Abstract

Heavy as well as misused backpacks can cause posterior trunk muscle injuries in both students and adults. In 2007 alone, there were over 23,000 backpack related injuries.\(^1\) Students who carry backpacks daily and adults who hike or serve in the military with heavy loads are at greater risk for pain and injury than those who do not. The physical risk was investigated and studied using the industry-standard biomechanical simulation software from AnyBody Technology\(^{TM}\). This software allows the user to observe the forces on individual muscles and joints through inverse dynamics. Forces of varying percentages of body weights were applied to the human body model and the effects were observed. Statistical analyses, such as the t-test, were utilized to determine if there was a significant difference between muscle forces of varied AnyBody\(^{TM}\) models wearing different bags. The data supports that bag stress is a prevalent issue, increased weight results in increased stress, and two-strap bags cause less muscle stress than one-strap bags. Several conducted analyses present readable data to educate students and adults who use backpacks in order to prevent detrimental damage to the back.

1. Introduction

The health and general well-being of the musculoskeletal system is affected by the external forces a body receives from daily activities. Although some of these forces are beneficial, others prove to be detrimental to people of all types. For example, heavy or improperly worn backpacks can produce harmful forces that cause back pain, headaches, neck strain, and numbness in the arms. Six out of every ten students ages 9 to 20 experience constant lumbar pain from backpacks.\(^2\) In 2001, the improper use of backpacks resulted in over seven thousand emergency room visits and countless complaints of muscle spasms and neck and shoulder pain.\(^3\) However, these injurious effects are not solely due to the weight of the backpack, but also the misuse of the bag.

One major reason for these harmful effects is that a backpack is often chosen for its aesthetics as opposed to functionality. A visually appealing backpack often does not have proper padding to distribute weight across the back or wide straps to protect the scapula and neck muscles from excessive strain.\(^4\) Similar to aesthetics, convenience is often the cause of pain and discomfort, for a backpack is often made heavy due to insufficient locker space, distance between classes, and supplies for hiking.\(^5\) Additionally, it has been observed that backpacks are commonly overloaded. As a
result, they are often too heavy for the specific bodies carrying them. Due to the ubiquity of backpacks for both young students and full grown adults, the targeted audience of the populations is the ages of 12 to 50.

Another major reason that causes backpacks to be harmful is that they are commonly worn using only one strap. Habitually wearing a backpack on only one side of the body can cause intense pain, strain, and a leaning in the upper body. The overcompensation of the spinal and back muscles causes fatigue and stress that can lead to further injury. If left untreated, these injuries can significantly alter the posture and gait of an adolescent. Backpacks that are worn with both straps help to distribute the weight of the backpack across the width of the trunk, as opposed to only one side supporting the pack when worn with one strap.

Aiding the visualization and verification of the effects of heavy bags on the human body, the AnyBody Technology™ program is utilized; this program is the leading musculoskeletal software that analyzes models by simulating conventional activities. This software provides models of the human musculoskeletal system, and provides the user with the ability to apply external forces to the body.

AnyBody Technology™ will be used to measure the muscle forces of a standing model without a load, with a two-strap bag, and with a one-strap bag in order to study the debilitating effects of an excessive load on an individual. It is assumed that the repository standing model is accurate and that the calculations and outputs are both precise and consistent with the repository model’s inverse dynamics.

2. Introduction

2.1 Biomechanics

Biomechanics applies the study of engineering to biological systems by utilizing Newtonian kinematics to estimate the mechanics of the human body. It also includes aspects of mechanical engineering such as dynamics and mechanical/structural analyses. Since the human body is far more complex and intricate than many other organisms and machines, advanced numerical methods are necessary for biomechanical study. The process for conducting a biomechanical study includes a cycle of hypotheses and confirmations through modeling, measurements of the human body, and in this case, computer simulation.

2.2 Trapezius Muscle

The trapezius muscle in the shoulder is commonly pinched and injured due to the straps of a backpack, especially with heavy loads. The muscle is large and extends from the neck down to the middle of the back, and stretches across the shoulders. The trapezius is largely superficial, meaning it is close to the skin, and as a result is a common source of pain in the shoulders, neck, and upper back areas. It is used to move the scapulae and support the arm. Straining, constricting, and pulling the trapezius muscle can cause pain as well as discomfort and inflammation.

![Figure 1. Trapezius Muscle](image)
2.3 Rhomboid Muscle

The rhomboid muscle, shaped like a triangle, is very thin skeletal muscle. This muscle is connected to bone and is used for joint movement. The rhomboid connects the spine to the inner edges of the shoulder blades and helps retain good posture. Pain in the rhomboid muscle is caused by excessive use, which can be caused by carrying heavy objects on the upper back, especially while making a muscle-intensive movement such as twisting or reaching.

![Figure 2. Rhomboid Muscle](image)

2.4 Serratus Anterior Muscle

The serratus anterior muscle is on the superolateral surfaces of the upper 8th and 9th ribs at the side of chest. This muscle stabilizes the vertebral border of the scapula, which is the bone that connects the humerus with the clavicle. It abducts and rotates the scapula, and pulls it upwards and forwards. Extending up into the shoulder, this muscle can potentially cause a significant amount of pain when utilized improperly, which begins in the arm and travels towards the extremities. Some difficulty with breathing when this muscle is strained or pulled is common.

![Figure 3. Serratus Anterior Muscle](image)

2.5 Deltoid Muscle

The deltoid muscle is triangular and forms the rounded contour of the shoulder. It is generally known as the common shoulder muscle. The long end of the triangle is attached to the scapula and the collarbone; the opposite vertex is connected to the humerus. The deltoid raises and twists the arm. Pain in the deltoid is common when the shoulder blade is pushed or held in an unnatural position, which can occur when a heavy weight is applied to the back.

![Figure 4. Deltoid Muscle](image)

2.6 AnyBody Technology Program™

The AnyBody Modeling System™ is a program that recreates the human body’s interaction with external forces. It includes over one thousand muscle elements, including muscle and joint forces, that a user can use to customize his/her own model to
simulate the biomechanical aspects of the human body. The user is able to study the movement of the muscles and bones that are used in everyday activities, such as walking, riding a bicycle, or carrying a bag.\(^7\)

### 2.7 Inverse Dynamics

One important feature of biomechanics is the usage of inverse dynamics. This involves measuring the ground reaction force, which is exerted by the ground as it comes into contact with the body. With this data, a simulation can be run to compute forces and net moments in the anatomical joints. In the AnyBody Technology Software\textsuperscript{TM}, inverse dynamics simulate muscle and joint forces in the entire body while undergoing complex movements, taking dynamic inertial forces into account without necessarily requiring measured forces in the interface between the body and the environment.\(^6\) Inverse dynamics have the advantage of allowing analysis of very complicated musculoskeletal systems comprising hundreds of muscles on desktop or laptop computers in a few seconds.

#### 1. Methodology

![Figure 5](image)

**3.1 Parameters**

The design of the experiment comprises of a control group with an external load of 0 pounds and experimental loads of 10, 20, and 50 pounds. The experimental weights were determined based on the target audience of ages 12 to 50. The first experimental data is set to 10 pounds, which simulates the weight of about two to three textbooks and notebooks.\(^7\) The following weight is 20 pounds, which mimics the average backpack composed of six books, supplies, and a laptop. The final experimental load of 50 pounds simulates a hiker’s backpack weight, which is composed of heavy clothes, sleeping bag, and other essentials for the task.

From the AnyBody Managed Model Repository\textsuperscript{TM}, a standing model was accessed. This model is based on an average human body with a mass of 75 kg.\(^8\) The body mass remained constant as the procedure later differentiated into varying loads and number of straps. After this consistency was established, forces were added to the shoulder area on both sides to replicate the forces associated with wearing a backpack with two straps. Forces were then added to only the right shoulder, to replicate the forces associated with wearing a backpack with one strap.

#### 3.2 Applying External Loads to the Shoulders

The code allows for a set of three dimensional vectors that apply external loads to various predefined points on the model:
In this code, the model has no force applied to the shoulders (Figure 6). In order to add force to the shoulders, coordinates were added in the x and y directions, and the program later ran the model. For example, in order to apply 10 pounds as the resultant force to each shoulder, the x and y forces were decomposed through vector analysis (Figure 7).

The triangle is constructed assuming that the forces of a backpack are directed at a $15^\circ$ angle to the shoulder. Known information is the load of the backpack, which is the experimental data. The load represents the resultant or the overall weight of the backpack. With the angle and the resultant force known, the x and y values were easily obtained in order to represent the applied x and y forces on the shoulders.

After this calculation, the code was modified (Figure 8).

All numerical values are represented in Newtons (N); the changes are shown in red.

### 3.3 Graphing the Data

In order to display results, the AnyBody Modeling System™ has a “Chart View,” which provides two-dimensional and three-dimensional surface plots. After loading the model, applying the external forces to the shoulders, and running the RunApplication Operation, the Chart View can be accessed through the “Chart FX
(New)” option. This chart has a large gallery of different graph types to choose from and has useful features for interfacing with other Windows applications, such as the option to copy data on many different formats. This view is restricted to two-dimensional graphs.

The AnyBody Modeling System™ contains output data. The tree in the Chart View (Figure 9) has been filtered such that only the output data is seen.

![Figure 9](image)

Charts and figures representing the strain and force applied to muscles can be found under “Abscissa” and “MaxMuscleActivity.” Charts comparing each muscle relative to each other were made in this manner. Figure 10 shows all the major shoulder back muscles and the forces applied to them when a 10 pound weight is applied.

![Figure 10](chart)

This represents the strain of right trapezius muscle after a 50lb force is applied to the shoulders.

2. Results

Virtually all the conducted tests verified the hypothesis: heavy loads can significantly increase the stress applied to individual muscles, causing extensive harm in the long run.

Figures 11 through 13 show the amount of force being applied to each muscle. Most muscles are not singular entities; instead, they have several components that serve the same function, but are slightly distinctive from each other. As such, the AnyBody™ modeling software chose to simulate the amount of force applied to each muscle group equally on both sides.
The stress on the trapezius muscle increased as the load applied grew (Figure 11). Although the force initially trended at roughly 5N (Newtons), some sub-muscles approached 20N as we applied fifty pounds of force. This means that the muscle experienced nearly four times the force than it would while at rest.

Similarly, there is an increase in stress on the rhomboid muscle (Figure 12). However, the results were even more apparent. At rest, the muscle experiences less than 1N, the muscle experienced 8.33N of force, an increase of 733%

Although according to literature, the trapezius and rhomboid are considered the most affected from carrying heavy loads, other muscles also experience related increases in stress. Figures 13 and 14, which show stress on the serratus anterior and deltoid muscles, exemplify a substantial increase, sometimes more than tripling in force. For example, the serratus anterior
muscle number 6 contracted a force that had not existed previously.

4.1 Single Strap

Tests were conducted to verify a substantial increase of force on the shoulder and back muscles when a backpack is worn using one strap versus two straps. However, when all of the force was shifted to only the right side, the muscles experienced a substantially increased amount of force—a maximum of 26 N (Figure 16).

4.2 Statistical Analysis

Part 1: Identification of Strained Muscles

The AnyBody Technology Program™ outputted the force values of several muscles of the trunk region. While the majority of the muscles received low force values, certain muscles received force values significantly greater. In order to identify the muscles that received considerable amounts of strain, scatter plots with y-error bars of one standard deviation were used. Force values that were in the higher 15% of the overall data set were identified and used in further analyses.

A force of 80 N was applied evenly to both shoulders and plotted (Figure 15). By doing so, the maximum force experienced by several muscles was nearly 12 N.

However, when all of the force was shifted to only the right side, the muscles experienced a substantially increased amount of force—a maximum of 26 N (Figure 16).

Figure 15. A force of 80 N was applied evenly to both shoulders and plotted (Figure 15). By doing so, the maximum force experienced by several muscles was nearly 12 N.

Figure 17. Scatter Plot with Y-error Bars of One Standard Deviation to Identify Strained Muscles
Thirty-two muscles on both the left and right sides of the human posterior trunk were identified as strained (Figure 17). The strained muscles included the deltoideus scapular, latissimus dorsi, deltoideus clavicular, serratus anterior, trapezius scapular, and trapezius clavicular on the left and right sides.

**Part 2: Two-strap Bag Analysis**

**Verification of Two-strap Bag Stress**

To verify the adverse effects of heavy bags, the AnyBody™ model without a bag was compared to the AnyBody™ model with a 20 lb two-strap bag. According to studies, bags that are 15% of one's body weight are prevalent and may have harmful effects. Since the 20lb two-strap bag is approximately 13% of the AnyBody™ model's body weight, the model with this bag is compared to the control.

Summative data tables are displayed to share the mean, standard deviation, variance, and number of data points. Bar graphs compare the paired data sets adjacent to each other. T-tests are utilized to analyze data further.

*Alternate Hypothesis: There is a significant difference between the muscle forces of the AnyBody™ model without a bag and of the AnyBody™ model with a 20 lb two-strap bag.*

*Null Hypothesis: There is no significant difference between the muscle forces of the AnyBody™ model without a bag and of the AnyBody™ model with a 20 lb two-strap bag.*

The data is quantitative, 2 tailed, paired, and compared next to one another in Figure 20. Figure 18 demonstrates that there are no outliers, so a t-test is used.

This study deals with the safety of humans and since alpha of 0.01 is common for medical studies, an alpha of 0.01 (lower than the conventional 0.05 alpha) was utilized. The t-test yields a p-value of 8.307E-11, which is less than the alpha. Thus, the data reject the null hypothesis and support the alternate hypothesis: there is significant difference between the muscle forces of the AnyBody model without a bag.
and an AnyBody model with a 20 lb two-strap bag.

Comparing Different Two-strap Bag Weights

Varied two-strap bag weights were applied onto the AnyBody™ Technology standing model. The data is compared and analyzed. Summative data tables are displayed to share the mean, standard deviation, variance, and number of data points. Bar graphs compare the independent means. T-tests are utilized to analyze the data further.

| Summative Data Table for Muscle Forces of AnyBody Models with Two-strap Bags |
|--------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 10 lb Two-strap Bag | 20 lb Two-strap Bag | 30 lb Two-strap Bag |
| mean | 11.583 | 14.342 | 22.575 |
| StDev | 2.875 | 4.139 | 8.410 |
| Var | 8.267 | 17.129 | 70.734 |
| n | 32 | 32 | 32 |

Figure 22. Summative Data Table

![Average Muscle Forces of AnyBody Models with Two-strap Bags](image)

Figure 23. Average Muscle Forces

10 lb vs. 20 lb

Alternate Hypothesis: There is a significant difference between the muscle forces of the AnyBody™ model with a 10 lb two-strap bag and of the AnyBody™ model with a 20 lb two-strap bag.

Null Hypothesis: There is no significant difference between the muscle forces of the AnyBody™ model with a 10 lb two-strap bag and of the AnyBody™ model with a 20 lb two-strap bag.

There are no outliers (Figure 21). Since the data is quantitative, two-tailed, and independent (separate weight levels), a t-test is used.

The t-test yields a p-value of 0.002931, which is less than the alpha 0.01. Thus, the null hypothesis is rejected. Data supports the alternative hypothesis that there is a significant difference between the muscle forces of the AnyBody™ model with a 10 lb two-strap bag and of the AnyBody™ model with a 20 lb two-strap bag.
10 lb vs. 50 lb
Alternate Hypothesis: There is a significant difference between the muscle forces of the AnyBody™ model with a 10 lb two-strap bag and of the AnyBody™ model with a 50 lb two-strap bag.

Null Hypothesis: There is no significant difference between the muscle forces of the AnyBody™ model with a 10 lb two-strap bag and of the AnyBody™ model with a 50 lb two-strap bag.

There are no outliers (Figure 21). Since the data is quantitative, two-tailed, and independent (separate weight levels), a t-test is used.

The t-test yields a p-value of 2.184E-9, which is less than the alpha 0.01. Thus, the null hypothesis is rejected. Data support the alternative hypothesis. The data supports that there is significant difference between the muscle forces of the AnyBody™ model with a 10 lb two-strap bag and of the AnyBody™ model with a 50 lb two-strap bag.

Part 3: One-strap Bag Analysis
Verification of One-strap Bag Stress
The AnyBody™ model without a one-strap bag and the AnyBody™ model with a 20 lb one-strap bag was compared to verify adverse effects. Studies indicate that bags that weigh 15% of one’s body weight are prevalent and may have harmful effects. Since the 20 lb one-strap bag is approximately 13% of the AnyBody™ Model’s body weight, the model wearing this bag is compared to the control.

Summative data tables are displayed to share the mean, standard deviation, variance, and number of data points. Bar graphs compare the paired data sets adjacent to each other. T-tests are utilized to analyze the data further.

20 lb vs. 50 lb
Alternate Hypothesis: There is a significant difference between the muscle forces of the AnyBody™ model with a 20 lb two-strap bag and of the AnyBody™ model with a 50 lb two-strap bag.

Null Hypothesis: There is no significant difference between the muscle forces of the AnyBody™ model with a 20 lb two-strap bag and of the AnyBody™ model with a 50 lb two-strap bag.

There are no outliers (Figure 21). Since the data is quantitative, 2 tailed, and independent (separate weight levels), a t-test is used.

The t-test yields a p-value of 5.605E-6, which is less than the alpha 0.01. Thus, the null hypothesis is rejected. Data support the alternative hypothesis. The data supports that there is significant difference between the muscle forces of the AnyBody™ model with a 20 lb two-strap bag and of the AnyBody™ model with a 50 lb two-strap bag.

The t-tests above demonstrated that additional weight made a significant difference on muscle stress.
Since the data is quantitative, 2 tailed, paired, and has no outliers, a t-test is used (Figure 24).

The t-test yields a p-value of 1.160E-12, which is less than the alpha of 0.01. Reject the null hypothesis. Data support the alternative hypothesis. The data supports that there is significant difference between the muscle forces of the AnyBody™ model without a bag and an AnyBody™ model with a 20 lb one-strap bag.

Comparing Different One-strap Bag Weights

One-strap bag weights were applied onto the standing model and data was analyzed. Summative data tables are displayed to share the mean, standard deviation, variance, and number of data points. Bar graphs compare the independent means. T-tests are utilized to analyze the data further.
### Summative Data Table for Muscle Forces of AnyBody Models with One-strap Bags

<table>
<thead>
<tr>
<th></th>
<th>30 lb One-strap</th>
<th>20 lb One-strap</th>
<th>50 lb One-strap</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>mean</strong></td>
<td>14.104</td>
<td>19.616</td>
<td>35.806</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>3.742</td>
<td>6.156</td>
<td>13.250</td>
</tr>
<tr>
<td><strong>Var</strong></td>
<td>14.000</td>
<td>37.900</td>
<td>175.574</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

Figure 28. Summative Data Table

### Average Muscle Forces of AnyBody Models with One-strap Bag

![Average Muscle Forces](image)

Figure 29. Average Muscle Forces

#### 10 lb vs. 20 lb

**Alternate Hypothesis:** There is a significant difference between the muscle forces of the AnyBody™ model with a 10 lb one-strap bag and of the AnyBody™ model with a 20 lb one-strap bag.

**Null Hypothesis:** There is no significant difference between the muscle forces of the AnyBody™ model with a 10 lb one-strap bag and of the AnyBody™ model with a 20 lb one-strap bag.

There are no outliers (Figure 27). Since the data is quantitative, two-tailed, and independent (separate weight levels), a t-test is used.

The t-test yields a p-value of 5.592E-5, which is less than the alpha 0.01. Thus, the data reject the null hypothesis and support the alternate hypothesis: there is significant difference between the muscle forces of the AnyBody model with a 10lb one-strap bag and of the AnyBody model with a 20lb one-strap bag.

#### 10 lb vs. 50 lb

**Alternate Hypothesis:** There is a significant difference between the muscle forces of the AnyBody™ model with a 10 lb one-strap bag and of the AnyBody™ model with a 50 lb one-strap bag.

**Null Hypothesis:** There is no significant difference between the muscle forces of the AnyBody™ model with a 10 lb one-strap bag and of the AnyBody™ model with a 50 lb one-strap bag.

There are no outliers (Figure 27). Since the data is quantitative, two-tailed, and independent (separate weight levels), a t-test is used.

The t-test yields a p-value of 1.035E-12, which is less than the alpha 0.01. Thus, the data reject the null hypothesis and support the alternate hypothesis; there is significant difference between the muscle forces of the AnyBody™ model with a 10 lb one-strap bag and of the AnyBody™ model with a 50 lb one-strap bag.

#### 20 lb vs. 50 lb

**Alternate Hypothesis:** There is a significant difference between the muscle forces of the AnyBody™ model with a 20 lb one-strap bag and of the AnyBody™ model with a 50 lb one-strap bag.

**Null Hypothesis:** There is no significant difference between the muscle forces of the AnyBody™ model with a 20 lb one-strap bag and of the AnyBody™ model with a 50 lb one-strap bag.

There are no outliers (Figure 27). Since the data is quantitative, 2 tailed, and independent (separate weight levels), a t-test is used.

The t-test yields a p-value of 3.894E-8, which is less than the alpha 0.01. Thus, the data reject the null hypothesis and support the alternate hypothesis.
support the alternate hypothesis: there is significant difference between the muscle forces of the AnyBody model with a 20lb one-strap bag and of the AnyBody model with a 50lb one-strap bag.

Overall, the t-tests above demonstrated that there was a significant difference in muscle force when additional weight was applied.

**Part 4: Comparison of Two-strap to One-strap**

Both the two-strap bag and one-strap bag caused adverse effects to the control model and increased forces with added weight. In this analysis, the performance of the two bags will be compared via a t-test. The 20 lb two-strap bag and 20 lb one-strap bag are compared since the 20 lb represents about 13% of the body weight. Fifteen percent of body weight in bags was a common value found in relevant studies.

Summative data tables are displayed to share the mean, standard deviation, variance, and number of data points. Bar graphs compare the paired data sets adjacent to each other. T-tests are utilized to analyze the data further.

*Alternate Hypothesis:* There is a significant difference between the muscle forces of the AnyBody™ model with a 20 lb two-strap bag and of the AnyBody™ model with a 20 lb one-strap bag.

*Null Hypothesis:* There is no significant difference between the muscle forces of the AnyBody™ model with a 20 lb two-strap bag and of the AnyBody™ model with a 20 lb one-strap bag.

There are no outliers. Since the data is quantitative, 2 tailed, paired, and has no outliers, a t-test is used (Figure 30).

The t-test yields a p-value of 1.146E-10, which is less than the alpha of 0.01. Thus, the data reject the null hypothesis and support the alternate hypothesis: there is significant difference between the muscle forces of the AnyBody model with a 20 lb two-strap bag and of the AnyBody model with a 20 lb one-strap bag.

This t-test demonstrates that the two-strap bag is significantly more effective at carrying about 15% of one’s body weight than a one-strap bag. The one-strap bag
exacerbates the repercussions of heavy weight and hurts surrounding muscles.

3. Discussion

When loads are applied to different areas of the human body, muscles naturally adjust to compensate. Unfortunately, excessive amounts of force often lead to detrimental consequences to the body. Data collected from analyzing the trapezius, rhomboid, serratus anterior, and deltoids muscle groups indicate a substantial increase in the force applied to each one. In many cases, the amount of stress increased by over 200%; in some extreme cases it increased by 400% or more.

The muscle parts collectively produce a much more noticeable increase in force; the serratus anterior muscles experience a total of 175.62 N after fifty pounds of force is applied. Such a substantial number cannot be neglected, especially if a load of fifty pounds or more is often sustained for long durations, such as school days, hiking trips, and other activities.

5.1 Challenges

Many challenges were encountered with the AnyBody Technology™ program. Since this program was created mainly for the use of the scientists who created it, it was difficult to manipulate the model for users unfamiliar with programming. Files were difficult to locate, and the special codes required for us to learn through numerous tutorials. As a result, altering the applied force values and collecting the data took much longer than previously expected. In addition to the program, the files themselves did not possess the backpack model that was necessary. Thankfully, we were able to overcome this challenge by importing a CAD model from Autodesk Inventor 2011 into the AnyBody™ program.

5.2 Ideas for Future Study

For the future, it would be interesting to observe the effects of backpack loads on varying body mass indexes (BMIs). The different trials would be composed of varying body masses, including underweight, average, and obese weights. Studies show that obesity and heavy backpacks often create a vicious cycle of muscle strain, and therefore less daily exercise. Students would also be included as future studies as they commonly wear backpacks daily. The target experimental factors would include children and adolescents to document the growth and development of muscles when backpacks are in daily use.

4. Conclusion

After conducting several statistical analyses, a few conclusions were established. In order to identify strained muscles, a scatter plot with one standard deviation y-error bars were made and located the higher 15% of values. The deltoideus scapular, latissimus dorsi, deltoideus clavicular, serratus anterior, trapezius scapular, and trapezius clavicular on the left and right sides were located as strained muscles. As a culminating analysis, the backpack data and shoulder data were compared with a t-test. A p-value of 1.146E-10 was produced and is less than alpha 0.01. As a result, the data supports that there is significant difference between the muscle forces and strain of the AnyBody™ model.
with a 20lb backpack and of the AnyBody™
model with a 20lb shoulder bag.

The results produce a clear and
comprehensive understanding of the effects
of bag strain. Through this study, it is
evident that current backpack and shoulder
bag models cause notable strain, heavier
bags cause a significant difference in muscle
strain, and backpacks perform better than
shoulder bags.

Acknowledgements

We greatly appreciate the
supervision of Dr. Noshir A. Langrana, who
shared his insight and helped us gain a better
understanding of biomechanics and the
AnyBody™ program. We are also thankful
to project mentors Jacob Jaslove and Maya
Saltzman for their assistance and dedication
throughout the duration of our project. We
are grateful to Rutgers University, the GSET
Program, its Director Dean Ilene Rosen, Ed.
D., Assistant Director Jean Patrick Antoine,
the Governor’s School Board of Overseers,
and the Residential Teaching Assistants,
especially Justin Yu, who guided us every
step of the way. Finally, we would like to
thank the sponsors of GSET: Rutgers
University, the State of New Jersey, Morgan
Stanley, NJ Resources, South Jersey
Industries, PSE&G, and the GSET alumni
community.
References


[22] "Lumbar Strain (Low Back Strain)." <http://medicalcenter.osu.edu/patientcare/healthcare_services/mens_health/sports_injuries/LumbarStrainWeightLifters4612/Pages/index.aspx>


countries-world-revealed-Extraordinary-graphic-charts-average-body-mass-index-men-women-country-surprising-results.html>