Quantitative Analysis of Gait Dynamics Using Foot-Worn Force Sensitive Resistor Insole: A Statistical Approach

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***Abstract*—This work introduces a novel statistical approach to the analysis of walking gait dynamics using a foot-worn force-sensitive resistor (FSR) insole. Gait analysis is an important aspect in many healthcare applications and biomechanical research pursuits but conventional methods often require expensive and complicated equipment that limit their widespread use. Conversely, our technique mainly uses statistical analysis to find insightful findings from FSR data as opposed to using conventional methods. An FSR insole records detailed fluctuations of pressure during walking, providing rich information about foot-ground interaction dynamics. We thus investigate correlations between gait dynamics and individualized parameters such as height, weight,and BMI using rigorous statistical analysis. This examination brings out hidden patterns and trends within the gait data that provide meaningful numerical insights into human locomotion. Thus, our model shows promising results on gait pattern recognition hence has potential applications in personalized healthcare, rehabilitation monitoring and sports performance analysis. The utilization of statistical techniques allows us to propose practical solution for gait analysis which is cost effective at the same time making it accessible and user friendly in real life situations.The fact that our approach accurately models and examines the patterns of walking gait is highlighted through such experimental validation. This step forward in methods for analyzing gait significantly improves on traditional ways. The applicability of our work can be seen in different areas from medical to wearable technologies that foster human abilities and health.**

***Index Terms*—foot-pressure analysis, Force Sensitive Resistor, healthcare, statistical analysis, walking gait analysis**

I. Introduction

WALKING gait analysis is a fundamental building ingredient in many fields, from sports performance enhancement to medical diagnoses. Understanding the intricacies of human movement is crucial to identifying abnormalities, developing personalized recovery programs, and enhancing sports training regimens. Gait analysis's scalability and accessibility have always been constrained by its reliance on complex and usually expensive technologies. Recent developments in sensor technology, most notably the integration of Force Sensitive Resistor (FSR) technology into wearable insoles, have revolutionized gait analysis. The dynamic pressure changes the foot creates while walking can be usefully and discreetly recorded with the help of these insoles. But considering the amount of data generated, making use of these trustworthy methods for gathering data is a major analytical and interpretive challenge. As a practical and reasonably priced approach to collect information on human gait dynamics, the authors of [6] claim that integrating wearable sensors into insole designs has demonstrated promise as a gait analysis technique. An insole gait acquisition system can be made using an Inertial Measurement Unit (IMU) and a piezoelectric disk (PZT), per one such study. The IMU is positioned on the shoe sole in crucial locations at the toe, metatarsal, and heel. Combining PZT sensors (data on pressure distribution) with IMUs (foot orientation and movement tracking) allows a comprehensive understanding of human gait dynamics. To support the sensors and ensure their dependability and longevity during data collection, aluminum frames are integrated into the hardware design.

The introduction of the Smart-Insole Dataset in [8] further emphasizes the significance of computational methods in gait research, particularly in relation to neurological and musculoskeletal issues. This dataset, which consists of pressure sensor insole data, includes subjects who are elderly, healthy, and patients with Parkinson's disease. The measurement method provides valuable insights into the temporal and spatial aspects of gait and includes standardized tests such as the Walk Straight and Turn test and a modified version of the Timed Up and Go test. This dataset uses algorithmic gait event detection and manual annotation to support the development and evaluation of computational models for gait analysis, with a focus on distinguishing between many participant groups.

Significant monitoring of gait parameters for various chronic diseases such as stroke, Parkinson's disease, and diabetes is discussed by Junliang Chen in [1]. Force platforms (FP) integrated with multiple sensors are generally used for the measurement of traditional plantar pressure distribution; however, they are limited in their accessibility due to its heavy weight, large volume, high cost among others.

The approach used in [1] aimed at optimizing the production of orthotic shoe insoles using two novel materials through experimental steps. The research procedure involves selecting one patient suffering from diabetes mellitus, scanning his/her foot, reverse engineering with CAD software, designing the insole using Curve Base Surface (CBS) Modeling, and then carrying out experiments to optimize manufacturing parameters using Taguchi method. These results indicate that traditional EVA rubber foam takes much longer times to manufacture than these new materials and it is also not as smooth on the surface as them.

The authors in [3] proposed a technique merging bio-mechanics and digital/physical technologies that facilitates redesigning of shoe soles through topological optimization based on individual foot shape together with plantar pressure maps. This method includes scanning of the participant's feet to get the data regarding plantar pressure, importation of this data into CAD software, doing structural simulations in order to confirm mechanical performance and choosing an appropriate material for additive manufacturing.

However, there are several limitations such as lack of validation beyond mechanical performance like comfort or durability testing possibly challenging scalability and mass production in the paper.

In [4], the authors present a new instrumented insole system that is built specifically for comprehensive gait monitoring and analysis by incorporating FSRs as well as flexible bend sensors (FBS) for accurate measurement of plantar flexion angle, foot force distribution during walking. Methodology includes developing hardware components consisting of sensors, signal conditioning circuits, a data acquisition device; alongside software for real-time signal visualisation and analysis.

The results illustrate how well the system can capture force as well as planter flexion dynamics during gait cycle though with insignificant limitations pertaining to sensor's accuracy and timing of changeover.

The research described in [5] involved careful designing and implementing an integrated insole system for gait analysis using pressure sensors, specifically force sensitive resistors (FSRs). The study adopted a systematic strategy starting from identification of sensor positions based on footprint analysis then integrating FSRs into the structure of the insole. It is important to note that this architecture provides wireless communication capabilities for easy data transmission. For rigorous testing, the obtained data are put to experiments with the aim of unveiling the nature of symmetrical gaits found among the healthy subjects.

Nonetheless, the study recognizes some limitations such as further exploration and validation of bio-mechanical parameters in various subject populations and environmental conditions.

For instance, [7] introduce an Internet of Things (IoT)-based monitoring system using Force Sensing Resistor (FSR) sensors embedded in shoe insoles that was designed for real-time analysis of foot pressure distribution. The research methodology involved placing FSR sensors at strategic locations within the insole; heel, lateral side, metatarsal head and anterior part capturing overall pressure data through out the foot. Wireless transmission takes this information, is fed into a microcontroller, which processes it for interpretation on pressure distribution patterns.

While this experiment is novel in its kind but there were shortcomings such as non-linearity and hysteresis of FSR sensors, which may lead to measurement faults regarding pressure levels showing how gait analysis results may not be reliable.

The study in [9] aims at investigating how different carrying methods affect human gait parameters and trunk bending when lifting and carrying a 5-gallon water bottle. This experiment included 23 healthy males aged between 18 and 30 who carried out different carry scenarios utilizing diverse assistive devices. The findings indicated that supportive devices helped to decrease the variation in gait pattern which improved the balance and stability during movements. However, this study has limitations like not considering various types of surfaces and age groups, which need further studies in future. Criticality Analysis (CA) using SVM classification is described in [10], to evaluate gait in overweight adolescents resulting into 78.2%-90% accuracy rates over a period of six weeks. Metabolic stress can be detected by it using IMUs; nevertheless, fluctuation in its accuracy due to individual factors makes it challenging for it to become highly accurate. It implies the method relies on non-linear data representation as well as supervised machine learning and highlights the potential for objective monitoring of gait disorders during treatment. The authors of [11] propose a photoelectric system by OptoGait is validated for studying children's gait against stereophotogrammetry. The methodology compared three LED filter settings, showing high consistency and acceptable biases. This indicates that OptoGate's 2 LED configuration performs better than any other in terms of spatiotemporal parameters.

[12] examines how variations in hemiparetic gait patterns can affect improvements in walking speed. It relies upon the use of Linear Fit Method to measure between stroke survivors' gait and healthy baseline walkers regarding walking speed. Linear Fit parameters that describe changes in gait pattern have been found to significantly correlate with walking speed in both paretic and non-paretic limbs indicating joint kinematics change with increasing walking speed.

In [13], the authors propose a gait analysis system based on smartphone helps to determine specific parameters for normal and abnormal walking, with a recognition accuracy of over 98% in step event detection and parameter estimation. Adaptive algorithms improve performance across different population groups and gait disorders, which offer personalized monitoring for diagnosis as well as rehabilitation in healthcare settings. [14] describes quantitative analysis for evaluating hemiplegic foot drop in post-stroke patients using IMUs for rehabilitation assistance.

[15] centers on kinematic and dynamic modeling of novel hybrid biped robot's mechanical leg and its gaits planning and simulation on a flat ground. At the initial stage, kinematics analysis was done on the hybrid leg whereby it established relevant models. Consequently, gait planning was performed by use of the inverted pendulum model, dividing walking into stages and calculating motion trajectories.

In [16], the authors analyze three ways of gauging steps with the help of depth sensors. Results indicate that foot velocity (FV) is a more detailed method for gaits while center of mass (CMH) is robust but provides less information. The investigation in [17] employs deep metric learning (DML), in order to use platform data for individual re-description (re-ID) and achieve the highest accuracy with FCNN models up to 85%. Some of these challenges include reduced precision rates in cross-speed, cross foot wear and this underlines the shoe variations as well as changes in walking speed.

[18] emphasizes on how important it is in assessing gait cycle as well as balance issues. A range of instruments like laboratory systems, non-wearable sensors (NWS), and wearable sensors (WS) offer physiotherapists and neurologists objective measures to enable them plan for personalized rehabilitation services.

[19] introduces an advanced wearable device based gait analysis system that evaluates health through motion. Traditional approaches are expensive and confined to laboratory environments, thus there has been a need for wearable alternatives. However, inertial methods lack precision and do not take into consideration regularities of movements and foot dynamics. The proposed technique achieves an accuracy level of 1.5 cm for stride length estimation as well as 1cm clearance height for the foot which is competitive with visual sensor-based systems. It employs multi-level information fusion architecture and human-walking constraints, thereby improving its accuracy. This includes a constraint Kalman filter implementation using low-cost hardware.

The authors of [20] introduces a low-cost, wearable and wireless insole-based gait analysis system using force sensitive resistors. This study provides an affordable way to analyze abnormal gait especially in the case of stroke patients. Insole measures accurately ground reaction forces and ankle moments that are highly correlating with clinical motion analysis laboratory data.

[21] focuses on the increasing need for prosthetics and orthotics by proposing a gait classification system in human walking through electromyography (EMG) signals. The initial, mid- and final gait phases are divided according to EMG signal from bicep femoris longus and gastrocnemius lateral head muscles using artificial neural networks (ANN) based machine learning. In fact this research reveals an overall accuracy of 96%; which is highly notable with the Levenberg–Marquardt backpropagation training algorithm.

[22] delves into gait recognition as a biometric system that uses unique walking patterns to identify people. It also argues how technical choices fit in different situations like security and medical tests. The study in [23] compares four deep learning models for generating personalized gait trajectories in rehabilitation robotics. The proposed LSTM-CNN sequential model has potential for producing stable trajectories across different walking speeds (0.49-1.76 m/s) using hip, knee and ankle joint data from a public dataset of healthy individuals. The model shows its potential in predicting accurate trajectory with high correlation of 0.98 and R2 Score of 0.94 between actual and forecasted trajectories. The aim of the meta-analysis, as in [24], was to compare the characteristics of gait between total knee arthroplasty (TKA) and unicompartmental knee arthroplasty (UKA). The study included thirteen studies (369 knees) which were analyzed, showing that there are significant differences favoring UKA in walking speed, stride length, degree of knee flexion when walking, vertical ground reaction forces, moment placed on the knee during turning, extent of the knee bending and Knee Society Score Function score.

The authors of [25] propose a novel optimization based metaheuristic approach for selecting the best gait parameter from 800 datasets resulting in 10 features that explain 85% variance (6 ankle, 4 knee).

Our research offers a novel solution to this problem by combining traditional statistical analysis methods with the usefulness of FSR insole technology. Through the use of statistical techniques, we are able to identify nuances in datasets that are useful for comparing and examining gait patterns. This method enables us to precisely identify and analyze individual walking patterns by measuring the degree of similarity between various gait cycles.

II. System Architecture

In this study, we provide a novel four-layered system design, as shown in 1, with the aim of improving gait analysis's efficacy and accuracy in identifying irregularities in gait that could be linked to various disorders. Using Force-Sensitive Resistor (FSR) insoles, which have sensors to record dynamic pressure changes while walking, is the initial stage in the data collection process. As seen in Fig.2. The ESP32 microcontroller is used in the second stage to process and facilitate the transfer of the data from the FSRs. In the third stage, the data is received and statistically evaluated on the local machine. The final, fourth step of data distribution makes use of sophisticated statistical techniques like regression modeling and correlation analysis. These methods provide information on data patterns and trends that can indicate underlying medical conditions.

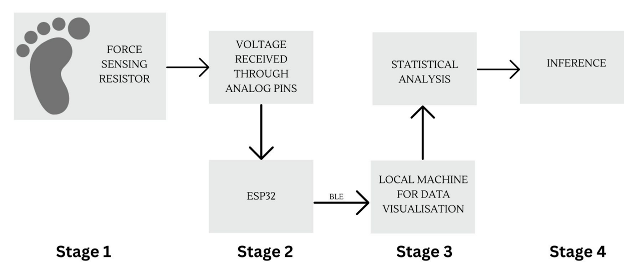

Fig. 1. Flowchart for the proposed 4-layered architecture.

Its unique architecture for processing spatial data allows it to interpret the intricate heat maps of the pressure points that the FSR insoles generate with ease. This setup not only captures detailed bio-mechanical data through the insoles but also processes and analyzes this data to identify potential health issues related to gait abnormalities. Fig.3 and Fig.**??** represents the actual hardware used for data collection.

A. Micro-controller

The ESP32 microcontroller serves as the primary processor for gathering, organising, and transmitting data. The ESP32 chip receives real-time sensor readings from the FSR insole and uses its processing power and Bluetooth capabilities to retrieve data.

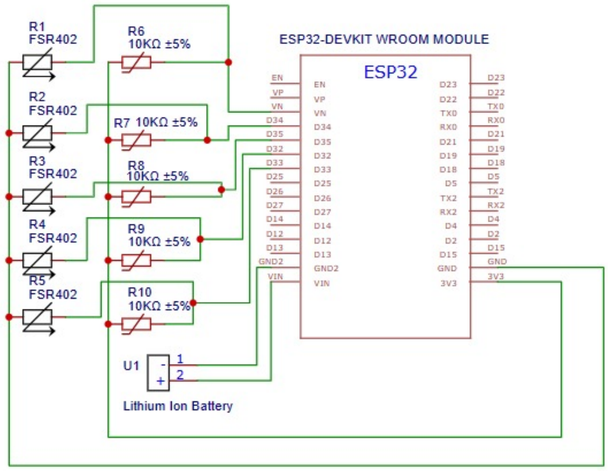

Fig. 2. Schematic of proposed architecture.

Fig. 3. Top-view of the hardware.

B. Python-based Streamlit Graphic User Interface Development

A significant system milestone is a Python-based graphical user interface (GUI) on Streamlit that enhances data management and user interaction. To make gait analysis complete, this GUI allows easier foot pressure recording from both feet at the same time whenever someone is walking. The Python-based Streamlit GUI does not just have basic file organization and recording, but also multiple other capabilities to improve user control thereby making it possible for real-time monitoring during recording. Among these helpful features is a slider which can be used by users to adjust the time length of the data collection session in minutes. Furthermore, via GUI users receive an updated status about their recording progress. Once a data collection session ends, users only need to choose a file name under which they would like to save such data. These two sections are then combined into one CSV file that contains raw pressure readings as well as characters necessary for labeling legs and sensors for easy analysis of the collected information. Users with varying levels of technical knowledge can effectively use this system because of the GUI's emphasis

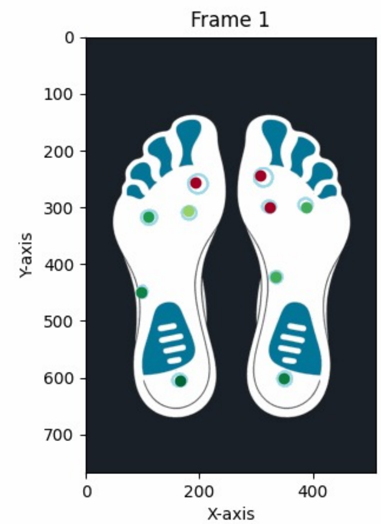

Fig. 4. Real-time sensor data visualisation.

on efficiency and simplicity.

C. Real-time Sensor Data Acquisition

Real-time sensor data collecting was essential to our study's ability to fully capture the nuances of walking gait dynamics. With the use of FSRs placed on each participant's shoe, we carried out intensive data collection sessions with a heterogeneous group of about ten people. During a standardised walking routine, foot pressure data was constantly captured in real-time for five minutes for every participant. During the data acquisition process, the ESP32 microcontroller transmitted data to the local machine via Bluetooth, allowing real-time feedback and monitoring. Data were collected, analyzed and saved as CSV files in case further research is required. 12-bit analog-to-digital converters (ADCs) were used, where 0 and 4095 represented the highest and lowest pressure respectively. This is due to the fact that an instantaneous voltage matching to the pressure of the Esp32's analog pins is obtained via a voltage divider circuit. The circuit makes use of pull-up resistors, each having a 10 kilo-ohm value. To convert these ADC values into equivalent pressure in kilograms-force (KgF), a calibration factor was applied to each sensor reading. Furthermore, as seen in 4, our specially designed foot GUI offered instantaneous visual feedback on the pressure spots that were activated when a person was walking during the data collecting stage. The GUI showed the real-time reaction of each FSR under the soles as red points indicated areas without pressure and green points represented places under pressure.

D. Data Pre-processing

Following the real-time data acquisition phase, the raw foot pressure data stored in CSV files underwent a meticulous data pre-processing regimen to ensure its readiness for statistical analysis. The data(ADC reading) when was being recorded was multiplied by the calculated sensitivity value based on the range of the FSR and 12-bit ADC.

$$\text{Sensitivity factor } (\phi) = \frac{RangeofFSR}{RangeofADC}$$
$$= \frac{10-0}{4095}$$
$$\approx 0.00244$$

This pre-processing pipeline included a number of essential steps meant to improve the dataset's quality and practicality. The first step involved a comprehensive data cleaning procedure to find and remove any noise, artefacts, or outliers from the raw sensor values. Normalisation procedures were then used to reduce variances in sensor sensitivity between multiple recordings or individuals and streamline the sensor data. Post standardisation, useful information was extracted through applying feature extraction techniques to the raw readings of pressure from the force-sensitive resistor (FSR) insole that was worn on the foot. These included high-pressure measurements, pressure distribution patterns over all of the foot components, and temporal aspects of the foot-ground interaction throughout the gait cycle. As dimensionality reduction methods, PCA (principal component analysis) and feature selection techniques were utilised as well to streamline the information set and reduce the computational burden without losing important data.

III. Statistical Findings of Walking Gait

In this section, we have explored the correlations between individuals' physical characteristics—namely height and weight—and their walking gait dynamics by analyzing the mean pressure values across different foot regions.

Sample	Weight (kgs)	Max Mean (Left)	Max Mean (Right)	Height (in m)	BMI	Sole size
1	80	8.806488	7.487	1.778	25.306	10
2	53	8.732272	7.035	1.7018	18.300	09
3	56	8.261842	5.045	1.6256	21.191	08
4	75	8.662976	6.793	1.8288	22.424	10
5	95	8.989448	6.372	1.8034	29.210	10
6	60	9.222712	6.914	1.7018	20.717	09
7	59	7.666968	7.268	1.524	25.402	08

A. Height-Mean Relationship in Gait Patterns

This section presents a detailed analysis of the relationship between height changes and various walking elements as determined by the force-sensitive resistor (FSR) insole worn on the foot, as seen in Fig5. We were able to determine the direction as well as the magnitude of relationship between multiple gait measures and height by use of quantitative method through correlation analysis. We used correlation coefficients to investigate if there existed significant associations between height and parameters such as stride length, step frequency, pressure distribution patterns and gait symmetry. This shows that there is a significant positive relationship in table 1 between height and average gait parameters and suggests that particular aspects of gait dynamics are markedly affected by one's stature. Tallness creates uniformity in gait features concerning stride size and pressure distribution. Taller individuals tend to have longer limb segments and different biomechanics which influence how they move hence this conclusion agrees with biomechanical principles.

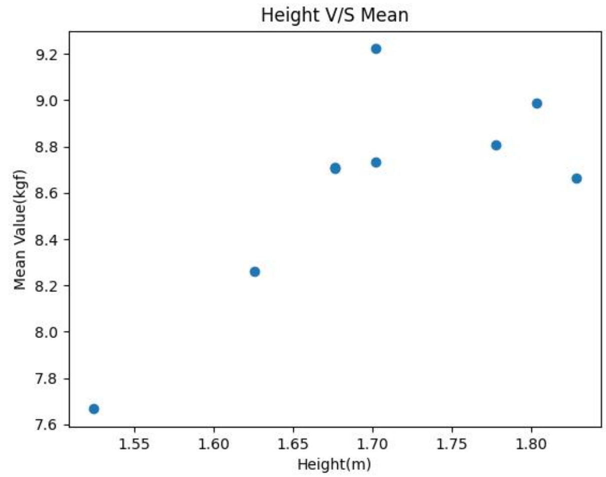

Fig. 5. Height vs Mean graph for data-points.

TABLE I
Coefficient Analysis

Parameters	Correlation with Mean
Height	0.74
Weight	0.36
BMI	0.08

B. Weight-Mean Analysis of Gait Dynamics

A thorough examination of the complex relationship between body weight and gait dynamics is necessary to fully understand this element of human movement. In this part, as illustrated in Fig6, we carried out a detailed analysis to determine the ways in which weight differences impact several gait characteristics recorded by the FSR insole. We used robust statistical methods to try to understand the intricate link between weight and gait patterns, including multivariate regression modelling, correlation analysis, and machine learning algorithms. The body weight and different gait metrics relationship was more clearly understood through the use of correlation analysis. There was quantification of association between weight and stances, duration of swinging, peak pressure values as well as entire gait symmetry by calculating correlation coefficients.The 0.36 correlation coefficient in Table.I is a reflection of moderate positive relation between mean gait parameter and weight. Some extent of connection exists between human weight and few aspects of locomotive dynamics. However, the correlation coefficient is rather small which indicates that there are other factors affecting walking patterns besides mass. Zones containing possible considerations for this weak connection may involve dissimilarities in how individual's bodies are made up together with mass allotment from person to person. For example, those people having higher weights could show differences in pressure distributions or asymmetries in stance time which

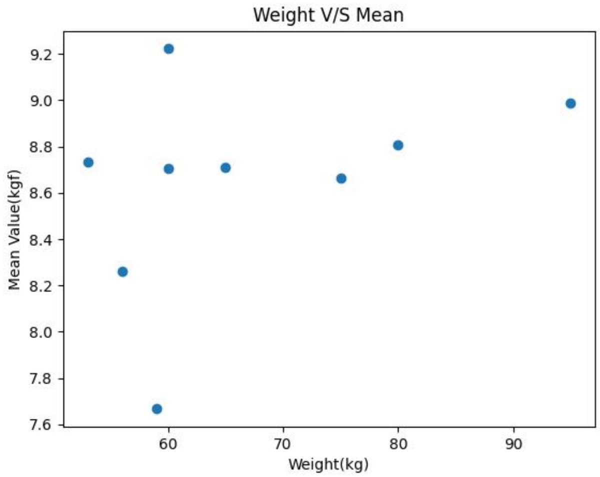

Fig. 6. Weight vs Mean graph for data-points.

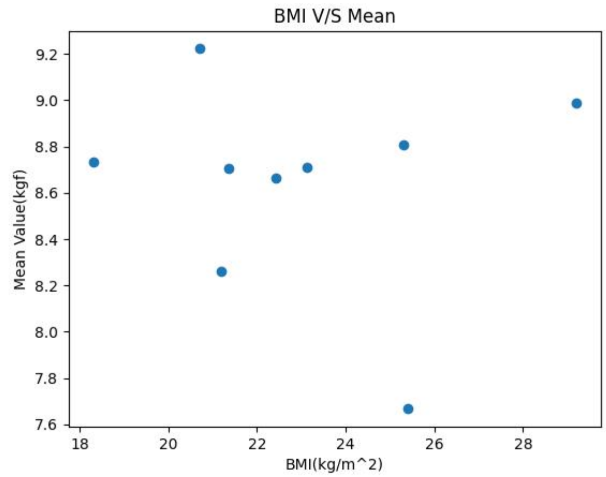

Fig. 7. BMI vs Mean graph for data-points.

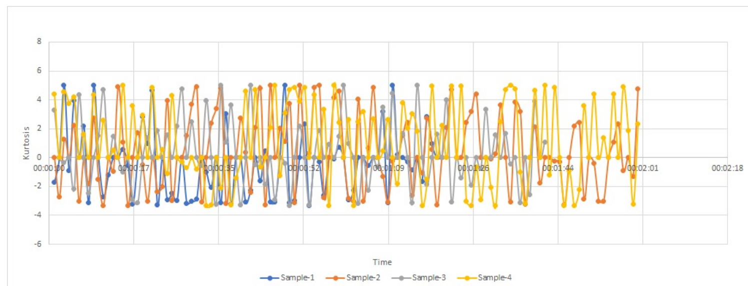

Fig. 8. Time vs Kurtosis graph for left foot for data-points.

are indications that their gait mechanics have been modified so as to bear much burden on them.

Regression multivariate modelling enabled us to separate the unique influence of weight on some aspects of movement by controlling for potential confounders. For regression analysis, we have used predictive models which can be used to determine gait parameters based on individual's weight, height and other important covariates. The application of these models has also improved our understanding about how weight affects gait dynamics and allowed identification of potential biomechanical markers associated with obesity or underweight conditions. We noted that subjects with relatively higher weights had been changing their gait parameters such as pressure distribution patterns, stance time asymmetry as well as dynamic balance control.

C. Body Mass Index and its Impact on Gait Dynamics

Body mass index (BMI) is a composite measure which relates an individual's weight relative to his/her height and widely used for assessing overall health and nutritional status. In this section,investigated how variations in BMI influence gait dynamics, leveraging the rich dataset obtained from the FSR insole, as represented by Fig7. With correlation analysis we were able to figure out how weak or strong the connection is between Body Mass Index (BMI) and different variables related to gait. In this connection, it showed us what happens when BMI varies in terms of crucial aspects of dynamic stability while walking. The small positive correlation coefficient obtained from Table.I is 0.08 for mean parameters, which implies that there is a weak effect. The surprising thing about this finding is that there does not appear to be much relationship between certain gaits' motifs and body mass index (BMI) in our database. As an example, other factors that may explain this lack of cohesion include the complex interplay between body composition and muscle mass with respect to one's walk mechanics. On the contrary, the BMI index does not tell whether someone has more fat content than muscles or vice versa. A lot of people with similar BMI but different underlying muscle strengths and distributions can exhibit entirely different gait patterns. Consequently, these findings imply that BMI alone might not be the best predictor of gait patterns but further research should aim at investigating complexities surrounding association between body composition and locomotor biomechanics. From there it is clear that until 24 kg/m^2, there are several variations in the data while thereafter, there is an almost constant increase in the mean. Our investigation into BMIs also provides significant input for understanding how BMI impacts on gaits mechanically and kinetically. This shows that higher BMIs were associated with changes in foot pressures pattern, duration asymmetry of stance phase as well as dynamic balance control during walking.

D. Kurtosis Analysis

By comparing time against kurtosis graphs provided for both legs, one could investigate the stability and uniformity of the distribution of pressure throughout gait cycle."Tailedness" of a random variable's probability distribution was established by kurtosis' in order to find any kind of inconsistencies or irregularities in pressure patterns needed to identify minor abnormalities during walking early,on as shown in Fig8 and Fig9.

The kurtosis-time graph oscillations are very clear with most of them clustering close to the positive or negative side of y-axis, their bases being along x-axis. The similarity between

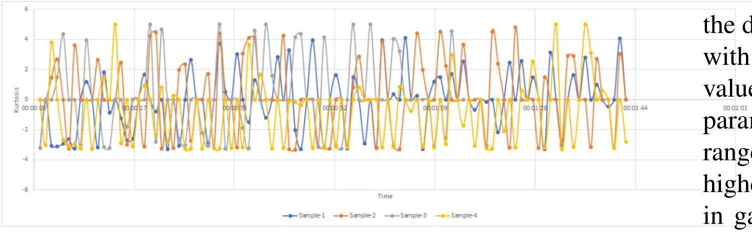

Fig. 9. Time vs Kurtosis graph for right foot for data-points.

these curves implies that there is a connection between the fluctuations in Kurtosis values to some specific phases of Gait Cycle.

IV. Results

A. Height vs Mean Analysis

The observation that mean values rise nearly linearly to a height of 1.68 metres before becoming dispersed indicates that there may be a shift in the correlation between height and the gait characteristic under study. This trend might point to several important conclusions:

1) Biomechanical Influence: The linear increase in mean values may represent the biomechanical laws guiding human mobility up to a given height. Growing taller people may show systematic changes in several gait characteristics because to differences in muscle activation patterns, joint mechanics, and limb length.

2) Threshold Effect: The dispersion of the mean values at 1.68 metres height might represent a threshold that, when exceeded, allows for the influence of other variables and increases the variability of gait characteristics.

3) Individual Variability: The larger scatter in mean values beyond the threshold height suggests that individuals of similar heights have more variation in their gait metrics.

B. Weight vs Mean Analysis

The observed rise in mean values over 70 kilograms points to the possibility of a threshold effect in the weight-to-analyzed gait parameter relationship. Weight fluctuations may not significantly affect the mean results below this level, suggesting a somewhat steady gait pattern. Once this threshold is exceeded, an increase in weight begins to impact the gait parameter and cause a discernible shift in average values. The marginally higher mean values found in association to increased weight suggest that weight may have a slight effect on the gait characteristic under investigation. This study raises the potential that those who weigh more than average may exhibit somewhat different gait dynamics from others who weigh less.

C. BMI vs Mean Analysis

The significant variations in mean values observed until a BMI of 24 kg/m^2 suggest the presence of a threshold effect in the relationship between BMI and the analyzed gait parameter. Below this threshold, variations in BMI lead to considerable fluctuations in the gait dynamics which indicated the differences in biomechanical adaptations across individuals with varying body types. An almost linear increase in the mean values beyond a BMI of 24 kg/m^2 indicates that the BMI parameter greatly influences the analyzed gait parameter in this range. This finding is indicative of the fact that individuals with higher BMI values may exhibit more consistent alterations in gait mechanics, potentially due to increased adiposity and associated biomechanical changes.

1) Kurtosis vs Time Analysis: The dynamic nature of foot movements when walking may be responsible for the observed oscillations in the kurtosis versus time graph. Specifically, there are phases during walking where the foot is raised off the ground (swing phase) and others where it touches the ground (stance phase). These periods correspond to different pressure levels on the force-sensitive resistor (FSR) insole. In swing phase, while lifting off from the earth's surface, FSR can record no or less pressure, such that kurtosis values reduce or alternatively move towards negative end of x-axis on graphs. However, when stances comes in contact with the earth again FSR picks up higher pressure which results into increased kurtosis values or oscillate towards positive end of x-axis on the graph. The results of the mean analyses among height, weight, and BMI have added to the existing literature in gait analysis by explaining complex relationships between anthropometric variables and gait dynamics. In this respect, it provides an explanation for the threshold effects and biomechanical factors as well as individual variations which are valuable in understanding human locomotion across populations. Additionally, kurtosis versus time analysis brings time dimension into gait analysis thereby emphasizing dynamic nature of foot movements during walking. The field of gait analysis has been made more convenient and accessible through a four-tier structure that included data collection, processing, analysis and prediction phases with GUI creation and statistical works. It is a structured architecture that enhances workflow efficiency so that there is a smooth flow of data from collection to prediction; while an intuitive GUI enables the users to simply record or manage data and monitor them in real-time. Through the use of advanced data analysis techniques such as correlation and regression, our analysis reveals complicated relationships existing between physical attributes and gait parameters that offer valuable insights into human locomotion.

V. Conclusion

In this study, a unique statistical technique was developed to analyze walking gait dynamics using a foot-worn force-sensitive resistor (FSR) insole. It was possible to gain important insights into the complicated interplay between anthropometric variables and human locomotion through an extensive statistical analysis of height, weight and body mass index (BMI) with respect to the parameters of gait. Furthermore, by analyzing kurtosis for temporal dynamics of foot movements during walk, it became apparent that there is a complex relationship between gait phases and distribution of pressure under the feet.

Our work has made a significant contribution to the field of gait analysis by identifying threshold effects, biomechanical influences and individual variations in gait dynamics. For clinicians, researchers and practitioners involved in mobility assessment, rehabilitation and injury prevention this study reveals useful findings about critical points of transition as well as variability in gait parameters. The incorporation of statistical analysis techniques sets the stage for further studies that seek to improve gait analysis methods. The findings of this research study will guide the designing of more advanced machine learning (ML) and neural network approaches that will accurately and efficiently predict gait patterns as well as detect anomalies. By using these findings, it will be possible to come up with highly accurate mathematical models such as ML and ANN in predicting GAIT patterns while identifying abnormalities within a high degree of accuracy. Additionally, this research has implications for health care applications, wearable technology development and sports performance analysis. This implies that researchers can extract useful information from FSR data through statistical analysis which can be used by clinicians to develop individualized interventions; optimize rehabilitation programs; or even enhance athletic training regimes.

To sum up, this study digs into our knowledge of walking mechanics and emphasizes on the significance of statistical evaluation in revealing typical models and tendencies relating to human motion. Based on this, future studies should develop upon these results by using different techniques and technologies that will advance gait analysis accuracy, efficiency and universal application.

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