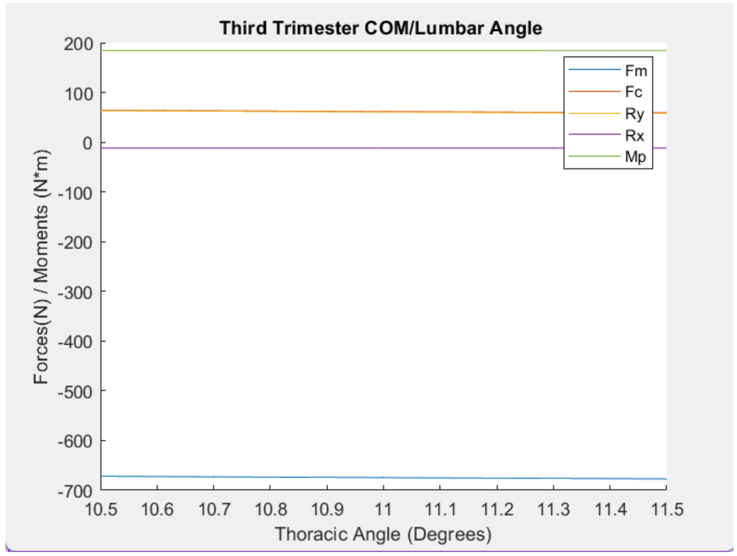
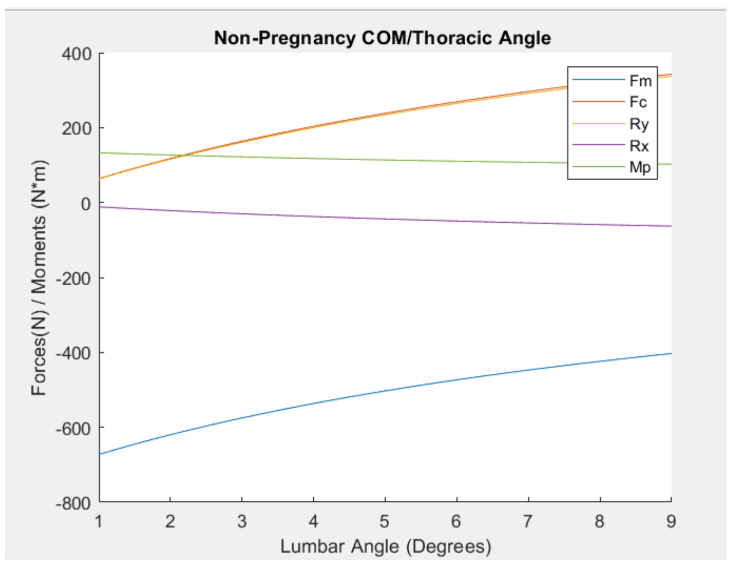
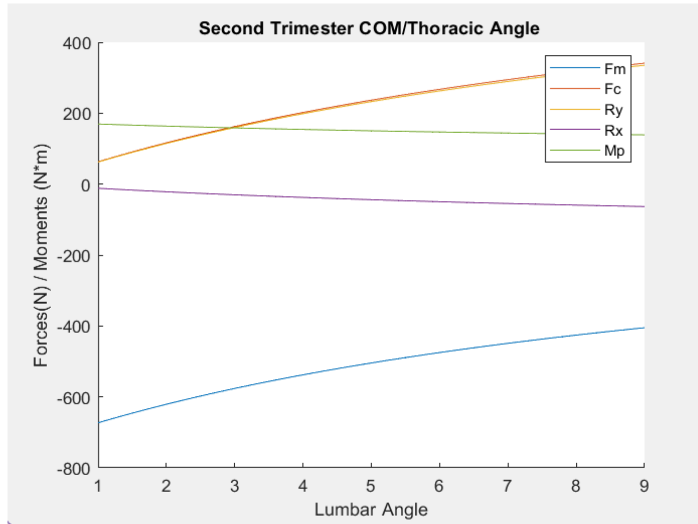
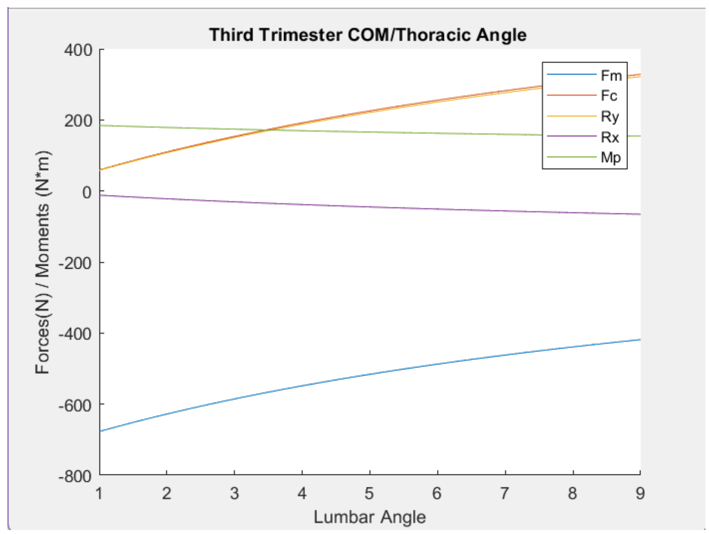
Third Trimester	

Figure 10: Fixed weight- 75 kg and fixed Center of Mass with lumbar angle variance

Non-Pregnant	

Second Trimester	
Third Trimester	

Discussion and Conclusions:

Mathematical Modeling as well as graphical analysis have allowed us to reach certain conclusions. Overall, three significant changes occur contributing to gestational back pain. These three factors include weight gain, changes in spinal curvature angles, and an anteriorly shifting center of mass. Our investigation included discovering which of these factors was the greatest contributor to lower back pain. While the Center of Mass was anticipated to be the primary influencing factor, especially in the forces between non-pregnancy and the second trimester–because of the larger COM difference between non-pregnancy and 2nd trimester than between 2nd and 3rd trimester. In Figures 5-7, our independent variable was weight and our dependent variable were the forces and moments experienced by the spinal column. For each graph, we kept thoracic and lumbar spinal curvature angles consistent with averages obtained from research. We did the same Center of mass shift. This preliminary analysis revealed a significant change in the forces experienced by the lower back between the second and third trimesters. Upon closer review of metrics used to complete this analysis, we found that the lumbar spinal curvature angle was much less in the third trimester, in which the spine becomes virtually vertical, which caused the elevation in the overall forces by a factor of 10. From there we concluded that the lumbar angle affected the forces during each trimester.

To be certain that the greatest contributing factor was spinal curvature, we performed further analysis by varying our dependent variables of interest and fixing other parameters. For example, in Figure 8, across all three trimesters, we fixed the weight of the corresponding thoracic and lumbar curvatures for each trimester. As a result, we observed that an anteriorly shifted center had little effect on the moments experienced on the spine between the second and third trimesters. This is because there is a large variance in the results from each trimester to each trimester, indicating that a shifting center of mass is likely not the greatest contributing factor. A similar analysis can be applied to Figure 9, in which we fixed weight, corresponded center of mass, and lumbar angle curvatures to that of research and varied the thoracic angles. Once again, there appeared to be large discrepancies between the second and third trimesters of data, indicating that spinal curvature of the thoracic region of the spine cannot be used to accurately predict spinal force behavior. The Fc and Ry force also represented very similar values to each other and decreased proportionally between second and third trimester. Finally, in Figure 10, we fixed weight, spinal curvature for the thoracic region of the spine, and shifting center of mass. Our independent variable was the spinal curvature for the lumbar region. The results of this analysis were that for each Trimester, the data appeared to be consistent, the values for all the forces did not change much. However, the forces decreased within each graph as the lumbar angles increased, revealing that lumbar spinal curvature angles can be used to accurately model the biomechanics of the spine during gestation. This is due to a large discrepancy between each trimester in this parameter. For example, the lumbar spinal curvature changes from 9.0 degrees to 1.0 degrees between the second and third trimester of gestation. This is significant and will cause the forces such as the muscle forces, and compressive forces acting on the spine to increase non-linearly. This can be seen in Figure 10, in which there appeared an exponential increase in the forces experienced by the spine as these degrees changed. Conclusively, the changes in the angles in the lumbar region of the spine during each trimester proved to be the contributing factor in the elevation of the intensity of the lower back pain, especially in the third trimester.

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