Foot Roll vs Ankle Pronation/Supination During Gait - Collection Protocol

🧠 Neural Rehabilitation Engineering Lab

ℹ️ Document Information

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1. Purpose

The purpose of this document is to define the testing protocol for the foot roll data collection using the ImpactSense, including the objectives, procedures, and responsibilities to ensure a comprehensive and standardized testing process.

2. Scope

This testing protocol applies to all testing activities related to the collection of foot roll measurement data using the treadmill. It will outline how to set up the angle in the treadmill to emulate a slanted environment in real life settings, in order to extract data related to pronation/supination (from Vicon motion capture) and foot roll (ImpactSense).

3. Responsibilities

- Data collector(s): Shall be responsible for recruiting participants, scheduling collection times, setting up for collection, collecting data from all sensor modalities, extracting data in between trials and at the end of data collection to be stored in a secure location.
    - Treadmill setup: Data collectors shall also be responsible for setting up the angle in the testing apparatus (treadmill).

4. Test Plan

4.1. Test Objectives

- The objective of this test is to compare foot roll measurement data taken from the ImpactSense to the ankle pronation and supination angles that come from the motion capture system. Doing so will enable the researchers to make conclusions as to whether the ImpactSense can be used as a viable tool for gathering reliable insights on pronation and supination from foot roll measurements.

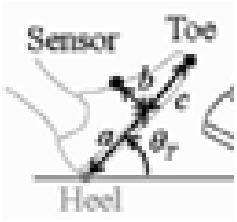
4.2. Test Resources

- 2x Impact sense (one for each foot)
- 2x Gait-up (one for each foot)
- 1x Treadmill

- 2x Wooden platforms for elevating treadmill unilaterally to create a lateral slant
- RoboHub lab space at the University of Waterloo
- Vicon motion capture system (including markers and adhesives)

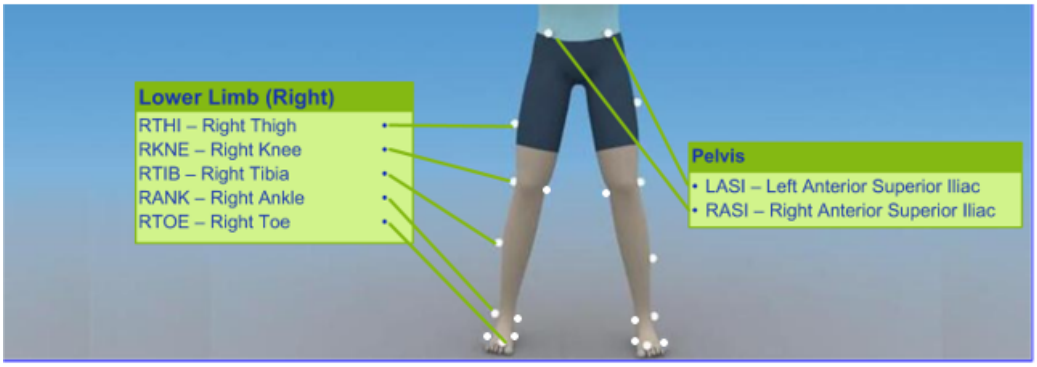
4.3. Test Preparation

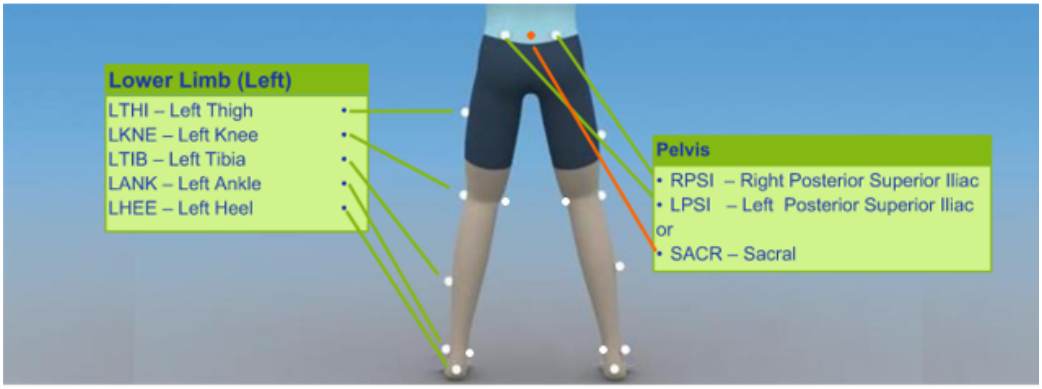
1. Turn on Vicon (~1 hour before collection)
2. Calibrate Vicon (~15 mins before collection)
3. Prepare motion capture markers
4. Delete any files on the ImpactSense and GaitUp (Physilog) sensors.
5. Place motion capture markers on the participant.
6. Subject calibration in Vicon.
7. Collect participants shoe size and the following measurements (a,b, and c from the image below) from the participant's shoe.



Motion capture marker layout:

- Pelvis: Right ASIS, left ASIS, right PSIS, left PSIS
- Right leg (7): Right thigh, right knee medial, right knee lateral, right tibia, right ankle medial, right ankle lateral, right foot medial (1st toe), right toe (2nd toe), right foot lateral (5th toe), right heel
- Left leg (7): Left thigh, left knee medial, left knee lateral, left tibia, left ankle medial, left ankle lateral, left foot medial (1st toe), left toe (2nd toe), left foot lateral (5th toe), left heel.





4.4. Test Procedures

1. Attach the left and right ImpactSense and GaitUp(Physilog) sensors to the laces of the left and right shoes respectively.
2. Insert wooden boards underneath the correct side of the treadmill (if required based on test condition). See Figure below.

3. Participant moves to stand on the treadmill
4. Begin logging on the ImpactSense app for both the left and right sensor.
5. Turn on the GaitUp(Physilog) sensors - sensors are now logging.
6. Wait 20 seconds (to ensure sensors will capture data).
7. Instruct the participant to hop three times on the spot (time syncing if needed).
8. Start the treadmill at a speed of 2 mph.
9. Subject walks on the treadmill for 2 minutes.
10. Stop the treadmill.
11. Instruct the participant to hop three times on the spot (time syncing if needed).
12. Wait 20 seconds to ensure sensors log the entire walking test.
13. Turn off GaitUp(Physilog) sensors.

14. Remove ImpactSense from the laces, place in the charging dock, and wait 5-10 seconds. (Leave GaitUp(Physilog) sensors in the laces.)
15. Remove the ImpactSense from the charging dock and extract the data from the ImpactSense using the app.
16. Place ImpactSense back in the charging dock and wait 5-10 seconds.
17. Remove ImpactSense from the charging dock, connect the ImpactSense and erase the previously collected data from the ImpactSense.
18. Place ImpactSense back in the charging dock and wait 5-10 seconds, remove and place the ImpactSense back in the participants' laces.
19. Repeat steps 2-7 for the two other test cases.

4.5. Test Cases

Test #	Duration	Speed	Treadmill Set-Up	Condition - Aim
1	1 x 2 mins	2 mph	Flat on the ground	Both ankles are neutral/natural orientation
2	1 x 2 mins	2 mph	Elevate the right side of the treadmill using wooden platform	Right ankle is pronated Left ankle is supinated
3	1 x 2 mins	2 mph	Elevate the left side of the treadmill using wooden platform	Right ankle is supinated Left ankle is pronated

4.6. Test Data

Modality	Data Type	File Type	# of Files/subject	Post-Processing
ImpactSense	IMU data - accelerometer, gyroscope, magnetometer	.csv	1/test condition/foot = 6 files	Developed Algorithm - Matlab Code Base
GaitUp(Physilog)	IMU data - accelerometer, gyroscope, magnetometer	.bin	1/test condition/foot = 6 files	GaitUp Software

Vicon	Position data, anatomical joint angles	.csv	1/test condition = 3 files	Reconstruct and run raw data through proprietary Vicon IK algorithms.

4.7. Test Acceptance Criteria

Success	Fail
• All expected data is collected during the 2 minutes trial • No abrupt start or stops in the data collection	• Failure to collect all data within the 2 minute collection period • Data is corrupted • Excessive noise • Unexpected start and stop times

5. Test Reporting

5.1. Test Results

- Test results will be generated by passing data through the previously created MATLAB code base. Test results include spatiotemporal metrics, foot roll estimation, and ankle pronation/supination estimation. Further results include comparison of foot roll estimation and ankle pronation/supination angle based on ground truth data (VIcon). Results will be recorded and stored in a secure digital location (NRE Lab diskshare) and shared with MegaInTech via PDF reports.

5.2. Defect Reporting

- Defects in results will be reported on a case by case basis. Defects in ImpactSense results include inability to segment data, extract gait metrics, and/or define foot roll measurements. Defects in GaitUp (Physilog) results include inability to generate a metric report using GaitUp (Physilog) software. Defects in motion capture results include inability to generate ankle pronation/supination angles.

6. Quality Assurance and Control

- ImpactSense data will be exported between each collection and inspected to ensure data has been properly captured - use script to quickly plot data and make sure both left and right sensors collected all the data.
- If data was not collected properly - the trial will be repeated.

7. Appendices

7.1. Definitions

- Vicon: System for capturing and analyzing human and animal movement. Uses cameras and sensors to track the positions of markers placed on subjects, enabling precise motion analysis for various applications, including biomechanics and entertainment.
- Gaitup: Wearable motion analysis solutions for gait analysis. Include inertial sensors and algorithms to track and analyze human movement during activities such as walking and running.
- ImpactSense: Wearable motion analysis device that includes inertial sensors to collect data on human movement during activities such as walking.
- Temporal Gait Parameters: Refers to measurements related to the timing aspects of walking or running. These parameters include variables such as step duration, stride duration, and the time spent in different phases of the gait cycle. They are essential for understanding and analyzing the temporal characteristics of human locomotion.
- Pronation: A natural movement of the ankle during walking or running, where the foot rolls inward and the arch flattens. It is a normal part of the gait cycle that helps with shock absorption and weight distribution.
- Supination: The opposite of pronation and refers to the outward rolling of the ankle during the gait cycle. It involves the elevation of the arch and is another natural movement that helps with stability and weight distribution.
- Foot Roll: Refers to the change in foot roll angle relative to foot flat. Foot roll angle is the angle of the foot segment in the anatomical frontal plane.