Lumbar Spine Force Sensing Device

Gabriel Sta. Rosa, Ziyang Gao, Andrew Conzo

Department of Biomedical Engineering The College of New Jersey, Ewing NJ

Abstract

The back squat is a compound movement focused on developing the lower body. During the back squat, the back muscles act at a mechanical disadvantage, generating greater forces than the weight being lifted. Spinal loads are variable to varying postures leading to injury; 85% to 90% of intervertebral disc herniations occur at the L4-5 joint. To maximize performance and reduce injury, form checkups are required. There are various modalities to assess squat form. Although biomechanical analysis is the most accurate, this method is not currently available for commercial use which prevents athletes from getting the most accurate form reassessments. To address this problem, the Lumbar Spine Force Sensing group designed a device that takes kinematic information on the L4-5 joint to perform kinetic analysis. Maximum permissible limits have been established to assess the efficacy of the user's form in terms of lordotic and force data. The device is composed of a nylon weightlifting belt equipped with a 3D printed case to house the electronics, sensors to detect kinematic data, a microcomputer to perform analysis calculations, and vibration sensors to provide the user with real time feedback. In addition, the device communicates via Bluetooth with an Apple application to give technique suggestions to the user.

Introduction

During the back squat, moments are created about the joints in the body due to gravity and inertial forces such as a barbell in the case of a barbell squat. In the interest of this project, moments about the l4/l5 joint in the lumbar spine will be determined mathematically. Tissues of the spine at the lumbar intervertebral joint produce an extensor moment of force to counteract this generated moment to maintain stability. The tissues consist of passive tissue and active musculature.

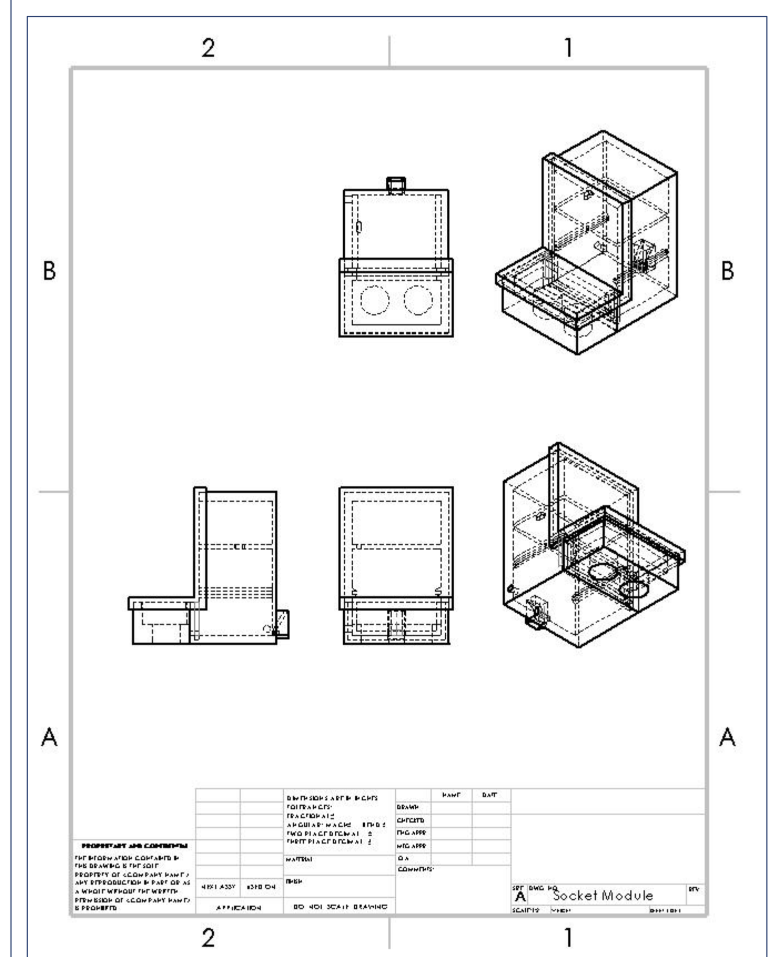
Lordosis is the curvature of the lumbar spine. In common practice, athletes are instructed to maintain a neutral spine or neutral lordosis. As inertial load is increased, the active musculature responds by increasing activation and therefore increasing extensor moment contribution. Interestingly, the passive tissue contribution remains constant. However, an athlete may deviate from a neutral spine in either extension or flexion. In the case of flexion, ligaments are strained, and anterior shear forces are increased. Consequently, this increases the extensor moment contribution of the anterior longitudinal ligament and decreases that of the active musculature.

Many cycles of compression and flexion can cause disc herniation. Therefore, it is important to monitor compression and shear forces acting on the L4/L5 joint, which experiences the greatest degree of flexion in the lumbar spine. It is equally important to monitor the degrees of flexion and extension that occur during the duration of squat exercises. By doing so, the athlete will be more conscious about their form and therefore reduce the chances of experiencing lower back pain because of this compound exercise.

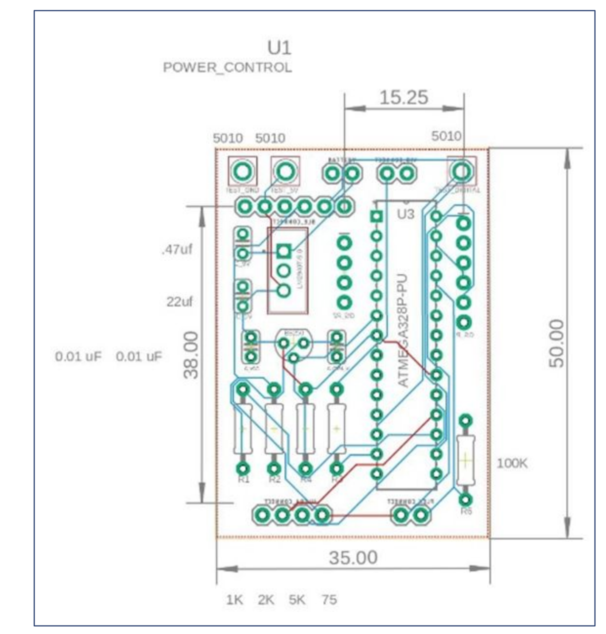
Design Requirements

1. The first requirement is that the device must recognize clinically relevant positions of the body to the stationary feet.
2. The second requirement is that the device must detect dynamic motion.
3. The third requirement is that the device must detect clinically improper form.
4. The fourth requirement is that the device must indicate to the user the level of deviation of proper squat form technique.
5. The fifth requirement is that the device must be water resistant.
6. The sixth requirement is that the device must not cause heat irritation.
7. The seventh requirement is that the device must be comparable with current powerlifting accessories.

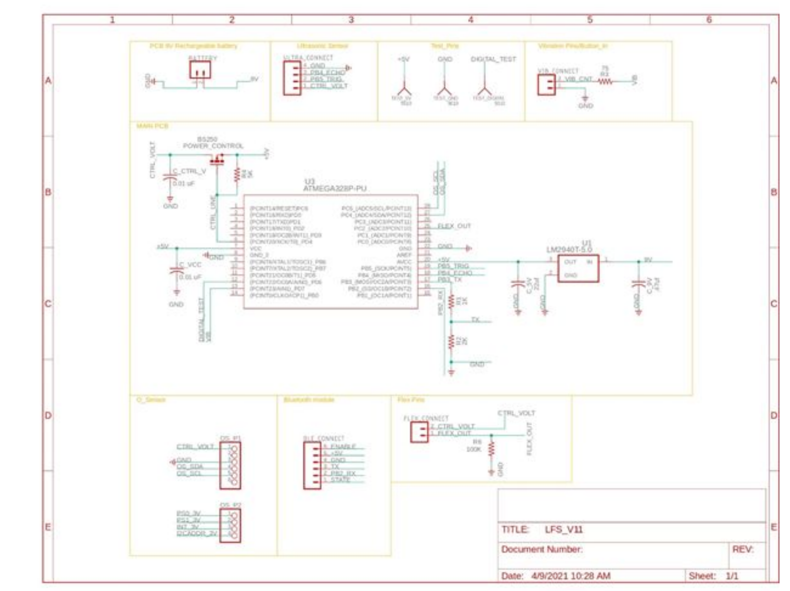
Design Solution



Socket Module that houses electronics and attaches to the weightlifting belt



PCB Board Layout



PCB Board Schematic

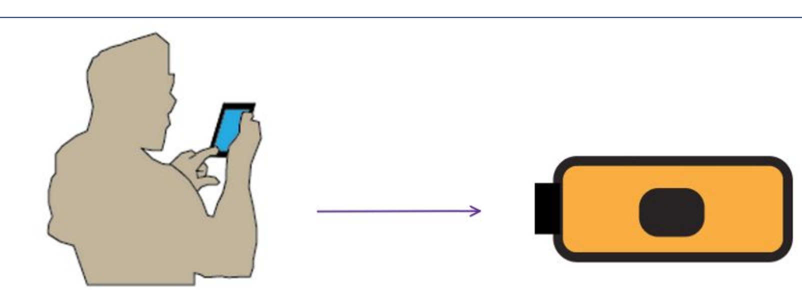
Grade Scale	Design Evaluation Description
Poor:	For the Given functionality, the design option completely or almost fails at every aspect necessary
Mediocre:	For the Given functionality, the design option is inferior to other options available
Adequate:	For the Given functionality, the design option can complete the bare minimum to be viewed as an acceptable choice
Fine:	For the Given functionality, the design option does a satisfactory job at meeting the necessary aspects for the function
Superb:	For the Given functionality, the design option completely or almost meets every aspect needed for that functionality

Design Evaluation

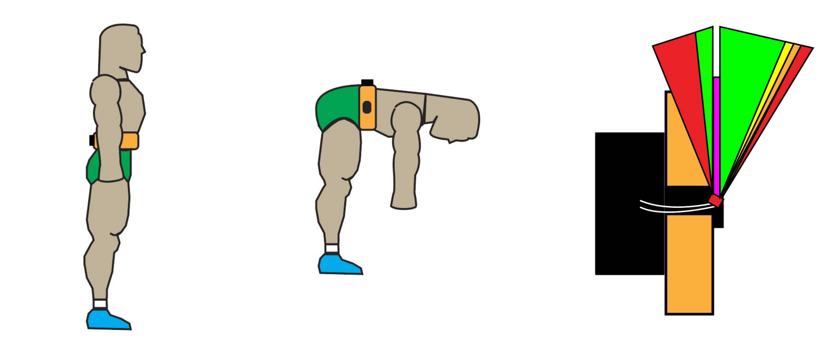
To determine our design solution a design solution matrix was utilized The evaluation rubric created was based on aspects of our functional requirements relating to both user and design. After our evaluation the LX force sensory socket module with belt easily prevailed as the best option in most aspects of functionality. To determine our components, each one was analyzed and evaluated, and the ones with the superior specifications that fit the projects constraints were selected When it came to the implementation of the device, the PCB pin layout was designed to be in sync with the custom created case for housing the device.

How it Works

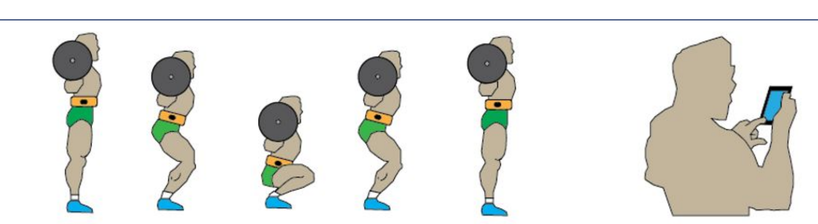
User Inputs Information into the Phone Application which gets stored onto the microcomputer as variables for future calculations



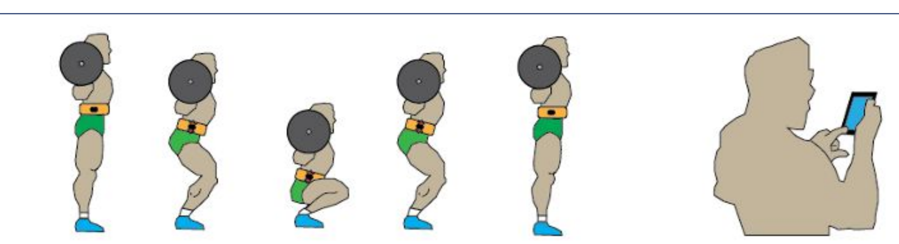
The user undergoes a full flexion procedure, and gets personalized Thresholds



If the user does not experience a form that meets any threshold value, no signal will be sensed. The user will be able to check their squat form after.



If the user does experience a form that meets any threshold value, a signal will be sensed. The user will be able to check their form after.



Conclusions

This project created a wearable technology to monitor athletic performance and to promote a safer and healthier lifestyle. The device is composed of a weightlifting belt, a 3D printed case, and an electronic component. By doing so, the device records kinematic data, performs kinetic analysis, and provides the user with real time feedback. While doing research and development, the project went through an FDA medical device design and documentation protocol. This prototype will continue to be developed in the future to "make good form the norm"!

References

1. Ahlborg, G, and Felig, P. Lactate and glucose exchange across the forearm, legs, and splanchnic bed during and after prolonged leg exercise. J Clin Invest 69:45-54, 1982.

Acknowledgements

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