BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Research article

Gait Analysis Technologies for Evaluating Biomechanical Deviations: Insights from a Pilot Study on Healthy Athletes and Foot Deformities

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Citation: Avramescu E.T., Amzolini A,M., Bumbea A.M., Patru S., Traistaru M.R., Neagoe C.D., Ionescu G., Munteanu C. and Matei D. - Gait Analysis Technologies for Evaluating Biomechanical Deviations: Insights from a Pilot Study on Healthy Athletes and Foot Deformities
Balneo and PRM Research Journal **2025**, *16(1): 772*

Academic Editor(s):
Gabriela Dogaru

Reviewer Officer:
Viorela Bembea

Production Officer:
Camil Filimon

Received: 16.02.2025
Published: 31.03.2025

Reviewers:
Mihai Hoteteu
Gyongyi Osser

Abstract: Gait analysis is an essential tool for assessing musculoskeletal function and identifying biomechanical abnormalities. This study aimed to establish normative reference values for gait parameters in young, physically active individuals and to identify deviations associated with foot deformities. Methods: A cross-sectional observational study was conducted on 102 healthy young adults engaged in performance sports. Gait parameters were recorded using the RSscan plantar pressure distribution platform. Outlier identification methods were applied to exclude 12 participants with significant deviations, resulting in a final sample of 90 subjects. Descriptive statistics and comparative analyses were used to evaluate maximum force, impulse, load rate, and contact area across ten anatomical foot regions. Results: The final normative dataset established baseline values for plantar pressure distribution and biomechanical force dynamics. Among excluded participants, 33% exhibited pes planus (flatfoot), and one case presented pes cavus (high arch), both associated with altered pressure distributions and deviations in temporal gait parameters. Statistical comparisons confirmed significant variations in foot loading patterns and pressure maps ($p<0.05$). Conclusions: This study provides a comprehensive reference for gait parameters in young, healthy adults and highlights the clinical relevance of individualized gait assessments. The findings underscore the utility of plantar pressure analysis for early detection of biomechanical abnormalities that could contribute to musculoskeletal dysfunction. These insights can aid in the optimization of rehabilitation strategies, sports performance assessments, and orthopedic interventions. Clinical Implications: The results emphasize the need for targeted interventions in individuals with foot deformities to prevent long-term functional impairments. Future research should explore longitudinal implications of biomechanical deviations in active populations.

Keywords: Gait analisys, Biomechanical Deviations, Foot Deformities

1. Introduction

Despite the apparent simplicity of walking—placing one foot in front of the other—it is a complex biomechanical process. Walking is not only fundamental to human movement but also reflects an individual's personality and physical state. While normal gait exhibits common patterns across individuals, subtle individual-specific variations are always present, making each person's walking pattern unique [1,2].

The study of gait alignment and three-dimensional (3D) kinematics of the lower limb, as well as plantar pressure measurement, has revealed that one of the most common and significant risk factors for dysfunction is improper movement execution. Gait analysis systematically evaluates human movement and walking dynamics, often referred to as motion analysis [3]. This process involves measuring and assessing gait patterns in both healthy individuals and patients with movement disorders. It is widely utilized in sports biomechanics to optimize performance, as well as in clinical settings to diagnose, plan, and monitor treatment for conditions affecting mobility. Gait analysis helps identify risk factors, guide intervention strategies, and assess recovery processes [4]. It can also significantly influence clinical decision-making, allowing for the tailoring of therapies or even postponement of surgical interventions when appropriate.

The functional assessment of gait, augmented with instrumental data, improves diagnostic accuracy and treatment planning. For example, advanced gait analysis technologies are used not only in clinical rehabilitation [5] but also in elite sports training to optimize performance and prevent injuries.

Over the years, gait analysis methodologies have evolved significantly, with remarkable advancements in research and interdisciplinary collaboration [6]. While experienced clinicians can derive substantial subjective insights through direct observation, human perception alone cannot capture the complex, multi-joint movements of even simple functional activities [7]. The human eye, functioning at an exposure time of approximately 1/30 of a second, is limited to observing slow movements, and the brain, despite its extraordinary capabilities, can only process a limited amount of information. Consequently, direct observation of complex movements provides incomplete and subjective data [8].

The use of instrumental techniques in the study of human movement enhances both the quantity and quality of acquired information. These techniques serve as feedback systems for patients and athletes. Current understanding of how muscles coordinate human gait is derived from motion analysis, ground reaction force measurements, and electromyographic (EMG) data. The field of human locomotion has a long history, with modern insights stemming from the ability to measure muscle activity using surface electrodes combined with body kinematics and ground reaction force studies [9].

The foundations of experimental gait analysis were laid by Giovanni Borelli in the 17th century, introducing mathematical models of muscle and tendon biomechanics [3,10]. Today, gait assessment employs pressure plates, force plates, motion capture systems, and computational models to analyze foot-ground interaction [11].

Although some studies use static measurements such as X-rays and anthropometric assessments for evaluating lower limb function, they fail to capture dynamic gait characteristics comprehensively. While numerous normative studies on plantar pressure have been conducted, their results are inconsistent regarding what constitutes "normal" plantar pressure values, locations, or dynamics. Furthermore, there are no universally accepted normative plantar pressure values to compare patient data, leaving interpretation largely reliant on user experience [12,13]. Discrepancies in normative studies are often attributed to variations in participant selection (e.g., “healthy” groups), sample sizes, study protocols, and measurement techniques, as well as individual anatomical differences like foot structure and gait speed.

Understanding the mechanisms by which various pathologies—ranging from rheumatological diseases to orthopedic-traumatic or neurological conditions—affect gait dynamics requires an in-depth analysis of the gait cycle, the functional role of the foot, and the interplay between the knee-ankle-foot complex.

Comprehensive evaluation methods, including multidisciplinary approaches, are essential for diagnosing and managing musculoskeletal disorders. Systemic factors, such as inflammation and metabolic health, also influence musculoskeletal function. Studies reveal the link between systemic conditions—such as fibromyalgia, post-COVID inflammation, and metabolic syndrome—and functional impairments [14,15,16]. These findings align with the potential of gait analysis to identify biomechanical deviations associated with systemic health issues. Dragoi et al. (2010) emphasize the need for integrated diagnostic tools in complex orthopaedic cases, such as osteoporotic femoral neck fractures [17]. Less attention has been given to biomechanical deviations in young, physically active individuals who may exhibit subclinical abnormalities affecting sports performance and long-term musculoskeletal health.

Given these challenges, there is an evident need for a systematic analysis of risk factors contributing to gait abnormalities and the development of tools to monitor functional recovery during rehabilitation [18].

The primary objective of this study is to investigate plantar pressure distribution and force dynamics in a young, athletic population. The study seeks to answer the following key research questions: What are the normative gait parameters for healthy young athletes, and how do they compare to standard reference values? How do foot deformities (e.g., pes planus and pes cavus) alter plantar pressure distribution and kinetic gait parameters?

We hypothesize that:

- Healthy athletes will exhibit distinct plantar pressure distributions compared to previously reported general population data.
- Individuals with foot deformities will demonstrate significant deviations in force application, load symmetry, and pressure patterns.

By establishing reference gait parameters and identifying subtle biomechanical deviations, this study aims to enhance clinical gait assessments, injury prevention strategies, and personalized rehabilitation protocols. The findings will contribute to the development of sport-specific interventions and early detection of potential musculoskeletal dysfunctions in young, active populations.

2. Materials and Methods

2.1. Design Overview

The A cross-sectional observational study was conducted on 102 young subjects who practice performance sports and are considered healthy. All participants were evaluated based on gait parameters measured using the RSscan platform. To ensure optimal interpretation of the data recorded within the study group, it was necessary to establish a reference dataset for the gait parameters measured using the RSscan platform. This normative dataset describes the behaviour of plantar anatomical zones during gait and was developed by recording biomechanical data from a cohort of 102 healthy subjects. Twelve participants were excluded due to incomplete data, technical errors in acquisition, or extreme deviations in gait parameters, which could have skewed the results. The final analysis was conducted on 90 participants, ensuring a consistent dataset for comparison.

To ensure the accuracy and reliability of the normative values it was taken into account:

- Exclusion of Outliers: These 12 participants were excluded from the control group to prevent skewing the calculation of normative biomechanical values. Their data were not included in the determination of minimum and maximum reference values;
- Individual Analysis: For the excluded participants, an individualized qualitative analysis of gait parameters was performed. This included a detailed examination and interpretation of imaging data to better understand the factors contributing to their deviations.

As a result, the final number of participants whose parameters were included in the calculation of physiological reference values was 90 subjects. This approach ensured that the calculated normative ranges were representative of typical biomechanical performance.

2.2. Study population

Participants *were eligible* for the study if they fulfilled the following Inclusion Criteria:

- Provided written informed consent;
- Were aged between 18 and 40 years;
- Had a Body Mass Index (BMI) within the normal range;
- Demonstrated equal lower limb lengths, as confirmed by a physician's measurements;
- Were able to understand and communicate effectively in the national language;
- Regularly participated in sports activities;
- Could follow instructions and respond appropriately;
- Had no history of lower limb conditions, including orthopaedic-traumatic or surgical injuries.
- Displayed a normal gait pattern during evaluation by a medical specialist.

Participants *were excluded* if they met any of the following conditions:

- Recent traumatic injuries;
- Diagnosed orthopedic, respiratory, or neurological conditions that could interfere with their ability to participate in the study evaluations;
- Demonstrated unwillingness or inability to comply with the study requirements or gait assessments.

We selected an adequate number of participants based on previous studies suggesting that a minimum of 30 subjects is sufficient for normative gait measurements [19]. Gait patterns are reported to reach full maturity during early school age [20], while certain parameters, such as walking speed, tend to decline after the fifth decade of life [19]. Based on this evidence, the present study focused on university students, whose ages fall within the range associated with stable and mature gait patterns. All eligible participants were fully informed about the study's objectives, procedures, and their responsibilities. Written informed consent was obtained from each participant before their enrolment in the study.

Pre-Enrolment Physical Assessment: before joining the study, each participant underwent a comprehensive physical evaluation. This included:

- Gait Analysis: To identify abnormalities or deviations, particularly those potentially linked to factors like obesity;
- Spinal Alignment: Assessing for structural changes, such as lumbar lordosis, which is common in certain populations;
- Lower Limb Joint Examination: Evaluating the hips, knees, ankles, and feet to detect any functional impairments or structural issues.

This detailed screening ensured that all participants met the inclusion criteria and provided a reliable baseline for further analysis. The rigorous assessment process guaranteed the validity and consistency of the data collected during the study.

2.3. Ethics approval

The study prioritized the safety and well-being of all participants. The subjects were thoroughly informed about the study's objectives, potential benefits, risks, and the measures implemented to protect their confidentiality in compliance with data protection regulations. They were also made aware of their right to withdraw from the study at any point, without the need to provide a reason and without any repercussions.

Written informed consent was obtained from all participants prior to their involvement. The study adhered strictly to the ethical principles outlined in the Declaration of Helsinki and the guidelines for Good Clinical Practice. Ethical approval for the study was obtained from the Ethics Committee (approval no. 19/09.02.2021).

2.4. Methods for Storing, Analyzing, and Interpreting Biomechanical Data Collected with the RSSCAN Platform

The gait analysis was performed individually for each subject in the study group using a plantar pressure distribution platform (Footscan Scientific Version, RSscan International, Olen, Belgium). The platform, measuring 0.5 m in length, was used exclusively for dynamic measurements.

To ensure the measurement closely mimics the natural physiological activity being evaluated (walking), the pressure plate was placed within a 6-meter-long walkway. This distance is sufficient to allow normal gait patterns. The plate was covered with a thin layer of EVA material, which does not affect the measurements. This setup provided a comfortable surface for athletes and made the plate invisible to participants, preventing them from "targeting" it during walking.

The single-step (automatic) method was used for data collection. Due to the platform's length, multiple measurements were required to achieve bilateral analysis. Measurements were recorded for both feet over two gait cycles, ensuring alternate placement of the right and left limbs. The technical features of the platform allow for bilateral data integration, with the software consolidating the information and presenting comparative images and values.

To ensure the reproducibility of the method, consecutive measurements were performed for each subject, and the average of valid measurements was used for the study. Between 3 and 5 consecutive measurements were taken for each subject until the gait speed was consistently between 600 and 800 ms.

The experimental setup involved a walkway of 6-9 meters in length, incorporating the pressure platform. Plantar pressure data were collected through a single foot contact with the platform. A fixed starting point was established for each subject at a distance of 2-3 meters from the platform. This ensured the foot initiating the gait cycle landed on the center of the pressure plate. Participants were instructed to walk naturally, at a speed that felt comfortable and free of strain.

The pressure platform software recorded and processed the parameters, after which a second gait cycle was recorded with the subject initiating movement with the opposite foot.

Measurements were considered valid after subjects became familiar with the platform and the following criteria were met:

- Consistent heel strike patterns;
- A constant walking speed of 600-800 ms;
- Similar parameter values for at least two measurements.

The plantar pressure sampling frequency was set to 200 Hz.

The RSscan pressure platform recorded the following parameters for each subject:

- Maximum Force (maxF): The peak force applied (N);
- Impulse (I): The force impulse measured in Ns/cm;
- Load Rate (LR): The rate of loading, expressed in N/cm.s;
- Contact Area (CA): The total contact area in cm^2;
- Contact Percentage (%C): The percentage of active surface contact during the stance phase;
- Maximum Pressure (MaxP): The peak pressure applied, expressed in N/cm^2, calculated as the maximum force divided by the sensor area.

Measurements were performed for 10 specific regions of the foot. The rationale for this experimental approach is supported by the literature, which highlights that the most commonly analysed areas for plantar pressure distribution are the anterior (forefoot), middle (midfoot), and posterior (heel) regions of the foot. To provide a more detailed analysis, the heel was divided into lateral and medial zones, allowing differentiation between lateral and medial loading during gait. Similarly, the forefoot was divided into regions corresponding to the five metatarsal heads, the hallux, and the remaining toes.

Key Metrics and Definitions:

- Start Time: Represents the first contact (in milliseconds) of the specified foot region with the pressure platform;
- End Time: The last contact (in milliseconds) for the specified foot region;
- Time to Max Force (Time Max F): The time point at which maximum force is recorded during the gait cycle.

Additionally, the contact time with the platform was recorded. For normal gait, this duration typically ranges between 600-800 milliseconds, and no significant variations were observed between the left and right feet.

Impact of Gait Speed on Plantar Pressure: speed control is critical because the ground reaction force (GRF) depends directly on walking speed, which also influences plantar pressures. Ensuring a consistent walking speed was therefore a priority during data collection.

Imaging Analysis and Software Features: the analysis software provides a comprehensive visual representation of the contact surface, divided into three main zones:

- Forefoot: Includes the toes and metatarsals;
- Midfoot: The plantar arch region;
- Rearfoot: The heel area.

For each zone, the software automatically calculates and provides numerical data, including contact surface area (expressed as a percentage) and impulse (also expressed as a percentage). Using the "single-step method," various phases of the gait cycle (foot roll-over) are displayed as percentages of the total gait cycle, which is standardized at 100%.

The application divides a single step into four distinct phases, displaying the start and end moments for each phase. A temporal table is also available, detailing temporal values for anatomical regions of the sole and the phases of gait relative to standardized values. This table includes:

- Start Time: The moment contact begins for a specific region;
- End Time: The moment contact ends;
- Total Contact Time: The duration of contact with the platform;
- Peak Time: When peak pressure is recorded;
- Impulse: The loading in terms of pressure and time.

Normalization and Comparison with Standard Values: all values are expressed as percentages. Temporal parameters are expressed as percentages of the total contact time (100%). Impulse parameters are expressed as percentages of the total loading of the heel and forefoot. To determine if these values fall within normal ranges, the recorded data can be compared with a set of pre-established reference values.

Key Output Metrics: the software calculates and displays the temporal parameters of the gait phases, expressed in milliseconds and percentages and the impulse parameters, reflecting the distribution of load across the foot regions (heel, midfoot, forefoot).

While RSscan Footscan® offers high-resolution plantar pressure mapping, it has certain limitations:

- It does not directly capture joint kinematics or muscle activation patterns, requiring complementary motion capture or electromyography for a comprehensive analysis.
- Results can be affected by foot placement inconsistencies, although repeated trials were used to mitigate this issue.
- The rigid surface may influence natural gait dynamics compared to real-world walking conditions, an inherent limitation of pressure plate systems.

By addressing these considerations, the study ensures reliable data interpretation while acknowledging the platform's constraints.

2.5. Statistical Interpretation and Use of Normative Data

The data gathered throughout the study were compiled and structured in a Microsoft Excel spreadsheet. Statistical analyses were conducted utilizing Microsoft 365 Excel alongside SPSS software version 26.0. For accurate interpretation of the recorded data, a normative reference dataset was established, providing baseline values for key gait parameters. This dataset was generated by analyzing biomechanical data from 102 healthy subjects, ensuring a representative sample of individuals with no known lower limb pathology and normal gait patterns as evaluated by a medical specialist.

Establishing Baseline Values: the normative dataset defines physiological ranges (minimum and maximum) for biomechanical parameters measured using the RSscan platform, such as:

- Plantar pressure distribution;
- Contact times;
- Force dynamics across different plantar zones.

These baselines were essential for comparing the study group's recorded values to identify deviations or outliers.

Statistical Methods:

- Descriptive Statistics: The mean, standard deviation, and range for each biomechanical parameter were calculated to define the normative values;
- Outlier Identification: Individual cases with parameter values exceeding predefined thresholds were flagged as outliers and excluded from the calculation of normative ranges;
- Comparative Analysis: Data from the study group were statistically compared to the normative dataset to assess deviations, patterns, and group-level trends.

Application of Normative Data:

- Interpretation of Variations: Deviations from the normative values were used to identify biomechanical abnormalities within the study group;
- Validation of Findings: The normative data served as a control, ensuring the accuracy and reliability of statistical comparisons and subsequent conclusions.

3. Results

3.1. The Demographic and Anthropometric Data

The demographic profile of the study participants is outlined in Table 1. The participants' average age was around 23 years, with females being marginally older than males. The average height was 1.70 meters, with males noticeably taller than females. The mean weight was 60.28 kg, with males weighing significantly more than females. The average BMI was 19.73 kg/m², falling within the normal range, with slightly higher values observed in males compared to females. The anthropometric characteristics of the participants confirm that SG and CG were comparable in terms of age, BMI, and body composition ($p > 0.05$). This ensures that observed gait variations are not confounded by baseline physical differences.

Table 1. Anthropometric data

Characteristics	Female mean (SD)	Male mean (SD)	Overall mean
Age (yr)	23.5(2.08)	22.11(2.1)	22.97
Heigh (m)	1.64(0.0)	1.81(0.04)	1.70
Weight (kg)	53.24(4.1)	71.8(6.93)	60.28
BMI (kg/m²)	19.14(1.76)	20.7(1.79)	19.73

Variables are reported as mean and SD=standard deviation, BMI=Body Mass Index.

Tables 2 and 3 present the average values of the biomechanical parameters considered, categorized by gender. This approach aimed to identify potential differences based on this criterion and establish a reference dataset useful for comparing cases with values outside the group average.

Table 2. The average values of the biomechanical parameters considered (male).

Region	Left Foot (% Contact, Max F, Impulse)	Right Foot (% Contact, Max F, Impulse)
Hallux	63.26%, 194.466 N, 41.988 Ns	63.7%, 194.166 N, 41.672 Ns
Toes 2-5	56.68%, 42.748 N, 7.932 Ns	55.36%, 43.846 N, 7.89 Ns
Metatarsal 1	73.44%, 120.62 N, 61.638 Ns	75.92%, 136.59 N, 61.032 Ns
Metatarsal 2	77.8%, 201.222 N, 70.52 Ns	79.98%, 217.702 N, 74.384 Ns
Metatarsal 3	81.58%, 238.458 N, 72.682 Ns	82.42%, 228.136 N, 71.522 Ns
Metatarsal 4	82.92%, 203.438 N, 63.438 Ns	82.42%, 228.136 N, 71.522 Ns
Metatarsal 5	79.54%, 159.186 N, 46.658 Ns	75.6%, 146.712 N, 45.659 Ns
Midfoot	72.02%, 225.102 N, 66.498 Ns	69.2%, 214.388 N, 66.706 Ns
Medial Heel	57.3%, 340.574 N, 86.414 Ns	57.24%, 360.936 N, 92.23 Ns
Lateral Heel	57.38%, 276.708 N, 74.008 Ns	56.28%, 287.47 N, 74.352 Ns

MaxF= Maximum Force

In male subjects group: The left and right foot show generally similar percentages of contact and impulses across most regions, indicating a balanced gait. However, slight variations are observed in Metatarsal 1 and 2 forces and heel areas, where the right foot exhibits higher forces and impulse values. Midfoot and Heel Regions: The medial heel shows the highest force applied (360.936 N on the right foot) and a significant impulse, reflecting a key area for weight transfer during gait. Toes and Metatarsals: The big toe (hallux) and metatarsals consistently show high contact and forces, highlighting their critical role in push-off phases of gait.

Table 3. The average values of the biomechanical parameters considered (female).

Region	Left Foot (% Contact, Max F, Impulse)	Right Foot (% Contact, Max F, Impulse)
Hallux	64.89%, 199.61 N, 40.62 Ns	63.47%, 183.67 N, 40.01 Ns
Toes 2-5	48.53%, 36.27 N, 7.49 Ns	48.00%, 37.65 N, 6.78 Ns
Metatarsal 1	69.29%, 72.36 N, 57.90 Ns	71.64%, 89.11 N, 47.11 Ns
Metatarsal 2	78.56%, 201.84 N, 48.05 Ns	79.34%, 207.57 N, 54.48 Ns
Metatarsal 3	80.24%, 174.13 N, 50.54 Ns	81.39%, 187.45 N, 54.02 Ns
Metatarsal 4	80.33%, 121.55 N, 56.02 Ns	80.09%, 104.95 N, 52.83 Ns
Metatarsal 5	70.58%, 65.30 N, 45.35 Ns	75.6%, 146.712 N, 45.659 Ns
Midfoot	62.29%, 178.80 N, 55.70 Ns	63.62%, 173.67 N, 56.16 Ns
Medial Heel	58.79%, 288.44 N, 73.41 Ns	58.50%, 280.21 N, 72.24 Ns
Lateral Heel	56.54%, 270.92 N, 69.03 Ns	58.49%, 277.93 N, 69.57 Ns

MaxF= Maximum Force

In female subjects group: Both feet show similar % contact and impulses in the hallux, reflecting symmetrical push-off mechanics. The slightly higher maximum force on the left hallux may suggest a slight dominance or compensation during toe-off. The metatarsal regions (especially Metatarsals 1 and 2) show high forces and impulses on both feet, consistent with their role in distributing loads during the stance and propulsion phases. Notably, Metatarsal 1 on the left foot demonstrates higher impulse, indicating prolonged contact time despite slightly lower peak forces compared to the right foot. The midfoot and heel areas demonstrate excellent symmetry in terms of % contact, forces, and impulses. This suggests balanced weight transfer during heel strike and midstance phases of the gait cycle. The medial heel exhibits the highest forces on both feet, reflecting its critical role in load absorption during initial contact. Toes 2-5 exhibit slightly higher forces on the right foot, but overall impulse values are comparable, indicating balanced secondary push-off contributions.

Step length and cadence values differed significantly between genders. Women displayed a higher cadence but shorter step length ($p = 0.001$), consistent with previous research indicating gender-based gait adaptations. This suggests that rehabilitation programs should account for these biomechanical differences when designing interventions.

3.2. Analysis of Outliers in Biomechanical Parameters

From the evaluated sample, subjects with biomechanical parameters that significantly deviated from the group average were excluded. A total of 12 participants were identified with substantial deviations from the mean values recorded in the control group. Among these, 5 subjects were male, and 7 were female, with an average age of 20.08 years. For these 12 participants, an individual analysis was conducted on the following variables:

- Plantar pressures (graphical representation of pressure distribution);
- Contact area (total and active contact);
- Foot angle, subtalar angle, and subtalar joint flexibility;
- Force and pressure graphs (dynamic representation);
- Balance and gait graphs (step-by-step evaluation).

The variables were selected based on the biomechanical parameter(s) that showed deviations from normal values. The evaluation was performed using 2D visualization, synchronized mode, and single-step analysis. This allowed a detailed investigation into the specific abnormalities.

Out of all the patients with abnormalities detected during gait analysis (including changes in the longitudinal arch of the foot, knee posture disorders, and leg length discrepancies), the following conditions were identified:

- Flatfoot (Pes Planus): 4 cases of bilateral flatfoot (Grades I and II);
- High Arch (Pes Cavus): 1 case with a high plantar arch.

3.2.1. Flatfoot (Pes Planus)

Represented the majority of identified abnormalities (33% of cases). These subjects demonstrated increased contact area and altered pressure distributions, consistent with the flattened medial longitudinal arch. From the cases analyzed, one subject with bilateral flatfoot (Grade II) was chosen to illustrate biomechanical parameter interpretation, as the other three cases with flatfoot exhibited similar variations. Dynamic measurements were conducted in the dynamic screen mode, with several key aspects directly observable (as shown in Figure 1):

- Foot rolling patterns (left or right): Movement can be fractionated, and various gait phases can be observed step-by-step. The left panel functions like a video player, displaying sequential frames;
- Plantar pressure mapping for the left and right foot;
- Maximum pressure visualization during gait for both feet. The right-hand scale represents normal force, and a slider indicates instantaneous normal force applied at the center of pressure during walking. The highest pressure is color-coded (red = highest, followed by orange, yellow, green, blue, and violet). The orange-red zone indicates high pressure at the right hallux.

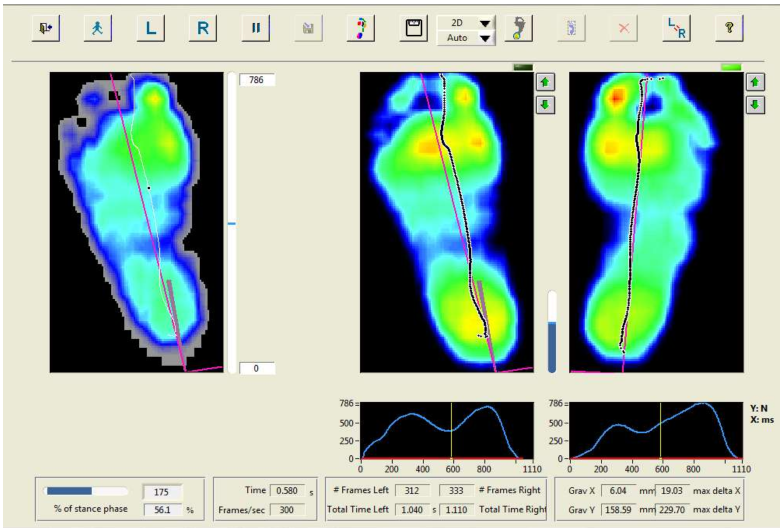
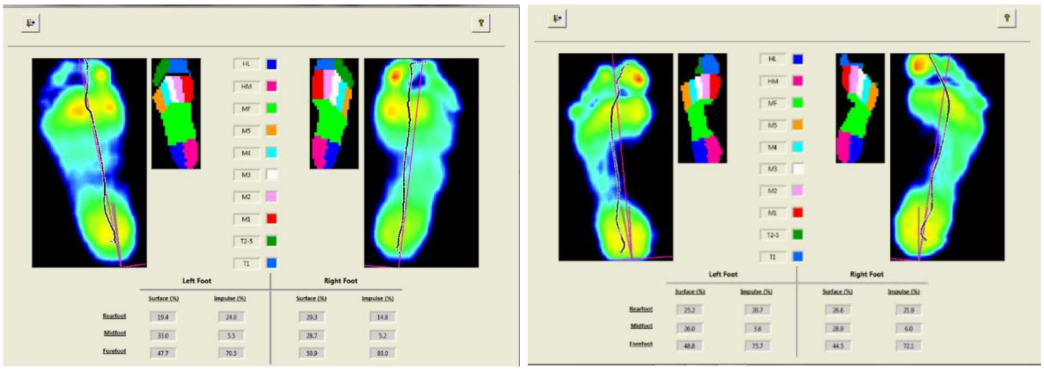


Figure 1. Plantar pressure images in syncro mode for a 22-year-old female subject with Grade II bilateral flatfoot, more pronounced on the right foot.

Contact areas for each foot were also evaluated (Figure 2a; 2b). The program divides the contact area into three regions: Forefoot (toes and metatarsals), Midfoot (plantar arch), Rearfoot (heel). For each region, automatic calculations provide numeric values for contact area (percentage) and impulse (percentage). In cases of structural foot anomalies, the percentage of contact in the midfoot region is particularly relevant: the midfoot contact area is 33% (a) compared to 26% (b) in a subject without foot pathology.



(**a**) (**b**)

Figure 2. Contact area for the three main regions of the foot: (a) for a 22-year-old female subject with flatfoot; (b) for a 23-year-old male subject without foot deformities.

For larger contact areas, proportional loading in the midfoot region is also examined. The impulse reflects the duration of pressure application in a given area. Red zones on the impulse screen indicate prolonged pressure, suggesting a higher risk of ulcers or overuse injuries. In the analyzed case, the impulse value in the midfoot was slightly elevated but comparable to that of a healthy subject, as confirmed by the colorimetric map. This indicates increased midfoot contact but no excessive weight-bearing in the region.

The single-step analysis screen further illustrates the phases of gait (foot rolling), divided into four distinct phases, shown as percentages of the total gait cycle:

- Initial Contact: Time between the first heel strike and the first metatarsal contact;
- Forefoot Contact Phase: Time from the first metatarsal contact to full metatarsal contact;

- Midstance (Flatfoot Phase): Time between full metatarsal contact and heel lift-off;
- Propulsion Phase: Time from heel lift-off to the last toe-off.

Figure 3 presents temporal parameters (in milliseconds and percentages) for the analyzed phases. Deviations are color-coded: blue/cyan (premature), green (within normal limits), and red (delayed).

Low | Optimal | High

		Start Time (%)		End Time (%)		Total Time (%)		Peak Time (%)		Impulse (%)
Left Foot										
Med heel	0	0.3	50-65	64.7	50-65	64.4	15-22	30.1	45-55	57.1
Lat heel	0	0.3	50-65	64.1	50-65	63.8	15-22	28.5	45-55	42.9
M1	13-25	20.5	73-96	94.9	60-83	74.4	50-78	64.4	13-21	23.7
M2	10-20	20.5	80-95	95.8	70-85	75.3	60-75	68.3	14-24	29.2
M3	8-16	17.9	85-93	95.8	77-85	77.9	59-74	76.6	15-23	23.1
M4	7-15	15.1	84-92	94.6	77-85	79.5	55-73	77.6	10-18	15.7
M5	5-15	16.3	65-87	91.0	60-82	74.7	50-77	75.0	4-11	8.2
Heelstrike	0	0.3	5-15	15.1	5-15	14.7				
Pre-Midstance	5-15	15.1	10-20	64.6	45-55	49.5				
Midstance	10-20	20.5	55-65	64.6	42-52	44.1				
Propulsion	55-65	64.6	100	100.0	35-45	35.4				
Right Foot										
Med heel	0	0.3	50-65	54.1	50-65	53.8	15-22	26.4	45-55	57.5
Lat heel	0	0.3	50-65	53.2	50-65	52.9	15-22	25.2	45-55	42.5
M1	13-25	11.4	73-96	94.9	60-83	83.5	50-78	65.5	13-21	30.9
M2	10-20	11.4	80-95	94.9	70-85	83.5	60-75	72.4	14-24	29.9
M3	8-16	9.9	85-93	94.0	77-85	84.1	59-74	67.3	15-23	24.0
M4	7-15	10.5	84-92	91.6	77-85	81.1	55-73	58.9	10-18	12.5
M5	5-15	17.4	65-87	85.0	60-82	67.6	50-77	52.6	4-11	2.8
Heelstrike	0	0.3	5-15	9.9	5-15	9.6				
Pre-Midstance	5-15	9.9	10-20	53.9	45-55	44.0				
Midstance	10-20	17.4	55-65	53.9	42-52	36.5				
Propulsion	55-65	53.9	100	100.0	35-45	46.1				

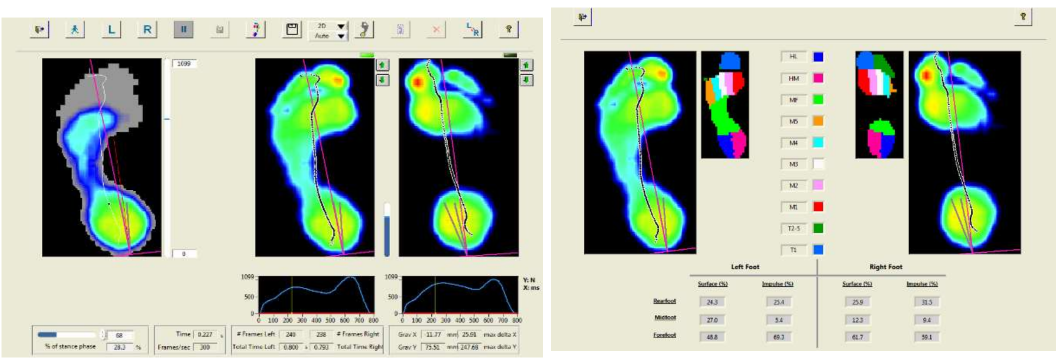
Figure 3. Temporal Parameters for a 22-Year-Old Female Subject with Flatfoot.

3.2.2. High Arch (Pes Cavus)

The single case of high arch demonstrated localized high pressure and reduced contact area, indicative of load concentration in specific regions of the foot. For the case of a right high plantar arch (male, 23 years old), the same biomechanical parameters were analyzed.

Figure 4 (a) shows syncro pressure images, and Figure 4 (b) illustrates contact area percentages for the three foot regions.

For the analyzed subject, most temporal parameters were within normal limits, with variations of up to 10% compared to the norm. However, the midstance phase (flatfoot phase) showed a significant deviation, with a recorded value of 64.6% compared to the normal range of 10-20%, aligning with the identified pathology. This indicates a flattened medial longitudinal arch.



(**a**) (**b**)

Figure 4. (a) Syncro Mode Pressure Images for a 23-Year-Old Male Subject with a Right High Plantar Arch. **(b)** Contact Area for the Three Main Regions of the Foot for the Same Analyzed Subject.

It is observed that the orange-red area on the screen indicates high pressure at the level of the right hallux. From the analysis of the figure, an increased contact surface for the right forefoot is noticeable, at the expense of the midfoot. For a better visualization of this aspect, Table 4 presents the contact surfaces for the three regions of the foot, for both feet in the case of the subject with plantar pathology, compared to a subject without pathology.

Table 4. Comparison between the contact surfaces of the foot (expressed as a percentage) for a subject without plantar arch pathology and a subject with a high plantar arch.

Contact area	Contact Surface (%) Subject with a high plantar arch in the right foot (23 years old)		Contact Surface (%) Subject without foot deformities (23 years old)	
	Left foot	Right foot	Left foot	Right foot
Heel	24,3	25,9	25,2	26,6
Midfoot	27	12,3	26	28,9
Forefoot	48,8	61,7	48,8	44.5

The subject with a high plantar arch in the right foot exhibits a significant redistribution of pressure. The midfoot contact surface is markedly reduced in the right foot, while the forefoot compensates with a substantial increase. The left foot values remain relatively similar between the two subjects.

In Figure 5, the plantar footprint is visualized during different phases of walking for both feet. The absence of a footprint in the midfoot area of the right foot is observed during the mid-support phase.

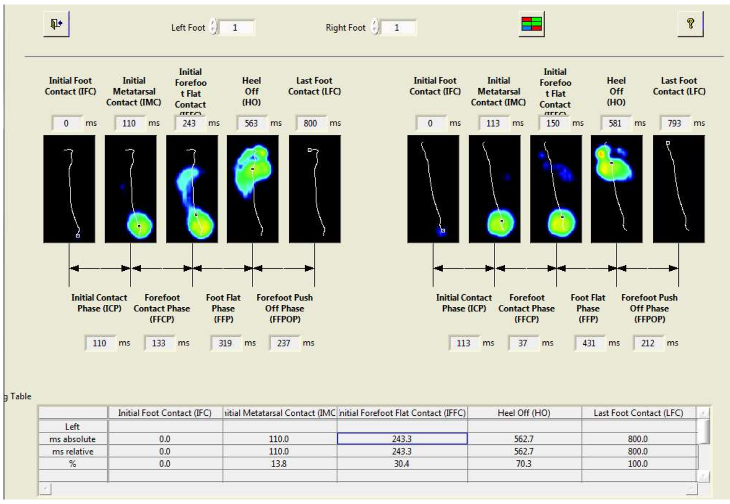


Figure 5. The "single-step method" screen for a male subject, 23 years old, with a high plantar arch in the right foot.

From the figure's analysis, temporal parameter changes are observed for the right foot during the early and mid-support phases, with a prolongation of these phases. This corresponds to the biomechanics of the investigated pathology.

Table 5 provides a comparative presentation of temporal parameters related to walking phases for both feet in the subject with a high plantar arch, compared to a subject without known pathology.

Table 5. Comparison of Temporal Parameters Related to Walking Phases for a Subject without foot deformities and a Subject With a High Plantar Arch

Walking Phase	Duration (ms) Subject with a high plantar arch in the right foot (23 years old)		Duration (ms) Subject without foot deformities (23 years old)	
	Left foot	Right foot	Left foot	Right foot
Initial contact	110	113	97	107
Early Mid-Support Phase	133	37	102	120
Mid-Support Phase	319	431	312	290
Propulsion Phase	237	212	201	211

The subject with a high plantar arch exhibits significant deviations in the temporal parameters of walking, particularly in the early and mid-support phases. The right foot, affected by the high plantar arch, shows a substantial reduction in the early mid-support phase duration and a pronounced prolongation in the mid-support phase. This highlights the altered biomechanics and compensatory mechanisms associated with the pathology. The left foot is less affected, showing only minor differences compared to the healthy subject.

4. Discussion

The diagnosis of foot dysfunctions must go beyond simple clinical observation and visual inspection [21]. In recent years, the information provided by plantar pressure distribution during walking has been recognized as a reliable tool for assessing the posture of both normal and pathological feet. However, the impact of structural foot characteristics on plantar pressures in various foot dysfunctions remains poorly defined [22]. Although often asymptomatic, there have been debates about whether flatfoot and high-arched feet have a noticeable impact on human gait. Several studies have utilized plantar pressure measurement systems to assess gait alterations in subjects with these pathologies.

This study investigated the utility of gait analysis technologies, such as the RSSCAN platform, in evaluating biomechanical deviations in healthy young athletes and individuals with foot deformities. Our findings revealed notable differences in plantar pressure distribution and temporal gait parameters between individuals with flatfoot, high plantar arches, and those without foot pathology.

For flatfoot cases, a flattened medial longitudinal arch, increased midfoot contact area, subtalar joint pronation, and valgus calcaneal alignment were evident. Despite these structural deviations, no significant differences were observed in time-distance or kinematic parameters compared to subjects without pathology. However, kinetic parameters, such as pressure distribution and loading rate during the support phase, showed significant differences, indicating greater muscular tension during walking in flatfoot cases. Studies by Fan et al. (2018) and others have reported no significant differences in time-distance and kinematic parameters for flatfoot cases, consistent with our findings. However, our results corroborate evidence of significant kinetic deviations, such as altered plantar pressure distribution and higher loading rates, which have been linked to increased muscular strain in flatfoot [23]. Meta-analyses on flexible flatfoot suggest that, while this condition often does not impair quality of life [24-26], it can influence balance and walking speed under specific conditions [27,28]. Our study supports these findings by identifying compensatory mechanisms during the support phase.

High arches have been less extensively studied compared to flatfoot. For the high-arched foot case, there was an increased forefoot contact area at the expense of the midfoot, accompanied by prolonged early and mid-support phases for the affected foot. These findings are consistent with the altered biomechanics of high plantar arches. Previous research has highlighted decreased shock absorption and increased stiffness in individuals with high plantar arches [29]. Our findings add to this body of evidence, demonstrating prolonged support phases and increased forefoot pressure, which likely result from biomechanical compensations. Sedaghati et al. (2023) [30] also reported that individuals with high-arched feet experience reduced postural control, similar to flatfoot individuals. Our study's observation of increased forefoot pressure in high-arched subjects aligns with these findings, indicating potential stability challenges.

Recent systematic reviews emphasize the value of pressure measurement platforms in detecting gait abnormalities and structural deviations in asymptomatic individuals [22,31]. Similar to our study, advanced technologies have proven effective in identifying subtle deviations that may not be apparent through observational analysis alone. A systematic review by Chinpeerasathian et al. (2024) [32] emphasized the effectiveness of gait analysis technologies, such as foot orthoses, in improving balance among individuals with flatfoot. 3D motion capture and inertial measurement unit (IMU)-based systems, offer complementary insights [33]. While 3D motion capture excels at tracking full-body kinematics, it requires specialized equipment, controlled lab conditions, and extensive post-processing, making it less practical for real-world applications. A potential hybrid approach—combining pressure analysis with IMU-based monitoring—may provide a more comprehensive understanding of gait mechanics. Our utilization of the RSSCAN platform provided detailed insights into plantar pressure distributions, reinforcing the value of advanced gait analysis tools in clinical assessments. Although there are not a large number of studies focused on this topic, it is certain that gait evaluation is becoming a priority even for Artificial Intelligence. Lim, A. C. Y., et al. (2022) focused on using AI-driven wearable technologies for assessing gait deviations in healthy and clinical populations [34].

Gait deviations, if left unaddressed, can contribute to chronic musculoskeletal issues, including joint degeneration, overuse injuries, and altered neuromuscular control [35, 36, 37]. From a rehabilitation perspective, early identification of gait abnormalities allows for proactive intervention, potentially reducing the need for invasive treatments such as surgery or prolonged physical therapy. The clinical significance of our findings lies in the potential for early detection and intervention for foot deformities. The broader implications of systemic health on biomechanics are further supported by the work of Amzolini et al. (2022) [38], Neagoe et al. (2020) [39], Ica et al. (2023) [40], Zastulka et al. or Matei et al. (2024) [41,42], who explored the role of metabolic syndrome in modulating physical outcomes, such as nonalcoholic liver disease,obesity, vitamine D metabolism and psoriasis treatment response. These studies reinforce the idea that systemic contributors, such as metabolic dysfunction or chronic inflammation, can profoundly affect musculoskeletal function. Finally, case reports by Patru et al. (2021) [43], and Matei et al. (2021) [44], illustrate how advanced diagnostic tools can play a pivotal role in uncovering rare musculoskeletal conditions, such as myositis ossificans. Similarly, our study highlights how gait analysis can identify subtle biomechanical deviations that might otherwise go unnoticed, particularly in asymptomatic or clinically complex cases.

Even in asymptomatic individuals or those without observable gait abnormalities, plantar pressure analysis can reveal biomechanical deviations that may predispose to future musculoskeletal issues. In the context of younger populations, studies by Popescu et al. (2024) [45], demonstrated that inflammation and excess weight negatively impact physical performance in overweight and obese schoolchildren. By addressing these issues through targeted interventions, such as those informed by gait analysis, it is possible to improve both mobility and long-term musculoskeletal health. According to these ipothesis another study highlighted the efficiency of the individualized rehabilitation program to improve gait for patients with partial hip replacement, elderly patients that could have physiological and pathological particularities [46]. Our study expands on this by showcasing the value of gait analysis as a preventive diagnostic tool, particularly in asymptomatic individuals who may be at risk for developing biomechanical dysfunctions. Specifically, for flatfoot, identifying increased midfoot pressures and altered loading rates can guide the use of orthotic devices or targeted physical therapy to reduce strain and improve alignment. For high-arched feet, interventions aimed at redistributing plantar pressure and improving shock absorption may help mitigate the risk of overuse injuries, particularly in athletes.

The combined use of numerical and imaging data in this study highlights the importance of a multimodal approach to gait analysis. By integrating qualitative and quantitative insights, clinicians can better understand foot-ground interaction and develop personalized treatment plans.

Limitations of the study: The study sample size was limited, particularly for the high-arched foot group, which may affect the generalizability of findings. The cross-sectional design does not allow for analysis of the long-term progression or impact of these conditions on gait and musculoskeletal health.

Further research is needed to address the limitations of this pilot study and expand on its findings. Suggested directions include conducting longitudinal studies to track the progression of flatfoot and high-arched foot over time and evaluate the effectiveness of interventions and integrating advanced technologies, such as 3D gait analysis or wearable sensors, to complement plantar pressure measurements and provide additional insights into foot biomechanics. Future studies should focus on longitudinal gait tracking, exploring how deviations evolve over time and how targeted interventions influence long-term movement patterns. Researchers should also investigate hybrid assessment models integrating RSscan with wearable sensors or machine learning algorithms to enhance predictive accuracy.

5. Conclusions

This study highlights the importance of precise gait assessment in both clinical rehabilitation and sports performance settings. The use of RSscan technology demonstrated clear advantages in identifying biomechanical deviations that could inform personalized treatment strategies. Several key methodological advancements are introduced, significantly contributing to the field of biomechanical evaluation. *Integration of Modern Technologies*: The use of the RSSCAN platform enabled the precise collection of functional gait data, including plantar pressure distribution, contact area, and gait phases. This approach ensures a high level of accuracy and detail in the analysis of foot biomechanics. *Multidimensional Approach*: By combining numerical analysis (biomechanical parameters) with imaging data, the study provides a comprehensive and qualitative perspective on foot-ground interaction. This dual approach enhances the depth and reliability of the findings. *Focus on Asymptomatic Subjects*: The inclusion of asymptomatic individuals, a less explored group in the literature, highlights the importance of preventive diagnostics. The study demonstrates that plantar pressure analysis can detect subtle biomechanical deviations, even in the absence of observable gait alterations or clinical symptoms. This early detection can help prevent potential complications associated with flatfoot and high plantar arches. *Identification of Biomechanical Anomalies*: Through this innovative methodology, the study identified significant biomechanical anomalies in subjects without prior clinical complaints or observable changes in gait. These findings emphasize the diagnostic value of advanced pressure analysis in uncovering hidden structural or functional abnormalities. *Applications in Athletic Evaluation*: The results provide a solid foundation for biomechanical assessment in athletes, offering insights into performance optimization and injury risk reduction. By addressing subtle deviations early, targeted interventions can improve both athletic performance and long-term musculoskeletal health. These methodological contributions establish a valuable framework for integrating modern technologies into clinical and sports practice, emphasizing the importance of early diagnostics and personalized interventions in maintaining optimal biomechanical health.

Author Contributions: Conceptualization, E.T.A. and G.I.; methodology, E.T.A.; software, G.I.; validation, A.M.B, S.P. and D.M.; formal analysis, E.T.A; investigation, M.R.T., S.P., A.M.B and D.M.; resources, D.M.; data curation, G.I.; writing—original draft preparation, D.M., C.D.N; writing—review and editing, A.M.A. and C.D.N; visualization, A.M.A and C.M.; supervision, E.T.A., M.R.T. and D.M.; project administration, E.T.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova (Ethical approval no. 19/09 February 2021)

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Fukuchi, C.A.; Fukuchi, R.K.; Duarte, M. Effects of walking speed on gait biomechanics in healthy participants: A systematic review and meta-analysis. Systematic Reviews 2019, 8(1):153. https://doi:10.1186/s13643-019-1063-z, PMID: 31248456. PMCID: PMC6595586
2. Horst, F.; Lapuschkin, S.; Samek, W.; Müller, K.R. Explaining the unique nature of individual gait patterns with deep learning. Scientific Reports 2019, https://doi:10.1038/s41598-019-38748-8. PMID: 30787319. PMCID: PMC6382912
3. Baker R. The history of gait analysis before the advent of modern computers. Gait & Posture. Elsevier 2007, https://doi:10.1016/j.gaitpost.2006.10.014
4. Perry, J.; Burnfield, J.M. Gait Analysis: Normal and Pathological Function. Slack Incorporated. J Sports Sci Med. 2010 PMCID: PMC3761742, ISBN: 978- 1556427664
5. Novacheck, T.F. The biomechanics of running. Gait & Posture 1998 7(1), 77-95, PMID: 10200378. https://doi:10.1016/s0966-6362(97)00038-6.
6. Prakash, C.; Kumar, R.; Mittal, N. Recent developments in human gait research: parameters, approaches, applications, machine learning techniques, datasets and challenges. Artificial Intelligence Review 2018, 49: 1-40. https://doi:10.1007/s10462-016-9514-6
7. Surer, E.; Kose, A. Methods and technologies for gait analysis. In: Computer analysis of human behavior. London: Springer London, 2011. p. 105-123. https://doi:10.1007/978-0-85729-994-9_5
8. Clayton, H.M.; Schamhardt, H.C. Measurement techniques for gait analysis. Equine locomotion, Souders Elsevier, Second Edition, 2001, 2: 31-60. ISBN 978-0-8020-2950-9.
9. Whittle, M.W.; Gait analysis: an introduction. Butterworth-Heinemann, 1991, ISBN 0 7506 0045 4.
10. Weber, E. H., Weber, W. Mechanics of the human Walking aparatus 1992 ISBN 10: 3540535411, ISBN 13: 9783540535416, Publisher: Springer
11. Leardini, A.; Chiari,L.; Croce, U.D.; Cappozzo, A., Human movement analysis using stereophotogrammetry. Gait & Posture, 2011. PMID: 15639400, https://doi: 10.1016/j.gaitpost.2004.05.002, 33(3), 328-336,
12. Orlin, M.N.; McPoil, T.G. Plantar pressure assessment. Physical Therapy 2000, PMID: 10758524, https://doi: 10.1093/ptj/80.4.399, 80(4), 399-409.
13. Pataky T.C.; Goulermas J.Y.; Pedobarographic statistical parametric mapping (pSPM): A pixel-level approach to foot pressure image analysis. Journal of Biomechanics 2008, Pages 2136-2143, https://doi:10.1016/j.jbiomech.2008.04.034
14. Popescu, C.; Matei, D.; Amzolini, A.M.; Trăistaru, M.R. Inflammation and Physical Performance in Overweight and Obese Schoolchildren. Life 2024, 14,1583. https://doi.org/10.3390/life14121583
15. Matei, D.; Traistaru, R.; Amzolini, A.M.; Ianosi, L.S.; Neagoe, C.D.; Mitrea, A.; Clenciu, D.; Avramescu, T.E. A Comparative Study on the Pain Threshold Experienced by Fibromyalgia Patients Following Acute SARS-CoV-2 Infection. Life 2024, 14, 942. https://doi.org/10.3390/ life14080942

16. Amzolini, A.M.; Neagoe, C. D.; Avramescu, T.E.; Mitrea, A.; Traistaru, R.; Micu, E. S.; Ianosi, S. L.; Matei, D. Understanding Non-Pharmacological Treatments for Fibromyalgia Functional and Well-Being Status: The Role of Literacy. Healthcare 2024, 12, 1956. https://doi.org/10.3390/ healthcare12191956
17. Dragoi, D.; Popescu, R.; Traistaru, R.; Matei, D.; Buzatu, A. M.; Ionovici, N.; Grecu, D. A multidisciplinary approach in patients with femoral neck fracture on an osteoporotic basis, Romanian Journal of Morphology and Embryology 2010, 51(4):707–711
18. van Gheluwe, B.; Dananberg, H.J.; Hagman, F.; Vanstaen, K. Effects of hallux limitus on plantar foot pressure and foot kinematics during walking. J Am Podiatry Med Assoc 2006; 96:428–436. doi: 10.7547/0960428.
19. Lau, L.K.; Wee, S.L.; Pang, W.J.B.; Chen, K.K.; Abdul Jabbar, K.; Yap, P.L.K.; Mallya, J.U.; Ng, D.H.M.; Tan, Q.L.L.; Seah, W.T.; Ng, T.P. Reference Values of Gait Speed and Gait Spatiotemporal Parameters for a South East Asian Population: The Yishun Study. Clin Interv Aging 2020; 15: 1753-1765 [PMID: 33061327 https://doi: 10.2147/CIA.S270407]
20. Hillman, S.J.; Stansfield, B.W.; Richardson, A.M.; Robb, J.E.; Development of temporal and distance parameters of gait in normal children. Gait Posture 2009; 29: 81-85 [PMID: 18701291 https://doi: 10.1016/j.gaitpost.2008.06.012]
21. Rose, G.K.; Welton, E.A.; Marshall, T.; The diagnosis of flat foot in the child, J Bone Joint Surg 1985, 67-B(1),71–78.
22. Pauk, J.; Viciene, K.D.; Ihnatouski, M.; Griskevicius, J.; Taso, V.J. Analysis of the plantar pressure distribution in children with foot deformities, Acta of Bioengineering and Biomechanics 2010, Vol. 12, No. 1, PMID: 20653322
23. Fan, Y.; Fan, Y.; Li, Z.; Lv, C.; Luo, D. Natural Gaits of the Non-Pathological Flat Foot and High-Arched Foot. PLoS ONE 2011, PMID: 21445254, PMCID: PMC3060814, https://doi:10.1371/journal.pone.0017749, 6(3): e17749
24. Pfeiffer M., Kotz R., Ledl T., Hauser G., Sluga M., Prevalence of flat foot in preschool-aged children. Pediatrics, 2006, PMID: 16882817, DOI: 10.1542/peds.2005-2126, 118: 634–639.
25. Walczak, M.; Napiontek, M. Flexible flatfoot in children–a controversial subject. Surgery of the Motor Systems and Polish Orthopedics, 2003, PMID: 14702679, 68: 261–267.
26. Chen, M.J.L.; Chen, C.P.C.; Lew, H.L.; Hsieh, W.C.; Yang, W.P.; Tang, S.F.T. Measurement of forefoot varus angle by laser technology in people with flexible flatfoot. American Journal of Physical Medicine and Rehabilitation 2003, PMID: 14566151, https://doi:10.1097/01.PHM.0000087455.38062.79, 82: 842–846.
27. Dowling, A.M.; Steele, J.R.; Baur, L.A. Does obesity influence foot structure and plantar pressure patterns in prepubescent children? International Journal of Obesity 2001, PMID: 11439299, https://doi:10.1038/sj.ijo.0801598, 25: 845–852.
28. Esterman, A.; Pilotto, L. Foot shape and its effect on functioning in royal Australian air force recruits. Part 1: Prospective cohort study. Military Medicine 2005, PMID: 16130646, https://doi:10.7205/milmed.170.7.623, 170: 623–628.
29. Nattiv, A.; Women in sport: Track and field, Book Editor: Barbara L. Drinkwater, 2000 http://dx.doi.org/10.1002/9780470757093.ch32
30. Sedaghati, P.; Kazemi, Pakdel, F.; Zarei, H. Investigating the Effects of High-Arch and Flat Foot Deformities on Postural Control: A Systematic Review and Meta-Analysis. Journal of Modern Rehabilitation 2023; 17(4):363-374. DOI:10.18502/jmr.v17i4.13884
31. Orlin, M.N.; McPoil, T.G.; Plantar pressure assessment. Phys Ther 2000; PMID: 10758524, https://doi:10.1093/ptj/80.4.399, 80: 399-409
32. Chinpeerasathian, C.; Sin, O. P.; Siriphorn, A.; Pensri, P. Effect of foot orthoses on balance among individuals with flatfoot: A systematic review and meta-analysis. PLoS One 2024 Mar 8;19(3):e0299446. https://doi:10.1371/journal.pone.0299446. PMID: 38457399; PMCID: PMC10923465.
33. Baker, R. Measuring walking: A handbook of clinical gait analysis. Mac Keith Press, 2013.
34. Lim, A.C.Y.; Natarajan, P.; Fonseka, R.D.; Maharaj, M.; Mobbs, R.J. The application of artificial intelligence and custom algorithms with inertial wearable devices for gait analysis and detection of gait-altering pathologies in adults: A scoping review of literature. Digital Health 2022, 8. https://doi:10.1177/20552076221074128.
35. Neumann, D. A. Kinesiology of the musculoskeletal system: Foundations for rehabilitation. Elsevier Health Sciences, 2016.
36. Perry, J.; Burnfield, J. M. Gait Analysis: Normal and Pathological Function. Slack Incorporated, 2010.
37. Febriyanti, I.; Setijono, H.; Marhaendra, F.J.; Muhammad, H.N.; Kafrawi, F.R.; Nurhayati, F.; Yulfadi nata, A.; Khory, F.D.; Kurtoğlu, A.; Tannoubi, A.; Govindasamy, K.; Setiawan, E. Pes Planus Level and Foot Pain Affect Selected Performance Parameters: A Study on Team Sport Athletes. Balneo and PRM Research Journal 2024, 15(4), 746.
38. Amzolini, A.M.; Forțofoiu, M.C.; Alhija, A.B.; Vladu, I.M.; Clenciu,D.; Mitrea, A.; Forțofoiu M., Matei, D.; Diaconu, M.; Tudor, M.S.; Micu, E.S. Triglyceride and Glucose Index as a Screening Tool for Nonalcoholic Liver Disease in Patients with Metabolic Syndrome. J Clin Med 2022 May 28;11(11):3043. https://doi:10.3390/jcm11113043. PMID: 35683431; PMCID: PMC9181222
39. Neagoe, C.D.; Farmazon, A.S.; Amzolini, A.M.; Singer, C.E.; Ianoşi, S.L.; Tutunaru, C.V.; Genunche-Dumitrescu, A.V.; Ianoşi, N.G.; Păun, I.; Leru, P.M.; Tica, O.S.; Popescu M. The role of non-invasive scores in determining the liver fibrosis in NAFLD and psoriatic patients. Rom J Morphol Embryol 2020 61(2):503-511. Httpa://doi:10.47162/RJME.61.2.20
40. Ica, O.A.; Mitroi, G.; Ianosi, S.L.; Tutunaru, C.V.; Leru, P.M.; Matei, D.; Avramescu, E.T.; Tanasie, C.A.; Mitroi, I.B.; Neagoe, C.D.; Cazacu, S.M. Defining the short-term and long-term skin manifestations of COVID-19: insights after more than

three years of the pandemic, Rom J Morphol Embryol 2023, 64(3):291–304 ISSN (print) 1220–0522, ISSN (online) 2066–8279 doi: 10.47162/RJME.64.3.01

41. Zastulka, A.; Clichici, S.; Pop, N.L.; Olteanu, C.D.; Delcea, C.; Sabău, L.I.; Mocan, T. Calcium and vitamin D: Roles, interactions, and nutritional programming for bone development. Balneo and PRM Research Journal 2024, 15(4), 747.
42. Matei, D.; Trăistaru, R.; Pădureanu, V.; Avramescu, T.E.; Neagoe, D.; Genunche, A.; Amzolini, A. The Efficiency of Kinesiotherapy versus Physical Modalities on Pain and Other Common Complaints in Fibromyalgia. Life 2024, 14, 604. PMID: 38792625 PMCID: PMC11122147 DOI: 10.3390/life14050604
43. Pătru, S., Pădureanu, V., Rădulescu, D., Mititelu, R.R., Rodica Pădureanu, Băcanoiu, M., Matei, D. A nontraumatic myo-sitis ossificans case of the forearm: Case report and literature review, Experimental And Therapeutic Medicine 2021, 21:531, PMID: 33815604, PMCID: PMC8014871, DOI: 10.3892/etm.2021.9963
44. Matei, D.; Marcu, I.R.; Pătru, G. L.; Pătru, L.; Bighea, A.C.; Pătru, S. A case of giant cell tumor of the tendon sheath in an elderly patient: diagnostic difficulties and therapeutic options-Case report, Rom J Morphol Embryol 2019, 60(1):293–296, PMID: 31263859
45. Popescu, C.; Matei, D.; Trăistaru, R. The Role of Kinesio therapy in Enhancing Physical Performance and Self-Esteem: A Prospective Observational Study in Obese Adolescents. Balneo and PRM Research Journal 2024, 15(4), 759.
46. Caimac, D.; Bumbea, A.M.; Rogoveanu, O. Value of kinetotherapy program in gait and balance rehabilitation in patients with osteoporosis and partial hip replacement for femoral neck fracture. Osteoporosis international, 2020, ISSN, 0937-941X, eISSN, 1433-2965.