Original Article

# Evaluation of the foot health with baropodometric analysis of acromegaly patients followed after pituitary surgery

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## ABSTRACT

### Background

The exposure to growth hormone (GH) and increase in insulin-like growth factor 1 (IGF-1) in acromegaly can cause various clinical findings related to the cardiovascular, respiratory, and musculoskeletal systems. GH exerts its anabolic effects directly or indirectly through IGF-1, by increasing cell proliferation and maturation in various tissues, including bone, cartilage, skeletal muscle, and tendons. The aim of this study is to analyze these changes using baropodometric gait analysis.

### Methods

Our study was conducted with a sample of 41 acromegaly patients and 42 control group individuals. Static, dynamic, and stabilometric baropodometric analyses were performed, as well as podoscanner analysis.

### Results

According to the dynamic and static baropodometric analyses of both groups, the standing load distribution and stabilometric Romberg index findings were similar. However, the acromegaly group showed a higher prevalence of pes planus findings compared to the control group ($p<0.003$). Conversely, the control group showed a higher incidence of callus and corn formation ($p=0.01$).

### Conclusions

Pes planus can disturb the load distribution in the foot, leading to the formation of pressure points. High pressure on the plantar surface of the foot is associated with the development of callus and corn. In this study, although pes planus was more common in the acromegaly group than in the control group, callus and corn formation in the forefoot region were higher in the control group ($p=0.01$). It was suggested that the soft tissue hypertrophy in acromegaly may be protective against callus and corn formation, which are expected to develop due to pressure. The podiatric approach can be used in other endocrinological diseases that affect the musculoskeletal system, such as acromegaly, especially in diabetic patients. Conducting baropodometric analysis and balancing load distribution with insoles can contribute to reducing the risk of fracture in acromegaly patients. Future studies with larger patient groups, including clinical and radiological findings, can be performed to further evaluate these results.

### Keywords

Acromegaly; Posture; Gait Analysis; Foot Health; Baropodometry; Podology

## INTRODUCTION

Acromegaly, a rare yet debilitating chronic condition, arises from the excessive production of growth hormone (GH) by a pituitary adenoma. Elevated GH and insulin-like growth factor (IGF)-I levels result in a range of clinical symptoms, including enlarged extremities, facial alterations, joint pain, diabetes mellitus, as well as complications affecting the cardiovascular,

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respiratory, and metabolic systems. Additionally, there is an increased incidence of certain neoplasms associated with this condition. [1,2]

The protracted progression of the disease and an average diagnostic delay of 8-10 years pose significant challenges in early detection. [3] Initial symptoms of acromegaly may be subtle and easily overlooked, underscoring the need for heightened awareness among healthcare professionals and the general populace. Timely recognition of early indicators and prompt medical attention are paramount for optimizing treatment outcomes and minimizing complications.

The objective of acromegaly treatment is to restore normal biochemical and clinical parameters, reduce morbidity and mortality, and enhance patients' overall quality of life. Therefore, effective patient care demands a collaborative, multidisciplinary approach involving specialists in pituitary medicine. [4] This approach ensures that patients receive comprehensive care, encompassing both medical and surgical interventions, hormonal replacement therapy, and rehabilitation.

Individuals with acromegaly frequently experience notable alterations in body composition, including increased lean body mass and body water, along with diminished adipose tissue. This condition also leads to arthropathy due to excessive growth hormone secretion, affecting both axial and appendicular skeletal elements. Weight-bearing joints in the lower extremities are predominantly affected. Arthropathic pain can significantly compromise quality of life and result in substantial functional decline over time. [5]

Muscle weakness and hypertrophy are characteristic manifestations of acromegaly owing to prolonged exposure to GH and IGF-1. Over time, excessive growth of bone and soft tissue may lead to deformities, alterations in gait, and difficulties in maintaining posture and balance. [6] Consequently, addressing these issues early on is crucial in preventing further complications and enhancing patients' quality of life.

Initiating with physical therapy interventions and podiatric strategies can serve as a foundational step in enhancing the well-being of individuals with acromegaly by focusing on posture and balance control. While podiatric treatments are commonly applied in conditions such as diabetes, rheumatological disorders, and orthopedic issues, they are not routinely integrated into the care of acromegalic patients. This underscores the necessity for exploring the potential advantages of podiatric approaches in this specific patient population.

This research endeavors to investigate posture and body balance in individuals with acromegaly through the use of baropodometric gait analysis. Baropodometry, a non-invasive technique, assesses the distribution of plantar pressure during walking, furnishing valuable insights into the foot function and gait patterns of patients. The findings of this study hold the potential to shed light on the advantages of podiatric interventions in managing acromegaly and thereby augmenting the quality of life of affected individuals.

In conclusion, acromegaly is a grave chronic condition associated with considerable morbidity and mortality. Early identification, swift diagnosis, and effective collaborative management are imperative in enhancing treatment outcomes and the well-being of patients. Physical therapy interventions and podiatric strategies targeting posture and balance control hold promise for enhancing the quality of life of individuals with acromegaly. This study has the potential to yield valuable insights into the benefits of podiatric approaches in managing acromegaly, thereby contributing to the improved quality of life of affected individuals.

## METHODS

This study included 41 patients with acromegaly who underwent surgery and were followed up at the Kocaeli University Department of Endocrinology and Metabolism, as well as 42 healthy volunteers. Ethics approval and consent to participate: Ethical approvement of this study is obtained by the Kocaeli University Hospital (Approvement Number: GOKAEK-2023/02.01)

Participants with neurovascular diseases, vestibular diseases, visual impairments, physical disabilities, orthotic or prosthetic users, and a past medical history of orthopedic surgery were excluded from the study. The drug use of the participants was assessed, and those who used medications that could cause balance disorders were also excluded. Demographic characteristics, anthropometric measurements, and disease status of the participants were recorded. Based on the Endocrine

Society guidelines, patients with a normal serum IGF-1 value according to age and sex-specific criteria, and a spot GH value < 1 µg/L or suppressible GH were classified as having controlled acromegaly. [7] The status of other pituitary hormones was also evaluated, and those with deficiencies received appropriate dose replacement therapy.

A modular electronic baropodometric measuring platform with a length of 200 cm, a Multi-Sensor with 25,600 sensors on 40x40 cm width, and four walkways of 50 cm each were used for the study. The measurements were analyzed with Miletrix Software, and static, dynamic, and stabilometric baropodometric analyses were performed. Values obtained from all measurements were evaluated with the Digitalized Biometry Images System (DBIS) software to determine whether Static/Dynamic/Stabilometric Biomechanical Postural Indexes deviated from normal. [8] A Podoscanner was also used to obtain information on foot morphology, such as foot length, metatarsal width, and shoe size. Using this baropodometric analysis system, 41 acromegaly patients and 42 control group participants were examined and compared. Five analyses were carried out for each patient: dynamic analysis to determine the walking and loading on the plantar area; stabilometric analysis to examine the standing posture of the body and balance; static analysis to examine the loading on the plantar area during the standing position; a podoscanner analysis to acquire data about foot anthropometry. All participants did not have primary diseases (e.g., torticollis myogenesis, orthopedic diseases) that would cause postural disorders and gait problems. Before starting the analysis, patients were asked to walk on the walking platform twice to ensure calibration. With these analyses, the center of gravity, the center of pressure of the foot, the loading disorders, and pressure points were measured during the function of the foot. [9] The load distribution during the function of the foot was measured, and the high-pressure points were determined. Miletrix software presented high-pressure points in red. For the stabilometric analysis, the patient stood on the baropodometric platform in the orthostatic position, eyes closed, arms at the side for two minutes. Oscillations, balance, and plantar load distribution were evaluated with this analysis. Miletrix software measured 0-10 oscillations as normal, ten or more oscillations as disordered, and those that deviated from normal were considered disordered. [8] For the static analysis, the patient was given a natural standing position, and data were taken from the platform for 5 seconds. The center of pressure, the plantar center of gravity, and pressure points were determined. The surface areas of both feet supporting the load, the percentage distribution of the load carried in the rearfoot and forefoot, and the pressure applied to both feet' medial and lateral surfaces were calculated. [10] As a result of all analyzes, static, dynamic, and stabilometric biomechanical index values were obtained, and those above ten were considered disordered.

Footprints were evaluated with three different measurement methods.

1- Staheli Index (SI): The ratio between the narrowest area of the midfoot and the widest area of the heel in the footprint. An index greater than 0.7 was accepted as pes planus [11] (Image 1a).

2- Chippaux-Smirak Index (CSI): The ratio between the narrowest part of the midfoot and the widest part of the metatarsal area. An index greater than 0.4 was named pes planus [12,13] (Image 1b).

## ETHICAL CLEARANCE

Ethics approval and consent to participate: Ethical approvement of this study is obtained by the Kocaeli University Hospital (Approvement Number: GOKAEK-2023/02.01)

## RESULTS

The CSI index, SI index values used for the evaluation of flat feet, and static, dynamic, stabilometric baropodometric analysis results are given in Table 1. According to these results, the CSI index and SI index data in Pes Planus findings, and forefoot high-pressure data in static baropodometric analysis, were statistically significant in the acromegaly group compared to the control group ($p < 0.05$). Nevertheless, both groups' plantar pressure findings of dynamic baropodometric analysis, static baropodometric analysis, and stabilometric-Romberg index findings were similar.

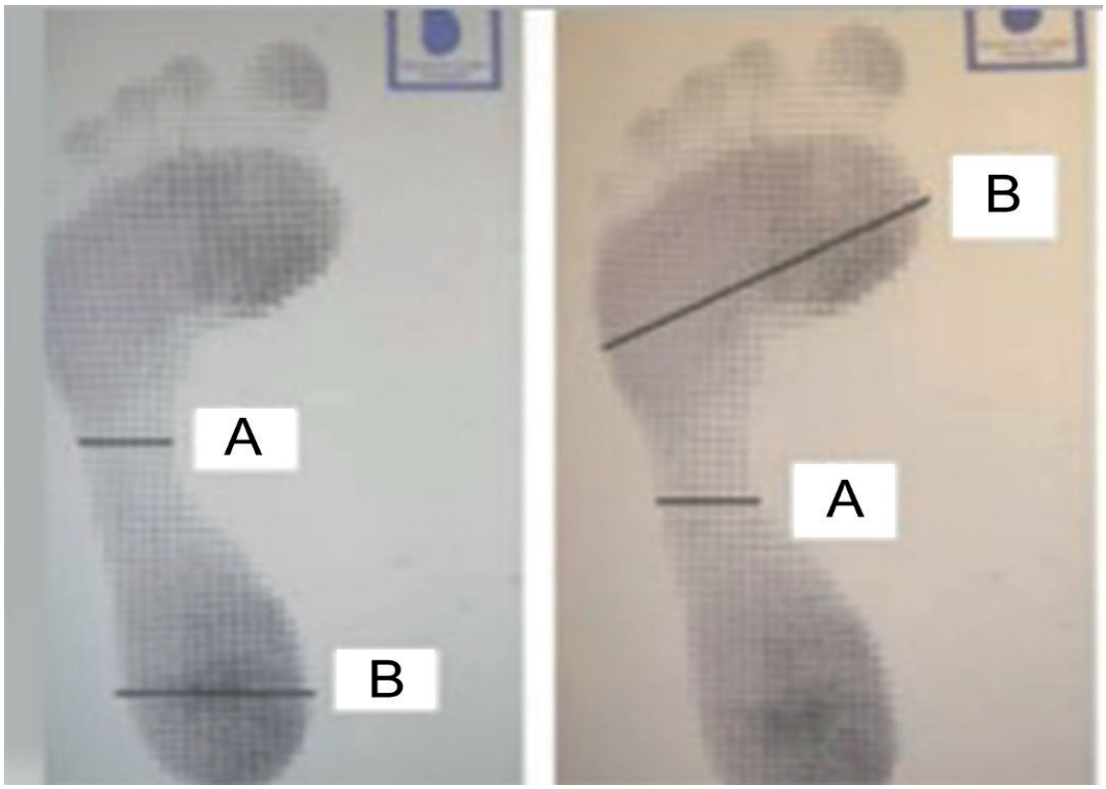


**Image 1. Evaluated footprints**

**Table 1:** Foot Examination

| | | | Acromegaly group (n=41) | Control group (n=42) |
|---|---|---|---|---|
| Pes Planus Findings | Sİ İndex | >0.7 | 33 (%80.4) | 21 (%50)* |
| | | <0.7 | 8 (%19.6) | 21 (%50)* |
| | CSİ İndex | > 0.4 | 33 (%80.4) | 17 (%40.4)* |
| | | < 0.4 | 8 (%19.6) | 25 (%59.6)* |
| Pes Cavus Findings | Increase in the Arch | Yes | 1 (%2.4) | 5 (%11.9) |
| | | No | 40 (%97.6) | 37 (%88.1) |
| Dynamic Baropodometric Analysis | High pressure in the forefoot | Yes | 39 (%95.1) | 39 (%92.8) |
| | | No | 2 (%4.9) | 3 (%7.2) |
| | High pressure in midfoot | Yes | 24(%58.5) | 24(%57.1) |
| | | No | 17(%41.5) | 18 (%42.9) |
| | High pressure in the hind foot | Yes | 14(%34.1) | 14 (%33.3) |
| | | No | 27 (%65.9) | 28(%66.7) |
| | Biomechanical Postural Index | Normal | 14 (%34.1) | 18 (%42.8) |
| | | Abnormal | 27 (%65.9) | 24 (%57.2) |

| | | | Acromegaly group (n=41) | Control group (n=42) |
|---|---|---|---|---|
| Static Baropodometric Analysis | High pressure in the forefoot | Yes | 29 (%70.7) | 10 (%23.8)* |
| | | No | 12 (%29.3) | 32 (%76.2)* |
| | High pressure in midfoot | Yes | 15 (%36.5) | 9 (%21.4) |
| | | No | 26 (%63.5) | 33 (%78.6) |
| | High pressure in the hind foot | Yes | 23(%56) | 9 (%21.4) |
| | | No | 18 (%44) | 33 (%78.6) |
| | Body Center of Gravity | Normal | 25 (%60.9) | 25 (%59.5) |
| | | Abnormal | 16(%39.1) | 27 (%40.5) |
| | Biomechanical Postural Index | Normal | 34 (%82.9) | 30 (%71.4) |
| | | Abnormal | 7 (%17.1) | 12 (%28.6) |
| | StabilometrikRomberg İndex | Normal | 14 (%34.1) | 14 (%23.8) |
| | | Abnormal | 27 (%65.9) | 28 (%76.2) |

*$p < 0.05$*

Callus and corn formation and other foot health problems are given in Table 3. Although both groups' static and dynamic baropodometric analysis findings were similar, callus and corn formation in the fore and hind feet were significantly higher in the control group than in the acromegaly group ($p < 0.05$). No difference was observed in other foot health problems such as onychomycosis, onychogryphosis, ingrown nail, and tinea pedis.

## DISCUSSION

In approximately 98% of acromegaly cases, excessive GH levels caused by a pituitary adenoma (somatotropinoma) lead to metabolic complications from IGF-I, including insulin resistance (IR), hyperglycemia, and hyperlipidemia. These complications result in increasing rates of cardiovascular and musculoskeletal comorbidities and mortality. [14,15] Treatment usually aims to normalize IGF1 levels to reduce the risk of comorbidities, control the disease, and lower the mortality rate. [16,17] Therefore, normalizing IGF1 levels is a key goal for clinicians. Physical therapy interventions and podological approaches can improve the quality of life of patients by providing posture and balance control. Thus, in this study, the posture and body balance of patients with acromegaly who underwent surgery and were followed up in the Kocaeli University Endocrinology and Metabolism Department were analyzed by baropodometric gait analysis. Additionally, callus and corn formation in the fore and hind feet were evaluated and compared to the control group.

GH and IGF-I play significant roles in bone metabolism and growth, although the precise mechanisms of bone disease in acromegaly are not fully understood. [17] Excessive GH may affect calcium homeostasis and bone remodeling and increase skeletal fragility. [18] It is widely accepted that GH mediates the effects of PTH, both directly and through systemic and local production of IGF-I, and might have an anabolic impact on bone. It accelerates osteoblastogenesis, osteoblast differentiation and function, and expands osteoprotegerin and its deposition in the bone matrix. [19] However, studies based on biochemical markers and histomorphometry show that GH increases bone

**Table 2. Other foot health problems**

| | | | Acromegaly group (n=41) | Control group (n=42) |
|---|---|---|---|---|
| Callus and Corn Formation | Fore foot | Yes | 12 (%29.3)* | 26 (%61.9) |
| | | No | 29 (%70.7)* | 16 (%39) |
| | Mid foot | Yes | - | 3 (%7.1) |
| | | No | 41 (%100) | 39 (%92.8) |
| | Hind foot | Yes | 2 (%4.8)* | 17 (%40.4) |
| | | No | 39 (%95.1)* | 24 (%57.1) |
| Other Foot Health Issues | Onychomycosis | Yes | 13 (%31.7) | 6 (%14.2) |
| | | No | 26 (%63.4) | 36 (%85.7) |
| | Onychogryphosis | Yes | 1 (%2.5) | 4 (%9.5) |
| | | No | 40 (%97.5) | 38 (%90.5) |
| | Ingrown Nail | Yes | 4 (%9.8) | 6 (%14.2) |
| | | No | 37 (%90.2) | 36 (%85.8) |
| | Tineapedis | Yes | 2 (%4.9) | 3 (%7.2) |
| | | No | 39 (%95.1) | 39 (%92.8) |

*$p< 0.05$*

turnover and causes deterioration of cortical and trabecular bone structure. [15] Patients with long-standing active acromegaly have the highest risk of fractures. [1] In Pes planus (flat feet) findings, which are used to define feet with visually lowered medial longitudinal arch together with valgus foot deformity, the High-Pressure forefoot data was found to be significant in the acromegaly group compared to the control group ($p<0.05$). This finding suggests that analyzing the load distribution by baropodometric analysis and balancing load distribution with insoles would contribute to reducing the risk of fracture (Table 2). Radiographic examinations are the reference point to define the size of the pes planus; however, they can be utilized clinically via a selection of static foot posture indices, each with its own restrictions. Apart from being simple and easy, another reason for choosing these three measurement methods is that when evaluating MLA height loss, heel marks in SI and metatarsal marks in CSI are included in the evaluation. [12]

The development of corns and calluses consists of hyperkeratosis, a typical physiological reaction of the skin to chronic excessive pressure or friction resulting from faulty shoes (wearing mismatched shoes), abnormal foot mechanics (a deformity of the foot that applies abnormal pressure), and high activity levels. [20] Hyperkeratosis is a normal protective response of the skin that becomes pathological when corns and calluses become too large and can become a source of symptoms. [21]

While the applied treatments provide symptomatic

relief, the underlying problem needs to be addressed to prevent the recurrence of corns and calluses. [20] In the acromegaly group, corns and calluses were found to be more common in the forefoot and heel regions compared to the control group ($p<0.05$). The results indicate that patients with acromegaly are at a higher risk of developing corns and calluses due to their altered foot mechanics and increased activity levels.

The findings of this study highlight the importance of early diagnosis and effective management of acromegaly to reduce the risk of comorbidities and improve quality of life. Normalizing IGF1 levels is crucial in controlling the disease and reducing the risk of metabolic complications. Physical therapy interventions, such as baropodometric gait analysis and the use of insoles, can aid in improving the posture and body balance of patients with acromegaly, reducing the risk of fracture. Furthermore, the increased prevalence of corns and calluses in acromegaly patients emphasizes the need for proper foot care and regular follow-up to prevent the recurrence of these conditions.

Consequently, acromegaly is a rare but serious endocrine disorder that can lead to significant comorbidities and mortality if left untreated. Normalizing IGF1 levels and effective management of metabolic complications are crucial in controlling the disease and reducing the risk of comorbidities. Physical therapy interventions, such as baropodometric gait analysis and insole use, can aid in improving the posture and body balance of patients with acromegaly, reducing the risk of fracture. Proper foot care and regular follow-up are essential in preventing the recurrence of corns and calluses in acromegaly patients. Overall, the findings of this study provide valuable insights into the management of acromegaly and highlight the importance of a multidisciplinary approach to care for these patients.

## CONCLUSION

The impact of metabolic disorders on the physical functioning and overall quality of life of individuals with acromegaly is of paramount significance. Advances in treatment options and a better understanding of disease-related complications have led to a decrease in mortality rates among well-managed patients, bringing them closer to levels observed in the general population. It is imperative that adequate pain management and targeted joint mobilization become standard components of the clinical monitoring protocol for individuals with acromegaly. Additionally, when deemed necessary, specific radiographic imaging should be integrated into the assessment process. [22]

Taking an interdisciplinary approach to orthopedic care is pivotal for optimal maintenance, particularly in select cases. Likewise, emphasizing bone health awareness among patients, ensuring sufficient calcium and vitamin D supplementation, and closely monitoring for indicators of fractures, such as height loss, are supplementary measures that are integral to the comprehensive care of individuals with acromegaly. The inclusion of baropodometric analyses and a podiatric treatment approach can also be instrumental in the treatment and ongoing management of acromegaly patients. By implementing physical therapy interventions and podiatric strategies that focus on posture and balance control, we establish a foundation for enhancing the overall quality of life for these patients.

Conducting a thorough analysis of load distribution through baropodometric assessment and effectively balancing this distribution with the use of insoles can contribute significantly to reducing the risk of fractures. However, further research is imperative to comprehensively understand the impacts of various treatment modalities.

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