UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

SIMULATION-BASED ESTIMATION OF SPINAL LOADING FROM SURGICAL LEAD VESTS: A MUSCULOSKELETAL MODELING STUDY OF SURGEON ERGONOMICS

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE

By

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Norman, Oklahoma

2025

SIMULATION-BASED ESTIMATION OF SPINAL LOADING FROM SURGICAL LEAD VESTS: A MUSCULOSKELETAL MODELING STUDY OF SURGEON ERGONOMICS

A THESIS APPROVED FOR THE

STEPHENSON SCHOOL OF BIOMEDICAL ENGINEERING

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Acknowledgements

I would like to express my sincere gratitude to my thesis advisor and committee chair, Dr. Dee Wu, for the unwavering support and mentorship throughout this journey the last 4 years. Thank you for challenging me to push beyond my limits, for encouraging me to approach problems from multiple perspectives, and for believing in my potential through every stage of this process. I am deeply grateful to my committee members Dr. Sarah Breen, Dr. Jin-Song Pei and Dr. Vassilos Sikavitsas, for their thoughtful insights, guidance and investment in my academic growth. I am fortunate to have had such a supportive and impactful committee that shaped not only my research but my development as an engineer and person. A special thank you goes to Dr. Dominique Pittenger, whose mentorship has been a cornerstone of my undergraduate and graduate experience. Your example of a resilient and compassionate leader inspires me to be a better student, mentor, and engineer. I will always carry your lessons.

To my family, thank you for being my constant foundation. Dad, Mom and Nana, your unwavering support and belief in me have carried me through every challenge. Garrett and Katie thank you for your patience with me this year and always being always cheering me up when I am stressed. Carl, Mattie, Emory, Sacra and Greer thank you for being my second home this semester. You were all a source of generosity, kindness, and encouragement when I needed it the most.

Finally thank you to all my friends and classmates for keeping me grounded. Specifically, Jules Hartwick, my partner in crime, through it all from us both doing thesis work to the many well-earned moments of fun we had. I could not have gotten through this without all these amazing people in my life.

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Abstract

Work-related musculoskeletal disorders (WMSDs) are highly prevalent among surgeons and are often exacerbated by prolonged postures and the use of heavy radiation protective lead vests. This study used validated full-body male and female musculoskeletal models in OpenSim 4.4 to quantify thoracolumbar spine loading under representative surgical postures with and without simulated lead vests. Seventy simulations were conducted across five postures and seven vest weight configurations, modeling compressive, anterior-posterior (AP) shear, medial-lateral (ML) shear, and resultant joint reaction forces across the T1–L5 spinal segments. Simulations revealed that the L5-S1 segment consistently experienced the highest compressive forces, with peak loads reaching 1523 N in males and 1161 N in females. While AP shear forces peaked at T1–T2, exceeding 90 N, particularly during axial twisting. Vest weight placement at the sternum induced up to 28% higher spinal loads than abdominal placement, particularly during twisting and trunk-flexed postures. Although male models exhibited greater absolute forces, female models demonstrated comparable or higher normalized (% body weight) loads, underscoring the ergonomic disparities in current vest designs. Although male models exhibited greater absolute forces, female models demonstrated comparable or higher normalized (%BW) loads, underscoring ergonomic disparities in current vest designs. While loads remained below single-exposure risk thresholds, the combination of elevated spinal forces and repeated exposure poses a long-term risk of degeneration and injury. These findings highlight the need for posture-specific ergonomic interventions, sex-specific vest designs, and further in vivo validation to mitigate the occupational toll of spinal loading in surgical professionals.

Chapter 1: Introduction

1.1 Background

Surgeons face a growing occupational health concern from musculoskeletal (MSK) injuries due to prolonged static postures, repetitive movements, and external loads from protective equipment such as lead vests [1], [2]. The goal of this study is to determine if there is a connection between wearing lead vests and potential health outcomes and impacts to MSK problems. Examining the clinical significance of work-related musculoskeletal disorders (WMSDs), evaluating the biomechanical impact, and underlying factors [3].

1.1.1 Clinical Significance of WMSDs in Surgeons

Work related musculoskeletal disorders (WMSDs), defined as injuries to the muscles, bones, nerves and connective tissues caused by occupational duties and stressors, affect the majority of surgeons, with prevalence rates ranging from 60% to 94% across specialties [2], [4], [5]. These disorders manifest as chronic back pain located in specific anatomical regions such as the lower back (lumbar spine), neck (cervical spine) and the upper back (thoracic spine) [2], [4], [6]. This can significantly impact the surgical duties and career longevity. Orthopedic surgery is among the specialties most WMSDs, with 68% reported experiencing lower back pain and 25% requiring time off from work due to symptoms related to WMSDs [3], [7]. Chronic back pain can compromise the quality and efficiency of surgical duties, contributing to reduced job satisfaction and secondarily an increased risk of absenteeism or early retirement [2], [8].

A potential contributor to WMSDs is the use of lead vests or aprons, which are an important and mandatory tool for radiation protection during fluoroscopy-guided procedures, orthopedic fracture fixation, and interventional radiology [9], [10]. Procedures like these are prevalent in specialties like cardiology, orthopedic and interventional radiology, where they can wear leads ranging from 2.3- 6.8 kg (5-15lbs.) for anywhere from 3- 20 hours per week depending on case load [11]. The cumulative weight with the mechanical demands of surgery can potentially accelerate degenerative changes or lead to chronic injury. The lead vests introduce an external weight that can shift the center of mass, inducing changes on the forces exerted on the thoracolumbar spine (T1-L5) [12]. These segments are responsible for bearing the majority of the weight of the torso and are important for movement in all directions of the trunk [13], [14]. The shift in the forces due to an external load could potentially exacerbate musculoskeletal injuries, contributing to disc degeneration or facet joint stress [15]. The lead vests are highly variable due to the differences in the brand, model year, or design which can influence the degree of biomechanical strain on the body. Newer models are designed to be lighter but have concerns about effectiveness. Older models may be heavier or lose ergonomic benefits overtime potentially providing poor fits, affecting where the load is held leading to further musculoskeletal strain. There are some specialties such as interventional radiology that implement scheduling strategies, alternating imaging days to potentially offset some of the impact of continuous lead apron usage, this may mitigate some WMSD risk [16].

Given that the thoracolumbar spine plays a central role in postural support and load transmission, an understanding of how lead vests can alter the forces in this region is critical. Despite the prevalence of WMSDs and the widespread use of radiation protective garments, there are few studies that have systematically quantified the spinal loading under clinically relevant conditions targeted to the occupational hazards of surgeons. There is a need for a more detailed biomechanical understanding to understand the impact this is having on MSK health and to provide insights into design improvements to this equipment and guide institutional policies to promote MSK health in surgical personnel.

1.1.2 Current Literature

Current research on work-related musculoskeletal disorders (WMSDs) in surgeons has primarily focused on prevalence, risk factors, and ergonomic interventions. However, significant gaps remain in quantifying the biomechanical impact of lead aprons on the thoracolumbar spine. This information is valuable for establishing the prevalence of WMSDs but falls short on the how the spinal mechanisms, external load and postures interact to produce strain on the thoracolumbar spine.

WMSDs are highly prevalent among surgeons, with numerous studies reporting occupationally induced pain in specific populations. One study surveyed plastic surgeons in the US, Norway and Canada, reporting that around 80% of plastic surgeons reported having MSK pain, specifically in the lower back, shoulders and neck [17]. Similarly, a study done to investigate musculoskeletal pain in resident orthopedic surgeons, those with pain attributed 54.8% in the lower back, 59.4% in the neck, 34.4% in the shoulders and 35.5% in the upper back, these results are similar to other documented complaints in surgeons [18], [19], [20]. Further, they highlight that many of their survey participants attribute this pain to their work as a surgeon. Among practicing orthopedic surgeons in Western New York, 77% reported having back pain, with 30% reporting to have had or are getting treatment for MSK pain, and 26.4% of the surgeons reported having to modify their clinical practice or OR set up due to the pain [21].

Based on those survey results the authors note that there is a need to investigate how time spent wearing lead vests contributes to the prevalence of these MSK issues.

Surgeons are often in awkward or non-neutral postures during procedures which play a role in evaluating the ergonomic risks associated with surgery. Open surgery is often more physically demanding on surgeons compared to laparoscopic or robotic surgeries. A study performed by Fan et al. sought to determine the difference in the physical workload during those surgical procedures and normal tasks [22]. They attached wearable sensors to the surgeons during surgical workdays; this allowed for the muscle activity of the trapezius muscle groups from EMG collection as well as the posture and movement of the head and trunk from the inertial measurement units. The results indicated that open surgery imposed higher workloads on robotic surgery and non-surgical tasks. Indicated by elevated muscle activity, reduced muscle rest time and more time spent in sustained low-level muscle activity. Both surgical procedures had more extreme posture of the head and torso than were seen in the non-surgical tasks [22]. Those findings support the proposed link between spinal loading and the prolonged postures in surgery.

Laparoscopic surgery is slightly more involved than robotic surgery but not as hands-on as open surgery. Berguer et al. investigated the ergonomic risks, including the physical fatigue and compared postures between laparoscopic and open surgery [23]. They completed a motion analysis study on laparoscopic and open surgical procedures, determining the percentage of time spent in certain postures and separately recorded by the surgeons in a walking trial. The authors determined that the static nature of the laparoscopic study may lead to more fatigue even though the postures appeared visually neutral. This was determined due to restricted postures during laparoscopic surgery to the measured decrease mobility in the head and back, as well as less weight shifting in the anterior-posterior (AP) direction. Whereas open allowed more natural shifts in posture [23]. A complementary study found that laparoscopic surgical techniques reduced the trunk movement but had an increase in internal shoulder rotation, elbow flexion and wrist deviation [24]. These studies both indicate that the static and awkward movement of laparoscopic surgery may shift the ergonomic burden across body regions depending on procedure and design of equipment. The study completed by Norasi et al. employed biomechanical data collection to quantify the workload and postural demands on vascular surgeons using Inertial Measurement Units (IMU) [25]. They reported that the low back and neck were held in strained postures. In this report they also recorded the use of lead vests as radiation personal protective equipment (RPPE), however, they did not investigate the biomechanical costs of them but did suggest that they pose cognitive or workflow burdens on the surgeons [25].

Lead vests are a source of ergonomic concern in hospitals. Monaco et al. reviewed the results of 12 studies, reporting that lead aprons are frequently associated with spine-related discomfort, but the level depends on weight, design and procedural context of use [12]. This study measured the ergonomic injuries from wearing lead vests in surgery using infrared thermography, used to determine muscle activity. They found that wearing the leads, even for a few hours, significantly increased the musculoskeletal strain, particularly in the upper trunk [26]. Noting that this increase in muscular workload and potential fatigue could be due to the asymmetric load distribution of the lead vests [26].

Few have investigated the underlying biomechanical mechanisms that are driving these conditions. The existing literature largely focuses on ergonomic assessment, self-reported symptoms, or epidemiological trends.

1.1.3 Musculoskeletal Modeling and OpenSim Framework

While prior research has established the prevalence of musculoskeletal strain in surgeons, few quantify the internal spinal forces that biomechanics that underlie these conditions. Musculoskeletal modeling provides a way to bridge this gap with an in-silico approach to estimate internal forces and loading conditions that are not easily measurable in vivo. OpenSim is a widely used and validated modeling tool that allows for simulating human movement and internal loading conditions. OpenSim is an open-source platform developed by Delp et al. to create and analyze dynamic and static simulations of human movement using anatomically detailed musculoskeletal models [27], [28]. It allows for the estimation of many biomechanics' calculations including joint reaction forces, muscle activations, and spinal loading using user defined motion and loading conditions. It has been extensively applied across sports, rehabilitation, and ergonomic research domains.

This present study utilized a validated full-body model thoracolumbar spine and rib cage model developed by Bruno and colleagues as a part of the Thoracolumbar Spine and Rib Cage model project [29],[30], [31], [32], [33], [34]. This model includes a fully articulated thoracic and lumbar spine with three degrees of freedom at each intervertebral joint, a fully modeled rib cage, and over six hundred musculotendon actuators representing major trunk and upper body muscle groups. It was originally developed using CT imaging of a twenty-five-year-old male (height 174 cm, mass of 78 kg), representing a 50th percentile adult. The muscle architecture was adjusted using in vivo CT data and strength parameters from a community-based sample of 125 men and 125 women in the Framingham Heart study. The male model has been described and validated extensively; the female model was added (61 kg) but the specific derivation of the model has not been specified. In OpenSim, the segmental mass (male 78 kg and female 61 kg) includes the entire mass of the body (fat skin, and visceral tissue, represented as a lumped parameter), not just the muscles and bones. The model has been validated against in vivo using implanted sensors intradiscal pressure measurements, vertebral loading, and surface EMG data, and is suitable for static optimization-based spine loading estimations [30], [31], [32], [33], [34].

For the posture analyses this study incorporated and selected motions most similar to surgical postures observed, from the subject specific motion and external force data from the publicly available data set released through the Framingham Heart Study [35]. This includes 250 individuals and 126 static activities [36]. These resources provided a robust and physiologically grounded foundation for this study simulating spine loading during quasi-static postures under lead vest conditions.

1.2 Anatomy of the Thoracolumbar Spine

Understanding the structural and functional characteristics of the thoracolumbar spine is essential for interpreting how occupational loading, such as from lead vest use, can lead to musculoskeletal strain or injury. This region of the spine, which spans vertebrae T1 to L5, plays a critical role in postural support, load transmission, and trunk mobility. It also houses key anatomical structures including vertebral discs, facet joints, and paraspinal musculature that collectively maintain spinal stability and alignment under dynamic and static conditions.

1.2.1 Anatomical Terminology and Planes of Motion

Throughout this study, standard anatomical terminology is used to describe the musculoskeletal system. The human body is divided into three principal planes: **the frontal (coronal) plane**, which separates front and back; **the sagittal plane**, which divides left from right; and the **transverse plane**, which divides top from bottom. Movement terminology includes:

- **Flexion and extension** which describe decreases or increases in joint angle (typically in the sagittal plane).
- **Abduction and adduction** which describe movement away from or toward the midline (typically in the frontal plane).
- **Axial rotation** or twisting about the spine.
- **Lateral flexion** which refers to side-bending motions in the frontal plane Throughout this study, standard anatomical terminology is used to describe the musculoskeletal system [37].

Additional terminology relevant to the pelvis includes:

- **Pelvic tilt** is the anterior or posterior rotation of the pelvis in the sagittal plane.
- **Pelvic list** is the elevation of one side of the pelvis in the frontal plane.
- **Pelvic rotation** is the transverse rotation of the pelvis about a vertical axis.

These planes and motions are foundational to describing the postures analyzed in this study and help define how external loading may deviate the body from its neutral biomechanical alignment [37].

1.2.2 The Vertebral Column and the Thoracolumbar Structure

The vertebral column consists of thirty-three vertebrae grouped into five regions: cervical (C1–C7), thoracic (T1–T12), lumbar (L1–L5), sacral (S1–S5, fused), and coccygeal (3–5 fused). The thoracic and lumbar regions, collectively known as the thoracolumbar spine, are the primary focus of this study due to their biomechanical role in supporting trunk weight and transmitting axial loads to the pelvis and lower limbs [38], [39]. The vertebral column and each of the segments can be visualized in **Figure 1.1** below.

Each vertebra consists of a vertebral body, arch, spinous and transverse processes, and facet joints that articulate with adjacent vertebrae. A labeled illustration of vertebral anatomy is provided in **Figure 1.2.** Intervertebral discs composed of an annulus fibrosus and nucleus pulposus provide shock absorption and allow for spinal flexibility. Posteriorly, paired facet joints guide and restrict specific motions, while ligaments and muscles such as the erector spinae, multifidus, and quadratus lumborum stabilize the spine against external and internal forces [39], [40].

The thoracic spine (T1–T12) articulates with the rib cage, contributing to spinal stability and organ protection. Although it is less mobile than the cervical and lumbar regions, it plays a key role in trunk rotation and postural support. Thoracic vertebrae increase in size from T1 to T12 and exhibit costal facets for rib articulation [40].

In contrast, the lumbar spine (L1–L5) is characterized by large, block-like vertebral bodies adapted to bear high compressive forces. It serves as the primary load-bearing segment of the axial skeleton during standing, lifting, and postural maintenance. Lumbar vertebrae also allow for flexion-extension but restrict axial rotation due to their orientation and facet joint geometry. The lumbar region houses the cauda equina, a bundle of spinal nerves responsible for lower limb and pelvic control [41].

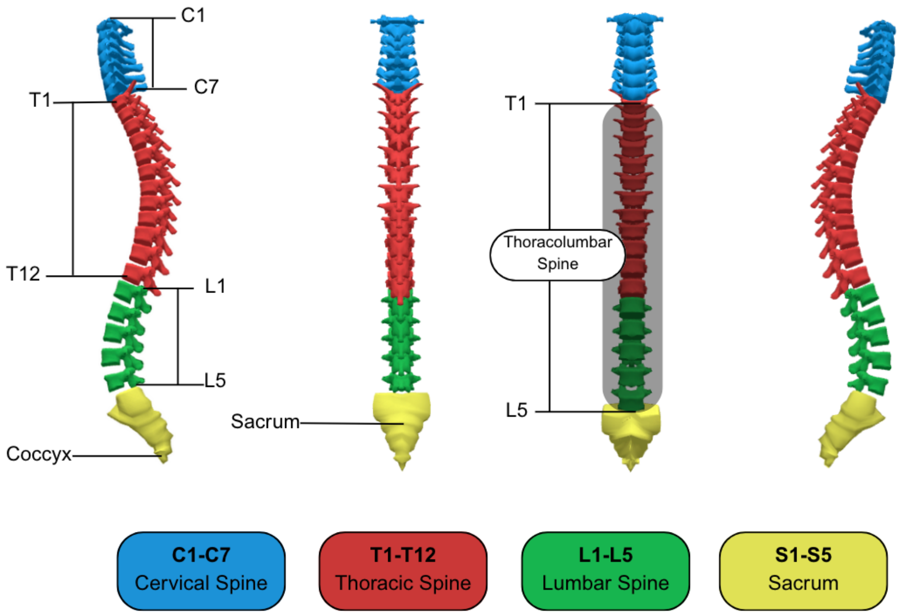

Figure 1. 1: Vertebral Column and Thoracolumbar Spine

The vertebral column is divided into five segments shown above. The cervical spine (C1-C7) in blue, thoracic spine (T1-T12) in red, lumbar spine (L1-L5) in green, sacrum (S1-S5) in yellow, and the coccyx at the tip of the sacrum. The thoracolumbar spine highlighted in the third panel is the combined thoracic and lumbar spine (T1-L5). This is the primary region of analysis in this study. Far left is the left lateral view, ventral view, dorsal view and right lateral views of the human spinal column. Image made using Canva.com.

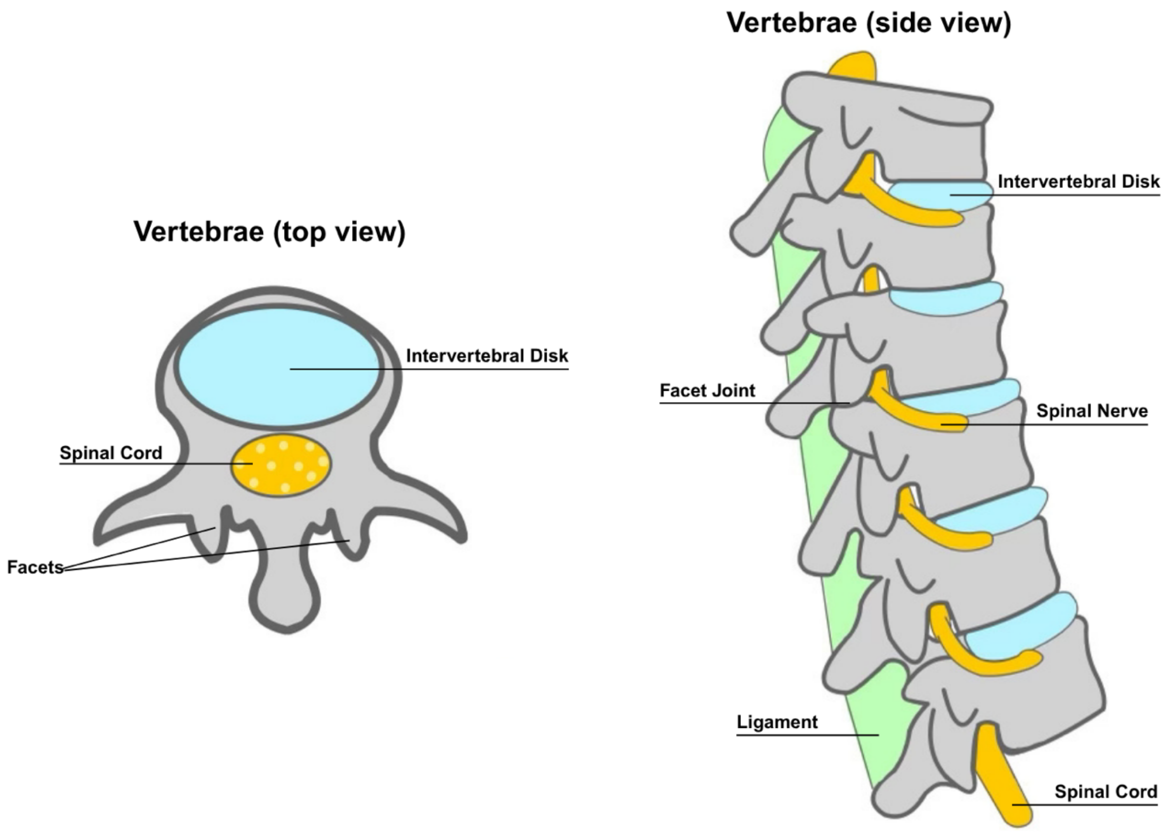

Figure 1. 2: Anatomy of a Typical Vertebrae

Left: Cross-sectional view showing the vertebra, intervertebral disk (blue), spinal cord (yellow), and facet joints (grey projections). This orientation highlights the central placement of the spinal cord in the vertebrae. Right: Lateral view of the spinal column illustrating the stacked vertebral bodies separated by the intervertebral disks (blue), posterior facet joints, emerging spinal verves(yellow), and supporting ligaments (green). Image created using Canva.com.

1.2.3 Muscular Mechanics and Internal Joint Loading

Human movement arises from the interplay between bones (levers), joints (axes), and muscles (actuators). Skeletal muscles generate movement and resist external loads through two types of contraction: concentric (shortening under tension) and eccentric (lengthening under load)[42]. While this study simulates static postures, these principles are still relevant because of the mechanical disadvantage at most joints. Muscles are often attached close to the joint axis, which requires them to generate much larger forces than the external load they are balancing. For example, in normal walking, hip joint reaction forces may reach 2–3 times body weight, while forces in the spine can exceed several times body weight even during static postures. This mechanical amplification explains how lead apron weights, although seemingly small (2.3- 6.8 kg (5–15 pounds)), can produce significant internal spinal loading due to compensatory muscle forces. Spinal loading behaves similarly. During static postures, compressive forces arise from both gravitational load and muscle activity required to maintain balance and alignment. These internal joint reaction forces, especially in the thoracolumbar spine, can be significantly amplified when external loads, ex lead vests, are introduced. Tendons help transmit muscle forces across joints efficiently, allowing for fine motor control and power generation without excessive joint displacement [37].

The thoracolumbar spine is susceptible to injury during sustained or asymmetrical loading due to its complex anatomy and its critical role in load transmission [31]. When externals loads are applied, especially during prolonged standing or forward flexion, the likelihood that the physiological loading thresholds can be exceeded [12], [43]. Musculoskeletal simulations like used in this study provide non-invasive ways to identify potential considerable risk postural configurations. By understanding and integrating anatomical accuracy into the model, this study aims to link observed patterns of musculoskeletal injury with internal mechanisms that underlie them.

1.3 Modeling Framework Overview

This study uses OpenSim 4.4, to estimate the thoracolumbar spine loading under representative static surgical postures with and without lead vests. The modeling framework incorporates the validated thoracolumbar spine models male (78 kg (172 lbs.), 170 cm) and female (61 kg (134 lbs.), 160 cm) anthropometrics, publicly available on the SimTk platform [29],[30], [31], [32], [33], [34]. These models enable non-invasive estimation of internal spinal forces in response to posture and external loading. As surgical procedures often involve sustained, quasi-static positions rather than dynamic movement, this study focuses on representative static configurations, allowing for controlled comparison across conditions.

The simulation workflow for this study involves two primary analyses from the OpenSim analysis tool: Static Optimization (SO) Joint Reaction Analyses (JRA). SO computes the muscle activations required to maintain postures given external loads. It can solve the muscle redundancy problem by minimizing the physiologically motivated cost function. This is typically the sum of cubed muscle activations.

Once the muscle forces are estimated, the Joint Reaction Analysis (JRA) is used to calculate the net reaction forces and moments at each joint. Following Joint Reaction Analysis, post-processing was performed in MATLAB to compute vertebral loads at each segment. Reaction forces from both the child and parent joint frames were averaged to estimate midvertebral body loading, consistent with validated approaches described in prior thoracolumbar modeling literature [30], [33]. This approach allows for quantification of compressive, shear, and resultant forces at each vertebral level (T1–L5), enabling segment-specific comparisons across postures and load conditions. These joint loads account for the contribution of added external forces and internal muscle forces. In this study, the reaction forces are resolved along three anatomical directions: superior-inferior (SI) for compressive loading, anterior-posterior (AP) shear, medial-lateral (ML) shear forces. The reaction forces are reported across the vertebral levels in the thoracolumbar spine (L5-T1). As well as normalized to the body weight of each model to allow for inter-condition and inter-model comparisons. By combining these analyses, it provides the quantitative basis for evaluating the biomechanical effects of lead vest use to improve MSK health in surgeons.

1.4 Rationale for Study

Work related musculoskeletal disorders (WMSDs) are the leading cause of occupational injury among surgeons, with lower back pain being one of the most frequently reported issues [21], [44]. The physical demand of surgery largely elevate the risk of this, this can be exacerbated with the prolonged static postures, trunk flexion, axial rotation and asymmetric handling of instruments [23], [24], [25]. As noted, literature lacks quantitative analysis of the joint loading in this population. This study is being conducted to analyze the impact that the added weight on the body due to surgeons and other medical professionals wearing lead vests. The use of lead vests is used in many different aspects of the medical field to protect from exposure to radiation, however they impose a significant ergonomic burden [12], [43], [45]. This study aims to address the critical gaps identified by applying the OpenSim modeling tools to simulate the thoracolumbar loading in five representative postures (1️⃣ Motion One- neutral standing, 2️⃣Motion Two- 30º axial twist with elbows flexed to 90º and 10 kg (22 lbs.) in each hand, 3️⃣Motion Three- 30º trunk flexion with arms down, 4️⃣Motion Four- 30º trunk flexion with arms extended forward and 5️⃣Motion Five- 90º elbow flexion with 1 kg (2.2 lbs.) in each hand) under seven loading conditions (no vest weight and 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) applied to either the sternum or abdomen) across both male and female full body musculoskeletal models. By analyzing compressive, AP shear, ML shear, and resultant forces at each vertebral level from L5-T1, the study aims to identify posture and load dependent risks that may underlie the high rates of WMSDs in the surgical population. As well as to evaluate if spinal forces are substantially different between sexes under identical posture and loading conditions.

The results of this simulation framework may support evidence-based improvements in surgical lead design, guide for ergonomic practices and provide evidence to inform policy level decisions to protect the MSK health of operating room personnel.

1.5 Research Objectives

This study aims to quantify the biomechanical effects of lead aprons on thoracolumbar spine loading using OpenSim simulations of male and female musculoskeletal models. The specific objectives are:

1. **Quantify** compressive, anterior-posterior (AP) shear, mediolateral (ML) shear, and resultant forces across the thoracolumbar spine (T1–L5) in male and female models during five static postures (neutral standing, 30º axial twist with elbows flexed to 90º and

10 kg (22 lbs.) in each hand, 30° trunk flexion with arms down, 30° trunk flexion with arms extended, 90° elbow flexion with 1 kg (2.2 lbs.) per hand) without added weight.

2. **Evaluate** the impact of simulated lead apron weights (2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) applied to the sternum or abdomen) on compressive, AP shear, ML shear, and resultant forces across T1–L5 in male and female models across the five postures.
3. **Analyze** the distribution and magnitude of forces across T1–L5 by posture, weight condition, and sex, calculating percent changes relative to no-vest baselines and normalizing forces to body weight to identify high-risk loading patterns.
4. **Validate** the OpenSim model outputs against literature-reported spinal loads to ensure biomechanical accuracy and physiological relevance.

These objectives provide a framework to quantify lead apron-induced spinal loading, elucidate sex-specific and posture-dependent differences, and support the development of strategies to mitigate work-related musculoskeletal disorders in surgeons.

Chapter 2: Materials and Methods

2.1 Overview of Methodology

This study employed musculoskeletal simulation techniques to quantify the thoracolumbar spine loading in response to simulated postures with and without loads modeled as surgical lead vests. A full body musculoskeletal model from OpenSim was adapted and analyzed under seven vest weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) applied to either the sternum or abdomen body in the model). These conditions were tested across five simulated postures (Motions 1-5). These simulations were conducted separately for the male musculoskeletal model and the female musculoskeletal model with specific anthropometrics to determine sex- specific loading patterns. This methodology builds upon and uses the validated thoracolumbar spine modeling framework established by Thoracolumbar Spine and Rib Cage model project, including model geometry, postural definitions, and analysis pipeline [29],[30], [31], [32], [33], [34]. OpenSim was used to perform static optimization (SO) and joint reaction analysis (JRA). MATLAB was used for automation and post-processing, including the extraction, analysis and plotting of vertebral compressive and shear loads.

2.2 Software Tools Used

- OpenSim 4.5 (Stanford University, CA) Used for musculoskeletal model development, static optimization (SO), and joint reaction analysis (JRA) [27], [28].

- MATLAB R2021b (The MathWorks, Natick, MA) was used for generating actuator files, customizing model specifications, processing model outputs, and automating simulations and analysis using scripting.

2.3 Musculoskeletal Model

This study utilized the Male and Female Full Body Thoracolumbar spine and rib cage model (v2.0_OS4) in OpenSim 4.4. These models were specifically chosen due to their detail in the Thoracolumbar spine and for their validated use in predicting spinal loads [30], [33]. Each model includes the anatomical and physiological differences in the male and female bodies representative during trunk motions. The models include a full spine, rib cage, upper and lower extremities, and detailed musculature of the torso.

The male model has a body mass of 78 kg (172 lbs.) and a height of approximately 170 cm. The female model is slightly smaller with a weight of 61 kg (134 lbs.) and height of around 160 cm. The models were previously adjusted and validated to anthropometric norms, including segment properties, inertial parameters, and muscle scaling based on CT data [30], [32]. Each model has 111 degrees of freedom and 620 musculotendon actuators that represent key muscle groups including the thoracic multifidus, transversus abdominis, erector spinae, lower trapezius and intercostals [33].

The thoracolumbar spine consists of seventeen vertebral bodies with three degrees of freedom (DOFs) at each joint. These are flexion-extension, lateral bending, and axial rotation. This mobility throughout the segments accurately represents the physiological spinal mechanisms that are required to calculate the compressive and shear loading across the vertebral column.

Musculotendon actuators are used to model the muscles according to the Hill-type model. This simulates the force-length and force velocity behavior, tendon slack, and activation dynamics [46]. The actuators are designed to reflect realistic physiological behavior based on experimental and anatomical datasets. These actuators provide the basis for calculating and estimating muscle forces and joint torques produced during simulated postures. The male and female models can be seen below showing musculature and marker placement, **Figures 2.1 and 2.2.**

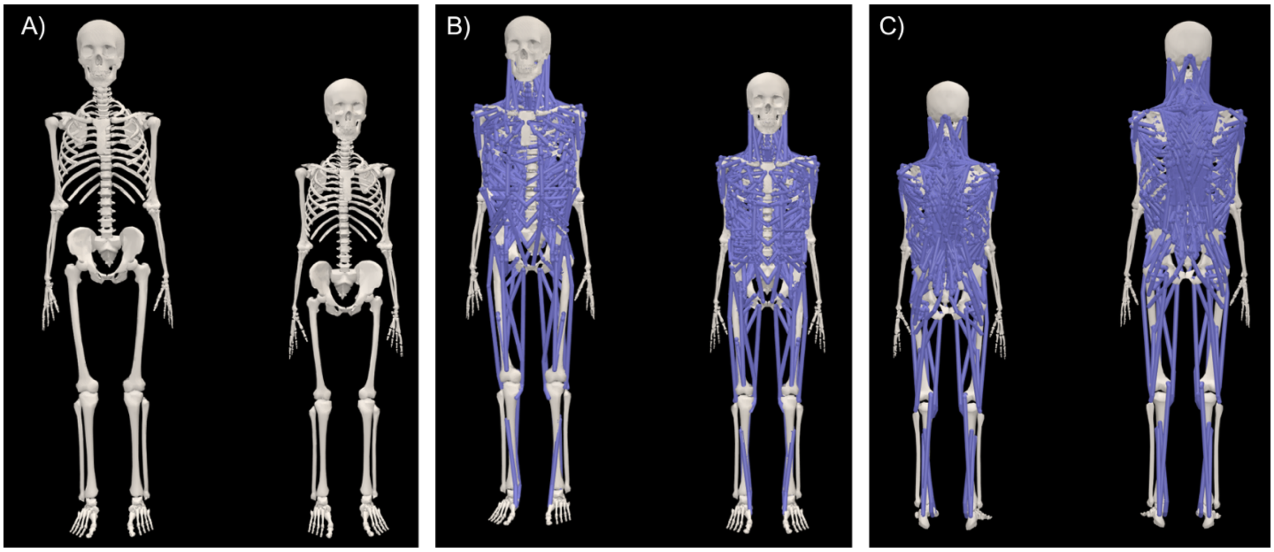

Figure 2. 1: Male and Female Musculoskeletal Model

Anatomical setup of both male and Female OpenSim musculoskeletal models used in this study. In all images (A, B) the Male model is seen on the left and the Female model is seen on the right and for (C) the Male is on the right and Female is on the left. ***(A)*** *Anterior view of the models with only the skeletal structures shown.* ***(B)*** *Anterior view of both models showing full musculoskeletal models.* ***(C)*** *Posterior view of both models showing the full musculoskeletal model. Figure made using OpenSim and Canva.com.*

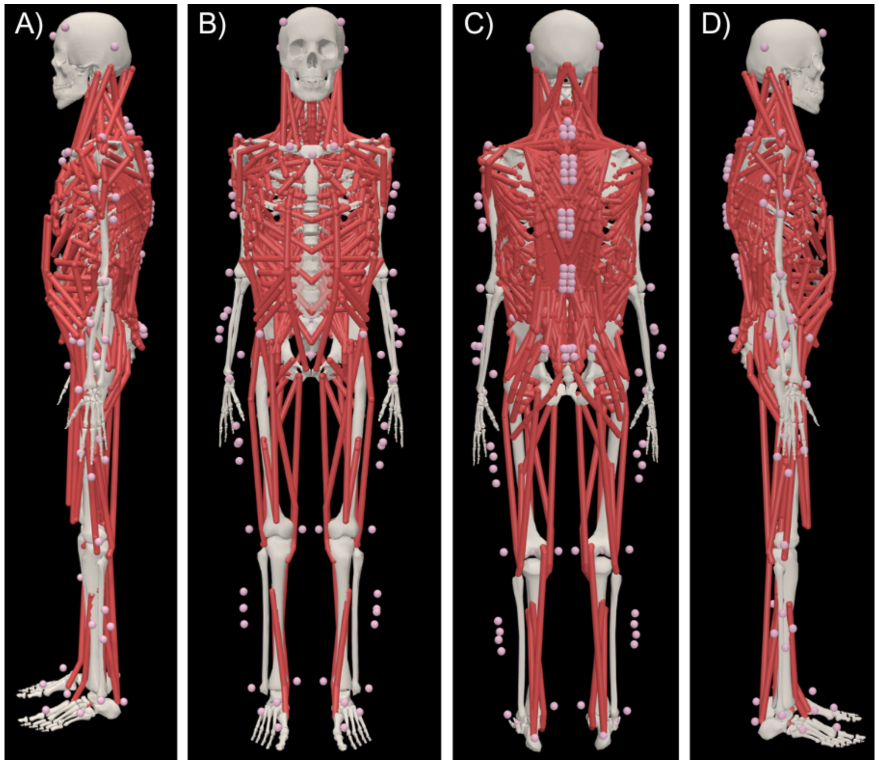

Figure 2. 2: Male Model with Markers

The Male model showing the marker set locations used for motion tracking and kinematic scaling of the model. The Female model isn't shown as the marker locations are the same.

(A) *Left lateral view,* ***(B)*** *Anterior view,* ***(C)*** *posterior view,* ***(D)*** *Lateral view.*

The markers are demonstrated by the pink spheres on the model above and are placed on key anatomical landmarks. Figure made using OpenSim and Canva.com.

2.4 Joint Degrees of Freedom and Locking Strategy

To simulate the quasi-static postures and improve stability of the model there were several techniques employed in the model and analysis set-up. Several of the non-essential degrees of freedom (DOF) were locked to ensure model stability and accurate results were produced. All three degrees of freedom in the thoracolumbar spine were retained to maintain physiologically accurate movements in the model. These included flexion-extension, lateral bending, and axial rotation, which are important variables for several of the postures. The joints that were unrelated to the thoracolumbar spine and primary analysis like the ankles, wrists and pelvis translation were among the joints locked. The locking of these joints reduced the numerical stability of the model during the SO calculations by ensuring that the model would converge and provide muscle force estimations. A detailed list of the locked joints and DOFs are included in **Table A.1 Appendix A**.

2.5 Muscle Actuators and Reserve Torque Implementation

During the initial testing it revealed that along with the DOF customization the default musculotendon configuration in the model was underactuated. Resulting in SO frequently failing to converge to any sort of result. To further stabilize the model to ensure that physiologically accurate results are being obtained, additional coordinate actuators were added to the model. These are commonly referred to as reserve actuators. These reserve actuators were created using the *createactuatorsfile.m* script provided by the OpenSim team [47] (**Appendix B.1)**. The actuators support the model by applying low magnitude torques along the underpowered DOFs in the model to support static equilibrium. Each actuator was appended to have an optimal force of 250 Nm, which was adjusted during testing to get a balance of accuracy and stability within the solver. These actuators were designed for both the male and female models. They were set to append the models force set in both the SO and JRA setup. These forces are appending the models force set not replacing the model's intrinsic muscle force set, meaning they are only used, as necessary. A full list of the actuators used in the model and their DOFs is in **Table A.1 Appendix A** along with the MATLAB script and male and female actuators files used in **Appendix B**. A record of observed SO issues and corrective actions can also be found in **Table C.1 Appendix C** for reference.

2.6 Motions and Postures

To evaluate spinal loading, five static postures were used to simulate positions that may mimic occupational postures commonly seen in surgical procedures. These included: 1️⃣Motion One- neutral standing, 2️⃣Motion Two- 30º axial twist with elbows flexed to 90º and 10 kg (22 lbs.) in each hand, 3️⃣Motion Three- 30º trunk flexion with arms down, 4️⃣Motion Four- 30º trunk flexion with arms extended forward and 5️⃣Motion Five- 90º elbow flexion with 1 kg (2.2 lbs.) in each hand. All these postures were implemented as static postures using the preprocessed motion (.mot) and external force (.mot) files derived from the thoracolumbar tutorial [29], [36].

Each model, male and female were evaluated for each motion and with each different simulated vest condition. These conditions were no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) were added at either the abdomen or sternum. This resulted in 70 unique simulations (2 models x 5 motions x 7 weight conditions). Images of each posture and motion setup are provided below in **Figure 2.6.1** and **2.6.2.**

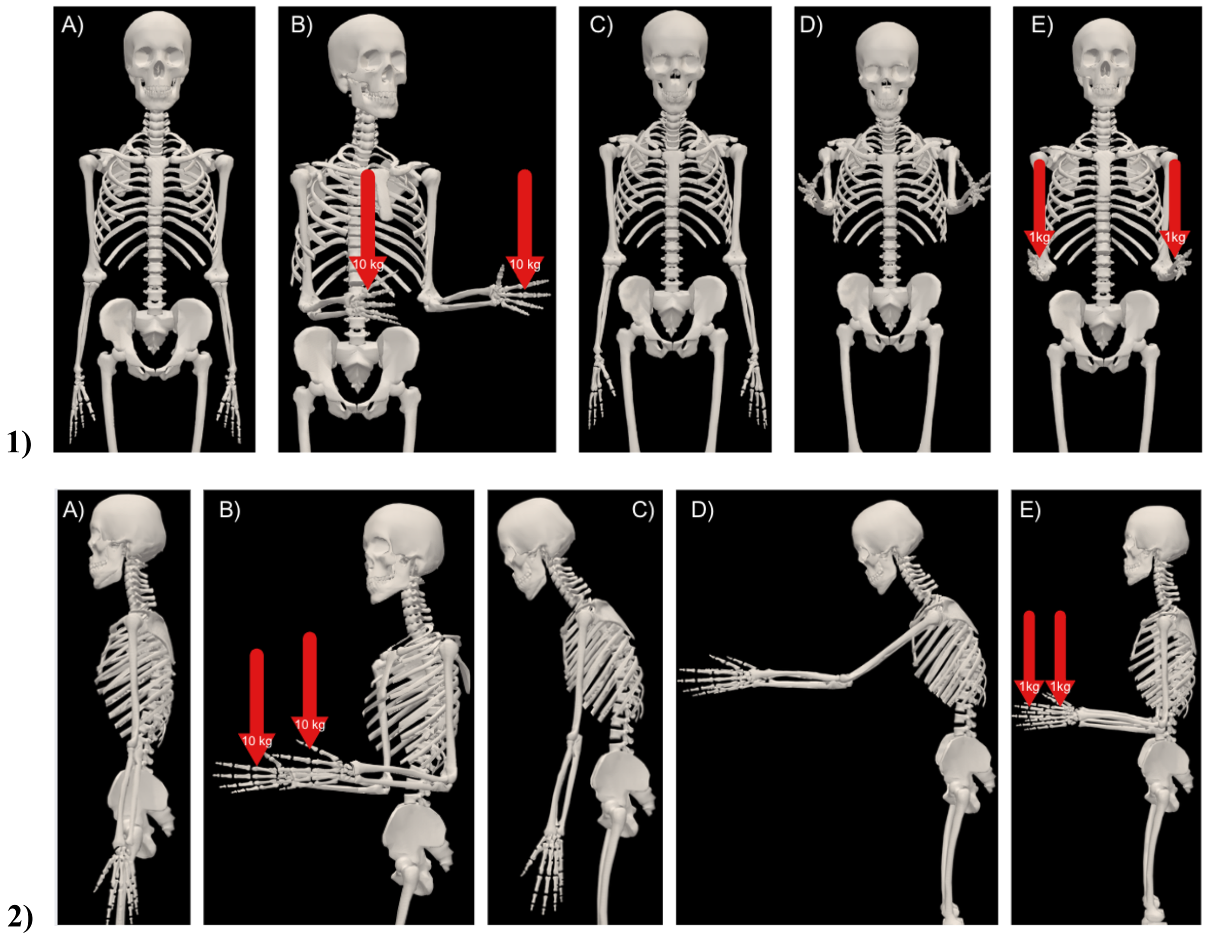

Figure 2.6. 1: Female Postures

The static postures applied to the female musculoskeletal model. Panel 1(top row) shows the postures from the frontal (anterior) view, while panel 2 (bottom row) displays the same postures from the left sagittal (lateral) view. Postures include: ***(A)*** 1️⃣*Motion One- Neutral standing,* ***(B)*** 2️⃣*Motion Two- 30° axial twist in the trunk, 90° elbow flexion with 10 kg (22 lbs.) in each hand,* ***(C)*** 3️⃣*Motion Three- 30° trunk flexion with arms down,* ***(D)*** 4️⃣*Motion Four- 30° trunk flexion with arms out,* ***(E)*** 5️⃣ *Motion Five- 90° elbow flexion with 1 kg (2.2 lbs.) in each hand. Red arrows represent the externally applied force on the hands. Images taken from the OpenSim visual window and figure made using Canva.com.*

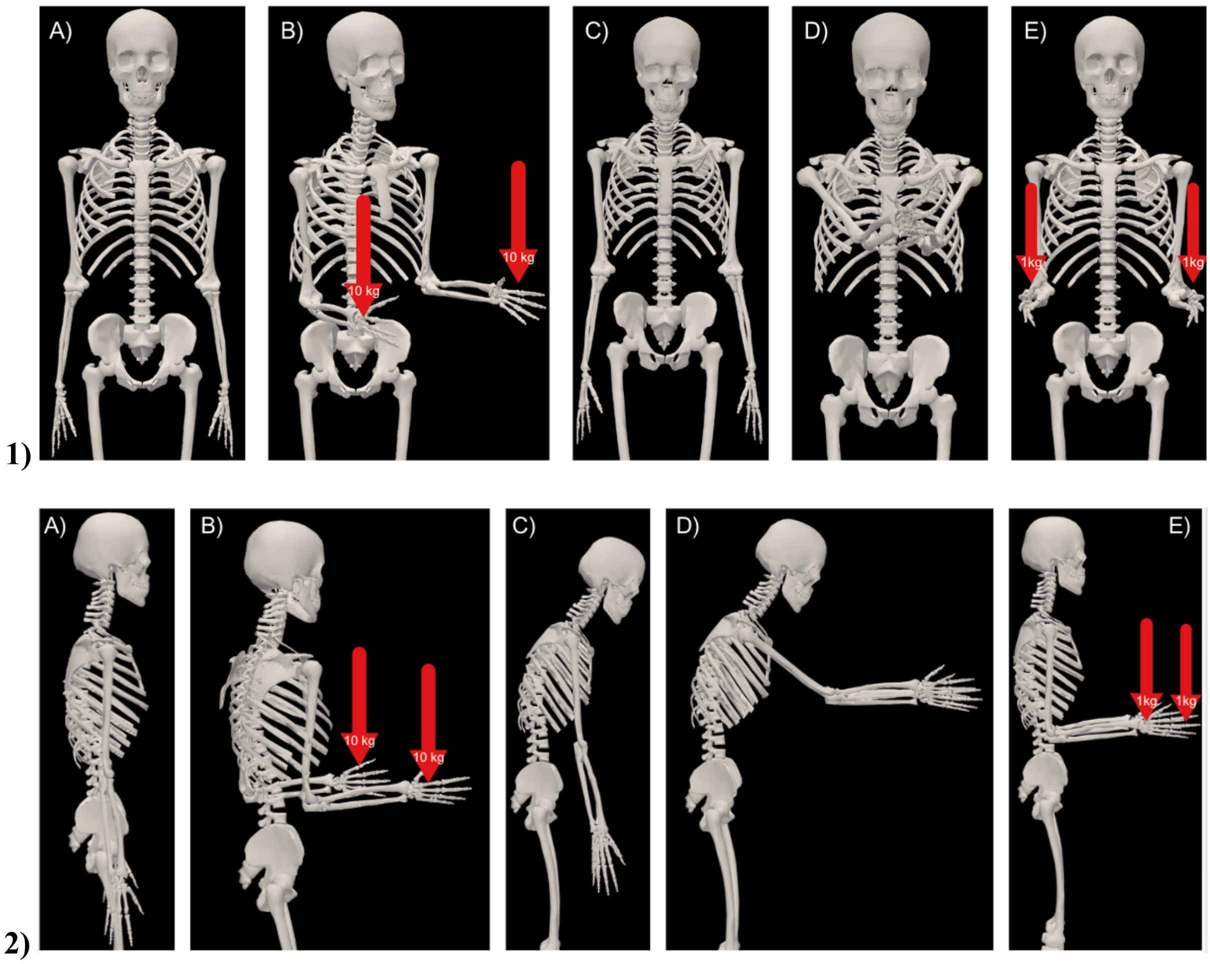

Figure 2.6. 2: Male Postures

The static postures applied to the male musculoskeletal model. Panel 1(top row) shows the postures from the frontal (anterior) view, while panel 2 (bottom row) displays the same postures from the right sagittal (lateral) view. Postures include: ***(A)*** 1️⃣ *Motion One- Neutral standing,* ***(B)*** 2️⃣*Motion Two- 30º axial twist in the trunk, 90º elbow flexion with 10 kg (22 lbs.) in each hand,* ***(C)*** 3️⃣*Motion Three- 30º trunk flexion with arms down,* ***(D)*** 4️⃣*Motion Four- 30º trunk flexion with arms out,* ***(E)*** 5️⃣*Motion Five- 90º elbow flexion with 1 kg (2.2 lbs.) in each hand. Red arrows represent the externally applied force on the hands Images taken from the OpenSim visual window and figures made using Canva.com.*

2.7 Vest Weight Simulation and Segment Mass Adjustments

Building on the defined postures, the model was further adapted to simulate the added weight conditions associated with wearing a surgical lead vest. The vests can range from 2.3- 6.8 kg (5 to 15 pounds), for this experiment 2.3 kg (5 lbs.), 4.5 kg (10 lbs.) and 6.8 kg (15 lbs.) added weights were applied [11], [48]. To simulate the mass of the lead apron in this study, weight was added to the sternum and abdomen body segments of the OpenSim model. The decision to model the weight in this way was due to anatomical and computational considerations. Based on validated biomechanical and anthropometric data, the center of mass (COM) of the human body during an upright posture is found at approximately 56-57% of the total body height, anterior to the second sacral vertebra. The torso segment of the body has a COM located near the sternum in the lower portion adjacent to the xiphoid process [49]. In the male and female musculoskeletal model, the abdomen and sternum were the only available anatomical regions sufficiently proximal to the physiological center of mass. The sternum aligns with the center of mass of the torso, and the abdomen is representative of a lower-load application site. Including the testing of both locations allowed for further evaluation into how the mass placement affects spinal loading. Additionally, this approach simplified the model's implementation for ease of use and to preserve fidelity. Quasi-static loading is when velocity and acceleration can be disregarded due to the time being small enough causing minimal inertial effects, which is what is seen in these simulations [50], [51]. The calculations in the simulations were done using static optimization (SO) and joint reaction analysis (JRA) which performs analysis frame by frame and assuming the body is in mechanical equilibrium. Due to these assumptions this validates the practice of adding weight to close to the center of mass instead of a true external force since during the quasi-static analysis inertial effects can be ignored.

Additionally, it was out of the scope of this research to use motion capture to collect data of participants wearing vests. The technique used in this study was able to produce reproduceable and valid means of simulating load conditions in lieu of that. The three different load conditions on the two different body masses were applied to both male and female models. This mass was added using the OpenSim GUI, under the navigator tab then opening the bodies section and locating either abdomen or sternum depending on the trial. Once you click on the body segment interested in and open the properties tab. Under the properties tab click on the mass and directly edit the mass there which is in kilograms. The original weights and the weights used with the added masses are outlined in **Table 2.7.1** below. Once the weight has been edited, save the model and ensure the change stays. Then proceed with setting up the analysis.

Table 2.7. 1: Adjusted body segment masses used in lead vest conditions

The sternum and the abdomen have the same starting mass for the male and female models. These masses were modified to simulate the distribution of the different vest weights, using the baseline body segment masses derived from the scaled OpenSim model.

Model	**Body Segment**	**Male Mass**	**Female Mass**
Original	Sternum/Abdomen	0.0001 kg (0.0002 lbs.)	0.000099 kg (0.0002 lbs.)
+2.3 kg (5 lbs.)	Sternum/Abdomen	2.27 kg (5 lbs.)	2.27 kg (5 lbs.)
+4.5 kg (10 lbs.)	Sternum/Abdomen	4.54 kg (10 lbs.)	4.54 (10 lbs.)
+6.8 kg (15 lbs.)	Sternum/Abdomen	6.80 kg (15lbs.)	6.80 kg (15 lbs.)

2.8 Analytical Techniques

There are four core stages in the analytical workflow used in this study: static optimization (SO), joint reaction analysis (JRA), MATLAB- based force extraction, and data analysis. The experimental design is outlined below in **Figure 2.8.1** showing all 70 trials. Each one of the 70 simulations was processed through the analytical techniques pipeline outlined in **Figure 2.8.2**.

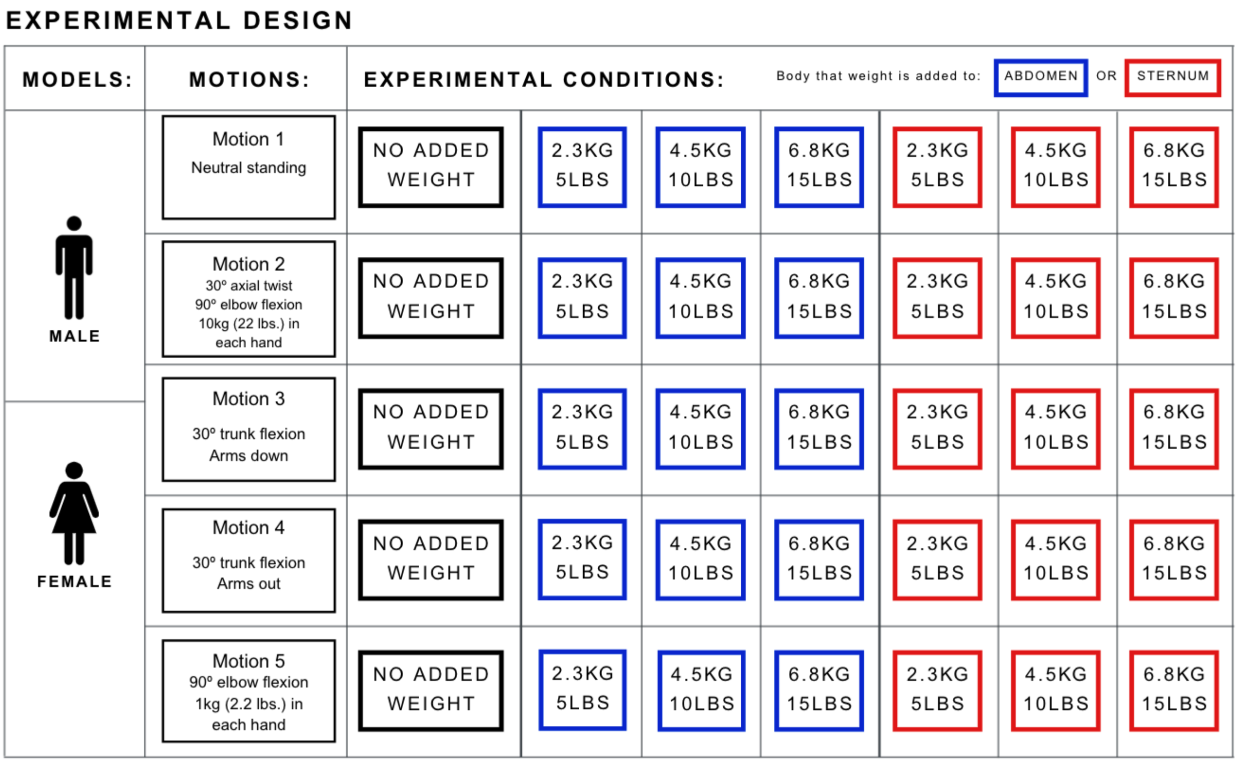

Figure 2.8. 1: Experimental Design Schematic Representation.

Two musculoskeletal models (male and female) were evaluated under five different postures (motions), each simulated with seven different vest loading conditions: no weight added and 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) added to either the abdomen (blue) or the sternum (red). Total simulations: 2 models x 5 motions x 7 conditions = 70 simulations. Figure created using Canva.com.

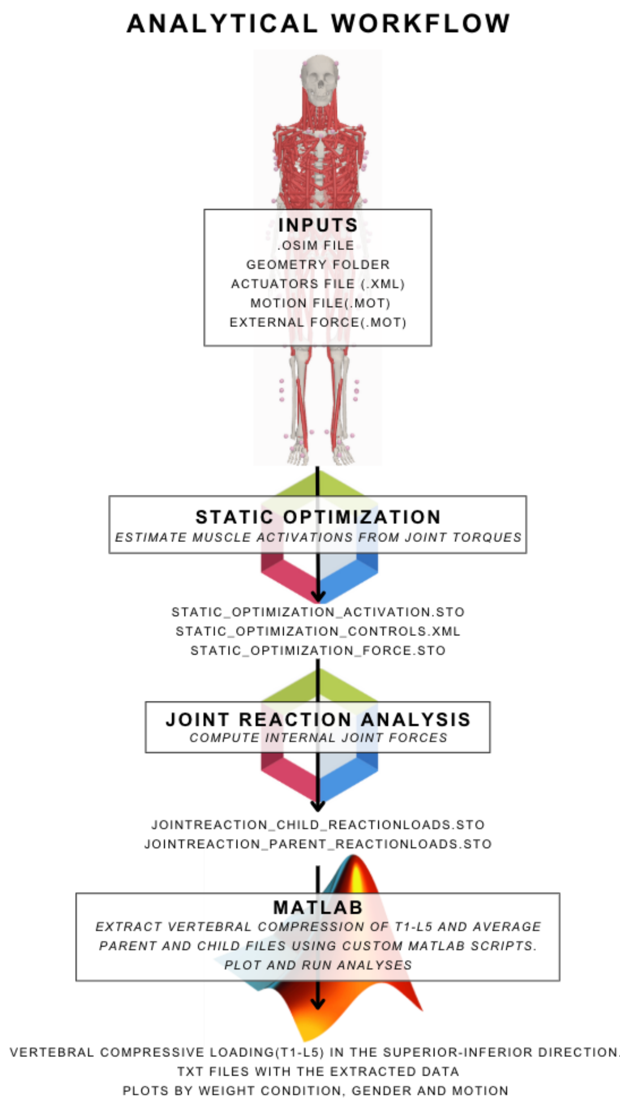

Figure 2.8. 2: Analytical Workflow Schematic

This is the pipeline that all 70 simulations conditions outlined in the experimental design will be ran through. Starting with the model and input files required to complete SO in the OpenSim analysis tool followed by the files that are produced by SO. The SO controls.xml and the force.sto are required in the setup for JRA. The JRA also requires the input files plus the two results from the SO which based on the settings input in the JRA they produce the child and parent reactionloads.sto files. These files are then processed in MATLAB to extract the superior-inferior compression in the joints from T1-L5, average the parent and child files. Compression (N) plotted along all of the spinal levels, and the numbers are printed in a text file. Once all data has been collected, plot by grouped by weight, by motion and by sex. Identify patterns and anything significant to further analyze. Figure created using Canva.com.

2.8.1 Static Optimization (SO)

Once the model has been optimized and requires motion files, external forces files and actuator files have been obtained. The next step is to perform static optimization (SO) calculations. SO was implemented using the OpenSim's Analyze tool framework. This tool solves the individual muscles forces at each interval defined. SO provides the physiological plausible muscle forces required for the body to perform a movement and provide joint stability. Static Optimization (SO) is a numerical method implemented in OpenSim to estimate muscle activation levels that satisfy net joint torques calculated from inverse dynamics, while minimizing a physiological cost function. In this study, SO was executed using the Analyze Tool in OpenSim v4.4, with specific inputs and the creation of a SOsetup.xml to use with all trials to ensure the analysis had the exact same specifications.

The cost function minimized the sum of muscle activations raised to the power of 3, which favors a more distributed muscle recruitment strategy making the calculations more accurate. This is consistent with the motor control hypothesis that muscles act synergistically to share load [52].

$J = \Sigma a_i^3$, where a_i represents the activation of muscle i.

Key optimizer settings included:

Activation exponent: 3

Maximum iterations: 100

Convergence tolerance: 0.0001

Assumptions of static mechanical equilibrium were enforced frame-by-frame. Each time step was treated independently, with net torques balanced by muscle and reserve actuator contributions. Reserve actuators were configured using the *createActuatorsFile.m* script to prevent instability.

Input files:

Scaled musculoskeletal model (.osim)

Joint kinematics (.mot)

External force data (.mot)

Actuators file(.xml)

Output files:

StaticOptimization_activation.sto: per-muscle activation levels

StaticOptimization_force.sto: estimated muscle and actuator forces

StaticOptimization_controls.xml: computed control signals

These outputs served as required inputs for the subsequent Joint Reaction Analysis (JRA) step. The complete *SO_Setup.xml* file, example external loads file(.xml), example .mot files used to configure this are found in **Appendix B.4-7** for reference and reproducibility.

2.8.2 Joint Reaction Analysis (JRA)

Joint Reaction Analysis (JRA) is a post-processing tool in the OpenSim Analyze tool used to compute the net forces and moments transmitted across joints due to muscle, passive, and external loads [28]. In this study, JRA was conducted on the outputs of Static Optimization to determine reaction loads acting on the thoracolumbar spine (T1–L5) in both male and female models to determine the compressive and shear forces.

The analysis was configured via a custom *JRA_Setup.xml* file, specifying reaction forces to be calculated at each intervertebral joint only in the thoracolumbar spine to narrow the output to only the variables interested in to simplify the data analysis **Appendix B.8**. The result file staticOptimizaton_controls.xml for each specific trial was specified in the JRA setup. Additionally, the full path to the *staticoptimization_force.sto* for each respective trial was explicitly defined in the settings to ensure that the JRA calculations were based on the muscle and actuator forces that were estimated during SO. The same actuator and external loads used in the SO set up need to be used in the JRA setup as well. The Reaction loads were reported in the frame of reference for the child and parent, not the ground. The parent reaction forces were expressed in the parent body reference frame, and the child reaction forces were expressed in the child body reference frame. This configuration was chosen to maintain the biomechanical fidelity of the joint-level force contributions that originate from each body segment connected by the joint. This further allowed for anatomically consistent interpretation of the directionality and magnitude of the forces at each of the vertebral levels along the thoracolumbar spine.

Each trial produced two primary output files:

jointReaction_child_reactionLoads.sto

jointReaction_parent_reactionLoads.sto

These files contained directional forces (fx, fy, fz) and moments (mx, my, mz) for each vertebral joint at each time frame. Each data column in the output (.sto) file follows a naming convention that encodes all the joint, segment and the reference frame. For example, of the column titles from a parent joint reaction loads file is *L4_L5_IVDjnt_on_lumbar5_in_lumbar5_fy*. The fy at the end means it is the superior- inferior force that is exerted by the L4/L5 intervertebral disc joint on the L5 vertebra, expressed in the L5's local coordinate frame. This represents the force contribution from the disc acting on the L5 body. The naming follows the general convention of *<joint>_on_<body>_in_<frame>_<component>,* allowing for the precise identification of the direction, anatomical segment, and coordinate system. Understanding the naming is critical for correctly understanding and matching the child and parent files across the entire thoracolumbar spine. For static postures, these values reflect frame-by-frame mechanical equilibrium in response to both muscle and modeled vest mass.

The full JRA setup configuration used in this study is provided in **Appendix B.8**, and for example *jointReaction_child_reactionLoads.sto* and *jointReaction_parent_reactionLoads.sto* files are in **Appendix B.9** for reproducibility and reference.

2.8.3 MATLAB Post-Processing

The parent and child .sto files from the JRA were imported into MATLAB R2024a for detailed post-processing using a custom script that merged, calculated, and plotted all joint loading data in a unified format per trial. For each simulation condition, the corresponding child and parent .sto files were loaded. The forces were extracted at each thoracolumbar vertebral level (T1–L5) using the force components from both the child and parent files as reported in their respective local coordinate systems. Since these files include more the just the forces, only values labeled with _F at the end were extracted. The naming convention discussed in the previous section for each directional component (fx, fy, fz) was matched across both the child and parent (.sto files). The vertebral column and time frame were used to ensure that the averaging was correct and had directional consistency.

These forces were extracted and analyzed for three orthogonal directions:

- Superior-Inferior (SI), represented by the fy component which is vertical compression. This is defined as the force acting along the spine's longitudinal axis (from superior to inferior)
- Anterior-Posterior (AP), represented by fx, is the shear force acting along the body in the sagittal plane. This corresponds to the forward-backward load displacement across the discs and facet joints.

- Medial-Lateral (ML), represented by fz is the shear force acting along the frontal plane. This represents the left-right load transmission that can affect spinal balance and the bending mechanics in lateral movements.

At each frame, the child and parent force values were averaged to compute net joint forces: Where t is the time frame or simulation step. $F_{avg}(t)$ gives the average of the child and parent forces at an instant t, shown in **Equation 1**.

$$\boldsymbol{Equation\ 1}: \ F_{avg}(t) = \frac{(F_{child}(t) + F_{parent}(t))}{2}$$

This averaging approach is reflective of the mechanical equilibrium experienced between the adjacent vertebrae along the spinal column that are connected by an intervertebral joint. At this joint, the forces are represented by two force values calculated from the JRA in separate files. One is acting on the child's body and one acting on the parent body, each in the respective local reference frame. By averaging these two numbers along each spinal level, the model is able to approximate the net force that is transmitted across the intervertebral disc [30]. This value is interpreted as the effective load that is experienced at the specific joint interface. It is a close approximation of the compressive or shear force experienced on the intervertebral disc and not solely the forces on the cortical vertebral bone alone [53]. Once the directional force components are sorted into the respective categories, fx for AP shear, fy for SI compression, and fz for ML shear. The averaging calculations of the parent and child files were performed independently for each of those directional components to produce three distinct data sets for each trial. These forces were plotted along the spinal column (L5-T1) to identify where peak forces occurred and visualize the distribution of the loading magnitudes across all spinal levels. These values were also produced in three separate excel data sheets known as the per trial data, for further analysis.

These average directional components were then used to calculate the total resultant joint force using **Equation 2:**

$$\boldsymbol{Equation\ 2}: F_{resultant} = \sqrt{f_x^2 + f_y^2 + f_z^2}$$

The resultant force ($F_{resultant}$) represents the magnitude of the total joint reaction force acting on the vertebral level by combining the three orthogonal force components, fx (AP shear), fy (SI compression) and fz (ML shear). This scalar value provides an integrated measure of the overall mechanical load on a joint. It is useful to assess the cumulative effects of the shear and compression simultaneously. This calculation was performed for each trial and the values were reported in a csv.

Next, all forces were normalized to body weight (%BW) using the following formula for the respective model's **Equation 3 and 4:**

$$\boldsymbol{Equation\ 3}:\ Male\ \%BW = \frac{F_{reaction}}{(78\ kg * 9.81\frac{m}{s^2})}$$

$$\boldsymbol{Equation\ 4}: Female\ \%BW = \frac{F_{reaction}}{(61\ kg * 9.81\frac{m}{s^2})}$$

$F_{reaction}$ is the magnitude of the joint reaction force at a specific vertebral level. For example, if calculating the %BW at L5-S1 for the compressive force, the average value for that joint would be used. The male and female models have separate equations due to the different weights of the models. This calculation normalizes the forces to the body weight and contextualizes the force magnitudes relative to the model's body weight. This allows for comparison across conditions, sexes, and postures on a physiologically interpretable scale. This calculation was applied to the compressive, AP shear, ML shear and the Resultant forces. The data was exported in a csv.

In addition to the %BW, the percent change in the force was calculated relative to the no-vest weight condition for the specified trial. The no weight condition for each motion is known as the baseline force. The percent change was calculated using **Equation 5:**

$$\boldsymbol{Equation\ 5}: \%change = \frac{(F_{weighted} - F_{baseline})}{F_{baseline}} * 100\%$$

$F_{weighted}$ is the force value at a given vertebral level for a specific weight and motion condition. $F_{baseline}$ is the corresponding force for the given motion with no weight at the specific vertebral level condition.

These calculations were implemented in the MATLAB script and performed independently for four of the different force files (Compression, AP, ML and Resultant). The MATLAB script exported individually to a new folder for the specified condition with .csv files for each trial, based on the calculations performed and opened a MATLAB plot. Each figure displayed all three force types (compression, AP, ML) with legends, annotations of peak values, and consistent color coding for trial comparison. A full version of the MATLAB script, example code to call the function, and a screenshot of what the output folder produces are found in **Appendix B.10.**

2.8.4 Statistical Summary and Interpretation

Due to the deterministic and frame-by-frame nature of Static Optimization and JRA in OpenSim, each trial represented a unique biomechanical condition rather than a repeated measure. As such, traditional inferential statistical tests were not applied due to the lack of repeated or independent subject data, consistent with previous simulation-based musculoskeletal modeling [54]. Instead, descriptive statistics and normalized comparative metrics were used to summarize and interpret outcomes.

For each force metric (compressive, AP shear, ML shear, and resultant), mean values were computed per vertebral level (T1–L5) and grouped by sex, motion, and vest condition. These were expressed in both absolute terms (Newtons) and relative terms (percent body weight, %BW). Percent changes in loading were calculated for each condition relative to its corresponding no-vest baseline using **Equation 5.** This metric was used to highlight how different vest loads and placements altered spinal loading patterns. Although inferential tests were considered, they were not performed due to the lack of repeated or independent subject data. Instead, high and low loading conditions were visually compared using group plots to identify consistent trends across spinal levels.

2.8.5 Model Verification and Validation

For numerical validation, all simulations were reviewed for convergence. Solver logs were examined to ensure successful optimization within predefined iteration limits. Trials with excessive actuator reliance were corrected by adjusting actuator strength and joint constraints. This was done by monitoring the messages produced in the command window in the OpenSim GUI. The data was visually validated to ensure that trends and patterns are shown consistently. This helped identify if one trial had been implemented with something missing. Further, the data was compared to published values for each of the forces. Baseline compressive forces (neutral standing) aligned with expected physiological ranges (400–1200 N), consistent with literature supporting model validity [53]. The segmental trends in load distribution across T1–L5 and across postures were biomechanically plausible. The resultant forces were also used to validate the results. These forces integrate shear and compression, serving as a composite metric. Their consistency across weight increments and posture shifts further supported the internal validity of the simulation framework.

Chapter 3: Results

3.1 Overview of Simulation Outcomes

A total of seventy static simulations were conducted in OpenSim 4.4 to quantify thoracolumbar spine loading under a range of postural and loading conditions. These included five representative static postures (Motions 1–5) and seven vest loading conditions: baseline (no vest), and vest weights of 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs.) applied either to the sternum or the abdomen. Simulations were performed independently for both a male (61 kg, 170 cm) and female (61 kg, 160 cm) musculoskeletal model [30].

Joint reaction forces were computed at each vertebral level (L5–T1) using a validated static optimization (SO) and joint reaction analysis (JRA) workflow. MATLAB was used to automate batch processing, extract relevant loading metrics, and generate plots. Forces were reported in three orthogonal directions: compressive (superior-inferior), anterior-posterior (AP) shear, and medial-lateral (ML) shear. From these data, additional metrics such as average force, percent change relative to baseline, and percent body weight (%BW) were derived. Due to the deterministic nature of the simulations, statistical testing was not applied; instead, comparisons were made descriptively using absolute values, percent change, and relative differences across models and conditions.

Each trial is organized by sex, posture, vest weight, and placement. Results in the following sections are structured accordingly: baseline (no vest) outcomes are presented first, followed by the effects of vest weight and placement, and finally posture-specific and sex-based comparisons. An overview of the experimental design and analysis pipeline are provided in the methods section **Figures 2.8.1 and 2.8.2,** for reference on the foundation of the detailed results that are presented.

3.2 Baseline Thoracolumbar Loading without Lead Vest

To evaluate the effect of lead apron weight and load placement on thoracolumbar spinal loading, seven vest conditions were simulated for both male and female models across five static postures. These included a baseline (no weight) trial, and three vest weights 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) applied at either the sternum or the abdomen. Masses were assigned to the corresponding torso segments in OpenSim to simulate these conditions, as described in **Table 2.7.1.** Joint reaction forces were computed using static optimization followed by joint reaction analysis. In both models, the L5-S1 vertebral level consistently experienced the highest compressive loads across all motions. For the male model, compressive loading peaked at 1400.7 N during 2️⃣Motion Two (axial trunk twist, with hand weights), followed by 1038.9 N in 4️⃣Motion Four (trunk flexion with forward reach). The lowest loads were recorded in the neutral standing posture (1️⃣Motion One), with an L5-S1 load of 623.4 N. These values represent 81.5% to 137.8% of body weight across postures **Figure 3.2.1** displays the baseline compressive force distribution for the male model across all five motions. See **Table F.1 and F.2 in Appendix F** for the table of %BW.

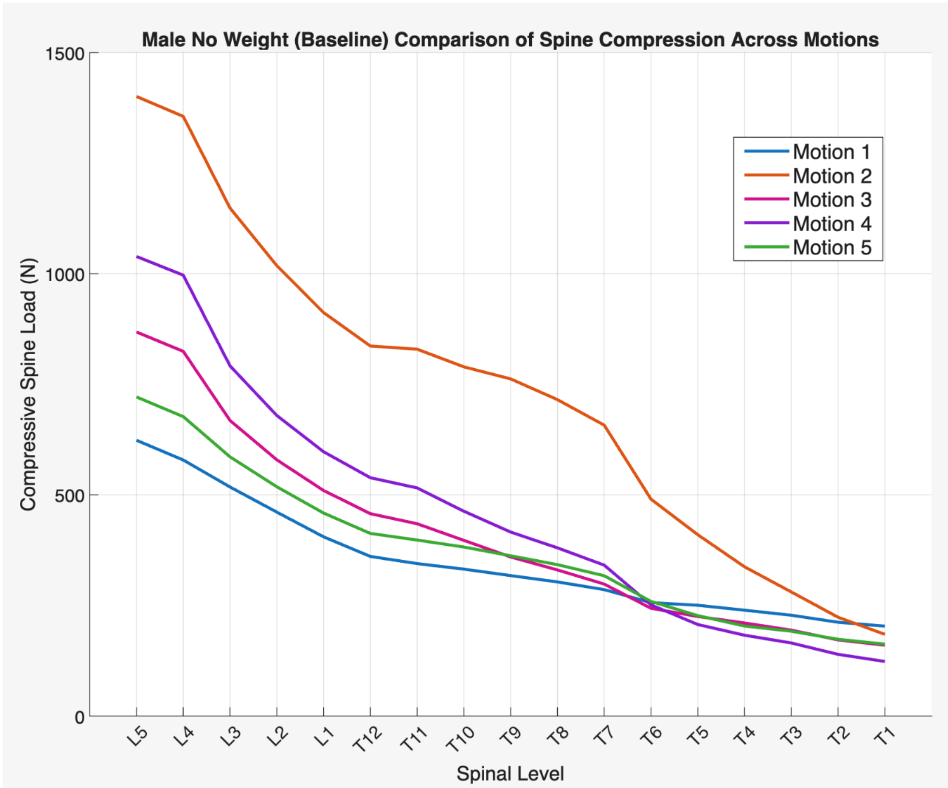

Figure 3.2.1: Male Baseline thoracolumbar spine Compressive forces

Compressive joint reaction forces (superior-inferior direction) at spinal levels L5-T1, 1️⃣Motion One- neutral standing, 2️⃣Motion Two- 30º axial trunk twist with elbows at 90º and 10 kg (22 lbs.) in each hand, 3️⃣Motion Three- 30º trunk flexion with arms in neutral position, 4️⃣ Motion Four- 30º trunk flexion with arms extended, 5️⃣Motion Five- neutral spine with elbows 90º flexion and 1kg (2.2 lbs.) in each hand. The highest compressive forces occurred in 2️⃣Motion Two, with peak forces seen on the lower lumbar. Created in MATLAB.

The female model followed a similar pattern, though with lower absolute loads due to reduced body mass. The highest compressive force at L5-S1 was observed during 2️⃣Motion Two (1059.3 N), and the lowest during 1️⃣Motion One (501.5 N). Compressive loads for the female model ranged from 69.6% to 123.3% of body weight. **Figure 3.2.2** presents the female model's baseline compressive loading profiles for each motion.

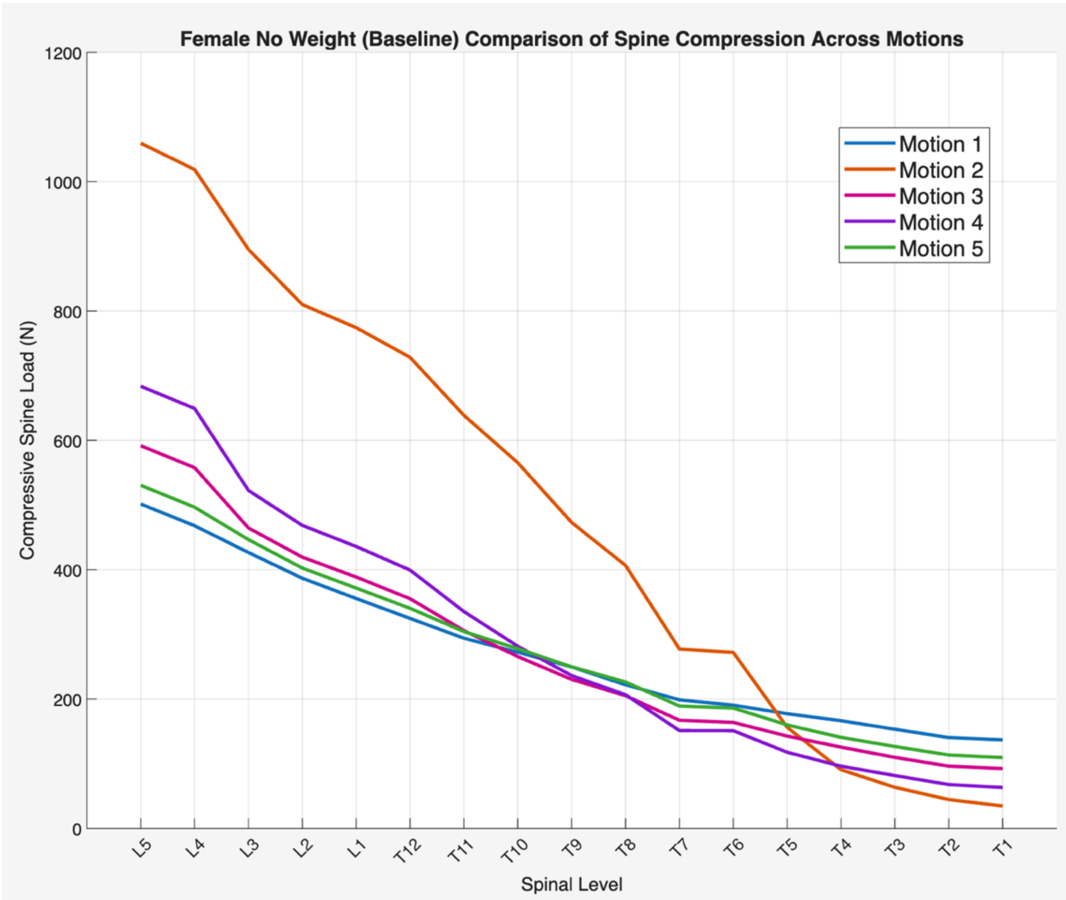

Figure 3.2.2: Female Baseline Thoracolumbar Spine Compressive Forces

Compressive thoracolumbar spine loads for the female model without any added weight across all five motions. Compressive forces across all the vertebral levels from L5-T1 in the superior-inferior direction. The highest compressive forces are seen along the lumbar spine with the highest force coming from 2️⃣Motion Two.

Across both models, compressive loading increased with the vest weight. The largest percentage increases were observed with the 6.8 kg (15 lbs.) vest applied to the sternum. In contrast, forces under abdominal loading remained closer to baseline, shown by the small percentage change values. Average percent changes in compressive force for the male model are summarized in **Table 3.2.1**, while those for the female model are shown in **Table 3.2.2.**

Table 3.2.1: Male Compressive Force Percentage Change Summary

Average percent change in compressive spinal loading across all thoracolumbar levels for the male model under the five motions with different weight conditions. Each row represents a different loading condition; 5lb 10lb and 15lb simulated vest weights at either the sternum or abdomen. The table shows the average percent change in compressive joint reaction forces in the superior-inferior direction, relative to the no weight condition for each motion. Increases in weight about the sternum generally corresponded to greater compressive forces and percent change across all motions. The full table of percentage changes and raw data in the compressive force are in ***Table D.2.1*** *and* ***Table D1.1, Appendix D.***

Male Compressive Force (N) Percent Change across all 5 trials					
	Average % Change across all spinal levels				
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	0.003	0.000	0.000	0.000	0.002
5lb Sternum	6.124	4.731	8.014	8.221	6.815
10lb Abdomen	0.015	0.000	0.000	0.024	0.012
10lb Sternum	12.466	9.473	16.193	16.482	13.720
15lb Abdomen	0.039	0.001	0.001	0.023	0.029
15lb Sternum	19.003	14.213	24.480	24.786	21.011

Table 3.2. 2: Female Compression Force Percentage Change Summary

Female average percent change in compressive spinal loading across all thoracolumbar levels under five simulated motions with added vest weights. *This table presents the average percent change in superior-inferior compressive joint reaction forces relative to the no-weight condition across spinal levels L5-T1 for five motion conditions (Motion 1, 2, 3, 4, and 5). Each row corresponds to different weight conditions for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) applied either at the abdomen or sternum. Positive values indicate increased compressive force compared to baseline, while negative values represent a reduction in compressive loading. Larger percent increases are observed with greater vest weights, particularly when applied at the sternum. The full table of percentage changes and raw data in the compressive force is in* ***Table E.2.1*** *and* ***Table E.1.1, Appendix E.***

Female Compression (N) Percent Change across all 5 trials					
Average % Change across all spinal levels					
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	0.068	-0.001	0.004	0.000	0.004
5lb Sternum	6.871	9.842	8.752	10.468	8.323
10lb Abdomen	0.081	0.000	0.017	0.002	0.020
10lb Sternum	12.702	19.703	18.105	20.938	16.755
15lb Abdomen	0.141	0.000	0.045	0.007	0.054
15lb Sternum	19.729	29.584	27.636	31.560	25.403

Anterior-posterior (AP) shear forces also increased with vest weight, particularly when applied to the sternum. Percent changes in AP shear for the male and female models are presented in **Table 3.2.3** and **Table 3.2.4**, respectively. In several trials, negative percentage changes were observed, indicating a reversal in shear direction compared to the baseline condition.

Table 3.2. 3: Male AP Shear Force Percentage Change Summary

Average percent change in the shear forces for the anterior-posterior (AP) direction across all thoracolumbar levels for the male model under the five different motions and six different load conditions. Each row represents a different load condition compared to the no weight trial for each respective motion. Positive percentage changes increase in AP shear loading compared to the no weight trial while negative values indicate a decrease in AP shear. The percentage changes reflect that the vest weight modeled at the sternum shows a higher change in force seen along the thoracolumbar spine compared to no weight. The full table of percentage changes and raw data in the AP Shear are in ***Table D.2.2*** *and* ***Table D.1.2 Appendix D.***

Male AP Shear (N) Percent Change across all 5 trials					
	Average % Change across all spinal levels				
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	-0.011	0.012	0.039	0.035	0.002
5lb Sternum	8.825	3.632	-0.609	3.062	-4.449
10lb Abdomen	-0.054	0.028	0.188	-0.023	0.005
10lb Sternum	20.151	7.153	-2.503	5.953	-9.389
15lb Abdomen	-0.127	0.060	0.498	0.135	0.008
15lb Sternum	33.438	10.864	-3.988	8.239	-15.106

Table 3.2. 4: Female AP Shear Force Percentage Change Summary

Female average percent change in anterior-posterior (AP) shear forces across all thoracolumbar levels under five simulated motions with added vest weights. This table shows the average percent change in AP shear joint reaction forces relative to the no-weight condition across spinal levels L5-T1 for five motions (Motion 1, 2, 3, 4, and 5). Each row corresponds to different weight conditions for 2.3 kg, 4.5 kg, 6.8 kg (5 lbs., 10 lbs., and 15 lbs.) applied either at the abdomen or sternum. The positive percentage change values indicate an increase in AP shear loading compared to the no-weight baseline, while negative values indicate a reduction in shear. Large negative values may reflect a reversal in shear direction, depending on the baseline force orientation. Full table of percent changes and raw data in the AP Shear are in ***Table E.1.2*** *and* ***Table E.2.2, Appendix E.***

Female AP Shear (N) Percent Change across all 5 trials					
Average % Change across all spinal levels					
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	0.017	-0.002	0.002	0.023	-0.004
5lb Sternum	-112.100	1.294	-14.940	-7.243	-20.767
10lb Abdomen	0.022	-0.001	0.008	0.019	-0.006
10lb Sternum	-191.570	0.959	-69.232	-14.617	-27.128
15lb Abdomen	0.057	0.000	0.019	-0.003	-0.009
15lb Sternum	-252.383	1.717	-128.903	-20.559	-40.920

Medial-Lateral (ML) shear forces are summarized in **Table 3.2.5** and **Table 3.2.6,** both the male and female models exhibited an increase in ML shear loading when the weight was added at the sternum. The largest percentage changes were seen in 3️⃣Motion Three and 4️⃣Motion Four, which involve a flexed or forward reaching movement, specifically during the 6.8 kg (15 lbs.) sternum condition. The abdomen placement had minimal influence on ML shear and was again similar or less than baseline. This is simulating a load and location dependent response to simulated vest weights.

Table 3.2. 5: Male ML Shear Percentage Change Summary

Average percent change in medial lateral (ML) shear force for the entire thoracolumbar spine for the male model during the five motions. The values represent the average percent change in ML shear joint reaction forces relative to the no weight condition for each respective motion. Each row corresponds to a different loading condition 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) at either the sternum or abdomen. Positive values indicate an increase in ML shear loading compared to the no weight trial, while negative values indicate a reduction. ML shear forces increased with higher vest weights positioned at the sternum. The full table of percentage changes and raw data in the ML force is in ***Table D.2.3*** *and* ***Table D.1.3, Appendix D.***

Male ML Shear (N) Percent Change across all 5 trials					
	Average % Change across all spinal levels				
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	-0.006	0.003	0.005	0.005	-0.010
5lb Sternum	7.902	3.824	10.000	9.496	7.305
10lb Abdomen	-0.032	0.006	0.026	0.044	-0.049
10lb Sternum	15.738	7.644	20.026	18.986	14.718
15lb Abdomen	-0.081	0.014	0.068	0.067	-0.119
15lb Sternum	23.569	11.482	30.321	28.465	22.820

Table 3.2. 6: Female ML Shear Percentage Change Summary

Average percent change in medial-lateral (ML) shear forces across all vertebral levels (L5 to T1) for the female model under five simulated motions with added vest weights. This table reports the average percent change in ML shear joint reaction forces relative to the no-weight condition for each of the respective five motions. Each row corresponds to a simulated vest weight condition (2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.)) applied at either the abdomen or sternum. Positive percent changes indicate increased ML shear loading compared to the no-weight baseline, while negative values represent a reduction. The full table of percentage changes and raw data in the compressive force is in ***Table E.2.3*** *and* ***Table E.1.3, Appendix E.***

Female ML Shear (N) Percent Change across all 5 trials					
Average % Change across all spinal levels					
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	0.067	0.004	0.001	-0.001	0.005
5lb Sternum	9.369	6.059	11.307	12.046	9.739
10lb Abdomen	0.079	0.003	0.012	-0.002	0.016
10lb Sternum	18.088	12.137	23.173	24.047	19.214
15lb Abdomen	0.136	0.000	0.037	-0.003	0.046
15lb Sternum	28.070	18.210	35.478	36.183	28.958

Resultant joint reaction forces at L5-S1 followed a similar increasing trend with vest weight. These values were consistently lower in the female model. Average percent changes in resultant forces for the male model are presented in **Table 3.2.7**, and those for the female model are shown in **Table 3.2.8**.

Table 3.2. 7: Male Resultant Force Percentage Change Summary

Spinal loading across all vertebral levels (L5 to T1) for the male model under five simulated motions with added vest weights. This table reports the average percent change in resultant joint reaction force magnitude, relative to the no-weight condition for each respective motion. Each row corresponds to a simulated vest weight condition (2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.)) applied either at the abdomen or sternum. Resultant force represents the vector sum of the compressive, anterior-posterior (AP), and mediolateral (ML) shear force components. Positive values indicate an increase in total spinal loading compared to the no-weight condition. Full table of percent changes and raw data in the AP Shear are in ***Table D.1.4*** *and* ***Table D.2.4, Appendix D.***

Male Resultant Force (N) Percent Change across all 5 trials					
	Average % Change across all spinal levels				
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	0.003	0.000	0.000	0.000	0.002
5lb Sternum	6.322	4.357	8.468	8.488	6.931
10lb Abdomen	0.014	0.001	0.002	0.020	0.010
10lb Sternum	12.844	8.728	17.074	17.011	13.945
15lb Abdomen	0.036	0.002	0.005	0.020	0.025
15lb Sternum	19.562	13.105	25.827	25.561	21.350

Table 3.2. 8*: Female Resultant Force Percentage Change Summary*

*Spinal loading across all vertebral levels (L5 to T1) for the female model under five simulated motions with added vest weights. This table reports the average percent change in resultant joint reaction force magnitude, relative to the no-weight condition for each respective motion. Each row corresponds to a simulated vest weight condition (*2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.)) *applied either at the abdomen or sternum. Resultant force represents the vector sum of the compressive, anterior-posterior (AP), and mediolateral (ML) shear force components. Positive values indicate an increase in total spinal loading compared to the no-weight condition.* Full table of percent changes and raw data in the AP Shear are in **Table E.1.4** and **Table E.2.4, Appendix E.**

Female Resultant Force Percent Change across all 5 trials					
Average % Change across all spinal levels					
Trial	**Motion 1**	**Motion 2**	**Motion 3**	**Motion 4**	**Motion 5**
5lb Abdomen	0.067	-0.001	0.004	0.000	0.004
5lb Sternum	7.033	7.976	9.474	11.081	8.388
10lb Abdomen	0.079	0.000	0.018	0.003	0.020
10lb Sternum	13.037	16.051	19.587	22.164	16.883
15lb Abdomen	0.138	0.000	0.047	0.008	0.052
15lb Sternum	20.237	24.182	29.991	33.410	25.622

To further evaluate placement-specific differences, the percent difference in compressive force between sternum and abdomen conditions was calculated at each vest weight across motions. In most conditions, compressive forces were higher under sternum-applied weight, particularly at the L5-S1 and L4-L5 joints. These comparisons are visualized in **Appendix F Figures F.1 and F.2** and supporting numerical data are available in **Appendix D.1.1 and E.1.1.**

Spinal loading varied across the five simulated surgical postures in both musculoskeletal models. In all trials, the L5-S1 vertebral level consistently experienced the highest compressive forces. In the male model**,** the baseline trial (no weight) produced a compressive force of 623.4 N at L5-S1 during 1️⃣Motion One (neutral standing). The highest compressive force was observed during 2️⃣Motion Two (30° axial rotation with hand weights) under the 6.8 kg (15 lbs.) sternum condition, reaching 1523.1 N. During 1️⃣Motion One, the same loading condition resulted in 716.6 N at L5-S1, corresponding to 93.6% of body weight, compared to 81.5% in the no-weight trial. Across all five motions, the average L5-S1 compressive force under the 6.8 kg (15 lbs.). sternum condition was 1067.8 N. In contrast, the 6.8 kg (15 lbs.) abdomen condition during 1️⃣Motion One produced a compressive force of 623.7 N, representing only a 0.04% increase from baseline. Percent change values for compressive and shear forces across motions are provided in **Appendix D.**

In the female model, similar trends were observed. The baseline 1️⃣Motion One trial yielded a compressive force of 501.5 N at L5-S1, while the 6.8 kg (15 lbs.) sternum load during 2️⃣Motion Two produced the peak force of 1435.7 N. 1️⃣Motion One with the 6.8 kg (15 lbs.) sternum load reached 562.1 N. Compressive forces remained close to baseline under abdomen-applied loads. Across all motions and loading conditions, the greatest increases in compressive force occurred during 2️⃣Motion Two and 4️⃣Motion Four. Summary percent change data for the female model are presented in **Appendix E.**

Motions involving forward reach or axial rotation (Motions 2️⃣Two and 4️⃣Four) consistently produced the highest loading across compressive, anterior-posterior (AP) shear, and mediolateral (ML) shear directions. More neutral postures (Motions 1️⃣One and 5️⃣Five) resulted in lower overall forces. The shear loading was generally elevated when the weight was applied at the sternum. Whereas the weight at the abdomen resulted in smaller deviations from the baseline. Full distributions of spinal joint reaction forces and percentage changes across postures and load conditions are visualized in **Appendices D and E.**

3.3 Posture Specific Forces

Spinal joint loading varied across the five postural simulations. Motions involving trunk rotation or forward reach produced the highest loading values across compressive, AP shear, and ML shear directions.

In the male model, 2️⃣Motion Two (30° axial twist, 90º elbow flexion with 10 kg (22 lbs.) hand weights) resulted in the highest spinal loading across all components. Under the 6.8 kg (15 lbs.) sternum condition, compressive force at L5-S1 reached 1523.1 N, and ML shear at L2-L3 peaked at 286.6 N, as shown in **Figure 3.3.7**. The AP shear plot revealed a peak of 92.1 N at T1–T2, where the diamond and star markers consistently identified the highest forces. Line spacing in all three plots clearly distinguished the seven weight conditions, with sternum-applied weights forming the upper boundary of each trendline. The abdomen-applied weights, by contrast, remained tightly clustered and exhibited lower slopes, particularly in compressive and ML force plots.

4️⃣Motion Four (forward flexion with arm extension) followed in magnitude, producing 1225.1 N compressive force and 236.4 N ML shear at L5-S1 (**Figure 3.3.9**). AP shear once again peaked at T1–T2. The compressive and ML shear plots for this motion showed noticeable separation between weight conditions, with sternum placement resulting in a steeper decline superiorly. The upper thoracic region showed convergence among all weight lines, particularly in the AP shear plot.

In 3️⃣Motion Three (trunk flexion, arms down), shown in **Figure 3.3.8**, spinal forces were moderate. Peak compressive force reached 1048.1 N in the male model at L5-S1. ML shares also peaked at L5-S1, while AP shear followed a familiar trend with a peak at T1–T2. Compared to other postures, the abdomen-applied conditions exhibited minimal deviation from the baseline. Line curvature was more pronounced in sternum-applied conditions, reflecting greater variability in force distribution along the spine.

5️⃣Motion Five, which maintained a neutral spine and featured light hand loads, induced the lowest overall forces aside from 1️⃣Motion One. Peak compressive force reached 826.2 N at L5-S1 in the male model, with ML shear peaking at 153.1 N. Despite the low-demand posture, AP shear remained elevated in the upper thoracic region, again converging near T1–T2 across all load conditions (**Figure 3.3.10**).

1️⃣Motion One (neutral standing), shown in **Figure 3.3.6**, consistently produced the lowest forces across all joints. Peak compressive force at L5-S1 was 623.4 N in the male model baseline, rising to 716.6 N with the 6.8 kg (15 lbs.) sternum load. ML shear remained below 150 N, and AP shear peaked under 35 N at T1–T2. Line trends were nearly flat, with only the sternum-applied 6.8 kg (15 lbs.) load diverging upward at the lower spine.

The female model showed the same postural force pattern, with lower magnitudes. 2️⃣Motion Two again produced the highest L5-S1 compressive force (1435.7 N), ML shear, and AP shear at T1–T2 (**Figure 3.3.2**). 4️⃣Motion Four followed, with **Figures 3.3.3 and 3.3.4** showing Motions 3️⃣Three and 4️⃣Four producing the second-highest loading across all directions. The lowest values occurred in Motions 1️⃣One and 5️⃣Five, shown in **Figures 3.3.1 and 3.3.5**, respectively. In each figure, sternum-applied conditions created visibly steeper trends, especially in compressive force. In contrast, abdomen-applied conditions showed flatter lines and smaller deviations from baseline.

Across all figures (3.3.1- 3.3.10), L5-S1 consistently showed the highest compressive and ML shear forces, while AP shear peaked in the upper thoracic spine (T1–T2) regardless of model or motion. The diamond markers identified the absolute peak force among the seven weight conditions for each motion, and the star markers denoted the condition with the highest mean force. In most cases, these markers aligned with the heaviest loading under the 6.8 kg (15 lbs.) sternum condition. Additionally, in both models, line convergence near the upper thoracic spine was a recurring feature, particularly in the AP shear plots, indicating reduced influence of vest load at superior vertebral levels.

These trends collectively show that spinal loading is posture-sensitive, weight-dependent, and spatially consistent across subjects. Motions 2️⃣Two and 4️⃣Four produced the most demanding biomechanical conditions, while 1️⃣Motion One and 5️⃣Motion Five remained the lowest across all directional forces.

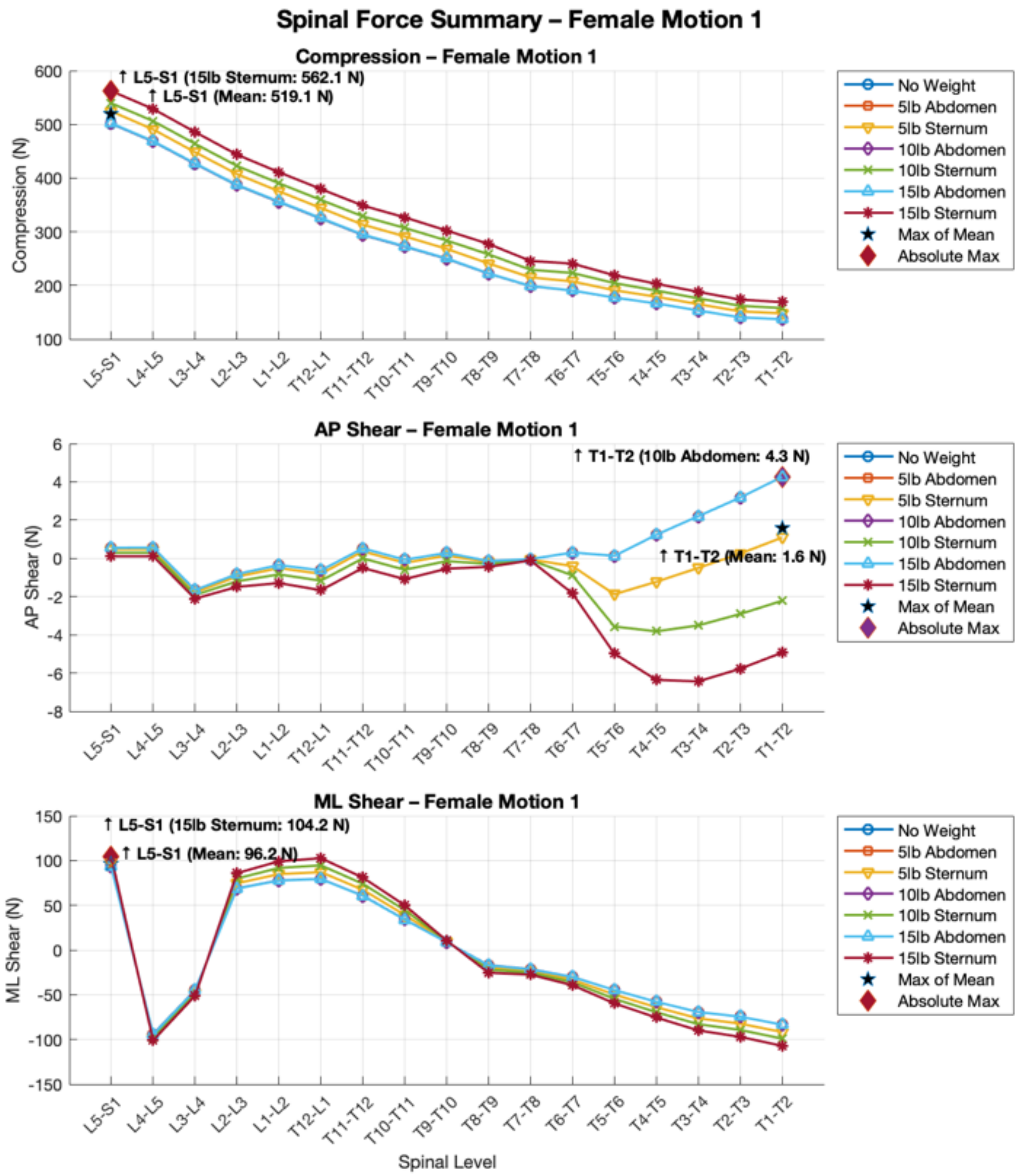

Figure 3.3. 1: Female 1️⃣Motion One Spinal Forces Summary

Mean compressive, anterior-posterior (AP) shear and medial-lateral (ML) shear forces across the thoracolumbar spine for female 1️⃣Motion One (neutral standing), evaluated across seven loading conditions. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. Figure made using MATLAB.

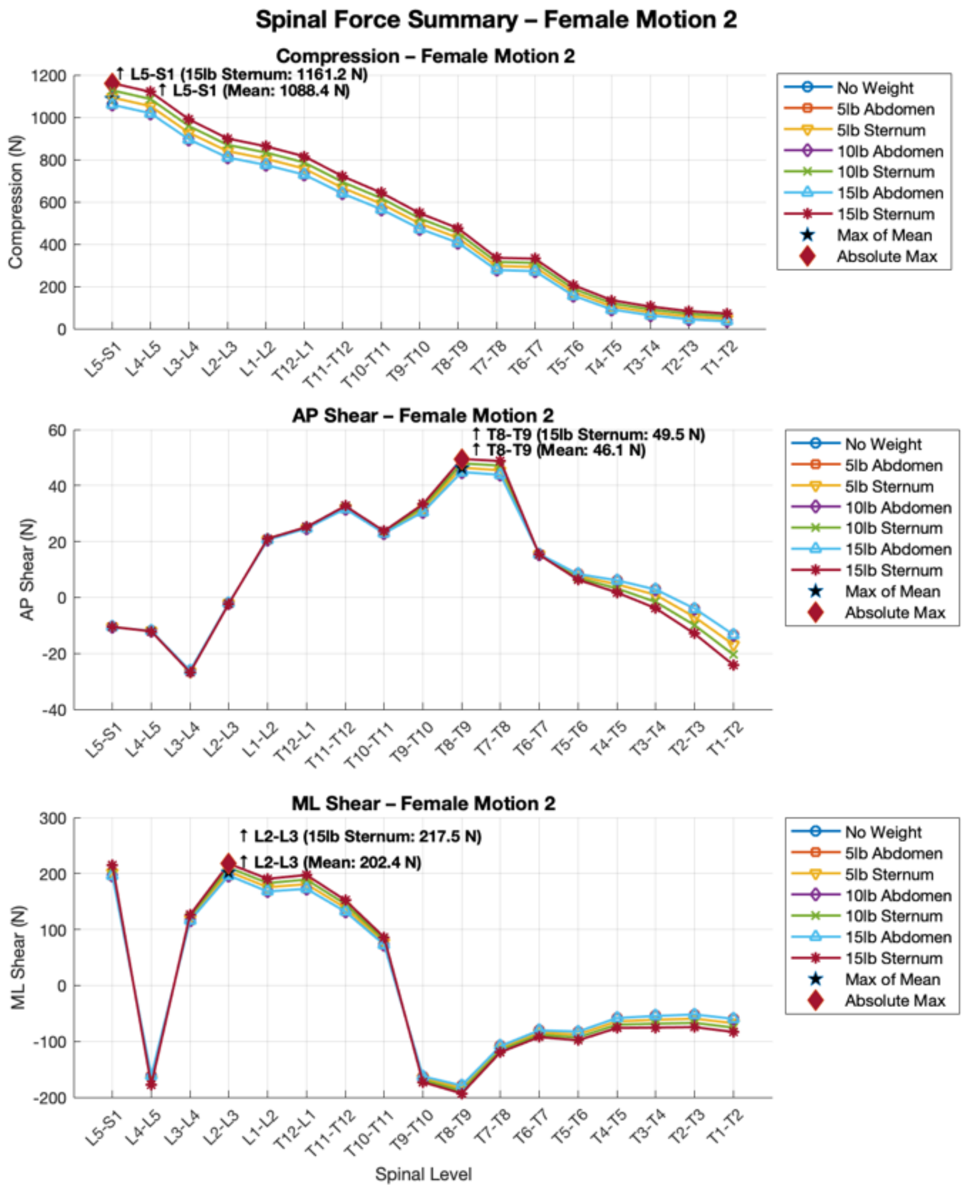

Figure 3.3. 2: Female Spinal Forces Summary for 2️⃣Motion Two

Mean compressive, anterior-posterior (AP) shear and medial-lateral (ML) shear forces across the thoracolumbar spine for female 2️⃣Motion Two (30º axial trunk twist with elbows at 90º and 10kg (22 lbs.) in each hand), evaluated across seven loading conditions. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. Figure made using MATLAB.

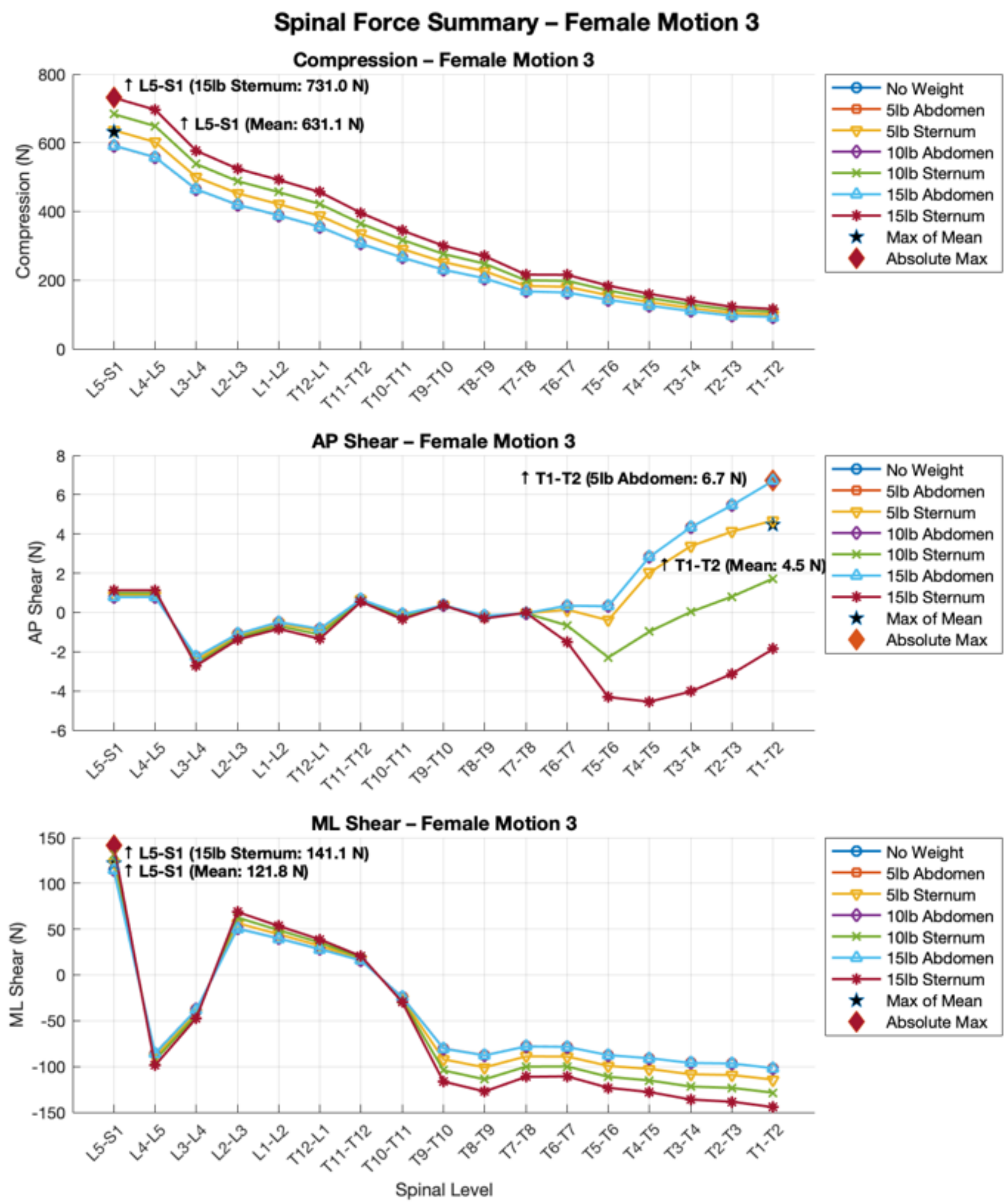

Figure 3.3. 3: Female Spinal Forces Summary for 3️⃣Motion Three

Mean compressive, anterior-posterior (AP) shear and medial-lateral (ML) shear forces across the thoracolumbar spine for female 3️⃣Motion Three (30º trunk flexion with arms in neutral position), evaluated across seven loading conditions. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. Figure made using MATLAB.

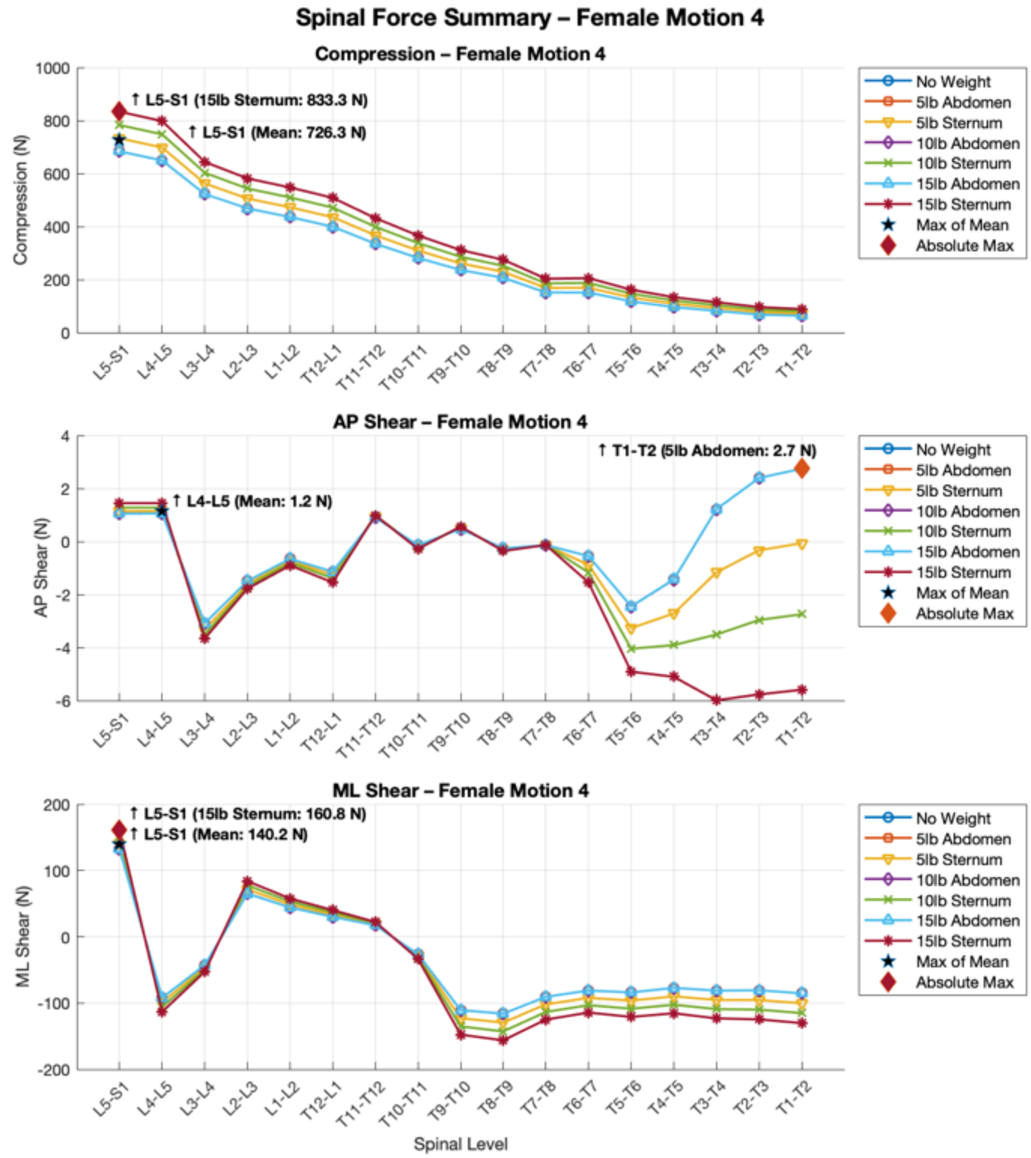

Figure 3.3. 4: Female Spinal Forces Summary for 4️⃣Motion Four

Mean compressive, anterior-posterior (AP) shear and medial-lateral (ML) shear forces across the thoracolumbar spine for female 4️⃣Motion Four (30º trunk flexion with arms extended), evaluated across seven loading conditions. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. Figure made using MATLAB.

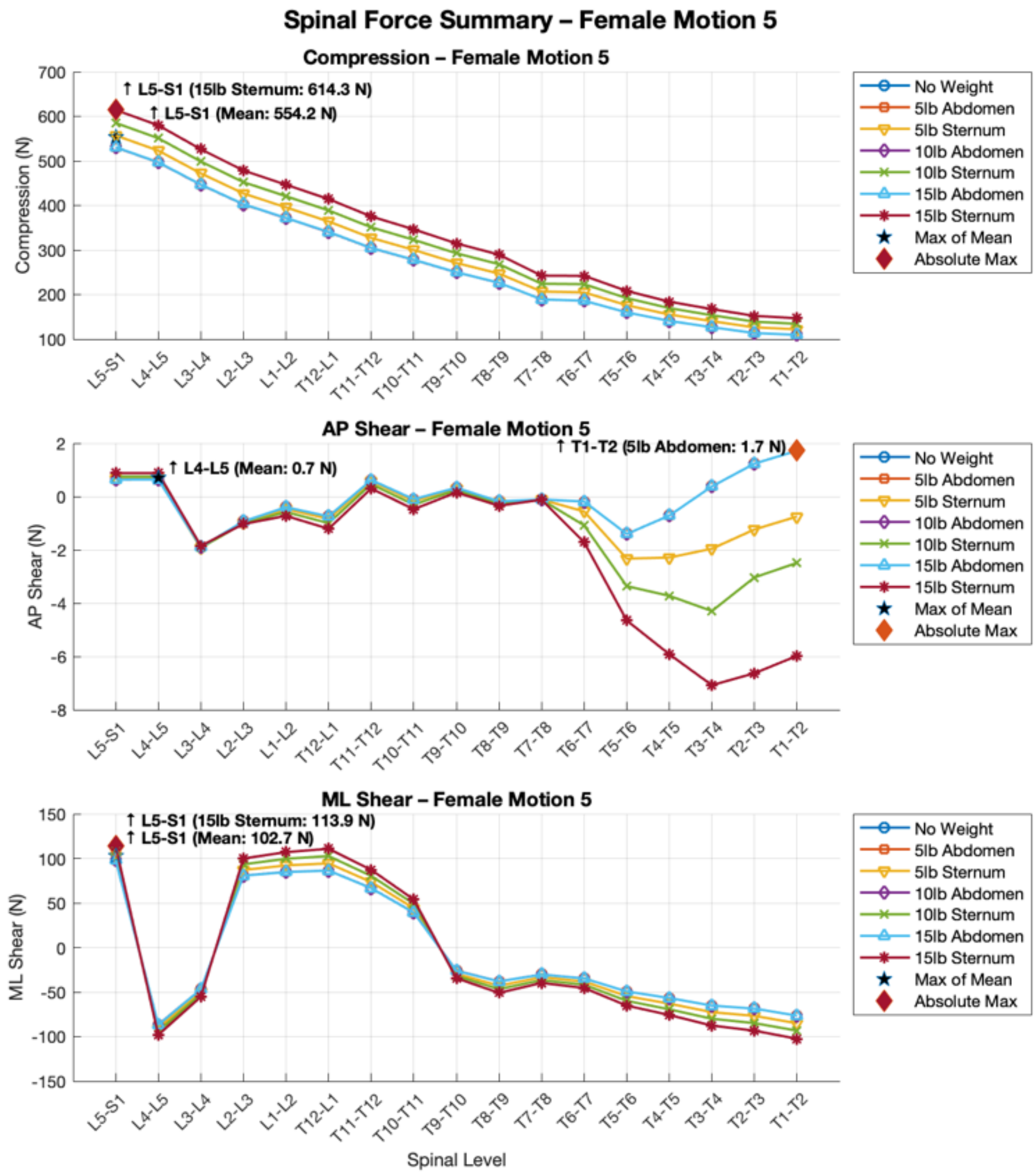

Figure 3.3. 5: Female Spinal Forces Summary for 5️⃣ Motion Five

Mean compressive, anterior-posterior (AP) shear and medial-lateral (ML) shear forces across the thoracolumbar spine for female 5️⃣Motion Five (neutral spine with elbows 90º flexion and 1kg (2.2 lbs.) in each hand), evaluated across seven loading conditions. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. Figure made using MATLAB.

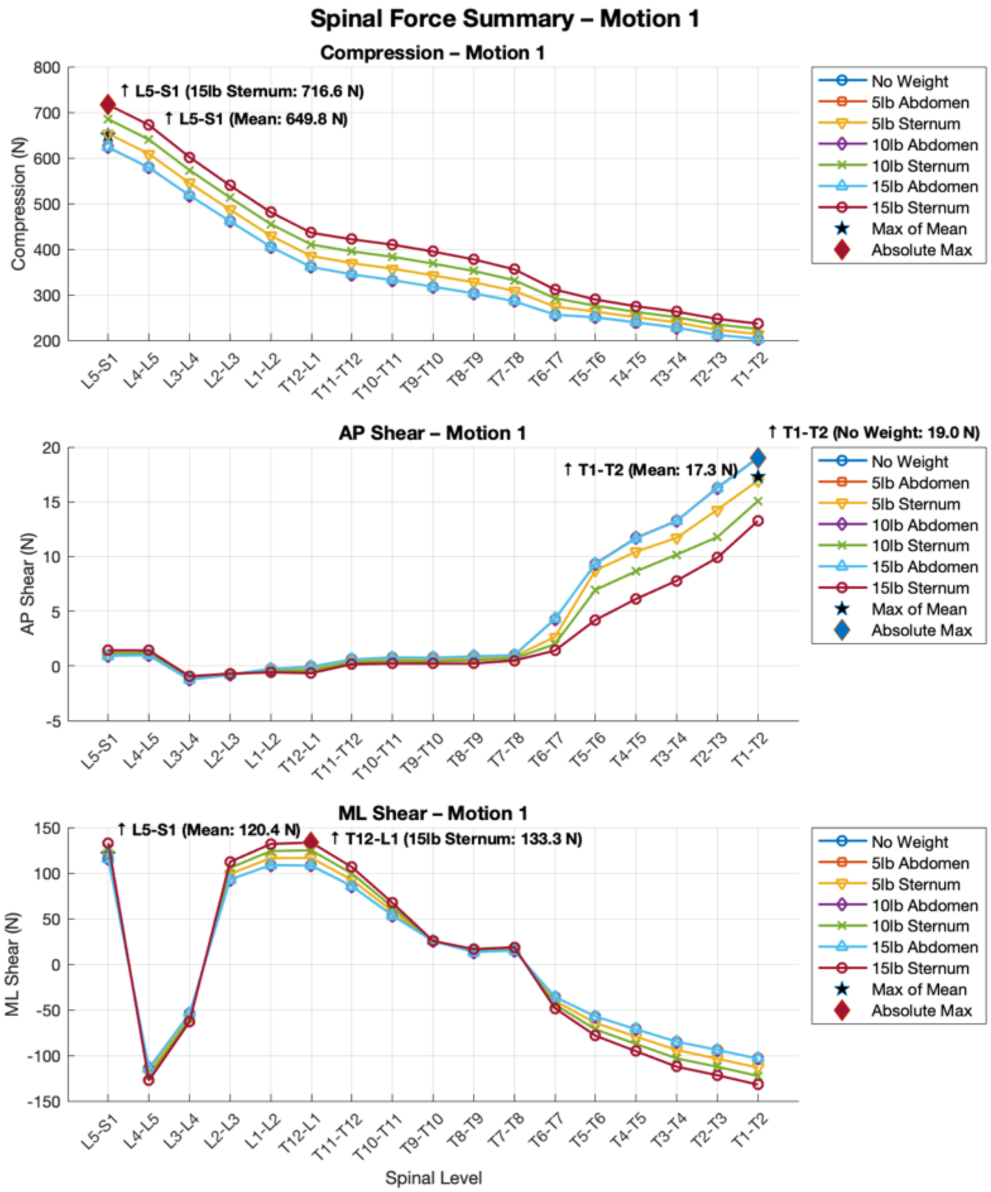

Figure 3.3. 6: Male Spinal Forces Summary for 1️⃣Motion One

Showing the results of the male model with seven loading conditions while in 1️⃣Motion One-neutral standing posture. The three graphs show the mean compressive, anterior/posterior (AP) shear, and medial/lateral (ML) shear forces across the thoracolumbar joints under seven loading conditions, respectively. The diamond shaped markers indicate the absolute force per plot out of all seven conditions and the star markers indicate the maximum mean of the force per plot. Figure made using MATLAB.

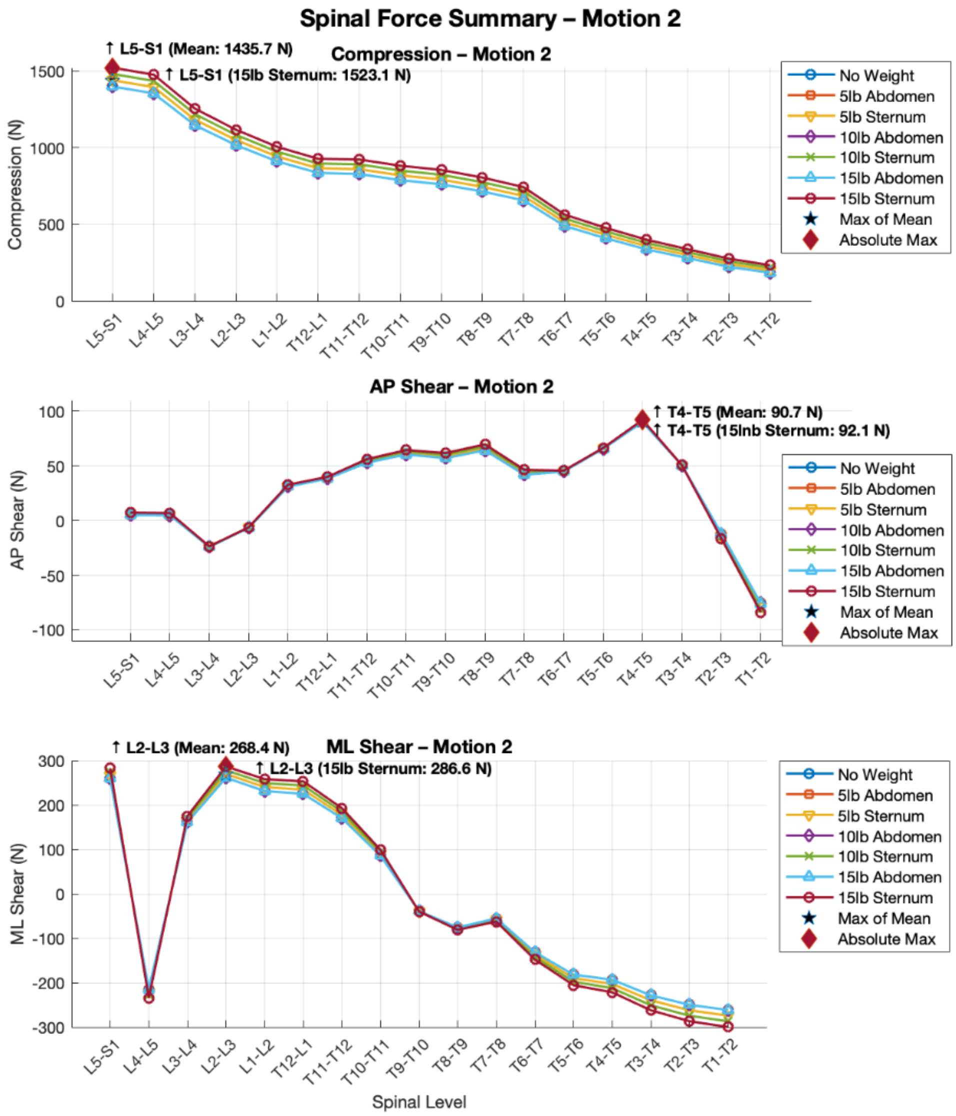

Figure 3.3. 7: Male Spinal Forces Summary for 2️⃣Motion Two

2️⃣Motion Two- 30^{o} axial trunk twist with 90^{o} elbow flexion and 10kg (22 lbs.) weights in each hand. Shown in the figure above are average compressive, anterior/posterior (AP) shear, and medial/lateral (ML) shear forces across the thoracolumbar joints under seven loading conditions, respectively. Each line is a different weighted vest condition all ran on the male model with 2️⃣Motion Two. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. Figure made using MATLAB.

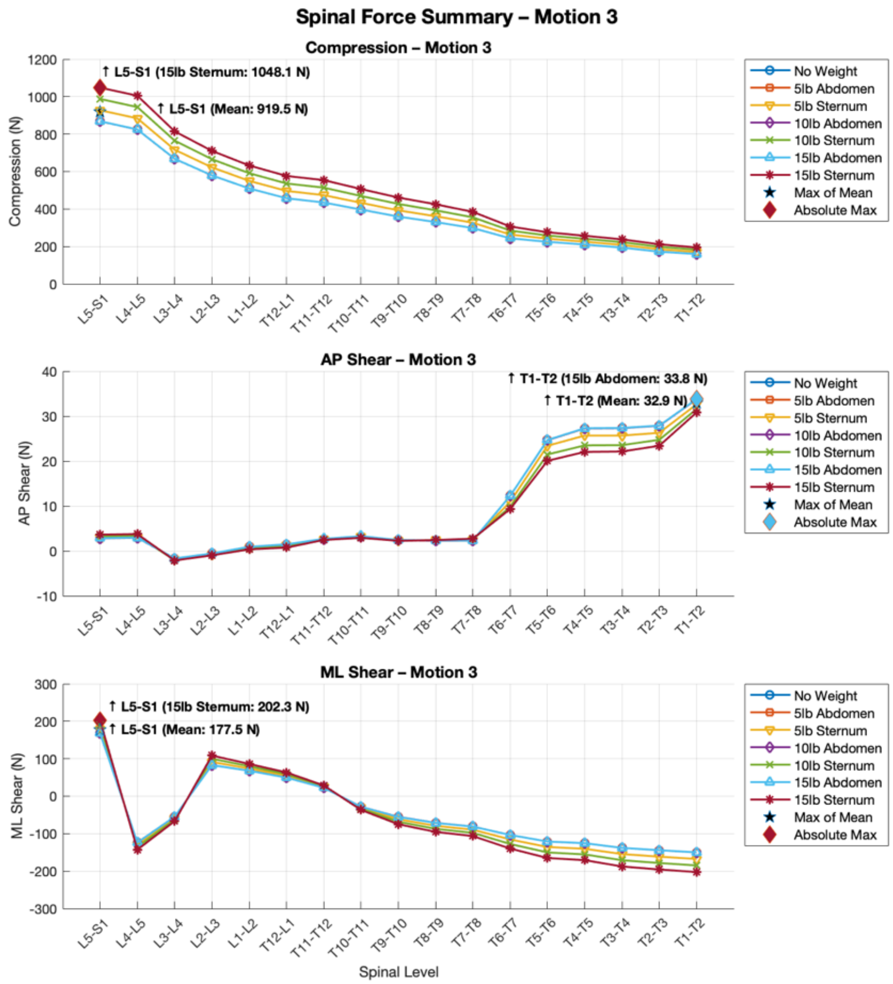

Figure 3.3. 8: Male Spinal Forces Summary for 3️⃣Motion Three

Spinal joint reaction forces during 30º trunk flexion with arms relaxed to the sides (3️⃣Motion Three). The plots above display the average compressive, anterior/posterior (AP) shear, and medial/lateral (ML) shear forces across the thoracolumbar joints under seven loading conditions, respectively. Each line is a different weighted vest condition all ran on the male model with 3️⃣Motion Three. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. The greatest compressive and ML shear forces were observed at L5-S1, while the AP shear peaked at T1-T2. These trends reflect the effect that the trunk flexion with load placement has on the lumbar loading and the upper thoracic shear forces. Figure made using MATLAB.

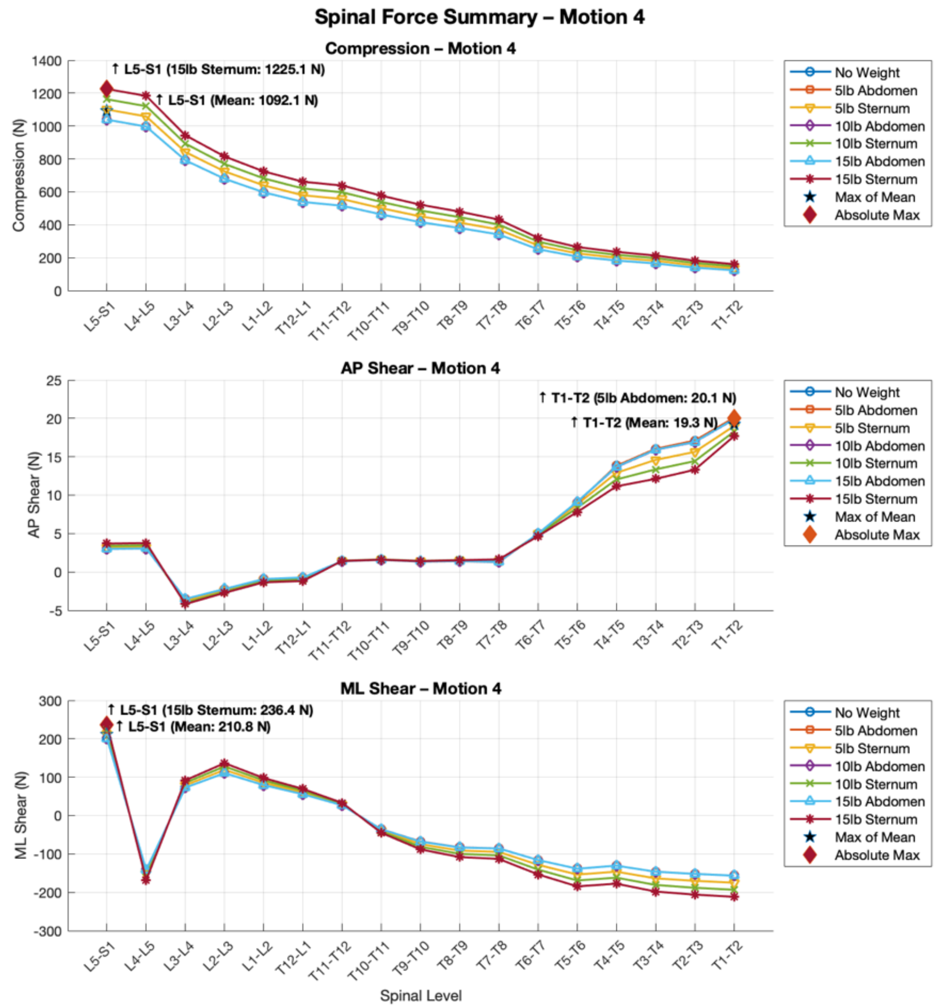

Figure 3.3. 9: Male Spinal Forces Summary for 4️⃣Motion Four

Spinal joint reaction forces during 30° trunk flexion with extended out (4️⃣Motion Four). Shown is the average compressive (top), anterior/posterior (AP) shear (middle), and medial/lateral (ML) shear (bottom) forces across the thoracolumbar joints under seven loading conditions, respectively. Each line is a different weighted vest condition all ran on the male model with 4️⃣Motion four. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. The compressive forces were greatest at L5-S1, specifically when the 6.8 kg (15 lbs.) were added at the sternum. AP shear forces peaked at T1-T2. Figure made using MATLAB.

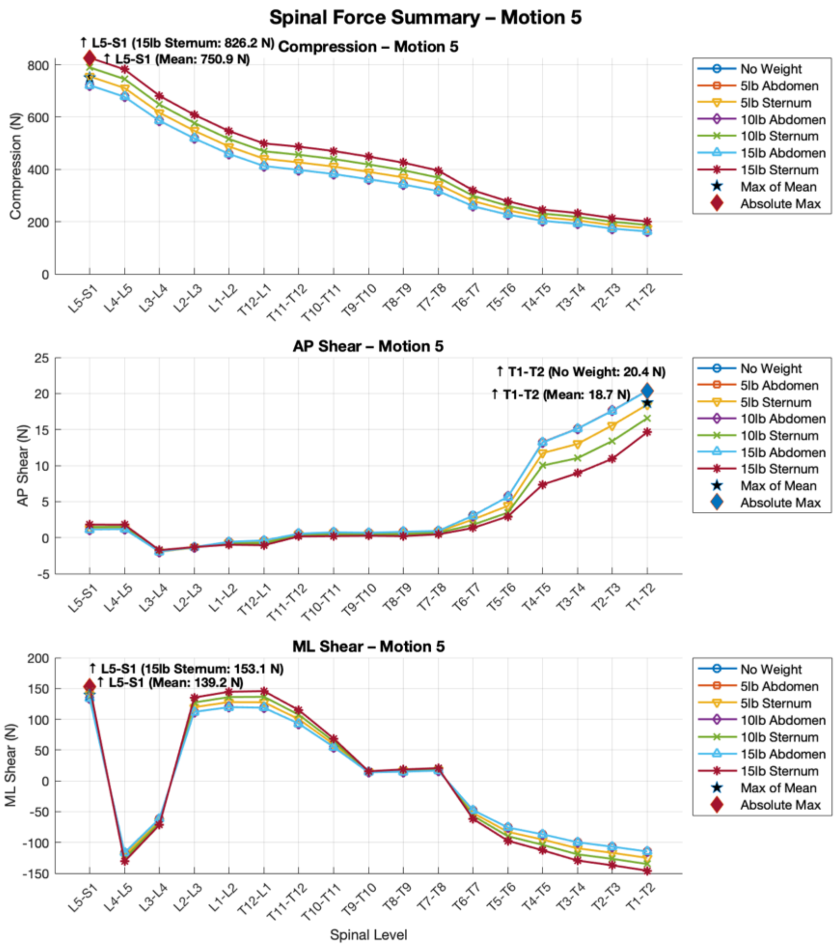

Figure 3.3. 10: Male Spinal Forces Summary for 5️⃣Motion Five

Spinal joint reaction forces for 5️⃣Motion Five, spine at neutral position with a 90º elbow flexion and 1 kg (2.2 lbs.) weights in each hand. Shown is the average compressive (top), anterior/posterior (AP) shear (middle), and medial/lateral (ML) shear (bottom) forces across the thoracolumbar joints under seven loading conditions, respectively. Each line is a different weighted vest condition all ran on the male model with 5️⃣Motion Five. The diamond shaped markers indicate the maximum force per plot out of all seven conditions and the star markers indicate the maximum mean force per plot. The L5-S1 experienced the max force for both compressive and ML shear. While the AP shear was the highest at T1-T2. Figure made using MATLAB.

3.4 Sex Comparison

Spinal compressive loading varied between the male and female models across all simulated motions and load conditions. This variation was observed in both absolute force values (N) and normalized forces expressed as percent body weight (%BW).

Figures 3.4.1- 3.4.4 display absolute compressive forces across spinal levels for each model under four vest conditions: no vest, and (2.3 kg (5 lbs.), 4.5 kg (10 lbs.), and 6.8 kg (15 lbs.) applied at the sternum. In all motions, the male model produced higher compressive forces than the female model at each spinal level. The greatest differences were observed at L5-S1, particularly under the 6.8 kg (15 lbs.) sternum condition. In 2️⃣Motion Two, compressive force at L5-S1 reached over 1500 N in the male model and 1435.7 N in the female model. In 1️⃣Motion One, values were 716.6 N (male) and 562.1 N (female) under 6.8 kg (15 lbs.) sternum loading. At the T1–T2 level, the force values for 2️⃣Motion Two were 234.2 N (male) and 71.6 N (female)**.** The force distribution across the spine followed a similar pattern in both models, with the highest loads at L5-S1 and a progressive decrease toward the thoracic spine. The curves for the female model showed steeper declines from lumbar to thoracic regions across several motions, particularly in Motions 3️⃣Three and 4️⃣ Four.

Figures 3.4.5- 3.4.8 show compressive forces expressed as percent of body weight. The %BW values were more closely aligned between models than the absolute values. For example, in 1️⃣Motion One with no vest (**Figure 3.4.5**), the L5-S1 load was 81.4% BW (male) and 71.0% BW (female)**.** In 2️⃣Motion Two under the 6.8 kg (15 lbs.) sternum condition (**Figure 3.4.6**), the L5-S1 values were 137.8% BW (male) and 123.3% BW (female)**.** The %BW profiles for both models followed the same general shape as the absolute force plots, with L5-S1 consistently displaying the highest loading and T1–T2 the lowest across all motions.

Bar plots also highlight that in the thoracic spine, values in the female model were more closely grouped between motions, while the male model showed more variation across motions and load conditions. These results demonstrate consistent differences in compressive loading between the male and female models across all spinal levels and weight conditions. Observed force magnitudes and distributions for both absolute and normalized data are detailed in **Figures 3.4.1–3.4.8**.

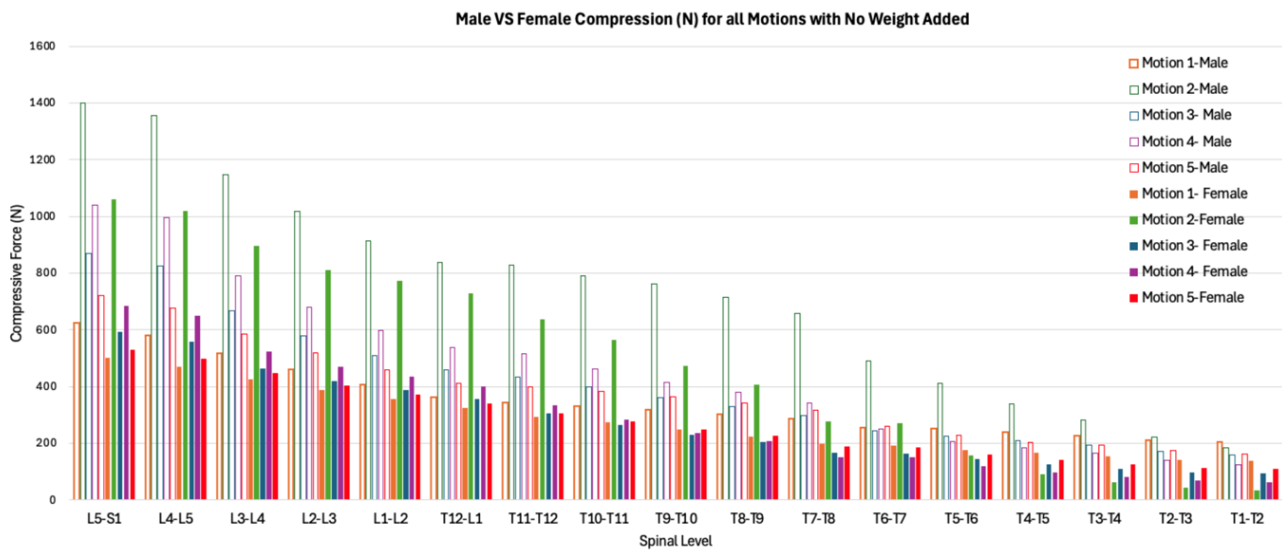

Figure 3.4. 1: Comparison of Spinal Compression Forces Between Male and Female Models-No-Weight

Bar plot of average compressive forces (N) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Male data ranges from 623.4 N (L5-S1, 1️⃣Motion One) to 184.6 N (T1-T2, 2️⃣Motion Two), while female data ranges from 501.5 N to 34.7 N, highlighting sex differences in baseline spinal loading. Figure created in Excel.

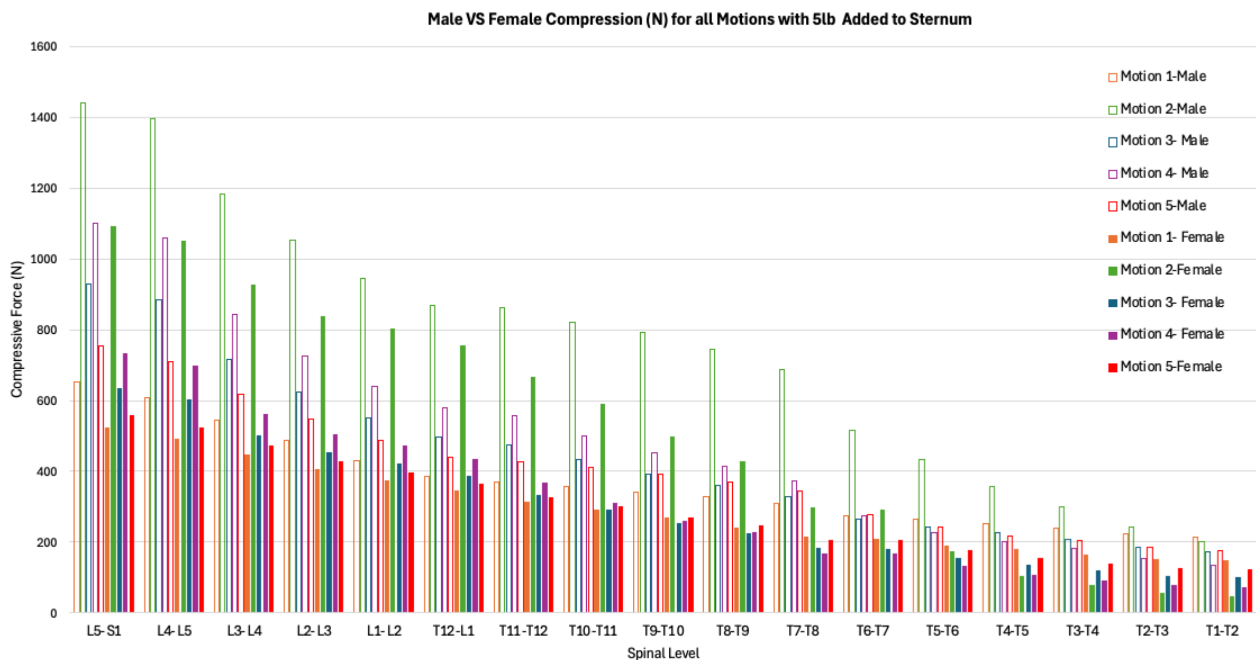

Figure 3.4. 2: Comparison of Spinal Compression Forces Between Male and Female Models- 2.3 kg (5 lbs.) Sternum

Bar plot of average compressive forces (N) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Male data ranges from 653.2 N (L5-S1, 1️⃣Motion) to 201.1 N (T1-T2, 2️⃣Motion Two), while female data ranges from 524.3 N to 46.9 N, illustrating increased loading and sex differences compared to no-weight conditions. Figure created in Excel.

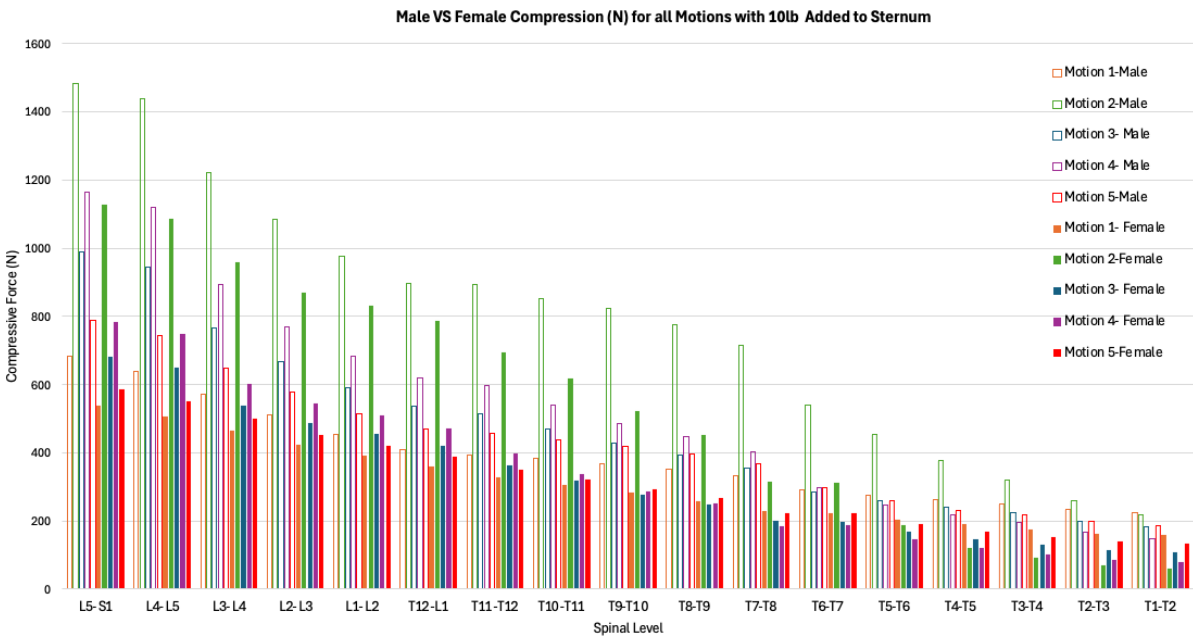

Figure 3.4. 3: Comparison of Spinal Compression Forces Between Male and Female Models- 4.5 kg (10 lbs.) Sternum

Bar plot of average compressive forces (N) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Male data ranges from 684.7 N (L5-S1, 1️⃣Motion One) to 217.7 N (T1-T2, 2️⃣Motion Two), while female data ranges from 539.5 N to 59.2 N, demonstrating further increased loading and sex differences compared to lower weight conditions. Created in Excel.

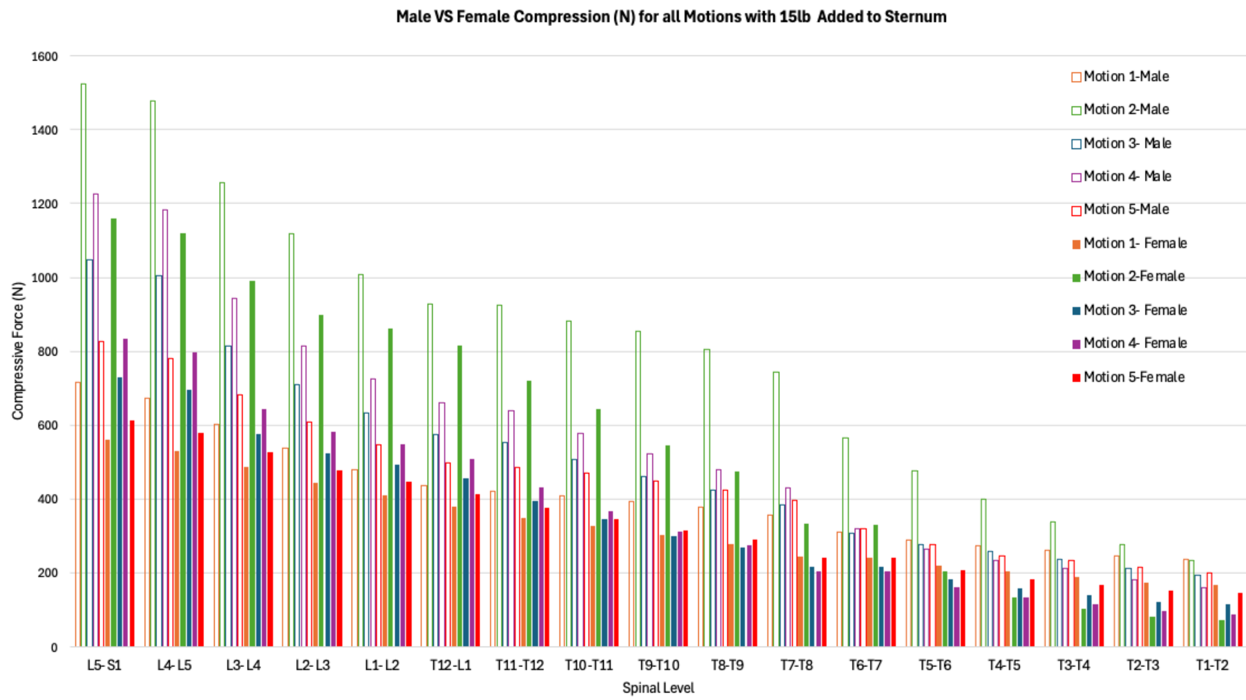

Figure 3.4. 4: Comparison of Spinal Compression Forces Between Male and Female Models- 6.8 kg (15 lbs.) Sternum

Bar plot of average compressive forces (N) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Male data ranges from 716.6 N (L5-S1, 1️⃣Motion One) to 234.2 N (T1-T2, 2️⃣Motion Two), while female data ranges from 562.1 N to 71.6 N, reflecting the highest loading observed and persistent sex differences. Created in Excel.

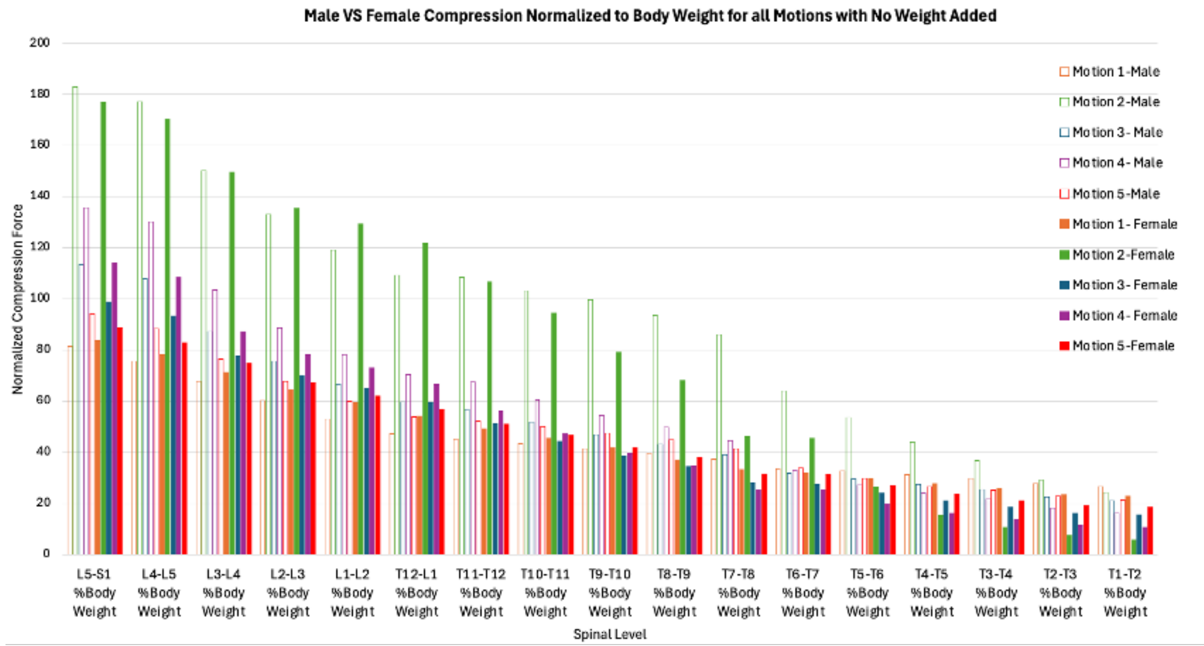

Figure 3.4. 5: Comparison of Spinal Percent Body Weight (%BW) Between Male and Female Models- No Weight

Bar plot of average percent body weight (%BW) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1 Motion One (neutral standing), 2 Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3 Motion Three (30° trunk flexion, arms down), 4 Motion Four (30° trunk flexion, arms extended), and 5 Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Created in Excel.

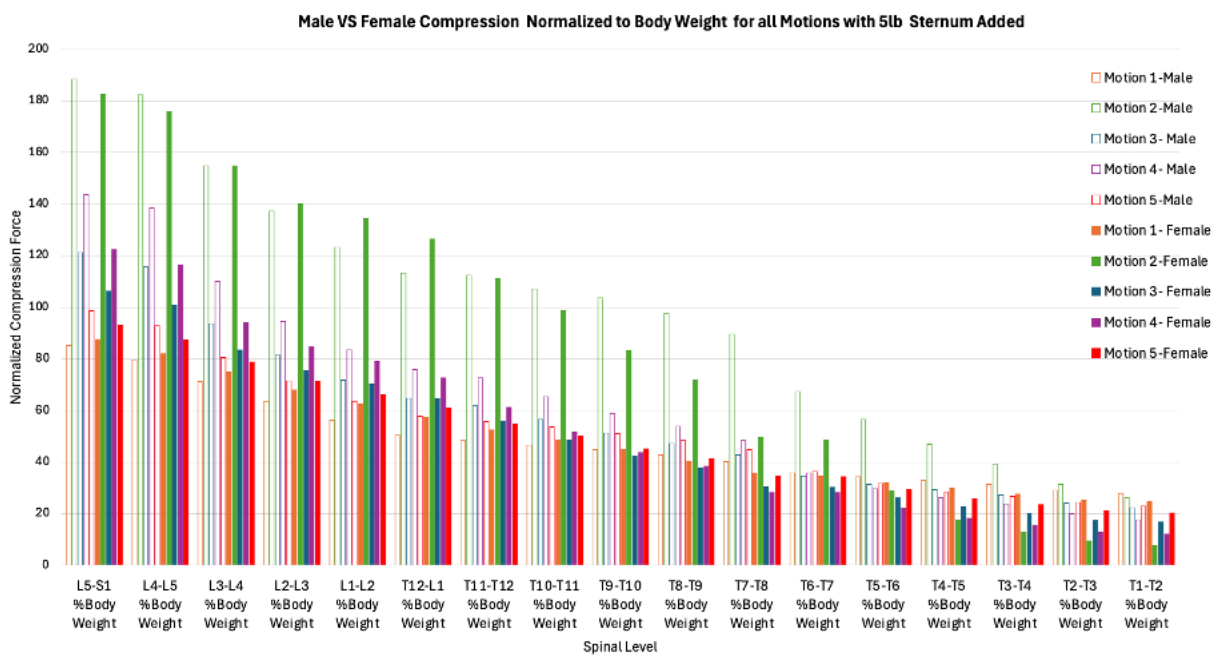

Figure 3.4. 6: Comparison of Spinal Percent Body Weight (%BW) Between Male and Female Models- 2.3 kg (5 lbs.) Sternum

Bar plot of average percent body weight (%BW) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Created in Excel.

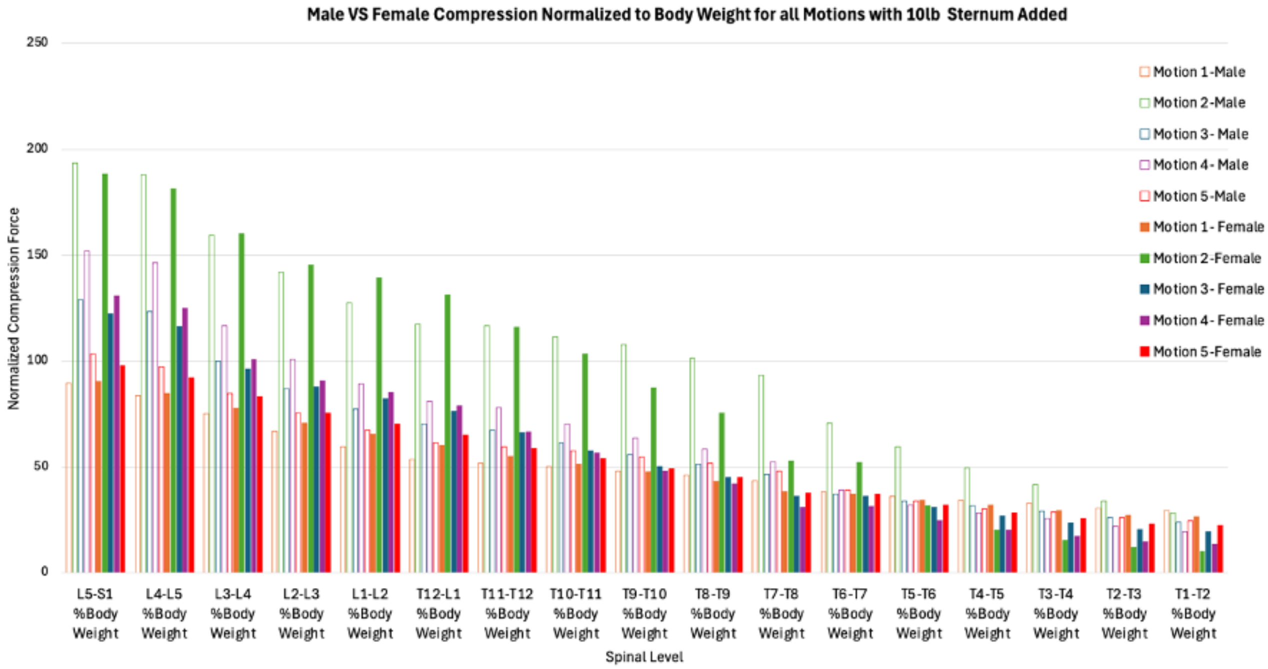

Figure 3.4. 7: Comparison of Spinal Percent Body Weight (%BW) Between Male and Female Models- 4.5 kg (10 lbs.) Sternum

Bar plot of average percent body weight (%BW) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90º and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Created in Excel.

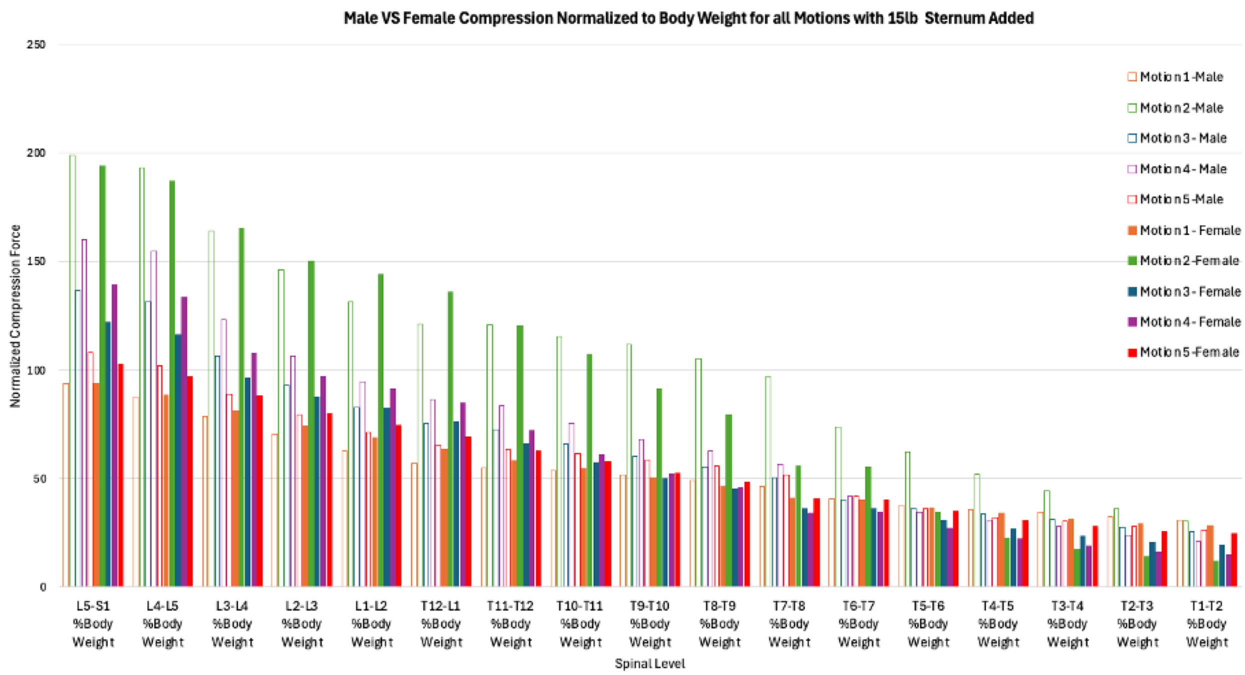

Figure 3.4. 8: Comparison of Spinal Percent Body Weight (%BW) Between Male and Female Models- 6.8 kg (15 lbs.) Sternum

Bar plot of average percent body weight (%BW) at spinal levels from L5-S1 to T1-T2 for male (open bars with colored rims) and female (filled bars) musculoskeletal models across five static postures: 1️⃣Motion One (neutral standing), 2️⃣Motion Two (30° axial twist, elbows at 90° and 10 kg (22 lbs.) hand weights), 3️⃣Motion Three (30° trunk flexion, arms down), 4️⃣Motion Four (30° trunk flexion, arms extended), and 5️⃣Motion Five (neutral, 90° elbow flexion, 1 kg (2.2 lbs.) hands). Created in Excel.

Chapter 4: Discussion

4.1 Summary of Findings

This study used musculoskeletal modeling and simulation in OpenSim to quantify thoracolumbar spine loading across a set of five simulated surgical postures and seven lead vest conditions in male and female models. The analysis captured compressive, anterior-posterior (AP) shear, and medial-lateral (ML) shear forces at each vertebral level (T1–L5) to investigate how load magnitude and distribution varied by posture, weight placement, and sex. The findings confirm that surgical postures and lead vest usage substantially influence spinal forces, and that these effects are both posture-specific and sex-dependent.

Key findings include:

- L5-S1 consistently experienced the highest compressive and ML shear forces, while AP shear forces peaked in the upper thoracic region (T1–T2).
- 2️⃣ Motion Two (axial twist with hand weights) consistently induced the greatest spinal loading across all force types and both sexes, highlighting the substantial demands of rotational postures under load.
- Sternum-applied vest weights resulted in higher spinal forces than abdomen-applied weights. This is attributed to a higher center of mass and increased moment arm relative to the spine.
- Increased vest weight (2.3, 4.5, 6.8 kg (5, 10, 15 lbs.)) produced proportional increases in compressive and shear forces, with non-linear amplification seen in combination with challenging postures.

- Female models exhibited lower absolute spinal forces compared to male models, but comparable or elevated normalized (percent body weight) loads at the lumbar spine. These results emphasize the importance of incorporating sex-specific anatomical scaling when evaluating loads.

These outcomes provide quantitative biomechanical evidence that aligns with and builds upon prior observations regarding work-related musculoskeletal disorders (WMSDs) in surgeons.

4.2 Posture- Dependent Risk Patterns

The relationship between posture and spinal loading was pronounced across simulations. As hypothesized, static standing (1️⃣Motion One) produced the lowest compressive and shear forces, serving as an effective baseline. Motions involving forward flexion (3️⃣Motion Three - 30º trunk flexion with arms down, 4️⃣Motion Four - 30º trunk flexion with arms out) or axial rotation with loading (2️⃣Motion Two - 30º axial twist with elbows flexed to 90º and 10 kg (22 lbs.) in each hand) substantially elevated all force metrics.

2️⃣Motion Two generated the highest overall loads, including compressive forces exceeding 1500 N in the male model under sternum-weighted conditions. This reflects the cumulative effect of axial rotation, trunk asymmetry, and external arm loadings. This motion was hypothesized to be to provide the largest forces due to the extreme weight and posture. It was able to serve as an extreme trial to compare the other motions to. These results parallel previous biomechanical studies that show torsional loading increases spinal joint reaction forces due to asymmetrical muscle recruitment and trunk rotation. The study evaluating backpack loads showed that load and posture interactions increased lumbar compression like observed in 2️⃣Motion Two [55]. The study done by Shan et al. found that sustained axial twisting causes viscoelastic creep and prolonged erector spinae activation while recognized as low back pain in subjects [56]. The results from our study produced distinct loading patterns in the mid-thoracic suggesting that sustained twisting may contribute to fatigue and musculoskeletal injury. These compressive and shear forces observed in the 2️⃣Motion Two trials align with Shan et al's conclusions, that rotational creep is a contributing factor to spinal instability and discomfort [56].

4️⃣Motion Four, which simulated forward reach with trunk flexion, also yielded elevated compressive and ML shear forces, indicating the added risk posed by spinal flexion and anterior arm extension, common in surgical positioning. These findings align with the study from Fan et al. which reported that surgical tasks induced higher sagittal trunk inclination and elevated trapezius activation compared to nonsurgical tasks, with postural demands often exceeding proposed action levels for musculoskeletal safety [22]. This suggests that the simulated 4️⃣Motion Four posture models are a realistic ergonomic risk factor observed in clinical surgical practice.

4.3 Effect of Load Placement and Weight

Simulated lead vest conditions showed consistent trends indicating that:

- Increasing weight consistently increased loading, particularly at L5-S1.
- Sternum-applied weights resulted in greater loading than abdominal placements across all force directions and spinal levels.

This supports the hypothesis that the superior placement of mass (closer to the upper thorax) shifts the center of mass forward and upward, increasing spinal extensor demands and resulting in higher joint reaction forces in both the lumbar and thoracic spine. It also provides evidence that this location is a more accurate placement to model where the weight is carried in the real world. The indications that the lumbar spine consistently experienced the highest forces is consistent with feedback and reporting from the population most commonly having pain in this area [22], [57]. This suggests that the fit and placement of lead vests may significantly influence spinal loading patterns and injury risk. As mentioned in the introduction, concerns have been raised about the inadequate fitting of the lead vests, specifically in females [58]. These findings reinforce the need for custom fitting lead vests that consider both the anthropometric and ergonomic principles specific to the sexes. Implementation of such solutions could be through hospital policy changes or funding for this equipment could potentially reduce the long-term musculoskeletal strain in surgical personnel.

The percent change analyses between weighted and non-weighted trials further demonstrate that even lighter vest weights (2.3- 4.5 kg (5–10 lbs.)) can still substantially increase spinal loading, particularly in non-neutral postures such as trunk flexion or reaching. These results are consistent with previous biomechanical studies showing an increased load magnitude and offset from the spine amplifies the muscle forces required to stabilize the joint [30], [59].

4.4 Male vs Female Spinal Loading Differences

The inclusion of both male and female full-body models allowed for an important comparison of sex-specific loading patterns. This is important because male and females have slightly different anatomy and body composition that impact the way that loads are held. Men typically have a center of mass located at the naval and women have a lower center of mass located closer to the hips [60]. Across all postures and conditions, the male model exhibited higher absolute compressive, AP shear, and ML shear forces. This reflects higher total body mass and greater trunk musculature in the male anthropometric model, consistent with prior simulation-based findings.

However, when spinal forces were normalized to percent body weight, differences narrowed and in some lumbar levels and postures, the female model experienced relatively greater loads. These differences were especially evident at L5-S1 and under sternum-applied loads, supporting the hypothesis that female proceduralists may face disproportionate relative loading even with lighter absolute masses. The increased normalized loading observed in the female model under sternum-applied conditions may partially reflect anatomical and biomechanical differences in mass distribution. Females typically have a lower and more anterior center of mass, positioning external load at the sternum may introduce greater moment arms and muscular demand relative to their baseline structure. Recent studies have suggested the females may adapt differently to muscle fatigue, specifically in the thoracic and lumbar regions, causing greater variability in joint kinematics compared to males. This could suggest why female clinicians, despite carrying a smaller absolute load may experience higher muscle strain [61]. This mismatch in modeled weight placement could disproportionately increase lumbar loading in female users, particularly during flexed or rotated postures. Further research is needed to assess whether sex-specific vest designs or lower weight positioning could better distribute load in female surgical personnel.

This has significant ergonomic implications, as most commercial lead vests are not sex specific. Poor anatomical fit, especially at the chest and waist, may exacerbate loading in female users due to improper distribution or mechanical advantage of mass.

4.5 Comparison with Existing Literature

These findings align with reports of lumbar compressive loads during lifting, backpack carriage, and prolonged static posture simulations. Prior studies using OpenSim and similar modeling platforms have reported compressive forces ranging from 400–1200 N during moderate trunk flexion activities [30], [32]. The forces reported here peaking at 1523.1 N in 2️⃣Motion Two fall within that upper range, particularly when external vest weights are added to loaded postures. This was to be expected due to the extremity of the hand weights, 10 kg (22 lbs.) in each hand is quite heavy and would rarely be seen to happen in the OR. This is why 5️⃣Motion Five was adapted have smaller weights of 1 kg (2.2 lbs.) in each hand to provide a more realistic lifting condition that surgical personnel would experience. This motion experienced peak compressive forces of around 826 N in males and 614.3 N in females.

Similar trends have been observed in military load carriage studies, which showed increases in lumbar spine curvature, disc compression, and paraspinal activation with increasing anterior weight [55]. However, most of these studies focus on dynamic locomotion, while the static postures modeled here better reflect the real demands placed on surgical professionals.

To date, very few studies have modeled vest-specific loading using validated OpenSim simulations. This work expands upon recent applications of OpenSim in occupational ergonomics and provides the first detailed assessment of spinal forces induced by typical lead vest weights across realistic postures used in the operating room.

4.6 Implications for Surgical Ergonomics

This study offers biomechanical support for modifying both lead vest design and surgical workflow strategies:

- **Vest placement matters-** The sternum loaded configurations substantially increase the spinal forces compared to the abdomen applied weights.

In this study the main focus was the over the shoulder lead vests, but this has proven it would be worthwhile to model the other designs. For instance, designs that have a skirt and a top. Since the skirt weight would be closer to the placement of the abdomen weight modeled in this study, this design could lead to a decrease in spinal forces seen in the thoracolumbar spine. The lumbar spine seems to be a key place that would benefit from a redesign, due to the reported pain from clinicians and the results of this study which showed they experienced the highest forces.

- **Postural awareness is critical-** Motions involving twisting or forward flexion under load are biomechanically demanding and may merit active scheduling breaks or robotic assistance.

Implementing ergonomic training programs and incorporating robotic assistance could mitigate musculoskeletal strain [23], [62].

- **Sex-specific considerations are needed** -Female surgical personnel may face increased ergonomic risk under current PPE designs due to suboptimal fit and higher normalized spine loads along with the implications in protection the vests can have for females. The results of this study however show that even the males could have decreased risk for MSK issues with having leads specifically designed to their bodies, so that the load is carried at a point of the least amount of impact on the forces exerted on the thoracolumbar spine.

These provide valuable insights for engineering interventions and policy recommendations aimed at reducing WMSDs in surgical populations. Incorporating this biomechanical data into ergonomic training and PPE procurement decisions could improve spinal health outcomes and extend career longevity for proceduralists.

4.7 Long-Term Implications of Observed Spinal Loading Patterns

The simulation results from this study revealed that specific surgical postures particularly those involving axial rotation or forward flexion, combined with the use of lead vests, result in substantial increases in spinal loading, particularly at the L5-S1 segment. While these values were obtained under static postures, they offer insight into the chronic mechanical demands placed on the thoracolumbar spine during typical surgical conditions. Due to the repeated nature of the postures, surgeons can experience these multiple days a week for years at a time. This sentence warrants the consideration of the long-term implications of this study.

According to biomechanical guidelines, the National Institute for Occupational Safety and Health (NIOSH) designates a maximum compressive force of 3,400 N at the lumbar spine to prevent injury in 95% of male workers and 70% of female workers [63]. In addition, shear forces above 500 N are considered to exceed the action limit (AL), and 1,000 N represents the maximum permissible limit (MPL) for shear before structural tissue damage becomes more probable [64].

In this study, the highest compressive force recorded was 1,523.1 N at L5-S1 during 2️⃣Motion Two under the 6.8 kg (15 lbs.) sternum condition. This value falls below the NIOSH-defined risk threshold, but it only reflects a single loading event. In reality, surgeons often maintain such postures for prolonged periods and may experience repetitive exposures to similar or greater loads over the course of hours, days, or years. This repeated exposure introduces the risk of cumulative spinal loading which can lead to chronic degeneration even if acute thresholds are not exceeded [65].

Although compressive forces remained within safe bounds, the AP shear and ML shear loads approached the 500 N action limit in some postures, particularly during twisting or reach motions combined with higher vest weights. Shear forces are more strongly associated with intervertebral disc herniation and facet joint degeneration due to the translational forces they place on spinal segments [66].

Existing literature supports these concerns. Studies have demonstrated that prolonged lumbar flexion alters passive tissue stiffness, predisposing individuals to disc injury upon resumption of movement [67]. Additionally, cyclic loading, even below peak force thresholds, has been shown to increase the likelihood of vertebral endplate damage and disc degeneration over time [63]. The combined effects of repetitive exposure, static loading, and poor posture are all well-established contributors to musculoskeletal fatigue and cumulative trauma disorders. In particular, the combination of spinal flexion with compression, such as that observed during 3️⃣Motion Three and 4️⃣Motion Four in this study, has been shown to exacerbate the risk of intervertebral disc herniation. This risk may be further amplified in surgical environments where these postures are maintained continuously for extended periods.

Taken together, these findings suggest that while short-term spinal forces may appear tolerable, the accumulated exposure experienced by surgical professionals could lead to long-term spinal degeneration, including:

- Intervertebral disc degeneration and herniation.
- Facet joint osteoarthritis.
- Muscular fatigue and imbalance.
- Chronic low back pain and functional disability.

To mitigate these risks, a multifaceted approach is warranted. Preventive measures may include:

- Development of ergonomic training programs targeting optimal posture and movement strategies.
- Redesign lead vest systems to redistribute mass more evenly and reduce upper trunk loading.
- Consideration of sex-specific fit for surgical PPE.
- Implementation of scheduling strategies to allow for micro-breaks, postural variation, and workload distribution.

- Along with further biomechanical analysis in this population, specifically in vivo measures.

While lead vests are essential for protection from radiation, they do represent a modifiable risk factor for developing WMSDs in surgical populations. Although this study provided some insight into the spinal loading mechanisms and the biomechanical impact of lead vests, there is still much work to do to get to the root of the problem.

Chapter 5: Conclusions and Recommendations

5.1 Conclusions

This study used OpenSim-based musculoskeletal simulations to evaluate the biomechanical impact of surgical lead vests on thoracolumbar spine loading under a set of representative static surgical postures. The simulations incorporated seven lead vest conditions, five distinct postures, and both male and female full-body models to assess the direction and magnitude of spinal joint reaction forces (JRFs) across key thoracolumbar joint levels in the superior-inferior (SI) compressive, anterior-posterior (AP) shear, and medial-lateral (ML) shear directions.

Across all simulations, the L5-S1 segment consistently exhibited the highest compressive and ML shear loading, while T1–T2 consistently exhibited peak AP shear, particularly during twisting or arm-loading postures. Spinal loading increased with vest weight, with the sternum-applied weights generating significantly greater loads than abdominal-applied conditions. Of the five postures studied, 2️⃣Motion Two (30º axial twist with elbows flexed to 90º and 10 kg (22 lbs.) in each hand) produced the highest forces, followed by 4️⃣Motion Four (30º trunk flexion with arms out).

The results also revealed sex-specific loading patterns, where the male model demonstrated higher absolute spinal forces due to overall mass, but the female model experienced comparable or higher normalized loads (percent body weight), especially in the lumbar spine. This finding is particularly relevant given the common use of unisex lead vests in surgical settings, potentially placing female proceduralists at higher relative risk.

From a long-term health perspective, while simulated spinal forces fall within safety thresholds for single exposures, the combination of increased load magnitude, unfavorable posture, and prolonged duration presents a meaningful risk for developing chronic musculoskeletal disorders (MSDs) over time. The data aligns with known risk factors for intervertebral disc degeneration, facet joint stress, and chronic low back pain, supporting growing concern about the occupational toll of prolonged surgical postures and ill-fitted protective equipment.

This study highlights the critical need for design and policy interventions targeting lead vest ergonomics, surgical posture optimization, and sex-specific protective strategies to reduce cumulative spinal stress in surgical professionals.

5.2 Recommendations and Future Work

Although this study provides foundational insights into the thoracolumbar spinal loading with surgical lead vest use, there are several limitations that must be acknowledged to guide future work.

The simulations were based on static, idealized postures, which do not capture micromovements, compensatory strategies, or dynamic muscle recruitment seen in real-life surgical movements, such as compensatory shifts. Joint reaction analysis provides a simplified approximation of load transfer, and does not account for spinal curvature, intervertebral disc behavior, or long-term tissue adaptation. Future work should incorporate dynamic motion capture datasets, including force plate and EMG recordings, to improve the realism and physiological accuracy of model outputs.

Additionally, while this model approximated the best weight by applying a mass at a fixed point anterior to torso segments, it does not account for vest motion, vest fitting, inertia, or friction. These factors may influence the distribution of load, especially in postural transitions. These limitations can be addressed by applying external force vectors, based on real time vest displacement and subject to specific motion profiles to capture shifting biomechanics and accurate load distribution.

At present, this model serves as a synthetic representation of surgical posture and vest loading, intended to explore trends rather than replicate individual conditions. Ultimate validation will require empirical marker and force data from live participants wearing weighted vests during similar postures, serving to confirm the magnitude and location of joint reaction forces predicted by the simulations. In the interim, benchmarking against known OpenSim tutorials and experimental trends provides confidence in model functionality and force trends, but not in absolute accuracy [30].

Another promising avenue for future work is the integration of muscle force analysis, particularly at key spinal levels like L5-S1. This could be done by further exploring the results of OpenSim's static optimization or running Computed Muscle Control (CMC) to estimate the contribution of specific muscles that stabilize the spine under loads, like the multifidus, erector spinae, quadratus lumborum. Parametric studies could assess how targeted strengthening of these muscles might mitigate peak joint forces during vest use. These findings could be used to inform clinical protocols, developed in collaboration with physical and occupational therapists, aimed at reducing injury risk through core muscle training and spinal stability exercises tailored to proceduralists. Such training may be particularly relevant for female surgical staff, who may experience disproportionately higher normalized spinal loads.

This study used average male and female models, but spinal load distribution can vary significantly based on age, BMI, height, muscle mass, and body composition. Future efforts should explore these factors using a range of anthropometrically scaled models to improve generalizability as well as collecting data and specifically measuring the surgical population. The inclusion of older individuals or those with previous spinal injury history may also shed light on high-risk subgroups.

In summary, while this model provides a robust framework for understanding thoracolumbar loading trends in surgical postures, its greatest strength lies in its potential to inform both clinical training and ergonomic product development. With further validation and integration of dynamic, in vivo data, this line of research may significantly advance occupational health outcomes in surgical environments.

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Appendix

Appendix: A- DOF and Locked Joints Table

Table A. 1: DOF and Locked Joints

This table lists the additional joints locked beyond those pre-locked in the model download. Notations _r and _l indicate right and left sides of the body, respectively. Rotational DOFs are denoted by terms such as angle, rotation, or tilt, while translational DOFs along the X, Y, or Z axes are indicated by tx, ty, or tz, respectively.

Joint (Coordinate)	**Description**
knee_angle_l, knee_angle_r	Knee flexion/ extension angle
ankle_angle_l, ankle_angle_r	Ankle plantarflexion/dorsiflexion angle
hip_adduction_l, hip_adduction_r	Hip motion in the frontal plane. Ex. leg moving towards the midline. The legs position does not move in any of these motions.
hip_rotation_l, hip_rotation_r	Internal/external rotation of hip.
wrist_flex_l, wrist_flex_r	Flexion/Extension of the wrist.
wrist_dev_l, wrist_dev_r	Radial/ulnar deviation of the wrist.
pro_sup_l, pro_sup_r	Pronation/supination of the forearm.
shoulder_elv_l, shoulder_elv_r	Shoulder elevation
sternumx, sternumy, sternumz	Translational positions of the sternum the directions: X- lateral, Y-vertical, Z-anterior/posterior
pelvis_tx	Translation of the pelvis in the X-direction, medial-lateral.
pelvis_ty	Vertical position of the pelvis, Y-axis
pelvis_tz	Translation of pelvis in the Z direction, anterior-posterior.
pelvis_list	Frontal plane rotation or the side-to-side tilt of the pelvis.
pelvis_tilt	Sagittal plane rotation or the anterior-posterior tilt of the pelvis.

Appendix: B- MATLAB CODE

Appendix B.1- Create Actuators Function File

```
function createActuatorsFile(modelpath)

%% Function to generate a generic OpenSim Actuator File from a Model by

%  identifying the coordinates that are connected to ground and placing

%  point or torque actuators on translational or rotational coordinates,

%  respectively. All other coordiantes will get coordinate actuators.

%  Any constrained coordinates will be ignored.

%  File is Printed to the same folder as the selected Model.

%

% Inputs - 'modelpath', path to an OSIM file (string)

%

% e.g. createActuatorsFile('myInputModel.osim')


% ----------------------------------------------------------------------- %

% The OpenSim API is a toolkit for musculoskeletal modeling and           %

% simulation. See http://opensim.stanford.edu and the NOTICE file         %

% for more information. OpenSim is developed at Stanford University       %

% and supported by the US National Institutes of Health (U54 GM072970,    %

% R24 HD065690) and by DARPA through the Warrior Web program.             %

%                                                                         %

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% Author(s): James Dunne                                                  %

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% ----------------------------------------------------------------------- %
```

```
% Author: James Dunne, Tom Uchida.

%% Import OpenSim Libraries
import org.opensim.modeling.*

%% If no model is input, get a path to one.
display('Loading the model...');
if nargin < 1
    [pathname,filename] = uigetfile('*.osim', 'PSelect an OpenSim Model File');
    modelpath = fullfile(filename,pathname);
elseif nargin > 1
    error('Too many inputs to function. Input is Model path');
end

%% Instantiate the model
model = Model(modelpath);

%% Instantiate the underlying computational System and return a handle to the State
state = model.initSystem();

%% Get the number of coordinates  and a handle to the coordainte set
coordSet = model.getCoordinateSet();
nCoord = coordSet.getSize();

%% Instantiate some empty vec3's for later.
massCenter = Vec3();
axisValues = Vec3();

%% Instantiate an empty Force set
forceSet = ForceSet();

%% Set the optimal force
optimalForce = 1;

%% Start going through the coordinates, creating an actuator for each
for iCoord = 0 : nCoord - 1

    % get a reference to the current coordinate
```

```
coordinate = coordSet.get(iCoord);
% If the coodinate is constrained (locked or prescribed), don't
% add an actuator
if coordinate.isConstrained(state)
   continue
end

% get the joint, parent and child names for the coordiante
joint = coordinate.getJoint();
parentName = joint.getParentFrame().getName();
childName = joint.getChildFrame().getName();

% If the coordinates parent body is connected to ground, we need to
% add residual actuators (torque or point).
if strcmp(parentName, model.getGround.getName() )

   % Custom and Free Joints have three translational and three
   % rotational coordinates.
   if strcmp(joint.getConcreteClassName(), 'CustomJoint') || strcmp(joint.getConcreteClassName(), 'FreeJoint')
        % get the coordainte motion type
        motion = char(coordinate.getMotionType());
        % to get the axis value for the coordinate, we need to drill
        % down into the coordinate transform axis
        eval(['concreteJoint = ' char(joint.getConcreteClassName()) '.safeDownCast(joint);'])
        sptr = concreteJoint.getSpatialTransform();
        for ip = 0 : 5
          if strcmp(char(sptr.getCoordinateNames().get(ip)), char(coordinate.getName))
               sptr.getTransformAxis(ip).getAxis(axisValues);
               break
          end
        end



        % make a torque actuator if a rotational coordinate
        if strcmp(motion, 'Rotational')
           newActuator = TorqueActuator(joint.getParentFrame(),...
                           joint.getParentFrame(),...
                           axisValues);
```

```
        % make a point actuator if a translational coordinate.
        elseif strcmp(motion, 'translational')
            % make a new Point actuator
            newActuator = PointActuator();
            % set the body
            newActuator.set_body(char(joint.getChildFrame().getName()))
            % set point that forces acts at
            newActuator.set_point(massCenter)
            % the point is expressed in the local
            newActuator.set_point_is_global(false)
            % set the direction that actuator will act in
            newActuator.set_direction(axisValues)
            % the force is expressed in the global
            newActuator.set_force_is_global(true)
        else % something else that we don't support right now
            newActuator = CoordinateActuator();
        end
    else % if the joint type is not free or custom, just add coordinate actuators
        % make a new coordinate actuator for that coordinate
        newActuator = CoordinateActuator();
    end

else % the coordinate is not connected to ground, and can just be a
    % coordinate actuator.
    newActuator = CoordinateActuator( char(coordinate.getName) );
end

% set the optimal force for that coordinate
newActuator.setOptimalForce(optimalForce);
% set the actuator name
newActuator.setName( coordinate.getName() );
% set min and max controls
newActuator.setMaxControl(Inf)
newActuator.setMinControl(-Inf)

% append the new actuator onto the empty force set
forceSet.cloneAndAppend(newActuator);
```

```
end


%% Print Actuators to file.

% Get the file parts

[pathname,filename,ext] = fileparts(modelpath);

% Make the print path

printPath = fullfile(pathname, [filename '_actuators.xml']);

%% Print the actuators xml file

forceSet.print(printPath);

%% Display printed file

display(['Printed actuators to ' printPath])


end
```

Appendix B.2- Male Actuators File


```xml
<?xml version="1.0" encoding="UTF-8" ?>
<OpenSimDocument Version="40500">
	<ForceSet>
		<objects>
			<CoordinateActuator name="pelvis_rotation">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>pelvis_rotation</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="pelvis_tilt">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>pelvis_tilt</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="pelvis_list">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>pelvis_list</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="Abs_FE">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
```

```
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>Abs_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="Abs_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>Abs_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="Abs_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>Abs_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L5_S1_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L5_S1_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L5_S1_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
```

```xml
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L5_S1_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L5_S1_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L5_S1_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L4_L5_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L4_L5_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L4_L5_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L4_L5_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L4_L5_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
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```
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L4_L5_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L3_L4_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L3_L4_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L3_L4_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L3_L4_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L3_L4_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L3_L4_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L2_L3_FE">
```

```
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L2_L3_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L2_L3_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L2_L3_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L2_L3_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L2_L3_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L1_L2_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L1_L2_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
```

```xml
<CoordinateActuator name="L1_L2_LB">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>L1_L2_LB</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L1_L2_AR">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>L1_L2_AR</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T12_L1_FE">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>T12_L1_FE</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T12_L1_LB">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>T12_L1_LB</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
```

```
</CoordinateActuator>
<CoordinateActuator name="T12_L1_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T12_L1_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_T12_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T11_T12_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_T12_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T11_T12_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_T12_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T11_T12_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
```

```
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T10_T11_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T10_T11_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T10_T11_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T10_T11_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T10_T11_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T10_T11_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T9_T10_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T9_T10_FE</coordinate>
```

<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T9_T10_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T9_T10_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T9_T10_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T9_T10_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T8_T9_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T8_T9_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T8_T9_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->

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		<coordinate>T8_T9_LB</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T8_T9_AR">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T8_T9_AR</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T7_T8_FE">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T7_T8_FE</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T7_T8_LB">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T7_T8_LB</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T7_T8_AR">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
```

```xml
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T7_T8_AR</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T6_T7_FE">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T6_T7_FE</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T6_T7_LB">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T6_T7_LB</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T6_T7_AR">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T6_T7_AR</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T5_T6_FE">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
```

```
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T5_T6_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T5_T6_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T5_T6_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T5_T6_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T5_T6_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T4_T5_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T4_T5_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T4_T5_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
```

```
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T4_T5_LB</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T4_T5_AR">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T4_T5_AR</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T3_T4_FE">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T3_T4_FE</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T3_T4_LB">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T3_T4_LB</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T3_T4_AR">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
```

```xml
		<min_control>-Inf</min_control>

		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

		<max_control>Inf</max_control>

		<!--Name of the generalized coordinate to which the actuator applies.-->

		<coordinate>T3_T4_AR</coordinate>

		<!--The maximum generalized force produced by this actuator.-->

		<optimal_force>250</optimal_force>

	</CoordinateActuator>

	<CoordinateActuator name="T2_T3_FE">

		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

		<min_control>-Inf</min_control>

		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

		<max_control>Inf</max_control>

		<!--Name of the generalized coordinate to which the actuator applies.-->

		<coordinate>T2_T3_FE</coordinate>

		<!--The maximum generalized force produced by this actuator.-->

		<optimal_force>250</optimal_force>

	</CoordinateActuator>

	<CoordinateActuator name="T2_T3_LB">

		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

		<min_control>-Inf</min_control>

		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

		<max_control>Inf</max_control>

		<!--Name of the generalized coordinate to which the actuator applies.-->

		<coordinate>T2_T3_LB</coordinate>

		<!--The maximum generalized force produced by this actuator.-->

		<optimal_force>250</optimal_force>

	</CoordinateActuator>

	<CoordinateActuator name="T2_T3_AR">

		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

		<min_control>-Inf</min_control>

		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

		<max_control>Inf</max_control>

		<!--Name of the generalized coordinate to which the actuator applies.-->

		<coordinate>T2_T3_AR</coordinate>

		<!--The maximum generalized force produced by this actuator.-->

		<optimal_force>250</optimal_force>

	</CoordinateActuator>

	<CoordinateActuator name="T1_T2_FE">
```

<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

<min_control>-Inf</min_control>

<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

<max_control>Inf</max_control>

<!--Name of the generalized coordinate to which the actuator applies.-->

<coordinate>T1_T2_FE</coordinate>

<!--The maximum generalized force produced by this actuator.-->

<optimal_force>250</optimal_force>

</CoordinateActuator>

<CoordinateActuator name="T1_T2_LB">

<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

<min_control>-Inf</min_control>

<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

<max_control>Inf</max_control>

<!--Name of the generalized coordinate to which the actuator applies.-->

<coordinate>T1_T2_LB</coordinate>

<!--The maximum generalized force produced by this actuator.-->

<optimal_force>250</optimal_force>

</CoordinateActuator>

<CoordinateActuator name="T1_T2_AR">

<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

<min_control>-Inf</min_control>

<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

<max_control>Inf</max_control>

<!--Name of the generalized coordinate to which the actuator applies.-->

<coordinate>T1_T2_AR</coordinate>

<!--The maximum generalized force produced by this actuator.-->

<optimal_force>250</optimal_force>

</CoordinateActuator>

<CoordinateActuator name="T1_head_neck_FE">

<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->

<min_control>-Inf</min_control>

<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->

<max_control>Inf</max_control>

<!--Name of the generalized coordinate to which the actuator applies.-->

<coordinate>T1_head_neck_FE</coordinate>

<!--The maximum generalized force produced by this actuator.-->

<optimal_force>250</optimal_force>

</CoordinateActuator>

```
<CoordinateActuator name="T1_head_neck_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T1_head_neck_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T1_head_neck_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T1_head_neck_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="SternumRotZ">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>SternumRotZ</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="SternumRotX">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>SternumRotX</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
```

```xml
				</CoordinateActuator>
				<CoordinateActuator name="SternumRotY">
					<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
					<min_control>-Inf</min_control>
					<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
					<max_control>Inf</max_control>
					<!--Name of the generalized coordinate to which the actuator applies.-->
					<coordinate>SternumRotY</coordinate>
					<!--The maximum generalized force produced by this actuator.-->
					<optimal_force>250</optimal_force>
				</CoordinateActuator>
			</objects>
			<groups />
		</ForceSet>
</OpenSimDocument>
```

Appendix B.3- Female Actuators File


```xml
<?xml version="1.0" encoding="UTF-8" ?>
<OpenSimDocument Version="40500">
	<ForceSet>
		<objects>
			<CoordinateActuator name="pelvis_rotation">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>pelvis_rotation</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="pelvis_tilt">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>pelvis_tilt</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="pelvis_list">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>pelvis_list</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="pelvis_tx">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
```

```xml
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>pelvis_tx</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
    </CoordinateActuator>
    <CoordinateActuator name="pelvis_ty">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>pelvis_ty</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
    </CoordinateActuator>
    <CoordinateActuator name="pelvis_tz">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>pelvis_tz</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
    </CoordinateActuator>
    <CoordinateActuator name="Abs_FE">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
        <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
        <max_control>Inf</max_control>
        <!--Name of the generalized coordinate to which the actuator applies.-->
        <coordinate>Abs_FE</coordinate>
        <!--The maximum generalized force produced by this actuator.-->
        <optimal_force>250</optimal_force>
    </CoordinateActuator>
    <CoordinateActuator name="Abs_LB">
        <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
        <min_control>-Inf</min_control>
```

```xml
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>Abs_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="Abs_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>Abs_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L5_S1_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L5_S1_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L5_S1_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>L5_S1_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L5_S1_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
```

```xml
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L5_S1_AR</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L4_L5_FE">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L4_L5_FE</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L4_L5_LB">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L4_L5_LB</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L4_L5_AR">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L4_L5_AR</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L3_L4_FE">
```

```xml
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L3_L4_FE</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L3_L4_LB">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L3_L4_LB</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L3_L4_AR">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L3_L4_AR</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="L2_L3_FE">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>L2_L3_FE</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
```

```xml
<CoordinateActuator name="L2_L3_LB">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>L2_L3_LB</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L2_L3_AR">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>L2_L3_AR</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L1_L2_FE">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>L1_L2_FE</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="L1_L2_LB">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>L1_L2_LB</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
```

```xml
</CoordinateActuator>
<CoordinateActuator name="L1_L2_AR">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>L1_L2_AR</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T12_L1_FE">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T12_L1_FE</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T12_L1_LB">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T12_L1_LB</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T12_L1_AR">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T12_L1_AR</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
```

```xml
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_T12_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T11_T12_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_T12_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T11_T12_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_T12_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T11_T12_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T10_T11_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T10_T11_FE</coordinate>
```

```
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T10_T11_LB">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T10_T11_LB</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T10_T11_AR">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T10_T11_AR</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T9_T10_FE">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T9_T10_FE</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T9_T10_LB">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
```

```xml
				&lt;coordinate&gt;T9_T10_LB&lt;/coordinate&gt;
				&lt;!--The maximum generalized force produced by this actuator.--&gt;
				&lt;optimal_force&gt;250&lt;/optimal_force&gt;
			&lt;/CoordinateActuator&gt;
			&lt;CoordinateActuator name="T9_T10_AR"&gt;
				&lt;!--Minimum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;min_control&gt;-Inf&lt;/min_control&gt;
				&lt;!--Maximum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;max_control&gt;Inf&lt;/max_control&gt;
				&lt;!--Name of the generalized coordinate to which the actuator applies.--&gt;
				&lt;coordinate&gt;T9_T10_AR&lt;/coordinate&gt;
				&lt;!--The maximum generalized force produced by this actuator.--&gt;
				&lt;optimal_force&gt;250&lt;/optimal_force&gt;
			&lt;/CoordinateActuator&gt;
			&lt;CoordinateActuator name="T8_T9_FE"&gt;
				&lt;!--Minimum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;min_control&gt;-Inf&lt;/min_control&gt;
				&lt;!--Maximum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;max_control&gt;Inf&lt;/max_control&gt;
				&lt;!--Name of the generalized coordinate to which the actuator applies.--&gt;
				&lt;coordinate&gt;T8_T9_FE&lt;/coordinate&gt;
				&lt;!--The maximum generalized force produced by this actuator.--&gt;
				&lt;optimal_force&gt;250&lt;/optimal_force&gt;
			&lt;/CoordinateActuator&gt;
			&lt;CoordinateActuator name="T8_T9_LB"&gt;
				&lt;!--Minimum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;min_control&gt;-Inf&lt;/min_control&gt;
				&lt;!--Maximum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;max_control&gt;Inf&lt;/max_control&gt;
				&lt;!--Name of the generalized coordinate to which the actuator applies.--&gt;
				&lt;coordinate&gt;T8_T9_LB&lt;/coordinate&gt;
				&lt;!--The maximum generalized force produced by this actuator.--&gt;
				&lt;optimal_force&gt;250&lt;/optimal_force&gt;
			&lt;/CoordinateActuator&gt;
			&lt;CoordinateActuator name="T8_T9_AR"&gt;
				&lt;!--Minimum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;min_control&gt;-Inf&lt;/min_control&gt;
				&lt;!--Maximum allowed value for control signal. Used primarily when solving for control values.--&gt;
				&lt;max_control&gt;Inf&lt;/max_control&gt;
```

```
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T8_T9_AR</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T7_T8_FE">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T7_T8_FE</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T7_T8_LB">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T7_T8_LB</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T7_T8_AR">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
            <max_control>Inf</max_control>
            <!--Name of the generalized coordinate to which the actuator applies.-->
            <coordinate>T7_T8_AR</coordinate>
            <!--The maximum generalized force produced by this actuator.-->
            <optimal_force>250</optimal_force>
        </CoordinateActuator>
        <CoordinateActuator name="T6_T7_FE">
            <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
            <min_control>-Inf</min_control>
            <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
```

```
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T6_T7_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T6_T7_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T6_T7_LB</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T6_T7_AR">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T6_T7_AR</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T5_T6_FE">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T5_T6_FE</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T5_T6_LB">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
```

```xml
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T5_T6_LB</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T5_T6_AR">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T5_T6_AR</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T4_T5_FE">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T4_T5_FE</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T4_T5_LB">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T4_T5_LB</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T4_T5_AR">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
```

```
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>T4_T5_AR</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="T3_T4_FE">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>T3_T4_FE</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="T3_T4_LB">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>T3_T4_LB</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="T3_T4_AR">
				<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
				<min_control>-Inf</min_control>
				<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
				<max_control>Inf</max_control>
				<!--Name of the generalized coordinate to which the actuator applies.-->
				<coordinate>T3_T4_AR</coordinate>
				<!--The maximum generalized force produced by this actuator.-->
				<optimal_force>250</optimal_force>
			</CoordinateActuator>
			<CoordinateActuator name="T2_T3_FE">
```

```
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T2_T3_FE</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T2_T3_LB">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T2_T3_LB</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T2_T3_AR">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T2_T3_AR</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T1_T2_FE">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T1_T2_FE</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
```

```xml
<CoordinateActuator name="T1_T2_LB">
	<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
	<min_control>-Inf</min_control>
	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>T1_T2_LB</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T1_T2_AR">
	<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
	<min_control>-Inf</min_control>
	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>T1_T2_AR</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T1_head_neck_FE">
	<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
	<min_control>-Inf</min_control>
	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>T1_head_neck_FE</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T1_head_neck_LB">
	<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
	<min_control>-Inf</min_control>
	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>T1_head_neck_LB</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
```

```xml
</CoordinateActuator>
<CoordinateActuator name="T1_head_neck_AR">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T1_head_neck_AR</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T12_r12R_X">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T12_r12R_X</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T11_r11R_X">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T11_r11R_X</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
    <optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T10_r10R_X">
    <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
    <min_control>-Inf</min_control>
    <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
    <max_control>Inf</max_control>
    <!--Name of the generalized coordinate to which the actuator applies.-->
    <coordinate>T10_r10R_X</coordinate>
    <!--The maximum generalized force produced by this actuator.-->
```

```xml
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T9_r9R_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T9_r9R_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T8_r8R_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T8_r8R_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T7_r7R_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T7_r7R_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T6_r6R_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T6_r6R_X</coordinate>
```

```xml
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T5_r5R_X">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T5_r5R_X</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T4_r4R_X">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T4_r4R_X</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T3_r3R_X">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T3_r3R_X</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T2_r2R_X">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
```

```
			<coordinate>T2_r2R_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T1_r1R_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T1_r1R_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T12_r12L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T12_r12L_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T11_r11L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T11_r11L_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T10_r10L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
```

```xml
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T10_r10L_X</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T9_r9L_X">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T9_r9L_X</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T8_r8L_X">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T8_r8L_X</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T7_r7L_X">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
		<max_control>Inf</max_control>
		<!--Name of the generalized coordinate to which the actuator applies.-->
		<coordinate>T7_r7L_X</coordinate>
		<!--The maximum generalized force produced by this actuator.-->
		<optimal_force>250</optimal_force>
	</CoordinateActuator>
	<CoordinateActuator name="T6_r6L_X">
		<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
		<min_control>-Inf</min_control>
		<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
```

```xml
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T6_r6L_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T5_r5L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T5_r5L_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T4_r4L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T4_r4L_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T3_r3L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
			<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
			<max_control>Inf</max_control>
			<!--Name of the generalized coordinate to which the actuator applies.-->
			<coordinate>T3_r3L_X</coordinate>
			<!--The maximum generalized force produced by this actuator.-->
			<optimal_force>250</optimal_force>
		</CoordinateActuator>
		<CoordinateActuator name="T2_r2L_X">
			<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
			<min_control>-Inf</min_control>
```

```
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T2_r2L_X</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="T1_r1L_X">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>T1_r1L_X</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="SternumRotZ">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>SternumRotZ</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="SternumRotX">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>SternumRotX</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="SternumRotY">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
```

```xml
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>SternumRotY</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="shoulder_elv_r">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>shoulder_elv_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="shoulder_rot_r">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>shoulder_rot_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="elv_angle_r">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>elv_angle_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="elbow_flexion_r">
```

```xml
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>elbow_flexion_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="shoulder_elv_l">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>shoulder_elv_l</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="shoulder_rot_l">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>shoulder_rot_l</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="elv_angle_l">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>elv_angle_l</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
```

```
<CoordinateActuator name="elbow_flexion_l">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>elbow_flexion_l</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="hip_flexion_r">
<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>hip_flexion_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="hip_adduction_r">
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<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>hip_adduction_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
</CoordinateActuator>
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<min_control>-Inf</min_control>
<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
<max_control>Inf</max_control>
<!--Name of the generalized coordinate to which the actuator applies.-->
<coordinate>hip_rotation_r</coordinate>
<!--The maximum generalized force produced by this actuator.-->
<optimal_force>250</optimal_force>
```

```xml
</CoordinateActuator>
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	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
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	<!--Name of the generalized coordinate to which the actuator applies.-->
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	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
</CoordinateActuator>
<CoordinateActuator name="ankle_angle_r">
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	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>ankle_angle_r</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
</CoordinateActuator>
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	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>hip_flexion_l</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
	<optimal_force>250</optimal_force>
</CoordinateActuator>
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	<!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
	<min_control>-Inf</min_control>
	<!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
	<max_control>Inf</max_control>
	<!--Name of the generalized coordinate to which the actuator applies.-->
	<coordinate>hip_adduction_l</coordinate>
	<!--The maximum generalized force produced by this actuator.-->
```

```xml
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                <max_control>Inf</max_control>
                <!--Name of the generalized coordinate to which the actuator applies.-->
                <coordinate>hip_rotation_l</coordinate>
                <!--The maximum generalized force produced by this actuator.-->
                <optimal_force>250</optimal_force>
            </CoordinateActuator>
            <CoordinateActuator name="knee_angle_l">
                <!--Minimum allowed value for control signal. Used primarily when solving for control values.-->
                <min_control>-Inf</min_control>
                <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
                <max_control>Inf</max_control>
                <!--Name of the generalized coordinate to which the actuator applies.-->
                <coordinate>knee_angle_l</coordinate>
                <!--The maximum generalized force produced by this actuator.-->
                <optimal_force>250</optimal_force>
            </CoordinateActuator>
            <CoordinateActuator name="ankle_angle_l">
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                <!--Maximum allowed value for control signal. Used primarily when solving for control values.-->
                <max_control>Inf</max_control>
                <!--Name of the generalized coordinate to which the actuator applies.-->
                <coordinate>ankle_angle_l</coordinate>
                <!--The maximum generalized force produced by this actuator.-->
                <optimal_force>250</optimal_force>
            </CoordinateActuator>
        </objects>
        <groups />
    </ForceSet>
</OpenSimDocument>
```

Appendix B.4- Example Motion File, Joint Kinematics(.mot)- 1️⃣ Motion One

```
NMB_Motion1

version=1

nRows=11

nColumns=151

inDegrees=yes

endheader

time  pelvic_tilt  Abs_FE  Abs_LB  Abs_AR  L5_S1_FE  L5_S1_LB  L5_S1_AR  L4_L5_FE  L4_L5_LB  L4_L5_AR  L3_L4_FE  L3_L4_LB
L3_L4_AR  L2_L3_FE  L2_L3_LB  L2_L3_AR  L1_L2_FE  L1_L2_LB  L1_L2_AR  T12_L1_FE  T12_L1_LB  T12_L1_AR  T11_T12_FE
T11_T12_LB  T11_T12_AR  T10_T11_FE  T10_T11_LB  T10_T11_AR  T9_T10_FE  T9_T10_LB  T9_T10_AR  T8_T9_FE  T8_T9_LB  T8_T9_AR  T7_T8_FE
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T3_T4_LB  T3_T4_AR  T2_T3_FE  T2_T3_LB  T2_T3_AR  T1_T2_FE  T1_T2_LB  T1_T2_AR  T1_head_neck_FE  T1_head_neck_LB
T1_head_neck_AR  T12_r12R_X  T12_r12R_Y  T12_r12R_Z  T11_r11R_X  T11_r11R_Y  T11_r11R_Z  T10_r10R_X  T10_r10R_Y  T10_r10R_Z  T9_r9R_X
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T5_r5R_Y  T5_r5R_Z  T4_r4R_X  T4_r4R_Y  T4_r4R_Z  T3_r3R_X  T3_r3R_Y  T3_r3R_Z  T2_r2R_X  T2_r2R_Y  T2_r2R_Z  T1_r1R_X
T1_r1R_Y  T1_r1R_Z  T12_r12L_X  T12_r12L_Y  T12_r12L_Z  T11_r11L_X  T11_r11L_Y  T11_r11L_Z  T10_r10L_X  T10_r10L_Y  T10_r10L_Z  T9_r9L_X
T9_r9L_Y  T9_r9L_Z  T8_r8L_X  T8_r8L_Y  T8_r8L_Z  T7_r7L_X  T7_r7L_Y  T7_r7L_Z  T6_r6L_X  T6_r6L_Y  T6_r6L_Z  T5_r5L_X
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T1_r1L_Y  T1_r1L_Z  SternumX  SternumY  SternumZ  SternumRotX  SternumRotY  SternumRotZ  shoulder_elv_r  shoulder_rot_r  elv_angle_r
elbow_flexion_r  pro_sup_r  wrist_dev_r  wrist_flex_r  shoulder_elv_l  shoulder_rot_l  elv_angle_l  elbow_flexion_l  pro_sup_l  wrist_dev_l  wrist_flex_l

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0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
```

Appendix B.5- Example External Force File (.mot)- 1️⃣Motion One

```
NMB_ExternalForce1
version=1
nRows=11
nColumns=25
inDegrees=yes
endheader
time	Hand_R_Force_x	Hand_R_Force_y	Hand_R_Force_z	Hand_R_pt_x	Hand_R_pt_y	Hand_R_pt_z	Hand_L_Force_x	Hand_L_Force_y	Hand_L_Force_z	Hand_L_pt_x	Hand_L_pt_y	Hand_L_pt_z	scapula_R_Force_x	scapula_R_Force_y	scapula_R_Force_z	scapula_R_pt_x	scapula_R_pt_y	scapula_R_pt_z	scapula_L_Force_x	scapula_L_Force_y	scapula_L_Force_z	scapula_L_pt_x	scapula_L_pt_y	scapula_L_pt_z
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.10000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.20000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.30000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.40000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.50000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.60000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.70000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.80000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.90000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
```

Appendix B.6- External Loads Setup File (.xml)- 3️⃣Motion Three

```
<?xml version="1.0" encoding="UTF-8" ?>

<OpenSimDocument Version="40500">

        <ExternalLoads name="externalloads">

                <objects>

                        <ExternalForce name="hand_R">

                                <!--Name of the body the force is applied to.-->

                                <applied_to_body>hand_R</applied_to_body>

                                <!--Name of the body the force is expressed in (default is ground).-->

                                <force_expressed_in_body>ground</force_expressed_in_body>

                                <!--Name of the body the point is expressed in (default is ground).-->

                                <point_expressed_in_body>hand_R</point_expressed_in_body>

                                <!--Identifier (string) to locate the force to be applied in the data source.-->

                                <force_identifier>Hand_R_Force_</force_identifier>

                                <!--Identifier (string) to locate the point to be applied in the data source.-->

                                <point_identifier>Hand_R_pt_</point_identifier>

                                <!--Identifier (string) to locate the torque to be applied in the data source.-->

                                <torque_identifier></torque_identifier>

                                <!--Name of the data source (Storage) that will supply the force data.-->

                                <data_source_name>NMB_ExternalForce3</data_source_name>

                        </ExternalForce>

                        <ExternalForce name="hand_L">

                                <!--Name of the body the force is applied to.-->

                                <applied_to_body>hand_L</applied_to_body>

                                <!--Name of the body the force is expressed in (default is ground).-->

                                <force_expressed_in_body>ground</force_expressed_in_body>

                                <!--Name of the body the point is expressed in (default is ground).-->

                                <point_expressed_in_body>hand_L</point_expressed_in_body>

                                <!--Identifier (string) to locate the force to be applied in the data source.-->

                                <force_identifier>Hand_L_Force_</force_identifier>

                                <!--Identifier (string) to locate the point to be applied in the data source.-->

                                <point_identifier>Hand_L_pt_</point_identifier>

                                <!--Identifier (string) to locate the torque to be applied in the data source.-->

                                <torque_identifier></torque_identifier>

                                <!--Name of the data source (Storage) that will supply the force data.-->

                                <data_source_name>NMB_ExternalForce3</data_source_name>

                        </ExternalForce>

                </objects>

                <groups />

                <!--Storage file (.sto) containing (3) components of force and/or torque and point of application.Note: this file overrides the data source specified by the individual external forces if specified.--
>
```

```
			<datafile>/Users/mymac/Desktop/female/Mot3/NMB_ExternalForce3.mot</datafile>

		</ExternalLoads>

</OpenSimDocument>
```

Appendix B.7- SO Setup File (.xml)- 3️⃣Motion Three


```xml
<?xml version="1.0" encoding="UTF-8" ?>
<OpenSimDocument Version="40500">
	<AnalyzeTool name="mot3_female">
		<!--Name of the .osim file used to construct a model.-->
		<model_file />
		<!--Replace the model's force set with sets specified in <force_set_files>? If false, the force set is appended to.-->
		<replace_force_set>false</replace_force_set>
		<!--List of xml files used to construct a force set for the model.-->
		<force_set_files> ../FemaleFullBodyModel_v2.0_OS4_actuators.xml</force_set_files>
		<!--Directory used for writing results.-->
		<results_directory>/Users/mymac/Desktop/female/Mot3/Mot3_female_SOresults</results_directory>
		<!--Output precision.  It is 8 by default.-->
		<output_precision>8</output_precision>
		<!--Initial time for the simulation.-->
		<initial_time>0</initial_time>
		<!--Final time for the simulation.-->
		<final_time>1</final_time>
		<!--Flag indicating whether or not to compute equilibrium values for states other than the coordinates or speeds.  For example, equilibrium muscle fiber lengths or muscle forces.-->
		<solve_for_equilibrium_for_auxiliary_states>false</solve_for_equilibrium_for_auxiliary_states>
		<!--Maximum number of integrator steps.-->
		<maximum_number_of_integrator_steps>20000</maximum_number_of_integrator_steps>
		<!--Maximum integration step size.-->
		<maximum_integrator_step_size>1</maximum_integrator_step_size>
		<!--Minimum integration step size.-->
		<minimum_integrator_step_size>1e-08</minimum_integrator_step_size>
		<!--Integrator error tolerance. When the error is greater, the integrator step size is decreased.-->
		<integrator_error_tolerance>1.0000000000000001e-05</integrator_error_tolerance>
		<!--Set of analyses to be run during the investigation.-->
		<AnalysisSet name="Analyses">
			<objects>
				<StaticOptimization name="StaticOptimization">
					<!--Flag (true or false) specifying whether on. True by default.-->
					<on>true</on>
					<!--Start time.-->
					<start_time>0</start_time>
					<!--End time.-->
					<end_time>1</end_time>
					<!--Specifies how often to store results during a simulation. More specifically, the interval (a positive integer) specifies how many successful integration steps should be taken before results are recorded again.-->
					<step_interval>1</step_interval>
```

```
                    <!--Flag (true or false) indicating whether the results are in degrees or not.-->
                    <in_degrees>true</in_degrees>
                    <!--If true, the model's own force set will be used in the static optimization computation.  Otherwise, inverse dynamics for coordinate actuators will be computed for all unconstrained degrees of freedom.-->
                    <use_model_force_set>true</use_model_force_set>
                    <!--A double indicating the exponent to raise activations to when solving static optimization.  -->
                    <activation_exponent>3</activation_exponent>
                    <!--If true muscle force-length curve is observed while running optimization.-->
                    <use_muscle_physiology>true</use_muscle_physiology>
                    <!--Value used to determine when the optimization solution has converged-->
                    <optimizer_convergence_criterion>0.0001</optimizer_convergence_criterion>
                    <!--An integer for setting the maximum number of iterations the optimizer can use at each time.  -->
                    <optimizer_max_iterations>100</optimizer_max_iterations>
                </StaticOptimization>
            </objects>
            <groups />
        </AnalysisSet>
        <!--Controller objects in the model.-->
        <ControllerSet name="Controllers">
            <objects />
            <groups />
        </ControllerSet>
        <!--XML file (.xml) containing the forces applied to the model as ExternalLoads.-->
        <external_loads_file>Mot3_ExtforceSetup.xml</external_loads_file>
        <!--Storage file (.sto) containing the time history of states for the model. This file often contains multiple rows of data, each row being a time-stamped array of states. The first column contains the time.  The rest of the columns contain the states in the order appropriate for the model. In a storage file, unlike a motion file (.mot), non-uniform time spacing is allowed.  If the user-specified initial time for a simulation does not correspond exactly to one of the time stamps in this file, interpolation is NOT used because it is sometimes necessary to use an exact set of states for analyses.  Instead, the closest earlier set of states is used.-->
        <states_file />
        <!--Motion file (.mot) or storage file (.sto) containing the time history of the generalized coordinates for the model. These can be specified in place of the states file.-->
        <coordinates_file>NMB_Motion3.mot</coordinates_file>
        <!--Storage file (.sto) containing the time history of the generalized speeds for the model. If coordinates_file is used in place of states_file, these can be optionally set as well to give the speeds. If not specified, speeds will be computed from coordinates by differentiation.-->
        <speeds_file />
        <!--Low-pass cut-off frequency for filtering the coordinates_file data (currently does not apply to states_file or speeds_file). A negative value results in no filtering. The default value is -1.0, so no filtering.-->
        <lowpass_cutoff_frequency_for_coordinates>6</lowpass_cutoff_frequency_for_coordinates>
    </AnalyzeTool>
</OpenSimDocument>
```

Appendix B.8- JRA Setup File (.xml)


```xml
<?xml version="1.0" encoding="UTF-8" ?>
<OpenSimDocument Version="40500">
	<AnalyzeTool name="Mot3_female">
		<!--Name of the .osim file used to construct a model.-->
		<model_file />
		<!--Replace the model's force set with sets specified in <force_set_files>? If false, the force set is appended to.-->
		<replace_force_set>false</replace_force_set>
		<!--List of xml files used to construct a force set for the model.-->
		<force_set_files> ../FemaleFullBodyModel_v2.0_OS4_actuators.xml</force_set_files>
		<!--Directory used for writing results.-->
		<results_directory>/Users/mymac/Desktop/female/Mot3/Mot3_female_JRAresults</results_directory>
		<!--Output precision.  It is 8 by default.-->
		<output_precision>8</output_precision>
		<!--Initial time for the simulation.-->
		<initial_time>0</initial_time>
		<!--Final time for the simulation.-->
		<final_time>1</final_time>
		<!--Flag indicating whether or not to compute equilibrium values for states other than the coordinates or speeds.  For example, equilibrium muscle fiber lengths or muscle forces.-->
		<solve_for_equilibrium_for_auxiliary_states>false</solve_for_equilibrium_for_auxiliary_states>
		<!--Maximum number of integrator steps.-->
		<maximum_number_of_integrator_steps>20000</maximum_number_of_integrator_steps>
		<!--Maximum integration step size.-->
		<maximum_integrator_step_size>1</maximum_integrator_step_size>
		<!--Minimum integration step size.-->
		<minimum_integrator_step_size>1e-08</minimum_integrator_step_size>
		<!--Integrator error tolerance. When the error is greater, the integrator step size is decreased.-->
		<integrator_error_tolerance>1.0000000000000001e-05</integrator_error_tolerance>
		<!--Set of analyses to be run during the investigation.-->
		<AnalysisSet name="Analyses">
			<objects>
				<JointReaction name="JointReaction_child">
					<!--Flag (true or false) specifying whether on. True by default.-->
					<on>true</on>
					<!--Start time.-->
					<start_time>0</start_time>
					<!--End time.-->
					<end_time>1</end_time>
					<!--Specifies how often to store results during a simulation. More specifically, the interval (a positive integer) specifies how many successful integration steps should be taken before results are recorded again.-->
					<step_interval>1</step_interval>
```

```
<!--Flag (true or false) indicating whether the results are in degrees or not.-->
<in_degrees>true</in_degrees>
<!--The name of a file containing forces storage. If a file name is provided, the forces for all actuators will be applied according to values specified in the forces_file instead of being computed from the states. This option should be used to calculate joint reactions from static optimization results.-->
<forces_file>/Users/mymac/Desktop/female/Mot3/Mot3_female_SOresults/mot3_female_StaticOptimization_force.sto</forces_file>
<!--Names of the joints on which to perform the analysis. The key word 'All' indicates that the analysis should be performed for all joints.-->
<joint_names> L5_S1_IVDjnt L4_L5_IVDjnt L3_L4_IVDjnt L2_L3_IVDjnt L1_L2_IVDjnt T12_L1_IVDjnt T11_T12_IVDjnt T10_T11_IVDjnt T9_T10_IVDjnt T8_T9_IVDjnt T7_T8_IVDjnt T6_T7_IVDjnt T5_T6_IVDjnt T4_T5_IVDjnt T3_T4_IVDjnt T2_T3_IVDjnt T1_T2_IVDjnt</joint_names>
<!--Choice of body ('parent' or 'child') for which the reaction loads are calculated. Child body is default. The array must either have one entry or the same number of entries as joints specified above. If the array has one entry only, that selection is applied to all chosen joints.-->
<apply_on_bodies> child</apply_on_bodies>
<!--Names of frames in which the calculated reactions are expressed, or the keyword 'child' or 'parent' to indicate the joint's 'child' or 'parent' Frame. ground is default. If a Frame named 'child' or 'parent' exists and the keyword 'child' or 'parent' is used, the analysis will use that Frame. The array must either have one entry or the same number of entries as joints specified above. If the array has one entry only, that selection is applied to all chosen joints.-->
<express_in_frame> child</express_in_frame>
</JointReaction>
<JointReaction name="JointReaction_parent">
<!--Flag (true or false) specifying whether on. True by default.-->
<on>true</on>
<!--Start time.-->
<start_time>0</start_time>
<!--End time.-->
<end_time>1</end_time>
<!--Specifies how often to store results during a simulation. More specifically, the interval (a positive integer) specifies how many successful integration steps should be taken before results are recorded again.-->
<step_interval>1</step_interval>
<!--Flag (true or false) indicating whether the results are in degrees or not.-->
<in_degrees>true</in_degrees>
<!--The name of a file containing forces storage. If a file name is provided, the forces for all actuators will be applied according to values specified in the forces_file instead of being computed from the states. This option should be used to calculate joint reactions from static optimization results.-->
<forces_file>/Users/mymac/Desktop/female/Mot3/Mot3_female_SOresults/mot3_female_StaticOptimization_force.sto</forces_file>
<!--Names of the joints on which to perform the analysis. The key word 'All' indicates that the analysis should be performed for all joints.-->
<joint_names> L5_S1_IVDjnt L4_L5_IVDjnt L3_L4_IVDjnt L2_L3_IVDjnt L1_L2_IVDjnt T12_L1_IVDjnt T11_T12_IVDjnt T10_T11_IVDjnt T9_T10_IVDjnt T8_T9_IVDjnt T7_T8_IVDjnt T6_T7_IVDjnt T5_T6_IVDjnt T4_T5_IVDjnt T3_T4_IVDjnt T2_T3_IVDjnt T1_T2_IVDjnt</joint_names>
<!--Choice of body ('parent' or 'child') for which the reaction loads are calculated. Child body is default. The array must either have one entry or the same number of entries as joints specified above. If the array has one entry only, that selection is applied to all chosen joints.-->
<apply_on_bodies> parent</apply_on_bodies>
<!--Names of frames in which the calculated reactions are expressed, or the keyword 'child' or 'parent' to indicate the joint's 'child' or 'parent' Frame. ground is default. If a Frame named 'child' or 'parent' exists and the keyword 'child' or 'parent' is used, the analysis will use that Frame. The array must either have one entry or the same number of entries as joints specified above. If the array has one entry only, that selection is applied to all chosen joints.-->
<express_in_frame> parent</express_in_frame>
</JointReaction>
</objects>
<groups />
</AnalysisSet>
<!--Controller objects in the model.-->
<ControllerSet name="Controllers">
```

```
<objects>
<ControlSetController name="controlsetcontroller">
<!--A Storage (.sto) or an XML control nodes file containing the controls for this controlSet.-->
<controls_file>Mot3_female_SOresults/mot3_female_StaticOptimization_controls.xml</controls_file>
</ControlSetController>
</objects>
<groups />
</ControllerSet>
<!--XML file (.xml) containing the forces applied to the model as ExternalLoads.-->
<external_loads_file>Mot3_ExtforceSetup.xml</external_loads_file>
<!--Storage file (.sto) containing the time history of states for the model. This file often contains multiple rows of data, each row being a time-stamped array of states. The first column contains the time.  The rest of the columns contain the states in the order appropriate for the model. In a storage file, unlike a motion file (.mot), non-uniform time spacing is allowed.  If the user-specified initial time for a simulation does not correspond exactly to one of the time stamps in this file, interpolation is NOT used because it is sometimes necessary to use an exact set of states for analyses.  Instead, the closest earlier set of states is used.-->
<states_file />
<!--Motion file (.mot) or storage file (.sto) containing the time history of the generalized coordinates for the model. These can be specified in place of the states file.-->
<coordinates_file>NMB_Motion3.mot</coordinates_file>
<!--Storage file (.sto) containing the time history of the generalized speeds for the model. If coordinates_file is used in place of states_file, these can be optionally set as well to give the speeds. If not specified, speeds will be computed from coordinates by differentiation.-->
<speeds_file />
<!--Low-pass cut-off frequency for filtering the coordinates_file data (currently does not apply to states_file or speeds_file). A negative value results in no filtering. The default value is -1.0, so no filtering.-->
<lowpass_cutoff_frequency_for_coordinates>-1</lowpass_cutoff_frequency_for_coordinates>
</AnalyzeTool>
</OpenSimDocument>
```

Appendix B.9- JRA Example Result Parent and Child files (.sto)

These files are from the baseline 3️⃣Motion Three female trial.

Parent File

```
Joint Reaction Loads

version=1

nRows=11

nColumns=154

inDegrees=no



This file contains the reaction forces and moments

applied to the specified body of a joint pair and expressed  in the specified reference frame.



Units are S.I. units (seconds, meters, Newtons, ...)

endheader

time	L5_S1_IVDjnt_on_sacrum_in_sacrum_fx	L5_S1_IVDjnt_on_sacrum_in_sacrum_fy	L5_S1_IVDjnt_on_sacrum_in_sacrum_fz	L5_S1_IVDjnt_on_sacrum_in_sacrum_mx
	L5_S1_IVDjnt_on_sacrum_in_sacrum_my	L5_S1_IVDjnt_on_sacrum_in_sacrum_mz	L5_S1_IVDjnt_on_sacrum_in_sacrum_px	L5_S1_IVDjnt_on_sacrum_in_sacrum_py
	L5_S1_IVDjnt_on_sacrum_in_sacrum_pz	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_fx	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_fy	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_fz
	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_mx	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_my	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_mz	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_px
	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_py	L4_L5_IVDjnt_on_lumbar5_in_lumbar5_pz	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_fx	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_fy
	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_fz	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_mx	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_my	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_mz
	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_px	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_py	L3_L4_IVDjnt_on_lumbar4_in_lumbar4_pz	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_fx
	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_fy	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_fz	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_mx	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_my
	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_mz	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_px	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_py	L2_L3_IVDjnt_on_lumbar3_in_lumbar3_pz
	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_fx	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_fy	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_fz	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_mx
	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_my	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_mz	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_px	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_py
	L1_L2_IVDjnt_on_lumbar2_in_lumbar2_pz	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_fx	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_fy	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_fz
	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_mx	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_my	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_mz	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_px
	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_py	T12_L1_IVDjnt_on_lumbar1_in_lumbar1_pz	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_fx
	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_fy	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_fz	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_mx
	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_my	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_mz	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_px
	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_py	T11_T12_IVDjnt_on_thoracic12_in_thoracic12_pz	T10_T11_IVDjnt_on_thoracic11_in_thoracic11_fx
	T10_T11_IVDjnt_on_thoracic11_in_thoracic11_fy	T10_T11_IVDjnt_on_thoracic11_in_thoracic11_fz	T10_T11_IVDjnt_on_thoracic11_in_thoracic11_mx
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	T10_T11_IVDjnt_on_thoracic11_in_thoracic11_py	T10_T11_IVDjnt_on_thoracic11_in_thoracic11_pz	T9_T10_IVDjnt_on_thoracic10_in_thoracic10_fx
	T9_T10_IVDjnt_on_thoracic10_in_thoracic10_fy	T9_T10_IVDjnt_on_thoracic10_in_thoracic10_fz	T9_T10_IVDjnt_on_thoracic10_in_thoracic10_mx
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	T9_T10_IVDjnt_on_thoracic10_in_thoracic10_py	T9_T10_IVDjnt_on_thoracic10_in_thoracic10_pz	T8_T9_IVDjnt_on_thoracic9_in_thoracic9_fx	T8_T9_IVDjnt_on_thoracic9_in_thoracic9_fy
	T8_T9_IVDjnt_on_thoracic9_in_thoracic9_fz	T8_T9_IVDjnt_on_thoracic9_in_thoracic9_mx	T8_T9_IVDjnt_on_thoracic9_in_thoracic9_my	T8_T9_IVDjnt_on_thoracic9_in_thoracic9_mz
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	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_fy	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_fz	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_mx	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_my
	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_mz	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_px	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_py	T7_T8_IVDjnt_on_thoracic8_in_thoracic8_pz
	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_fx	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_fy	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_fz	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_mx
	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_my	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_mz	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_px	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_py
	T6_T7_IVDjnt_on_thoracic7_in_thoracic7_pz	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_fx	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_fy	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_fz
	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_mx	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_my	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_mz	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_px
	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_py	T5_T6_IVDjnt_on_thoracic6_in_thoracic6_pz	T4_T5_IVDjnt_on_thoracic5_in_thoracic5_fx	T4_T5_IVDjnt_on_thoracic5_in_thoracic5_fy
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	T4_T5_IVDjnt_on_thoracic5_in_thoracic5_px	T4_T5_IVDjnt_on_thoracic5_in_thoracic5_py	T4_T5_IVDjnt_on_thoracic5_in_thoracic5_pz	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_fx
	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_fy	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_fz	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_mx	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_my
	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_mz	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_px	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_py	T3_T4_IVDjnt_on_thoracic4_in_thoracic4_pz
	T2_T3_IVDjnt_on_thoracic3_in_thoracic3_fx	T2_T3_IVDjnt_on_thoracic3_in_thoracic3_fy	T2_T3_IVDjnt_on_thoracic3_in_thoracic3_fz	T2_T3_IVDjnt_on_thoracic3_in_thoracic3_mx
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	T1_T2_IVDjnt_on_thoracic2_in_thoracic2_py	T1_T2_IVDjnt_on_thoracic2_in_thoracic2_pz


   0.00000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680
0.00000000	-32.34559650	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074122	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200
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2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620
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   0.10000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680
0.00000000	-32.34559650	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620
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0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401996	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430791	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559650	-389.43964154	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399206	
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524960	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866135	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576271	-233.93674131	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071148	-209.79723098	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469990	-172.00713001	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420205	-168.60616654	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293001	-147.94871177	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122925	-131.01811472	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818195	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269053	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
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0.30000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721194	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559649	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208	
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
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0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559650	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208	
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15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127136	-94.15654859	-6.70583857	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

0.50000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721194	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559649	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208	
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127137	-94.15654859	-6.70583857	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

0.60000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559650	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208	
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127136	-94.15654859	-6.70583857	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

0.70000000	-60.01591762	-602.12364317	-0.77977755	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645236	-545.68439696	-
0.78549425	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401992	2.27094984	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430787	1.10251656	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559649	-389.43964150	0.49310384	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651169	-354.26399202	
0.83644726	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524956	-0.66074125	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889457	-267.05866131	0.09023712	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576271	-233.93674127	-0.36151069	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071146	-209.79723094	
0.16593971	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469989	-172.00712997	0.04819331	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420203	-168.60616650	-0.34417183	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30292998	-147.94871173	-0.31459851	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122920	-131.01811466	-
2.83088465	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818188	-113.78494249	-4.33569840	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269043	-99.40979802	-5.45821640	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127122	-94.15654855	-6.70583861	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

0.80000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559650	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208	
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127136	-94.15654859	-6.70583857	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

0.90000000	-60.01591762	-602.12364317	-0.77977757	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645236	-545.68439695	-
0.78549427	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721193	-466.05401991	2.27094982	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430786	1.10251654	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559649	-389.43964149	0.49310382	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651169	-354.26399202	
0.83644724	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524956	-0.66074126	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866130	0.09023710	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576271	-233.93674126	-0.36151071	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071147	-209.79723094	

0.16593969	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469989	-172.00712996	0.04819328	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420203	-168.60616649	-0.34417186	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30292998	-147.94871173	-0.31459853	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122920	-131.01811465	-
2.83088468	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818188	-113.78494249	-4.33569843	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269043	-99.40979802	-5.45821643	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127123	-94.15654854	-6.70583865	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

1.00000000	-60.01591761	-602.12364323	-0.77977754	0.02020364	-0.05034026	-11.37478948	-0.09800000	0.07100000	0.00000000	164.74645238	-545.68439701	-
0.78549424	0.06523841	-0.03945491	-5.90505680	0.00000000	0.03502990	0.00000000	19.64721194	-466.05401998	2.27094985	-0.01721116	0.11104481	-
9.21233055	0.00000000	0.03257040	0.00000000	-36.36274415	-421.20430793	1.10251658	-0.05038356	0.04268030	-11.39016775	-0.00000000	0.03253680	
0.00000000	-32.34559649	-389.43964156	0.49310386	-0.06587291	0.02846337	-12.83037420	0.00000000	0.03013840	0.00000000	-40.44651170	-354.26399208	
0.83644728	-0.08641144	0.04736009	-14.11608982	-0.00000000	0.03141540	0.00000000	-19.95417324	-305.66524962	-0.66074123	-0.13548384	-0.00697518	-
15.80382188	-0.00000000	0.02994630	0.00000000	9.31889458	-267.05866137	0.09023714	-0.12092755	0.00093978	-16.16293034	0.00000000	0.02614690	
0.00000000	70.31576272	-233.93674133	-0.36151066	-0.12404473	-0.02800111	-8.67446213	0.00000000	0.02566550	0.00000000	77.12071149	-209.79723100	
0.16593974	-0.11199165	-0.02575532	-7.59476885	0.00000000	0.02224490	0.00000000	67.88469992	-172.00713002	0.04819333	-0.11034926	-0.05395932	-
6.89166796	-0.00000000	0.02178470	0.00000000	68.77420207	-168.60616655	-0.34417180	-0.03258998	-0.03951602	-8.83744354	0.00000000	0.02295200	
0.00000000	79.30293003	-147.94871178	-0.31459847	0.08771659	0.16096758	-5.90681698	0.00000000	0.02272020	0.00000000	83.63122927	-131.01811473	-
2.83088462	0.18368081	0.40907296	-3.71438049	-0.00000000	0.02324670	0.00000000	91.69818197	-113.78494255	-4.33569837	0.25723498	0.60265762	-
1.49513176	0.00000000	0.02166080	0.00000000	93.63269055	-99.40979807	-5.45821636	0.33157160	0.77969976	0.32321630	0.00000000	0.01965620	
0.00000000	100.48127137	-94.15654859	-6.70583857	0.39818989	0.96706765	2.16015771	0.00000000	0.01794020	0.00000000			

Child File

Joint Reaction Loads

version=1

nRows=11

nColumns=154

inDegrees=no

This file contains the reaction forces and moments

applied to the specified body of a joint pair and expressed in the specified reference frame.

Units are S.I. units (seconds, meters, Newtons, ...)

endheader

time	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_fx	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_fy	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_fz	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_mx
	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_my	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_mz	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_px	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_py
	L5_S1_IVDjnt_on_lumbar5_in_lumbar5_pz	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_fx	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_fy	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_fz
	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_mx	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_my	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_mz	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_px
	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_py	L4_L5_IVDjnt_on_lumbar4_in_lumbar4_pz	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_fx	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_fy
	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_fz	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_mx	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_my	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_mz
	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_px	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_py	L3_L4_IVDjnt_on_lumbar3_in_lumbar3_pz	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_fx
	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_fy	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_fz	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_mx	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_my
	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_mz	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_px	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_py	L2_L3_IVDjnt_on_lumbar2_in_lumbar2_pz
	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_fx	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_fy	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_fz	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_mx
	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_my	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_mz	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_px	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_py
	L1_L2_IVDjnt_on_lumbar1_in_lumbar1_pz	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_fx	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_fy	
	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_fz	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_mx	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_my	
	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_mz	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_px	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_py	
	T12_L1_IVDjnt_on_thoracic12_in_thoracic12_pz	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_fx	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_fy	
	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_fz	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_mx	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_my	
	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_mz	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_px	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_py	
	T11_T12_IVDjnt_on_thoracic11_in_thoracic11_pz	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_fx	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_fy	
	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_fz	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_mx	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_my	
	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_mz	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_px	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_py	
	T10_T11_IVDjnt_on_thoracic10_in_thoracic10_pz	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_fx	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_fy	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_fz
	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_mx	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_my	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_mz	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_px
	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_py	T9_T10_IVDjnt_on_thoracic9_in_thoracic9_pz	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_fx	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_fy
	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_fz	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_mx	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_my	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_mz
	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_px	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_py	T8_T9_IVDjnt_on_thoracic8_in_thoracic8_pz	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_fx
	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_fy	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_fz	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_mx	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_my
	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_mz	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_px	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_py	T7_T8_IVDjnt_on_thoracic7_in_thoracic7_pz
	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_fx	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_fy	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_fz	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_mx
	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_my	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_mz	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_px	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_py
	T6_T7_IVDjnt_on_thoracic6_in_thoracic6_pz	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_fx	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_fy	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_fz
	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_mx	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_my	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_mz	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_px
	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_py	T5_T6_IVDjnt_on_thoracic5_in_thoracic5_pz	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_fx	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_fy
	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_fz	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_mx	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_my	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_mz
	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_px	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_py	T4_T5_IVDjnt_on_thoracic4_in_thoracic4_pz	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_fx
	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_fy	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_fz	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_mx	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_my
	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_mz	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_px	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_py	T3_T4_IVDjnt_on_thoracic3_in_thoracic3_pz
	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_fx	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_fy	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_fz	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_mx
	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_my	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_mz	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_px	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_py
	T2_T3_IVDjnt_on_thoracic2_in_thoracic2_pz	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_fx	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_fy	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_fz
	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_mx	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_my	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_mz	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_px
	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_py	T1_T2_IVDjnt_on_thoracic1_in_thoracic1_pz		

0.00000000	-168.36638452	581.21214085	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290440	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264722	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074122	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411123	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003349	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476507	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	

1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791756	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.10000000	-168.36638452	581.21214085	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290440	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264722	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411123	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476507	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791756	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.20000000	-168.36638451	581.21214083	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548561	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290438	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438171	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027293	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264720	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386047	306.09143232	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200086	264.32411121	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306629	226.97547797	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061767	200.64922274	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802714	162.50795618	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422157	159.27133280	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426220	137.78238017	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509491	120.46476506	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673605	105.98987869	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901891	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866363	91.23791755	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.30000000	-168.36638452	581.21214084	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752657	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290439	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012787	356.20264721	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411122	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476506	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791755	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.40000000	-168.36638452	581.21214085	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290440	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264722	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411123	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476507	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791756	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.50000000	-168.36638452	581.21214084	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752657	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290439	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012787	356.20264721	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411122	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476506	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791755	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.60000000	-168.36638452	581.21214085	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290440	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264722	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411123	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476507	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791756	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.70000000	-168.36638449	581.21214079	0.77977755	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548557	
0.78549425	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290434	-2.27094984	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961317	417.74438167	-1.10251656	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226724	387.88027289	-0.49310384	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264715	-
0.83644726	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386047	306.09143228	0.66074125	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200086	264.32411116	-0.09023712	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306628	226.97547793	0.36151069	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061765	200.64922270	-
0.16593971	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802712	162.50795614	-0.04819331	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422155	159.27133276	0.34417183	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426217	137.78238013	0.31459851	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509485	120.46476500	
2.83088465	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673597	105.98987864	4.33569840	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901880	93.26053199	5.45821640	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866350	91.23791752	6.70583861	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

0.80000000	-168.36638452	581.21214085	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290440	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012788	356.20264722	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	

15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411123	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476507	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791756	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			
0.90000000	-168.36638449	581.21214079	0.77977757	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752656	569.97548557	
0.78549427	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290433	-2.27094982	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961317	417.74438166	-1.10251654	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226724	387.88027289	-0.49310382	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012787	356.20264715	-
0.83644724	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386047	306.09143228	0.66074126	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200086	264.32411116	-0.09023710	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306628	226.97547793	0.36151071	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061765	200.64922269	-
0.16593969	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802712	162.50795613	-0.04819328	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422155	159.27133276	0.34417186	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426217	137.78238013	0.31459853	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509485	120.46476500	
2.83088468	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673597	105.98987864	4.33569843	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901881	93.26053198	5.45821643	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866350	91.23791751	6.70583865	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			
1.00000000	-168.36638452	581.21214084	0.77977754	-0.03748600	0.03920623	11.37478948	0.00000000	0.00000000	0.00000000	-6.38752657	569.97548563	
0.78549424	-0.05168214	0.05605084	5.90505680	0.00000000	0.00000000	0.00000000	56.42367555	463.04290439	-2.27094985	-0.00108082	-0.11236550	
9.21233055	0.00000000	0.00000000	0.00000000	64.99961318	417.74438173	-1.10251658	0.04735596	-0.04601656	11.39016775	0.00000000	0.00000000	
0.00000000	47.52226725	387.88027295	-0.49310386	0.06471167	-0.03101295	12.83037420	0.00000000	0.00000000	0.00000000	16.08012787	356.20264721	-
0.83644728	0.08945313	-0.04132858	14.11608982	0.00000000	0.00000000	0.00000000	-11.72386048	306.09143234	0.66074123	0.13403877	0.02093162	
15.80382188	0.00000000	0.00000000	0.00000000	-39.24200087	264.32411122	-0.09023714	0.12026855	0.01264240	16.16293034	0.00000000	0.00000000	
0.00000000	-90.29306630	226.97547799	0.36151066	0.12115679	0.03862887	8.67446213	0.00000000	0.00000000	0.00000000	-98.50061768	200.64922275	-
0.16593974	0.10870966	0.03725152	7.59476885	0.00000000	0.00000000	0.00000000	-88.23802715	162.50795619	-0.04819333	0.10299323	0.06693999	
6.89166796	0.00000000	0.00000000	0.00000000	-88.26422159	159.27133281	0.34417180	0.02767912	0.04309860	8.83744354	0.00000000	0.00000000	
0.00000000	-95.88426222	137.78238018	0.31459847	-0.06850818	-0.17003350	5.90681698	0.00000000	0.00000000	0.00000000	-98.22509493	120.46476506	
2.83088462	-0.13512915	-0.42757390	3.71438049	0.00000000	0.00000000	0.00000000	-100.60673607	105.98987870	4.33569837	-0.20761384	-0.62150023	
1.49513176	0.00000000	0.00000000	0.00000000	-99.75901893	93.26053203	5.45821636	-0.28136775	-0.79918936	-0.32321630	0.00000000	0.00000000	
0.00000000	-103.13866364	91.23791755	6.70583857	-0.37030864	-0.97808309	-2.16015771	0.00000000	0.00000000	0.00000000			

Appendix B.10- MATLAB post-processing and analysis function file

```
function Run_JRA_GroupAnalysis(childFiles, parentFiles, trialIDs, conditionLabel)

%with the percent change

    assert(length(childFiles) == length(parentFiles) && ...

           length(parentFiles) == length(trialIDs), ...

           'All input arrays must be the same length.');


    nTrials = length(childFiles);

    BW = 78 * 9.81;


    outDir = [conditionLabel '_GroupOutput'];

    if ~exist(outDir, 'dir')

        mkdir(outDir);

    end


    % Preload structure

    childData = importdata(childFiles{1}, '\t');

    fy_idx_c = find(contains(childData.colheaders, '_fy') & contains(childData.colheaders, 'IVDjnt'));

    nJoints = length(fy_idx_c);

    joint_labels = erase(childData.colheaders(fy_idx_c), '_fy');

    xlabels = cellfun(@(s) regexp(s, '^[A-Z]+\d+_[A-Z]+\d+', 'match', 'once'), ...

                      joint_labels, 'UniformOutput', false);

    xlabels = strrep(xlabels, '_', '-');


    % Allocate trial data

    comp_all = zeros(nTrials, nJoints);

    aps_all  = zeros(nTrials, nJoints);

    mls_all  = zeros(nTrials, nJoints);

    res_all  = zeros(nTrials, nJoints);


    %%  PROCESS EACH TRIAL

    for t = 1:nTrials

        childData = importdata(childFiles{t}, '\t');

        parentData = importdata(parentFiles{t}, '\t');


        fx_idx_c = find(contains(childData.colheaders, '_fx') & contains(childData.colheaders, 'IVDjnt'));

        fy_idx_c = find(contains(childData.colheaders, '_fy') & contains(childData.colheaders, 'IVDjnt'));

        fz_idx_c = find(contains(childData.colheaders, '_fz') & contains(childData.colheaders, 'IVDjnt'));


        fx_idx_p = find(contains(parentData.colheaders, '_fx') & contains(parentData.colheaders, 'IVDjnt'));
```

```
    fy_idx_p = find(contains(parentData.colheaders, '_fy') & contains(parentData.colheaders, 'IVDjnt'));

    fz_idx_p = find(contains(parentData.colheaders, '_fz') & contains(parentData.colheaders, 'IVDjnt'));


    nFrames = size(childData.data, 1);

    comp_force = zeros(nFrames, nJoints);

    ap_shear   = zeros(nFrames, nJoints);

    ml_shear   = zeros(nFrames, nJoints);

    resultant  = zeros(nFrames, nJoints);


    for j = 1:nJoints

        fx_c = childData.data(:, fx_idx_c(j));

        fy_c = childData.data(:, fy_idx_c(j));

        fz_c = childData.data(:, fz_idx_c(j));


        fx_p = parentData.data(:, fx_idx_p(j));

        fy_p = parentData.data(:, fy_idx_p(j));

        fz_p = parentData.data(:, fz_idx_p(j));


        for i = 1:nFrames

            sign_y = -1; if fy_p(i) <= 0, sign_y = 1; end

            sign_x = -1; if fx_p(i) <= 0, sign_x = 1; end

            sign_z = -1; if fz_p(i) <= 0, sign_z = 1; end


            comp_force(i,j) = sign_y * (abs(fy_c(i)) + abs(fy_p(i))) / 2;

            ml_shear(i,j) = sign_x * (abs(fx_c(i)) + abs(fx_p(i))) / 2;

            ap_shear(i,j) = sign_z * (abs(fz_c(i)) + abs(fz_p(i))) / 2;

            resultant(i,j) = sqrt(comp_force(i,j)^2 + ap_shear(i,j)^2 + ml_shear(i,j)^2);

        end

    end


    comp_all(t,:) = mean(comp_force, 1);

    aps_all(t,:)  = mean(ap_shear, 1);

    mls_all(t,:)  = mean(ml_shear, 1);

    res_all(t,:)  = mean(resultant, 1);

end


%%  PLOT PER TRIAL

forceData = {comp_all, aps_all, mls_all};

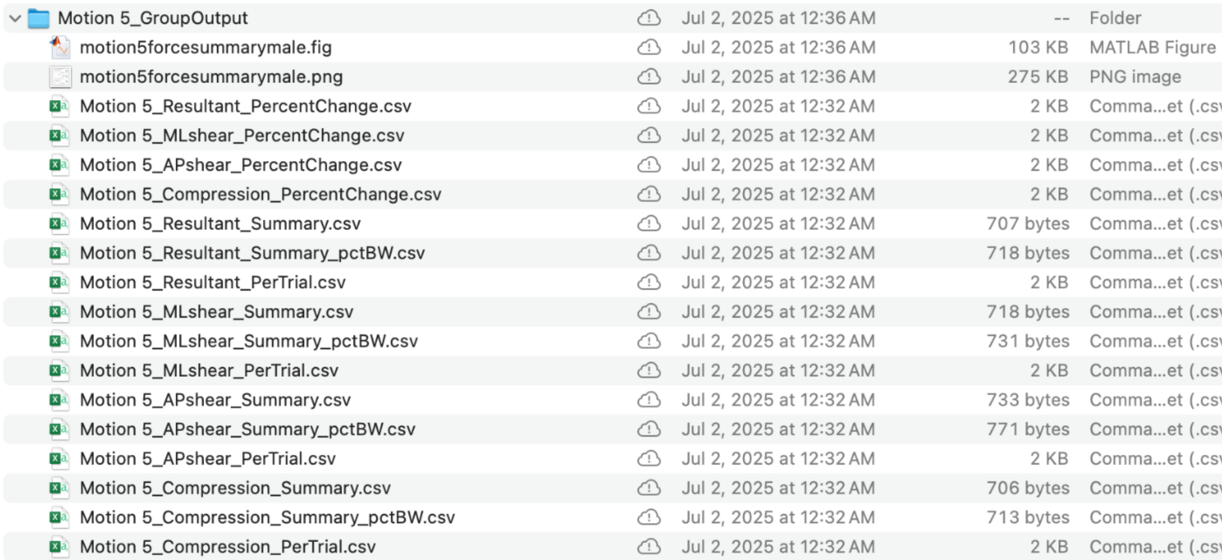
forceTitles = {'Compression', 'AP Shear', 'ML Shear'};

colors = lines(nTrials);
```

```matlab
% Define fixed markers only
styleMap = containers.Map;
styleMap('No Weight')       = 'o';
styleMap('5lb Abdomen')     = 's';
styleMap('10lb Abdomen')    = 'd';
styleMap('15lb Abdomen')    = '^';
styleMap('5lb Sternum')     = 'v';
styleMap('10lb Sternum')    = 'x';
styleMap('15lb Sternum')    = '*';

figure('Name', ['Spinal Forces – ' conditionLabel], ...
       'Color', 'w', 'Position', [100 100 900 900]);

for f = 1:3
    subplot(3,1,f); hold on;

    % Plot all trial curves with consistent line style but unique markers
    for t = 1:nTrials
        if isKey(styleMap, trialIDs{t})
            marker = styleMap(trialIDs{t});
        else
            marker = 'o';
        end
        plot(1:nJoints, forceData{f}(t,:), ...
            'LineWidth', 1.5, ...
            'Color', colors(t,:), ...
            'LineStyle', '-', ...
            'Marker', marker, ...
            'DisplayName', trialIDs{t});
    end

    % Peak of the average across trials
    meanValsPlot = mean(forceData{f}, 1);
    [peakAvgVal, peakAvgIdx] = max(meanValsPlot);
    hStar = plot(peakAvgIdx, peakAvgVal, 'p', ...
         'MarkerSize', 10, 'MarkerFaceColor', 'k', ...
         'DisplayName', 'Max of Mean');
    text(peakAvgIdx, peakAvgVal, ...
        sprintf('  ↑ %s (Mean: %.1f N)', xlabels{peakAvgIdx}, peakAvgVal), ...
```

```
        'FontWeight', 'bold', 'VerticalAlignment', 'bottom');
    uistack(hStar, 'top');

    % True max value across all trials
    [peakAbsVal, linearIdx] = max(forceData{f}(:));
    [peakTrialIdx, peakJointIdx] = ind2sub(size(forceData{f}), linearIdx);
    hDiamond = plot(peakJointIdx, peakAbsVal, 'd', ...
         'MarkerSize', 10, 'MarkerFaceColor', colors(peakTrialIdx,:), ...
         'DisplayName', 'Absolute Max');
    text(peakJointIdx, peakAbsVal, ...
        sprintf('  ↑ %s (%s: %.1f N)', ...
        xlabels{peakJointIdx}, trialIDs{peakTrialIdx}, peakAbsVal), ...
        'FontWeight', 'bold', 'VerticalAlignment', 'top');
    uistack(hDiamond, 'top');

    % Axis styling
    xticks(1:nJoints);
    xticklabels(xlabels);
    xtickangle(45);
    ylabel([forceTitles{f} ' (N)']);
    title([forceTitles{f} ' – ' strrep(conditionLabel, '_', '\_')], ...
          'Interpreter', 'tex');
    grid on;
    legend('show', 'Location', 'northeastoutside');
end

xlabel('Spinal Level');
sgtitle(['Spinal Force Summary – ' strrep(conditionLabel, '_', '\_')], ...
        'Interpreter', 'tex', 'FontWeight', 'bold');
%%  SAVE PER-TRIAL AND SUMMARY CSV
metrics = {'Compression', 'APshear', 'MLshear', 'Resultant'};
allData = {comp_all, aps_all, mls_all, res_all};
for m = 1:4
    dat = allData{m};
    trialNames = trialIDs(:);
    tableOut = array2table(dat, 'VariableNames', xlabels);
    tableOut.TrialID = trialNames;
    tableOut = movevars(tableOut, 'TrialID', 'Before', 1);
    writetable(tableOut, fullfile(outDir, [conditionLabel '_' metrics{m} '_PerTrial.csv']));
```

```matlab
        % Summary
        meanVals = mean(dat, 1);
        stdVals  = std(dat, 0, 1);

        % Compute %BW
        meanPctBW = meanVals / (78 * 9.81) * 100;
        stdPctBW  = stdVals  / (78 * 9.81) * 100;

        T_pctBW = table(xlabels(:), meanPctBW(:), stdPctBW(:), ...
            'VariableNames', {'SpinalLevel', 'Mean_pctBW', 'Std_pctBW'});
        writetable(T_pctBW, fullfile(outDir, [conditionLabel '_' metrics{m} '_Summary_pctBW.csv']));
        meanVals = mean(dat, 1);
        stdVals = std(dat, 0, 1);
        T = table(xlabels(:), meanVals(:), stdVals(:), ...
                  'VariableNames', {'SpinalLevel', 'Mean_N', 'Std_N'});
        writetable(T, fullfile(outDir, [conditionLabel '_' metrics{m} '_Summary.csv']));
    end

    %% CALCULATE AND SAVE PERCENT CHANGE
    for m = 1:4
        dat = allData{m};
        ref = dat(1, :); % baseline = first trial (e.g., 'No Weight')
        pctChange = 100 * (dat - ref) ./ ref;
        pctChange(1,:) = 0; % baseline = 0% change

        pctTable = array2table(pctChange, 'VariableNames', xlabels);
        pctTable.TrialID = trialIDs(:);
        pctTable = movevars(pctTable, 'TrialID', 'Before', 1);

        writetable(pctTable, fullfile(outDir, [conditionLabel '_' metrics{m} '_PercentChange.csv']));
    end

    fprintf(' All analysis complete for %s. Results saved in: %s\n', conditionLabel, outDir);
end
% example how to call funciton and run
%childFiles = {'NMB_JointReaction_child_1.sto', 'NMB_JointReaction_child_2.sto'};
%parentFiles = {'NMB_JointReaction_parent_1.sto', 'NMB_JointReaction_parent_2.sto'};
%trialIDs = {'No Weight', '5lb Abdomen'};
%conditionLabel = 'Male_Motion1';
%Run_JRA_GroupAnalysis(childFiles, parentFiles, trialIDs, conditionLabel)
```



Name	Date Modified	Size	Kind
Motion 5_GroupOutput	Jul 2, 2025 at 12:36 AM	--	Folder
motion5forcesummarymale.fig	Jul 2, 2025 at 12:36 AM	103 KB	MATLAB Figure
motion5forcesummarymale.png	Jul 2, 2025 at 12:36 AM	275 KB	PNG image
Motion 5_Resultant_PercentChange.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_MLshear_PercentChange.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_APshear_PercentChange.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_Compression_PercentChange.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_Resultant_Summary.csv	Jul 2, 2025 at 12:32 AM	707 bytes	Comma...et (.csv
Motion 5_Resultant_Summary_pctBW.csv	Jul 2, 2025 at 12:32 AM	718 bytes	Comma...et (.csv
Motion 5_Resultant_PerTrial.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_MLshear_Summary.csv	Jul 2, 2025 at 12:32 AM	718 bytes	Comma...et (.csv
Motion 5_MLshear_Summary_pctBW.csv	Jul 2, 2025 at 12:32 AM	731 bytes	Comma...et (.csv
Motion 5_MLshear_PerTrial.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_APshear_Summary.csv	Jul 2, 2025 at 12:32 AM	733 bytes	Comma...et (.csv
Motion 5_APshear_Summary_pctBW.csv	Jul 2, 2025 at 12:32 AM	771 bytes	Comma...et (.csv
Motion 5_APshear_PerTrial.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv
Motion 5_Compression_Summary.csv	Jul 2, 2025 at 12:32 AM	706 bytes	Comma...et (.csv
Motion 5_Compression_Summary_pctBW.csv	Jul 2, 2025 at 12:32 AM	713 bytes	Comma...et (.csv
Motion 5_Compression_PerTrial.csv	Jul 2, 2025 at 12:32 AM	2 KB	Comma...et (.csv

Appendix C: Troubleshooting Log for Static Optimization Failures

In the first few runs of static optimization it was found to be under actuated which caused the SO to fail and give some combination of the following error messages.

Table C. 1: SO Error Message Table.

This table outlines error messages from initial static optimization runs that failed due to an underactuated model, along with their explanations. The errors indicate issues such as convergence failures, kinematic misalignments, insufficient muscle torque, or incorrect external force inputs.

Error Message	**Explanation**
“Static Optimization failed to converge after maximum iterations”	The optimization solver couldn’t find a solution within the tolerance limits. This was the most consistent message received in my initial analyses and typically occurred when running an underactuated model. This message was often times accompanies by specific joints or muscles that are too weak causing the SO to fail and need to be appended.
“ERROR: No solution found for static optimization at time = [t]”	This will specify a specific time (most cases it ends up being every time in the tolerance limits) where the muscle activations didn’t satisfy the dynamics or constraints. This was another common one that was an indicator that the kinematics were misaligned, or external forces were wrong. Due to not properly inputting the data or an error in the SO parameters
“Muscle Redundancy problem is not solvable at time =[t]’	This is when the muscles in the system were unable to produce sufficient torque to satisfy equilibrium constraints. Another sign of an under actuated model.

Appendix: D- Male Data Tables

Appendix D.1 Male Raw Per Trial Data Sorted by Motion for all Weight Conditions

Table D.1.1: Male Raw Compression Data

Compression forces sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Male Compression(N) Pertrial																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight	623.423	578.798	517.780	461.002	405.092	360.778	344.598	332.055	317.445	303.156	285.731	256.311	250.380	239.249	227.842	211.948	203.193	348.164	128.674
5lb Abdomen	623.442	578.817	517.792	461.011	405.099	360.784	344.605	332.062	317.455	303.164	285.734	256.316	250.394	239.266	227.854	211.954	203.199	348.173	128.676
5lb Sternum	653.189	608.675	545.035	486.468	429.547	384.919	369.306	357.088	342.427	327.259	308.515	273.949	263.026	250.678	239.284	222.975	213.791	369.184	134.552
10lb Abdome	623.522	578.894	517.842	461.049	405.129	360.811	344.630	332.093	317.497	303.196	285.745	256.335	250.451	239.340	227.905	211.982	203.224	348.215	128.687
10lb Sternum	684.669	640.231	573.211	512.743	454.904	410.022	394.998	383.055	368.204	352.069	331.846	292.413	275.856	262.319	250.616	234.752	224.949	390.992	140.905
15lb Abdome	623.675	579.042	517.939	461.120	405.185	360.863	344.680	332.153	317.578	303.257	285.768	256.371	250.561	239.482	228.001	212.032	203.272	348.293	128.707
15lb Sternum	716.557	672.222	601.695	539.481	480.856	435.799	421.444	409.762	394.674	377.476	355.626	311.443	289.422	274.657	262.907	246.991	236.543	413.385	147.264
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	1400.661	1355.646	1148.398	1018.216	912.121	836.460	829.344	789.362	762.155	715.249	657.565	490.235	409.879	337.277	280.455	223.244	184.605	726.522	373.671
5lb Abdomen	1400.676	1355.660	1148.407	1018.222	912.124	836.462	829.346	789.366	762.157	715.250	657.563	490.234	409.878	337.276	280.454	223.243	184.604	726.525	373.675
5lb Sternum	1441.567	1396.463	1184.506	1051.663	943.760	867.142	860.828	820.590	793.331	745.479	686.286	514.856	432.468	358.129	299.745	241.009	201.095	755.231	381.017
10lb Abdome	1400.689	1355.672	1148.416	1018.229	912.129	836.466	829.350	789.372	762.162	715.251	657.561	490.233	409.875	337.274	280.452	223.241	184.603	726.528	373.680
10lb Sternum	1482.442	1437.249	1220.670	1085.144	975.447	897.871	892.366	851.899	824.547	775.778	715.071	539.556	455.135	379.053	319.118	258.835	217.662	783.991	388.338
15lb Abdome	1400.722	1355.702	1148.439	1018.247	912.142	836.475	829.360	789.387	762.174	715.255	657.557	490.230	409.869	337.269	280.448	223.237	184.598	726.536	373.692
15lb Sternum	1523.142	1477.873	1256.707	1118.609	1007.154	928.658	923.990	883.230	855.859	806.128	743.896	564.330	477.806	399.952	338.404	276.612	234.170	812.736	395.633
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	868.205	824.431	668.123	579.215	509.813	457.436	434.652	397.080	359.576	330.250	298.261	243.568	224.974	210.369	194.074	172.040	160.052	407.772	220.619
5lb Abdomen	868.231	824.455	668.136	579.223	509.818	457.439	434.655	397.085	359.581	330.254	298.264	243.570	224.969	210.365	194.067	172.032	160.045	407.776	220.629
5lb Sternum	927.545	883.952	716.417	622.402	550.272	496.661	474.085	433.051	392.961	361.398	326.608	263.908	241.353	225.522	208.462	184.771	171.235	440.036	235.817
10lb Abdome	868.329	824.546	668.187	579.256	509.838	457.453	434.665	397.103	359.599	330.270	298.274	243.577	224.954	210.350	194.040	172.005	160.019	407.792	220.664
10lb Sternum	987.699	944.188	765.162	666.036	591.165	536.321	513.985	469.486	426.894	393.120	355.482	284.922	258.342	241.086	223.066	198.238	182.878	472.828	251.111
15lb Abdome	868.528	824.732	668.290	579.322	509.878	457.480	434.687	397.141	359.636	330.303	298.293	243.591	224.926	210.319	193.987	171.950	159.967	407.825	220.736
15lb Sternum	1048.074	1004.789	814.769	710.273	632.519	576.358	554.205	506.444	461.201	425.220	384.698	306.580	275.831	257.109	237.953	211.569	194.632	506.013	266.506
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	1038.963	996.643	791.567	679.472	597.425	538.736	515.660	463.008	415.848	380.164	341.058	251.247	206.886	182.647	165.106	139.390	123.302	460.419	287.188
5lb Abdomen	1038.999	996.677	791.587	679.484	597.433	538.741	515.665	463.017	415.856	380.170	341.058	251.249	206.883	182.639	165.097	139.382	123.294	460.425	287.202
5lb Sternum	1100.595	1058.490	842.001	724.488	639.519	579.505	556.535	500.723	451.075	413.188	371.124	274.319	226.085	200.223	181.132	153.468	135.730	494.600	302.623
10lb Abdome	1038.905	996.612	791.549	679.481	597.446	538.771	515.709	463.044	415.932	380.202	341.048	251.354	206.861	182.960	165.226	139.430	123.380	460.465	287.139
10lb Sternum	1162.729	1120.794	892.854	769.849	681.912	620.520	597.614	538.742	486.478	446.416	401.404	297.486	245.494	217.656	197.106	167.620	148.189	528.992	318.235
15lb Abdome	1039.081	996.778	791.645	679.542	597.485	538.797	515.732	463.087	415.970	380.228	341.048	251.362	206.841	182.920	165.184	139.390	123.343	460.496	287.202
15lb Sternum	1225.117	1183.336	943.893	815.354	724.386	661.556	638.692	576.824	521.984	479.795	431.805	320.842	265.098	235.239	213.106	181.948	160.800	563.516	333.886
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	721.289	676.870	585.889	518.314	458.861	412.767	397.817	382.018	362.262	342.163	317.164	259.008	226.953	203.460	191.677	173.451	162.556	376.030	172.085
5lb Abdomen	721.298	676.877	585.893	518.317	458.861	412.767	397.817	382.022	362.269	342.170	317.168	259.019	226.964	203.474	191.687	173.458	162.563	376.037	172.083
5lb Sternum	755.147	710.717	616.745	547.625	487.268	440.800	426.613	410.647	390.412	369.297	342.600	278.845	243.442	217.184	205.108	186.547	174.880	400.228	179.010
10lb Abdome	721.345	676.919	585.915	518.330	458.867	412.769	397.819	382.038	362.298	342.199	317.186	259.062	227.010	203.529	191.725	173.487	162.590	376.064	172.081
10lb Sternum	789.460	744.969	648.043	577.312	515.974	469.069	455.699	439.565	418.858	396.742	368.364	299.085	260.342	231.132	218.483	199.891	187.446	424.731	186.058
15lb Abdome	721.429	676.995	585.954	518.355	458.877	412.773	397.824	382.069	362.349	342.251	317.218	259.139	227.092	203.629	191.793	173.538	162.638	376.113	172.077
15lb Sternum	826.167	781.685	681.220	608.654	546.291	498.974	486.456	469.985	448.762	425.584	395.420	319.856	277.843	246.085	233.037	213.974	200.707	450.629	193.682

Table D.1.2: Male Raw AP Shear Data

AP Shear sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Male AP SHEAR PER Trial																		
Motion 1																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
No Weight	0.927	0.970	-1.259	-0.792	-0.265	-0.060	0.595	0.783	0.744	0.877	0.980	4.279	9.348	11.703	13.253	16.278	19.010	4.551	6.614
5lb Abdomen	0.927	0.970	-1.259	-0.792	-0.264	-0.060	0.596	0.784	0.744	0.877	0.981	4.280	9.345	11.700	13.251	16.276	19.007	4.551	6.612
5lb Sternum	1.001	1.033	-1.257	-0.823	-0.351	-0.221	0.488	0.645	0.621	0.735	0.864	2.646	8.743	10.433	11.708	14.266	16.933	3.969	5.909
10lb Abdomen	0.929	0.972	-1.258	-0.791	-0.264	-0.059	0.596	0.784	0.745	0.878	0.982	4.288	9.334	11.687	13.246	16.265	18.995	4.549	6.607
10lb Sternum	1.171	1.183	-1.149	-0.795	-0.461	-0.420	0.337	0.451	0.441	0.509	0.697	1.986	6.953	8.648	10.171	11.768	15.059	3.326	5.087
15lb Abdomen	0.932	0.975	-1.257	-0.790	-0.262	-0.058	0.598	0.786	0.747	0.881	0.984	4.304	9.314	11.665	13.238	16.244	18.973	4.545	6.598
15lb Sternum	1.432	1.417	-0.938	-0.707	-0.581	-0.660	0.161	0.219	0.221	0.219	0.495	1.401	4.202	6.119	7.790	9.887	13.245	2.584	4.214
Motion 2																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	4.968	4.809	-24.141	-6.696	31.039	38.395	52.895	60.517	57.124	64.314	41.896	44.867	65.690	90.137	50.446	-11.933	-75.767	28.739	41.509
5lb Abdomen	4.972	4.813	-24.137	-6.692	31.043	38.399	52.899	60.521	57.131	64.321	41.903	44.870	65.696	90.141	50.446	-11.934	-75.769	28.743	41.511
5lb Sternum	5.742	5.498	-23.967	-6.557	31.613	38.912	53.973	61.841	58.654	66.095	43.383	45.177	65.909	90.721	50.434	-13.473	-78.522	29.143	42.345
10lb Abdomen	4.978	4.818	-24.131	-6.686	31.048	38.404	52.903	60.525	57.141	64.331	41.913	44.875	65.705	90.148	50.450	-11.933	-75.771	28.748	41.513
10lb Sternum	6.485	6.166	-23.776	-6.408	32.195	39.444	55.065	63.182	60.212	67.912	44.892	45.479	66.157	91.331	50.415	-14.908	-81.275	29.563	43.196
15lb Abdomen	4.990	4.829	-24.118	-6.673	31.060	38.415	52.914	60.536	57.163	64.356	41.935	44.888	65.727	90.164	50.459	-11.933	-75.776	28.761	41.518
15lb Sternum	7.304	6.903	-23.571	-6.233	32.802	39.976	56.150	64.518	61.760	69.709	46.408	45.715	66.438	92.122	50.595	-16.378	-83.936	30.017	44.059
Motion 3																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	2.810	2.945	-1.688	-0.590	0.907	1.452	2.672	3.259	2.396	2.297	2.296	12.269	24.635	27.257	27.317	27.849	33.736	10.107	12.451
5lb Abdomen	2.813	2.947	-1.686	-0.588	0.909	1.454	2.674	3.261	2.399	2.301	2.299	12.268	24.641	27.262	27.321	27.853	33.740	10.110	12.452
5lb Sternum	2.997	3.130	-1.917	-0.772	0.719	1.238	2.609	3.161	2.379	2.394	2.437	10.933	23.401	25.674	25.669	26.288	32.621	9.586	11.825
10lb Abdomen	2.821	2.956	-1.678	-0.579	0.916	1.462	2.682	3.269	2.411	2.317	2.311	12.265	24.658	27.278	27.336	27.866	33.755	10.120	12.454
10lb Sternum	3.252	3.377	-2.071	-0.914	0.512	0.999	2.515	3.027	2.317	2.432	2.587	9.816	21.465	23.487	23.539	24.734	31.572	8.979	11.075
15lb Abdomen	2.840	2.974	-1.661	-0.562	0.932	1.478	2.698	3.285	2.435	2.350	2.336	12.260	24.690	27.310	27.365	27.893	33.786	10.142	12.459
15lb Sternum	3.636	3.747	-2.111	-0.972	0.357	0.749	2.457	2.919	2.259	2.426	2.723	9.337	20.050	22.045	22.129	23.410	30.821	8.587	10.534
Motion 4																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	2.989	3.054	-3.527	-2.226	-0.937	-0.740	1.393	1.565	1.346	1.410	1.279	4.968	9.047	13.808	16.027	17.097	20.061	5.095	7.308
5lb Abdomen	2.991	3.055	-3.526	-2.224	-0.935	-0.739	1.394	1.566	1.348	1.412	1.282	4.969	9.049	13.815	16.032	17.102	20.066	5.097	7.309
5lb Sternum	3.151	3.221	-3.819	-2.434	-1.075	-0.860	1.429	1.606	1.395	1.491	1.409	4.966	8.796	12.909	14.593	15.633	18.991	4.788	6.848
10lb Abdomen	2.990	3.055	-3.525	-2.225	-0.932	-0.731	1.400	1.573	1.356	1.423	1.297	4.986	9.127	13.658	15.900	16.910	19.868	5.066	7.241
10lb Sternum	3.393	3.463	-4.028	-2.588	-1.203	-0.995	1.454	1.627	1.433	1.548	1.539	4.858	8.343	12.039	13.356	14.433	18.261	4.526	6.474
15lb Abdomen	2.997	3.062	-3.520	-2.220	-0.926	-0.725	1.406	1.579	1.364	1.433	1.310	4.993	9.138	13.690	15.923	16.931	19.892	5.078	7.248
15lb Sternum	3.691	3.753	-4.186	-2.723	-1.354	-1.182	1.434	1.599	1.412	1.528	1.632	4.665	7.803	11.143	12.123	13.305	17.672	4.254	6.139
Motion 5																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	1.134	1.181	-1.943	-1.314	-0.581	-0.405	0.541	0.745	0.680	0.802	0.922	3.042	5.670	13.243	15.129	17.618	20.382	4.520	7.227
5lb Abdomen	1.134	1.182	-1.943	-1.314	-0.581	-0.405	0.541	0.745	0.681	0.803	0.922	3.042	5.670	13.239	15.128	17.616	20.380	4.520	7.226
5lb Sternum	1.259	1.295	-1.972	-1.366	-0.687	-0.565	0.451	0.627	0.584	0.677	0.820	2.521	4.398	11.731	13.004	15.591	18.446	3.930	6.447
10lb Abdomen	1.135	1.183	-1.942	-1.313	-0.581	-0.405	0.541	0.745	0.681	0.803	0.923	3.040	5.667	13.226	15.120	17.606	20.368	4.517	7.221
10lb Sternum	1.480	1.497	-1.901	-1.362	-0.820	-0.761	0.347	0.468	0.451	0.489	0.670	1.788	3.467	10.006	11.030	13.411	16.564	3.343	5.666
15lb Abdomen	1.137	1.185	-1.942	-1.313	-0.581	-0.405	0.542	0.745	0.682	0.805	0.924	3.036	5.663	13.202	15.107	17.588	20.347	4.513	7.213
15lb Sternum	1.800	1.787	-1.738	-1.308	-0.983	-1.050	0.160	0.215	0.258	0.213	0.444	1.340	2.945	7.360	8.944	10.946	14.633	2.704	4.795

Table D.1.3: Male Raw ML Shear Data

ML shear sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Male ML Shearpertrial																			
Motion 1																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight	115.545	-114.213	-54.421	92.782	108.667	108.167	85.438	53.526	25.708	13.236	14.975	-35.939	-57.272	-71.387	-84.929	-93.981	-103.519	0.140	82.586
5lb Abdomen	115.548	-114.222	-54.422	92.776	108.663	108.163	85.433	53.520	25.677	13.236	14.975	-35.945	-57.274	-71.388	-84.929	-93.984	-103.522	0.136	82.586
5lb Sternum	121.062	-118.672	-57.286	99.034	116.266	116.442	92.374	58.103	25.774	14.288	16.169	-40.213	-64.375	-79.487	-94.084	-103.622	-113.332	-0.680	88.899
10lb Abdomen	115.563	-114.260	-54.428	92.750	108.648	108.146	85.414	53.493	25.551	13.238	14.975	-35.968	-57.279	-71.394	-84.929	-93.998	-103.538	0.117	82.585
10lb Sternum	126.896	-123.126	-60.247	105.531	123.972	124.831	99.386	62.668	25.719	15.372	17.391	-44.284	-71.475	-87.519	-103.292	-112.480	-122.506	-1.362	95.201
15lb Abdomen	115.592	-114.334	-54.438	92.702	108.619	108.114	85.377	53.441	25.311	13.240	14.976	-36.014	-57.289	-71.406	-84.929	-94.026	-103.568	0.081	82.584
15lb Sternum	132.806	-127.571	-63.241	112.197	131.768	133.330	106.452	67.212	25.421	16.481	18.638	-48.241	-78.436	-95.453	-112.398	-121.762	-132.041	-2.049	101.602
Motion 2																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	259.644	-214.666	161.122	261.118	231.320	225.055	170.188	85.799	-39.078	-75.831	-55.407	-131.672	-182.005	-193.353	-228.445	-249.783	-261.492	-13.970	197.794
5lb Abdomen	259.647	-214.668	161.122	261.118	231.320	225.055	170.187	85.797	-39.087	-75.838	-55.413	-131.672	-182.005	-193.353	-228.445	-249.783	-261.491	-13.971	197.794
5lb Sternum	267.233	-221.124	165.739	269.599	240.196	234.374	177.677	90.168	-39.396	-77.583	-57.782	-137.161	-189.908	-202.790	-239.626	-262.073	-274.251	-15.101	205.721
10lb Abdomen	259.649	-214.670	161.121	261.117	231.321	225.055	170.187	85.795	-39.099	-75.849	-55.420	-131.672	-182.005	-193.354	-228.446	-249.783	-261.491	-13.973	197.795
10lb Sternum	274.815	-227.577	170.355	278.081	249.078	243.703	185.178	94.532	-39.664	-79.367	-60.156	-142.646	-197.814	-212.243	-250.823	-274.382	-286.984	-16.230	213.661
15lb Abdomen	259.656	-214.675	161.119	261.117	231.323	225.055	170.187	85.791	-39.128	-75.878	-55.436	-131.672	-182.006	-193.355	-228.447	-249.784	-261.491	-13.978	197.797
15lb Sternum	282.366	-234.004	174.961	286.574	257.959	253.035	192.683	98.922	-40.025	-81.129	-62.547	-148.110	-205.708	-221.699	-262.063	-286.737	-299.836	-17.374	221.623
Motion 3																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	167.563	-123.783	-54.703	83.003	67.965	49.799	22.507	-28.267	-55.020	-71.152	-81.019	-103.548	-121.050	-125.513	-137.954	-144.300	-150.046	-47.383	94.097
5lb Abdomen	167.567	-123.794	-54.704	82.995	67.958	49.791	22.507	-28.277	-55.045	-71.171	-81.027	-103.551	-121.050	-125.511	-137.949	-144.295	-150.040	-47.388	94.096
5lb Sternum	179.015	-129.437	-58.657	91.423	73.972	54.339	24.549	-30.995	-61.607	-79.120	-89.454	-115.540	-135.495	-140.449	-154.436	-161.507	-167.573	-52.998	103.182
10lb Abdomen	167.586	-123.835	-54.709	82.964	67.931	49.761	22.508	-28.317	-55.142	-71.247	-81.062	-103.561	-121.050	-125.505	-137.934	-144.275	-150.018	-47.406	94.093
10lb Sternum	190.625	-135.170	-62.649	99.876	79.997	58.882	26.615	-33.778	-68.175	-87.118	-97.925	-127.565	-150.120	-155.441	-170.897	-178.363	-184.828	-58.590	112.318
15lb Abdomen	167.625	-123.917	-54.717	82.902	67.878	49.701	22.509	-28.398	-55.337	-71.402	-81.132	-103.582	-121.048	-125.493	-137.903	-144.236	-149.975	-47.443	94.086
15lb Sternum	202.277	-142.622	-66.710	108.495	86.114	63.463	28.698	-36.694	-74.877	-95.234	-106.567	-139.777	-165.039	-170.722	-187.628	-195.701	-202.499	-64.413	121.712
Motion 4																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	200.518	-141.465	72.916	110.557	79.284	55.685	26.702	-35.679	-67.574	-82.849	-85.659	-115.900	-138.422	-130.545	-146.264	-151.946	-156.371	-41.589	110.980
5lb Abdomen	200.525	-141.470	72.908	110.549	79.277	55.677	26.702	-35.692	-67.607	-82.879	-85.678	-115.901	-138.420	-130.541	-146.257	-151.937	-156.362	-41.594	110.979
5lb Sternum	212.414	-150.244	79.208	119.170	85.414	60.248	28.819	-38.704	-74.540	-91.351	-94.703	-128.310	-153.750	-146.170	-163.576	-170.134	-174.924	-47.125	121.013
10lb Abdomen	200.507	-141.461	72.864	110.509	79.250	55.653	26.704	-35.722	-67.838	-83.043	-85.736	-115.876	-138.420	-130.547	-146.330	-152.051	-156.431	-41.645	110.990
10lb Sternum	224.405	-159.088	85.536	127.831	91.581	64.832	30.946	-41.771	-81.374	-99.730	-103.778	-140.800	-169.105	-161.795	-180.772	-188.122	-193.311	-52.618	131.083
15lb Abdomen	200.541	-141.485	72.825	110.469	79.217	55.613	26.706	-35.783	-67.990	-83.179	-85.824	-115.881	-138.409	-130.527	-146.295	-152.008	-156.386	-41.670	110.984
15lb Sternum	236.446	-167.965	91.820	136.451	97.747	69.410	33.073	-44.855	-88.099	-108.175	-112.927	-153.297	-184.463	-177.430	-197.933	-205.970	-211.567	-58.102	141.165
Motion 5																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	133.683	-116.537	-61.580	112.061	119.661	118.773	92.964	55.103	14.249	14.939	16.622	-47.532	-75.755	-86.823	-99.737	-106.894	-114.680	-1.852	93.077
5lb Abdomen	133.685	-116.544	-61.580	112.055	119.658	118.770	92.961	55.097	14.226	14.939	16.622	-47.534	-75.756	-86.823	-99.737	-106.896	-114.682	-1.855	93.076
5lb Sternum	139.959	-121.196	-64.823	119.588	127.840	127.589	100.179	59.605	14.331	16.124	17.955	-52.094	-82.820	-95.328	-109.482	-116.878	-124.976	-2.613	99.871
10lb Abdomen	133.694	-116.572	-61.582	112.030	119.649	118.758	92.947	55.076	14.133	14.941	16.623	-47.542	-75.759	-86.825	-99.735	-106.901	-114.688	-1.868	93.074
10lb Sternum	146.318	-125.949	-68.112	127.202	136.076	136.446	107.405	64.085	14.627	17.322	19.305	-56.704	-89.883	-103.875	-119.289	-126.609	-135.044	-3.334	106.697
15lb Abdomen	133.709	-116.622	-61.586	111.988	119.632	118.737	92.923	55.038	13.968	14.943	16.625	-47.555	-75.763	-86.827	-99.732	-106.909	-114.700	-1.890	93.071
15lb Sternum	153.121	-130.815	-71.599	135.308	144.678	145.683	114.910	68.750	15.671	18.581	20.723	-61.721	-97.288	-112.700	-129.390	-137.051	-145.806	-4.056	113.902

***Table D.1.4*: Male Raw Resultant Force Data**

Resultant force sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Male Resultant Force (N) Per trial																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight	634.041	589.960	520.633	470.247	419.414	376.644	355.032	336.342	318.485	303.446	286.124	258.854	257.017	249.946	243.517	232.420	228.834	357.703	127.626
5lb Abdomen	634.060	589.980	520.645	470.255	419.420	376.649	355.037	336.348	318.493	303.454	286.127	258.859	257.031	249.963	243.529	232.427	228.841	357.713	127.629
5lb Sternum	664.314	620.136	548.038	496.447	445.004	402.146	380.684	361.785	343.396	327.571	308.939	276.897	270.930	263.186	257.382	246.291	242.565	379.748	132.866
10lb Abdomen	634.142	590.064	520.696	470.286	419.445	376.670	355.058	336.375	318.524	303.486	286.139	258.881	257.087	250.035	243.576	232.457	228.869	357.752	127.640
10lb Sternum	696.330	651.964	576.370	523.491	471.494	428.604	407.310	388.148	369.102	352.405	332.303	295.754	285.050	276.669	271.259	260.574	256.587	402.554	138.596
15lb Abdomen	634.297	590.222	520.794	470.347	419.492	376.710	355.097	336.425	318.586	303.547	286.162	258.924	257.195	250.173	243.665	232.513	228.923	357.828	127.662
15lb Sternum	728.761	684.221	605.010	551.025	498.584	455.739	434.680	415.238	395.492	377.835	356.114	315.160	299.892	290.835	286.032	275.551	271.224	425.964	144.295
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	1424.532	1372.545	1159.897	1051.185	941.507	867.058	848.276	796.314	765.291	722.128	661.223	509.589	453.257	399.081	365.222	335.219	328.934	764.780	347.764
5lb Abdomen	1424.547	1372.560	1159.906	1051.191	941.511	867.060	848.279	796.318	765.295	722.129	661.222	509.589	453.256	399.081	365.221	335.218	328.933	764.783	347.769
5lb Sternum	1466.138	1413.873	1196.286	1085.690	974.360	899.100	880.629	827.842	796.471	752.414	690.080	534.725	476.904	421.439	387.055	356.299	349.025	794.608	354.387
10lb Abdomen	1424.560	1372.572	1159.915	1051.198	941.517	867.064	848.283	796.324	765.300	722.133	661.222	509.588	453.256	399.082	365.221	335.217	328.933	764.787	347.773
10lb Sternum	1507.713	1455.168	1232.729	1120.227	1007.260	931.193	913.039	859.454	827.694	782.779	718.999	559.943	500.655	443.926	409.011	377.496	369.246	824.502	360.967
15lb Abdomen	1424.594	1372.602	1159.937	1051.215	941.530	867.074	848.293	796.339	765.315	722.142	661.221	509.586	453.253	399.082	365.219	335.215	328.932	764.797	347.784
15lb Sternum	1549.111	1496.300	1269.047	1154.751	1040.182	963.343	945.535	891.092	859.017	813.193	747.962	585.230	524.431	466.474	430.992	398.749	389.592	854.412	367.478
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	884.232	833.677	670.360	585.132	514.324	460.141	435.243	398.099	363.769	337.836	309.078	264.950	256.658	246.478	239.671	226.265	221.965	426.346	209.082
5lb Abdomen	884.258	833.702	670.374	585.139	514.328	460.143	435.246	398.104	363.778	337.844	309.083	264.952	256.655	246.474	239.663	226.257	221.956	426.350	209.091
5lb Sternum	944.667	893.384	718.817	629.082	555.222	499.626	474.727	434.171	397.768	369.965	338.646	288.299	277.773	266.918	260.702	246.812	241.798	461.081	222.100
10lb Abdomen	884.358	833.799	670.425	585.167	514.345	460.153	435.256	398.125	363.810	337.876	309.101	264.962	256.643	246.460	239.634	226.225	221.925	426.369	209.126
10lb Sternum	1005.931	953.821	767.726	673.484	596.553	539.545	514.679	470.710	432.310	402.665	368.732	312.329	299.562	287.812	281.990	267.812	261.920	496.328	235.220
15lb Abdomen	884.561	833.995	670.528	585.224	514.377	460.174	435.278	398.169	363.877	337.940	309.139	264.983	256.620	246.432	239.576	226.161	221.863	426.406	209.197
15lb Sternum	1067.421	1014.868	817.498	718.512	638.355	579.842	554.953	507.780	467.245	435.761	399.194	337.069	322.060	309.414	303.835	289.151	282.555	532.089	248.346
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	1058.140	1006.637	794.927	688.411	602.663	541.607	516.353	464.383	421.304	389.089	351.653	276.735	249.087	224.928	221.157	206.905	200.144	483.184	271.825
5lb Abdomen	1058.177	1006.672	794.945	688.422	602.670	541.611	516.358	464.393	421.318	389.101	351.658	276.738	249.083	224.920	221.146	206.893	200.133	483.190	271.839
5lb Sternum	1120.910	1069.105	845.727	734.228	645.198	582.629	557.282	502.219	457.194	423.168	383.019	302.885	273.553	248.237	244.497	229.657	222.220	520.102	284.890
10lb Abdomen	1058.081	1006.607	794.904	688.412	602.680	541.638	516.402	464.422	421.430	389.168	351.662	276.823	249.068	225.174	221.280	206.993	200.220	483.233	271.774
10lb Sternum	1184.191	1132.034	896.951	780.394	688.036	623.899	598.417	540.361	493.239	457.423	414.605	329.160	298.217	271.472	267.782	252.378	244.259	557.224	298.125
15lb Abdomen	1058.260	1006.773	794.995	688.467	602.714	541.660	516.425	464.470	421.492	389.223	351.683	276.832	249.046	225.132	221.227	206.936	200.164	483.265	271.839
15lb Sternum	1247.731	1195.203	948.358	826.697	730.952	665.189	639.549	578.567	529.368	491.841	446.330	355.614	323.055	294.861	291.099	275.146	266.326	594.464	311.407
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	733.574	686.830	589.120	530.291	474.207	429.516	408.535	385.972	362.543	342.490	317.600	263.351	239.329	221.606	216.602	204.504	199.978	388.591	167.779
5lb Abdomen	733.583	686.838	589.124	530.293	474.207	429.515	408.534	385.975	362.549	342.497	317.605	263.362	239.340	221.619	216.610	204.511	199.985	388.597	167.777
5lb Sternum	768.008	720.978	620.145	560.533	503.760	458.894	438.217	414.951	390.676	369.650	343.072	283.680	257.182	237.474	232.862	220.688	215.736	413.912	173.917
10lb Abdomen	733.630	686.884	589.145	530.301	474.210	429.513	408.533	385.989	362.574	342.526	317.623	263.406	239.384	221.670	216.643	204.537	200.009	388.622	167.776
10lb Sternum	802.906	755.542	651.616	591.161	533.617	488.512	468.186	444.212	419.113	397.120	368.870	304.418	275.443	253.598	249.171	236.993	231.619	439.535	180.176
15lb Abdomen	733.716	686.967	589.185	530.316	474.215	429.511	408.532	386.013	362.619	342.578	317.655	263.484	239.463	221.761	216.701	204.583	200.053	388.668	167.774
15lb Sternum	840.239	792.557	684.974	623.514	565.125	519.807	499.844	474.987	449.036	425.989	395.963	325.759	294.398	270.764	266.698	254.338	248.509	466.618	186.957

Appendix D.2 Male Percentage Change All Trials

Table D.2.1: Male Compressive Force Percentage Change for all Trials

Male Compressive Force % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum and abdomen compared to baseline (no weight) for all motions. The right two columns consist of the average of the forces experienced for each motion across the entire spinal level.

Male Compressive Force (N) Percent Change																	
Motion 1																	
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**
5lb Abdomen	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.001	0.002	0.005	0.007	0.005	0.003	0.003	0.003
5lb Sternum	4.775	5.162	5.264	5.524	6.037	6.691	7.170	7.539	7.870	7.951	7.974	6.881	5.050	4.777	5.022	5.203	5.216	6.124
10lb Abdomen	0.016	0.017	0.012	0.010	0.009	0.009	0.009	0.012	0.016	0.013	0.005	0.009	0.028	0.038	0.027	0.016	0.015	0.015
10lb Sternum	9.824	10.614	10.706	11.223	12.296	13.649	14.626	15.359	15.990	16.135	16.140	14.085	10.175	9.643	9.995	10.759	10.707	12.466
15lb Abdomen	0.040	0.042	0.031	0.026	0.023	0.023	0.024	0.030	0.042	0.033	0.013	0.023	0.072	0.097	0.070	0.040	0.039	0.039
15lb Sternum	14.939	16.141	16.207	17.023	18.703	20.794	22.300	23.402	24.329	24.515	24.462	21.509	15.593	14.800	15.390	16.534	16.413	19.003
Motion 2																	
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	
5lb Abdomen	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5lb Sternum	2.920	3.011	3.144	3.285	3.469	3.668	3.796	3.956	4.091	4.226	4.368	5.022	5.511	6.183	6.878	7.958	8.933	4.731
10lb Abdomen	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	-0.001	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	0.000
10lb Sternum	5.839	6.019	6.293	6.573	6.943	7.342	7.599	7.923	8.186	8.463	8.745	10.061	11.041	12.386	13.786	15.943	17.907	9.473
15lb Abdomen	0.004	0.004	0.004	0.003	0.002	0.002	0.002	0.003	0.002	0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.003	-0.003	0.001
15lb Sternum	8.745	9.016	9.431	9.860	10.419	11.022	11.412	11.892	12.295	12.706	13.129	15.114	16.572	18.583	20.662	23.906	26.849	14.213
Motion 3																	
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	
5lb Abdomen	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	-0.002	-0.002	-0.004	-0.004	-0.004	0.000
5lb Sternum	6.835	7.220	7.228	7.456	7.936	8.575	9.072	9.059	9.285	9.432	9.504	8.351	7.280	7.203	7.413	7.400	6.987	8.014
10lb Abdomen	0.014	0.014	0.010	0.007	0.005	0.004	0.003	0.006	0.006	0.006	0.004	0.004	-0.009	-0.009	-0.017	-0.020	-0.021	0.000
10lb Sternum	13.763	14.526	14.524	14.990	15.957	17.245	18.252	18.235	18.721	19.037	19.185	16.978	14.832	14.601	14.939	15.228	14.261	16.193
15lb Abdomen	0.037	0.037	0.025	0.018	0.013	0.010	0.008	0.015	0.017	0.016	0.011	0.009	-0.022	-0.024	-0.045	-0.052	-0.053	0.001
15lb Sternum	20.717	21.877	21.949	22.627	24.069	25.998	27.505	27.542	28.262	28.757	28.980	25.870	22.606	22.218	22.609	22.976	21.606	24.480
Motion 4																	
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	
5lb Abdomen	0.003	0.003	0.003	0.002	0.001	0.001	0.001	0.002	0.002	0.002	0.000	0.001	-0.002	-0.004	-0.005	-0.006	-0.006	0.000
5lb Sternum	5.932	6.206	6.371	6.625	7.046	7.568	7.927	8.146	8.471	8.687	8.816	9.183	9.280	9.623	9.706	10.099	10.079	8.221
10lb Abdomen	-0.006	-0.003	-0.002	0.001	0.004	0.006	0.009	0.008	0.020	0.010	-0.003	0.043	-0.012	0.171	0.072	0.028	0.063	0.024
10lb Sternum	11.913	12.457	12.796	13.301	14.142	15.181	15.893	16.357	16.985	17.427	17.694	18.404	18.661	19.168	19.381	20.252	20.184	16.482
15lb Abdomen	0.011	0.014	0.010	0.010	0.010	0.011	0.014	0.017	0.029	0.017	-0.003	0.046	-0.022	0.149	0.047	0.000	0.033	0.023
15lb Sternum	17.917	18.732	19.244	19.998	21.251	22.798	23.859	24.582	25.523	26.208	26.607	27.700	28.137	28.794	29.072	30.531	30.412	24.786
Motion 5																	
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	
5lb Abdomen	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.002	0.002	0.001	0.004	0.005	0.007	0.005	0.004	0.004	0.002
5lb Sternum	4.694	5.001	5.266	5.655	6.191	6.791	7.238	7.494	7.771	7.930	8.020	7.659	7.266	6.746	7.007	7.550	7.581	6.815
10lb Abdomen	0.008	0.007	0.004	0.003	0.001	0.000	0.001	0.005	0.010	0.011	0.007	0.021	0.025	0.034	0.025	0.020	0.021	0.012
10lb Sternum	9.451	10.061	10.608	11.383	12.447	13.640	14.550	15.064	15.623	15.951	16.143	15.473	14.712	13.601	13.985	15.243	15.312	13.720
15lb Abdomen	0.019	0.018	0.011	0.008	0.004	0.001	0.002	0.013	0.024	0.026	0.017	0.051	0.061	0.083	0.061	0.050	0.051	0.029
15lb Sternum	14.540	15.485	16.271	17.430	19.054	20.885	22.281	23.027	23.878	24.380	24.674	23.493	22.424	20.950	21.578	23.363	23.470	21.011

Table D.2. 2: ***Male AP Shear Percentage Change for all Trials***

Male AP Shear % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum and abdomen compared to baseline (no weight) for all motions. The right two columns consist of the average of the forces experienced for each motion across the entire spinal level.

Male AP Shear (N) Percent Change																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average
5lb Abdomen	0.037	0.035	-0.015	-0.025	-0.070	-0.261	0.038	0.022	0.037	0.037	0.031	0.043	-0.027	-0.025	-0.011	-0.016	-0.015	-0.011
5lb Sternum	7.923	6.464	-0.145	3.823	32.798	269.761	-18.100	-17.670	-16.468	-16.103	-11.854	-38.152	-6.463	-10.845	-11.657	-12.359	-10.925	8.825
10lb Abdomen	0.193	0.181	-0.079	-0.131	-0.364	-1.310	0.196	0.112	0.193	0.194	0.160	0.219	-0.146	-0.130	-0.051	-0.083	-0.077	-0.054
10lb Sternum	26.308	21.954	-8.778	0.356	74.167	603.033	-43.397	-42.468	-40.756	-41.929	-28.882	-53.573	-25.622	-26.098	-23.250	-27.709	-20.784	20.151
15lb Abdomen	0.486	0.456	-0.198	-0.328	-0.910	-3.202	0.489	0.279	0.486	0.489	0.405	0.595	-0.360	-0.320	-0.114	-0.211	-0.196	-0.127
15lb Sternum	54.479	46.074	-25.482	-10.812	119.582	1005.237	-73.013	-72.009	-70.281	-74.978	-49.522	-67.254	-55.047	-47.711	-41.216	-39.264	-30.328	33.438
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.095	0.085	-0.017	-0.064	0.012	0.009	0.007	0.006	0.012	0.011	0.017	0.009	0.009	0.004	0.001	0.006	0.003	0.012
5lb Sternum	15.599	14.334	-0.723	-2.082	1.849	1.345	2.037	2.188	2.679	2.768	3.548	0.692	0.333	0.648	-0.024	12.909	3.637	3.632
10lb Abdomen	0.219	0.198	-0.042	-0.153	0.028	0.022	0.016	0.013	0.029	0.026	0.040	0.020	0.022	0.012	0.008	0.006	0.005	0.028
10lb Sternum	30.539	28.223	-1.510	-4.303	3.722	2.730	4.103	4.403	5.407	5.594	7.149	1.364	0.711	1.325	-0.062	24.931	7.270	7.153
15lb Abdomen	0.456	0.427	-0.095	-0.350	0.066	0.051	0.036	0.030	0.069	0.064	0.093	0.047	0.056	0.030	0.025	0.002	0.012	0.060
15lb Sternum	47.039	43.549	-2.360	-6.924	5.679	4.117	6.153	6.611	8.115	8.388	10.770	1.890	1.137	2.202	0.295	37.250	10.781	10.864
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.081	0.078	-0.127	-0.369	0.216	0.138	0.075	0.061	0.125	0.178	0.134	-0.013	0.024	0.018	0.015	0.013	0.011	0.039
5lb Sternum	6.646	6.298	13.542	30.929	-20.683	-14.715	-2.355	-3.015	-0.702	4.208	6.138	-10.887	-5.011	-5.805	-6.033	-5.607	-3.304	-0.609
10lb Abdomen	0.391	0.375	-0.615	-1.788	1.051	0.673	0.368	0.296	0.610	0.868	0.656	-0.036	0.092	0.077	0.069	0.061	0.056	0.188
10lb Sternum	15.707	14.658	22.686	54.896	-43.486	-31.171	-5.880	-7.110	-3.284	5.890	12.670	-19.993	-12.869	-13.829	-13.829	-11.187	-6.414	-2.503
15lb Abdomen	1.040	0.998	-1.639	-4.758	2.793	1.788	0.977	0.784	1.616	2.291	1.749	-0.071	0.220	0.194	0.176	0.156	0.149	0.498
15lb Sternum	29.381	27.231	25.074	64.753	-60.607	-48.397	-8.039	-10.429	-5.739	5.587	18.598	-23.899	-18.611	-19.122	-18.991	-15.942	-8.642	-3.988
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.050	0.050	-0.034	-0.059	-0.137	-0.185	0.103	0.092	0.141	0.169	0.229	0.028	0.019	0.050	0.033	0.026	0.026	0.035
5lb Sternum	5.408	5.480	8.275	9.356	14.717	16.225	2.581	2.649	3.655	5.732	10.130	-0.028	-2.774	-6.511	-8.947	-8.564	-5.333	3.062
10lb Abdomen	0.030	0.032	-0.053	-0.014	-0.553	-1.249	0.509	0.550	0.732	0.914	1.384	0.364	0.886	-1.082	-0.789	-1.095	-0.963	-0.023
10lb Sternum	13.505	13.412	14.205	16.279	28.383	34.493	4.377	3.998	6.490	9.773	20.290	-2.205	-7.775	-12.808	-16.664	-15.585	-8.973	5.953
15lb Abdomen	0.254	0.255	-0.198	-0.265	-1.145	-2.042	0.952	0.948	1.338	1.632	2.375	0.505	1.006	-0.851	-0.647	-0.974	-0.841	0.135
15lb Sternum	23.487	22.885	18.675	22.348	44.532	59.712	2.939	2.179	4.916	8.380	27.598	-6.101	-13.747	-19.295	-24.359	-22.181	-11.907	8.239
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.028	0.026	-0.006	-0.009	-0.012	-0.011	0.026	0.009	0.024	0.027	0.022	-0.015	-0.007	-0.026	-0.012	-0.013	-0.014	0.002
5lb Sternum	11.057	9.660	1.492	3.951	18.210	39.332	-16.562	-15.815	-14.177	-15.613	-11.129	-17.141	-22.430	-11.418	-14.048	-11.507	-9.500	-4.449
10lb Abdomen	0.134	0.124	-0.024	-0.040	-0.044	-0.004	0.089	0.014	0.089	0.114	0.092	-0.086	-0.051	-0.125	-0.060	-0.069	-0.071	0.005
10lb Sternum	30.606	26.689	-2.166	3.632	41.159	87.829	-35.859	-37.165	-33.769	-39.003	-27.358	-41.220	-38.847	-24.441	-27.096	-23.877	-18.734	-9.389
15lb Abdomen	0.321	0.299	-0.055	-0.093	-0.097	0.019	0.193	0.016	0.200	0.261	0.213	-0.214	-0.134	-0.304	-0.148	-0.173	-0.175	0.008
15lb Sternum	58.807	51.249	-10.517	-0.432	69.107	159.201	-70.399	-71.085	-62.023	-73.469	-51.855	-55.938	-48.067	-44.423	-40.881	-37.869	-28.210	-15.106

Table D.2.3: Male ML Shear Percentage Change for all Trials

Male ML Shear % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum and abdomen compared to baseline (no weight) for all motions. The right two columns consist of the average of the forces experienced for each motion across the entire spinal level.

Male ML Shear (N) Percent Change																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average
5lb Abdomen	0.003	0.008	0.002	-0.007	-0.003	-0.004	-0.005	-0.012	-0.118	0.003	0.001	0.016	0.002	0.002	0.000	0.003	0.003	-0.006
5lb Sternum	4.775	3.904	5.264	6.738	6.993	7.650	8.118	8.551	0.257	7.951	7.974	11.894	12.402	11.348	10.779	10.259	9.480	7.902
10lb Abdomen	0.016	0.042	0.012	-0.034	-0.018	-0.019	-0.028	-0.063	-0.609	0.013	0.005	0.082	0.011	0.011	0.000	0.018	0.018	-0.032
10lb Sternum	9.824	7.804	10.706	13.741	14.085	15.406	16.326	17.079	0.045	16.135	16.140	23.220	24.799	22.598	21.622	19.684	18.342	15.738
15lb Abdomen	0.040	0.106	0.031	-0.087	-0.044	-0.049	-0.071	-0.159	-1.543	0.033	0.013	0.208	0.028	0.027	0.000	0.048	0.048	-0.081
15lb Sternum	14.939	11.696	16.207	20.925	21.259	23.263	24.596	25.567	-1.115	24.515	24.462	34.231	36.953	33.712	32.343	29.561	27.552	23.569
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.001	0.001	0.000	0.000	0.000	0.000	0.000	-0.002	0.024	0.010	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.003
5lb Sternum	2.923	3.008	2.866	3.248	3.837	4.141	4.400	5.092	0.815	2.311	4.285	4.168	4.342	4.881	4.894	4.921	4.879	3.824
10lb Abdomen	0.002	0.002	-0.001	0.000	0.000	0.000	0.000	-0.004	0.055	0.025	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.006
10lb Sternum	5.843	6.015	5.730	6.496	7.677	8.286	8.808	10.179	1.501	4.664	8.571	8.334	8.686	9.770	9.796	9.848	9.749	7.644
15lb Abdomen	0.004	0.004	-0.002	0.000	0.001	0.000	-0.001	-0.009	0.128	0.063	0.053	0.000	0.000	0.001	0.001	0.000	0.000	0.014
15lb Sternum	8.751	9.008	8.589	9.749	11.516	12.432	13.218	15.296	2.423	6.987	12.885	12.484	13.023	14.660	14.716	14.795	14.664	11.482
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.003	0.009	0.002	-0.010	-0.010	-0.016	0.001	0.037	0.045	0.027	0.011	0.002	0.000	-0.001	-0.003	-0.004	-0.004	0.005
5lb Sternum	6.835	4.568	7.228	10.144	8.838	9.116	9.072	9.651	11.972	11.199	10.411	11.581	11.932	11.900	11.948	11.924	11.681	10.000
10lb Abdomen	0.014	0.042	0.010	-0.047	-0.049	-0.076	0.003	0.179	0.221	0.134	0.053	0.012	-0.001	-0.006	-0.014	-0.017	-0.018	0.026
10lb Sternum	13.763	9.199	14.524	20.327	17.703	18.239	18.252	19.496	23.909	22.439	20.868	23.194	24.014	23.845	23.880	23.605	23.181	20.026
15lb Abdomen	0.037	0.108	0.025	-0.122	-0.127	-0.198	0.008	0.465	0.576	0.351	0.140	0.033	-0.002	-0.015	-0.037	-0.045	-0.047	0.068
15lb Sternum	20.717	15.219	21.949	30.712	26.704	27.438	27.505	29.814	36.089	33.846	31.534	34.988	36.339	36.020	36.008	35.621	34.958	30.321
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.003	0.003	-0.012	-0.008	-0.009	-0.015	0.001	0.036	0.049	0.036	0.022	0.001	-0.002	-0.003	-0.005	-0.006	-0.006	0.005
5lb Sternum	5.932	6.206	8.629	7.790	7.731	8.194	7.927	8.476	10.309	10.262	10.557	10.708	11.073	11.968	11.836	11.970	11.865	9.496
10lb Abdomen	-0.006	-0.003	-0.071	-0.044	-0.044	-0.059	0.009	0.121	0.390	0.234	0.090	-0.021	-0.001	0.001	0.045	0.069	0.038	0.044
10lb Sternum	11.913	12.457	17.307	15.624	15.510	16.425	15.893	17.073	20.422	20.375	21.151	21.484	22.166	23.938	23.592	23.809	23.623	18.986
15lb Abdomen	0.011	0.014	-0.126	-0.080	-0.085	-0.130	0.014	0.291	0.616	0.398	0.192	-0.017	-0.009	-0.014	0.021	0.041	0.009	0.067
15lb Sternum	17.917	18.732	25.925	23.421	23.287	24.647	23.859	25.716	30.374	30.568	31.832	32.266	33.261	35.914	35.325	35.555	35.298	28.465
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	
5lb Abdomen	0.001	0.006	0.001	-0.006	-0.002	-0.003	-0.004	-0.010	-0.166	0.002	0.001	0.004	0.001	0.001	0.000	0.001	0.002	-0.010
5lb Sternum	4.694	3.998	5.266	6.717	6.835	7.422	7.760	8.171	0.570	7.930	8.020	9.597	9.325	9.796	9.771	9.340	8.978	7.305
10lb Abdomen	0.008	0.030	0.004	-0.027	-0.010	-0.013	-0.018	-0.049	-0.817	0.011	0.007	0.020	0.004	0.002	-0.002	0.006	0.008	-0.049
10lb Sternum	9.451	8.077	10.608	13.512	13.718	14.880	15.534	16.300	2.648	15.951	16.143	19.296	18.649	19.640	19.604	18.443	17.757	14.718
15lb Abdomen	0.019	0.073	0.011	-0.065	-0.024	-0.031	-0.044	-0.118	-1.975	0.026	0.017	0.047	0.010	0.005	-0.005	0.014	0.018	-0.119
15lb Sternum	14.540	12.252	16.271	20.745	20.907	22.656	23.607	24.767	9.977	24.380	24.674	29.851	28.424	29.805	29.731	28.212	27.142	22.820

Table D.2. 4:* *Male Resultant Force Percentage Change for all Trials

Male Resultant Force % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum and abdomen compared to baseline (no weight) for all motions. The right two columns consist of the average of the forces experienced for each motion across the entire spinal level.

Male Resultant Force % change																	
Motion 1																	
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**
5lb Abdomen	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003	0.001	0.002	0.005	0.007	0.005	0.003	0.003	0.003
5lb Sternum	4.775	5.115	5.264	5.571	6.101	6.771	7.225	7.565	7.822	7.950	7.974	6.970	5.413	5.297	5.694	5.968	6.000	6.322
10lb Abdomen	0.016	0.018	0.012	0.008	0.007	0.007	0.007	0.010	0.012	0.013	0.005	0.011	0.027	0.036	0.024	0.016	0.015	0.014
10lb Sternum	9.824	10.510	10.706	11.322	12.417	13.795	14.725	15.403	15.893	16.134	16.139	14.255	10.907	10.692	11.392	12.113	12.128	12.844
15lb Abdomen	0.040	0.044	0.031	0.021	0.018	0.017	0.018	0.025	0.032	0.033	0.013	0.027	0.069	0.091	0.061	0.040	0.039	0.036
15lb Sternum	14.939	15.978	16.207	17.178	18.876	21.000	22.434	23.457	24.179	24.515	24.461	21.752	16.682	16.359	17.458	18.557	18.524	19.562
Motion 2																	
5lb Abdomen	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5lb Sternum	2.921	3.011	3.137	3.282	3.489	3.696	3.814	3.959	4.074	4.194	4.364	4.933	5.217	5.602	5.978	6.289	6.108	4.357
10lb Abdomen	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
10lb Sternum	5.839	6.020	6.279	6.568	6.984	7.397	7.635	7.929	8.154	8.399	8.738	9.881	10.457	11.237	11.990	12.612	12.255	8.728
15lb Abdomen	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.002	0.000	-0.001	-0.001	0.000	-0.001	-0.001	-0.001	0.002
15lb Sternum	8.745	9.016	9.410	9.852	10.480	11.105	11.465	11.902	12.247	12.611	13.118	14.844	15.703	16.887	18.008	18.952	18.441	13.105
Motion 3																	
5lb Abdomen	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001	-0.001	-0.002	-0.003	-0.004	-0.004	0.000
5lb Sternum	6.835	7.162	7.228	7.511	7.952	8.581	9.072	9.061	9.346	9.510	9.566	8.813	8.227	8.293	8.775	9.081	8.935	8.468
10lb Abdomen	0.014	0.015	0.010	0.006	0.004	0.003	0.003	0.007	0.011	0.012	0.008	0.005	-0.006	-0.007	-0.015	-0.018	-0.018	0.002
10lb Sternum	13.763	14.411	14.524	15.099	15.988	17.256	18.251	18.239	18.842	19.190	19.301	17.883	16.716	16.770	17.657	18.362	18.001	17.074
15lb Abdomen	0.037	0.038	0.025	0.016	0.010	0.007	0.008	0.018	0.030	0.031	0.020	0.013	-0.015	-0.019	-0.039	-0.046	-0.046	0.005
15lb Sternum	20.717	21.734	21.949	22.795	24.115	26.014	27.504	27.551	28.445	28.986	29.157	27.220	25.482	25.534	26.772	27.793	27.297	25.827
Motion 4																	
5lb Abdomen	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.002	0.003	0.003	0.001	0.001	-0.002	-0.004	-0.005	-0.006	-0.006	0.000
5lb Sternum	5.932	6.206	6.391	6.655	7.058	7.574	7.927	8.148	8.519	8.759	8.920	9.449	9.822	10.363	10.554	10.997	11.030	8.488
10lb Abdomen	-0.006	-0.003	-0.003	0.000	0.003	0.006	0.009	0.008	0.030	0.020	0.002	0.032	-0.008	0.109	0.056	0.043	0.038	0.020
10lb Sternum	11.913	12.457	12.834	13.362	14.166	15.194	15.893	16.361	17.074	17.563	17.902	18.944	19.724	20.692	21.083	21.978	22.042	17.011
15lb Abdomen	0.011	0.014	0.009	0.008	0.008	0.010	0.014	0.019	0.045	0.034	0.009	0.035	-0.017	0.091	0.032	0.015	0.010	0.020
15lb Sternum	17.917	18.732	19.301	20.088	21.287	22.818	23.859	24.588	25.650	26.408	26.923	28.503	29.696	31.091	31.626	32.982	33.067	25.561
Motion 5																	
5lb Abdomen	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.001	0.004	0.005	0.006	0.004	0.003	0.003	0.002
5lb Sternum	4.694	4.972	5.266	5.703	6.232	6.840	7.266	7.508	7.760	7.930	8.020	7.720	7.459	7.160	7.507	7.914	7.880	6.931
10lb Abdomen	0.008	0.008	0.004	0.002	0.001	-0.001	0.000	0.004	0.009	0.011	0.007	0.021	0.023	0.029	0.019	0.016	0.016	0.010
10lb Sternum	9.451	10.004	10.608	11.479	12.528	13.736	14.601	15.089	15.604	15.951	16.143	15.594	15.089	14.436	15.036	15.887	15.822	13.945
15lb Abdomen	0.019	0.020	0.011	0.005	0.002	-0.001	-0.001	0.011	0.021	0.026	0.017	0.050	0.056	0.070	0.046	0.038	0.038	0.025
15lb Sternum	14.540	15.393	16.271	17.579	19.173	21.022	22.350	23.062	23.857	24.380	24.673	23.698	23.010	22.183	23.128	24.368	24.268	21.350

Appendix D.3 Male Per Trial Data Sorted by Sternum Weights

Table D.3.1: Male Compression Data for the Baseline and Sternum Weights

Male raw compression (N) data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) *added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.*

Male Compression per trial																		
No Weight																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
Motion 1	623.42	578.80	517.78	461.00	405.09	360.78	344.60	332.05	317.44	303.16	285.73	256.31	250.38	239.25	227.84	211.95	203.19	348.16	128.67
Motion 2	1400.66	1355.65	1148.40	1018.22	912.12	836.46	829.34	789.36	762.15	715.25	657.56	490.24	409.88	337.28	280.45	223.24	184.60	726.52	373.67
Motion 3	868.21	824.43	668.12	579.21	509.81	457.44	434.65	397.08	359.58	330.25	298.26	243.57	224.97	210.37	194.07	172.04	160.05	407.77	220.62
Motion 4	1038.96	996.64	791.57	679.47	597.42	538.74	515.66	463.01	415.85	380.16	341.06	251.25	206.89	182.65	165.11	139.39	123.30	460.42	287.19
Motion 5	721.29	676.87	585.89	518.31	458.86	412.77	397.82	382.02	362.26	342.16	317.16	259.01	226.95	203.46	191.68	173.45	162.56	376.03	172.08
Avg	930.51	886.48	742.35	651.24	576.66	521.24	504.41	472.70	443.46	414.20	379.96	300.07	263.81	234.60	211.83	184.01	166.74		
STDEV	306.09	306.07	248.86	220.52	200.47	187.92	192.01	183.09	181.55	170.56	156.58	106.47	83.10	60.87	44.36	33.78	29.99		
5lb Sternum																		
Motion 1	653.19	608.67	545.03	486.47	429.55	384.92	369.31	357.09	342.43	327.26	308.51	273.95	263.03	250.68	239.28	222.98	213.79	369.18	134.55
Motion 2	1441.57	1396.46	1184.51	1051.66	943.76	867.14	860.83	820.59	793.33	745.48	686.29	514.86	432.47	358.13	299.75	241.01	201.09	755.23	381.02
Motion 3	927.55	883.95	716.42	622.40	550.27	496.66	474.09	433.05	392.96	361.40	326.61	263.91	241.35	225.52	208.46	184.77	171.23	440.04	235.82
Motion 4	1100.60	1058.49	842.00	724.49	639.52	579.51	556.53	500.72	451.07	413.19	371.12	274.32	226.09	200.22	181.13	153.47	135.73	494.60	302.62
Motion 5	755.15	710.72	616.74	547.63	487.27	440.80	426.61	410.65	390.41	369.30	342.60	278.84	243.44	217.18	205.11	186.55	174.88	400.23	179.01
Avg	975.61	931.66	780.94	686.53	610.07	553.81	537.47	504.42	474.04	443.32	407.03	321.18	281.27	250.35	226.75	197.75	179.35		
STDEV	311.29	311.26	251.68	222.60	202.15	189.34	193.33	184.10	182.59	171.66	157.80	108.41	85.53	62.94	45.74	34.51	30.20		
10lb Sternum																		
Motion 1	684.67	640.23	573.21	512.74	454.90	410.02	395.00	383.06	368.20	352.07	331.85	292.41	275.86	262.32	250.62	234.75	224.95	390.99	140.91
Motion 2	1482.44	1437.25	1220.67	1085.14	975.45	897.87	892.37	851.90	824.55	775.78	715.07	539.56	455.14	379.05	319.12	258.83	217.66	783.99	388.34
Motion 3	987.70	944.19	765.16	666.04	591.16	536.32	513.98	469.49	426.89	393.12	355.48	284.92	258.34	241.09	223.07	198.24	182.88	472.83	251.11
Motion 4	1162.73	1120.79	892.85	769.85	681.91	620.52	597.61	538.74	486.48	446.42	401.40	297.49	245.49	217.66	197.11	167.62	148.19	528.99	318.23
Motion 5	789.46	744.97	648.04	577.31	515.97	469.07	455.70	439.56	418.86	396.74	368.36	299.08	260.34	231.13	218.48	199.89	187.45	424.73	186.06
Avg	1021.40	977.49	819.99	722.22	643.88	586.76	570.93	536.55	505.00	472.83	434.43	342.69	299.03	266.25	241.68	211.87	192.22		
STDEV	316.56	316.56	254.62	224.73	203.86	190.76	194.62	185.01	183.50	172.63	158.88	110.19	87.93	65.13	47.30	35.41	30.69		
15lb Sternum																		
Motion 1	716.56	672.22	601.70	539.48	480.86	435.80	421.44	409.76	394.67	377.48	355.63	311.44	289.42	274.66	262.91	246.99	236.54	413.39	147.26
Motion 2	1523.14	1477.87	1256.71	1118.61	1007.15	928.66	923.99	883.23	855.86	806.13	743.90	564.33	477.81	399.95	338.40	276.61	234.17	812.74	395.63
Motion 3	1048.07	1004.79	814.77	710.27	632.52	576.36	554.20	506.44	461.20	425.22	384.70	306.58	275.83	257.11	237.95	211.57	194.63	506.01	266.51
Motion 4	1225.12	1183.34	943.89	815.35	724.39	661.56	638.69	576.82	521.98	479.80	431.80	320.84	265.10	235.24	213.11	181.95	160.80	563.52	333.89
Motion 5	826.17	781.68	681.22	608.65	546.29	498.97	486.46	469.98	448.76	425.58	395.42	319.86	277.84	246.09	233.04	213.97	200.71	450.63	193.68
Avg	1067.81	1023.98	859.66	758.47	678.24	620.27	604.96	569.25	536.50	502.84	462.29	364.61	317.20	282.61	257.08	226.22	205.37		
STDEV	321.80	321.80	257.46	226.75	205.41	192.01	195.71	185.66	184.18	173.37	159.77	111.80	90.20	67.20	48.80	36.38	31.32		

Table D.3.2: Male AP Shear Data for the Baseline and Sternum Weights

Male raw AP Shear data sorted by weight conditions (no weight 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) *added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.*

Male AP Shear Per trial																		
No Weight																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
Motion 1	0.927	0.970	-1.259	-0.792	-0.265	-0.060	0.595	0.783	0.744	0.877	0.980	4.279	9.348	11.703	13.253	16.278	19.010	4.551	6.614
Motion 2	4.968	4.809	-24.141	-6.696	31.039	38.395	52.895	60.517	57.124	64.314	41.896	44.867	65.690	90.137	50.446	-11.933	-75.767	28.739	41.509
Motion 3	2.810	2.945	-1.688	-0.590	0.907	1.452	2.672	3.259	2.396	2.297	2.296	12.269	24.635	27.257	27.317	27.849	33.736	10.107	12.451
Motion 4	2.989	3.054	-3.527	-2.226	-0.937	-0.740	1.393	1.565	1.346	1.410	1.279	4.968	9.047	13.808	16.027	17.097	20.061	5.095	7.308
Motion 5	1.134	1.181	-1.943	-1.314	-0.581	-0.405	0.541	0.745	0.680	0.802	0.922	3.042	5.670	13.243	15.129	17.618	20.382	4.520	7.227
Avg	2.566	2.592	-6.512	-2.324	6.033	7.728	11.619	13.374	12.458	13.940	9.475	13.885	22.878	31.229	24.434	13.382	3.484		
STDEV	1.639	1.571	9.892	2.525	13.996	17.164	23.090	26.374	24.979	28.166	18.133	17.691	25.032	33.520	15.550	14.919	44.714		
5lb Sternum																		
Motion 1	1.001	1.033	-1.257	-0.823	-0.351	-0.221	0.488	0.645	0.621	0.735	0.864	2.646	8.743	10.433	11.708	14.266	16.933	3.969	5.909
Motion 2	5.742	5.498	-23.967	-6.557	31.613	38.912	53.973	61.841	58.654	66.095	43.383	45.177	65.909	90.721	50.434	-13.473	-78.522	29.143	42.345
Motion 3	2.997	3.130	-1.917	-0.772	0.719	1.238	2.609	3.161	2.379	2.394	2.437	10.933	23.401	25.674	25.669	26.288	32.621	9.586	11.825
Motion 4	3.151	3.221	-3.819	-2.434	-1.075	-0.860	1.429	1.606	1.395	1.491	1.409	4.966	8.796	12.909	14.593	15.633	18.991	4.788	6.848
Motion 5	1.259	1.295	-1.972	-1.366	-0.687	-0.565	0.451	0.627	0.584	0.677	0.820	2.521	4.398	11.731	13.004	15.591	18.446	3.930	6.447
Avg	2.830	2.836	-6.586	-2.390	6.044	7.701	11.790	13.576	12.727	14.278	9.782	13.249	22.249	30.294	23.081	11.661	1.694		
STDEV	1.899	1.799	9.763	2.423	14.309	17.466	23.597	27.001	25.685	28.975	18.794	18.172	25.444	34.330	16.262	14.863	45.286		
10lb Sternum																		
Motion 1	1.171	1.183	-1.149	-0.795	-0.461	-0.420	0.337	0.451	0.441	0.509	0.697	1.986	6.953	8.648	10.171	11.768	15.059	3.326	5.087
Motion 2	6.485	6.166	-23.776	-6.408	32.195	39.444	55.065	63.182	60.212	67.912	44.892	45.479	66.157	91.331	50.415	-14.908	-81.275	29.563	43.196
Motion 3	3.252	3.377	-2.071	-0.914	0.512	0.999	2.515	3.027	2.317	2.432	2.587	9.816	21.465	23.487	23.539	24.734	31.572	8.979	11.075
Motion 4	3.393	3.463	-4.028	-2.588	-1.203	-0.995	1.454	1.627	1.433	1.548	1.539	4.858	8.343	12.039	13.356	14.433	18.261	4.526	6.474
Motion 5	1.480	1.497	-1.901	-1.362	-0.820	-0.761	0.347	0.468	0.451	0.489	0.670	1.788	3.467	10.006	11.030	13.411	16.564	3.343	5.666
Avg	3.156	3.137	-6.585	-2.413	6.045	7.653	11.944	13.751	12.971	14.578	10.077	12.786	21.277	29.102	21.702	9.888	0.036		
STDEV	2.115	1.991	9.669	2.343	14.632	17.788	24.123	27.653	26.420	29.826	19.478	18.561	26.000	35.278	16.914	14.763	45.927		
15lb Sternum																		
Motion 1	1.432	1.417	-0.938	-0.707	-0.581	-0.660	0.161	0.219	0.221	0.219	0.495	1.401	4.202	6.119	7.790	9.887	13.245	2.584	4.214
Motion 2	7.304	6.903	-23.571	-6.233	32.802	39.976	56.150	64.518	61.760	69.709	46.408	45.715	66.438	92.122	50.595	-16.378	-83.936	30.017	44.059
Motion 3	3.636	3.747	-2.111	-0.972	0.357	0.749	2.457	2.919	2.259	2.426	2.723	9.337	20.050	22.045	22.129	23.410	30.821	8.587	10.534
Motion 4	3.691	3.753	-4.186	-2.723	-1.354	-1.182	1.434	1.599	1.412	1.528	1.632	4.665	7.803	11.143	12.123	13.305	17.672	4.254	6.139
Motion 5	1.800	1.787	-1.738	-1.308	-0.983	-1.050	0.160	0.215	0.258	0.213	0.444	1.340	2.945	7.360	8.944	10.946	14.633	2.704	4.795
Avg	3.573	3.521	-6.509	-2.389	6.048	7.567	12.072	13.894	13.182	14.819	10.340	12.492	20.288	27.758	20.316	8.234	-1.513		
STDEV	2.327	2.178	9.613	2.285	14.969	18.134	24.659	28.322	27.169	30.699	20.184	18.857	26.670	36.523	17.843	14.763	46.598		

Table D.3.3: Male ML Shear Data for the Baseline and Sternum Weights

Male raw ML shear data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) *added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.*

Male ML Shear Per trial																		
No Weight																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
Motion 1	115.54	-114.21	-54.42	92.78	108.67	108.17	85.44	53.53	25.71	13.24	14.97	-35.94	-57.27	-71.39	-84.93	-93.98	-103.52	0.14	82.59
Motion 2	259.64	-214.67	161.12	261.12	231.32	225.05	170.19	85.80	-39.08	-75.83	-55.41	-131.67	-182.00	-193.35	-228.45	-249.78	-261.49	-13.97	197.79
Motion 3	167.56	-123.78	-54.70	83.00	67.96	49.80	22.51	-28.27	-55.02	-71.15	-81.02	-103.55	-121.05	-125.51	-137.95	-144.30	-150.05	-47.38	94.10
Motion 4	200.52	-141.47	72.92	110.56	79.28	55.69	26.70	-35.68	-67.57	-82.85	-85.66	-115.90	-138.42	-130.55	-146.26	-151.95	-156.37	-41.59	110.98
Motion 5	133.68	-116.54	-61.58	112.06	119.66	118.77	92.96	55.10	14.25	14.94	16.62	-47.53	-75.76	-86.82	-99.74	-106.89	-114.68	-1.85	93.08
Avg	175.39	-142.13	12.67	131.90	121.38	111.50	79.56	26.10	-24.34	-40.33	-38.10	-86.92	-114.90	-121.52	-139.47	-149.38	-157.22		
STDEV	57.25	41.93	100.28	73.26	64.96	70.50	60.16	54.61	41.90	49.86	50.53	42.63	49.87	47.37	55.94	61.21	62.49		
5lb Sternum																			
Motion 1	121.06	-118.67	-57.29	99.03	116.27	116.44	92.37	58.10	25.77	14.29	16.17	-40.21	-64.38	-79.49	-94.08	-103.62	-113.33	-0.68	88.90
Motion 2	267.23	-221.12	165.74	269.60	240.20	234.37	177.68	90.17	-39.40	-77.58	-57.78	-137.16	-189.91	-202.79	-239.63	-262.07	-274.25	-15.10	205.72
Motion 3	179.02	-129.44	-58.66	91.42	73.97	54.34	24.55	-30.99	-61.61	-79.12	-89.45	-115.54	-135.49	-140.45	-154.44	-161.51	-167.57	-53.00	103.18
Motion 4	212.41	-150.24	79.21	119.17	85.41	60.25	28.82	-38.70	-74.54	-91.35	-94.70	-128.31	-153.75	-146.17	-163.58	-170.13	-174.92	-47.13	121.01
Motion 5	139.96	-121.20	-64.82	119.59	127.84	127.59	100.18	59.61	14.33	16.12	17.95	-52.09	-82.82	-95.33	-109.48	-116.88	-124.98	-2.61	99.87
Avg	183.94	-148.13	12.84	139.76	128.74	118.60	84.72	27.64	-27.09	-43.53	-41.56	-94.66	-125.27	-132.84	-152.24	-162.84	-171.01		
STDEV	58.44	42.65	104.69	73.63	66.06	72.50	62.62	58.52	45.01	53.89	55.35	45.14	51.49	48.43	56.97	62.29	63.51		
10lb Sternum																			
Motion 1	126.90	-123.13	-60.25	105.53	123.97	124.83	99.39	62.67	25.72	15.37	17.39	-44.28	-71.48	-87.52	-103.29	-112.48	-122.51	-1.36	95.20
Motion 2	274.82	-227.58	170.35	278.08	249.08	243.70	185.18	94.53	-39.66	-79.37	-60.16	-142.65	-197.81	-212.24	-250.82	-274.38	-286.98	-16.23	213.66
Motion 3	190.62	-135.17	-62.65	99.88	80.00	58.88	26.62	-33.78	-68.18	-87.12	-97.93	-127.57	-150.12	-155.44	-170.90	-178.36	-184.83	-58.59	112.32
Motion 4	224.41	-159.09	85.54	127.83	91.58	64.83	30.95	-41.77	-81.37	-99.73	-103.78	-140.80	-169.10	-161.80	-180.77	-188.12	-193.31	-52.62	131.08
Motion 5	146.32	-125.95	-68.11	127.20	136.08	136.45	107.41	64.08	14.63	17.32	19.31	-56.70	-89.88	-103.87	-119.29	-126.61	-135.04	-3.33	106.70
Avg	192.61	-154.18	12.98	147.70	136.14	125.74	89.91	29.15	-29.77	-46.70	-45.03	-102.40	-135.68	-144.17	-165.01	-175.99	-184.53		
STDEV	59.65	43.40	109.19	73.96	67.16	74.52	65.11	62.47	48.18	58.02	60.24	47.94	53.40	49.76	58.19	63.85	64.94		
15lb Sternum																			
Motion 1	132.81	-127.57	-63.24	112.20	131.77	133.33	106.45	67.21	25.42	16.48	18.64	-48.24	-78.44	-95.45	-112.40	-121.76	-132.04	-2.05	101.60
Motion 2	282.37	-234.00	174.96	286.57	257.96	253.03	192.68	98.92	-40.02	-81.13	-62.55	-148.11	-205.71	-221.70	-262.06	-286.74	-299.84	-17.37	221.62
Motion 3	202.28	-142.62	-66.71	108.50	86.11	63.46	28.70	-36.69	-74.88	-95.23	-106.57	-139.78	-165.04	-170.72	-187.63	-195.70	-202.50	-64.41	121.71
Motion 4	236.45	-167.96	91.82	136.45	97.75	69.41	33.07	-44.85	-88.10	-108.18	-112.93	-153.30	-184.46	-177.43	-197.93	-205.97	-211.57	-58.10	141.17
Motion 5	153.12	-130.81	-71.60	135.31	144.68	145.68	114.91	68.75	15.67	18.58	20.72	-61.72	-97.29	-112.70	-129.39	-137.05	-145.81	-4.06	113.90
Avg	201.40	-160.60	13.05	155.81	143.65	132.98	95.16	30.67	-32.38	-49.90	-48.54	-110.23	-146.19	-155.60	-177.88	-189.44	-198.35		
STDEV	60.87	44.00	113.76	74.22	68.24	76.56	67.64	66.49	51.52	62.29	65.23	50.89	55.55	51.31	59.63	65.39	66.42		

Table D.3.4: Male Resultant Force Data for the Baseline and Sternum Weights

Male raw resultant data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) *added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.*

Male Resultant Force Per trial																		
No Weight																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
Motion 1	634.04	589.96	520.63	470.25	419.41	376.64	355.03	336.34	318.48	303.45	286.12	258.85	257.02	249.95	243.52	232.42	228.83	357.70	127.63
Motion 2	1424.53	1372.55	1159.90	1051.19	941.51	867.06	848.28	796.31	765.29	722.13	661.22	509.59	453.26	399.08	365.22	335.22	328.93	764.78	347.76
Motion 3	884.23	833.68	670.36	585.13	514.32	460.14	435.24	398.10	363.77	337.84	309.08	264.95	256.66	246.48	239.67	226.27	221.96	426.35	209.08
Motion 4	1058.14	1006.64	794.93	688.41	602.66	541.61	516.35	464.38	421.30	389.09	351.65	276.74	249.09	224.93	221.16	206.90	200.14	483.18	271.83
Motion 5	733.57	686.83	589.12	530.29	474.21	429.52	408.54	385.97	362.54	342.49	317.60	263.35	239.33	221.61	216.60	204.50	199.98	388.59	167.78
Avg	946.90	897.93	746.99	665.05	590.42	534.99	512.69	476.22	446.28	419.00	385.14	314.70	291.07	268.41	257.23	241.06	235.97		
STDEV	311.38	308.47	252.40	230.29	207.34	195.01	196.43	184.67	182.03	172.17	156.12	109.15	90.95	74.13	61.46	54.00	53.54		
5lb Sternum																		
Motion 1	664.31	620.14	548.04	496.45	445.00	402.15	380.68	361.79	343.40	327.57	308.94	276.90	270.93	263.19	257.38	246.29	242.56	379.75	132.87
Motion 2	1466.14	1413.87	1196.29	1085.69	974.36	899.10	880.63	827.84	796.47	752.41	690.08	534.73	476.90	421.44	387.06	356.30	349.02	794.61	354.39
Motion 3	944.67	893.38	718.82	629.08	555.22	499.63	474.73	434.17	397.77	369.97	338.65	288.30	277.77	266.92	260.70	246.81	241.80	461.08	222.10
Motion 4	1120.91	1069.10	845.73	734.23	645.20	582.63	557.28	502.22	457.19	423.17	383.02	302.88	273.55	248.24	244.50	229.66	222.22	520.10	284.89
Motion 5	768.01	720.98	620.15	560.53	503.76	458.89	438.22	414.95	390.68	369.65	343.07	283.68	257.18	237.47	232.86	220.69	215.74	413.91	173.92
Avg	992.81	943.50	785.80	701.20	624.71	568.48	546.31	508.19	477.10	448.55	412.75	337.30	311.27	287.45	276.50	259.95	254.27		
STDEV	316.71	313.70	255.22	232.29	208.82	196.17	197.57	185.62	183.05	173.22	157.26	110.78	92.91	75.83	62.78	55.00	54.27		
10lb Sternum																		
Motion 1	696.33	651.96	576.37	523.49	471.49	428.60	407.31	388.15	369.10	352.41	332.30	295.75	285.05	276.67	271.26	260.57	256.59	402.55	138.60
Motion 2	1507.71	1455.17	1232.73	1120.23	1007.26	931.19	913.04	859.45	827.69	782.78	719.00	559.94	500.65	443.93	409.01	377.50	369.25	824.50	360.97
Motion 3	1005.93	953.82	767.73	673.48	596.55	539.54	514.68	470.71	432.31	402.66	368.73	312.33	299.56	287.81	281.99	267.81	261.92	496.33	235.22
Motion 4	1184.19	1132.03	896.95	780.39	688.04	623.90	598.42	540.36	493.24	457.42	414.60	329.16	298.22	271.47	267.78	252.38	244.26	557.22	298.12
Motion 5	802.91	755.54	651.62	591.16	533.62	488.51	468.19	444.21	419.11	397.12	368.87	304.42	275.44	253.60	249.17	236.99	231.62	439.54	180.18
Avg	1039.41	989.71	825.08	737.75	659.39	602.35	580.33	540.58	508.29	478.48	440.70	360.32	331.79	306.70	295.84	279.05	272.73		
STDEV	322.11	319.02	258.16	234.32	210.30	197.29	198.65	186.47	183.95	174.14	158.29	112.27	94.92	77.70	64.36	56.21	55.21		
15lb Sternum																		
Motion 1	728.76	684.22	605.01	551.02	498.58	455.74	434.68	415.24	395.49	377.84	356.11	315.16	299.89	290.83	286.03	275.55	271.22	425.96	144.30
Motion 2	1549.11	1496.30	1269.05	1154.75	1040.18	963.34	945.53	891.09	859.02	813.19	747.96	585.23	524.43	466.47	430.99	398.75	389.59	854.41	367.48
Motion 3	1067.42	1014.87	817.50	718.51	638.35	579.84	554.95	507.78	467.24	435.76	399.19	337.07	322.06	309.41	303.83	289.15	282.56	532.09	248.35
Motion 4	1247.73	1195.20	948.36	826.70	730.95	665.19	639.55	578.57	529.37	491.84	446.33	355.61	323.05	294.86	291.10	275.15	266.33	594.46	311.41
Motion 5	840.24	792.56	684.97	623.51	565.13	519.81	499.84	474.99	449.04	425.99	395.96	325.76	294.40	270.76	266.70	254.34	248.51	466.62	186.96
Avg	1086.65	1036.63	864.98	774.90	694.64	636.78	614.91	573.53	540.03	508.92	469.11	383.77	352.77	326.47	315.73	298.59	291.64		
STDEV	327.49	324.30	260.99	236.21	211.60	198.21	199.52	187.06	184.62	174.85	159.13	113.61	96.82	79.47	65.80	57.36	56.11		

Appendix D.4 Male Sternum Weights Percentage Change

Table D.4.1: Male Sternum Weight Compressive Force Percentage Change

Male Compressive Force % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Male Compressive Force (N) % Change																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
5lb Sternum																			
Motion 1	4.77	5.16	5.26	5.52	6.04	6.69	7.17	7.54	7.87	7.95	7.97	6.88	5.05	4.78	5.02	5.20	5.22	6.12	1.21
Motion 2	2.92	3.01	3.14	3.28	3.47	3.67	3.80	3.96	4.09	4.23	4.37	5.02	5.51	6.18	6.88	7.96	8.93	4.73	1.79
Motion 3	6.83	7.22	7.23	7.46	7.94	8.58	9.07	9.06	9.28	9.43	9.50	8.35	7.28	7.20	7.41	7.40	6.99	8.01	0.95
Motion 4	5.93	6.21	6.37	6.63	7.05	7.57	7.93	8.15	8.47	8.69	8.82	9.18	9.28	9.62	9.71	10.10	10.08	8.22	1.39
Motion 5	4.69	5.00	5.27	5.66	6.19	6.79	7.24	7.49	7.77	7.93	8.02	7.66	7.27	6.75	7.01	7.55	7.58	6.82	1.07
Average	5.03	5.32	5.45	5.71	6.14	6.66	7.04	7.24	7.50	7.65	7.74	7.42	6.88	6.91	7.21	7.64	7.76		
STDEV	1.47	1.57	1.53	1.57	1.67	1.83	1.97	1.94	2.00	2.01	1.99	1.59	1.68	1.77	1.67	1.74	1.86		
10lb Sternum																			
Motion 1	9.82	10.61	10.71	11.22	12.30	13.65	14.63	15.36	15.99	16.13	16.14	14.08	10.17	9.64	10.00	10.76	10.71	12.47	2.46
Motion 2	5.84	6.02	6.29	6.57	6.94	7.34	7.60	7.92	8.19	8.46	8.75	10.06	11.04	12.39	13.79	15.94	17.91	9.47	3.59
Motion 3	13.76	14.53	14.52	14.99	15.96	17.25	18.25	18.23	18.72	19.04	19.18	16.98	14.83	14.60	14.94	15.23	14.26	16.19	1.89
Motion 4	11.91	12.46	12.80	13.30	14.14	15.18	15.89	16.36	16.98	17.43	17.69	18.40	18.66	19.17	19.38	20.25	20.18	16.48	2.77
Motion 5	9.45	10.06	10.61	11.38	12.45	13.64	14.55	15.06	15.62	15.95	16.14	15.47	14.71	13.60	13.98	15.24	15.31	13.72	2.16
Average	10.16	10.74	10.99	11.49	12.36	13.41	14.18	14.59	15.10	15.40	15.58	15.00	13.88	13.88	14.42	15.49	15.67		
STDEV	2.97	3.16	3.08	3.15	3.37	3.70	3.97	3.93	4.05	4.07	4.03	3.20	3.40	3.49	3.36	3.37	3.61		
15lb Sternum																			
Motion 1	14.94	16.14	16.21	17.02	18.70	20.79	22.30	23.40	24.33	24.52	24.46	21.51	15.59	14.80	15.39	16.53	16.41	19.00	3.71
Motion 2	8.74	9.02	9.43	9.86	10.42	11.02	11.41	11.89	12.29	12.71	13.13	15.11	16.57	18.58	20.66	23.91	26.85	14.21	5.39
Motion 3	20.72	21.88	21.95	22.63	24.07	26.00	27.51	27.54	28.26	28.76	28.98	25.87	22.61	22.22	22.61	22.98	21.61	24.48	2.84
Motion 4	17.92	18.73	19.24	20.00	21.25	22.80	23.86	24.58	25.52	26.21	26.61	27.70	28.14	28.79	29.07	30.53	30.41	24.79	4.18
Motion 5	14.54	15.49	16.27	17.43	19.05	20.89	22.28	23.03	23.88	24.38	24.67	23.49	22.42	20.95	21.58	23.36	23.47	21.01	3.26
Average	15.37	16.25	16.62	17.39	18.70	20.30	21.47	22.09	22.86	23.31	23.57	22.74	21.07	21.07	21.86	23.46	23.75		
STDEV	4.47	4.76	4.67	4.77	5.10	5.60	6.01	5.97	6.15	6.19	6.11	4.86	5.11	5.16	4.90	4.96	5.30		

Table D.4.2: Male Sternum Weight AP Shear Percentage Change

Male AP Shear % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Male AP Shear (N) % Change																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
5lb Sternum																		
Motion 1	7.92	6.46	-0.14	3.82	32.80	269.76	-18.10	-17.67	-16.47	-16.10	-11.85	-38.15	-6.46	-10.85	-11.66	-12.36	-10.93	8.83	68.91
Motion 2	15.60	14.33	-0.72	-2.08	1.85	1.34	2.04	2.19	2.68	2.77	3.55	0.69	0.33	0.65	-0.02	12.91	3.64	3.63	5.31
Motion 3	6.65	6.30	13.54	30.93	-20.68	-14.71	-2.36	-3.02	-0.70	4.21	6.14	-10.89	-5.01	-5.81	-6.03	-5.61	-3.30	-0.61	11.70
Motion 4	5.41	5.48	8.28	9.36	14.72	16.23	2.58	2.65	3.65	5.73	10.13	-0.03	-2.77	-6.51	-8.95	-8.56	-5.33	3.06	7.62
Motion 5	11.06	9.66	1.49	3.95	18.21	39.33	-16.56	-15.81	-14.18	-15.61	-11.13	-17.14	-22.43	-11.42	-14.05	-11.51	-9.50	-4.45	16.23
Average	9.33	8.45	4.49	9.20	9.38	62.39	-6.48	-6.33	-5.00	-3.80	-0.63	-13.10	-7.27	-6.79	-8.14	-5.03	-5.09		
STDEV	4.09	3.66	6.20	12.81	20.10	117.62	10.10	9.78	9.59	11.06	10.19	15.89	8.85	4.85	5.44	10.37	5.76		
10lb Sternum																		
Motion 1	26.31	21.95	-8.78	0.36	74.17	603.03	-43.40	-42.47	-40.76	-41.93	-28.88	-53.57	-25.62	-26.10	-23.25	-27.71	-20.78	20.15	153.58
Motion 2	30.54	28.22	-1.51	-4.30	3.72	2.73	4.10	4.40	5.41	5.59	7.15	1.36	0.71	1.32	-0.06	24.93	7.27	7.15	10.39
Motion 3	15.71	14.66	22.69	54.90	-43.49	-31.17	-5.88	-7.11	-3.28	5.89	12.67	-19.99	-12.87	-13.83	-13.83	-11.19	-6.41	-2.50	22.57
Motion 4	13.51	13.41	14.21	16.28	28.38	34.49	4.38	4.00	6.49	9.77	20.29	-2.21	-7.78	-12.81	-16.66	-15.58	-8.97	5.95	15.08
Motion 5	30.61	26.69	-2.17	3.63	41.16	87.83	-35.86	-37.16	-33.77	-39.00	-27.36	-41.22	-38.85	-24.44	-27.10	-23.88	-18.73	-9.39	36.33
Average	23.33	20.99	4.89	14.17	20.79	139.38	-15.33	-15.67	-13.18	-11.93	-3.23	-23.13	-16.88	-15.17	-16.18	-10.69	-9.53		
STDEV	8.19	6.77	13.05	24.01	44.00	262.87	22.72	22.60	22.44	26.12	23.21	23.99	15.55	11.01	10.42	20.96	11.22		
15lb Sternum																		
Motion 1	54.48	46.07	-25.48	-10.81	119.58	1005.24	-73.01	-72.01	-70.28	-74.98	-49.52	-67.25	-55.05	-47.71	-41.22	-39.26	-30.33	33.44	256.07
Motion 2	47.04	43.55	-2.36	-6.92	5.68	4.12	6.15	6.61	8.12	8.39	10.77	1.89	1.14	2.20	0.29	37.25	10.78	10.86	15.92
Motion 3	29.38	27.23	25.07	64.75	-60.61	-48.40	-8.04	-10.43	-5.74	5.59	18.60	-23.90	-18.61	-19.12	-18.99	-15.94	-8.64	-3.99	30.34
Motion 4	23.49	22.89	18.67	22.35	44.53	59.71	2.94	2.18	4.92	8.38	27.60	-6.10	-13.75	-19.29	-24.36	-22.18	-11.91	8.24	23.73
Motion 5	58.81	51.25	-10.52	-0.43	69.11	159.20	-70.40	-71.08	-62.02	-73.47	-51.86	-55.94	-48.07	-44.42	-40.88	-37.87	-28.21	-15.11	64.08
Average	42.64	38.20	1.08	13.79	35.66	235.97	-28.47	-28.95	-25.00	-25.22	-8.88	-30.26	-26.87	-25.67	-25.03	-15.60	-13.66		
STDEV	15.52	12.41	20.84	31.25	67.84	436.85	39.83	39.39	38.03	44.75	38.63	30.35	23.81	20.60	17.26	31.19	16.70		

Table D.4.3: Male Sternum Weight ML Shear Percentage Change

Male ML shear % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Male ML Shear (N) % Change																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
5lb Sternum																			
Motion 1	4.77	3.90	5.26	6.74	6.99	7.65	8.12	8.55	0.26	7.95	7.97	11.89	12.40	11.35	10.78	10.26	9.48	7.90	3.15
Motion 2	2.92	3.01	2.87	3.25	3.84	4.14	4.40	5.09	0.82	2.31	4.29	4.17	4.34	4.88	4.89	4.92	4.88	3.82	1.15
Motion 3	6.83	4.57	7.23	10.14	8.84	9.12	9.07	9.65	11.97	11.20	10.41	11.58	11.93	11.90	11.95	11.92	11.68	10.00	2.18
Motion 4	5.93	6.21	8.63	7.79	7.73	8.19	7.93	8.48	10.31	10.26	10.56	10.71	11.07	11.97	11.84	11.97	11.86	9.50	2.02
Motion 5	4.69	4.00	5.27	6.72	6.84	7.42	7.76	8.17	0.57	7.93	8.02	9.60	9.33	9.80	9.77	9.34	8.98	7.31	2.48
Average	5.03	4.34	5.85	6.93	6.85	7.30	7.46	7.99	4.78	7.93	8.25	9.59	9.82	9.98	9.85	9.68	9.38		
STDEV	1.47	1.18	2.19	2.49	1.86	1.89	1.78	1.71	5.83	3.45	2.54	3.16	3.28	2.98	2.91	2.89	2.82		
10lb Sternum																			
Motion 1	9.82	7.80	10.71	13.74	14.08	15.41	16.33	17.08	0.04	16.13	16.14	23.22	24.80	22.60	21.62	19.68	18.34	15.74	6.23
Motion 2	5.84	6.01	5.73	6.50	7.68	8.29	8.81	10.18	1.50	4.66	8.57	8.33	8.69	9.77	9.80	9.85	9.75	7.64	2.33
Motion 3	13.76	9.20	14.52	20.33	17.70	18.24	18.25	19.50	23.91	22.44	20.87	23.19	24.01	23.84	23.88	23.61	23.18	20.03	4.32
Motion 4	11.91	12.46	17.31	15.62	15.51	16.43	15.89	17.07	20.42	20.38	21.15	21.48	22.17	23.94	23.59	23.81	23.62	18.99	3.99
Motion 5	9.45	8.08	10.61	13.51	13.72	14.88	15.53	16.30	2.65	15.95	16.14	19.30	18.65	19.64	19.60	18.44	17.76	14.72	4.69
Average	10.16	8.71	11.78	13.94	13.74	14.65	14.96	16.03	9.71	15.91	16.57	19.11	19.66	19.96	19.70	19.08	18.53		
STDEV	2.97	2.39	4.39	4.98	3.73	3.78	3.60	3.48	11.48	6.88	5.09	6.23	6.58	5.95	5.80	5.68	5.60		
15lb Sternum																			
Motion 1	14.94	11.70	16.21	20.93	21.26	23.26	24.60	25.57	-1.12	24.52	24.46	34.23	36.95	33.71	32.34	29.56	27.55	23.57	9.43
Motion 2	8.75	9.01	8.59	9.75	11.52	12.43	13.22	15.30	2.42	6.99	12.89	12.48	13.02	14.66	14.72	14.79	14.66	11.48	3.47
Motion 3	20.72	15.22	21.95	30.71	26.70	27.44	27.51	29.81	36.09	33.85	31.53	34.99	36.34	36.02	36.01	35.62	34.96	30.32	6.32
Motion 4	17.92	18.73	25.93	23.42	23.29	24.65	23.86	25.72	30.37	30.57	31.83	32.27	33.26	35.91	35.33	35.55	35.30	28.46	5.94
Motion 5	14.54	12.25	16.27	20.75	20.91	22.66	23.61	24.77	9.98	24.38	24.67	29.85	28.42	29.80	29.73	28.21	27.14	22.82	6.28
Average	15.37	13.38	17.79	21.11	20.73	22.09	22.56	24.23	15.55	24.06	25.08	28.76	29.60	30.02	29.62	28.75	27.92		
STDEV	4.47	3.72	6.58	7.53	5.64	5.70	5.45	5.37	16.75	10.37	7.69	9.32	9.86	8.95	8.70	8.50	8.37		

Table D.4.4: Male Sternum Weight Resultant Force Percentage Change

Male Resultant Force % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Male Resultant Force % change																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
5lb Sternum																		
Motion 1	4.77	5.11	5.26	5.57	6.10	6.77	7.23	7.56	7.82	7.95	7.97	6.97	5.41	5.30	5.69	5.97	6.00	6.32	1.08
Motion 2	2.92	3.01	3.14	3.28	3.49	3.70	3.81	3.96	4.07	4.19	4.36	4.93	5.22	5.60	5.98	6.29	6.11	4.36	1.13
Motion 3	6.83	7.16	7.23	7.51	7.95	8.58	9.07	9.06	9.35	9.51	9.57	8.81	8.23	8.29	8.78	9.08	8.94	8.47	0.86
Motion 4	5.93	6.21	6.39	6.66	7.06	7.57	7.93	8.15	8.52	8.76	8.92	9.45	9.82	10.36	10.55	11.00	11.03	8.49	1.70
Motion 5	4.69	4.97	5.27	5.70	6.23	6.84	7.27	7.51	7.76	7.93	8.02	7.72	7.46	7.16	7.51	7.91	7.88	6.93	1.12
Average	5.03	5.29	5.46	5.74	6.17	6.69	7.06	7.25	7.50	7.67	7.77	7.58	7.23	7.34	7.70	8.05	7.99		
STDEV	1.47	1.55	1.54	1.58	1.67	1.83	1.96	1.94	2.02	2.05	2.02	1.76	1.94	2.08	2.02	2.07	2.10		
10lb Sternum																		
Motion 1	9.82	10.51	10.71	11.32	12.42	13.80	14.72	15.40	15.89	16.13	16.14	14.25	10.91	10.69	11.39	12.11	12.13	12.84	2.20
Motion 2	5.84	6.02	6.28	6.57	6.98	7.40	7.63	7.93	8.15	8.40	8.74	9.88	10.46	11.24	11.99	12.61	12.26	8.73	2.27
Motion 3	13.76	14.41	14.52	15.10	15.99	17.26	18.25	18.24	18.84	19.19	19.30	17.88	16.72	16.77	17.66	18.36	18.00	17.07	1.74
Motion 4	11.91	12.46	12.83	13.36	14.17	15.19	15.89	16.36	17.07	17.56	17.90	18.94	19.72	20.69	21.08	21.98	22.04	17.01	3.38
Motion 5	9.45	10.00	10.61	11.48	12.53	13.74	14.60	15.09	15.60	15.95	16.14	15.59	15.09	14.44	15.04	15.89	15.82	13.94	2.25
Average	10.16	10.68	10.99	11.57	12.42	13.48	14.22	14.60	15.11	15.45	15.64	15.31	14.58	14.77	15.43	16.19	16.05		
STDEV	2.97	3.13	3.09	3.19	3.37	3.69	3.96	3.93	4.09	4.15	4.08	3.55	3.93	4.13	4.04	4.12	4.17		
15lb Sternum																		
Motion 1	14.94	15.98	16.21	17.18	18.88	21.00	22.43	23.46	24.18	24.51	24.46	21.75	16.68	16.36	17.46	18.56	18.52	19.56	3.32
Motion 2	8.75	9.02	9.41	9.85	10.48	11.10	11.47	11.90	12.25	12.61	13.12	14.84	15.70	16.89	18.01	18.95	18.44	13.11	3.42
Motion 3	20.72	21.73	21.95	22.79	24.12	26.01	27.50	27.55	28.45	28.99	29.16	27.22	25.48	25.53	26.77	27.79	27.30	25.83	2.66
Motion 4	17.92	18.73	19.30	20.09	21.29	22.82	23.86	24.59	25.65	26.41	26.92	28.50	29.70	31.09	31.63	32.98	33.07	25.56	5.07
Motion 5	14.54	15.39	16.27	17.58	19.17	21.02	22.35	23.06	23.86	24.38	24.67	23.70	23.01	22.18	23.13	24.37	24.27	21.35	3.42
Average	15.37	16.17	16.63	17.50	18.79	20.39	21.52	22.11	22.88	23.38	23.67	23.20	22.11	22.41	23.40	24.53	24.32		
STDEV	4.47	4.73	4.69	4.83	5.09	5.58	6.00	5.97	6.21	6.30	6.20	5.40	5.92	6.17	5.99	6.10	6.20		

Appendix: E- Female Data Tables

Appendix E.1 Female Raw Per Trial Data Sorted by Motion for all Weight Conditions

Table E.1.1: Female Raw Compression Data

Compression forces sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Female Compression(N) Per trial																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight	501.54	468.11	426.58	386.83	355.50	324.73	294.09	272.40	249.70	222.10	198.80	190.56	177.43	166.54	153.41	140.53	137.03	274.46	118.05
5lb Abdomen	501.90	468.46	426.96	387.22	355.89	325.12	294.47	272.76	250.04	222.29	198.95	190.60	177.43	166.54	153.41	140.53	137.03	274.68	118.20
5lb Sternum	524.33	490.69	448.31	407.47	375.44	344.26	313.33	291.48	268.12	241.02	215.07	207.51	191.06	179.01	165.19	151.79	148.02	291.89	121.71
10lb Abdomen	501.97	468.53	427.03	387.29	355.97	325.20	294.54	272.83	250.11	222.33	198.98	190.61	177.43	166.54	153.41	140.53	137.03	274.73	118.22
10lb Sternum	539.49	506.18	463.87	422.63	390.39	359.34	328.78	307.23	283.72	258.00	229.24	223.28	204.41	190.50	176.01	162.13	157.89	306.06	123.07
15lb Abdomen	502.31	468.86	427.37	387.64	356.31	325.54	294.87	273.14	250.40	222.50	199.10	190.65	177.44	166.55	153.41	140.54	137.04	274.92	118.36
15lb Sternum	562.12	528.78	485.83	443.66	410.94	379.65	348.75	326.86	302.28	277.38	245.61	240.72	218.97	203.17	188.04	173.63	169.02	323.85	126.71
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	1059.33	1018.75	895.19	809.89	774.19	728.33	638.65	565.35	473.02	406.58	277.40	272.16	156.34	90.75	63.62	44.67	34.68	488.76	352.99
5lb Abdomen	1059.31	1018.73	895.18	809.87	774.18	728.31	638.64	565.34	473.01	406.58	277.41	272.16	156.34	90.75	63.62	44.67	34.68	488.75	352.98
5lb Sternum	1093.27	1052.35	926.64	839.66	803.56	757.12	665.83	591.25	497.38	429.28	296.65	291.78	172.80	105.34	77.26	57.51	46.95	512.04	360.41
10lb Abdomen	1059.32	1018.74	895.18	809.88	774.19	728.32	638.64	565.34	473.01	406.58	277.41	272.16	156.34	90.75	63.62	44.67	34.68	488.75	352.98
10lb Sternum	1127.23	1085.95	958.11	869.51	832.98	785.96	693.04	617.22	521.81	452.13	315.81	311.44	189.26	119.95	90.94	70.39	59.24	535.35	367.85
15lb Abdomen	1059.33	1018.75	895.19	809.89	774.19	728.33	638.65	565.35	473.02	406.58	277.40	272.16	156.34	90.75	63.62	44.67	34.68	488.76	352.99
15lb Sternum	1161.19	1119.58	989.58	899.34	862.41	814.83	720.32	643.19	546.26	474.92	334.99	331.13	205.80	134.61	104.64	83.30	71.57	558.69	375.27
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	591.67	557.83	464.55	419.47	388.66	355.23	305.88	265.69	230.46	205.22	167.26	163.94	142.87	125.74	109.89	96.34	92.70	275.49	162.10
5lb Abdomen	591.71	557.87	464.58	419.50	388.68	355.26	305.90	265.71	230.47	205.23	167.26	163.94	142.86	125.74	109.89	96.33	92.70	275.51	162.11
5lb Sternum	636.44	602.38	500.24	452.80	421.45	387.34	334.41	290.90	252.79	226.17	183.00	180.67	155.99	136.22	118.95	104.29	99.90	299.06	174.28
10lb Abdomen	591.85	558.00	464.67	419.59	388.77	355.34	305.98	265.77	230.53	205.25	167.27	163.94	142.86	125.74	109.89	96.34	92.70	275.56	162.16
10lb Sternum	683.25	648.86	538.23	488.37	456.51	421.62	364.76	317.39	276.15	247.93	199.42	198.01	169.86	147.95	129.23	113.28	107.96	324.04	187.01
15lb Abdomen	592.09	558.23	464.87	419.78	388.96	355.52	306.13	265.91	230.65	205.30	167.29	163.95	142.86	125.74	109.89	96.34	92.70	275.66	162.25
15lb Sternum	731.04	696.32	576.89	524.46	492.03	456.31	395.69	344.55	300.13	270.02	216.12	215.54	183.87	160.00	139.93	122.52	116.02	349.50	199.98
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	683.66	649.30	522.56	468.54	435.96	399.41	335.30	281.70	236.35	206.69	151.41	151.17	117.78	96.30	81.82	67.88	63.37	291.13	203.86
5lb Abdomen	683.67	649.31	522.57	468.54	435.96	399.42	335.30	281.71	236.35	206.69	151.41	151.17	117.78	96.30	81.82	67.88	63.37	291.13	203.86
5lb Sternum	732.92	698.21	562.49	505.83	472.69	435.32	367.16	309.64	261.06	229.28	168.63	169.19	132.41	108.74	92.77	77.42	71.84	317.39	217.22
10lb Abdomen	683.71	649.34	522.59	468.56	435.98	399.43	335.32	281.71	236.36	206.70	151.41	151.17	117.77	96.30	81.82	67.88	63.37	291.14	203.87
10lb Sternum	782.88	747.81	602.81	543.52	509.81	471.56	399.25	337.82	285.95	251.97	185.73	187.26	146.98	121.01	103.57	86.82	80.20	343.82	230.88
15lb Abdomen	683.78	649.40	522.63	468.60	436.02	399.47	335.34	281.73	236.38	206.70	151.41	151.16	117.77	96.30	81.82	67.88	63.37	291.16	203.89
15lb Sternum	833.31	797.84	643.65	581.69	547.43	508.33	431.78	366.38	311.18	274.92	203.16	205.50	161.75	133.53	114.58	96.40	88.69	370.59	244.66
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	530.50	496.66	446.59	402.56	371.64	340.35	304.39	277.90	249.90	226.46	189.25	186.13	160.06	140.88	126.71	113.56	109.64	274.89	136.80
5lb Abdomen	530.53	496.68	446.61	402.59	371.66	340.38	304.41	277.92	249.92	226.47	189.26	186.14	160.06	140.88	126.71	113.56	109.64	274.91	136.81
5lb Sternum	557.15	523.14	472.05	426.96	395.68	364.09	327.29	300.09	270.93	247.04	206.92	204.88	176.11	155.24	140.21	126.42	122.04	295.07	141.47
10lb Abdomen	530.63	496.78	446.71	402.69	371.77	340.48	304.51	278.01	250.00	226.50	189.27	186.14	160.06	140.88	126.71	113.56	109.64	274.96	136.86
10lb Sternum	585.17	551.01	498.67	452.33	420.69	388.80	350.97	322.90	292.63	268.18	224.29	223.32	192.06	169.60	153.61	139.14	134.29	315.74	146.73
15lb Abdomen	530.85	496.99	446.92	402.90	371.98	340.70	304.71	278.20	250.17	226.57	189.31	186.16	160.07	140.88	126.71	113.56	109.64	275.08	136.94
15lb Sternum	614.29	579.92	526.19	478.55	446.54	414.30	375.36	346.36	314.85	289.62	242.40	242.02	208.15	184.04	167.36	152.23	146.87	337.00	152.28

Table E.1.2: Female Raw AP Shear Data

AP Shear sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Female AP SHEAR PER Trial																		
Motion 1																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
No Weight	0.556	0.561	-1.659	-0.822	-0.349	-0.629	0.523	-0.069	0.283	-0.139	-0.039	0.308	0.133	1.233	2.206	3.177	4.265	0.561	1.466
5lb Abdomen	0.557	0.562	-1.659	-0.822	-0.349	-0.629	0.523	-0.069	0.283	-0.139	-0.039	0.308	0.133	1.233	2.206	3.177	4.266	0.561	1.466
5lb Sternum	0.479	0.483	-1.778	-0.955	-0.511	-0.810	0.368	-0.236	0.147	-0.200	-0.058	-0.406	-1.879	-1.225	-0.501	0.245	1.089	-0.338	0.809
10lb Abdomen	0.557	0.562	-1.659	-0.822	-0.349	-0.629	0.523	-0.069	0.283	-0.139	-0.039	0.308	0.133	1.234	2.207	3.178	4.267	0.561	1.466
10lb Sternum	0.297	0.298	-1.921	-1.198	-0.839	-1.168	-0.001	-0.594	-0.142	-0.294	-0.083	-0.892	-3.566	-3.818	-3.509	-2.912	-2.220	-1.327	1.408
15lb Abdomen	0.557	0.562	-1.660	-0.822	-0.349	-0.630	0.523	-0.069	0.283	-0.139	-0.039	0.308	0.133	1.234	2.206	3.178	4.266	0.561	1.466
15lb Sternum	0.108	0.108	-2.109	-1.490	-1.291	-1.666	-0.503	-1.085	-0.543	-0.442	-0.108	-1.832	-4.980	-6.357	-6.438	-5.776	-4.933	-2.314	2.369
Motion 2																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	-10.599	-11.979	-26.164	-2.002	20.586	24.645	31.656	22.938	30.556	44.799	43.822	15.500	8.334	6.125	2.820	-3.965	-13.275	10.812	20.804
5lb Abdomen	-10.599	-11.979	-26.164	-2.003	20.583	24.642	31.654	22.937	30.556	44.800	43.822	15.500	8.334	6.124	2.820	-3.964	-13.275	10.811	20.804
5lb Sternum	-10.585	-12.030	-26.355	-2.075	20.737	24.810	31.984	23.184	31.453	46.376	45.448	15.432	7.648	4.693	0.910	-7.011	-16.813	10.459	21.735
10lb Abdomen	-10.600	-11.979	-26.164	-2.003	20.584	24.643	31.655	22.937	30.556	44.799	43.822	15.500	8.334	6.125	2.820	-3.965	-13.275	10.811	20.804
10lb Sternum	-10.511	-12.029	-26.506	-2.147	20.887	24.981	32.331	23.444	32.388	47.919	47.107	15.331	6.921	3.221	-1.622	-9.898	-20.435	10.081	22.729
15lb Abdomen	-10.599	-11.979	-26.164	-2.002	20.586	24.644	31.656	22.938	30.556	44.799	43.822	15.500	8.334	6.125	2.820	-3.965	-13.275	10.812	20.804
15lb Sternum	-10.523	-12.109	-26.756	-2.219	21.045	25.155	32.678	23.699	33.324	49.475	48.744	15.236	6.303	1.779	-3.862	-12.941	-24.132	9.700	23.793
Motion 3																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	0.780	0.785	-2.271	-1.103	-0.493	-0.836	0.661	-0.090	0.362	-0.166	-0.048	0.344	0.315	2.831	4.336	5.458	6.706	1.034	2.408
5lb Abdomen	0.780	0.786	-2.271	-1.103	-0.493	-0.836	0.661	-0.090	0.362	-0.166	-0.048	0.344	0.314	2.831	4.336	5.458	6.706	1.034	2.408
5lb Sternum	0.868	0.874	-2.434	-1.188	-0.563	-0.944	0.675	-0.131	0.374	-0.192	-0.051	0.142	-0.397	2.029	3.375	4.116	4.683	0.661	1.901
10lb Abdomen	0.780	0.786	-2.271	-1.103	-0.493	-0.837	0.661	-0.090	0.362	-0.166	-0.048	0.344	0.315	2.831	4.336	5.458	6.706	1.034	2.408
10lb Sternum	0.981	0.985	-2.586	-1.290	-0.692	-1.128	0.623	-0.231	0.361	-0.247	-0.040	-0.663	-2.294	-0.978	0.025	0.806	1.726	-0.273	1.164
15lb Abdomen	0.780	0.786	-2.272	-1.103	-0.493	-0.837	0.661	-0.090	0.362	-0.166	-0.048	0.344	0.315	2.831	4.336	5.458	6.706	1.034	2.408
15lb Sternum	1.128	1.130	-2.714	-1.387	-0.838	-1.342	0.546	-0.351	0.354	-0.307	-0.019	-1.511	-4.316	-4.550	-4.033	-3.131	-1.862	-1.365	1.845
Motion 4																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	1.052	1.057	-3.082	-1.490	-0.656	-1.137	0.904	-0.140	0.476	-0.257	-0.135	-0.551	-2.448	-1.431	1.220	2.397	2.745	-0.087	1.577
5lb Abdomen	1.052	1.057	-3.082	-1.490	-0.656	-1.137	0.904	-0.140	0.476	-0.257	-0.135	-0.552	-2.449	-1.434	1.219	2.398	2.747	-0.087	1.578
5lb Sternum	1.142	1.147	-3.314	-1.610	-0.733	-1.259	0.945	-0.177	0.501	-0.287	-0.138	-0.882	-3.265	-2.715	-1.162	-0.331	-0.064	-0.718	1.394
10lb Abdomen	1.052	1.057	-3.082	-1.490	-0.656	-1.137	0.904	-0.140	0.476	-0.257	-0.135	-0.552	-2.449	-1.433	1.219	2.398	2.747	-0.087	1.578
10lb Sternum	1.278	1.282	-3.498	-1.702	-0.806	-1.385	0.981	-0.214	0.537	-0.314	-0.136	-1.169	-4.046	-3.908	-3.509	-2.960	-2.745	-1.313	1.849
15lb Abdomen	1.052	1.057	-3.083	-1.490	-0.656	-1.137	0.904	-0.140	0.477	-0.257	-0.135	-0.551	-2.448	-1.431	1.220	2.398	2.745	-0.087	1.577
15lb Sternum	1.448	1.450	-3.655	-1.780	-0.902	-1.545	0.984	-0.279	0.560	-0.358	-0.132	-1.545	-4.913	-5.104	-5.990	-5.767	-5.594	-1.948	2.668
Motion 5																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	0.637	0.641	-1.895	-0.933	-0.400	-0.745	0.619	-0.101	0.329	-0.182	-0.107	-0.190	-1.406	-0.714	0.380	1.235	1.720	-0.065	0.922
5lb Abdomen	0.637	0.641	-1.895	-0.933	-0.400	-0.745	0.619	-0.101	0.329	-0.182	-0.107	-0.190	-1.406	-0.714	0.379	1.235	1.720	-0.065	0.923
5lb Sternum	0.670	0.674	-1.931	-0.975	-0.467	-0.841	0.576	-0.174	0.301	-0.213	-0.114	-0.559	-2.329	-2.290	-1.957	-1.235	-0.750	-0.683	1.000
10lb Abdomen	0.637	0.642	-1.895	-0.933	-0.400	-0.745	0.619	-0.101	0.330	-0.182	-0.107	-0.190	-1.406	-0.714	0.379	1.235	1.720	-0.065	0.923
10lb Sternum	0.749	0.750	-1.919	-1.011	-0.579	-1.000	0.464	-0.304	0.242	-0.269	-0.119	-1.081	-3.362	-3.726	-4.296	-3.034	-2.488	-1.234	1.619
15lb Abdomen	0.638	0.642	-1.895	-0.933	-0.400	-0.745	0.620	-0.101	0.330	-0.182	-0.107	-0.190	-1.406	-0.714	0.380	1.235	1.720	-0.065	0.923
15lb Sternum	0.881	0.879	-1.850	-1.030	-0.727	-1.210	0.300	-0.476	0.153	-0.345	-0.119	-1.714	-4.650	-5.918	-7.078	-6.630	-5.977	-2.089	2.780

Table E.1.3: Female Raw ML Shear Data

ML shear sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Female ML Shear per trial																			
Motion 1																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
No Weight	92.96	-93.95	-44.83	68.93	77.81	79.49	60.77	34.22	8.72	-16.88	-21.39	-30.04	-44.73	-57.86	-69.30	-74.46	-83.40	-6.70	63.77
5lb Abdomen	93.02	-94.19	-44.88	68.82	77.74	79.43	60.69	34.11	8.73	-16.99	-21.50	-30.09	-44.74	-57.86	-69.30	-74.46	-83.40	-6.76	63.78
5lb Sternum	97.18	-96.89	-47.12	74.61	84.83	87.10	67.38	39.27	9.36	-19.38	-23.33	-33.18	-49.75	-63.93	-76.38	-82.22	-91.67	-7.30	69.03
10lb Abdome	93.03	-94.23	-44.88	68.80	77.72	79.42	60.67	34.09	8.73	-17.01	-21.52	-30.10	-44.74	-57.86	-69.31	-74.46	-83.40	-6.77	63.78
10lb Sternum	99.99	-98.16	-48.75	79.95	91.76	94.65	74.06	44.67	9.91	-21.97	-25.13	-35.99	-54.52	-69.50	-82.85	-89.32	-98.97	-7.66	73.83
15lb Abdome	93.10	-94.44	-44.92	68.72	77.66	79.36	60.60	33.99	8.74	-17.10	-21.63	-30.13	-44.74	-57.86	-69.31	-74.47	-83.40	-6.81	63.78
15lb Sternum	104.18	-100.96	-51.06	85.97	99.14	102.68	81.00	50.00	10.56	-25.42	-27.54	-39.25	-59.60	-75.44	-89.85	-97.04	-107.05	-8.22	79.29
Motion 2																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	196.24	-161.47	116.30	196.40	167.92	172.66	132.00	73.08	-162.52	-178.86	-108.32	-80.41	-82.45	-58.26	-54.51	-51.88	-59.73	3.31	135.39
5lb Abdomen	196.23	-161.47	116.31	196.42	167.93	172.68	132.02	73.10	-162.51	-178.87	-108.32	-80.41	-82.45	-58.26	-54.51	-51.88	-59.73	3.31	135.40
5lb Sternum	202.53	-166.80	119.67	203.45	175.47	180.91	138.78	77.51	-165.87	-183.71	-111.93	-84.35	-87.65	-64.18	-61.40	-59.36	-67.50	2.68	140.93
10lb Abdome	196.24	-161.47	116.31	196.41	167.93	172.67	132.02	73.09	-162.51	-178.86	-108.32	-80.41	-82.45	-58.26	-54.51	-51.88	-59.73	3.31	135.40
10lb Sternum	208.82	-172.12	122.96	210.46	183.01	189.13	145.52	81.89	-169.29	-188.30	-115.61	-88.31	-92.86	-70.13	-68.37	-66.96	-75.34	2.03	146.50
15lb Abdome	196.24	-161.47	116.30	196.40	167.92	172.66	132.00	73.08	-162.52	-178.86	-108.32	-80.41	-82.45	-58.26	-54.51	-51.88	-59.73	3.31	135.39
15lb Sternum	215.12	-177.44	126.28	217.47	190.53	197.34	152.26	86.26	-172.82	-193.07	-119.29	-92.26	-98.08	-76.08	-75.29	-74.51	-83.14	1.37	152.12
Motion 3																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	114.19	-85.57	-38.04	50.68	39.93	28.26	15.84	-24.28	-80.30	-87.81	-78.06	-78.52	-87.59	-90.93	-96.15	-96.70	-101.81	-40.99	66.32
5lb Abdomen	114.20	-85.58	-38.04	50.67	39.92	28.25	15.84	-24.30	-80.31	-87.81	-78.06	-78.52	-87.59	-90.93	-96.15	-96.70	-101.81	-40.99	66.32
5lb Sternum	122.83	-89.01	-40.96	56.58	44.47	31.86	17.32	-25.80	-92.16	-100.95	-89.00	-89.11	-99.32	-102.66	-108.47	-109.33	-114.29	-46.35	73.76
10lb Abdome	114.23	-85.64	-38.05	50.63	39.88	28.21	15.84	-24.35	-80.36	-87.84	-78.08	-78.53	-87.60	-90.93	-96.15	-96.70	-101.81	-41.01	66.32
10lb Sternum	131.87	-93.06	-44.07	62.66	48.96	35.35	18.89	-27.66	-104.24	-114.03	-100.11	-99.87	-111.26	-115.16	-121.89	-123.32	-128.57	-52.09	81.65
15lb Abdome	114.27	-85.77	-38.06	50.55	39.80	28.12	15.85	-24.47	-80.51	-87.90	-78.12	-78.56	-87.60	-90.93	-96.15	-96.70	-101.81	-41.06	66.32
15lb Sternum	141.09	-98.84	-47.23	68.82	53.45	38.79	20.49	-29.69	-116.46	-127.26	-111.30	-110.73	-123.24	-127.89	-136.08	-138.41	-144.37	-58.17	89.88
Motion 4																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	131.95	-92.16	-42.79	65.13	44.29	30.08	17.36	-26.30	-110.71	-116.02	-90.65	-81.10	-84.01	-77.07	-81.29	-80.72	-85.32	-39.96	71.85
5lb Abdomen	131.95	-92.16	-42.79	65.13	44.28	30.07	17.36	-26.31	-110.71	-116.02	-90.65	-81.10	-84.01	-77.07	-81.29	-80.72	-85.32	-39.96	71.85
5lb Sternum	141.45	-99.11	-46.05	71.42	48.76	33.47	19.01	-28.56	-123.02	-129.38	-101.97	-92.17	-96.31	-89.95	-95.33	-95.46	-100.39	-46.09	79.85
10lb Abdome	131.95	-92.17	-42.79	65.10	44.26	30.05	17.36	-26.34	-110.73	-116.03	-90.66	-81.11	-84.02	-77.07	-81.29	-80.72	-85.32	-39.97	71.85
10lb Sternum	151.10	-106.15	-49.36	77.63	53.21	36.83	20.67	-30.88	-135.31	-142.81	-113.40	-103.25	-108.54	-102.60	-109.11	-109.94	-115.20	-52.18	87.90
15lb Abdome	131.97	-92.18	-42.79	65.05	44.21	30.00	17.36	-26.39	-110.77	-116.04	-90.67	-81.11	-84.02	-77.08	-81.29	-80.73	-85.32	-39.99	71.84
15lb Sternum	160.83	-113.25	-52.70	83.94	57.67	40.18	22.36	-33.30	-147.65	-156.29	-124.84	-114.41	-120.89	-115.45	-123.13	-124.66	-130.27	-58.34	96.08
Motion 5																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**		
No Weight	98.32	-86.55	-46.94	80.73	84.76	86.39	66.69	39.26	-25.90	-38.02	-30.30	-34.66	-49.32	-56.69	-65.18	-68.57	-76.45	-7.20	66.29
5lb Abdomen	98.33	-86.57	-46.94	80.72	84.76	86.38	66.68	39.25	-25.92	-38.03	-30.30	-34.67	-49.32	-56.69	-65.18	-68.57	-76.45	-7.21	66.29
5lb Sternum	103.26	-90.24	-49.61	86.97	92.13	94.46	73.50	44.18	-29.33	-42.87	-33.30	-38.15	-54.54	-62.98	-72.55	-76.72	-85.00	-8.28	72.03
10lb Abdome	98.35	-86.63	-46.95	80.69	84.73	86.36	66.65	39.21	-25.97	-38.05	-30.31	-34.68	-49.32	-56.69	-65.18	-68.57	-76.45	-7.22	66.29
10lb Sternum	108.45	-94.03	-52.41	93.39	99.58	102.61	80.34	49.07	-31.74	-46.69	-36.60	-41.75	-59.81	-69.35	-79.94	-84.83	-93.29	-9.24	77.81
15lb Abdome	98.39	-86.77	-46.97	80.62	84.67	86.31	66.59	39.14	-26.09	-38.09	-30.35	-34.69	-49.33	-56.69	-65.18	-68.57	-76.45	-7.26	66.29
15lb Sternum	113.85	-98.06	-55.31	99.87	107.04	110.79	87.17	53.89	-34.44	-50.88	-39.75	-45.42	-65.15	-75.74	-87.59	-93.31	-102.42	-10.32	83.78

Table E.1.4: Female Raw Resultant Force Data

Resultant force sorted for motions 1-5 across every spinal level and with each weight condition. The right columns give the average and standard deviation across the entire thoracolumbar spine at each weight condition.

Female Resultant Force(N) Per trial																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight	510.08	477.44	428.93	392.93	363.91	334.32	300.30	274.54	249.85	222.74	199.95	192.91	182.98	176.31	168.35	159.07	160.47	282.06	116.44
5lb Abdomen	510.45	477.84	429.31	393.29	364.28	334.69	300.66	274.89	250.20	222.94	200.11	192.96	182.99	176.31	168.35	159.07	160.47	282.28	116.59
5lb Sternum	533.26	500.17	450.79	414.25	384.90	355.11	320.49	294.12	268.29	241.80	216.33	210.15	197.44	190.08	181.99	172.63	174.10	300.35	119.64
10lb Abdomen	510.52	477.91	429.38	393.36	364.35	334.76	300.72	274.95	250.26	222.98	200.14	192.97	182.99	176.31	168.35	159.08	160.47	282.32	116.61
10lb Sternum	548.68	515.61	466.43	430.13	401.03	371.59	337.02	310.46	283.90	258.94	230.61	226.16	211.58	202.82	194.56	185.13	186.36	315.35	120.54
15lb Abdomen	510.86	478.28	429.73	393.68	364.68	335.08	301.03	275.24	250.55	223.15	200.27	193.01	182.99	176.32	168.36	159.08	160.48	282.52	116.74
15lb Sternum	571.69	538.33	488.51	451.91	422.73	393.29	358.03	330.67	302.47	278.54	247.15	243.90	226.99	216.81	208.51	198.99	200.13	334.04	123.70
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	1077.41	1031.54	903.09	833.36	792.46	748.92	652.92	570.51	501.09	446.43	301.01	284.22	176.94	108.02	83.83	68.58	70.33	508.86	349.56
5lb Abdomen	1077.39	1031.52	903.08	833.35	792.45	748.91	652.91	570.51	501.08	446.43	301.01	284.22	176.94	108.02	83.83	68.58	70.33	508.86	349.55
5lb Sternum	1111.92	1065.56	934.70	863.96	822.75	778.83	680.90	596.76	525.25	469.23	320.30	304.12	193.91	123.44	98.69	82.95	83.92	532.78	356.84
10lb Abdomen	1077.40	1031.53	903.09	833.36	792.46	748.91	652.91	570.51	501.09	446.43	301.01	284.22	176.94	108.02	83.83	68.58	70.33	508.86	349.55
10lb Sternum	1146.45	1099.57	966.33	894.62	853.10	808.78	708.89	623.07	549.54	492.11	339.59	324.08	210.93	138.99	113.78	97.65	97.99	556.79	364.03
15lb Abdomen	1077.41	1031.54	903.09	833.36	792.46	748.92	652.92	570.51	501.09	446.43	301.01	284.22	176.94	108.02	83.83	68.58	70.33	508.86	349.56
15lb Sternum	1181.00	1133.61	997.97	925.26	883.46	838.76	736.96	649.39	573.92	515.05	358.92	344.08	228.06	154.64	128.97	112.50	112.32	580.87	371.18
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	602.59	564.36	466.11	422.53	390.71	356.36	306.29	266.80	244.05	223.22	184.58	181.77	167.58	155.20	146.08	136.60	137.85	291.33	151.42
5lb Abdomen	602.63	564.40	466.14	422.55	390.73	356.38	306.31	266.82	244.06	223.23	184.58	181.77	167.58	155.20	146.08	136.60	137.85	291.35	151.43
5lb Sternum	648.18	608.92	501.92	456.32	423.79	388.65	334.86	292.04	269.07	247.68	203.49	201.45	184.93	170.59	161.02	151.15	151.87	317.41	161.50
10lb Abdomen	602.77	564.53	466.23	422.64	390.82	356.46	306.39	266.89	244.14	223.26	184.60	181.78	167.58	155.20	146.08	136.60	137.85	291.40	151.48
10lb Sternum	695.86	655.50	540.03	492.37	459.13	423.10	365.25	318.60	295.17	272.89	223.13	221.77	203.07	187.49	177.64	167.45	167.90	345.08	171.95
15lb Abdomen	603.02	564.78	466.43	422.81	390.99	356.63	306.54	267.03	244.30	223.32	184.63	181.80	167.58	155.20	146.08	136.61	137.85	291.51	151.56
15lb Sternum	744.53	703.30	578.82	528.96	494.92	457.96	396.22	345.82	321.94	298.51	243.09	242.33	221.39	204.88	195.23	184.87	185.23	373.41	182.48
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	696.28	655.81	524.32	473.05	438.20	400.55	335.75	282.93	261.00	237.03	176.48	171.55	144.69	123.36	115.34	105.50	106.32	308.71	192.91
5lb Abdomen	696.29	655.82	524.32	473.05	438.21	400.55	335.75	282.93	261.00	237.03	176.48	171.55	144.69	123.36	115.34	105.50	106.32	308.72	192.91
5lb Sternum	746.45	705.21	564.38	510.85	475.20	436.61	367.65	310.95	288.59	263.27	197.06	192.67	163.76	141.15	133.02	122.91	123.44	337.83	203.93
10lb Abdomen	696.32	655.85	524.34	473.07	438.22	400.56	335.77	282.94	261.01	237.04	176.48	171.55	144.69	123.36	115.34	105.50	106.32	308.73	192.92
10lb Sternum	797.33	755.30	604.84	549.04	512.58	473.00	399.78	339.23	316.35	289.63	217.61	213.84	182.76	158.70	150.48	140.12	140.40	367.12	215.25
15lb Abdomen	696.40	655.91	524.39	473.10	438.25	400.59	335.79	282.96	261.04	237.05	176.48	171.55	144.69	123.36	115.34	105.50	106.32	308.75	192.94
15lb Sternum	848.69	805.84	645.81	587.71	550.46	509.91	432.36	367.89	344.43	316.24	238.45	235.20	201.99	176.59	168.30	157.69	157.70	396.78	226.65
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
No Weight	539.54	504.14	449.05	410.58	381.18	351.15	311.61	280.66	251.24	229.63	191.66	189.33	167.49	151.86	142.50	132.66	133.67	283.41	134.59
5lb Abdomen	539.56	504.17	449.08	410.60	381.21	351.17	311.63	280.68	251.26	229.64	191.67	189.34	167.49	151.86	142.50	132.66	133.67	283.42	134.60
5lb Sternum	566.64	530.87	474.66	435.73	406.26	376.15	335.44	303.33	272.51	250.74	209.58	208.40	184.38	167.54	157.88	147.88	148.73	304.51	138.79
10lb Abdomen	539.67	504.28	449.18	410.69	381.30	351.26	311.72	280.76	251.35	229.67	191.69	189.35	167.50	151.86	142.50	132.66	133.67	283.48	134.64
10lb Sternum	595.13	558.98	501.42	461.87	432.32	402.11	360.04	326.60	294.34	272.22	227.26	227.19	201.19	183.27	173.22	162.99	163.54	326.10	143.59
15lb Abdomen	539.89	504.51	449.39	410.89	381.50	351.46	311.90	280.93	251.53	229.75	191.72	189.37	167.50	151.86	142.50	132.67	133.67	283.59	134.73
15lb Sternum	624.75	588.15	529.10	488.86	459.20	428.86	385.35	350.53	316.72	294.06	245.64	246.25	218.15	199.10	189.03	178.67	179.15	348.33	148.62

Appendix E.2 Female Percentage Change All Trials

Table E.2.1: Female Compressive Force Percentage Change

Percentage change in compressive thoracolumbar spine loading for the male model relative to the no-weight condition, across vertebral levels, motions, vest weights, and load positions. The table reports the percent change in compressive force (N) (superior-inferior direction) between adjacent vertebral levels from L5–S1 through T1–T2 for motions 1-5. Values represent the percent difference in compressive loading for each vest weight condition 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) applied either at the abdomen or sternum, calculated relative to the corresponding no-weight trial for each motion. The far-right 2 columns are the average of the percent change across the entire thoracolumbar segment for each trial and the standard deviation, respectfully. This data quantifies how additional anterior loads affect local spinal compression across different postures in the male model. This shows that the weight added at the sternum is a better model for the effect of added weight due to the vest as seen by the numbers above the vest modeled at the abdomen provides almost the exact same results as having no weight.

Female Compression % Change																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Abdomen	0.072	0.076	0.089	0.100	0.111	0.122	0.129	0.133	0.137	0.088	0.075	0.023	0.001	0.001	0.001	0.001	0.000	0.068	0.053
5lb Sternum	4.544	4.824	5.096	5.334	5.609	6.015	6.543	7.005	7.379	8.522	8.182	8.897	7.679	7.483	7.677	8.008	8.015	6.871	1.384
10lb Abdomen	0.086	0.090	0.106	0.119	0.132	0.145	0.154	0.158	0.164	0.105	0.090	0.026	0.001	0.001	0.001	0.001	0.000	0.081	0.063
10lb Sternum	7.566	8.133	8.742	9.253	9.814	10.658	11.797	12.785	13.626	16.166	15.309	17.172	15.204	14.384	14.731	15.365	15.221	12.702	3.107
15lb Abdomen	0.153	0.160	0.186	0.207	0.230	0.251	0.264	0.270	0.280	0.180	0.150	0.048	0.005	0.003	0.004	0.003	0.002	0.141	0.107
15lb Sternum	12.078	12.960	13.890	14.689	15.596	16.912	18.587	19.994	21.059	24.891	23.542	26.324	23.412	21.991	22.576	23.549	23.343	19.729	4.549
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.002	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.002	-0.001	0.001
5lb Sternum	3.204	3.299	3.512	3.677	3.793	3.954	4.257	4.582	5.149	5.584	6.936	7.208	10.530	16.074	21.434	28.744	35.372	9.842	9.789
10lb Abdomen	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
10lb Sternum	6.409	6.596	7.028	7.362	7.593	7.913	8.516	9.175	10.315	11.204	13.846	14.430	21.059	32.175	42.927	57.569	70.826	19.703	19.605
15lb Abdomen	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15lb Sternum	9.615	9.897	10.544	11.045	11.395	11.877	12.788	13.770	15.485	16.811	20.758	21.667	31.638	48.331	64.461	86.468	106.377	29.584	29.450
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.006	0.006	0.004	0.004	0.000	-0.001	0.000	0.000	0.000	0.000	0.004	0.003
5lb Sternum	7.566	7.986	7.683	7.945	8.436	9.039	9.328	9.487	9.692	10.206	9.410	10.208	9.189	8.333	8.249	8.253	7.774	8.752	0.874
10lb Abdomen	0.030	0.030	0.027	0.028	0.029	0.031	0.032	0.031	0.033	0.015	0.009	0.002	-0.002	0.000	0.000	0.000	0.000	0.017	0.014
10lb Sternum	15.478	16.319	15.860	16.424	17.457	18.688	19.249	19.459	19.829	20.808	19.226	20.781	18.898	17.659	17.601	17.588	16.464	18.105	1.670
15lb Abdomen	0.072	0.071	0.068	0.072	0.076	0.081	0.083	0.083	0.085	0.037	0.020	0.005	-0.003	0.003	0.003	0.003	0.003	0.045	0.036
15lb Sternum	23.556	24.826	24.182	25.029	26.596	28.454	29.361	29.679	30.233	31.576	29.213	31.478	28.701	27.242	27.338	27.178	25.165	27.636	2.492
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.001
5lb Sternum	7.205	7.532	7.641	7.959	8.426	8.991	9.500	9.916	10.451	10.928	11.370	11.918	12.421	12.917	13.383	14.047	13.357	10.468	2.288
10lb Abdomen	0.006	0.006	0.005	0.005	0.005	0.005	0.004	0.003	0.003	0.001	0.000	-0.002	-0.003	-0.001	-0.001	-0.001	-0.001	0.002	0.003
10lb Sternum	14.513	15.171	15.358	16.003	16.940	18.064	19.070	19.920	20.983	21.907	22.666	23.872	24.797	25.653	26.584	27.895	26.550	20.938	4.474
15lb Abdomen	0.017	0.015	0.013	0.013	0.013	0.014	0.012	0.010	0.009	0.004	0.000	-0.004	-0.007	0.000	0.000	0.001	0.001	0.007	0.007
15lb Sternum	21.889	22.876	23.172	24.149	25.569	27.268	28.772	30.058	31.658	33.009	34.178	35.936	37.336	38.650	40.046	42.007	39.954	31.560	6.717
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.005	0.005	0.006	0.006	0.007	0.008	0.008	0.008	0.008	0.003	0.004	0.003	0.001	0.000	0.000	0.000	0.000	0.004	0.003
5lb Sternum	5.023	5.332	5.703	6.059	6.469	6.976	7.524	7.987	8.417	9.090	9.335	10.072	10.028	10.192	10.652	11.323	11.315	8.323	2.126
10lb Abdomen	0.024	0.025	0.028	0.031	0.035	0.038	0.039	0.040	0.041	0.018	0.013	0.007	0.002	0.001	0.001	0.001	0.000	0.020	0.016
10lb Sternum	10.305	10.944	11.663	12.362	13.200	14.234	15.303	16.192	17.098	18.423	18.515	19.979	19.991	20.389	21.225	22.522	22.485	16.755	4.094
15lb Abdomen	0.066	0.067	0.076	0.084	0.093	0.101	0.105	0.107	0.110	0.048	0.030	0.016	0.004	0.002	0.002	0.002	0.001	0.054	0.043
15lb Sternum	15.793	16.764	17.826	18.875	20.156	21.726	23.316	24.635	25.990	27.891	28.084	30.025	30.042	30.636	32.079	34.050	33.957	25.403	6.070

Table E.2.2: Female AP Shear Percentage Change

Percentage change in anterior-posterior (AP) shear loading for the thoracolumbar spine in the male model. These are represented relative to the no-weight condition across vertebral levels, motions, and load positions. The table shows the percent change in AP shear across the vertebral levels from L5- T1 across all five motions, the average percent change and standard deviation across the whole thoracolumbar spine. For each motion, the AP shear under the vest load conditions (2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) at the abdomen or sternum) compared to the corresponding no weight condition for each motion. This shows that the weight added at the sternum is a better model for the effect of added weight due to the vest as seen by the numbers above the vest modeled at the abdomen provides almost the exact same results as having no weight.

Female AP SHEAR % CHANGE																		
Motion 1																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Abdomen	0.033	0.032	0.034	0.037	0.040	0.030	0.018	0.018	0.017	0.007	-0.342	0.064	0.221	0.031	0.019	0.018	0.018	0.017	0.105
5lb Sternum	-13.999	-13.955	7.231	16.260	46.403	28.674	-29.661	241.350	-48.051	44.249	50.470	-231.794	-1514.082	-199.329	-122.726	-92.284	-74.461	-112.100	376.748
10lb Abdomen	0.039	0.038	0.039	0.042	0.044	0.034	0.023	0.010	0.022	0.003	-0.511	0.064	0.371	0.054	0.035	0.034	0.036	0.022	0.161
10lb Sternum	-46.697	-46.832	15.823	45.774	140.484	85.590	-100.235	758.254	-150.320	112.201	115.518	-389.769	-2783.999	-409.675	-259.102	-191.655	-152.041	-191.570	717.670
15lb Abdomen	0.081	0.080	0.085	0.094	0.106	0.077	0.034	0.072	0.029	0.056	-0.410	0.155	0.393	0.046	0.024	0.022	0.022	0.057	0.148
15lb Sternum	-80.503	-80.733	27.148	81.360	270.122	164.738	-196.283	1467.047	-292.047	218.721	178.125	-695.279	-3848.053	-615.522	-391.885	-281.798	-215.661	-252.383	1041.108
Motion 2																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.002	0.000	0.002	0.007	-0.015	-0.010	-0.006	-0.006	-0.001	0.001	0.000	0.001	0.000	-0.004	0.007	-0.020	0.004	-0.002	0.007
5lb Sternum	-0.131	0.428	0.730	3.606	0.732	0.670	1.035	1.073	2.936	3.519	3.710	-0.435	-8.226	-23.371	-67.742	76.816	26.650	1.294	27.200
10lb Abdomen	0.002	0.001	0.001	0.005	-0.010	-0.007	-0.004	-0.004	-0.001	0.000	0.000	0.001	0.000	-0.002	0.003	-0.008	0.002	-0.001	0.004
10lb Sternum	-0.831	0.422	1.307	7.198	1.459	1.367	2.132	2.206	5.996	6.964	7.496	-1.090	-16.952	-47.416	-157.511	149.627	53.936	0.959	57.466
15lb Abdomen	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15lb Sternum	-0.717	1.085	2.264	10.790	2.229	2.071	3.227	3.317	9.058	10.438	11.231	-1.703	-24.368	-70.946	-236.948	226.369	81.792	1.717	86.649
Motion 3																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.007	0.007	0.005	0.006	0.008	0.005	0.001	0.001	0.000	0.004	0.001	0.022	-0.043	0.000	0.003	0.003	0.003	0.002	0.013
5lb Sternum	11.338	11.240	7.190	7.795	14.229	12.816	2.187	45.109	3.353	15.910	5.267	-58.870	-226.265	-28.339	-22.163	-24.598	-30.169	-14.940	59.552
10lb Abdomen	0.030	0.030	0.022	0.024	0.023	0.015	0.007	-0.039	0.013	-0.017	-0.077	0.038	0.061	0.007	0.004	0.002	0.001	0.008	0.031
10lb Sternum	25.831	25.446	13.852	17.045	40.412	34.905	-5.645	155.821	-0.160	48.575	-17.756	-292.749	-829.063	-134.542	-99.413	-85.242	-74.266	-69.232	218.513
15lb Abdomen	0.067	0.066	0.048	0.050	0.043	0.028	0.021	-0.124	0.040	-0.055	-0.233	0.079	0.273	0.021	0.006	0.000	-0.003	0.019	0.102
15lb Sternum	44.686	43.873	19.505	25.787	69.872	60.423	-17.360	289.473	-1.961	84.808	-60.527	-539.153	-1471.908	-260.737	-193.008	-157.362	-127.763	-128.903	389.672
Motion 4																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	-0.004	-0.004	0.002	0.003	-0.002	-0.002	0.001	-0.008	-0.004	0.002	-0.002	0.101	0.055	0.217	-0.049	0.029	0.062	0.023	0.060
5lb Sternum	8.627	8.527	7.527	8.025	11.659	10.724	4.498	26.249	5.243	11.809	2.236	59.963	33.398	89.758	-195.240	-113.805	-102.334	-7.243	68.382
10lb Abdomen	0.007	0.007	0.005	0.004	-0.005	-0.005	0.006	-0.056	0.008	-0.011	-0.014	0.090	0.049	0.198	-0.045	0.027	0.057	0.019	0.058
10lb Sternum	21.571	21.341	13.490	14.177	22.842	21.782	8.511	52.667	12.728	22.230	0.774	112.109	65.283	173.143	-387.663	-223.474	-199.996	-14.617	134.444
15lb Abdomen	0.032	0.032	0.008	0.005	-0.008	-0.006	0.014	-0.143	0.034	-0.035	-0.036	-0.003	0.000	0.014	0.007	0.012	0.015	-0.003	0.041
15lb Sternum	37.677	37.184	18.579	19.447	37.402	35.862	8.822	98.930	17.461	39.083	-2.308	180.265	100.714	256.792	-591.055	-340.563	-303.789	-20.559	205.689
Motion 5																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.005	0.005	0.003	0.003	0.002	0.002	0.004	-0.009	0.005	-0.004	-0.020	-0.070	0.001	0.016	-0.019	0.007	0.008	-0.004	0.020
5lb Sternum	5.195	5.010	1.945	4.572	16.753	12.960	-7.053	71.604	-8.538	17.078	6.267	193.940	65.703	220.797	-615.678	-199.981	-143.608	-20.767	181.853
10lb Abdomen	0.028	0.028	0.016	0.015	0.007	0.008	0.018	-0.056	0.028	-0.023	-0.079	-0.076	0.003	0.002	-0.010	-0.002	-0.005	-0.006	0.034
10lb Sternum	17.574	16.954	1.278	8.416	44.948	34.312	-25.023	200.464	-26.552	47.856	11.468	468.166	139.222	421.961	-1232.024	-345.589	-244.614	-27.128	366.492
15lb Abdomen	0.075	0.075	0.043	0.039	0.017	0.018	0.048	-0.160	0.074	-0.066	-0.202	-0.065	0.005	-0.030	0.008	-0.013	-0.022	-0.009	0.078
15lb Sternum	38.306	36.977	-2.367	10.475	81.793	62.433	-51.486	370.257	-53.562	89.455	10.858	800.384	230.862	729.112	-1964.965	-636.703	-447.471	-40.920	603.533

Table E.2.3: Female ML Shear Percentage Change

Percentage change in medial-lateral (ML) shear loading for the male model relative to the no weight condition, across vertebral levels, motions, vest weights, and load positions. The table is reporting the percentage change in the ML shear forces between the vertebral levels form L5-T1 across all five motions. Each load condition (2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) at either the sternum or abdomen) is compared to the corresponding no weight trial. The 2 right column provides the average and standard deviation of the percent change in the ML shear across the entire thoracolumbar spinal column for each condition. This shows that the weight added at the sternum is a better model for the effect of added weight due to the vest as seen by the numbers above the vest modeled at the abdomen provides almost the exact same results as having no weight.

Female ML Shear % Change																			
Motion 1																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Abdomen	0.072	0.255	0.089	-0.150	-0.094	-0.078	-0.137	-0.327	0.137	0.654	0.544	0.144	0.011	0.002	0.002	0.002	0.002	0.067	0.241
5lb Sternum	4.544	3.137	5.096	8.250	9.025	9.579	10.872	14.760	7.379	14.837	9.080	10.447	11.209	10.502	10.218	10.421	9.916	9.369	3.113
10lb Abdomen	0.086	0.304	0.106	-0.179	-0.113	-0.093	-0.163	-0.390	0.164	0.776	0.647	0.173	0.013	0.004	0.004	0.003	0.003	0.079	0.287
10lb Sternum	7.566	4.486	8.742	15.996	17.932	19.065	21.874	30.517	13.626	30.198	17.504	19.794	21.878	20.130	19.550	19.959	18.679	18.088	6.854
15lb Abdomen	0.153	0.520	0.186	-0.302	-0.193	-0.160	-0.282	-0.672	0.280	1.329	1.124	0.293	0.022	0.005	0.005	0.005	0.005	0.136	0.493
15lb Sternum	12.078	7.464	13.890	24.726	27.414	29.173	33.292	46.114	21.059	50.599	28.786	30.639	33.234	30.392	29.651	30.315	28.366	28.070	10.755
Motion 2																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	-0.002	-0.002	0.016	0.009	0.010	0.010	0.014	0.025	-0.009	0.001	-0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.004	0.008
5lb Sternum	3.205	3.297	2.898	3.588	4.502	4.776	5.132	6.052	2.060	2.711	3.332	4.906	6.304	10.163	12.646	14.424	13.011	6.059	3.964
10lb Abdomen	-0.001	-0.001	0.011	0.006	0.007	0.007	0.009	0.017	-0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.006
10lb Sternum	6.412	6.592	5.732	7.156	8.989	9.538	10.242	12.053	4.163	5.275	6.734	9.824	12.618	20.384	25.428	29.064	26.130	12.137	7.992
15lb Abdomen	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15lb Sternum	9.621	9.890	8.589	10.726	13.465	14.291	15.345	18.035	6.335	7.943	10.132	14.740	18.946	30.586	38.127	43.620	39.187	18.210	11.983
Motion 3																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.007	0.017	0.006	-0.019	-0.026	-0.040	0.007	0.060	0.004	0.000	0.004	0.003	0.000	-0.001	-0.001	-0.001	-0.001	0.001	0.020
5lb Sternum	7.566	4.024	7.683	11.638	11.361	12.709	9.328	6.266	14.760	14.968	14.012	13.485	13.386	12.904	12.811	13.064	12.255	11.307	3.183
10lb Abdomen	0.030	0.088	0.027	-0.096	-0.124	-0.188	0.032	0.291	0.071	0.031	0.028	0.018	0.002	0.000	0.000	0.000	-0.001	0.012	0.100
10lb Sternum	15.478	8.753	15.860	23.643	22.609	25.062	19.249	13.931	29.805	29.857	28.239	27.197	27.019	26.651	26.765	27.536	26.286	23.173	6.248
15lb Abdomen	0.072	0.243	0.068	-0.265	-0.330	-0.498	0.083	0.771	0.255	0.096	0.080	0.047	0.007	0.001	0.001	0.001	0.001	0.037	0.269
15lb Sternum	23.556	15.508	24.182	35.785	33.838	37.251	29.361	22.270	45.029	44.920	42.581	41.021	40.695	40.651	41.523	43.141	41.805	35.478	9.142
Motion 4																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.001	0.001	0.001	-0.010	-0.014	-0.021	0.001	0.026	0.005	0.001	0.001	0.001	0.000	-0.001	-0.001	0.000	0.000	-0.001	0.010
5lb Sternum	7.205	7.532	7.641	9.646	10.107	11.264	9.500	8.580	11.123	11.516	12.487	13.653	14.636	16.706	17.274	18.256	17.658	12.046	3.721
10lb Abdomen	0.006	0.006	0.005	-0.049	-0.069	-0.105	0.004	0.130	0.023	0.007	0.007	0.006	0.003	-0.001	-0.001	0.000	0.000	-0.002	0.047
10lb Sternum	14.513	15.171	15.358	19.185	20.156	22.453	19.070	17.415	22.223	23.094	25.095	27.309	29.199	33.118	34.232	36.191	35.020	24.047	7.296
15lb Abdomen	0.017	0.015	0.013	-0.124	-0.176	-0.269	0.012	0.334	0.060	0.017	0.018	0.015	0.007	0.000	0.000	0.000	0.000	-0.003	0.121
15lb Sternum	21.889	22.876	23.172	28.869	30.220	33.582	28.772	26.601	33.371	34.712	37.714	41.071	43.889	49.785	51.474	54.428	52.680	36.183	10.934
Motion 5																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdomen	0.005	0.021	0.006	-0.012	-0.009	-0.008	-0.013	-0.027	0.089	0.028	0.010	0.006	0.001	-0.001	-0.001	-0.001	-0.001	0.005	0.025
5lb Sternum	5.023	4.267	5.703	7.737	8.691	9.338	10.216	12.543	13.238	12.777	9.913	10.069	10.585	11.083	11.307	11.878	11.192	9.739	2.682
10lb Abdomen	0.024	0.095	0.028	-0.051	-0.040	-0.036	-0.057	-0.119	0.255	0.076	0.059	0.030	0.007	-0.001	-0.001	0.000	0.000	0.016	0.081
10lb Sternum	10.305	8.642	11.663	15.691	17.480	18.778	20.465	24.993	22.542	22.819	20.819	20.437	21.284	22.326	22.642	23.719	22.036	19.214	4.879
15lb Abdomen	0.066	0.254	0.076	-0.135	-0.106	-0.094	-0.150	-0.316	0.714	0.191	0.172	0.082	0.021	0.000	0.001	0.001	0.001	0.046	0.221
15lb Sternum	15.793	13.301	17.826	23.715	26.284	28.243	30.708	37.253	32.976	33.841	31.213	31.021	32.100	33.597	34.371	36.079	33.969	28.958	7.225

Table E.2.4: Female Resultant Force Percentage Change

Percentage change in resultant joint reaction loading for the female model relative to the no weight condition, across vertebral levels, motions, vest weights, and load positions. The table presents the percentage change in the resultant forces at each vertebral level from L5 to T1 across all five simulated surgical postures. Each load condition (2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) at either the sternum or abdomen) is compared to its respective no-weight trial. The two columns on the right summarize the average and standard deviation of the percent change in resultant force across the entire thoracolumbar spine for each condition. These data highlight the amplified loading effect of weight applied at the sternum, reinforcing its biomechanical relevance as a proxy for surgical lead vest burden compared to abdominal-applied weights.

Female Resultant Force % change																			
Motion 1																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Abdome	0.072	0.083	0.089	0.092	0.102	0.110	0.118	0.125	0.137	0.092	0.081	0.026	0.002	0.001	0.001	0.001	0.001	0.067	0.050
5lb Sternum	4.544	4.759	5.096	5.425	5.768	6.219	6.724	7.130	7.379	8.559	8.193	8.934	7.898	7.812	8.103	8.520	8.496	7.033	1.465
10lb Abdom	0.086	0.098	0.106	0.110	0.121	0.131	0.141	0.149	0.164	0.109	0.096	0.030	0.002	0.001	0.001	0.001	0.001	0.079	0.059
10lb Sternu	7.566	7.994	8.742	9.467	10.198	11.150	12.227	13.082	13.626	16.252	15.335	17.237	15.630	15.034	15.571	16.379	16.133	13.037	3.263
15lb Abdom	0.153	0.174	0.186	0.192	0.210	0.228	0.242	0.256	0.280	0.187	0.161	0.054	0.006	0.004	0.004	0.004	0.003	0.138	0.101
15lb Sternu	12.078	12.753	13.891	15.011	16.163	17.640	19.225	20.444	21.060	25.053	23.604	26.433	24.051	22.974	23.852	25.091	24.715	20.237	4.789
Motion 2																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdome	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	-0.001	0.001
5lb Sternum	3.203	3.298	3.500	3.672	3.823	3.994	4.285	4.601	4.820	5.107	6.409	7.004	9.588	14.279	17.732	20.960	19.325	7.976	6.112
10lb Abdom	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
10lb Sternu	6.408	6.595	7.002	7.350	7.652	7.993	8.573	9.212	9.668	10.231	12.818	14.025	19.205	28.673	35.732	42.399	39.332	16.051	12.400
15lb Abdom	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15lb Sternu	9.615	9.896	10.506	11.027	11.483	11.997	12.872	13.825	14.533	15.370	19.239	21.064	28.889	43.159	53.847	64.061	59.705	24.182	18.776
Motion 3																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdome	0.007	0.007	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.003	0.004	0.001	0.000	0.000	0.000	-0.001	-0.001	0.004	0.003
5lb Sternum	7.566	7.896	7.683	7.999	8.467	9.062	9.328	9.461	10.252	10.956	10.247	10.827	10.351	9.914	10.226	10.646	10.168	9.474	1.155
10lb Abdom	0.030	0.032	0.027	0.026	0.028	0.030	0.032	0.033	0.037	0.017	0.013	0.005	-0.001	0.000	0.000	0.000	0.000	0.018	0.014
10lb Sternu	15.478	16.151	15.860	16.531	17.512	18.730	19.249	19.414	20.949	22.252	20.888	22.005	21.178	20.803	21.606	22.585	21.794	19.587	2.444
15lb Abdom	0.072	0.075	0.068	0.068	0.072	0.077	0.083	0.088	0.104	0.046	0.030	0.012	0.000	0.002	0.002	0.002	0.002	0.047	0.037
15lb Sternu	23.556	24.620	24.182	25.190	26.674	28.511	29.361	29.620	31.915	33.728	31.704	33.313	32.111	32.010	33.644	35.336	34.366	29.991	3.889
Motion 4																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdome	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	-0.001	-0.001	0.000	0.000	0.000	0.001
5lb Sternum	7.205	7.532	7.641	7.991	8.444	9.004	9.500	9.905	10.572	11.069	11.666	12.308	13.179	14.425	15.330	16.501	16.108	11.081	3.108
10lb Abdom	0.006	0.006	0.005	0.004	0.004	0.004	0.004	0.005	0.007	0.003	0.002	0.000	-0.001	-0.001	-0.001	0.000	0.000	0.003	0.003
10lb Sternu	14.513	15.171	15.358	16.064	16.974	18.089	19.070	19.898	21.207	22.192	23.311	24.649	26.311	28.650	30.467	32.813	32.052	22.164	6.108
15lb Abdom	0.017	0.015	0.013	0.011	0.012	0.012	0.012	0.012	0.018	0.007	0.005	0.000	-0.002	0.000	0.000	0.001	0.001	0.008	0.007
15lb Sternu	21.889	22.876	23.172	24.240	25.618	27.304	28.772	30.029	31.967	33.419	35.120	37.103	39.602	43.151	45.919	49.470	48.325	33.410	9.193
Motion 5																			
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2		
5lb Abdome	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.008	0.009	0.004	0.004	0.003	0.001	0.000	0.000	0.000	0.000	0.004	0.003
5lb Sternum	5.023	5.301	5.703	6.125	6.580	7.120	7.648	8.078	8.469	9.192	9.349	10.072	10.081	10.326	10.798	11.471	11.267	8.388	2.141
10lb Abdom	0.024	0.027	0.028	0.028	0.031	0.033	0.035	0.037	0.044	0.019	0.014	0.008	0.002	0.001	0.000	0.000	0.000	0.020	0.015
10lb Sternu	10.305	10.877	11.663	12.492	13.415	14.515	15.544	16.371	17.157	18.546	18.573	19.995	20.116	20.685	21.560	22.859	22.342	16.883	4.133
15lb Abdom	0.066	0.072	0.076	0.075	0.083	0.089	0.093	0.098	0.117	0.051	0.034	0.018	0.005	0.001	0.002	0.001	0.001	0.052	0.040
15lb Sternu	15.793	16.663	17.826	19.065	20.466	22.131	23.664	24.894	26.066	28.057	28.163	30.061	30.247	31.109	32.655	34.682	34.025	25.622	6.173

Appendix E.3 Female Per Trial Data Sorted by Sternum Weights

Table E.3.1: Female Compression Data for the Baseline and Sternum Weights

Female raw compression(N) data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) *added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.*

Female Compression Per trial																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight																			
Motion 1	501.54	468.11	426.58	386.83	355.50	324.73	294.09	272.40	249.70	222.10	198.80	190.56	177.43	166.54	153.41	140.53	137.03	274.46	118.05
Motion 2	1059.33	1018.75	895.19	809.89	774.19	728.33	638.65	565.35	473.02	406.58	277.40	272.16	156.34	90.75	63.62	44.67	34.68	488.76	352.99
Motion 3	591.67	557.83	464.55	419.47	388.66	355.23	305.88	265.69	230.46	205.22	167.26	163.94	142.87	125.74	109.89	96.34	92.70	275.49	162.10
Motion 4	683.66	649.30	522.56	468.54	435.96	399.41	335.30	281.70	236.35	206.69	151.41	151.17	117.78	96.30	81.82	67.88	63.37	291.13	203.86
Motion 5	530.50	496.66	446.59	402.56	371.64	340.35	304.39	277.90	249.90	226.46	189.25	186.13	160.06	140.88	126.71	113.56	109.64	274.89	136.80
Average per v	673.34	638.13	551.09	497.46	465.19	429.61	375.66	332.61	287.89	253.41	196.83	192.79	150.89	124.04	107.09	92.60	87.48		
STDEV	226.76	223.81	195.66	177.32	175.34	169.29	147.81	130.24	103.84	86.13	48.71	47.21	22.24	31.50	35.59	37.61	39.82		
5lb Sternum																			
Motion 1	524.33	490.69	448.31	407.47	375.44	344.26	313.33	291.48	268.12	241.02	215.07	207.51	191.06	179.01	165.19	151.79	148.02	291.89	121.71
Motion 2	1093.27	1052.35	926.64	839.66	803.56	757.12	665.83	591.25	497.38	429.28	296.65	291.78	172.80	105.34	77.26	57.51	46.95	512.04	360.41
Motion 3	636.44	602.38	500.24	452.80	421.45	387.34	334.41	290.90	252.79	226.17	183.00	180.67	155.99	136.22	118.95	104.29	99.90	299.06	174.28
Motion 4	732.92	698.21	562.49	505.83	472.69	435.32	367.16	309.64	261.06	229.28	168.63	169.19	132.41	108.74	92.77	77.42	71.84	317.39	217.22
Motion 5	557.15	523.14	472.05	426.96	395.68	364.09	327.29	300.09	270.93	247.04	206.92	204.88	176.11	155.24	140.21	126.42	122.04	295.07	141.47
Average per v	708.82	673.35	581.95	526.54	493.76	457.63	401.60	356.67	310.06	274.56	214.05	210.81	165.67	136.91	118.88	103.48	97.75		
STDEV	229.49	226.51	197.36	178.89	176.97	170.83	149.03	131.36	104.95	86.91	49.75	48.07	22.39	31.22	35.40	37.59	39.92		
10lb Sternum																			
Motion 1	539.49	506.18	463.87	422.63	390.39	359.34	328.78	307.23	283.72	258.00	229.24	223.28	204.41	190.50	176.01	162.13	157.89	306.06	123.07
Motion 2	1127.23	1085.95	958.11	869.51	832.98	785.96	693.04	617.22	521.81	452.13	315.81	311.44	189.26	119.95	90.94	70.39	59.24	535.35	367.85
Motion 3	683.25	648.86	538.23	488.37	456.51	421.62	364.76	317.39	276.15	247.93	199.42	198.01	169.86	147.95	129.23	113.28	107.96	324.04	187.01
Motion 4	782.88	747.81	602.81	543.52	509.81	471.56	399.25	337.82	285.95	251.97	185.73	187.26	146.98	121.01	103.57	86.82	80.20	343.82	230.88
Motion 5	585.17	551.01	498.67	452.33	420.69	388.80	350.97	322.90	292.63	268.18	224.29	223.32	192.06	169.60	153.61	139.14	134.29	315.74	146.73
Average per v	743.60	707.96	612.34	555.27	522.08	485.46	427.36	380.51	332.05	295.64	230.90	228.66	180.51	149.80	130.67	114.35	107.92		
STDEV	234.05	230.92	200.07	181.35	179.39	173.07	150.71	132.78	106.24	87.81	50.72	48.90	22.46	30.71	34.99	37.38	39.78		
15lb Sternum																			
Motion 1	562.12	528.78	485.83	443.66	410.94	379.65	348.75	326.86	302.28	277.38	245.61	240.72	218.97	203.17	188.04	173.63	169.02	323.85	126.71
Motion 2	1161.19	1119.58	989.58	899.34	862.41	814.83	720.32	643.19	546.26	474.92	334.99	331.13	205.80	134.61	104.64	83.30	71.57	558.69	375.27
Motion 3	731.04	696.32	576.89	524.46	492.03	456.31	395.69	344.55	300.13	270.02	216.12	215.54	183.87	160.00	139.93	122.52	116.02	349.50	199.98
Motion 4	833.31	797.84	643.65	581.69	547.43	508.33	431.78	366.38	311.18	274.92	203.16	205.50	161.75	133.53	114.58	96.40	88.69	370.59	244.66
Motion 5	614.29	579.92	526.19	478.55	446.54	414.30	375.36	346.36	314.85	289.62	242.40	242.02	208.15	184.04	167.36	152.23	146.87	337.00	152.28
Average per v	780.39	744.49	644.43	585.54	551.87	514.68	454.38	405.47	354.94	317.37	248.46	246.98	195.71	163.07	142.91	125.61	118.44		
STDEV	237.42	234.24	201.76	182.89	180.96	174.53	151.72	133.63	107.13	88.37	51.55	49.64	22.86	30.58	35.04	37.64	40.17		

***Table E.3.2:* Female AP Shear Data for the Baseline and Sternum Weights**

Female raw AP Shear data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Female AP SHEAR PER Trial																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight																			
Motion 1	0.556	0.561	-1.659	-0.822	-0.349	-0.629	0.523	-0.069	0.283	-0.139	-0.039	0.308	0.133	1.233	2.206	3.177	4.265	0.561	1.466
Motion 2	-10.599	-11.979	-26.164	-2.002	20.586	24.645	31.656	22.938	30.556	44.799	43.822	15.500	8.334	6.125	2.820	-3.965	-13.275	10.812	20.804
Motion 3	0.780	0.785	-2.271	-1.103	-0.493	-0.836	0.661	-0.090	0.362	-0.166	-0.048	0.344	0.315	2.831	4.336	5.458	6.706	1.034	2.408
Motion 4	1.052	1.057	-3.082	-1.490	-0.656	-1.137	0.904	-0.140	0.476	-0.257	-0.135	-0.551	-2.448	-1.431	1.220	2.397	2.745	-0.087	1.577
Motion 5	0.637	0.641	-1.895	-0.933	-0.400	-0.745	0.619	-0.101	0.329	-0.182	-0.107	-0.190	-1.406	-0.714	0.380	1.235	1.720	-0.065	0.922
Average per v	-1.515	-1.787	-7.014	-1.270	3.738	4.259	6.873	4.507	6.401	8.811	8.699	3.082	0.986	1.609	2.192	1.661	0.432		
STDEV	5.082	5.701	10.719	0.482	9.419	11.397	13.855	10.303	13.503	20.118	19.635	6.952	4.263	3.027	1.518	3.503	7.889		
5lb Sternum																			
Motion 1	0.479	0.483	-1.778	-0.955	-0.511	-0.810	0.368	-0.236	0.147	-0.200	-0.058	-0.406	-1.879	-1.225	-0.501	0.245	1.089	-0.338	0.809
Motion 2	-10.585	-12.030	-26.355	-2.075	20.737	24.810	31.984	23.184	31.453	46.376	45.448	15.432	7.648	4.693	0.910	-7.011	-16.813	10.459	21.735
Motion 3	0.868	0.874	-2.434	-1.188	-0.563	-0.944	0.675	-0.131	0.374	-0.192	-0.051	0.142	-0.397	2.029	3.375	4.116	4.683	0.661	1.901
Motion 4	1.142	1.147	-3.314	-1.610	-0.733	-1.259	0.945	-0.177	0.501	-0.287	-0.138	-0.882	-3.265	-2.715	-1.162	-0.331	-0.064	-0.718	1.394
Motion 5	0.670	0.674	-1.931	-0.975	-0.467	-0.841	0.576	-0.174	0.301	-0.213	-0.114	-0.559	-2.329	-2.290	-1.957	-1.235	-0.750	-0.683	1.000
Average per v	-1.485	-1.771	-7.163	-1.361	3.693	4.191	6.909	4.493	6.555	9.097	9.017	2.745	-0.044	0.099	0.133	-0.843	-2.371		
STDEV	5.093	5.740	10.746	0.478	9.529	11.527	14.019	10.449	13.919	20.840	20.365	7.102	4.423	3.170	2.095	4.007	8.340		
10lb Sternum																			
Motion 1	0.297	0.298	-1.921	-1.198	-0.839	-1.168	-0.001	-0.594	-0.142	-0.294	-0.083	-0.892	-3.566	-3.818	-3.509	-2.912	-2.220	-1.327	1.408
Motion 2	-10.511	-12.029	-26.506	-2.147	20.887	24.981	32.331	23.444	32.388	47.919	47.107	15.331	6.921	3.221	-1.622	-9.898	-20.435	10.081	22.729
Motion 3	0.981	0.985	-2.586	-1.290	-0.692	-1.128	0.623	-0.231	0.361	-0.247	-0.040	-0.663	-2.294	-0.978	0.025	0.806	1.726	-0.273	1.164
Motion 4	1.278	1.282	-3.498	-1.702	-0.806	-1.385	0.981	-0.214	0.537	-0.314	-0.136	-1.169	-4.046	-3.908	-3.509	-2.960	-2.745	-1.313	1.849
Motion 5	0.749	0.750	-1.919	-1.011	-0.579	-1.000	0.464	-0.304	0.242	-0.269	-0.119	-1.081	-3.362	-3.726	-4.296	-3.034	-2.488	-1.234	1.619
Average per v	-1.441	-1.743	-7.286	-1.469	3.594	4.060	6.880	4.420	6.677	9.359	9.346	2.305	-1.269	-1.842	-2.582	-3.600	-5.232		
STDEV	5.083	5.762	10.764	0.455	9.668	11.696	14.232	10.636	14.375	21.556	21.109	7.284	4.623	3.086	1.759	3.882	8.694		
15lb Sternum																			
Motion 1	0.108	0.108	-2.109	-1.490	-1.291	-1.666	-0.503	-1.085	-0.543	-0.442	-0.108	-1.832	-4.980	-6.357	-6.438	-5.776	-4.933	-2.314	2.369
Motion 2	-10.523	-12.109	-26.756	-2.219	21.045	25.155	32.678	23.699	33.324	49.475	48.744	15.236	6.303	1.779	-3.862	-12.941	-24.132	9.700	23.793
Motion 3	1.128	1.130	-2.714	-1.387	-0.838	-1.342	0.546	-0.351	0.354	-0.307	-0.019	-1.511	-4.316	-4.550	-4.033	-3.131	-1.862	-1.365	1.845
Motion 4	1.448	1.450	-3.655	-1.780	-0.902	-1.545	0.984	-0.279	0.560	-0.358	-0.132	-1.545	-4.913	-5.104	-5.990	-5.767	-5.594	-1.948	2.668
Motion 5	0.881	0.879	-1.850	-1.030	-0.727	-1.210	0.300	-0.476	0.153	-0.345	-0.119	-1.714	-4.650	-5.918	-7.078	-6.630	-5.977	-2.089	2.780
Average per v	-1.392	-1.708	-7.417	-1.581	3.458	3.879	6.801	4.302	6.770	9.605	9.673	1.727	-2.511	-4.030	-5.480	-6.849	-8.500		
STDEV	5.129	5.835	10.833	0.446	9.834	11.895	14.476	10.848	14.850	22.288	21.841	7.553	4.934	3.322	1.453	3.651	8.888		

Table E.3.3: Female ML Shear Data for the Baseline and Sternum Weights

Female raw ML shear data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), 6.8 kg (15lbs) added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Female ML Shear Per trial																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight																			
Motion 1	92.96	-93.95	-44.83	68.93	77.81	79.49	60.77	34.22	8.72	-16.88	-21.39	-30.04	-44.73	-57.86	-69.30	-74.46	-83.40	-6.70	63.77
Motion 2	196.24	-161.47	116.30	196.40	167.92	172.66	132.00	73.08	-162.52	-178.86	-108.32	-80.41	-82.45	-58.26	-54.51	-51.88	-59.73	3.31	135.39
Motion 3	114.19	-85.57	-38.04	50.68	39.93	28.26	15.84	-24.28	-80.30	-87.81	-78.06	-78.52	-87.59	-90.93	-96.15	-96.70	-101.81	-40.99	66.32
Motion 4	131.95	-92.16	-42.79	65.13	44.29	30.08	17.36	-26.30	-110.71	-116.02	-90.65	-81.10	-84.01	-77.07	-81.29	-80.72	-85.32	-39.96	71.85
Motion 5	98.32	-86.55	-46.94	80.73	84.76	86.39	66.69	39.26	-25.90	-38.02	-30.30	-34.66	-49.32	-56.69	-65.18	-68.57	-76.45	-7.20	66.29
Average per v	126.73	-103.94	-11.26	92.37	82.94	79.38	58.53	19.20	-74.14	-87.52	-65.74	-60.95	-69.62	-68.16	-73.29	-74.47	-81.34		
STDEV	41.72	32.36	71.38	59.13	51.46	58.72	47.40	43.28	67.79	64.42	38.11	26.17	20.78	15.28	15.98	16.42	15.25		
5lb Sternum																			
Motion 1	97.18	-96.89	-47.12	74.61	84.83	87.10	67.38	39.27	9.36	-19.38	-23.33	-33.18	-49.75	-63.93	-76.38	-82.22	-91.67	-7.30	69.03
Motion 2	202.53	-166.80	119.67	203.45	175.47	180.91	138.78	77.51	-165.87	-183.71	-111.93	-84.35	-87.65	-64.18	-61.40	-59.36	-67.50	2.68	140.93
Motion 3	122.83	-89.01	-40.96	56.58	44.47	31.86	17.32	-25.80	-92.16	-100.95	-89.00	-89.11	-99.32	-102.66	-108.47	-109.33	-114.29	-46.35	73.76
Motion 4	141.45	-99.11	-46.05	71.42	48.76	33.47	19.01	-28.56	-123.02	-129.38	-101.97	-92.17	-96.31	-89.95	-95.33	-95.46	-100.39	-46.09	79.85
Motion 5	103.26	-90.24	-49.61	86.97	92.13	94.46	73.50	44.18	-29.33	-42.87	-33.30	-38.15	-54.54	-62.98	-72.55	-76.72	-85.00	-8.28	72.03
Average per v	133.45	-108.41	-12.82	98.61	89.13	85.56	63.20	21.32	-80.20	-95.26	-71.90	-67.39	-77.51	-76.74	-82.83	-84.62	-91.77		
STDEV	42.35	32.92	74.13	59.60	52.69	60.77	49.73	46.66	70.58	66.19	40.77	29.15	23.61	18.42	18.84	18.94	17.44		
10lb Sternum																			
Motion 1	99.99	-98.16	-48.75	79.95	91.76	94.65	74.06	44.67	9.91	-21.97	-25.13	-35.99	-54.52	-69.50	-82.85	-89.32	-98.97	-7.66	73.83
Motion 2	208.82	-172.12	122.96	210.46	183.01	189.13	145.52	81.89	-169.29	-188.30	-115.61	-88.31	-92.86	-70.13	-68.37	-66.96	-75.34	2.03	146.50
Motion 3	131.87	-93.06	-44.07	62.66	48.96	35.35	18.89	-27.66	-104.24	-114.03	-100.11	-99.87	-111.26	-115.16	-121.89	-123.32	-128.57	-52.09	81.65
Motion 4	151.10	-106.15	-49.36	77.63	53.21	36.83	20.67	-30.88	-135.31	-142.81	-113.40	-103.25	-108.54	-102.60	-109.11	-109.94	-115.20	-52.18	87.90
Motion 5	108.45	-94.03	-52.41	93.39	99.58	102.61	80.34	49.07	-31.74	-46.69	-36.60	-41.75	-59.81	-69.35	-79.94	-84.83	-93.29	-9.24	77.81
Average per v	140.05	-112.70	-14.33	104.82	95.31	91.71	67.90	23.42	-86.13	-102.76	-78.17	-73.83	-85.40	-85.35	-92.43	-94.88	-102.28		
STDEV	43.36	33.61	76.80	60.05	53.95	62.86	52.08	50.22	73.90	68.41	43.78	32.46	26.78	21.94	22.21	22.06	20.47		
15lb Sternum																			
Motion 1	104.18	-100.96	-51.06	85.97	99.14	102.68	81.00	50.00	10.56	-25.42	-27.54	-39.25	-59.60	-75.44	-89.85	-97.04	-107.05	-8.22	79.29
Motion 2	215.12	-177.44	126.28	217.47	190.53	197.34	152.26	86.26	-172.82	-193.07	-119.29	-92.26	-98.08	-76.08	-75.29	-74.51	-83.14	1.37	152.12
Motion 3	141.09	-98.84	-47.23	68.82	53.45	38.79	20.49	-29.69	-116.46	-127.26	-111.30	-110.73	-123.24	-127.89	-136.08	-138.41	-144.37	-58.17	89.88
Motion 4	160.83	-113.25	-52.70	83.94	57.67	40.18	22.36	-33.30	-147.65	-156.29	-124.84	-114.41	-120.89	-115.45	-123.13	-124.66	-130.27	-58.34	96.08
Motion 5	113.85	-98.06	-55.31	99.87	107.04	110.79	87.17	53.89	-34.44	-50.88	-39.75	-45.42	-65.15	-75.74	-87.59	-93.31	-102.42	-10.32	83.78
Average per v	147.01	-117.71	-16.00	111.21	101.57	97.96	72.66	25.43	-92.16	-110.58	-84.55	-80.41	-93.39	-94.12	-102.39	-105.59	-113.45		
STDEV	44.15	33.95	79.60	60.41	55.21	65.00	54.47	53.85	77.55	70.69	46.91	35.83	30.04	25.53	25.86	25.65	24.09		

Table E.3.4: Female Resultant Force Data for the Baseline and Sternum Weights

Female raw resultant data sorted by weight conditions (no weight, 2.3 kg (5 lbs.), 4.5 kg (10 lbs.), *6.8 kg (15lbs) added at the sternum) for motions 1-5 across all spinal levels. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.*

Female Resultant Force Per Trial																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
No Weight																		
Motion 1	510.08	477.44	428.93	392.93	363.91	334.32	300.30	274.54	249.85	222.74	199.95	192.91	182.98	176.31	168.35	159.07	160.47	282.06	116.44
Motion 2	1077.41	1031.54	903.09	833.36	792.46	748.92	652.92	570.51	501.09	446.43	301.01	284.22	176.94	108.02	83.83	68.58	70.33	508.86	349.56
Motion 3	602.59	564.36	466.11	422.53	390.71	356.36	306.29	266.80	244.05	223.22	184.58	181.77	167.58	155.20	146.08	136.60	137.85	291.33	151.42
Motion 4	696.28	655.81	524.32	473.05	438.20	400.55	335.75	282.93	261.00	237.03	176.48	171.55	144.69	123.36	115.34	105.50	106.32	308.71	192.91
Motion 5	539.54	504.14	449.05	410.58	381.18	351.15	311.61	280.66	251.24	229.63	191.66	189.33	167.49	151.86	142.50	132.66	133.67	283.41	134.59
Average per v	685.18	646.66	554.30	506.49	473.29	438.26	381.37	335.09	301.45	271.81	210.73	203.96	167.94	142.95	131.22	120.48	121.73		
STDEV	230.58	225.79	198.20	185.14	180.53	175.38	152.39	131.75	111.77	97.79	51.20	45.61	14.56	27.14	32.50	34.70	34.58		
5lb Sternum																		
Motion 1	533.26	500.17	450.79	414.25	384.90	355.11	320.49	294.12	268.29	241.80	216.33	210.15	197.44	190.08	181.99	172.63	174.10	300.35	119.64
Motion 2	1111.92	1065.56	934.70	863.96	822.75	778.83	680.90	596.76	525.25	469.23	320.30	304.12	193.91	123.44	98.69	82.95	83.92	532.78	356.84
Motion 3	648.18	608.92	501.92	456.32	423.79	388.65	334.86	292.04	269.07	247.68	203.49	201.45	184.93	170.59	161.02	151.15	151.87	317.41	161.50
Motion 4	746.45	705.21	564.38	510.85	475.20	436.61	367.65	310.95	288.59	263.27	197.06	192.67	163.76	141.15	133.02	122.91	123.44	337.83	203.93
Motion 5	566.64	530.87	474.66	435.73	406.26	376.15	335.44	303.33	272.51	250.74	209.58	208.40	184.38	167.54	157.88	147.88	148.73	304.51	138.79
Average per v	721.29	682.14	585.29	536.22	502.58	467.07	407.87	359.44	324.74	294.54	229.35	223.36	184.88	158.56	146.52	135.50	136.41		
STDEV	233.37	228.53	199.88	186.69	182.07	176.83	153.60	132.88	112.39	97.97	51.34	45.67	13.09	26.25	31.89	34.27	34.40		
10lb Sternum																		
Motion 1	548.68	515.61	466.43	430.13	401.03	371.59	337.02	310.46	283.90	258.94	230.61	226.16	211.58	202.82	194.56	185.13	186.36	315.35	120.54
Motion 2	1146.45	1099.57	966.33	894.62	853.10	808.78	708.89	623.07	549.54	492.11	339.59	324.08	210.93	138.99	113.78	97.65	97.99	556.79	364.03
Motion 3	695.86	655.50	540.03	492.37	459.13	423.10	365.25	318.60	295.17	272.89	223.13	221.77	203.07	187.49	177.64	167.45	167.90	345.08	171.95
Motion 4	797.33	755.30	604.84	549.04	512.58	473.00	399.78	339.23	316.35	289.63	217.61	213.84	182.76	158.70	150.48	140.12	140.40	367.12	215.25
Motion 5	595.13	558.98	501.42	461.87	432.32	402.11	360.04	326.60	294.34	272.22	227.26	227.19	201.19	183.27	173.22	162.99	163.54	326.10	143.59
Average per v	756.69	716.99	615.81	565.60	531.63	495.72	434.20	383.59	347.86	317.16	247.64	242.61	201.91	174.25	161.94	150.67	151.24		
STDEV	238.03	232.99	202.56	189.08	184.31	178.86	155.19	134.29	113.36	98.41	51.63	45.85	11.65	25.29	31.18	33.70	33.97		
15lb Sternum																		
Motion 1	571.69	538.33	488.51	451.91	422.73	393.29	358.03	330.67	302.47	278.54	247.15	243.90	226.99	216.81	208.51	198.99	200.13	334.04	123.70
Motion 2	1181.00	1133.61	997.97	925.26	883.46	838.76	736.96	649.39	573.92	515.05	358.92	344.08	228.06	154.64	128.97	112.50	112.32	580.87	371.18
Motion 3	744.53	703.30	578.82	528.96	494.92	457.96	396.22	345.82	321.94	298.51	243.09	242.33	221.39	204.88	195.23	184.87	185.23	373.41	182.48
Motion 4	848.69	805.84	645.81	587.71	550.46	509.91	432.36	367.89	344.43	316.24	238.45	235.20	201.99	176.59	168.30	157.69	157.70	396.78	226.65
Motion 5	624.75	588.15	529.10	488.86	459.20	428.86	385.35	350.53	316.72	294.06	245.64	246.25	218.15	199.10	189.03	178.67	179.15	348.33	148.62
Average per v	794.13	753.85	648.04	596.54	562.15	525.76	461.78	408.86	371.90	340.48	266.65	262.35	219.32	190.40	178.01	166.55	166.91		
STDEV	241.49	236.32	204.23	190.53	185.70	180.11	156.12	135.11	113.94	98.51	51.69	45.87	10.50	24.76	31.01	33.67	34.11		

Appendix E.4 Female Sternum Weights Percentage Change

Table E.4.1: Female Sternum Weight Compressive Force Percentage Change

Female Compressive Force % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Female Compression % Change																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Sternum																			
Motion 1	4.544	4.824	5.096	5.334	5.609	6.015	6.543	7.005	7.379	8.522	8.182	8.897	7.679	7.483	7.677	8.008	8.015	6.871	1.384
Motion 2	3.204	3.299	3.512	3.677	3.793	3.954	4.257	4.582	5.149	5.584	6.936	7.208	10.530	16.074	21.434	28.744	35.372	9.842	9.789
Motion 3	7.566	7.986	7.683	7.945	8.436	9.039	9.328	9.487	9.692	10.206	9.410	10.208	9.189	8.333	8.249	8.253	7.774	8.752	0.874
Motion 4	7.205	7.532	7.641	7.959	8.426	8.991	9.500	9.916	10.451	10.928	11.370	11.918	12.421	12.917	13.383	14.047	13.357	10.468	2.288
Motion 5	5.023	5.332	5.703	6.059	6.469	6.976	7.524	7.987	8.417	9.090	9.335	10.072	10.028	10.192	10.652	11.323	11.315	8.323	2.126
Average per	5.508	5.795	5.927	6.195	6.547	6.995	7.430	7.796	8.218	8.866	9.047	9.660	9.969	11.000	12.279	14.075	15.167		
STDEV	1.843	1.950	1.774	1.822	1.973	2.143	2.165	2.142	2.081	2.061	1.644	1.744	1.745	3.520	5.592	8.565	11.534		
10lb Sternum																			
Motion 1	7.566	8.133	8.742	9.253	9.814	10.658	11.797	12.785	13.626	16.166	15.309	17.172	15.204	14.384	14.731	15.365	15.221	12.702	3.107
Motion 2	6.409	6.596	7.028	7.362	7.593	7.913	8.516	9.175	10.315	11.204	13.846	14.430	21.059	32.175	42.927	57.569	70.826	19.703	19.605
Motion 3	15.478	16.319	15.860	16.424	17.457	18.688	19.249	19.459	19.829	20.808	19.226	20.781	18.898	17.659	17.601	17.588	16.464	18.105	1.670
Motion 4	14.513	15.171	15.358	16.003	16.940	18.064	19.070	19.920	20.983	21.907	22.666	23.872	24.797	25.653	26.584	27.895	26.550	20.938	4.474
Motion 5	10.305	10.944	11.663	12.362	13.200	14.234	15.303	16.192	17.098	18.423	18.515	19.979	19.991	20.389	21.225	22.522	22.485	16.755	4.094
Average per	10.854	11.433	11.730	12.281	13.001	13.911	14.787	15.506	16.370	17.702	17.912	19.247	19.990	22.052	24.614	28.188	30.309		
STDEV	4.051	4.253	3.913	4.012	4.325	4.657	4.658	4.557	4.415	4.255	3.464	3.598	3.477	7.006	11.154	17.119	23.110		
15lb Sternum																			
Motion 1	12.078	12.960	13.890	14.689	15.596	16.912	18.587	19.994	21.059	24.891	23.542	26.324	23.412	21.991	22.576	23.549	23.343	19.729	4.549
Motion 2	9.615	9.897	10.544	11.045	11.395	11.877	12.788	13.770	15.485	16.811	20.758	21.667	31.638	48.331	64.461	86.468	106.377	29.584	29.450
Motion 3	23.556	24.826	24.182	25.029	26.596	28.454	29.361	29.679	30.233	31.576	29.213	31.478	28.701	27.242	27.338	27.178	25.165	27.636	2.492
Motion 4	21.889	22.876	23.172	24.149	25.569	27.268	28.772	30.058	31.658	33.009	34.178	35.936	37.336	38.650	40.046	42.007	39.954	31.560	6.717
Motion 5	15.793	16.764	17.826	18.875	20.156	21.726	23.316	24.635	25.990	27.891	28.084	30.025	30.042	30.636	32.079	34.050	33.957	25.403	6.070
Average per	16.586	17.465	17.923	18.757	19.862	21.247	22.565	23.627	24.885	26.835	27.155	29.086	30.226	33.370	37.300	42.650	45.759		
STDEV	6.046	6.355	5.862	6.009	6.479	6.982	7.013	6.881	6.684	6.442	5.206	5.390	5.033	10.323	16.497	25.488	34.547		

Table E.4.2: Female Sternum Weight AP Shear Percentage Change

Female AP Shear % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Female AP SHEA R %change																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Sternum																			
Motion 1	-13.999	-13.955	7.231	16.260	46.403	28.674	-29.661	241.350	-48.051	44.249	50.470	-231.794	-1514.082	-199.329	-122.726	-92.284	-74.461	-112.100	376.748
Motion 2	-0.131	0.428	0.730	3.606	0.732	0.670	1.035	1.073	2.936	3.519	3.710	-0.435	-8.226	-23.371	-67.742	76.816	26.650	1.294	27.200
Motion 3	11.338	11.240	7.190	7.795	14.229	12.816	2.187	45.109	3.353	15.910	5.267	-58.870	-226.265	-28.339	-22.163	-24.598	-30.169	-14.940	59.552
Motion 4	8.627	8.527	7.527	8.025	11.659	10.724	4.498	26.249	5.243	11.809	2.236	59.963	33.398	89.758	-195.240	-113.805	-102.334	-7.243	68.382
Motion 5	5.195	5.010	1.945	4.572	16.753	12.960	-7.053	71.604	-8.538	17.078	6.267	193.940	65.703	220.797	-615.678	-199.981	-143.608	-20.767	181.853
Average per v	2.206	2.250	4.925	8.051	17.955	13.169	-5.799	77.077	-9.011	18.513	13.590	-7.439	-329.894	11.903	-204.710	-70.771	-64.784		
STDEV	10.020	9.922	3.305	4.983	17.036	10.035	14.031	95.391	22.490	15.337	20.673	156.625	671.749	155.869	238.636	103.590	65.718		
10lb Sternum																			
Motion 1	-46.697	-46.832	15.823	45.774	140.484	85.590	-100.235	758.254	-150.320	112.201	115.518	-389.769	-2783.999	-409.675	-259.102	-191.655	-152.041	-191.570	717.670
Motion 2	-0.831	0.422	1.307	7.198	1.459	1.367	2.132	2.206	5.996	6.964	7.496	-1.090	-16.952	-47.416	-157.511	149.627	53.936	0.959	57.466
Motion 3	25.831	25.446	13.852	17.045	40.412	34.905	-5.645	155.821	-0.160	48.575	-17.756	-292.749	-829.063	-134.542	-99.413	-85.242	-74.266	-69.232	218.513
Motion 4	21.571	21.341	13.490	14.177	22.842	21.782	8.511	52.667	12.728	22.230	0.774	112.109	65.283	173.143	-387.663	-223.474	-199.996	-14.617	134.444
Motion 5	17.574	16.954	1.278	8.416	44.948	34.312	-25.023	200.464	-26.552	47.856	11.468	468.166	139.222	421.961	-1232.024	-345.589	-244.614	-27.128	366.492
Average per v	3.490	3.466	9.150	18.522	50.029	35.591	-24.052	233.882	-31.662	47.565	23.500	-20.667	-685.102	0.694	-427.143	-139.267	-123.396		
STDEV	29.841	29.681	7.227	15.765	53.382	31.081	44.412	303.599	67.983	40.216	52.647	341.773	1236.437	314.726	463.071	186.268	117.518		
15lb Sternum																			
Motion 1	-80.503	-80.733	27.148	81.360	270.122	164.738	-196.283	1467.047	-292.047	218.721	178.125	-695.279	-3848.053	-615.522	-391.885	-281.798	-215.661	-252.383	1041.108
Motion 2	-0.717	1.085	2.264	10.790	2.229	2.071	3.227	3.317	9.058	10.438	11.231	-1.703	-24.368	-70.946	-236.948	226.369	81.792	1.717	86.649
Motion 3	44.686	43.873	19.505	25.787	69.872	60.423	-17.360	289.473	-1.961	84.808	-60.527	-539.153	-1471.908	-260.737	-193.008	-157.362	-127.763	-128.903	389.672
Motion 4	37.677	37.184	18.579	19.447	37.402	35.862	8.822	98.930	17.461	39.083	-2.308	180.265	100.714	256.792	-591.055	-340.563	-303.789	-20.559	205.689
Motion 5	38.306	36.977	-2.367	10.475	81.793	62.433	-51.486	370.257	-53.562	89.455	10.858	800.384	230.862	729.112	-1964.965	-636.703	-447.471	-40.920	603.533
Average per v	7.890	7.677	13.026	29.572	92.284	65.106	-50.616	445.805	-64.210	88.501	27.476	-51.097	-1002.551	7.740	-675.572	-238.011	-202.578		
STDEV	52.568	52.199	12.500	29.649	104.116	60.795	84.790	589.322	130.323	79.856	89.256	598.782	1732.954	512.136	737.464	313.665	198.022		

Table E.4.3: Female Sternum Weight ML Shear Percentage Change

Female ML shear % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Female ML Shear % Change																		
TrialID	L5-S1	L4-L5	L3-L4	L2-L3	L1-L2	T12-L1	T11-T12	T10-T11	T9-T10	T8-T9	T7-T8	T6-T7	T5-T6	T4-T5	T3-T4	T2-T3	T1-T2	Average	STDEV
5lb Sternum																			
Motion 1	4.544	3.137	5.096	8.250	9.025	9.579	10.872	14.760	7.379	14.837	9.080	10.447	11.209	10.502	10.218	10.421	9.916	9.369	3.113
Motion 2	3.205	3.297	2.898	3.588	4.502	4.776	5.132	6.052	2.060	2.711	3.332	4.906	6.304	10.163	12.646	14.424	13.011	6.059	3.964
Motion 3	7.566	4.024	7.683	11.638	11.361	12.709	9.328	6.266	14.760	14.968	14.012	13.485	13.386	12.904	12.811	13.064	12.255	11.307	3.183
Motion 4	7.205	7.532	7.641	9.646	10.107	11.264	9.500	8.580	11.123	11.516	12.487	13.653	14.636	16.706	17.274	18.256	17.658	12.046	3.721
Motion 5	5.023	4.267	5.703	7.737	8.691	9.338	10.216	12.543	13.238	12.777	9.913	10.069	10.585	11.083	11.307	11.878	11.192	9.739	2.682
Average per v	5.509	4.451	5.804	8.172	8.737	9.533	9.010	9.640	9.712	11.362	9.765	10.512	11.224	12.272	12.851	13.609	12.806		
STDEV	1.843	1.787	1.991	2.975	2.588	2.989	2.253	3.874	5.097	5.048	4.103	3.548	3.199	2.695	2.689	2.988	2.951		
10lb Sternum																			
Motion 1	7.566	4.486	8.742	15.996	17.932	19.065	21.874	30.517	13.626	30.198	17.504	19.794	21.878	20.130	19.550	19.959	18.679	18.088	6.854
Motion 2	6.412	6.592	5.732	7.156	8.989	9.538	10.242	12.053	4.163	5.275	6.734	9.824	12.618	20.384	25.428	29.064	26.130	12.137	7.992
Motion 3	15.478	8.753	15.860	23.643	22.609	25.062	19.249	13.931	29.805	29.857	28.239	27.197	27.019	26.651	26.765	27.536	26.286	23.173	6.248
Motion 4	14.513	15.171	15.358	19.185	20.156	22.453	19.070	17.415	22.223	23.094	25.095	27.309	29.199	33.118	34.232	36.191	35.020	24.047	7.296
Motion 5	10.305	8.642	11.663	15.691	17.480	18.778	20.465	24.993	22.542	22.819	20.819	20.437	21.284	22.326	22.642	23.719	22.036	19.214	4.879
Average per v	10.855	8.729	11.471	16.334	17.433	18.979	18.180	19.782	18.472	22.249	19.678	20.912	22.400	24.522	25.723	27.294	25.630		
STDEV	4.050	4.002	4.324	6.048	5.142	5.879	4.577	7.778	9.840	10.127	8.310	7.156	6.418	5.470	5.504	6.102	6.125		
15lb Sternum																			
Motion 1	12.078	7.464	13.890	24.726	27.414	29.173	33.292	46.114	21.059	50.599	28.786	30.639	33.234	30.392	29.651	30.315	28.366	28.070	10.755
Motion 2	9.621	9.890	8.589	10.726	13.465	14.291	15.345	18.035	6.335	7.943	10.132	14.740	18.946	30.586	38.127	43.620	39.187	18.210	11.983
Motion 3	23.556	15.508	24.182	35.785	33.838	37.251	29.361	22.270	45.029	44.920	42.581	41.021	40.695	40.651	41.523	43.141	41.805	35.478	9.142
Motion 4	21.889	22.876	23.172	28.869	30.220	33.582	28.772	26.601	33.371	34.712	37.714	41.071	43.889	49.785	51.474	54.428	52.680	36.183	10.934
Motion 5	15.793	13.301	17.826	23.715	26.284	28.243	30.708	37.253	32.976	33.841	31.213	31.021	32.100	33.597	34.371	36.079	33.969	28.958	7.225
Average per v	16.587	13.808	17.532	24.764	26.244	28.508	27.496	30.054	27.754	34.403	30.085	31.699	33.773	37.002	39.029	41.517	39.202		
STDEV	6.045	5.937	6.507	9.172	7.716	8.729	7.012	11.475	14.670	16.382	12.404	10.770	9.659	8.264	8.240	9.067	9.128		

Table E.4. 4: Female Sternum Weight Resultant Force Percentage Change

Female Resultant Force % change for 2.3 kg, 4.5 kg, 6.8 kg (5lbs., 10lbs., 15lbs.) weight at the sternum compared to baseline for all motions. The right two columns consist of the average and standard deviation of the forces experienced for each motion across the entire spinal level. The bottom two rows for each weight condition are the average and standard deviation of the forces experienced at each spinal level across all five motions.

Female Resultant Force % Change																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
5lb Sternum																			
Motion 1	4.544	4.759	5.096	5.425	5.768	6.219	6.724	7.130	7.379	8.559	8.193	8.934	7.898	7.812	8.103	8.520	8.496	7.033	1.465
Motion 2	3.203	3.298	3.500	3.672	3.823	3.994	4.285	4.601	4.820	5.107	6.409	7.004	9.588	14.279	17.732	20.960	19.325	7.976	6.112
Motion 3	7.566	7.896	7.683	7.999	8.467	9.062	9.328	9.461	10.252	10.956	10.247	10.827	10.351	9.914	10.226	10.646	10.168	9.474	1.155
Motion 4	7.205	7.532	7.641	7.991	8.444	9.004	9.500	9.905	10.572	11.069	11.666	12.308	13.179	14.425	15.330	16.501	16.108	11.081	3.108
Motion 5	5.023	5.301	5.703	6.125	6.580	7.120	7.648	8.078	8.469	9.192	9.349	10.072	10.081	10.326	10.798	11.471	11.267	8.388	2.141
Average per v	5.508	5.757	5.925	6.242	6.616	7.080	7.497	7.835	8.298	8.977	9.173	9.829	10.220	11.351	12.438	13.619	13.073		
STDEV	1.843	1.935	1.779	1.833	1.955	2.115	2.139	2.118	2.343	2.423	2.000	1.999	1.909	2.901	3.961	5.041	4.498		
10lb Sternum																			
Motion 1	7.566	7.994	8.742	9.467	10.198	11.150	12.227	13.082	13.626	16.252	15.335	17.237	15.630	15.034	15.571	16.379	16.133	13.037	3.263
Motion 2	6.408	6.595	7.002	7.350	7.652	7.993	8.573	9.212	9.668	10.231	12.818	14.025	19.205	28.673	35.732	42.399	39.332	16.051	12.400
Motion 3	15.478	16.151	15.860	16.531	17.512	18.730	19.249	19.414	20.949	22.252	20.888	22.005	21.178	20.803	21.606	22.585	21.794	19.587	2.444
Motion 4	14.513	15.171	15.358	16.064	16.974	18.089	19.070	19.898	21.207	22.192	23.311	24.649	26.311	28.650	30.467	32.813	32.052	22.164	6.108
Motion 5	10.305	10.877	11.663	12.492	13.415	14.515	15.544	16.371	17.157	18.546	18.573	19.995	20.116	20.685	21.560	22.859	22.342	16.883	4.133
Average per v	10.854	11.358	11.725	12.381	13.150	14.095	14.932	15.595	16.522	17.895	18.185	19.582	20.488	22.769	24.987	27.407	26.331		
STDEV	4.051	4.235	3.921	4.019	4.262	4.569	4.580	4.493	4.933	4.983	4.203	4.126	3.866	5.863	8.021	10.241	9.250		
15lb Sternum																			
Motion 1	12.078	12.753	13.891	15.011	16.163	17.640	19.225	20.444	21.060	25.053	23.604	26.433	24.051	22.974	23.852	25.091	24.715	20.237	4.789
Motion 2	9.615	9.896	10.506	11.027	11.483	11.997	12.872	13.825	14.533	15.370	19.239	21.064	28.889	43.159	53.847	64.061	59.705	24.182	18.776
Motion 3	23.556	24.620	24.182	25.190	26.674	28.511	29.361	29.620	31.915	33.728	31.704	33.313	32.111	32.010	33.644	35.336	34.366	29.991	3.889
Motion 4	21.889	22.876	23.172	24.240	25.618	27.304	28.772	30.029	31.967	33.419	35.120	37.103	39.602	43.151	45.919	49.470	48.325	33.410	9.193
Motion 5	15.793	16.663	17.826	19.065	20.466	22.131	23.664	24.894	26.066	28.057	28.163	30.061	30.247	31.109	32.655	34.682	34.025	25.622	6.173
Average per v	16.586	17.361	17.915	18.907	20.081	21.517	22.779	23.762	25.108	27.126	27.566	29.595	30.980	34.480	37.983	41.728	40.227		
STDEV	6.047	6.336	5.874	6.025	6.394	6.864	6.907	6.794	7.459	7.526	6.316	6.188	5.669	8.666	11.848	15.215	13.770		

Appendix: F- Supplementary Figures and %BW Tables

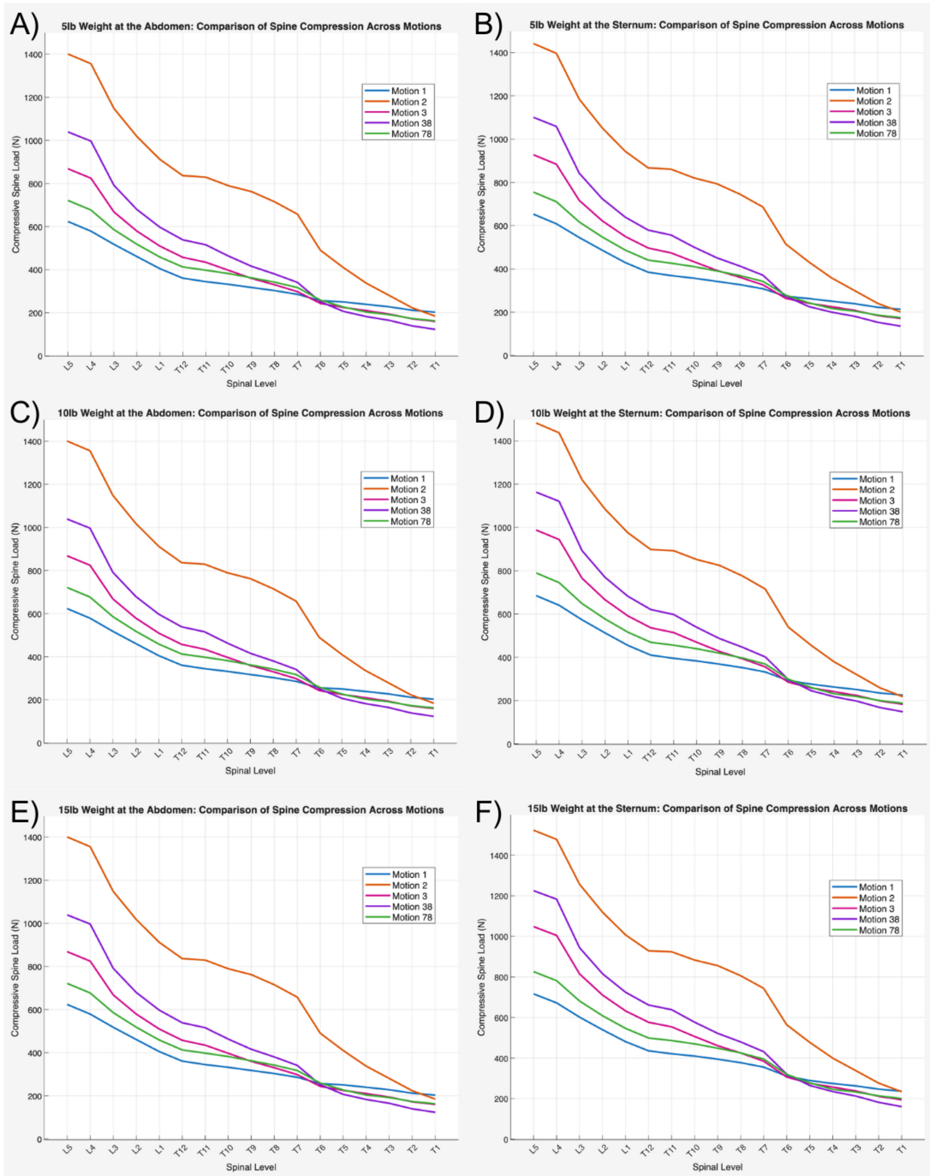


Figure F.1: Male Compressive Load Plots Sorted by Weight

Compressive thoracolumbar spine loads for the male model across the five motions with simulated vest weights applied at different magnitudes and different positions. Panels A, C, and E represent the vest loads of 5lb, 10lb, 15lb positioned at the abdomen, respectively. Panels B, D, and F represent the vest loads of 5lb, 10lb, 15lb positioned at the sternum, respectively. Created in MATLAB.

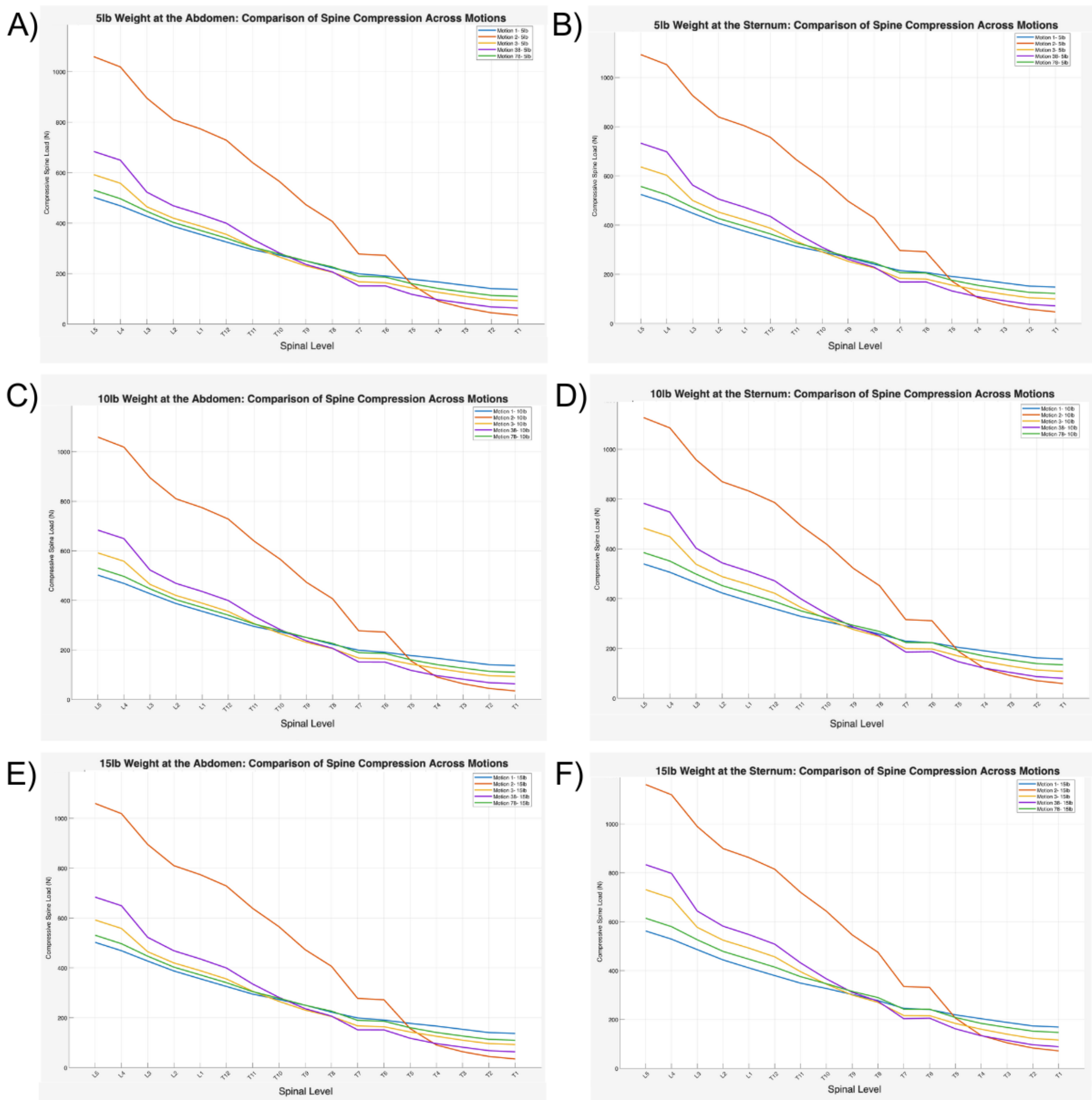


Figure F. 2: Female Compressive Load Plots by Weight

Compressive thoracolumbar spine loads for the female model across the five motions with simulated vest weights applied at different magnitudes and different positions. Panels A, C, and E represent the vest loads of 5lb, 10lb, 15lb positioned at the abdomen, respectively. Panels B, D, and F represent the vest loads of 5lb, 10lb, 15lb positioned at the sternum, respectively. Created in MATLAB.

Table F.1: Male Compressive Force Percent Body Weight (%BW)

Compressive Forces Across Thoracolumbar Spine for All Sternum-Loaded Conditions. This table presents the compressive joint reaction forces normalized to body weight (%BW) at each vertebral level (L5–T1) for the male musculoskeletal model across all simulated vest weight conditions applied to the sternum (no weight, 2.3 kg, 4.5 kg, 6.8 kg (5 lbs., 10 lbs., and 15 lbs.)). Data are reported for each of the five motion postures (Motion 1–5), including averaged values per motion condition and an overall average across all spinal levels.

Male Compression per trial %BW																		
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
No Weight																			
Motion 1	81.47	75.64	67.67	60.25	52.94	47.15	45.03	43.40	41.49	39.62	37.34	33.50	32.72	31.27	29.78	27.70	26.55	45.50	16.82
Motion 2	183.05	177.17	150.08	133.07	119.20	109.32	108.39	103.16	99.60	93.47	85.94	64.07	53.57	44.08	36.65	29.18	24.13	94.95	48.83
Motion 3	113.46	107.74	87.32	75.70	66.63	59.78	56.80	51.89	46.99	43.16	38.98	31.83	29.40	27.49	25.36	22.48	20.92	53.29	28.83
Motion 4	135.78	130.25	103.45	88.80	78.08	70.41	67.39	60.51	54.35	49.68	44.57	32.83	27.04	23.87	21.58	18.22	16.11	60.17	37.53
Motion 5	94.26	88.46	76.57	67.74	59.97	53.94	51.99	49.93	47.34	44.72	41.45	33.85	29.66	26.59	25.05	22.67	21.24	49.14	22.49
5lb Sternum																			
Motion 1	85.36	79.55	71.23	63.58	56.14	50.30	48.26	46.67	44.75	42.77	40.32	35.80	34.37	32.76	31.27	29.14	27.94	48.25	17.58
Motion 2	188.40	182.50	154.80	137.44	123.34	113.33	112.50	107.24	103.68	97.43	89.69	67.29	56.52	46.80	39.17	31.50	26.28	98.70	49.79
Motion 3	121.22	115.52	93.63	81.34	71.91	64.91	61.96	56.59	51.36	47.23	42.68	34.49	31.54	29.47	27.24	24.15	22.38	57.51	30.82
Motion 4	143.83	138.33	110.04	94.68	83.58	75.73	72.73	65.44	58.95	54.00	48.50	35.85	29.55	26.17	23.67	20.06	17.74	64.64	39.55
Motion 5	98.69	92.88	80.60	71.57	63.68	57.61	55.75	53.67	51.02	48.26	44.77	36.44	31.82	28.38	26.81	24.38	22.85	52.31	23.39
10lb Sternum																			
Motion 1	89.48	83.67	74.91	67.01	59.45	53.59	51.62	50.06	48.12	46.01	43.37	38.21	36.05	34.28	32.75	30.68	29.40	51.10	18.41
Motion 2	193.74	187.83	159.53	141.82	127.48	117.34	116.62	111.33	107.76	101.39	93.45	70.51	59.48	49.54	41.70	33.83	28.45	102.46	50.75
Motion 3	129.08	123.39	100.00	87.04	77.26	70.09	67.17	61.36	55.79	51.38	46.46	37.24	33.76	31.51	29.15	25.91	23.90	61.79	32.82
Motion 4	151.95	146.47	116.69	100.61	89.12	81.09	78.10	70.41	63.58	58.34	52.46	38.88	32.08	28.45	25.76	21.91	19.37	69.13	41.59
Motion 5	103.17	97.36	84.69	75.45	67.43	61.30	59.55	57.45	54.74	51.85	48.14	39.09	34.02	30.21	28.55	26.12	24.50	55.51	24.32
15lb Sternum																			
Motion 1	93.65	87.85	78.63	70.50	62.84	56.95	55.08	53.55	51.58	49.33	46.48	40.70	37.82	35.89	34.36	32.28	30.91	54.02	19.25
Motion 2	199.06	193.14	164.24	146.19	131.62	121.36	120.75	115.43	111.85	105.35	97.22	73.75	62.44	52.27	44.23	36.15	30.60	106.22	51.70
Motion 3	136.97	131.31	106.48	92.82	82.66	75.32	72.43	66.19	60.27	55.57	50.28	40.07	36.05	33.60	31.10	27.65	25.44	66.13	34.83
Motion 4	160.11	154.65	123.36	106.56	94.67	86.46	83.47	75.38	68.22	62.70	56.43	41.93	34.65	30.74	27.85	23.78	21.01	73.64	43.63
Motion 5	107.97	102.16	89.03	79.54	71.39	65.21	63.57	61.42	58.65	55.62	51.68	41.80	36.31	32.16	30.46	27.96	26.23	58.89	25.31

Table F. 2: Female Compressive Force Percent Body Weight (%BW)

Compressive Forces Across Thoracolumbar Spine for All Sternum-Loaded Conditions. This table displays compressive joint reaction forces normalized to body weight (%BW) at each vertebral level (L5–T1) for the female musculoskeletal model across all simulated vest weight conditions applied to the sternum (no weight (baseline), 2.3 kg, 4.5 kg, 6.8 kg (5 lbs., 10 lbs., and 15 lbs.)). Results are shown for each of the five motion postures (Motion 1–5), including individual vertebral values, per-motion averages, and a global average across all levels.

Female Compression Per trial %BW																			
TrialID	**L5-S1**	**L4-L5**	**L3-L4**	**L2-L3**	**L1-L2**	**T12-L1**	**T11-T12**	**T10-T11**	**T9-T10**	**T8-T9**	**T7-T8**	**T6-T7**	**T5-T6**	**T4-T5**	**T3-T4**	**T2-T3**	**T1-T2**	**Average**	**STDEV**
No Weight																			
Motion 1	83.81	78.23	71.28	64.64	59.41	54.27	49.14	45.52	41.73	37.11	33.22	31.84	29.65	27.83	25.64	23.48	22.90	45.87	19.73
Motion 2	177.02	170.24	149.60	135.34	129.38	121.71	106.72	94.47	79.05	67.94	46.36	45.48	26.13	15.17	10.63	7.47	5.80	81.68	58.99
Motion 3	98.87	93.22	77.63	70.10	64.95	59.36	51.12	44.40	38.51	34.29	27.95	27.40	23.87	21.01	18.36	16.10	15.49	46.04	27.09
Motion 4	114.25	108.50	87.32	78.30	72.85	66.75	56.03	47.08	39.50	34.54	25.30	25.26	19.68	16.09	13.67	11.34	10.59	48.65	34.07
Motion 5	88.65	83.00	74.63	67.27	62.10	56.88	50.87	46.44	41.76	37.84	31.63	31.10	26.75	23.54	21.17	18.98	18.32	45.94	22.86
5lb Sternum																			
Motion 1	87.62	82.00	74.92	68.09	62.74	57.53	52.36	48.71	44.81	40.28	35.94	34.68	31.93	29.91	27.60	25.37	24.73	48.78	20.34
Motion 2	182.70	175.86	154.85	140.32	134.28	126.52	111.27	98.80	83.12	71.74	49.57	48.76	28.88	17.60	12.91	9.61	7.85	85.57	60.23
Motion 3	106.35	100.66	83.59	75.67	70.43	64.73	55.88	48.61	42.24	37.79	30.58	30.19	26.07	22.76	19.88	17.43	16.69	49.97	29.12
Motion 4	122.48	116.68	94.00	84.53	78.99	72.75	61.36	51.74	43.62	38.32	28.18	28.27	22.13	18.17	15.50	12.94	12.00	53.04	36.30
Motion 5	93.11	87.42	78.88	71.35	66.12	60.84	54.69	50.15	45.28	41.28	34.58	34.24	29.43	25.94	23.43	21.13	20.39	49.31	23.64
10lb Sternum																			
Motion 1	90.15	84.59	77.52	70.63	65.24	60.05	54.94	51.34	47.41	43.11	38.31	37.31	34.16	31.83	29.41	27.09	26.38	51.15	20.57
Motion 2	188.37	181.47	160.11	145.30	139.20	131.34	115.81	103.14	87.20	75.55	52.78	52.04	31.63	20.05	15.20	11.76	9.90	89.46	61.47
Motion 3	114.18	108.43	89.94	81.61	76.29	70.46	60.95	53.04	46.15	41.43	33.32	33.09	28.39	24.72	21.60	18.93	18.04	54.15	31.25
Motion 4	130.83	124.97	100.74	90.83	85.19	78.80	66.72	56.45	47.78	42.11	31.04	31.29	24.56	20.22	17.31	14.51	13.40	57.46	38.58
Motion 5	97.79	92.08	83.33	75.59	70.30	64.97	58.65	53.96	48.90	44.82	37.48	37.32	32.09	28.34	25.67	23.25	22.44	52.76	24.52
15lb Sternum																			
Motion 1	93.94	88.36	81.19	74.14	68.67	63.44	58.28	54.62	50.51	46.35	41.04	40.23	36.59	33.95	31.42	29.01	28.24	54.12	21.17
Motion 2	194.05	187.09	165.37	150.29	144.12	136.17	120.37	107.48	91.29	79.36	55.98	55.34	34.39	22.50	17.49	13.92	11.96	93.36	62.71
Motion 3	122.16	116.36	96.40	87.64	82.22	76.25	66.12	57.58	50.15	45.12	36.12	36.02	30.73	26.74	23.38	20.47	19.39	58.40	33.42
Motion 4	139.25	133.33	107.56	97.21	91.48	84.95	72.15	61.23	52.00	45.94	33.95	34.34	27.03	22.31	19.15	16.11	14.82	61.93	40.89
Motion 5	102.65	96.91	87.93	79.97	74.62	69.23	62.73	57.88	52.61	48.40	40.51	40.44	34.78	30.75	27.97	25.44	24.54	56.32	25.45