Effect of Weightlifting Belts on Erector Spinae and Obliquis Externus Abdominis During the Squat Exercise

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Abstract

Injury prevention is the first thing on any athlete or coach’s mind as they train. Many pow-erlifting techniques, like the squat, are used in athletic programs and fitness centers, and need to be executed precisely and correctly to avoid potential permanent damage in the lower back. A common way to support the lower spine during strenuous lifting, specifically the squat exercise, is to use a tight weight belt around the abdomen to increase spinal stiffness. This study into the effectiveness of weight belts examined their influence on muscle activity in the erector spinae and obliqus externus abdominis muscles during the squat exercise. Increased stabilizer muscle activity correlates with incorrect form and increased injury risk. 6 test subjects of varying weight, gender, and lifting ability were monitored with EMG sensors while performing the squat exercise with different loads. It was empirically determined with 95% confidence that erector spinae muscle activity decreases by up to 42%, and with 90% confidence that obliqus externus abdominis activity decreases by up to 25% with the addition of a weight belt when performing the squat exercise.

1. Introduction

Weightlifting has developed from a niche ultra-competitive sport to a common fitness activity in the past several decades. But proper lifting technique has not necessarily followed this growth in adoption and popularity. Injury prevention is a top priority in any physical activity, especially competitive sports. The risk of injury due to improper weightlifting technique is significant, specifically with the squat exercise. If performed incorrectly, large stresses can develop in the spine, leading to potential vertebrae misalignment, lower back fatigue, or other serious chronic problems [5]. The risk of serious injury is greater for inexperienced lifters who have not mastered the proper technique.

One way that professional and experienced lifters protect their backs from damage is by wearing a weight belt (Figure 1) when attempting heavy lifts to help support the spinal column. These belts are typically only worn when the weight being squatted is heavy enough that any mistake could have catastrophic results (Figure 2).

![Figure 1: The synthetic material weight belt that was used in this investigation. The large width of the belt helps to maximize stabilization while minimizing discomfort.](image-url)
While it is widely accepted that weight belts help lifters support their backs, lift safely, and push themselves to lift heavier, the underlying mechanism behind the belt has not been confirmed. Previous similar work in this area has come to three, sometimes conflicting conclusions: the weight belt supports the spine by increasing intra-abdominal pressure [3,5,6]; the weight belt does not affect muscle activity in the lower back [6]; and the weight belt does affect muscle activity in the lower back [1,3]. Increased stabilizer muscle activity indicates off-axis spinal loading that must be supported by the lower back and abdominal muscles. Off axis loading can lead to slipped disks, fractured vertebrae, and other spinal injuries. This investigation was focused on determining whether wearing a weight belt at lighter weights affects lower back muscle activity. If it is determined empirically that weight belts decrease lower back muscle activity, then it can be inferred that wearing a belt during the squat exercise despite the level of lifting experience or loading of the bar decreases spinal loading and thus the chances of unwanted injury.

Instead of recruiting professional weightlifters and loading them with maximal weights [6], this investigation sampled a range of novice and experienced lifters with relatively light loading. This was done to not only randomize test subjects, but also to make the study more relevant to the general public: inexperienced weightlifters are at a much more elevated risk of injury than professional athletes. By not selecting the test subjects based on ability, data for both proper and improper lifting form could be collected and analyzed.

2. Background

2.1 Squat Biomechanics

The squat is a power lifting exercise primarily targeting the quadriceps, Gluteus Maximus, and Gluteus Medius muscles (Figure 3). Additionally, several auxiliary and stabilizing muscles are activated during the motion, specifically the Erector Spinae and Obliques Externus Abdominis (oblique) muscles (Figures 4 & 5). These muscles are theoretically supposed to only act as stabilizers, and with perfect form, are actually not used at all. The entire load of the weight
at the shoulders is transferred to the heels through the spine. In incorrect technique however, these stabilizing muscles are activated to support the load. This causes the spine to experience lateral loading and torque, potentially leading to injury. Even with correct form, the high forces experienced by the spine (sometimes exceeding 10,000N [6,7]) additional spinal support is desired to mitigate risk.

Figure 3: An illustration of the primary activated muscles during the squat exercise and proper lifting form. Note the straight lower back, open chest, and exaggerated abdominal extension. [10]

Weight belts are worn under the assumption that they help stabilize the spine. The belts are constructed of either tough leather or a thick synthetic fabric, and are designed to be worn extremely tightly around the abdomen. It has been shown that a tightly worn belt can increase the intra-abdominal pressure and effectively reduce the forces in the spinal column by bearing up to 50% of the load [6]. An increase in intra-abdominal pressure increases the effective stiffness of the lower spine, helping it bear load. Weight belts also have the potential to affect the activity of lower back muscles [3,6]. Whether muscle activity changes with the addition of a weight belt has been a subject of scholarly debate [5,6]. This investigation only focused on measuring the muscle activity of only the erector spinae and obliqus externus abdominis muscles to determine whether a weight belt affects muscle activity.

Figure 4: A schematic of the muscles in the human back. The Erector Spinae muscle is labeled Sacrospinalis in the figure, and extends from the lower left of the pelvis to the mid-back. [2]

Figure 5: A schematic of the muscles in the lateral abdominal region where the Obliqus Externus Abdominis is labeled Obliqus Lateralis. [2]
2.2 Muscle Dynamics

Increased stabilizer muscle activity indicates uneven spinal loading and can lead to injury. Muscle activity is measured by detecting the electrical pulses of the motor unit, composed of a motor neuron and a muscle fiber. Electrical impulses triggered by the neurotransmitter acetylcholine are sent through the axon terminal of the neuron to the muscle fiber, which responds by either contracting or relaxing [8]. Contraction in turn releases an electrical signal, and it is this larger electrographic signal that is measured with an EMG sensor. After amplification and rectification, this signal gives a quantitative measure of muscle activity, with higher voltages corresponding to increased motor unit firing frequency and thus increased activity [4].

3. Experimental Design

3.1 Method

In this investigation, 6 subjects of varying weightlifting experience (novice to experienced) each performed 3 repetitions of a 90-degree squat exercise with varying weight levels starting at no weight, progressing to 50% of body weight, and finishing with 75% body weight. EMG sensors were attached to the right lower back to measure erector spinae activity, and to the lower left lateral abdomen to measure oblique activity. Grounding electrodes were attached to the right and left elbows, respectively (See Figure 6). After an initial calibration run where the sensor baseline voltage was recorded by keeping the subject completely relaxed and motionless, 3 phases of lifting were performed: no weight, 50% body weight, and 75% bodyweight. These 3 phases were performed both with and without a weight belt. Subjects were instructed to perform 3 repetitions at a constant velocity in the span of 10 seconds. Each subject performed all trials in one testing session, and all electrodes remained attached for the duration of the experiment.

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Gender</th>
<th>Weight [lbs]</th>
<th>Lifting Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>165</td>
<td>Novice</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>140</td>
<td>Intermediate</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>175</td>
<td>Intermediate</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>180</td>
<td>Advanced</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>165</td>
<td>Advanced</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>125</td>
<td>Novice</td>
</tr>
</tbody>
</table>

Table 1: Subjects tested in this experiment
3.2 Apparatus

The primary analysis tool used was the Sparkfun EMGKIT Sensor attached to a Vernier Lab Pro (#46), which was connected to a computer. The signal from the EMG pad is amplified, rectified, and low pass filtered by onboard circuits, providing a clean and accurate voltage reading. For all trials, EMGKIT 1 was attached to the erector spinae, and EMGKIT2 was connected to the oblique. Sample rate was set to the maximum allowable, 500 samples/second for a duration of 10 seconds.

For each subject, 7 trials of data were collected and analyzed. Raw EMG voltage was first normalized, and then average voltages with uncertainties for each trial were calculated. Normalization involved averaging the 3 maximum voltage values from a subject’s “No Weight + No Belt” trial, then dividing every EMG signal trace by this mean value, producing uniformly scaled data sets that could be compared to others.

4. Results and Discussion

Histograms of each data trial for each subject, for each lifting phase (0, 50%, 75%) across all subjects, and a belt vs. no belt histogram for all trials and all subjects were generated to provide a qualitative portrait of the results. Note: oblique data for subjects 2 and 3 were excluded from analysis due to a sensor malfunction anomaly that corrupted the data. Several t-tests were ultimately performed to quantify the significance of the numerical findings. The results of the t-tests confirmed the qualitative observations of the histograms. Throughout analysis, uncertainty was carefully tracked, and error propagation calculations were performed at each intermediate step. Table 2 contains a summary of all relevant uncertainty calculation results.
Figure 8 shows a single trial of pure raw EMG data that has not yet been normalized. The traces appear noisy, but upon closer inspection, peaks of activity can be seen. These peaks occur at the bottom of the squat where the lifter must change the direction of acceleration to go from easing the weight down to lifting it up.

The three maximum peaks corresponding to the 3 repetitions occur at about 4.5, 6.5, and 8.9 seconds. The voltage values at the three peaks were extracted and averaged following normalization. The uncertainty in the measurement was also calculated using the statistical method with a t-factor. This simple analysis gave an average maximum voltage value for each trial that could later be collected into a more comprehensive data set of multiple trials across multiple subjects. Figure 9 shows a comparison of raw data for a single repetition for a single subject in the erector spinae muscle. This plot gives an early indication into what to expect from analysis: in this particular set of data taken from subject 1 differences between traces with a belt and without are visible. It is however limited in its accuracy and only examines one muscle during a single repetition in one trial with one subject. This plot serves only as a visual cue for later analysis.
Following normalization of each trial by dividing all EMG data by the mean of the 3 maximums during the “No Weight + No Belt” trial, histograms comparing the fraction of mean maximum voltage (referred to as ‘Normalized’) to the number of samples were generated to observe any evidence of changes in muscle activity.

Figures 10 and 11 are examples of histograms generated for a single trial for a single subject. They represent erector spinae and oblique muscle activity respectively. In these graphs, a shift to the left indicates that a larger fraction of voltage samples are at a lower fraction of the mean, which in turn is interpreted as a decrease in activity. Figures 10 and 11 illustrate an intriguing trend towards a decrease in muscle activity with the addition of a weight belt.

Figure 9: A superposition of a set of trials for subject 1. Peaks of Erector Spinae activity were extracted from separate trials, translated through time, and overlaid. This data has not yet been normalized.
This analysis should be extended to include multiple trials. To accomplish this, normalized EMG voltage data from each trial was combined and analyzed together. Meanwhile as the data is manipulated, averaged, and normalized, uncertainty calculations are performed and carried through the analysis. Figure 12 displays a sample histogram for a single lifting phase across all subjects in the oblique muscle, while Figure 13 shows the same in the erector spinae muscle. As can be seen in this pair of histograms as well, there appears to be a trend of decreasing voltage magnitude when a subject is wearing a belt vs. not. As seen in Figure 12, not only is the distribution narrower for the trial with the belt, it also completely avoids any high voltages above about 1.1 times the mean, signifying that the belt is likely affecting muscle activity in both the lower back, and the lateral abdomen. Quantitative figures have not been assigned to the analysis yet, so only qualitative conclusions can be drawn.
One final pair of histograms was generated to encompass all trials and all subjects to ultimately compare all lifts with and without a belt. The normalized data was once again manipulated and care was taken to preserve values of uncertainty. Figures 14 and 15 respectively show the visual qualitative evidence that lifting with a belt decreases muscle activity in both the lower back (erector spinae) and the lateral abdomen (oblique externus abdominis).

**Figure 12:** A histogram of normalized EMG voltages across all subjects for a single trial in the oblique muscle showing an overall decrease in muscle activity with the belt.

**Figure 13:** A histogram of normalized EMG voltages across all subjects for a single trial in the erector spinae muscle showing an overall decrease in muscle activity with the belt.
Quantitative support for the qualitative observations is presented in Table 3. Table 3 contains results from multiple t-tests that were performed on the normalized data. The t-tests performed confirmed the histogram data for the most general case of all subjects and all trials, but failed to pass the 95% confidence level for one of the erector spinae tests, even though it was only 1.5% away.
Table 2: A collection of calculation parameters and their corresponding uncertainties. The first 4 entries were chosen as most critical to analysis since they are the final averages of all subjects and all trials. The remaining 4 were chosen at random to show that calculations were completed during every step.

<table>
<thead>
<tr>
<th>Average Quantity</th>
<th>Value [V]</th>
<th>Signal Uncertainty [V]</th>
<th>Propagated Uncertainty [V]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erector Spinae No Belt (All Subjects)</td>
<td>1.9334</td>
<td>±0.4935</td>
<td>±0.9857</td>
</tr>
<tr>
<td>Erector Spinae With Belt (All Subjects)</td>
<td>1.4154</td>
<td>±0.7452</td>
<td>±1.0015</td>
</tr>
<tr>
<td>Oblique No Belt (All Subjects)</td>
<td>3.5360</td>
<td>±2.7538</td>
<td>±3.2017</td>
</tr>
<tr>
<td>Oblique With Belt (All Subjects)</td>
<td>1.9995</td>
<td>±1.5864</td>
<td>±1.8958</td>
</tr>
<tr>
<td>Erector Spinae No Belt No Weight (All Subjects)</td>
<td>1.7045</td>
<td>±1.1545</td>
<td>±1.2072</td>
</tr>
<tr>
<td>Oblique With Belt 75% Body Weight (All Subjects)</td>
<td>1.6853</td>
<td>±1.0976</td>
<td>±1.1272</td>
</tr>
<tr>
<td>Oblique With Belt 50% Body Weight (Subject 5)</td>
<td>1.4465</td>
<td>±1.2160</td>
<td>±0.7062</td>
</tr>
<tr>
<td>Erector Spinae No Belt 75% Body Weight (Subject 1)</td>
<td>4.9809</td>
<td>±2.7378</td>
<td>±1.0023</td>
</tr>
</tbody>
</table>

Table 3: Presents all the outcomes of t-tests performed on the data. Only one passed the 95% confidence interval, although the second test was very close. Individual parameter tests were not as successful, which can either be attributed to a lack of correlation, improper measurement, or calculation error.

<table>
<thead>
<tr>
<th>Parameter 1</th>
<th>Parameter 2</th>
<th>Outcome</th>
<th>p = ?</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erector Spinae No Belt</td>
<td>Erector Spinae With Belt</td>
<td>Success!</td>
<td>0.0384</td>
<td>96.2%</td>
</tr>
<tr>
<td>Oblique No Belt</td>
<td>Oblique With Belt</td>
<td>Fail</td>
<td>0.0617</td>
<td>93.8%</td>
</tr>
<tr>
<td>Erector Spinae No Weight No Belt</td>
<td>Erector Spinae No Wight With Belt</td>
<td>Fail</td>
<td>0.1693</td>
<td>83.1%</td>
</tr>
<tr>
<td>Erector Spinae 50% Body Weight no Belt</td>
<td>Erector Spinae 50% Body Weight With Belt</td>
<td>Fail</td>
<td>0.2518</td>
<td>74.8%</td>
</tr>
<tr>
<td>Erector Spinae 75% Body Weight No Belt</td>
<td>Erector Spinae 75% Body Weight Belt</td>
<td>Fail</td>
<td>0.3282</td>
<td>67.2%</td>
</tr>
<tr>
<td>Oblique No Wight No Belt</td>
<td>Oblique No Wight With Belt</td>
<td>Fail</td>
<td>0.0919</td>
<td>90.8%</td>
</tr>
<tr>
<td>Oblique 50% Body Weight No Belt</td>
<td>Oblique 50% Body Weight With Belt</td>
<td>Fail</td>
<td>0.1342</td>
<td>86.6%</td>
</tr>
<tr>
<td>Oblique 75% Body Weight No Belt</td>
<td>Oblique 75% Body Weight With Belt</td>
<td>Fail</td>
<td>0.1515</td>
<td>84.9%</td>
</tr>
</tbody>
</table>

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Since one test passed the 95% confidence interval, we can then perform a calculation to see how much larger the voltage is lifting without a belt. This calculation requires re-running the t-test and changing values for the hypothesized mean difference until the desired confidence level (95%) is reached. The difference at that level is the difference between the two parameters with 95% confidence.

We can now say with 95% confidence that squatting with a weight belt will reduce erector spinae muscle activity by up to 1.01V, and with 90% confidence that squatting with a weight belt will reduce obliqus externus abdominis muscle activity by up to 1.55V.

With 95% confidence we conclude that wearing a weight belt while performing the squat exercise can reduce erector spinae muscle activity by up to 1.01V. This is a great quantitative result that agrees with previous qualitative observations of trends. It also raises some questions about other measurements and calculations, mainly with the just-shy-of 95% confidence interval of the oblique belt data. Our results do however disagree with [6] where it was determined that erector spinae activity was unaffected by a weight belt. More inquiry should be undertaken to uncover the source of this inconsistency.

One possibility why the results differ is the testing environment and subjects used. Human physiological tests are inherently prone to error and variance, as seen by the widely different data sets gathered during this experiment. Perhaps the differences between test subjects and their gradients of weightlifting altered the results: in [6] professional weightlifters with almost perfect form were tested, while in this investigation technique was not as closely monitored or controlled.

5. Conclusions

An area of improvement for this investigation is to increase the number of repetitions per trial, the number of trials, and the number of test subjects to lower overall uncertainty and gather more data. A further improvement to the experiment would be the addition of a mechanism to measure intra-abdominal pressure. Admittedly such a mechanism was tried: a strain gauge was attached to a rubber belt that would be worn around the abdomen and theoretically stretch according to increases in pressure during the exercise. Unfortunately reliable data could not be gathered from the initial attempt, mostly because the belt was too rigid and would slide along the subject’s back instead of stretching. Perhaps a future round of data collection could use this addition to generate a more comprehensive report on the performance of weight belts during the squat exercise.

This investigation yielded a convincing finding: weight belts worn tightly around the abdomen during the squat exercise decrease stabilizer muscle activity, thus decreasing the risk of spinal injury due to incorrect form. Two important conclusions and recommendations can be drawn: Beginner weightlifters should always wear lifting belts to encourage correct technique, and all weightlifters, regardless of experience, should wear weight belts while squatting to reduce the risk of spinal injury.

Acknowledgments

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References


[9] http://catalystfitness.typepad.com/.a/6a00e554f403b68834010536584e68970c-pi