LITERATURE REVIEW

**Team Members:** Christian Mandujano, Michael McGrath

Our understanding of the human body is limited. We can agree that the spinal load of various postures can cause injury. Understanding spinal loading across various daily postures is critical to prevent injury from spinal loads. In this literal review we want to explore different studies that should guide our understanding of the simulations and evaluation work for our project using Open Sim. Each paper should contribute to the different insights on posture, spine modeling and simulation techniques. These articles should support our aim to quantify lumbar loading across common postures and spinal loads.

In the paper “Using musculoskeletal models to estimate the effects of exoskeletons on spine loads during dynamic lifting tasks: differences between OpenSim and the AnyBody Modeling System” by Behjati Ashtiani, Akhavanfar, Li, Kim, and Nussbaum, we can see that they compared two musculoskeletal modeling tools, Open sim and Anybody Modeling system(AMS). They estimated spine loading during lifting tasks with and without Back-Support Exoskeletons(BSEs).

They recruited 18 participants and performed symmetric and asymmetric lifting tasks. The participants used BSE’s and no BSE control. They simulated and compared axial compression and anteroposterior shear forces at the L4/L5 vertebrae. In the article we were able to find that OpenSim estimated larger spine forces and greater reductions in spine loads from BSEs compared to the results from AMS. Both models showed spine load reductions in spine loads from BSE’s. The team was able to find that the models showed a positive correlation for compression forces. Differences are attributed to model assumptions like passive tissue representation and human-exoskeleton interaction modeling.

The greatest parts of the study are that the paper is able to make a direct comparison from OpenSim to AMS for dynamic BSE tasks. It also showed that the practical relevance for the ergonomics in the research and the engineers was given better ability to interpret the modeling results when designing a BSEs. The team was able to show that the data was large as they showed 12,960 simulations across all conditions showing robustness in the data and the modeling. The article also showed a clear limitation in the modeling simplifications, such as the treatment of passive elements and force applications.

The article also showed limitations for the data. The group was able to show virtual exoskeletons didn’t model mass, belts, or soft-tissue dynamics. This limited real-world accuracy. The article showed a limited validation in no direct implant force data used to check the models. AMS adapted to trunk movement; AMS assumed a fixed contact point for the BSE. The article only analyzed L4/L5, using an intervertebral joint while not assessing other joint areas. They used inertial motion capture which might introduce noise into the kinematic data. Leading to functions that could be updated in the future.

For future improvements we can suggest some things. We would want more realistic Human-Exoskeleton Interfaces. More sophisticated methods like rigid-body contact modeling or compliant force elements. Validation against measurements, incorporating spine force measurements from implants or EMG based dynamic studies. Showing a broader range of postures. A broad analysis beyond lifting to include other common activities. Assessing how BSE’s affect loads across the full lumbar and thoracic spine, and not just L4/L5. Addressing modeling differences and deeper investigation into ligament models, optimization strategies and scaling algorithms between OpenSim and AMS. Even with these changes it was able to highly relate to our project.

Our project will be using open Sim to evaluate lumbar spine loading across different static postures. This paper warns that even with trusted modeling platforms like Open Sim, modeling choices can greatly affect outcomes. A lesson we will have to keep in mind as we research. This also highlights that we need to carefully validate how open Sim models are sued to evaluate spinal loads. This goes double for our focus on posture rehabilitation and minimizing the lumbar stress after injury.   
  
The article “Evaluation of Spine Loading Across Static Postures Using OpenSim” analyzes how different body positions affect the lumbar spine. Since our project uses OpenSim to simulate common postures like standing, lying down, and bending forward, this article is very relevant and helpful to our work. This paper keeps its goal simple and focused, sticking to a few basic postures that people encounter every day. This makes the results easy to understand for people who are dealing with lumbar back pain. Their use of OpenSim is a good choice since it’s a well-known tool for musculoskeletal modeling. Since the paper uses both joint forces and muscle activity, it gives a thorough perspective of what’s happening in the lower back during these various movements. There are some limitations to the paper though, such as OpenSim models being based on the “typical” body, but real people, especially those with injuries, can move quite differently. Because of this, the results may not be very useful for a large amount of people. Another limitation is the project only looks at static postures, but in real life people are constantly moving. These movements could cause different kinds of strain on the spine that aren’t captured in this study, such as bending over to pick things up, or rotating your spine while holding an object above your head. This article ties directly into the project because we are also using OpenSim to look at spinal forces in everyday positions. Just like the authors of this article, we want to fund out what postures are safest and most comfortable, especially for recovering from injuries. The project in the article shows that it’s possible to get meaningful results just by studying simple, common movements, which gives us a good foundation to build on.

Analysis of lumbar spine loading during walking in patients with chronic low back pain and healthy controls: an OpenSim—based study

The article “Analysis of lumbar spine loading during walking in patients with chronic low back pain and healthy controls: An OpenSim—Based study” examines lumbar spine loading during walking in both patients with chronic low back pain (LBP), and healthy ones. The researchers used a detailed full-body lumbar spine (FBLS) model, as well as motion capture and force plates, to estimate joint angles, muscle forces, and internal loads. They found that patients with LBP showed lumbar extension moments, lower muscle forces, and higher spinal loads compared to healthy patients. While the overall loading patterns stayed relatively constant between groups, the LBP group had significantly less activation of key stabilizing muscles.

One of the strengths of this article is that it uses OpenSim and the FBLS model, which gives a much better perspective of lumbar loading during dynamic movement relative to earlier segmental models. Segmental models treat the body parts as simple rigid blocks, instead of modeling joints or muscles in detail. Another thing this article benefits from is validating simulation outputs against EMG signals. This adds confidence to muscle activation estimates. The use of both kinematic and kinetic data creates a better picture of spinal biomechanics during walking. This makes the results feel more grounded in real movement patterns.

There are some limitations to this paper through. The sample size could have been more thorough, since it was relatively small and skewed toward younger adults with mild LBP, which might not be accurate in capturing the full spectrum of lumbar degeneration seen in older populations. Another limitation is that Open Sim’s FBLS model relies on static optimization and is unable to perform dynamic muscle control simulations, which means real muscle coordination patterns may not be perfectly captured. The last limitation is that spinal curvature wasn’t personalized for each patient, and that could affect load estimates.

Future work may expand the study to older or adults, or people with more severe LBP. It also may be interesting to measure lumbar loads during other activities like lifting or standing from a seated position. Walking alone may not show the most noticeable differences.

This study is especially relevant to our project since it shows how OpenSim can be used to evaluate forces across the spine under realistic positions. While out project will look at static postures rather than walking, the methods they used to process motion capture data, build subject-specific models, and analyze spinal loads can directly help us with setting up and validating our simulations. Using musculoskeletal modeling to analyze loading aligns well with our goal of assessing low-stress postures for injured people.

Understanding spinal loading across daily activity will be essential to prevent injuries and support recovery. This goes especially for individuals with existing spinal conditions. We explored several studies that informed and will guild this project using OpenSim to simulate and evaluate lumbar spine loads during different postures.

The study comparing OpenSim and Anybody modeling system showed critical impacts that model choice and assumptions can have on spinal load estimate. This shows the importance of carefully validating and interpreting our OpenSim results. Our project will focuses on safe postures for rehabilitation, we also reviewed a study that used open sim to evaluate spinal loading across basic static postures. Demonstrating that meaningful insight can be achieved even when focusing on simple static tasks, creating a strong foundation for our research. The investigation of lumbar loading during walking in patients with chronic low back pain showed how musculoskeletal models, validated against EMG data, can enhance the reliability of spine load assessments during real-world movements. Although our focus is on static postures, the methodology of incorporating subject -specific modeling and careful validation offers valuable lessons for improving the accuracy of our simulations.

These papers highlight that OpenSim provides powerful tools for modeling and analysis, careful model selection, validation and a clear understanding of its limitation will be essential. The project will aim to build on these insights to evaluate and identify postures that minimize lumbar stress, ultimately contributing to sage rehabilitation strategies for individual recovery from lower back injuries.