Electrical signal recording on leg muscle for footwear ergonomic analysis

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Abstract. Pain on muscle, bone and joint often become a problem related to footwear users. The muscles and bones of the feet, especially the sole part, have complex and unique shapes. The biomechanical forces that occurred when we run or walk involving many muscles. Available footwear products such as slippers or shoes were designed to support all movements with minimal force applied to these muscles. Therefore, designing appropriate footwear should be ideally done by measuring its impact on involved muscles work. In this study, we designed an electrical signal recording of leg muscle activity for ergonomic analysis of footwear by using muscle sensor MyoWare, Arduino, and interface display. The measurements included the electric activity using 3 types of footwears: none, slippers and sports shoe with 2 different scenarios: walk and run. As a result, the recording system can show different muscle contraction in those different conditions. In both activities walking and running, it was found that without footwear, there was higher muscle contraction compared to using slippers and shoes with the highest contraction reaches 85.7% when running. This method can support the ergonomic analysis of footwear designed by the factory and may also contribute to sports engineering.

1. Introduction
Footwear affects not only a person's appearance but also their health. The use of footwear that does not comply ergonomic requirements can cause problems to health. Unsuitable footwear will provide great impact on health, especially foot health. Some health problems in the foot is basically not due to an accident or unpredictable things but mostly from the misuse and wrong selection of the footwear.

Pain on muscle, bone and joint often become a problem related to footwear users. The muscles and bones of the feet, especially the sole part, have complex and unique shapes (figure 1). The biomechanical forces that occurred when we run or walk involving many muscles.

When someone wears footwear like slippers and shoes, the legs are supported by the footwear structure. The footwear should be well designed to accommodate the biomechanics that occurs. For this, sports shoes especially when used for run, must have a good sole to dampen the influence of the force from the body to the foot. The force supported by the heel is 3 times the body weight when we are running [1,2].

Electromyography (EMG) is the process of recording the electrical activity of a muscle, to determine level of contraction [3]. Muscle function plays an important role in every human activity, especially in work, exercise, learning, and even when we were sleep. EMG has a frequency range at...
20 - 500Hz, with a dominant energy at the amplitude of 0-10 mV. Most of these electronic signal are weak signals. Electronic devices with weak signals are widely available in medical instrumentation.

The purpose of this study is to design an electrical signal recording of leg muscle activity for ergonomic analysis of different type of footwears.

![Human legs muscle](image1)

**Figure 1.** Human legs muscle

### 2. Material and methods

#### 2.1 Surface Electrodes

The surface electrode is used to capture Motor Unit Action Potential (MUAP) or the myoelectric signals. MUAP is captured with the electrodes placed on the surface of the skin. Signals with large amplitudes are obtained in the muscle fiber area near the electrode (figure 2).

Three electrodes are used in the detection of myoelectric signals, two electrodes connected to the input with impedance t and the third electrode as ground placed at the input with low impedance. Detection mode is done in two ways: mono-polar and bipolar. The electrode sensor on the skin is a sensor that can be used to help detect bioelectric signals released by the human body through the skin. The sensor is made from Ag | AgCl material (figure 3). To obtain electrical contact when using the sensors, there is an electrolyte paste smeared between the electrodes and the skin [4].

![Motor Units Action Potential](image2)

**Figure 2.** Motor Units Action Potential

![Skin electrodes](image3)

**Figure 3.** Skin electrodes
2.2 Human Foot Mass
The human foot is an extraordinarily complex part of the body. It absorbs and distributes hundreds of Newton pressure force with each step taken. Its unique structures support balance system of the body. Even mild toe injuries can affect a person's balance, posture, and alignment of the spine [5].

Legs are needed daily to be able to walk upright. The anatomy of the foot consists of 26 bones, 33 joints, and hundreds of tendons, ligaments, and muscles which were interconnected. The foot's anatomy is such that all elements work together, with the sole purpose of enabling one to be able to walk in the most convenient and efficient possible way.

2.3 Arduino
Arduino is defined as an open source electronic platform, based on flexible and easy-to-use software and hardware. Arduino is intended for artists, designers, hobbies, and anyone interested in creating interactive objects or environments [6,7].

The Arduino name here is not only used to name the circuit board but also to name its programming language and software as well as its programming environment or Integrated Development Environment (IDE). Several other application using Arduino such as biometric [8], monitoring system [9], robotic [10] and wireless sensor networks [11].

2.4 Research Design
The design of electrical signal recording system of foot muscle activities integrated with Arduino microcontroller and display it in user interface done according to the following stages:

Stage 1 Create a system modeling system
At this stage modeling of the recording system was made to get an overview of the needs of the recording system of muscle activity to be implemented, in both hardware and software aspect.

Stage 2 Device Design
At this stage the integration of hardware devices in accordance with the protocol of each device. The design of this device centered on the Arduino as a controller. The recording system used hardware such as Arduino UNO, MyoWare (figure 4) muscle sensor, and Electrode with the schematic circuit shown as in figure 5.

Figure 4. MyoWare sensors

Figure 5. Schematic circuit
Stage 3 Software Design
At this stage, the program was made to the hardware designed. Programming was tailored to the algorithm of the recording system. Figure 6 shows the flow chart of the program.

![Figure 6. Arduino Flowchart Program](image)

Stage 4 display interface
In this design, display interface was used to display data sent by Arduino UNO through serial communication. Display interface will read the incoming data through serial computer communications and display it in graphical form (figure 7). When the program starts, the program will request serial port input to look for serial communications sent by an Arduino microcontroller.

![Figure 7. Display interface](image)
We set the serial port on the interface display to read serial communication data sent by Arduino microcontroller. It will appear in the graph in accordance with the readings of the sensor. In the the column, amplitude was shown as the value of muscle contraction every time we do the activity. To stop the program, the stop button is available.

3. Result and Discussion
Arduino IDE and display interface were used to monitor the electrical signals of muscle activity captured by the myOware muscle sensor. It began with the opening of serial monitor on Arduino IDE and interface display on PC. Here's the signal of foot muscle contractions in a state of silence will not showed on the serial monitor Arduino IDE. Figure 8 shows the appearance of muscle contraction in the Arduino IDE.

![Figure 8. Display of Muscle Contraction in Arduino IDE](image)

Then the data will be displayed on the display interface and graph form in order to see if the sensor data obtained in the measurement was sent according to the measurement. Figure 9 shows the graphical display in display interface.

![Figure 9. Display of Muscle Contraction in display interface](image)

Each footwear has different muscle contractions when walking or running. The difference can be seen in the graph below (figure 10 and figure 11) with one single person sample.
On the graph, it can be seen that the largest muscle contraction occurred when walking without using footwear. The maximum amplitude value is 689, and its minimum amplitude is 199 with contraction of 71.4% while using the slippers by 38% and shoes by 9.8%. Differences in muscle contractions between walking and running was obvious where the maximum amplitude when running without using footwear is 759. While at the time of walking is 689 with 85.7% muscle contraction, 28.57% for slippers and 19% using shoes.

4. Conclusion
Data sent by MyoWare muscle sensor can be read through the serial monitor on Arduino IDE, and display interface which can display data of sensor muscle reading result in a graphic form.

In the experiment, it was evident that both walking and running without footwear had a great muscle contraction compared with slippers and shoes with the highest contraction was 85.7%.

Measurement data can provide information about the state of muscle contraction, the values of each footwear used and can be used for good footwear selection. This method can support the ergonomic analysis of footwear designed by the factory and may also contribute to sports engineering.

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References
[1] Sadayuki U 1997 The measurement and evaluation of the Cushioning abilities 3rd Symposium on Footwear Biomechanics Tokyo Institute of Technology Japan
[2] Nainggolan F, Siregar B and Fahmi F 2016 Anatomy learning system on human skeleton using Leap Motion Controller 3rd International Conference on Computer and Information Sciences (ICCOINS) p465-470
[3] Wardana PS and Arifin A 2012 Instrumentasi dan Pendeteksian Sinyal EMG Dinamik selama Elbow Joint Bergerak 6th Electrical Power Electronics Communications Control and Informatics Seminar Universitas Brawijaya Malang
[4] Andriawan O, Putera E and Faradisa IS 2011 Rancang Bangun Electroencephalograph (EEG) Sebagai Perekam Dan Pendeteksi Sinyal Biolistrik Otak Yang Terintegrasi Dengan PC Berbasis Mikrokontroler ATMEGA8535 Jurnal Teknik Listrik dan Mekatronika vol 2 no 1 p8–13
[5] Siregar B, Andayani U, Bahri RP and Fahmi F 2018 Real-time monitoring system for elderly people in detecting falling movement using accelerometer and gyroscope Journal of Physics: Conference Series vol 978 issue 1 p1211
[6] Company-Bosch BE 2003 ECG Front-End Design is Simplified with MicroConverter ® Bosch
Germany

[7] Ellys O, Pramartaningthyas K and Muntini MS 2012 Optimasi Rancangan Filter Bandpass Aktif Untuk Sinyal Lemah Menggunakan Algoritma Genetik Studi Kasus : Sinyal EEG ITS Digital Library Institut Teknologi Sepuluh November Surabaya

[8] Siswanto A, Tarigan P and Fahmi F 2013 Design of contactless hand biometric system with relative geometric parameters Instrumentation Communications Information Technology and Biomedical Engineering (ICICI-BME) 3rd International Conference on p199-203

[9] Siregar B, Nasution ABA and Fahmi F 2016 Integrated pollution monitoring system for smart city ICT for Smart Society (ICISS) 2016 International Conference on p 49-52

[10] Siregar B, Purba HA, Efendi S and Fahmi F 2017 Fire Extinguisher Robot Using Ultrasonic Camera and Wi-Fi Network Controlled with Android Smartphone IOP Conference Series: Materials Science and Engineering vol.180(1) p12106

[11] Siregar B, Fadli F, Andayani U, Harahap LA and Fahmi F 2017 Monitoring of Solar Radiation Intensity using Wireless Sensor Network for Plant Growing Journal of Physics: Conference Series vol801(1) p12087