Gait Analysis of Stairs Ascending and Descending

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***Abstract*—** Stair ascent and decent is a common functional and challenging task for several populations. Older adults are at a greater risk for a stairs-related fall due to biomechanical, perception-action or environmental constraints and exhibit altered stair-gait characteristics. [1[1]] During the stance phase of stair ascent, the hip and the knee joints undergo extension while the ankle joint undergoes plantar flexion. Staircase slope proves to be an important characteristic affecting temporal and kinematic gait parameters. Our study is a broader attempt to analyze that how staircase inclination affects the kinematic patterns of stair climbing. [2] It can be used to investigate stair climbing of patients with knee and hip implants [3]. This knowledge can serve as a reference for the imitation of natural motor control strategies in intelligent prostheses. For this purpose we are using FSR and EMG sensor to get output response to analyze the difference between ascending and descending. To get smooth response apply different filtration techniques for noise removal.

Keywords—FSR, EMG, Planter flexion

Introduction

The climbing a stair is very important movement because of its relevance to the daily activities, and the cooperation of the human with the machine can be analyzed in phases where higher support from the exoskeleton can be contributed, as well as smaller forces have to be applied to allow positioning the foot over the next step [4].

Jonathan et al (2002) [5] evaluate weighted stair climbing exercise as a means of increasing lower extremity muscle power in mobility-limited older people. They suggest that stair climbing exercise be a useful component of a home exercise program designed to enhance lower extremity muscle power, aerobic capacity and functional performance. Wells et al [6] studied a functional comparison of biomechanical outcomes during gait and stair climbing was carried out for younger individuals with these two alternative hip arthroplasties. They conclude that reduction in the abduction and flexion moments appear to be the most significant outcomes effecting function. Resurfaced hips may function slightly better.

The purpose of the study is to show a biomechanical study for stair climbing in order to get measurement values that can be depended on in the hospitals of rehabilitation, the centers of physical therapy and the clinical of medical sports, instead of depending on the measurement values that are dependent on the development countries for the same movement. The analysis investigated the biomechanics and motor co-ordination in humans during stair climbing at different stair height.

It is observed that upward movement is against the gravity stair ascent shown to be the more demanding biomechanical task when compared to stair descent for healthy young subjects. [7]. It is found that greater hip and knee angles, hip and knee moments are found in stair ascent compared to stair descent. Greater dorsi and plantar flexion are observed in stair descent than stair ascent. The maximum value of hip, knee, and ankle joints are rising in accordance with the increases of subject heights and different inclination [8].

There are two main phases during stair ascending and descending. First one is stance phase and second one is swing phase. In ascending during stance phase weight acceptance (WA) phase in which the body moves into optimal position in order to lift the body in next phase. In pull-up (PU) phase in which the one leg and whole body is pulled up to the next step. Forward Continuance (FCN) phase in which the subject has ascended the step and moving forward to the next step. During swing phase foot clearance (FCL) in which the whole foot takes off the previous step. Foot Placement (FP) in which the foot is ready to touch the next step as shown in **Fig.1. 1**. For descending the stance and swing phases properties are shown in **Fig.1. 2**.

Stair ascent and descent have similar patterns to those described for walking and running. However, the hip muscles generally contribute less than the muscles acting on the knee and ankle joints. Going upstairs, or ascent, is first initiated with a limb lift via vigorous contraction of the iliopsoas, which pulls the limb up against gravity to the next stair. The rectus femoris becomes active in this phase as it assists in the thigh flexion and eccentrically slows the knee flexion.

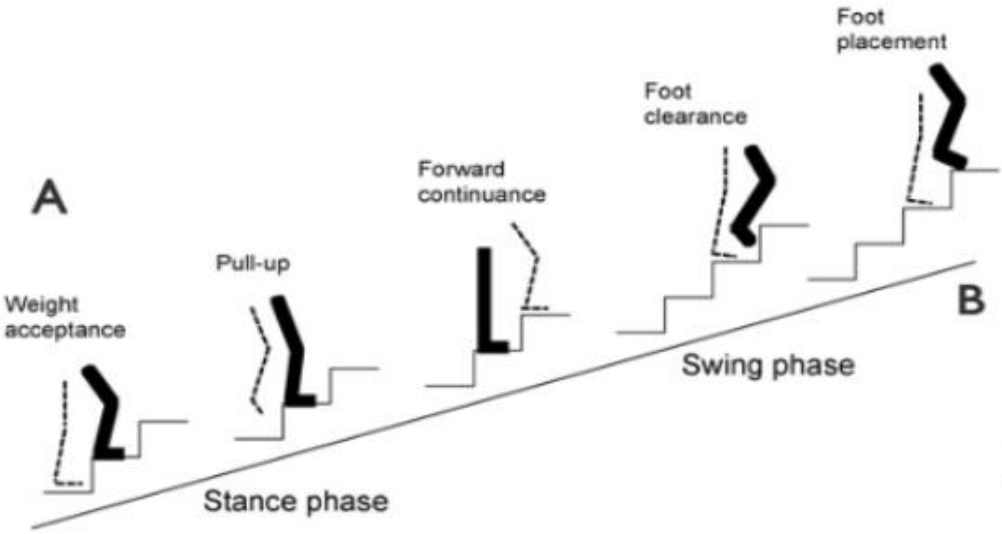


Fig.1. 1: Stance and swing phase during ascending

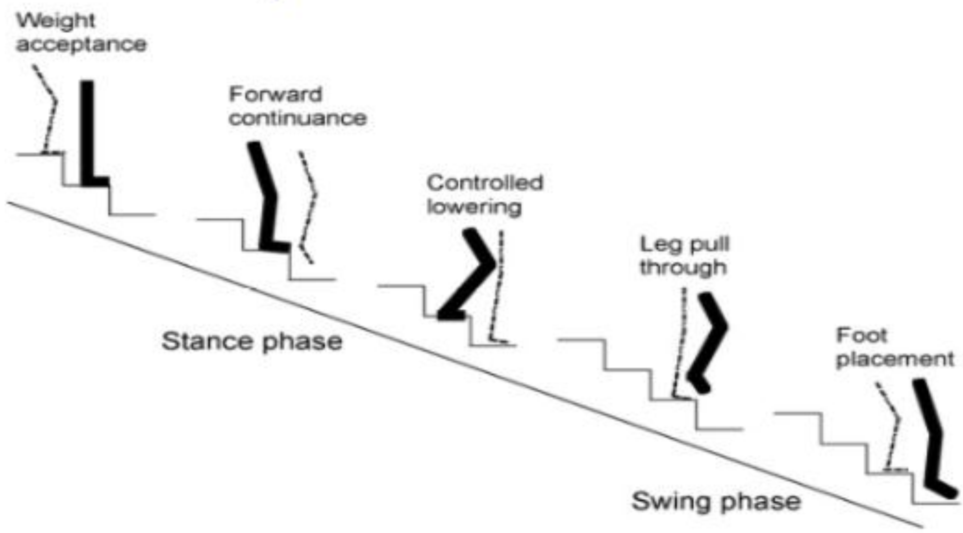


Fig.1. 2: stance and swing phase during descending.

Objectives:

- Analysis of EMG and FSR output response during stair ascending and descending.
- Differentiate ascent and descent response..
- Noise removal of acquired data using filtering techniques.

Hardware:

- FSR sensor
- EMG sensor
- Arduino Uno
- Resistance
- EMG electrodes

FSR Sensor:

A **force-sensing resistor** is a material whose resistance changes when a force, pressure or mechanical stress is applied. They are also known as "force-sensitive resistor" and are sometimes referred to by the initialism "FSR".

Force-sensing resistors consist of a conductive polymer, which changes resistance in a predictable manner following application of force to its surface. They are normally supplied as a polymer sheet or ink that can be applied by screen printing. The sensing film consists of both electrically conducting and non-conducting particles suspended in matrix. The particles are sub-micrometer sizes, and are formulated to reduce the temperature dependence, improve mechanical properties and increase surface durability. Applying a force to the surface of the sensing film causes particles to touch the conducting electrodes, changing the resistance of the film. As with all resistive based sensors, force-sensing resistors require a relatively simple interface and can operate satisfactorily in moderately hostile environments. Compared to other force sensors, the advantages of FSRs are their size (thickness typically less than 0.5 mm), low cost and good shock resistance. A disadvantage is their low precision: measurement results may differ 10% and more. Force-sensing capacitors offer superior sensitivity and long term stability, but require more complicated drive electronics. New mechanistic explanations have been established to explain the performance of force sensing resistors these are based on the property of contact resistance occurring between the sensor electrodes and the conductive polymer.

Fig.1. 3: FSR Sensor

EMG Sensor

Electromyography (EMG) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyography to produce a record called an electromyogram. An electromyograph detects the electric potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order, or to analyze the biomechanics of human or animal movement.

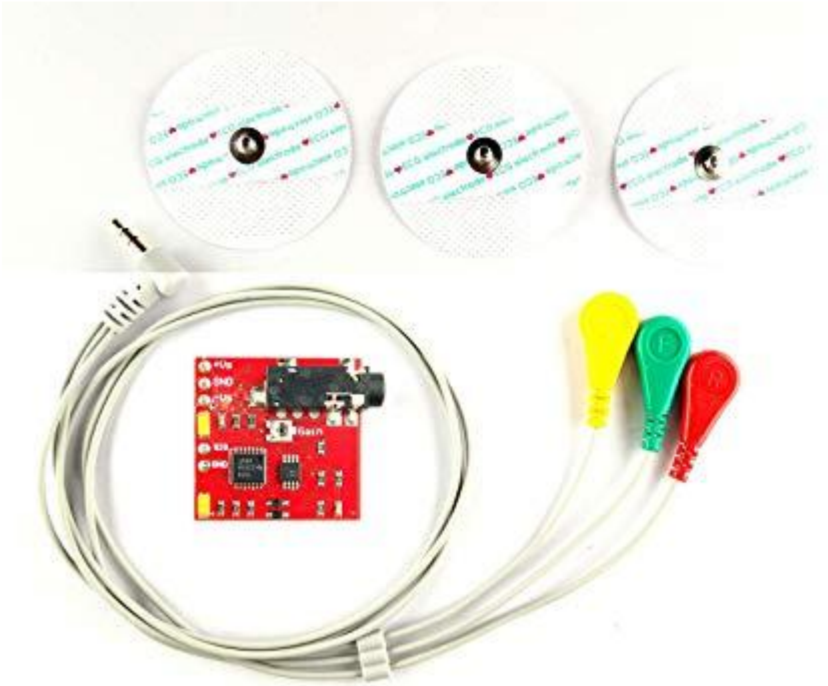
The Electromyography Sensor (EMG) allows the user to measure the electrical activity of muscles. It can be used as a control signal for prosthetic devices. An electromyogram (EMG) measures the electrical activity of muscles at rest and during contraction. EMG signals are used in many clinical and biomedical applications. EMG is used as a diagnostics tool for identifying neuromuscular diseases, assessing low-back pain, kinesiology, and disorders of motor control. EMG signals are also used as a control signal for prosthetic devices such as prosthetic hands, arms, and lower limbs. This sensor will measure the filtered and rectified electrical activity of a muscle, depending the amount of activity in the selected muscle.

Features:

- Adjustable gain
- Small Form Factor
- Full integrated

Use your muscles to control any type of actuator (motors, servos, lights ...). Interact with the environment with your own muscles.

This sensor comes with everything you need to start sensing muscle activity with your Arduino or Raspberry Pi.



Methodology

A. Block Diagram

The main objectives of this to differentiate between the output responses of selous muscle for stair ascending and descending. The purpose methodology is shown in **Fig. 2. 1**

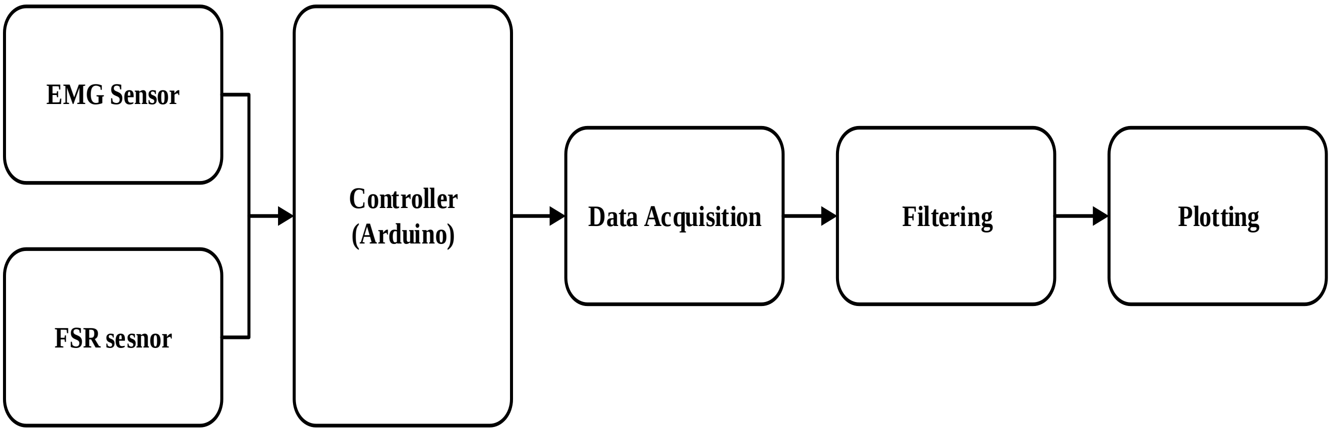


Fig. 2. 1: Methodology Block diagram

B. Description

For the objectives defined above, we are using two type of sensors first one is Electromyography sensor (EMG) and Force resistance sensor (FSR). This EMG is type of non-invasive. These sensors are used as for input. For data acquisition we are using Arduino Uno as micro-controller. When muscle extent or contract EMG gives measure some millivolts due to potential difference between electrodes of sensor. After this signal is amplified and rectified then goes to controller. Controller read the data extract the valuable information then plot the output response. The FSR is lies behind the toe for force and pressure measurement. As EMG electrodes are connected at Soleous muscle which is located at as shown in **Fig. 2. 2**. Circuit diagram and sesors location as shown in **Fig. 2. 3**.

Fig. 2. 2: Soleous Muscle Location

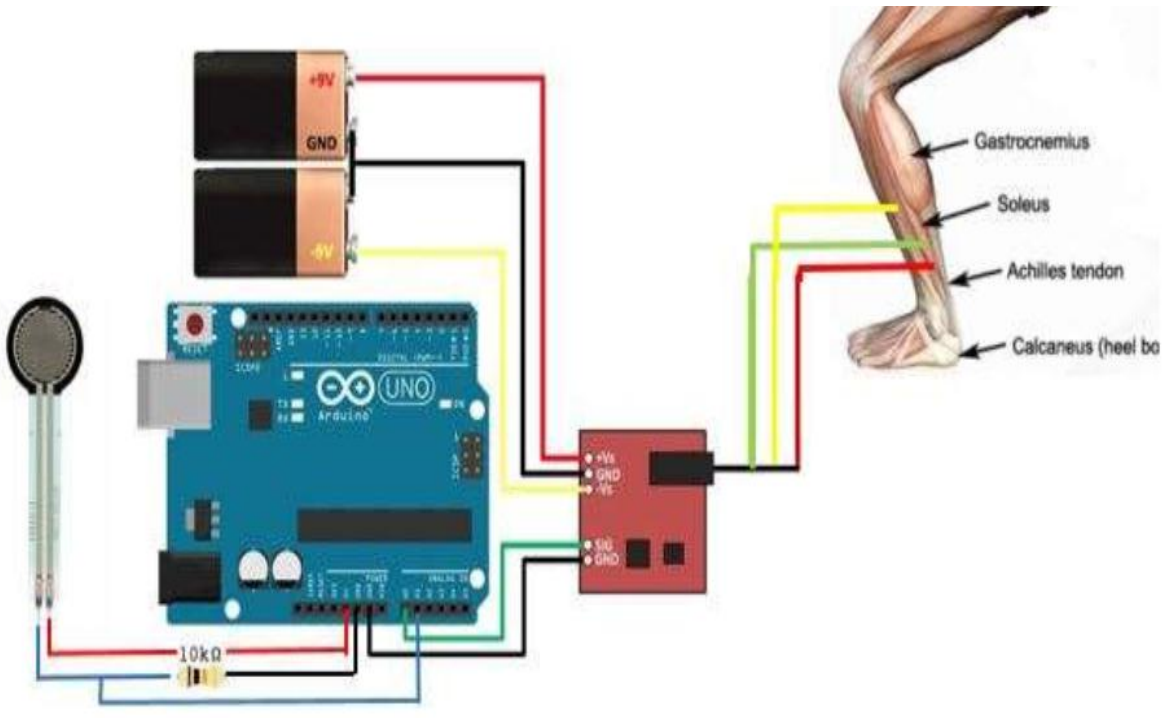


Fig. 2. 3: FSR and EMG location and Circuit diagram

Results and output

Stairs ascending response (Data 01)

From experiment stair climbing time is 13.4 second and gait cycle is 6. As subject climb with the speed of 0.215 m/s. the step length will be 48cm. The output results plot is shown in **Fig. 2. 4**.

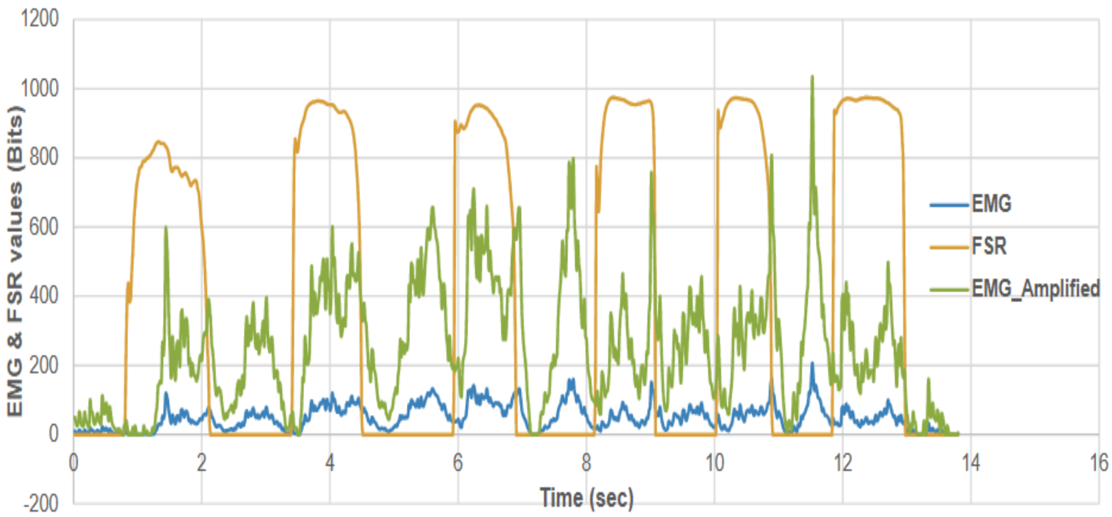


Fig. 2. 4: stair ascending response

Phase terminologies during ascending is given as shown in **Fig. 2. 5**

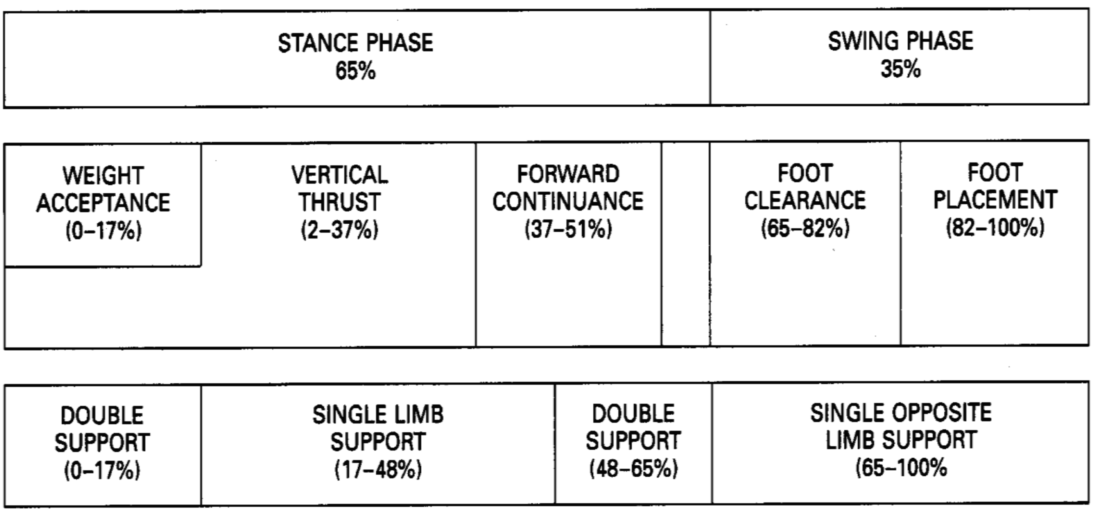


Fig. 2. 5: Phase terminologies during stairs ascending

Stairs descending response (Data 01)

From experiment stair climbing time is 11.4 second and gait cycle is 6. As subject climb with the speed of 0.25 m/s. the step length will be 48cm. The output results plot is shown in **Fig. 2. 6**.

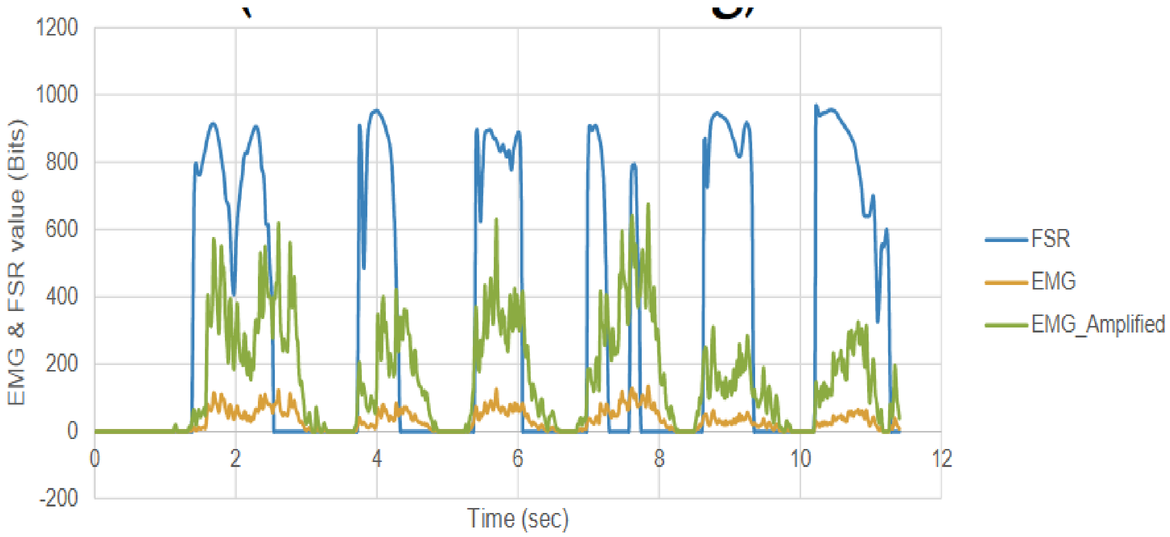


Fig. 2. 6: Stairs descending response

Phase terminologies during descending is shown in

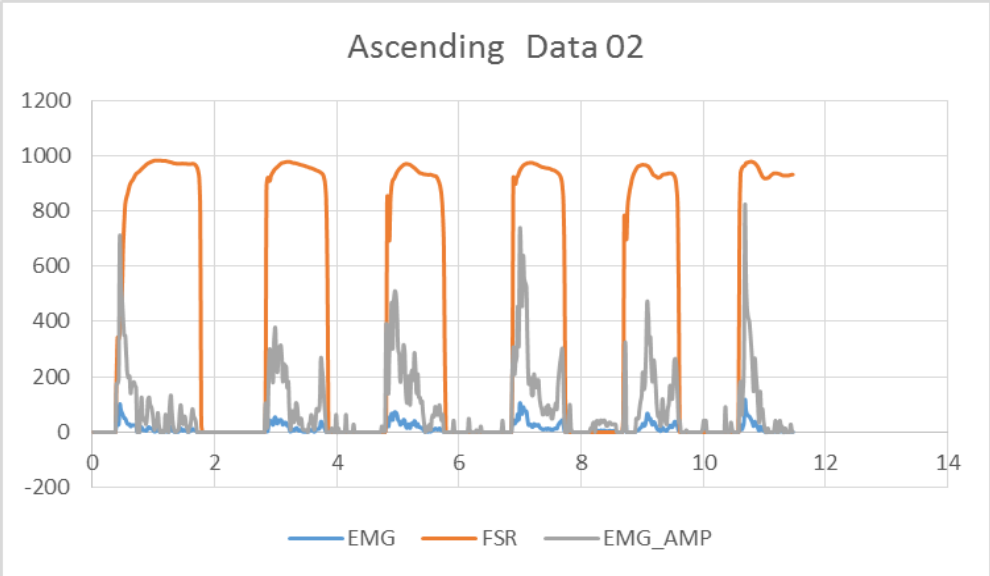
STANCE PHASE 68%	SWING PHASE 32%

WEIGHT ACCEPTANCE (0-14%)	FORWARD CONTINUANCE (14-34%)	CONTROLLED LOWERING (34-68%)	LEG PULL THROUGH (68-84%)	FOOT PLACEMENT (84-100%)

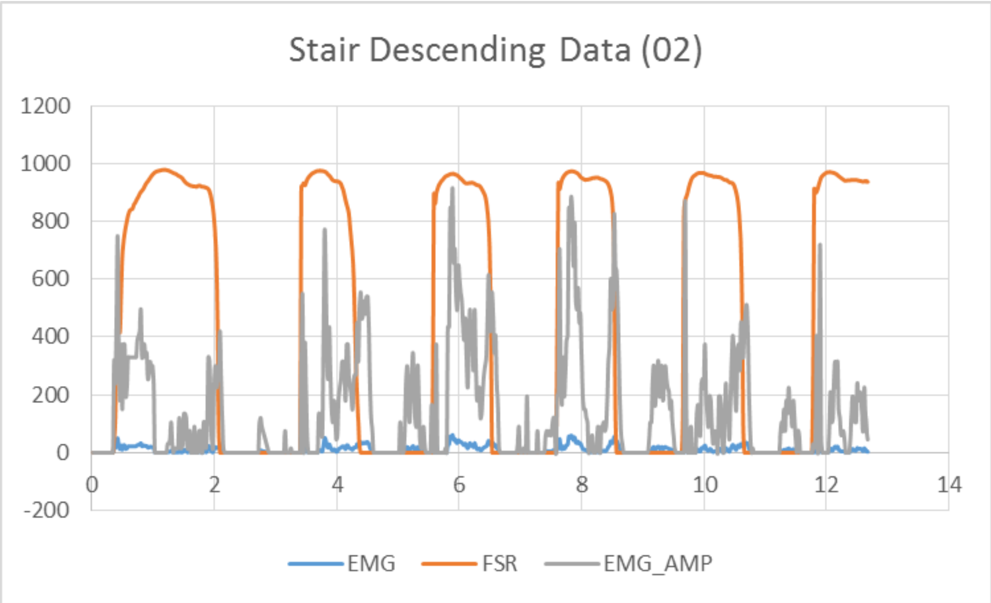
DOUBLE SUPPORT (0-14%)	SINGLE LIMB SUPPORT (14-53%)	DOUBLE SUPPORT (53-68%)	SINGLE OPPOSITE LIMB SUPPORT (68-100%)

Fig. 2. 7: Phase terminologies during stairs descending

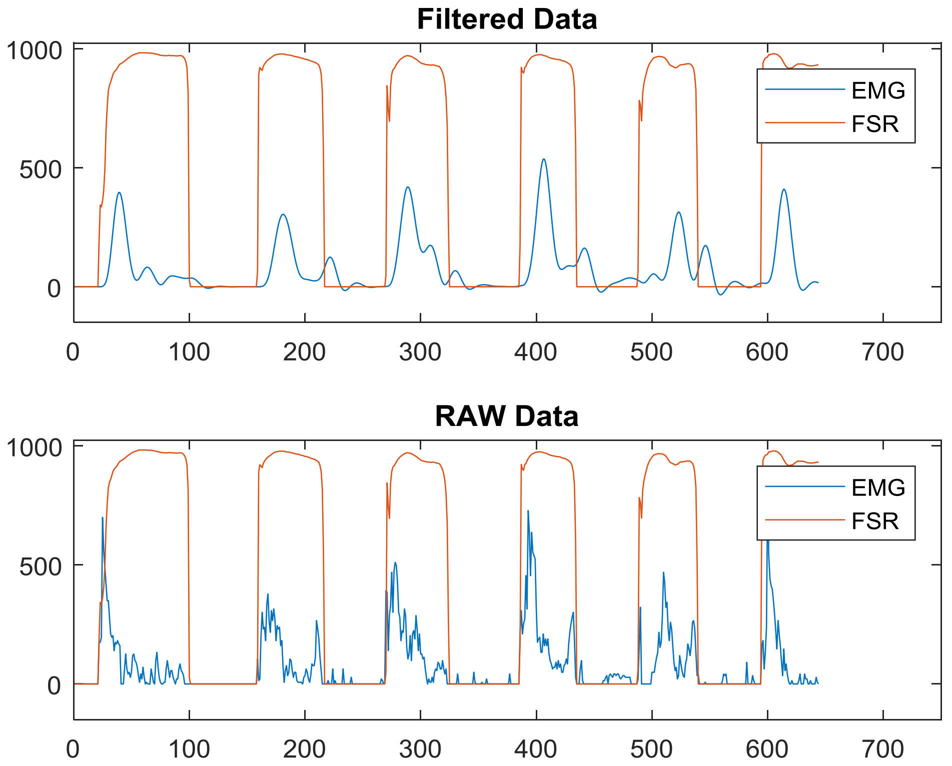
Stair Ascending Response (Data 02)



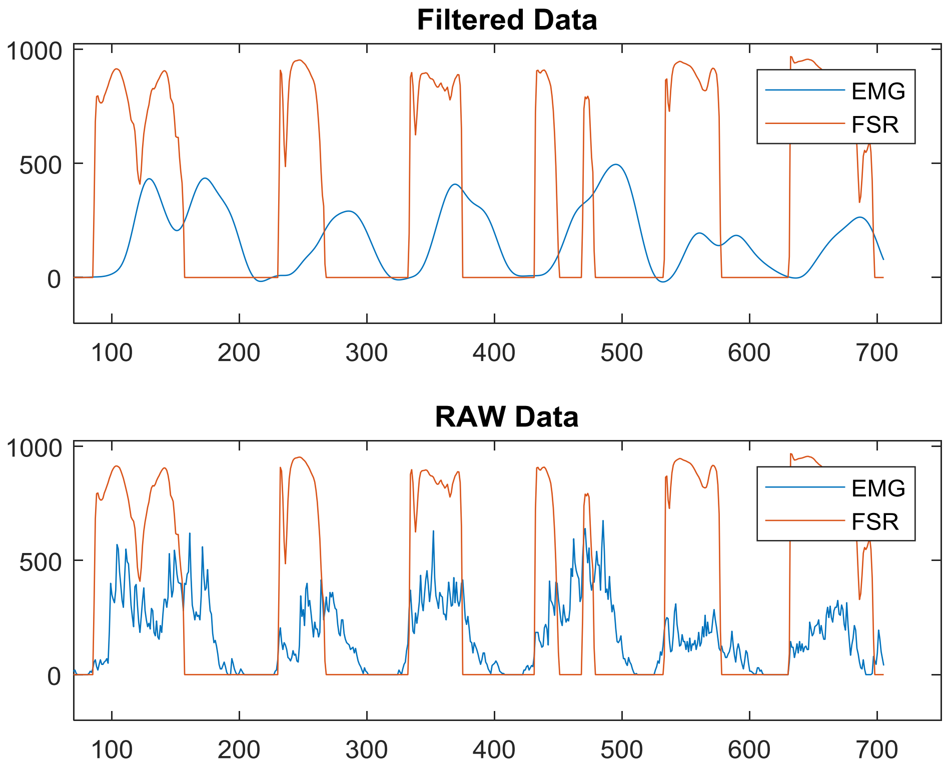
Stair Descending Response (Data 02)



- **Apply Filters for Ascending:**



- **Apply Filter on Descending Data**



Conclusion:

According to our filtered graphs, stance phase 64.3% and swing phase 35.7% in case of ascending stairs. And stance phase 66.67% and swing phase 33.33% in case of descending. Our results are very close to theoretical values.

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