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# Investigations of the Impact of Excess Gut Volume on Spinal Angles

Carly Stoops, Biomedical Sciences, Grand Valley State University

Honors Senior Research Project

Mentor: Dr Natalie Laudicina, BMS Department

## Introduction

The curvature of the spine is necessary to support bipedal gait but can be altered or vary based on pregnancy, age, sex, and potentially, gut volume. It is known that pregnancy leads to an increase in lumbar spinal curvature, specifically in the third trimester, likely due to the weight of the growing fetus (Yoo, 2015). This increase may lead to a change in walking gait or potentially cause lower back pain (Onwuasoigwe, 2016).

Studies on the impact of obesity tend to focus on the diseases that often result, such as cardiovascular disease, hypertension, or respiratory problems. However, excess body weight can have a harmful impact on the skeletal system as well. It is not fully clear how obesity affects the spine, but the excess weight can be detrimental to the bone joints, especially the knees (American Academy of Orthopaedic Surgeons, 2015). This project seeks to investigate on how excess body weight can impact the curvature of the lower spine. By measuring two different lumbar angles of the spine, we can determine if the lower spinal column experiences change due to obesity, specifically excess truncal, or gut volume weight.

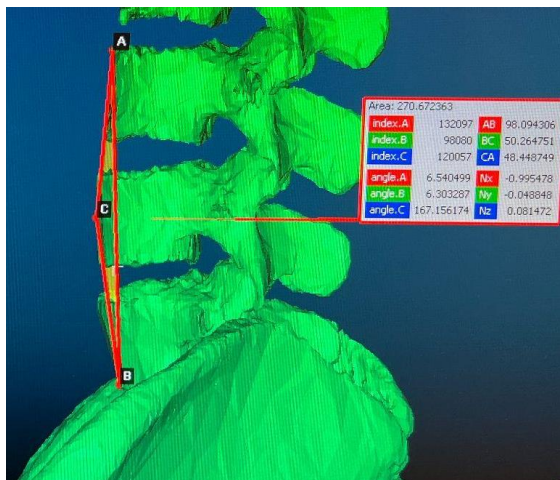


Figure 1. Central Lumbar Angle

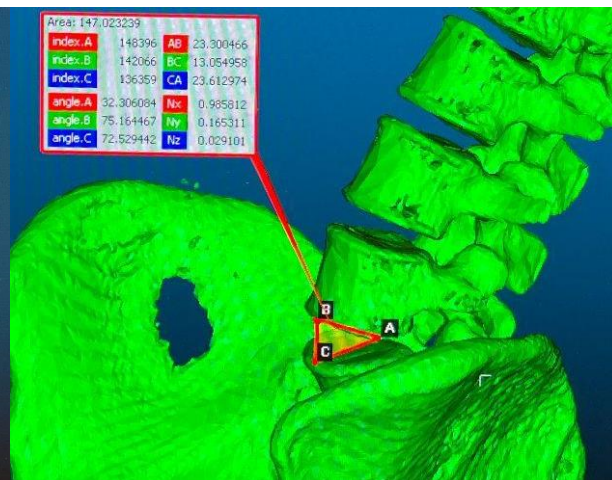


Figure 2. Lumbosacral Disc Angle

The two angles being measured are the Lumbosacral Disc Angle (LDA) and the Central Lumbar Angle (CLA), shown in Figures 1 and 2 above. The LDA is a spinal angle measured from the lower surface of the L5 to the upper surface of the S1. The CLA is the angle formed between the anterior surfaces of

three lumbar vertebrae: the upper L3, the lower L5, and a central point in the middle of L4. The magnitude of both the LDA and CLA can change due to age, pregnancy, sex, and, as we hypothesize, gut volume. This is important because these changes can result in pain, specifically in the lower back. However, this lower back pain is often idiopathic, meaning it has an unknown cause, so it is difficult to determine a way to treat it. The consequences of being overweight or obese rarely include the anatomical changes that result due to excess gut volume and center of mass changes. This research examines this skeletal adjustment by comparing lumbosacral angle measurements from a sample of 94 adult pelvis (45 males, 49 females) using online measuring software programs, CloudCompare and Image J.

## **Methodology**

Two different software programs were utilized throughout this research, Image J and CloudCompare. As I progressed through my first project, I realized several limitations of Image J, including the inability to accurately measure angles on the 3D scans. That limitation led me to my second project, where I compared the capabilities of the two software programs to determine which was better for my research projects. I found Cloud Compare to be the better program for my research and used it for my third project (see Project 2 section). In order to measure the spinal angles, I utilized the point-picking tool on each of the 94 de-identified computed tomography (CT) scans and recorded them in an Excel sheet. These scans were originally obtained for another study (Uy and Laudicina, 2021) from a database at the University of Wisconsin-Madison School of Medicine and Public Health. As the scans were already previously de-identified, the IRB did not require a new review for this present study. The gut volume data had already been collected for a previous project (Uy and Laudicina, 2021) and did not need to be re-collected for this study. The gut volumes were broken down into three categories: normal (BMI 18.5-24.9), overweight (BMI 25.0-29.9), and obese (BMI 30 or higher) (Centers for Disease Control and Prevention, 2020). Two different angles were measured, the LDA and CLA, which both had three pelvic landmarks. Statistical analysis (t-tests, regressions) followed to compare the two angles to gut volume.

## **Project 1: LDA and Gut Volume**

This project examined the impact of excess gut volume on the Lumbosacral Disc Angle (LDA). The LDA is a spinal angle measured between the L5 vertebrae and the S1 of the sacrum. The magnitude of the LDA can change due to age, pregnancy, sex, and, as we hypothesized, gut volume. This is important because lower back pain can result from these anatomical changes. Additionally, little attention has been given to the anatomical consequences of being overweight or obese. This project investigated if high gut volume can lead to a change in this lumbar spine angle, which is potentially the cause of lower back pain.

Three-dimensional imaging software, Image J, was used to measure the pelvic landmarks for comparison with previously measured gut volumetry. The landmarks were the most anterior superior point of the S1 vertebrae, the most anterior inferior point of the L5 vertebrae, and the most posterior superior point of the S1 vertebral body. Image J did not allow measurement directly on the 3D scan, however, so I captured screenshots of the angle on each scan and measured them from those photos. That process should not have impacted the angle because the scaling of the images would not change the value. The gut volumes were broken down into three categories: normal (BMI 18.5-24.9), overweight (BMI 25.0-29.9), and obese (BMI 30 or higher) (Centers for Disease Control and Prevention, 2020).

Statistical analysis, including linear regression analysis, followed to determine if there was a correlation between LDA and gut volume. The results showed a weak negative correlation between gut volume and the LDA, indicating that as gut volume increased, the size of the LDA decreased. That correlation was slightly stronger in males. It is not possible to identify increased gut volume as the reason the LDA became smaller, however. There was no significant difference between the LDA and gut volume ( $p > 0.05$ ).

I presented the results of this project to many GVSU professors and fellow researchers at the annual Student Scholar's Day in 2022. I was probed with questions about my research and future avenues throughout the event as well, allowing me to share my plans for projects to come.

# Lumbosacral disc angle changes due to gut volume

## Carly Stoops

Faculty Mentor: Natalie Laudicina

### Introduction

The lumbosacral disc angle (LDA) is an anatomical measure on lower spine. The magnitude of the LDA can change due to age, pregnancy, and sex<sup>1</sup>. An increased LDA can result in lower back pain, which can impede gait and mobility. In this research we investigate how the LDA is impacted by gut volume.

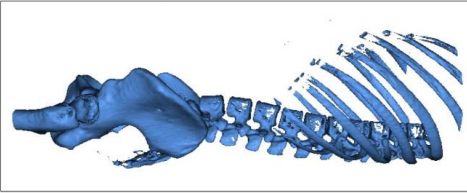


Fig. 1. Lateral view of the thoracic and pelvic regions of the human skeleton. Spinal curvature can be examined from this angle.

The consequences of being overweight or obese rarely include the anatomical changes that result due to excess gut volume and center of mass changes. This study allows us to understand the impact of skeletal alterations on walking gait and lower back pain.

### Methods

The LDA (Fig 2) was measured on 94 adult pelvis (45 males, 49 females) using FIJI (Image J). The LDA was then compared with previously-measured gut volumetry<sup>2</sup>. The gut volumetry was measured for another study<sup>2</sup> from an archival database at the University of Wisconsin-Madison School of Medicine and Public Health. As the scans were already previously de-identified, the IRB did not require a new review for this present study. The individuals were divided into gut volume categories (small, large) based on their gut volume, allowing us to compare the measured angle with the recorded gut volume. Statistical analysis, (R), followed to determine if there were any changes in the lumbosacral disc angle due to gut volume changes.

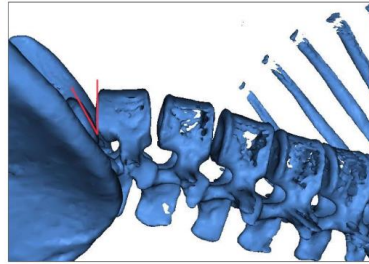


Fig. 2. LDA (shown in red) on the inferior surface of L5 vertebrae and the superior surface of the S1 vertebrae.

### Results

1. There is a weak negative correlation between gut volume and the LDA (-0.197).
2. Males have a slightly stronger negative correlation (-0.29039).
3. There was no significant difference between the LDA and gut volume ( $p > 0.05$ ).

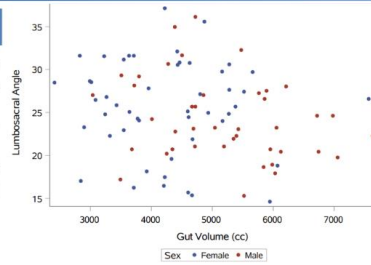


Fig. 3. Correlation between LDA and gut volume

### Conclusions

**Males show a slight negative correlation where the larger the gut volume, the smaller the LDA. We hypothesize that this means that the increased mass (gut volume) is impacting the vertebral disc.**

**With no significant difference between gut volume and the LDA however, a future direction could be looking at the lumbosacral angle as a better indicator of changes due to mass.**



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**ACKNOWLEDGEMENTS:** We thank Dr Jeanelle Uy (Cal State, Long Beach) for access to the CT scans and for the gut volume measures. We thank undergraduate students Katelyn Hamm and Nicholas Duley who did much of the statistical analysis (STA 419).

Figure 2. Dissemination of Project 1's results. Presented at Grand Valley State University's Student Scholars Day, April 2022.

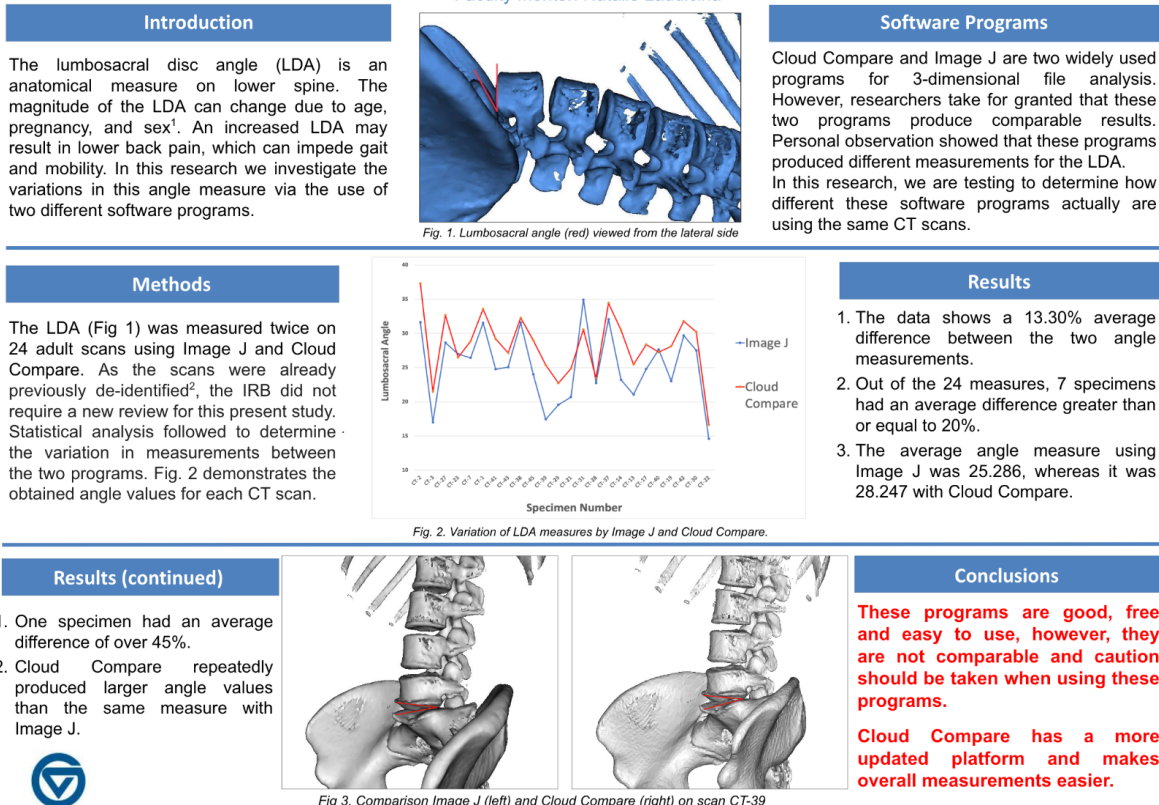
## Project 2: Comparison of Image J and CloudCompare Software Programs

The purpose of this project was to compare the capabilities of two different measuring programs that I have used in my research. Two freely available and commonly utilized software programs, Image J and CloudCompare, were compared by measuring the Lumbosacral Disc Angle (LDA) on 24 adult CT scans. This research provided insight into how this lower spinal angle was better measured and which software is more useful for measurements of these specific angles. The results showed that CloudCompare provided a clearer view of the 3D scans, making the pelvic landmarks easier to locate. It also repeatedly produced larger angle values than Image J.

I presented the results of this project to fellow researchers and mentors at the annual GVSU Student Scholar's Day in 2023. I think this research has merit in skeletal measurement research because it is clear that CloudCompare is a more reliable and functional program than Image J, which is lower quality and difficult to use.

### The lumbosacral disc angle: comparison of two software programs

Carly Stoops, Department of Biomedical Sciences  
Faculty Mentor: Natalie Laudicina



**SOURCES CITED:** 1. Whitcome, K. K., Shapiro, L. J., & Lieberman, D. E. (2007). Fetal load and the evolution of lumbar lordosis in bipedal hominins. *Nature*, 450(7172), 1075-1078. 2. Uy, J., & Laudicina, N. M. (2021). Assessing the role of the pelvic canal in supporting the gut in humans. *PLoS one*, 16(10), e0258341.

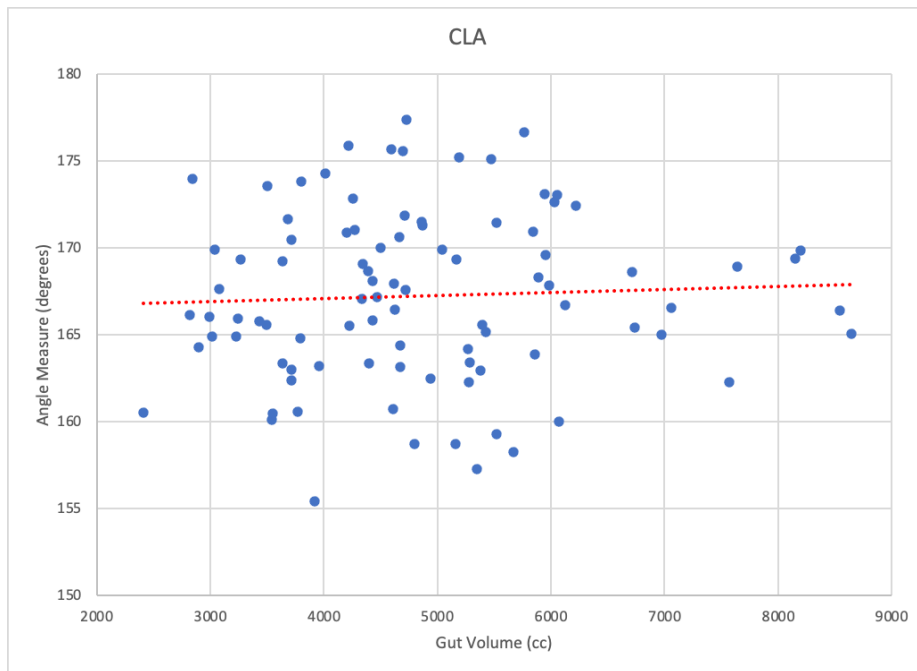
**ACKNOWLEDGEMENTS:** We thank Dr Jeanelle Uy (Cal State, Long Beach) for access to the CT scans and for the gut volume measures.

**Figure 3.** Dissemination of Project 2's results. Presented at Grand Valley State University's Student Scholar Day, April 2023.

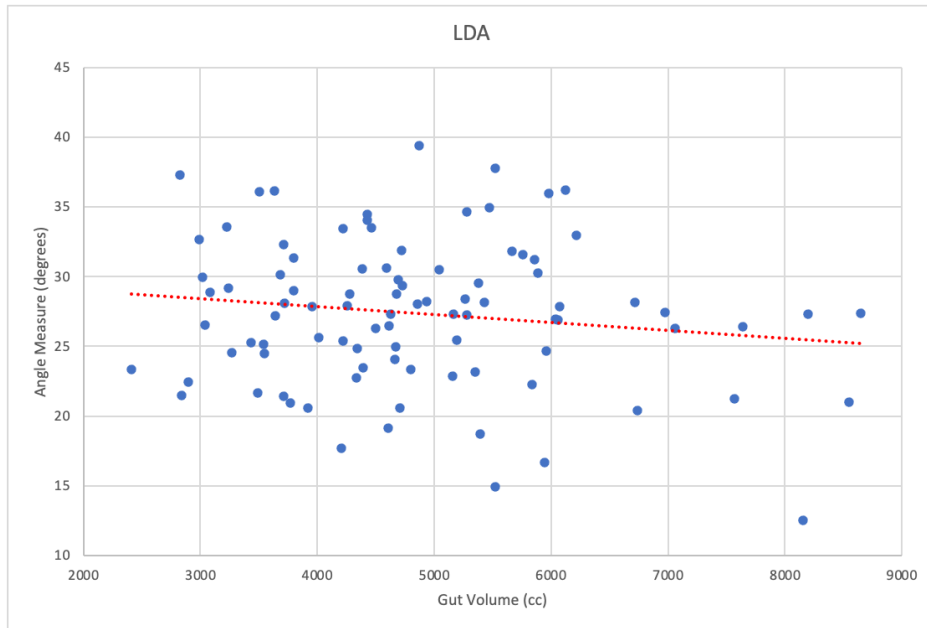
### Project 3: LDA and CLA Changes Due to Gut Volume

This project is a comparison of how both the Lumbosacral Disc Angle (LDA) and the Central Lumbar Angle (CLA) change due to gut volume. I previously measured this change in the LDA in my first project, but the angles were measured using Image J. Since my second project, where I tested Image J and CloudCompare, I determined that CloudCompare was the better program for measuring spinal angles. Using those results, I remeasured the LDA and CLA using CloudCompare to see how each of them was impacted by excess gut volume.

The results of this project demonstrate a slight positive correlation between the CLA and gut volume, indicating that an increase in gut volume causes an increase in the CLA. It also shows a slight negative correlation between the LDA and gut volume, indicating that an increase in gut volume causes a decrease in the LDA. These findings are important because an increase in the CLA suggests that excess gut volume causes increased curvature in the lumbar spine, whereas a decrease in the LDA suggests that the extra weight causes compression of the vertebrae. Both of these anatomical changes could contribute to lower back pain, especially if muscles and nerves are being misplaced or compressed.



**Figure 4.** Correlation between gut volume and the Central Lumbar Angle



**Figure 5.** Correlation between gut volume and the Lumbar Sacral Disc Angle

In conclusion, this research shows no significant relationship between excess gut volume and changes in the Central lumbar angle and Lumbar sacral disc angle, however, there are weak correlations present. These correlations suggest that excess gut volume may cause an increase in the CLA and a decrease in the LDA. The results of these projects were beneficial in determining the best angle-measuring software for anatomical measures, which will be useful for subsequent projects. Future research may include larger sample sizes to attempt to obtain significant results that suggest that increased gut volume can change anatomical structure. The introduction of a third spinal angle measure may be worthwhile as well, allowing examination of another area of the lower spine.

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