Related Works

Soul Tech

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EGR 555: Mechatronics Device Innovation
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3 Smart Sole Inserts

TEAM MISSION

The team aims to expand and apply the knowledge of the real engineering industry to develop a compact and portable embedded system for gait analysis, provide real-time therapy feedback to doctors and improve gait balance for patients at the Barrow Institute.

BENCHMARKING RELATED SOLUTIONS

The following 4 products listed below are the competitors in the insole industry.

Competitor 1: Feetme
Cost: $640.00

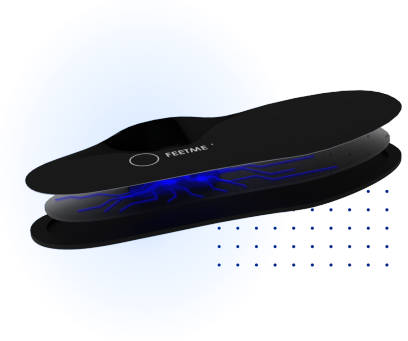

Fig 1. Feetme

Description:
Feetme is a fully functional professional mobility device that can be installed and used with ease. It involves integrating pressure and motion sensors into the insoles of shoes, which accurately calculate a set of gait parameters with each step [1].

Table 1. Feetme Insole Specifications

Battery:	Li-ion
Full charging time:	2 hrs 30 min
Active mode autonomy:	16hr
Connectivity:	Bluetooth
Cleaning:	Protective disposable over-soles
Real-time data:	Spatio temporal & pressure data
Gait parameters:	Pace, rhythm, variability, asymmetry, posture, & dynamics

Sensors Used:

- 6-axis motion sensors/IMU (Inertial Measurement Unit)
- 18 pressure sensors
- Gyroscope
- Acceleration sensor

Pros:

- Real-time analysis
- Real-time Biofeedback (Visual, vocal, or haptic) during exercise
- Compliant with medical electrical equipment safety standards
- IP55 water and dust resistant
- Wireless
- Internal storage

Cons:

- Price information is unreliable (not given through its main website)
- Limited range of sizes (35-46)

Competitor 2
Solution: Moticon
Cost: $1,995.00 (Sole) + $1,195.00 (Software License) = **$3,190.00**

Fig 2. Moticon

Description:
Moticon Sensor Insoles use pressure distribution, force readings, and motion sensing technology to provide clinical-grade mobile motion assessments. They are easy for trainers, health professionals, and researchers to use [2].

Table 2. Motion Insole Specifications

Battery:	Li-ion 2032 coin cell battery
Supply Voltage:	3.7V
Nominal Voltage:	3.0V
Capacity:	75 mAh
Memory:	32MB internal
Connectivity:	Bluetooth LE 4.2 or higher
Data Output:	Pressure, total force, COP, acceleration, angular rates, time

Sensors Used:

- 16 Plantar Pressure Sensors
- 6-Axis IMU (Inertial Measurement Unit)
- 3 Acceleration sensors
- 3 Angular rate sensors

Pros:

- No wires
- Real-time analysis
- Fits most shoe sizes
- Flexible sampling rate
- Data back-up

Cons:

- Expensive
- Lacks Biofeedback

Competitor 3
Solution: PodoSmart PRO
Cost: €2,300.00

Fig 3. PodoSmart PRO [3]

Description:
This insole uses AI algorithms and an inertial platform to record foot movements and detect mobility disorders in under 30 seconds. It calculates a variety of metrics, including cadence, walking speed, stride length, contact time, and pronation/supination angle [3].

Table 3. PodoSmart PRO Insole Specifications

Battery	Li-ion

Nominal voltage	3.6V
Charging voltage	70mA
Life cycle	+/-500loads
Full charging time	2 hrs 30 min
Active mode autonomy	33hr
Full sleep autonomy	2000h
Connectivity	USB
Cleaning	Wipe

Sensors Used:
BLE
Pressure sensors
Gyroscope [3]
Pros:

- Comes with a transport kit that includes 6 pairs of insoles with 4 cables with dual micro USB connectors, and a Bluetooth connection box.
- 33 hrs battery life
- Lightweight 66 grams
- 6 sizes from 4 to 14
- Comes with an integrated app
- Cleanable

Cons:
Extremely expensive

Competitor 4
Solution: XSENSOR Intelligent Insoles Clinical

Fig 4. Intelligent Insoles Clinical [4]

Description:
This product is a plantar pressure and gait measurement system that enables clinicians to quantify loading, motion, and footwear performance, improving patient outcomes by validating treatment plans. Measurement tools are crucial, especially for those with reduced foot sensation, and practical measurement of baseline, progress, and intervention effectiveness is essential for improving gait and footwear performance. Without an easy way to quantify changes, improvements in functional gait, loading, comfort, and safety cannot be validated [4].

Table 3. XSENSOR Intelligent Insoles Clinical Specifications

Accuracy	+/- 5%
Thickness	2mm
Pressure Range	1-128 psi, 9.7-gg.3 N/cm^3
Resolution	6.5 mm (233 sensels/sensor)

Sensors Used:
BLE
Pressure sensors
IMU
Pros:

- Comes with a transport kit that includes 7 pairs of insoles
- Lightweight 42 grams
- 8 sizes from 2 to 15
- Comes with an integrated app

Cons:
Does not have price information

The following 2 products listed below are the competitors in the socks industry.

Competitor 5
Solution: Sensoria Socks

Fig 5. Sensoria Socks [5]

Description:
Sensoria Fitness Socks are smart socks that measure gait and running metrics. The socks have textile pressure sensors and a detachable anklet that collects data on foot landing, stride length, and cadence. The data is sent to a smartphone app via Bluetooth. The app provides real-time feedback and coaching to help improve running form and also tracks steps taken, distance traveled, and calories burned. The socks are comfortable, made of a breathable material, and are available in different sizes [5].

3 sensors at 3 key positions

- Plantar pressure sensor(flexible textile pressure sensors)
- Hallux(big toe) pressure sensor- for measuring the push-off phase of stride
- The detachable anklet contains an accelerometer and a gyroscope

Pros:

- Accurate gait analysis
- Real-time coaching and Personalized training plans
- Convenient and comfortable
- User-friendly app
- Multi-functionality(not just gait analysis but other metrics like cadence, calories burned etc)
- Compatibility with a range of third-party fitness tracking apps, including Strava and Runkeeper.
- Designed with moisture-wicking fabric to keep feet cool and dry during exercise.
- Machine Washable

Cons:

- Limited battery life
- No pressure distribution across entire feet
- Inaccurate readings (especially distance tracking)
- Limited features (doesn't offset oxygen levels and heart rate)
- Low Durability
- Limited compatibility(not compatible with all smart watches and phones)
- Primarily for running, activities like working out are not explored yet.

Competitor 6
Solution: DanuSports Compression socks

Fig 6. DanuSports Compression socks [6]

Description:
DanuSports Compression Socks are designed to provide support and improve circulation for

athletes and individuals who are on their feet for extended periods of time. The socks are made from a breathable, moisture-wicking fabric that helps keep feet cool and dry, while the graduated compression technology works to improve blood flow and reduce muscle fatigue. The socks also feature a padded footbed and seamless toe construction for added comfort and support and are available in a variety of sizes and colors to suit different preferences. DanuSports Compression Socks may be a good option for athletes or individuals looking for comfortable and supportive socks to wear during sports or other physical activities [6].

All gait measurements like stance speed, length, cadence, G-force, Flight time etc and Load characteristics like Fatigue index, load and step balance etc are offered.

Pros:

- Analyze all gait characteristics.
- Track the rehab process.
- Measure and visualize parameters and progress.
- Live feedback and analysis.
- Measure walk, jog, sprint and plyometric activities.
- Compression technology, which provides a snug and comfortable fit that may help improve blood flow and reduce muscle fatigue during exercise.

Cons:

- Since it's compression socks, wearing the wrong sizes causes some serious problems.
- Possible itching, discomfort and irritation.
- Strictly for athletics purposes as they are knee length.
- The amount of time patients wear compression socks like these gradually increases with their comfort levels so it's not typical to buy and wear socks.
- Still in Beta testing so price is not known but looking at the features and target market they seem expensive.

Existing Research Papers and Patents

Research 1: A smart sock system for running gait analysis

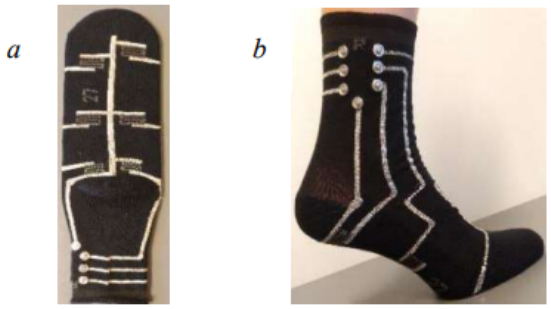

Figure 1: DAid Pressure Sock System, (a) sensors on the insole, and (b) connectors for the data acquisition unit.

Fig 7. DAid Pressure Sock

Description:
A smart sock system to monitor temporal walking and running gait characteristics and measure planar loading supination and pronation conditions for normal and flat feet. The socks are produced using ordinary knitting machines and the number of sensors can be modified according to the requirement. This system was tested by 6 participants and the results were compared with measurements taken by Pedar system insoles.
Inference: From the data, the sock system has good temporal accuracy, step and stride times calculated were close to pedar insoles, and pressure measurement was in agreement in both systems [7].

System hardware:
The sock system developed has 6 pressure sensors, two on the heel, two under the arch, and two under the metatarsals which are connected to a data acquisition unit through conductive pathways. The data acquisition unit collects measurements from all 6 sensors simultaneously and transmits them via Bluetooth to a data processing device at a sampling frequency of 200Hz, which can be adjusted to lower energy consumption [7].

Research 2: A wireless flexible sensorized insole for gait analysis.

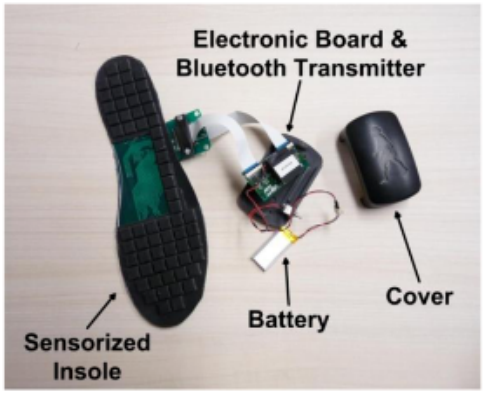

Fig 8. Wireless sensorized insole for gait analysis.

Description:
A pressure-sensitive flexible foot insole system for monitoring pressure distribution during walking. The system was experimented on two normal subjects and was compared with results from an instrumented force platform.
Inference: The developed system had quantitative disparities when compared with the force platform but has a high qualitative correlation [8].

Pros:
- Non-sensitive to humidity and temperature.
- Non-amplified output due to which amplifiers are not required leading to a smaller size electronic board.

Cons:
- Usage of a unique calibration curve for the sensors which may affect the estimation of vGRF
- The noise threshold applied may lead to errors in the estimation of vGRF.

System Hardware:
A transduction unit consisting of a black-dyed silicone layer divided into 64 cells and a 0.2mm PCB housing the optoelectronic

components. An electronic board consisting of four ADC, STM32F103x8 microcontrollers, power, and communication socket. Data transmission to a remote device is done through Bluetooth at a sampling rate of 100Hz [8].

Research 3: Gait analysis by using Smart Socks system

Description:
Gait analyzing socks inspecting the gait and concluding whether the gait is normal gait or pronation or supination.

Method:
A set of parameters is extracted from the measurements obtained from the sensor and then combined into a multi-dimensional vector. This vector is compared to other predetermined vectors by the sum of the Manhattan distance method and then concludes the type of gait.

Hardware:
Five textile pressure sensors are incorporated into cotton with elastane/polyamide yarn socks shown below.

Fig 9. Socks [9]

Knitted silver-coated thread Shieldex 117/17 (Statex Produktions und Vertriebs GmbH) is used as electro-conductive lines. A circuit was attached to the end of the lines with a Bluetooth transmitter as shown in the figure below [9].

Fig 10. Ankle Attachment Microcontroller and other embedded controllers

Pros:
- Easy to wear
- Easy to wash
- Inexpensive
- Comfortable
- No size constrain
- Wireless data transfer

Cons:
- No information on gait types other than normal pronation and supination
- No information about spatial data
- No bio-feedback
- No information on exact values of pressure and other data

Inference:
The electro-conductive line is clean and good, we can incorporate this into our product. The Manhattan distance method is also so useful in distinguishing between gait types.

Patent 1: Method and apparatus for analyzing gait pattern

Description:
Sole-like Apparatus to measure gait pattern and provide instructions for guiding the user.

Method:
Valid pressure points are calculated by the data from the sensor by eliminating the pressure lower than the threshold and calculating the center of pressure (COP). The COP movement trace from heel strike to toe-off is used to find the gait pattern. The process is shown in the figure below [10].

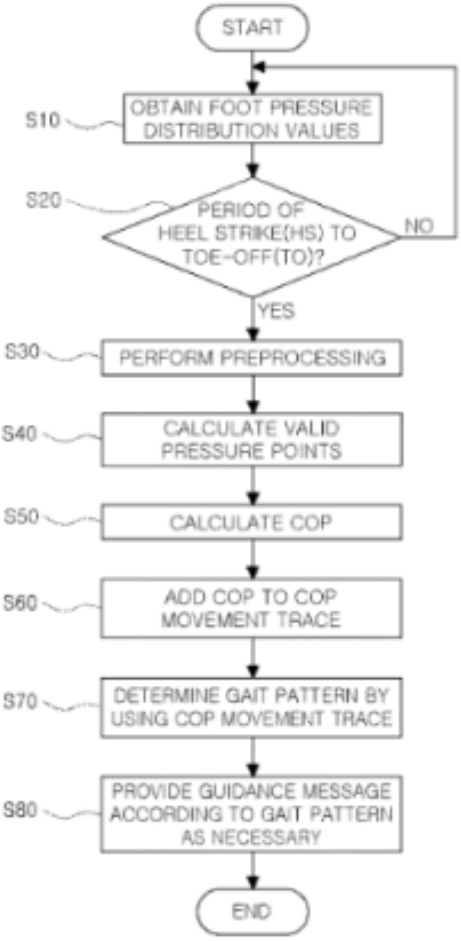

Fig 11. Process Graph [10]

Hardware:
Many Force sensing resistors (FSR) are aligned together as an array in a sole as shown in figure 12 and it is connected to a center of pressure (COP) movement trace calculation unit, a gait pattern correction unit, a gait pattern determining unit and an alarm unit. It is also connected to a wireless unit that sends data to a computer [10].

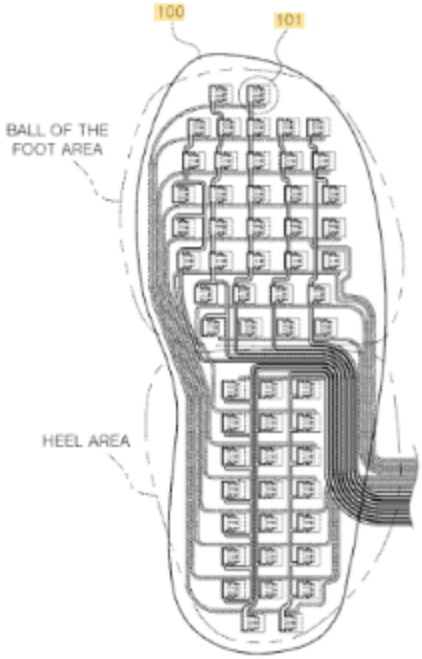

Fig 12. Pressure Sensor Array [10]

Pros:
- Measures and identifies every gait type
- Wireless data transfer
- Inbuilt alarm unit

Cons:
- assumed pressure
- No bio-feedback
- No information of spatial data
- Not easy to wash

Inference:
A large number of sensors provide more information but it gets too complex, soles can bend and provide inaccuracies but that can be rectified by software by eliminating the false pressure values.

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Contributions

Danis: Researched competitors in the Sole industry and Format of paper.

Tatwik: Researched competitors in the Sole industry and Format of paper.

Sriram: Researched existing papers and patents.

Sabareesh: Researched existing papers and patents

Vishnu: Researched competitors in the sock industry