# Pressure Sensors for Load Detection: Considerations of Non-Invasive Methods of Measuring Human Weight and Load

*By Ashton Stephens, ECE '19*

## Introduction

We are all going to die [1]—and taking on tasks that our bodies are ill-equipped to handle speeds up this process in ways we often never realize. We want a method to recognize when we exert our bodies beyond the tolerances that cause long term injury—and it is with smart biometric devices that we will be able to do that.

Carrying too much for long periods can lead to musculoskeletal injuries which manifest themselves as long term back pain and irreversible muscle damage [2]. Our team researched several methods with which we can non-invasively measure the amount a person is carrying in the hopes that this type of data can later be matched with a user's health over time to determine a causal relationship between weight carried and its effects on their physical health. With these kinds of measurements, it will eventually be possible to alert a user when they have exceeded their load bearing limitations, and warn them about the impact it might have on their body.

### *Lack of use in project*

The sponsor for this project was the military, who intended to use the product to make more informed decisions about who should go on missions and when trainees have exceeded their physical limitations.

Finding out how much soldiers can carry safely doesn't directly help decision makers choose who is ready to go on a mission, so foot pressure sensors were scrapped—allowing the team to focus project resources on parts that can detect musculoskeletal health. Using accelerometers allows the user's walking to be analyzed and generate a picture of the user's health, but they cannot on their own connect deteriorations in health to exceeding one's load bearing capacity.

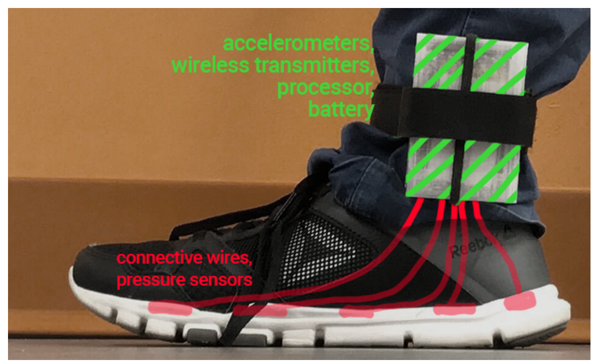


*Figure 1. Product layout. The red section is not in the final design*

## Hardware Considerations

### *Concept Overview*

Detecting the pressure along the soles of a person's foot (i.e. plantar pressure) has a history of giving insights into a person's health [3]. Medical professionals typically use methods that rely on large systems that need to stay in a lab and cannot be moved to the user's natural environment [4]. This makes them nearly useless in an active military context. The hardware concerns we address are 1. how to arrange your pressure sensors directly on a person's foot and 2. the problems incurred by pressure sensors in this context.

## Pressure Sensor Arrangement

The arrangement of pressure sensors needs to allow for two things: mapping the distribution of pressure across the foot (think heat map) and aggregating all the pressure measurement to get total weight

### *Arrangement for Pressure distribution*

A research team in 1995 successfully found a sensor distribution that enabled them to measure the pressure across the foot such that a relative heat map could be generated. Figure 1 shows the sensor distribution from the 1995 research team next to a typical pressure heat map generated by a different method.

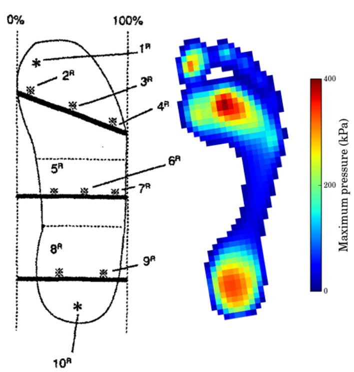


*Figure 2. typical foot pressure versus pressure sensor placement [5]*

Unfortunately, the above sensor distribution could not accurately generate a picture of how much a person is carrying in 1995 due to the sensors being too far apart to infer total weight.

### *Arrangement for Total Weight*

A separate research paper was able to correctly find the weight of a person using in-shoe pressure sensors. They achieved this by placing a carpet of medical sensors into the sole of a person's shoe [3]. Unfortunately the price of these sensors is outside of the project budget.

## Pressure Sensor Calibration

Pressure sensors are designed have electrical properties that change when the space between two ends of them are compressed. The nature of compression is that—like a spring—whatever material used will change over time to either stay compressed for longer or becomes stuck with a certain position after continual use. Even with perfect pressure sensors, the bottom of a shoe is necessarily compressible, leading to changes in sensor values with continued shoe use. While there are many ways of making these types of measurements accurate, there are some more typical methods that will not work in this context.

### *Calibration Methods That Will Not Work*

Many methods of compensating for sensor inaccuracies rely on a single more accurate sensor to occasionally correct the surrounding cheaper sensors [6]. These methods will not work in this context because there is not enough connection to the pressure at different places in the foot to assume the sensors will be experiencing similar inaccuracies.

Other methods of sensor calibration rely on the drifting of measurements to be centered around a typical expected inaccuracy. An insole under repeated use will experience sensor inaccuracies building up in a single direction over time, leading these types of methods not to work either.

## Further Research

The sensor distribution in Figure 2. was deemed too sparse to conclude total weight back in 1995. It may be possible with modern signal processing to generate total weight from this limited dataset. This part of the overall project never fully left the research stages.

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