# Project – Spring 2024
# *Rehabilitation of Biomechanics (336506)*

*Lecturer: Dr. Firas Mawase*

*Instructor: Dr. Deborah Solomonow-Avnon*

*Tutor: Alen Zilbert*

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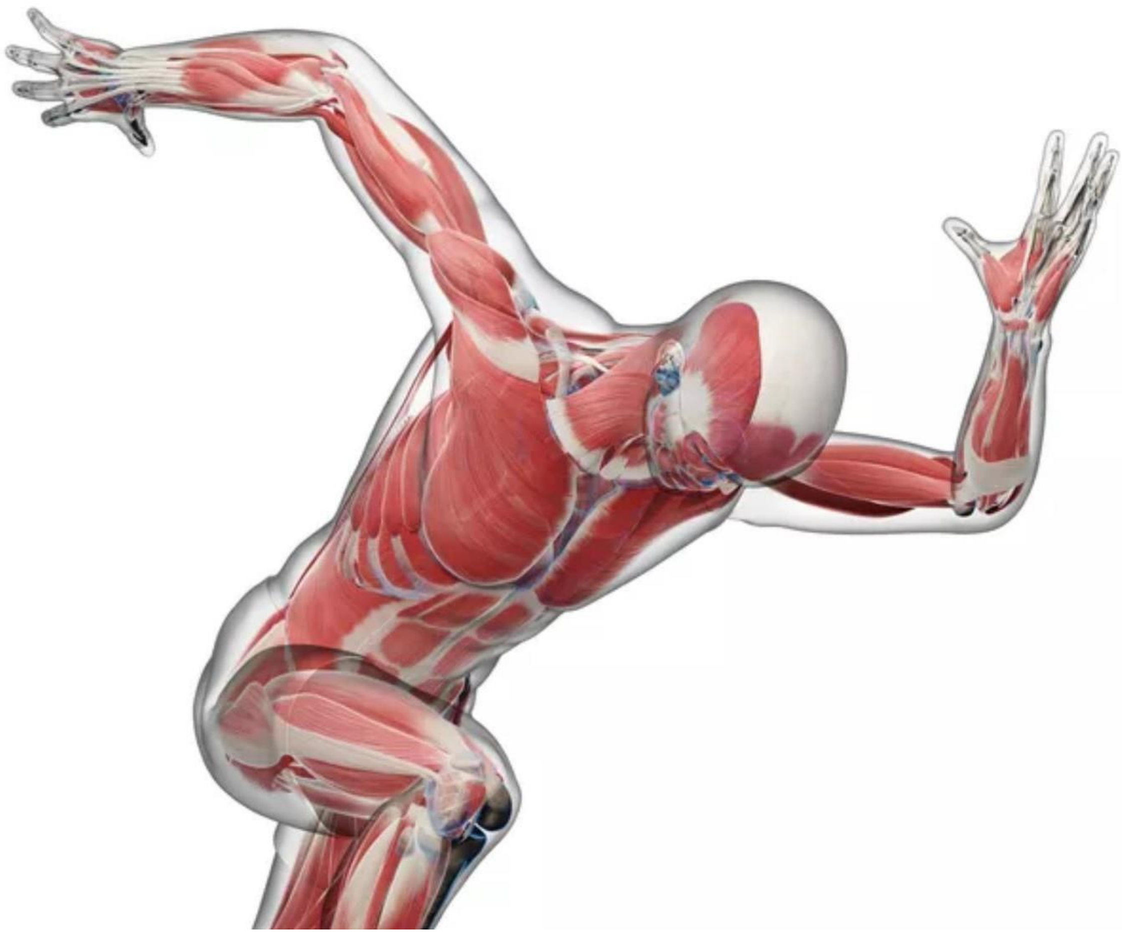


General Requirements:

All graphs, equations, explanations, and images should be included in the project report (and not only in the code). Each group must submit one zip file which includes - project report (pdf file) and code (Matlab).

# Part 1 – Gait Analysis (50 points)*

**Data Explanation (explanation for data relevant to the project only):**
You have been given data files in different conditions. There are 4 trials for each experiment (each either walking away from the computer station or toward the computer station). The filenames indicate foot condition (bf - barefoot; heels), speed (normal; slow; fast), direction of walking (away; toward station), and trial number (1-4). In total, there are 16 csv files of data.

Each file contains the following:

- *Events* – contains the time in seconds of the gait cycle events, foot strike and foot off, for each leg
- *Devices* – analog data captured at 2160 [Hz] comprised of:
  Force plates (i.e., FP) – contains the names of each dataset (F=force, M=moment, etc.).
- *Model Outputs* – the gait model outputs from the motion capture data, captured at 120 [Hz], comprised of:
  - Joint kinematics and kinetics (“Model Outputs”) - contains the following relevant information for this project:
    Angles – estimated joints angles by the software:
    Contains the joints angles in the X,Y, and Z directions, according to the coordinate systems of each joint (this is not the same as the x,y,z reference frame as the lab, and here X refers to the sagittal-plane angles of each joint, Y to the frontal-plane angles, and Z to the transverse plane angles).
- *Trajectories* - contains the the (x,y,z) coordinates of each marker, captured at 120 [Hz] within the laboratory reference frame (x axis is perpendicular to the direction of walking, y axis is along the direction of walking, z axis is vertical). See figure for understanding the marker names; note that we did not use the SACR marker.

* Note that each block of data (i.e., Events, Devices, Model Outputs, Trajectories) is located one after the other in a vertical manner. You will have to scroll down to the end of each block in order to find the row where the next block starts.

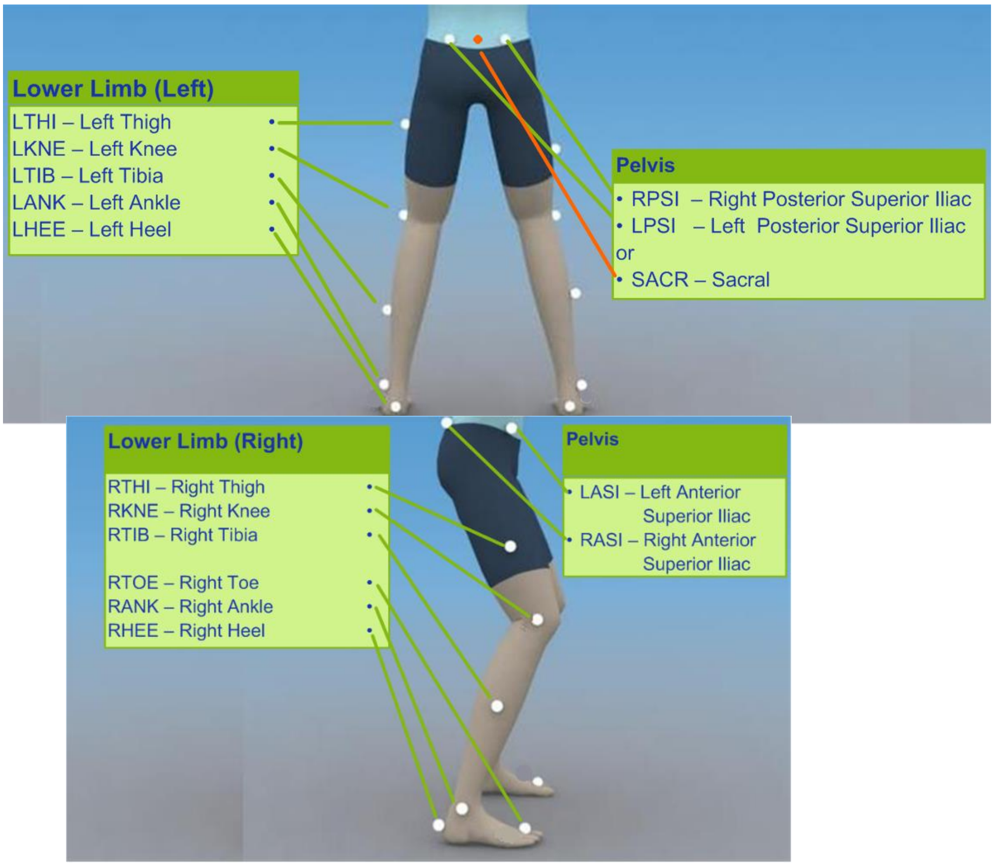
* Please note that all questions refer to the right and left feet for all experiments, unless indicated otherwise, and both walking speeds for the barefoot experiment (i.e., normal and fast) and that with heels (i.e., normal and slow).

## Introduction (5 points):

**Describe the experiment we conducted, and refer to the following topics:**

- A short description of each device and the sensors we used.
- What types of data did we collect?
- What are the possible measurement errors for each data type we collected?

PlugInGait Model Marker Names and Locations




1) Gait Cycle (10 points):

For the barefoot condition at the normal speed.

Specific parameters can be obtained using gait cycle visualization, and more specifically applying time normalization and then averaging the relevant parameters of the gait cycles. In order calculate the relevant parameters in part b, you must first find the appropriate time vectors and become familiar with the gait events (foot strike and foot off).

a) A time vector in seconds is not given to you in the data, but rather a column containing the frame and subframe (frame is before the decimal point, and subframe after the decimal point). (i) You will need to calculate the time vectors (in seconds) using the sampling rate (2160 samples/sec for analog device data and 120 samples/sec for marker and model data). For data processing purposes, parts of the trial at the beginning and end were cut and discarded, and thus the trials in the files start at a frame >1. You will need to find the time in seconds corresponding to the frame/subframe that the trial starts in the data files. (ii) Include plots of the raw Z-axis force plate data with the points of the gait events marked on them. General Remark: Use green to plot right limb values and red to plot left foot values.

To average the gait cycle parameters, we need to normalize the time for each gait cycle so each normalized vector has the same length and each element represents the same gait cycle phase (%). For the next question, use the biomechanical angles of the pelvis.

b) Split the data into gait cycles according to gait events. Interpolate each cycle into 100 evenly distributed samples, so each sample represents the percent gait cycle instead of the time. Plot the average data and the standard deviation (as shaded areas/ error bars) of the three components of the pelvic angles of the left and right side vs. percent gait cycle and indicate how many cycles you averaged (see further explanation below). Only use whole gait cycles (foot strike to foot strike). Plot each component in a different graph and indicate in the title of the graph the component (X,Y, or Z) and the biomechanical term for the component (pelvic rotation, tilt, or obliquity which you will determine by the conventions given to you).

The software extracted the data according to biomechanical conventions. The sign convention, therefore, is based on flexion (+) or extension (-), adduction (+) or abduction (-), internal (+) or external rotation (-), no matter what side. Here in this question, you are going to use the X, Y, and Z components of pelvic angles (again, please note that X,Y,Z referred to here are not the same as the x,y,z axes of the lab, in which x is the axis perpendicular to that of the walking direction in the horizontal plane, y is in the direction of walking, and z is the vertical axis).

c) Compare your results with the literature on healthy young female subjects, and cite the sources that you used for comparison.

2) Ground Reaction Forces (20 points):

During the experiment, we collected data from the force plates. In a table given to you (FP_LEG.xlsx) you can find which force plate (1 or 2) is related to which leg (R-right or L-left) for each trial.

a) Plot the total (not the separate components) of the Ground Reaction Force (GRF) for each walking condition (barefoot and heels) at normal speed for the right leg only.
b) Explain any differences in GRF between the two conditions (e.g., amplitude of peak1/peak2, etc.).

3) Estimation of spatio-temporal parameters (15 points):

a) Using the gait event times and one of the markers on the foot (either ankle, heel, or toe), estimate the average gait speed (average of gait speed for all whole gait cycles within all trials) for both barefoot and heels at all tested speeds for the right leg only. Explain your calculations and show your calculations for each individual gait cycle in addition to the average.
b) Estimate the average stride length (the distance between the point of initial contact of one foot to the next point of initial contact of the same foot) for the right leg for all conditions and speeds. Explain your calculations and show your calculations for each individual gait cycle in addition to the average.

## Part 2 – Electromyography (EMG) (25 points)

**Data explanation:** In the same data files, you can find the EMG data of the two sensors in the column AY (*Imported Delsys EMG 2.0.1 #2 - Sensor 1*) and BC (*Imported Delsys EMG 2.0.1 #2 - Sensor 2*)

In this part, you are requested to analyze the data sets for the two conditions:

1. Barefoot at normal speed
2. Heels at normal speed

Questions:

Q1) For each muscle (i.e., sensor) and each condition (see above), plot on the same figure (1) the raw EMG data, (2) the rectified EMG and (3) the envelope of the signal and indicate the gait events on all graphs. Use different color for each signal. Describe the differences between the Heels and Barefoot conditions. Explain when in the gait cycle, the muscle is mostly active.

Q2) We positioned one sensor on the rectus femoris (RF) muscle and one sensor on the lateral gastrocnemius (LG) muscle. Find, in the literature, graphs of EMG activity (either raw or processed) for healthy subjects during normal walking. Using the information you now have from Q1 to determine which sensor (i.e., 1 or 5) was placed on which muscle (i.e., RF or LG). Explain in detail how you made your decision.

## Part 3 – Pedobarography (25 Points)

This part relates to the data collected by the Pedar insoles (a pedobarographic device which measures the pressure distribution acting on the plantar surface of the foot). This data was collected separately from the data in Parts 1 and 2. Here we collected data while walking in sandals at 2 different speeds, slow and fast.

Each insole contains a matrix of 99 one-dimensional pressure sensors.

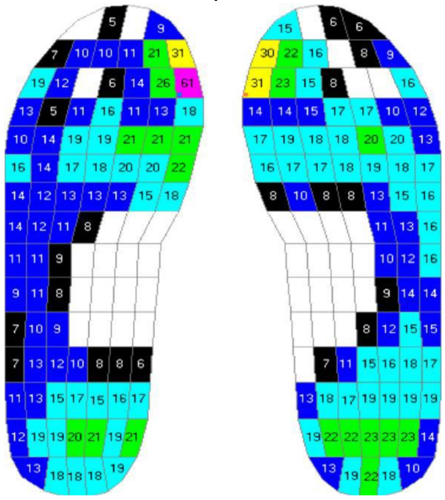


Figure: Example of pressure distributions measured by pedar insoles, showing the pressure sensor matrix.
Data collected: GRF and foot center of pressure (COP) were sampled and recorded. COP was measured represents a weighted average of the pressures distributed at the plantar surface of the foot and is given in x,y coordinates (see figure below) vs. time.

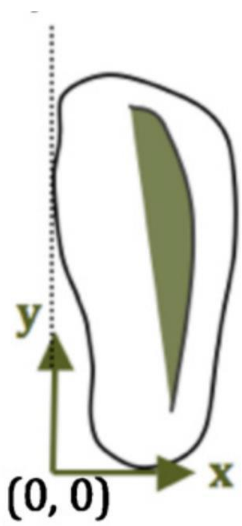



Figure: x,y coordinate system for Pedar insoles. The black curve represents the COP trajectory for the time in the gait cycle in which the foot is in contact with the ground. The trajectory starts at the heel and ends at the toe, curving towards the lateral direction in between.

In this part, you are requested to analyze the data set for the ***slow*** and ***fast*** speeds for the ***right*** foot only:

Questions:

Q1) Calculate the sampling rate of the Pedar device (5 points).

Q2) For each condition, detect stance phases (5 points):
Split the time up into the start and end of stance phase (the time when the foot is contact with the ground) using the GRF. Plot the indexes as lines on top of the GRF plots in Q2.

Q3) Then, for each condition (10 points):

(a) Plot the average time-normalized GRF during stance phase

(b) Compare the difference between the GRFs w.r.t. walking conditions

Q4) Plot the $COP_X$ Vs. $COP_Y$ (all stance phase COP trajectories on the same figure) for each condition (5 points).