Thesis

Prevalence of intraosseous calcaneus lipomas as identified on MRI.

submitted by

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Graz. 13.04.2026

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Graz, 13.04.26 Max Jünemann, m.p.

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Abstract in English

Title: Prevalence of intraosseous calcaneus lipomas as identified on MRI.

Introduction

Intraosseous lipomas are rare tumors, they are accounting for approximately 2.5% of all bone tumors. In studies involving the largest population, the proportion of lipomas in the calcaneus in relation to the total number of intraosseous lipomas was found to be between 27.5% and 32%. Up to 40.1% of intraosseous calcaneus lipomas are asymptomatic and found incidentally. The prevalence of intraosseous calcaneal lipomas remains unclear. The aim of this study was to obtain data on the prevalence of intraosseous calcaneal lipomas and detect risk factors related to sex, age and location.

Methods

This retrospective observational study, evaluated 18 373 MRI scans of the left (*N* = 8458) and right (*N* = 9915) foot and ankle of a total of 15 348 patients (50% male, n=7680, 50% female, n=7668), performed between 01.01.2014 and 12.11.2024 at a single radiology institute in Austria. A total of 3 025 double or multiple scans per patient (838 on the left and 2187 on the right) were excluded.

Results

A total of 46 patients were diagnosed with a calcaneal lipoma, including 12 females (26.1%), with a median age of 42.5 years IQR (28.3–52.3).

The lesion was detected incidentally in 46.7% (21/45) of patients. Stage 2 Milgram was the most common and seen in 22 patients (47.8%), followed by Milgram stage 1 lesions (20 [43.5%]) and stage 3 lesions (4 [8,7%]). 2.5 (IQR 1.5–3.0) cm was the median lesion size. Smaller tumours were observed in females 1.8 [IQR 1.2–2.3] cm vs 2.5 [IQR 1.9–3.2] cm in males; p=0.030).

All lesions were unilateral and located in Ward´s triangle. The prevalence over the entire period was 0,3%. No significant variation was observed over the years (p=0.310). Males were more frequently affected with a prevalence of 0,44% compared to a prevalence of 0,16% in females (p=0.001).

Conclusion:

This study represents the largest population to this date on the prevalence of intraosseous calcaneus lipomas. The prevalence was 0,30% over a period of almost 11 years and included MRI scans of a total of 15 348 patients.

Abstract in German

Titel: Prävalenz von intraossären Calcaneuslipomen mittels MRT-Diagnostik

Hintergrund

Intraossäre Lipome stellen seltene Tumoren dar und machen etwa 2,5 % aller Knochentumoren aus. In Studien mit der größten untersuchten Population lag der Anteil der intraossären Calcaneuslipome im Verhältnis zur Gesamtzahl der intraossären Lipome zwischen 27,5 % und 32 %. Bis zu 40,1 % der intraossären Calcaneuslipome sind asymptomatisch und werden zufällig entdeckt. Die Prävalenz intraossärer Calcaneuslipome ist bisher unklar. Ziel dieser Studie war es, Daten zur Prävalenz intraossärer Calcaneuslipome zu erheben und mögliche Risikofaktoren in Bezug auf Alter, Geschlecht und Lokalisation zu identifizieren.

Methoden

In dieser retrospektiven Beobachtungsstudie wurden 18.373 MRT-Scans des linken (n = 8.458) und rechten Fußes/Sprunggelenks (n = 9.915) von insgesamt 15.348 Patient*innen (50 % männlich, n = 7.680; 50 % weiblich, n = 7.668), durchgeführt zwischen dem 01.01.2014 und 12.11.2024 an einem einzelnen radiologischen Institut in Österreich, analysiert. Doppel- oder Mehrfachuntersuchungen pro Patient wurden ausgeschlossen (n = 3.025), davon 838 auf der linken Seite und 2.187 auf der rechten Seite.

Ergebnisse

Bei 46 Patient*innen wurde ein Calcaneuslipom diagnostiziert, darunter 12 Frauen (26,1 %) und 34 Männer (73,9 %), mit einem medianen Alter von 42,5 Jahren (IQR 28,3–52,3). In 21 von 45 Fällen (46,7 %) wurde die Läsion zufällig entdeckt. Milgram-Stadium 2 war am häufigsten (22 Patienten; 47,8 %), gefolgt von Stadium 1 (20 Patienten; 43,5 %) und Stadium 3 (4 Patienten; 8,7 %). Die mediane Tumorgröße betrug 2,5 cm (IQR 1,5–3,0), wobei Tumoren bei Männern signifikant größer waren als bei Frauen (2,5 cm [IQR 1,9–3,2] vs. 1,8 cm [IQR 1,2–2,3]; p = 0,030). Alle Läsionen waren unilateral und im Ward’schen Dreieck lokalisiert. Die Gesamtprävalenz über den gesamten Untersuchungszeitraum betrug 0,30 %. Über die Jahre hinweg wurden keine signifikanten Unterschiede festgestellt (p = 0,310). Männer waren häufiger betroffen mit einer Prävalenz von 0,44 % im Vergleich zu 0,16 % bei Frauen (p = 0,001).

Schlussfolgerung

Diese Studie umfasst die bisher größte Population zur Prävalenz intraossärer Calcaneuslipome. Die Prävalenz über einen Zeitraum von fast 11 Jahren betrug 0,30 % und basiert auf MRT-Scans von insgesamt 15.348 Patient*innen. Das männliche Geschlecht scheint häufiger betroffen zu sein als das weibliche.

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List of Abbreviations

MRI	Magnetic resonance imaging
CT	Computed tomography
LPP	Lipoma preferred partner
HMG	Human-mobility group
TSE	Turbo spin echo
GRE	Gradient echo sequence
SD	Standard-deviation

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1 Introduction

1.1 Definition

An intraosseous lipoma is a rarely diagnosed primary benign bone tumour comprising mature lipocytes. These lesions often regress spontaneously through a process of infarction, calcification and cyst formation. (13)
Osseus lipomas, i.e. an atypical accumulation of fat in or on the bone, can be subdivided according to the site of origin. A distinction is made between lipomas on the surface of the bone (juxtacortical) and lipomas occurring in the bone (intraosseous). (11) Superficial lipomas can be subdivided into parosteal and subperiosteal lipomas. (11) This study will focus on the prevalence of intraosseous lipomas occurring in the calcaneus.

According to Milgram, intraosseous lipomas are not as rare as commonly believed because they are often misdiagnosed.(13) In addition, they usually cause no symptoms and are thus diagnosed incidentally. (2)
The precise prevalence of intraosseous lipomas remains uncertain due to the limited size of the study populations investigated so far. To date, intraosseous lipomas in general are estimated to account for up to 2.5 percent of all bone tumours. (4) In studies with the largest populations, the proportion of intraosseous calcaneus lipomas in relation to the total number of intraosseous lipomas was 27.5 – 32 percent. (3, 11)

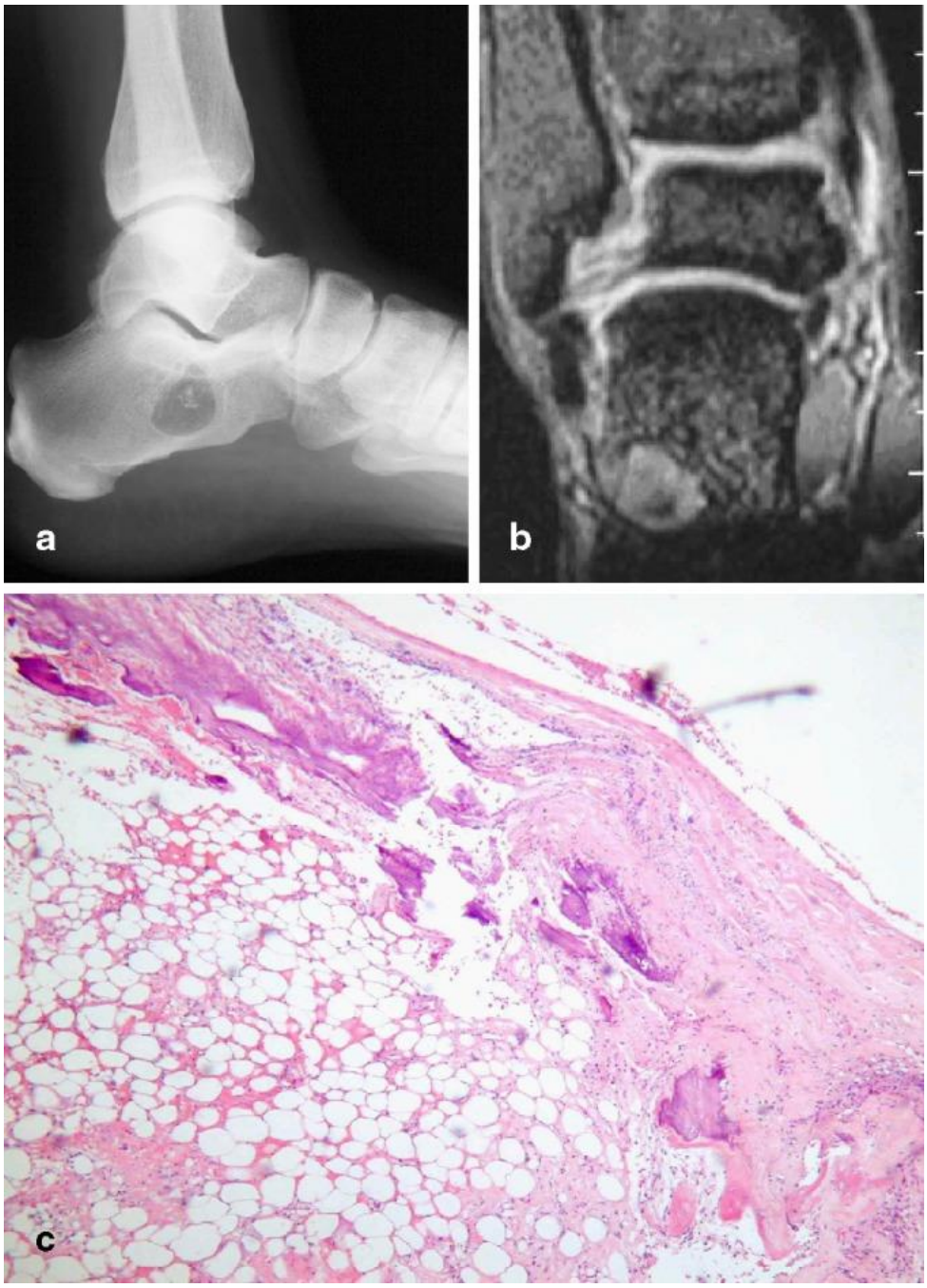
1.2 Classification of Milgram

The lack of specific histopathologic features of intraosseous lipomas presents a significant challenge for pathologists. (7) According to Milgram, the tumour is an independent entity with different characteristics depending on the stage of development. (13)
Accordingly, he proposes a classification to categorize intraosseous lipomas according to their degree of involution: The first stage comprises solid tumours with viable lipocytes. The second stage is considered transitional and includes lesions with fat necrosis, focal calcification, but also regions with viable lipocytes. The third stage refers to the advanced involution of intraosseous lipomas, in which

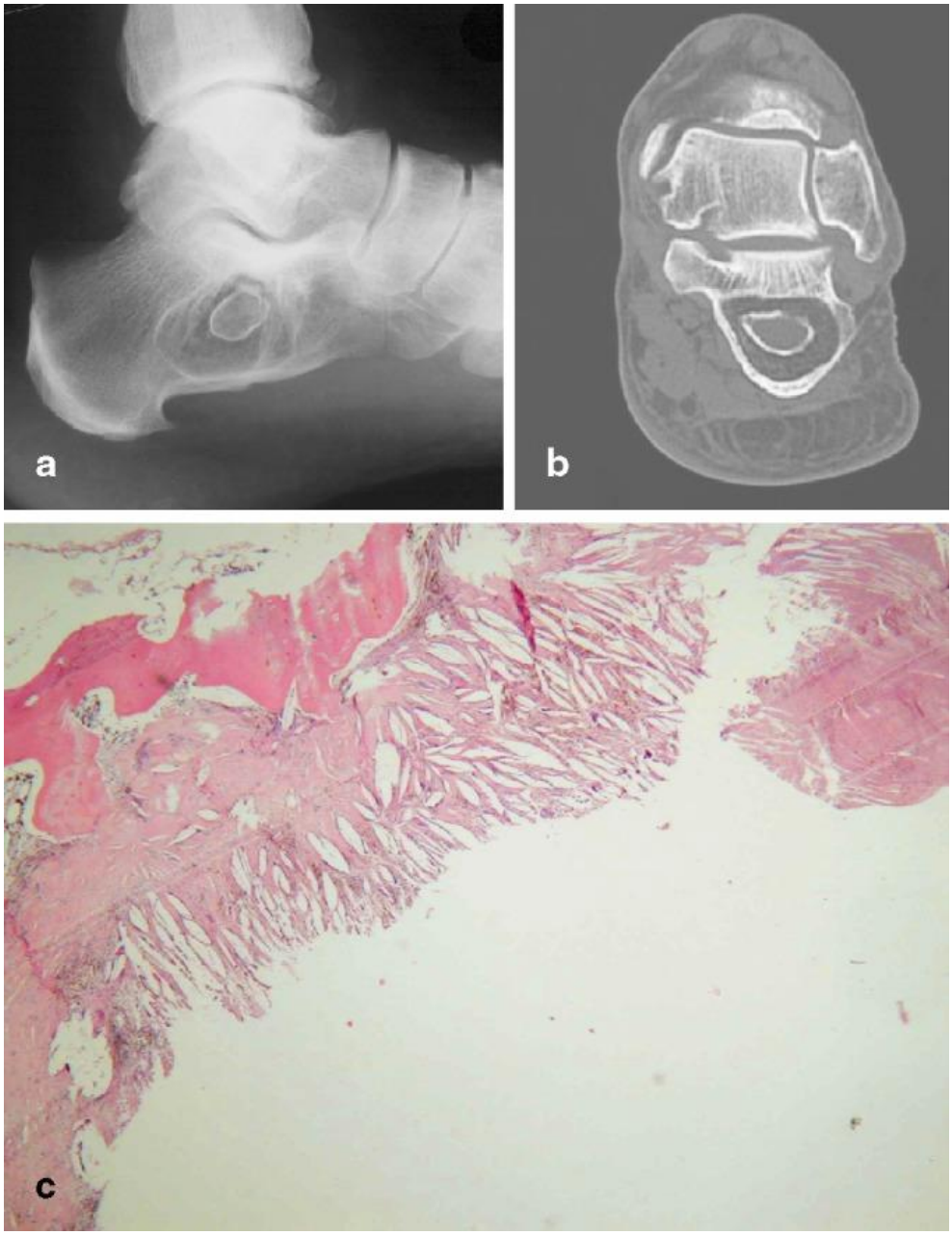
the fat cells have undergone necrosis. Cyst formation, calcification and reactive bone formation are typically present. (13)

1 a) Radiograph of the right femur of a 61-year old woman showing a radiolucent lesion with a well-defined margin. b) MRI appearance of the intraosseous lipoma in the femur shows a hyperintense lesion. c) Histology revealed mature fat cells of a lipoma without any signs of calcifications (original

magnification x40). Both radiograph and histology correspond to a stage I intraosseous lipoma according to Milgram classification. From Radl et al. (2004) Reprinted with permission from the journal *International Orthopaedics*.



2 a) Lateral radiograph of the left calcaneus of a 43-year-old female patient with a radiolucent lesion and slight central calcification. b) MRI revealed a hyperintense lesion surrounded by thin hypointense areas and a central hypodensity corresponding with the calcification as seen on the radiograph. C) Histology showed an intraosseous lipoma with sclerotic fatty tissue, local fibrosis, and incipient signs of calcifications (original magnification x40), which corresponds to a stage II intraosseous lipoma. From Radl et al. (20) Reprinted with permission from the journal *International Orthopaedics*.



3 a) Lateral radiograph of the calcaneus of a 73-year-old male patient with a radiolucent lesion and a central calcification. b) CT examination revealed a well-circumscribed radiolucent lesion in the calcaneus surrounded by bone sclerosis. c) Histology showed a massive ossification and calcification of necrotic fat (original magnification x40). Both radiograph and histology correspond to a stage III intraosseous lipoma. From Radl et al. (20) Reprinted with permission from the journal *International Orthopaedics*.

1.3 Epidemiology

1.3.1 Intraosseous lipomas

In the study of Campbell et al. (3), the age range of patients diagnosed with intraosseous lipoma was 13 to 67 years, with the mean age of 40 years. In other studies, the age range was 4 to 85 years, with a mean of 42,5 years. (2, 3, 13)
In his literature review, Kapukaya et al. (11) provide an age range of 4 to 85 years, and a mean age of 41 years. However, due to the limited number of patients with an intraosseous calcaneus lipoma included in the studies, the values varied depending on the study, with some of them indicating an age range of 50 to 63 years. (7, 11) The sex distribution appears to be similar. Due to small populations investigated so far, several studies reported on all-female, or predominantly female cohorts, though.(20,15,7)
In larger populations, males accounted for 59% to 71% of patients, and females for 29% to 41%. These literature reviews suggest that men are more frequently affected than women. (3, 11, 13)

1.3.2 Intraosseous Lipomas of the calcaneus

The study by Campbell et al. describes an age range of 13 to 60 years with an average age of 37 years with regard to the occurrence of an intraosseous calcaneus lipoma.
The sex distribution is given as 2 males to 1 female, a population of 22 patients was analysed. (3) The literature review conducted by Campbell et al., which included Milgram's data and other case reports, revealed a comparable age distribution. (3, 13)

1.4 Dignity

In general, intraosseous lipomas are considered as benign, "leave-me-alone" lesions that consist of fatty tissue on imaging.(16) The benign nature of an intraosseous lipoma is supported by studies that have analyzed the presence of fatty tissue in benign and malignant bone tumours of various histological structures. The findings indicate that fatty tissue in a malignant bone lesion is an unusual occurrence and therefore very rare. (16, 23) Nevertheless, the possibility of malignant degeneration of an intraosseous lipoma is supported by a study

published by Milgram who reported on four cases in which malignant transformation of an intraosseous lipoma was observed. (14)

,,These lesions demonstrated radiologic and histologic features of benign lipomas together with histologic fields of either malignant fibrous histiocytoma or liposarcoma. In two of the three patients who were followed up, the tumors were fatal despite amputation. Malignant transformation of a lipoma should be suspected when rapid bone destruction is seen in a stage I radiolucent lipoma." (Milgram, 1990, Source nr.14)

It should be noted that the degeneration of stage three intraosseous lipomas can be mistaken with the degeneration of bone infarcts, though.(14)

1.5 Localisation

1.5.1 Intraosseous Lipoma

A meta-analysis of 206 patients conducted by Campbell et al. (3) revealed that the localization of intraosseous lipomas varied depending on the study investigated. (3)

It was concluded that the most common localization was the lower limb, amounting to 71% across all studies. (3, 13) The studies by Palcewski et al.(16) and Kapukaya et al. (11) also indicate that the lower limb is the most common localization. (16, 11)

,,Other common sites in the lower limb include the sub-trochanteric region of the femur, proximal tibial metaphysis, distal femoral metaphysis and the proximal and distal fibular metaphyses." (Campbell, 2003, Source Nr.3) In addition, Uguz et al. described an intraosseous lipoma in the V metatarsal bone. (27)

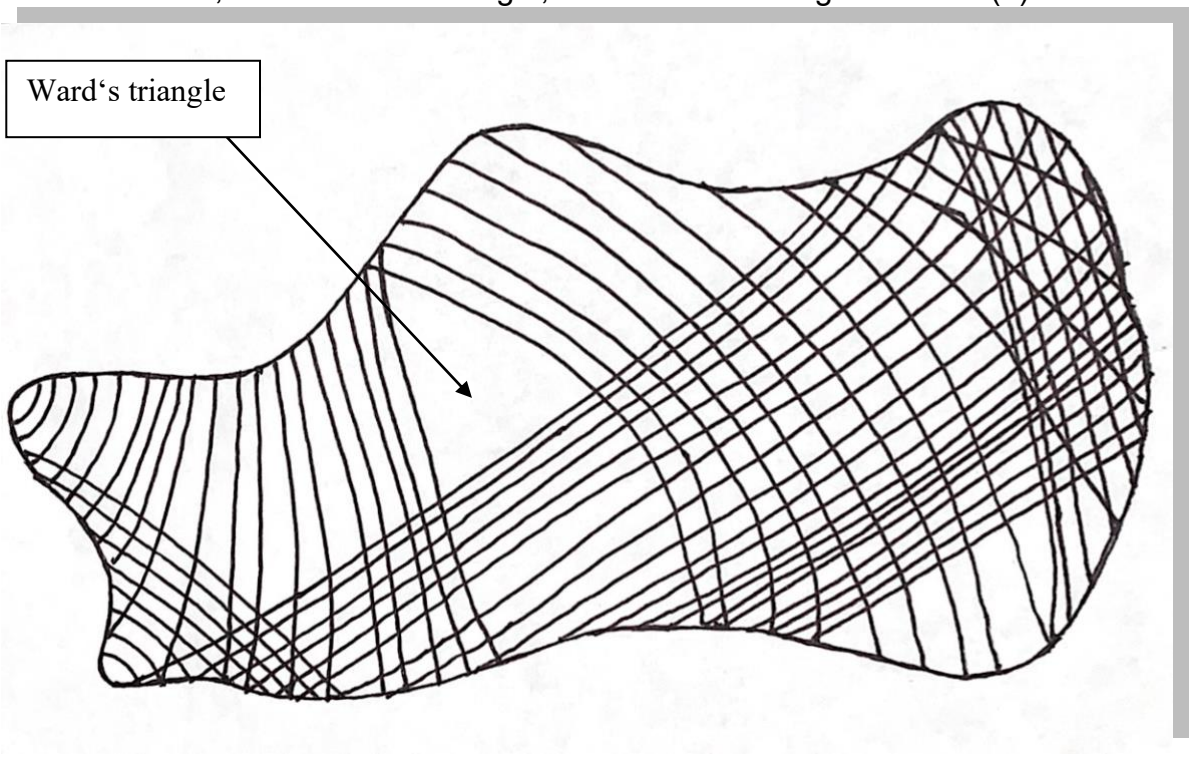
The upper extremity is less frequently reported as a localization (7%) and if, it typically affects the proximal and distal humerus as well as the metaphysis of the radius. Notably, Campbell et al. described isolated diaphyseal or epiphyseal involvement as unusual. (3, 13)

,,Sites of lipomas of the axial skeleton include the skull (4%), mandible (3%), spine (4%), sacrum (2%), pelvis (5%) and ribs (2.5%)." (Campbell 2003, Source Nr. 3)

According to literature, intraosseous lipomas are usually solitary, but patients with multiple and/or bilateral involvement have also been described. (11, 24, 21)

1.5.2 Calcaneal bone

The most frequent localization of intraosseous lipomas is the calcaneal bone with 32% across studies, although the variation is large, ranging from 8% in the study by Milgram to 63% in the study published by Campbell et al.. (3, 13) All intraosseous calcaneus lipomas in this study were documented in the base of the calcaneal neck, i.e. the Ward-Triangle, as shown on the figure below. (2)



4 Ward's Triangle of the calcaneal bone (painted by the author, MJ).

In terms of lipoma size, Campbell et al. observed a range of 10 to 41 mm, with a mean value of 30 mm in a population of 22 affected calcaneal lipomas. The Literature Review conducted by Campbell et al. shows a range from 20 to 40 mm. (3)

1.6 Etiology

The etiology of intraosseous lipomas is not yet fully understood and is the subject of ongoing debate. A number of hypotheses have been put forward trying to explain the etiology. (2) These include post-traumatic changes, reaction to biomechanical stress, healing of a bone infarction, genetic conditions, and transformation of a solitary cyst. (2)

1.6.1 Post-trauma

One hypothesis suggests that intraosseous lipomas emerge post-traumatic as a secondary bone reaction, as described by Poussa & Holmström among others. (18) However, the hypothesis is contradicted by the large number of patients without a history of trauma, and the frequent occurrence of asymptomatic cases as well as incidental discovery of the lesions. Of 49 patients in the study by Bertram et al. only 5 (10.2%) had a preceding trauma, and 16 (32.7%) of the intraosseous lipomas were discovered incidentally. (2)

1.6.2 Biomechanical stress

The frequent location of intraosseous lipomas in the calcaneus indicates that their formation may be associated with biomechanical stress lines. (3) In other localizations, Campbell et al. suspected that the regression of pre-existing lesions (e.g. cysts) may play an important role. (3)

1.6.3 Healing bone infarction

This theory is rather unlikely, given that one study showed that 83.3% of bone infarcts in the calcaneus occur in the posterior part. (1) On the other hand, intraosseous calcaneus lipomas are observed in Ward's triangle. (2) Furthermore, calcification is observed in the periphery of infarcts, whereas it is centrally located in lipomas. (2) Another point against the theory is the occurrence of bone expansion in 30% of the cases described. (3)However, infarcts do not expand the original contours of the bone. (2)

1.6.4 Genetics

Translocations between chromosome 3 and 12 frequently occur in lipomas. More precisely, on chromosome 12 in the region q13-15. Chromosome 3 was observed as the preferred partner chromosome. The breakpoints observed on chromosome 3 are located in the region covered by the YAC clone 192B12. Furthermore, it is assumed that the lipoma preferred partner (LPP) fuses with the human mobility group (HMG)I-C gene through translocation, leading to a disturbed regulation of cell growth through a genetic change, thus favoring development of lipomas. (22)

1.6.5 Transformation from cysts

Another theory is the transformation of a simple bone cyst into an intraosseous lipoma. Intralesional hemorrhage plays an important role in this process. ,,Hemorrhage itself could act as a sclerosing agent, obliterating the cyst." (Elias et al. 2007, Source nr. 6) The subsequently stimulated healing and replacement of the lesion by trabecular fatty tissue could result in a transformation into a lipomatous lesion.(6) This theory offers an explanation for the co-occurrence of cystoid and lipomatous components within a single lesion. (10) Furthermore, the theory could explain the observed discrepancy in the mean age of occurrence of calcaneal cysts (33,2 years) and intraosseous calcaneus lipomas (42,5 years). (2, 17) The theory is also supported by the study carried out by Tins et al.(25) in 2021 that examined the time course of bone cysts. The study concluded that some, and probably most, bone cysts heal with a fatty transformation. (25)

1.7 Clinical presentation

Intraosseous calcaneus lipomas may remain asymptomatic, and are thus most likely discovered incidentally (24-40.1%). (11, 13) According to literature, they are associated with symptoms in 60-67.3% of cases, though. (11, 13) Nevertheless, it remains unclear whether the lesion is causing any discomfort, or rather the symptoms experienced by patients (deriving from another source) lead to imaging, and thus incidental diagnosis of the intraosseous calcaneus lipoma itself.

Accordingly, in various studies, 83%-100% of symptomatic patients described pain in the heel; according to Bertram et al. (2), 6.1% experienced an increase in pain during exercise.

Furthermore, 6.1 – 15.2% described swelling, and 1.9% suffered from a pathological fracture. A positive trauma history was reported by 10.2% of the patients. (2, 11)

1.8 Imaging

In the following, various imaging procedures for the diagnosis of intraosseous lipomas are explained based on a study conducted by Propeck et al. in the year 2000. (19)

In this study, imaging modalities were analyzed with the knowledge of an intraosseous lipoma in place based on histologically confirmed diagnosis.

1.8.1 X-Ray

It is important to note that x-ray is not sufficient for the diagnosis of an intraosseous lipoma. The radiological appearance may mimic other bone lesions, and thus lead to misdiagnosis. (11, 13, 15) In most cases, intraosseous lipomas manifest as well demarcated, radiolucent lesions on X-Ray. The surrounding area may have a sclerotic border, and internal trabeculae may be present. (15) ,,Radiographically, these lesions may mimic other entities such as fibrous dysplasia, aneurysmal bone cysts, simple cysts, bone infarcts and chondroid tumors.” (Öztekin et al. 2008, Source nr. 15)

Intraosseous lipomas present with a variable appearance depending on the respective stage according to Milgram (13). The appearance can vary from a transparent lesion with slight onset of sclerosis in the marginal area to pronounced radiolucency with thick marginal sclerosis. (19)

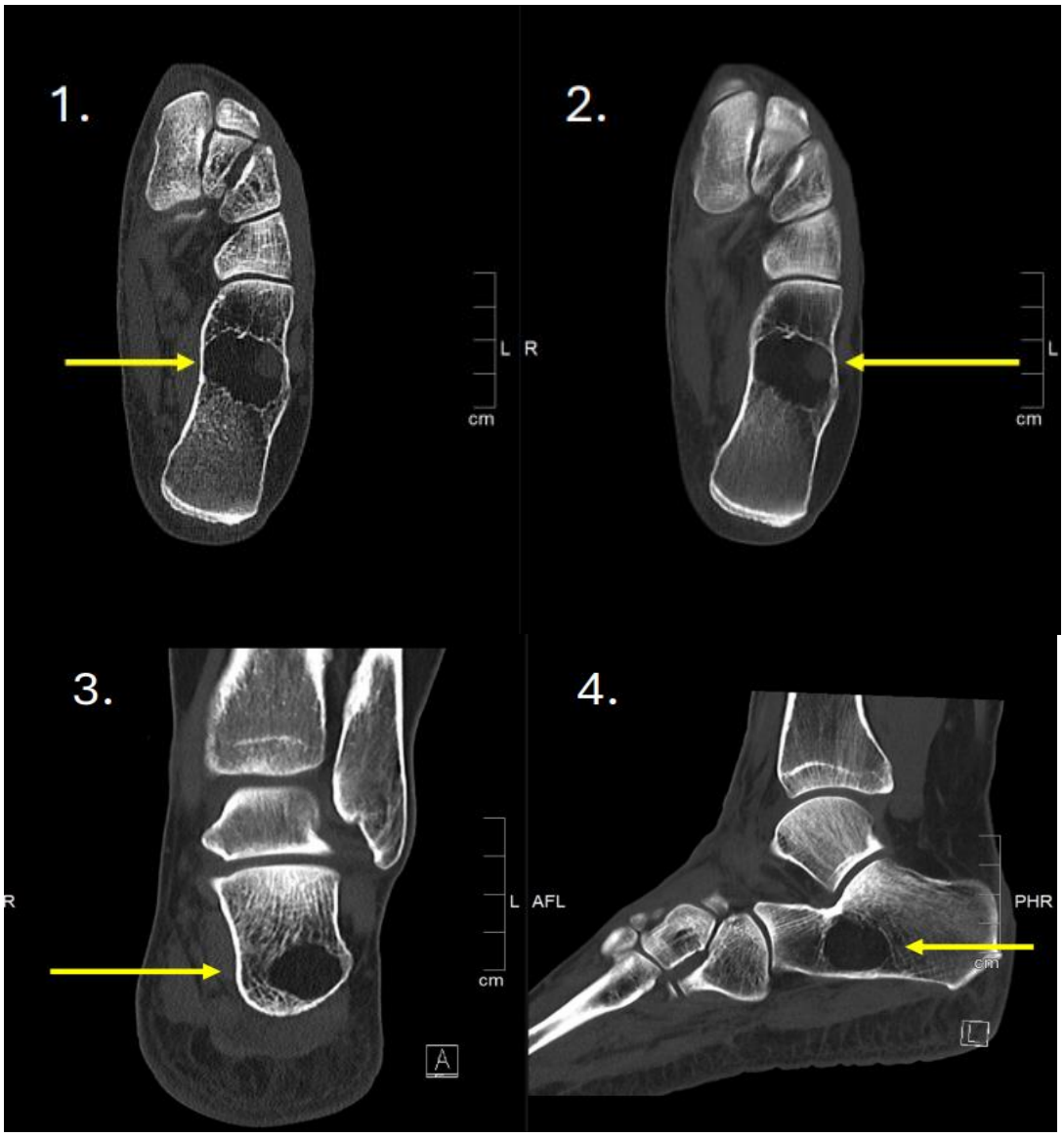
5 XRay of an intraosseous lipoma in the calcaneus (Male, 36 Years)

1.8.2 CT

According to Milgram (13), stage 1 computed tomography (CT) scans of intraosseous lipomas show resorption of the bone (the trabeculae) in the lesion as well as bone enlargement as seen on the CT Scan in the Figure 2. Lesions appearing as transparent on the X-Ray image equivalent to a fat damping on the CT scan. (19)

Intraosseous lipomas in stage 2 show areas of fat attenuation as well as areas of increased density, indicating both bone necrosis and fat necrosis. (19)

Stage 3 lesions are the most difficult ones to diagnose due to various processes within the lesion itself, including ossification, calcification, necrosis and cyst formation. The presence of a peripheral rim of fat is helpful in ruling out other potential diagnoses. (19)



6 CT Scan of an intraosseous lipoma of the calcaneus on the Siemens Somatom Force (Female, 24 years)

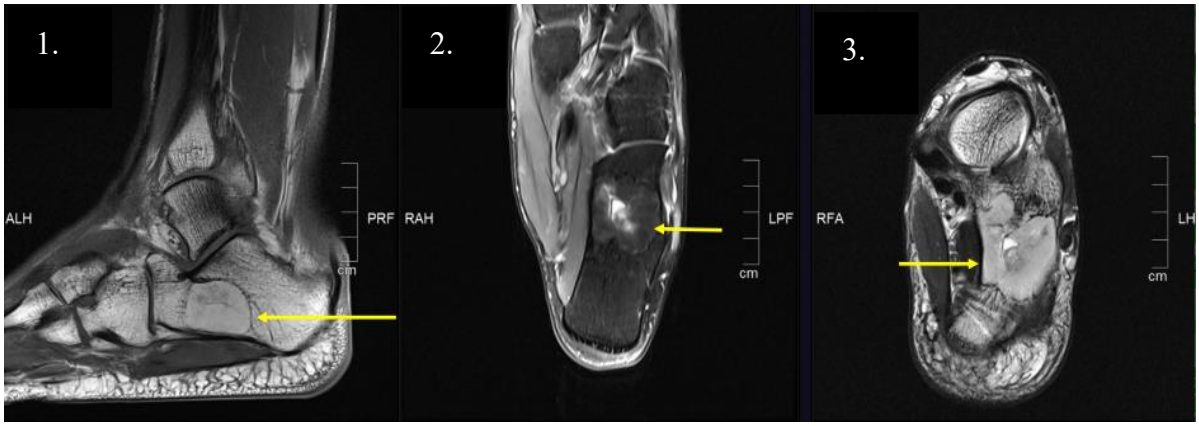
1.8.3 Magnet resonance imaging (MRI)

In case an intraosseous lipoma is suspected, MRI examination is the method of choice. (20)

Stage 1 intraosseous lipomas demonstrate the presence of viable fat on magnetic resonance imaging (MRI). On T1-weighted sequences, fat exhibits an isointense signature in comparison to subcutaneous fat, as seen on the figure 3.1. (Figure 3) On T2-weighted sequences, it displays a low signal intensity with fat suppression. On both T1- and T2- weighted sequences, there is typically a thin surrounding rim with low signal intensity, to mark off the fat lesion. Additionally, stage 2 lesions demonstrate adipose tissue on T1 and T2-weighted sequences, as well as a thin

rim of reduced signal surrounding the intraosseous lipoma. There are regions of poor signal in the lesion's center, which is consistent with central calcification, as opposed to stage 1 lesions. According to Milgram (13), lesions of stage 3 show a thin peripheral fat rim on MRI. Additionally, they demonstrate marked central necrosis with a thick rim of surrounding sclerosis, which is of low intensity on both T1- and T2-weighted sequences. Existing fat necrosis are variable in T1, and show increased signal in T2. (19)

All of the 24 MRI examinations carried out by Campbell et al. were composed entirely or partially by fat that exhibited an identical signal intensity to subcutaneous fat on both T1 and T2 weighted images. Cysts were a common finding in intraosseous lipomas and were more frequently observed in the calcaneus. Cysts were noted in 16 of 24 (67%) patients with intraosseous lipomas according to Campbell et al., and varied in size from 2 mm to 35 mm (mean 15 mm). (3, 13)



7 MRI (Siemens Magnetom) of an intraosseous lipoma of the Calcaneus. (Male, 30 Years) 1. T1, turbo spin echo, sagittal. 2. Proton density, turbo spin echo, transversal, fat suppression. 3. T2, turbo spin echo, transversal.

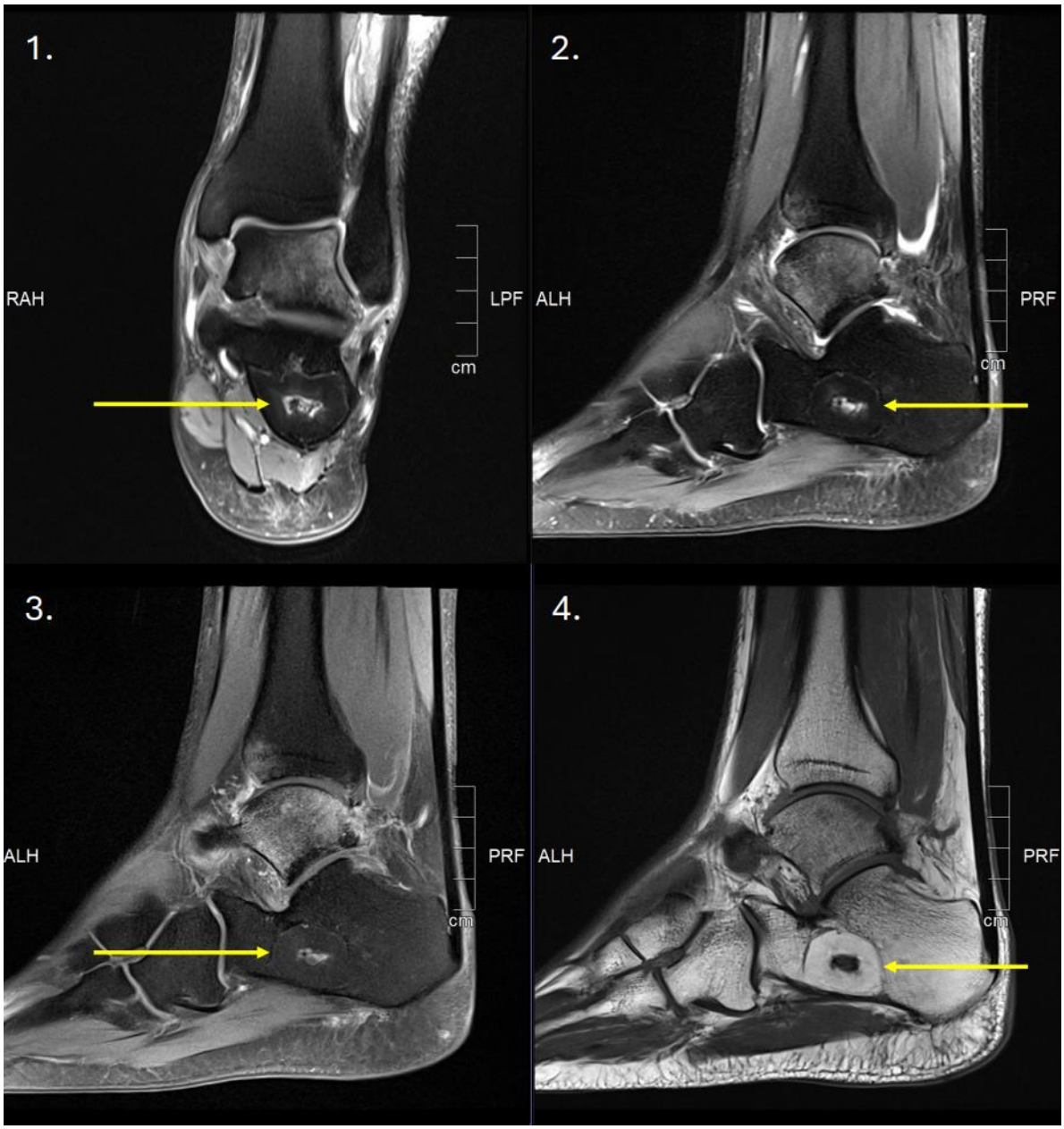
1.9 Differentiation between calcaneal cyst and intraosseous calcaneus lipoma

The difference between an intraosseous lipoma and a calcaneal cyst has not been conclusively clarified ,,It should be noted that in the current 2020 edition of the WHO classification of soft tissue and bone tumors, SBC and IOL are listed as separate entities and their etiology is considered unknown. However, several

publications have documented the transition of SBC to IOL over time, suggesting that IOL may actually represent a developmental form of SBC.” (Toepfer et al., 2023, Source Nr. 26)

In many cases, MRI shows a mixed form of the two entities that includes both lipomatous and cystic regions. (Figure 3)

According to Milgram, this mixed appearance is characteristic for stage 3 intraosseous lipomas. Nevertheless, some studies suggest that intraosseous lipomas represent a development stage of bone cyst. (26) This is supported by the fact that calcaneal cysts primarily occur in childhood, while intraosseous lipomas of the calcaneus tend to occur in adulthood.(26) As already described, Tins et al. came to the conclusion that most, or possibly all, bone cysts undergo a fatty transformation and thus become intraosseous lipomas. (25) It remains unclear from the available literature whether bone cysts and intraosseous lipomas are independent entities or whether the lipoma is a secondary condition of the bone cyst.



8 MRI (Siemens Magnetom) of an intraosseous lipoma in the calcaneus (Male, 33 Years old) 1. Proton density, turbo spin echo, fat suppression, coronal. 2. Proton density, turbo spin echo, fat suppression, sagittal. 3. T1, turbo spin echo, sagittal, fat suppression- 4. T1, turbo spin echo, sagittal.

1.10 Therapy

Which therapy to choose depends on the patient's symptoms. In general, there are different views on the treatment of intraosseous calcaneal lipomas. Kozlowski et al. believe that the lesions do not require treatment (20, 28). Exceptionally – mostly in symptomatic patients – curettage and bone filling offer an adequate therapy. (13, 28). The findings of Radl et al. lend support to the hypothesis that the

surgical removal and subsequent filling of a symptomatic intraosseous lipoma constitutes a suitable therapeutic intervention.(20) Notably, the use of phenol as an adjuvant for local tumour control following curettage was found to be ineffective. (20)

In patients who are asymptomatic and can be definitively diagnosed and assigned to a Milgram (13) stage via imaging, surgical treatment is to be avoided.(20)

In the majority of cases, surgical intervention is not required due to the potential for spontaneous regression of the lipoma, their benign nature, and the relative ease of radiological diagnosis. (8) The radiological diagnosis of an intraosseous lipoma can be regarded as the end point in the majority of cases, and therefore no biopsy or surgery is indicated. (3) The treatment of intraosseous lipomas that occur specifically in the calcaneus likewise depends on presenting symptoms. Again, no surgical intervention is necessary in general. Curettage and bone grafting are only recommended for patients who are clearly symptomatic, with the pain deriving from the lesion itself. (9)

A study of 29 operated intraosseous lipomas, either by curettage only (3%) or by curettage and bone grafting/substitution (97%), revealed no recurrences. (20) Likewise, Milgram reported no case of recurrence. (13)

There is no documented case of recurrence following surgical intervention. Given the low probability of malignant transformation, surgical removal of an asymptomatic lipoma is not necessary if the diagnosis is certain. (13) In addition, asymptomatic intraosseous calcaneus lipomas should not be treated surgically as they occur in the area of Ward’s tringle, which is not subjected to significant stress load. Furthermore, a pathological fracture due to an intraosseous lipoma appears to be rare, and was only reported once by Milgram. (2, 13)

1.11 Aim of the Thesis

As previously outlined in the text, the majority of intraosseous calcaneus lipomas are asymptomatic, and therefore discovered incidentally. (2)This, together with the very small population of studies to this date, leads to a considerable range of assumptions regarding the prevalence of intraosseous calcaneus lipomas. (4)

The objective of this study was to calculate the prevalence of intraosseous calcaneus lipomas, and to draw further conclusions by collecting additional data such as age, sex and tumor size.

2 Material and methods

2.1 Data

The data was collected via a partnership between the “Diagnostikum Graz” and the Department of Orthopaedics and Trauma, Medical University of Graz. All data was collected and organized by the “Diagnostikum Graz” and could be exchanged and used for this diploma thesis on the basis of a data transfer agreement, and by adhering to ethical requirements and data protection directives. This study was approved by the institutional review board of the Medical University of Graz, Austria (IRB-number: 1210/2024; date: 17.10.24).

2.2 Study design

Within this retrospective observational study, all MRI scans of the foot and ankle (see below) obtained over a 10 year and 11 month period (i.e. 01.01.2014 to 12.11.2024) at the “Diagnostikum Graz” were investigated.
Certain anatomical regions were defined to answer the research question:

- Calcaneus
- Hindfoot
- Forefoot
- Ankle joint
- Foot
- Achilles tendon
- Plantar fascia
- Tarsus
- Lower leg

All anatomical regions refer to both unilateral and bilateral imaging.The objective of the study was to calculate the prevalence. Therefore, all MRI examinations of the designated anatomical regions during a specific period were utilized as the population.

Within the specific time frame, the ,,Diagnostikum Graz” performed 18 373 MRI examinations of the predefined anatomical regions, 8458 of these were performed on the left side and 9915 were performed on the right side.

After excluding duplicate or multiple MRI scans per patient and side (left: n = 838; right: n = 2187), a total Number of 15 348 MRI scans remained, with 7 620 on the left side and 7 728 on the right side. Half of the population (50.0%) were male (n=7680) and half were female (n=7668).

The dataset was then subjected to further filtering to ascertain whether any of the following terms were present in the written radiological reports (in German, given the official language of the country):

- ,,Lipom” (lipoma)
- ,,Expansion” (expansion)
- ,,Lipo & Läsion” (lipo & lesion)
- ,,Lipo & Tumor” (lipo & tumor)
- ,,Liposarkom” (liposarcoma)
- ,,Calcaneuslipom” (calcaneal lipoma)
- „Fettäquivalente” (fat equivalent)

2.3 Patient selection

2.3.1 Right side

The following description is based on the collected MRI images of the right side of the lower leg, encompassing the calcaneus, the ankle, the Achilles tendon, the plantar fascia and the foot as a whole, including the forefoot and the back foot.
In total, 9915 MRI images of the right ankle and foot, as described above, were performed.
After excluding duplicate and multiple MRI scans (n=2187), 7728 scans remained.
Out of the 7728 radiological findings, 325 were found to match one or more of the defined terms.
In the next step, patients who had been identified through multiple keywords were filtered in order to avoid duplicate entries.
Subsequently, 229 patients were selected for further analysis.

These patients underwent in-depth analysis of the MRI images by a trained student to determine whether an intraosseous calcaneus lipoma was actually present.
A number of 203 patients were subsequently excluded for one of the following reasons:

- The diagnosis was different and the keywords were used in the radiological report to describe an atrophy or other lesion (e.g. a lipomatous atrophy of the muslces).
- The radiological re-evaluation ruled out presence of an intraosseous calcaneus lipoma.
- A lipoma was identified on MRI, but at other locations than the calcaneus.
- Findings unrelated to a calcaneus lipoma had been described with one of the keywords (e.g. expansive growth of a hemangioma).

The MRI Images of the remaining patients were reviewed again by the trained medical student, who confirmed the written diagnosis based on the radiological features.

In order to provide a professional opinion, a radiologist with expertise in the relevant field was consulted to either confirm or disprove the diagnosis. Therefore, one further patient was excluded. In total, 25 patients were finally identified with an intraosseous calcaneus lipoma on the right side.

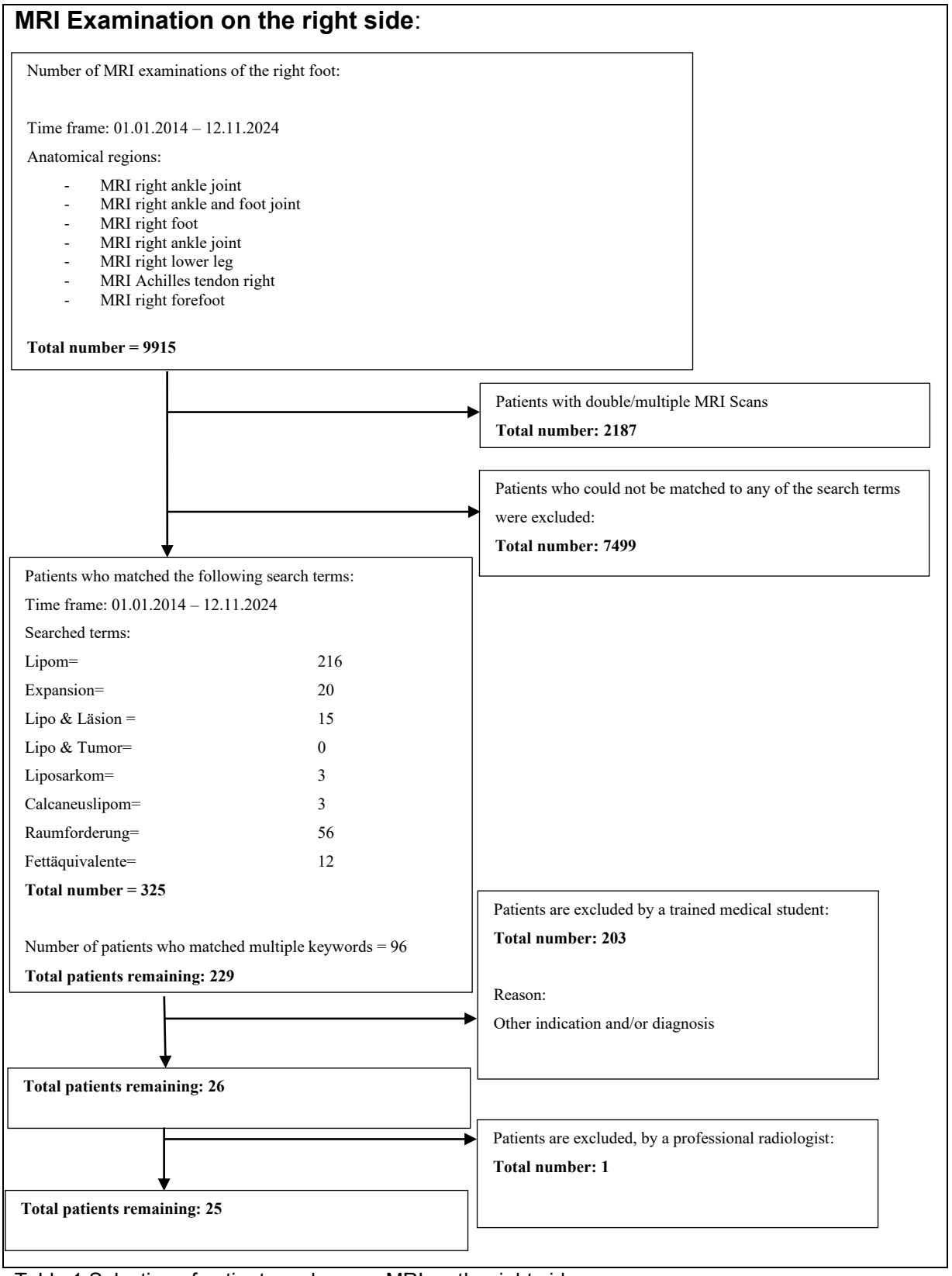


Table 1 Selection of patients undergone MRI on the right side.

2.3.2 Left side

In comparison to the examination on the right side, a total of 8458 MRI examinations were performed, after excluding the double and multiple MRI scans on one patient (n=838), 7620 patients remained during the specified period. On both sides, the same anatomical regions were examined.
Out of the 7620 patients, 7377 were excluded because the radiological findings did not include any of the specified search terms. The remaining 280 patients were shortened by 37 patients who corresponded to more than one keyword.
243 patients thus remained and were radiologically reexamined by a trained medical student. The student was able to exclude 221 patients for the reasons listed on the right side. After review by a professional radiologist, a further patient was excluded, leaving 21 patients with an intraosseous calcaneus lipoma on the left side.

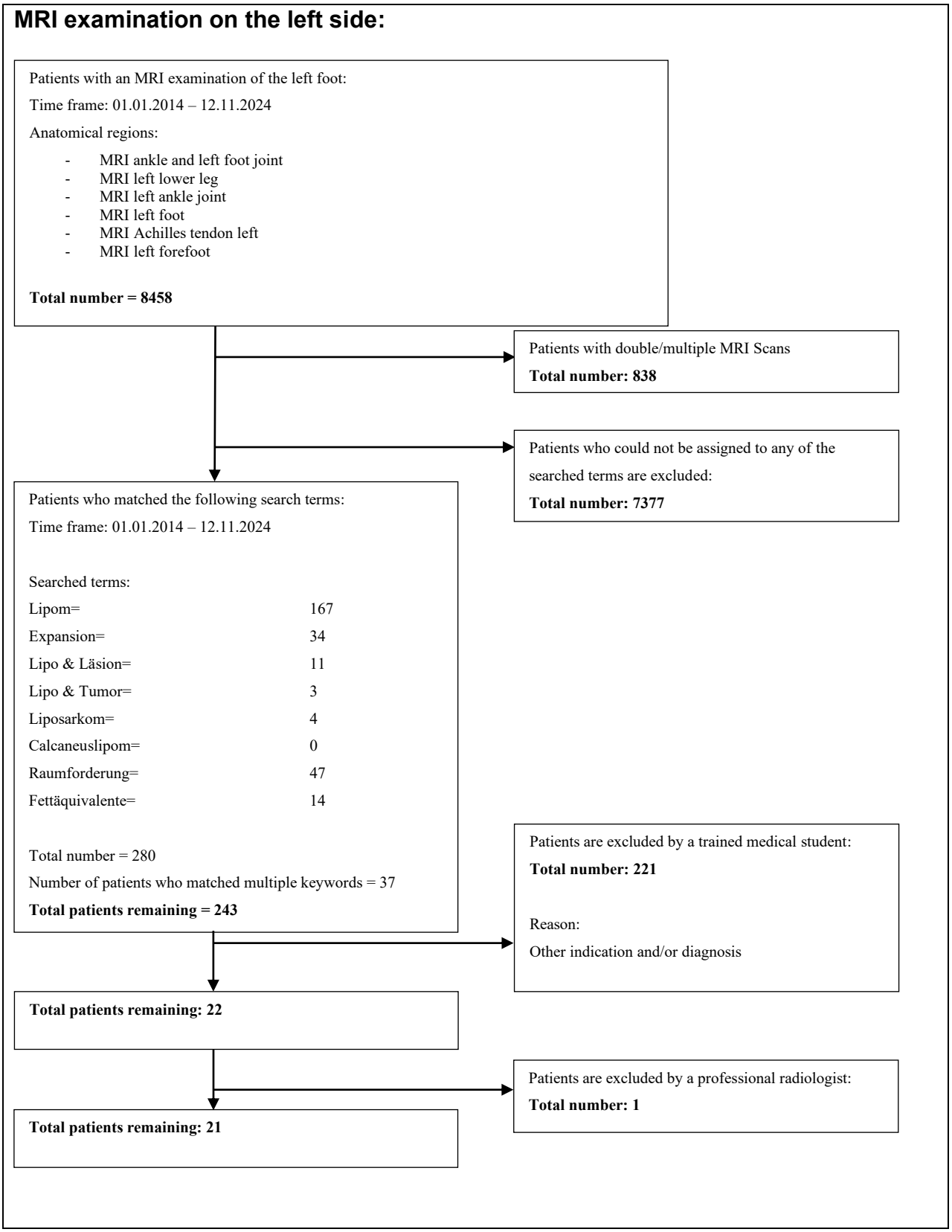


Table 2 Selection of patients undergone MRI on the left side.

2.3.3 Collected variables

In all patients with an intraosseous calcaneus lipoma, detailed demographic and clinical variables were additionally collected.
Table 3 shows all the variables analysed.

	Variable		
Sex	Male	Other	Female
Age			
Lipoma size (in cm; median + IQR)			
Side	Left/Right		
Location	Ward's triangle		Other
Contrast agent	Yes		No
Milgram Stage	1,2,3		
Incidental finding	No		Yes

Table 3 Collected variables in each case.

Additionally, the reasons for referral to MRI were analyzed.

2.4 Technical Data

MRI examinations were conducted on different MRI devices. The following devices were used:

- Siemens Magnetom Skyra (Siemens Healthcare Diagnostics, GmbH; Wien, Austria)
- Siemens Magnetom Lumina (Siemens Healthcare Diagnostics, GmbH; Wien, Austria)
- Siemens Magnetom Symphony (Siemens Healthcare Diagnostics, GmbH; Wien, Austria)
- Siemens Magnetom Essenza (Siemens Healthcare Diagnostics, GmbH; Wien, Austria)

The Siemens Magnetom Skyra and the Siemens Magnetom Lumina employ a magnetic field strength of 3 Tesla, whereas the other two devices utilize a magnetic field strength of 1.5 Tesla.

The following sequences were generated with Siemens Magnetom Skyra and Siemens Magnetom Lumina: Sagittal, axial and coronal T1, T2 and proton-weighted turbo spin echo (TSE) sequences, as well as fat suppression.
The Siemens Magnetom Symphony used the coronary T1 weighted SE sequence, axial GRE (gradient echo) sequences, coronary T1 weighted TSE sequences and fat suppression.

2.4.1 Contrast agents

Two different contrast agents were used: Prohance (15 ml) and Clariscan (0.5 mmol/ml). As shown in Figure 5, the contrast agent injection was followed by a sequence using T1-weighted imaging, Turbo Spin Echo (TSE), sagittal orientation, and fat suppression.

9 MRI with contrast agent (clariscan) of an intraosseous lipoma in the calcaneus. (Male, 24) Seq: T1, TSE, sagittal, fat suppression.

2.5 Statistical analyses

All statistical analyses were conducted using SPSS (International Business Machines Corporation, New York, USA). The total number of patients with an MRI of the region of interest (foot/ankle) was used to calculate the overall prevalence of intraosseous calcaneus lipomas.

A chi-squared test was conducted to ascertain the prevalence of the respective genders in relation to frequency.

Quantitative variables were analysed using mean with standard deviation (SD) for normally distributed variables, and median with interquartile range (IQR) for non-normally distributed variables. Qualitative characteristics were analysed as

frequencies (e.g. sex, anatomical region). Correlations between variables were assessed with regression line and R-Square.
A T-Test for independent samples was performed to analyse the relationship between lipoma size and gender. Additionally a Mann–Kendall trend test was performed to evaluate temporal trends in the annual prevalence of calcaneus lipomas over the study period.

3 Results

3.1 Observed Frequency of the calcaneal lipoma

Over the entire time period, the observed frequency of calcaneus lipomas was 0.30%. Both the number of patients as well as the annual observed frequency showed an increase over time. Figure 4 below illustrates the change in the observed frequency of calcaneus lipomas as well as the number of MRI examinations of the foot and ankle over the period from 1 January 2014 to 12 November 2024.
The X axis shows the course of time in years while the Y axis shows both the observed frequency of calcaneal lipomas (right) and the total number of patients with an MRI (left).

The annual prevalence of calcaneal lipomas from 2014 to 2024 is shown in Figure 5. The dotted red line indicates the overall prevalence across the study period. Year-to-year variations were observed; however, statistical analysis using the Mann–Kendall trend test showed no significant temporal trend ($p = 0.310$).

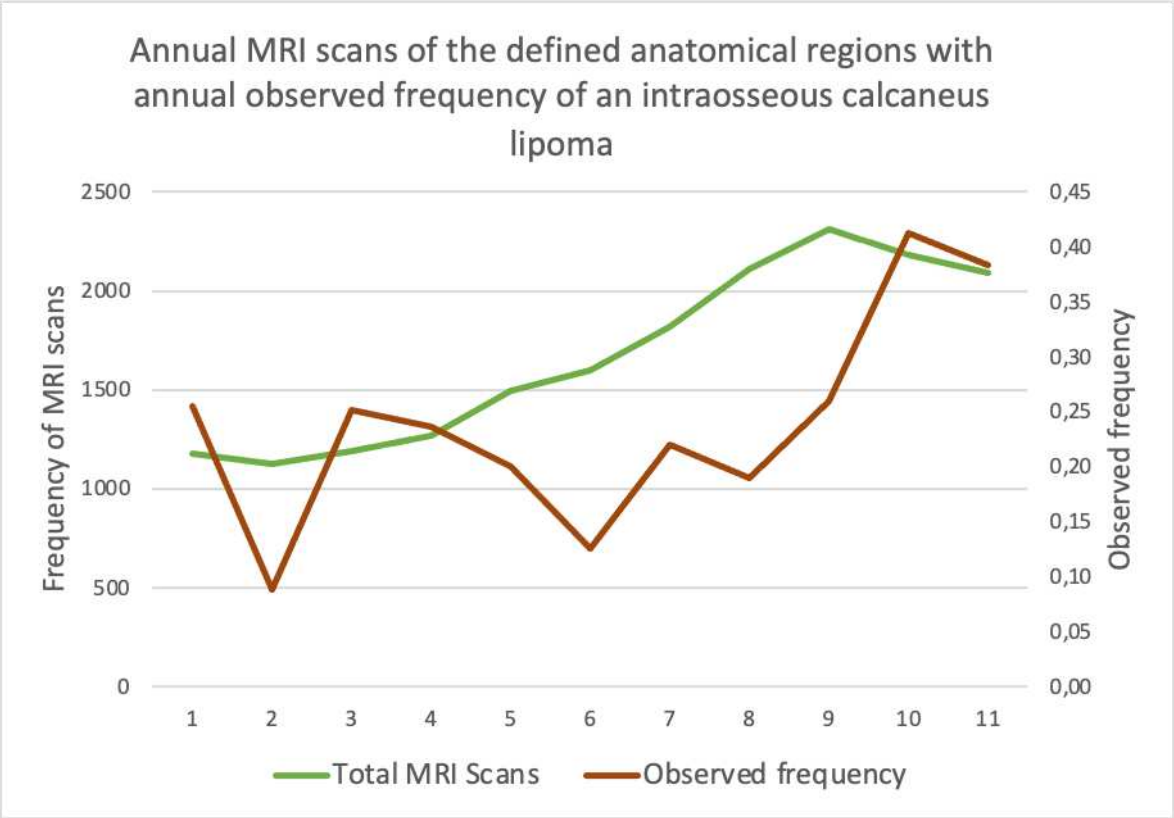


Table 4 Annual MRI scans of the defined anatomical regions (left y-axis) with annual observed frequency of an intraosseous calcaneus lipoma (right y-axis).

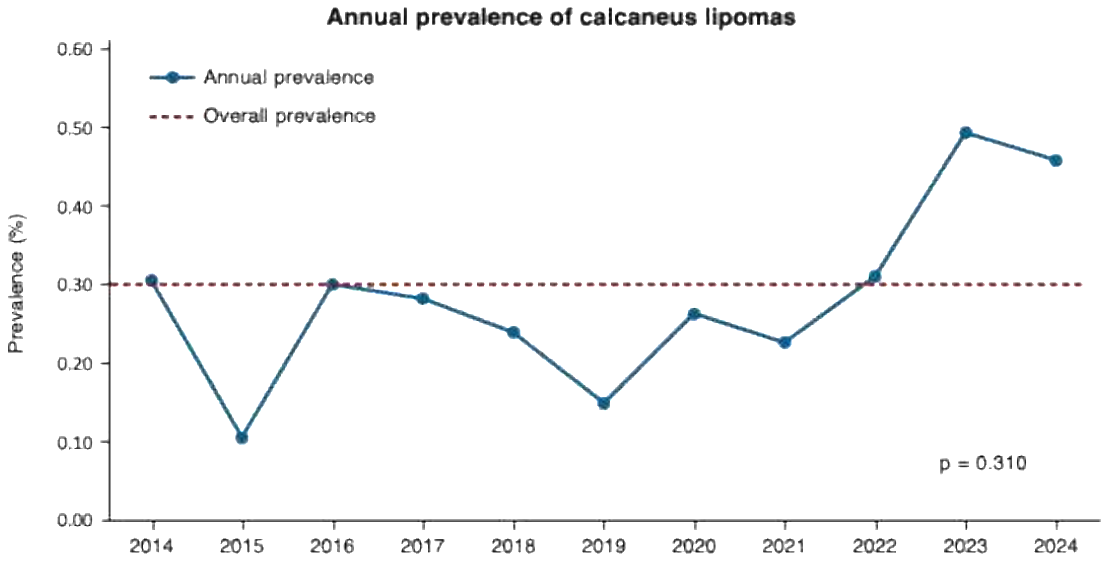


Table 5 Prevalence (annual) of calcaneus lipomas throughout the study period (2014–2024). *The p-value is based on the Mann–Kendall trend test, the dotted red line represents the overall prevalence.*

3.2 Prevalence

An intraosseous calcaneus lipoma was identified in 46 of the 15 348 patients, with an overall prevalence of 0.30% over the study period. This study shows more affected man (n=34; 74%) than woman (n=12; 26%).

In General, out of the 15 348 patients, 50% were male (n=7680) and 50% were female (n=7668).

The corresponding prevalence was found to be significantly higher in male patients (0.44%) than in female patients (0.16%; p=0.001).

3.3 Patient and tumour characteristics

All 46 intraosseous calcaneus lipomas identified in the study were localized in Ward's triangle. A slight predominance towards the right side was observed (n=25; 54%) in comparison to the left side (n=21; 46%).

None of the patients had a bilateral intraosseous calcaneus lipoma. In one case (2,2%) a multilocular intraosseous calcaneus lipoma was diagnosed.

A total of 46 lesions were classified according to the Milgram staging system. Stage 1 lesions accounted for 20 of the 46 cases (43.5%), stage 2 lesions for 22 cases (47.8%), and stage 3 lesions for 4 cases (8.7%). Accordingly, lesions in stage 1 and 2 predominated, compromising 42 of 46 lesions (91.3%) of the study cohort. The distribution was highly comparable between left and right side (Table 6).

	All patients (n=46) (n/N [%])	**Females (n=12)** (n/N [%])	**Males (n=34)** (n/N [%])	**p-value**
Sex				
Female	12/46 (26.1)	..	..	..
Male	34/46 (73.9)	..	..	..
Age (in years)	42.5 [28.3–52.3]	41.0 [28.0–47.3]	42.5 [28.3–53.8]	0.388
Location of calcaneus lipoma in Ward's triangle	46/46 (100)	12/12 (100)	34/34 (100)	..
Side				0.122
Left	20/46 (43.5)	8/12 (66.7)	12/34 (35.3)	
Right	26/46 (56.5)	4/12 (33.3)	22/34 (64.7)	
Size of calcaneus lipoma (in cm)	2.5 [1.5–3.0]	1.8 [1.2–2.3]	2.5 [1.9–3.2]	0.030
Contrast enhancement				0.818
No	16/46 (34.8)	5/12 (41.7)	11/34 (32.4)	
Yes	30/46 (65.2)	7/12 (58.3)	23/34 (67.6)	
Multilocular disease				1.000
No	45/46 (97.8)	12/12 (100)	33/34 (97.1)	
Yes	1/46 (2.2)	0/12 (0.0)	1/34 (2.9)	
Milgram stage				0.357
1	20/46 (43.5)	6/12 (50.0)	14/34 (41.2)	
2	22/46 (47.8)	4/12 (33.3)	18/34 (52.9)	
3	4/46 (8.7)	2/12 (16.7)	2/34 (5.9)	
Incidental finding				1.000
No	24/45 (53.3)	6/12 (50)	18/33 (54.5)	
Yes	21/45 (46.7)	6/12 (50)	15/33 (45.5)	

Table 6 Characteristics of the patients detected with calcaneus lipomas.

At the time of diagnosis, the average age of patients was 42.5 years (IQR 28.3-52.3 years). The youngest patient was 14 years old at time of diagnosis, and the oldest 76 years.

The box plot below illustrates the age distribution separated by sex.

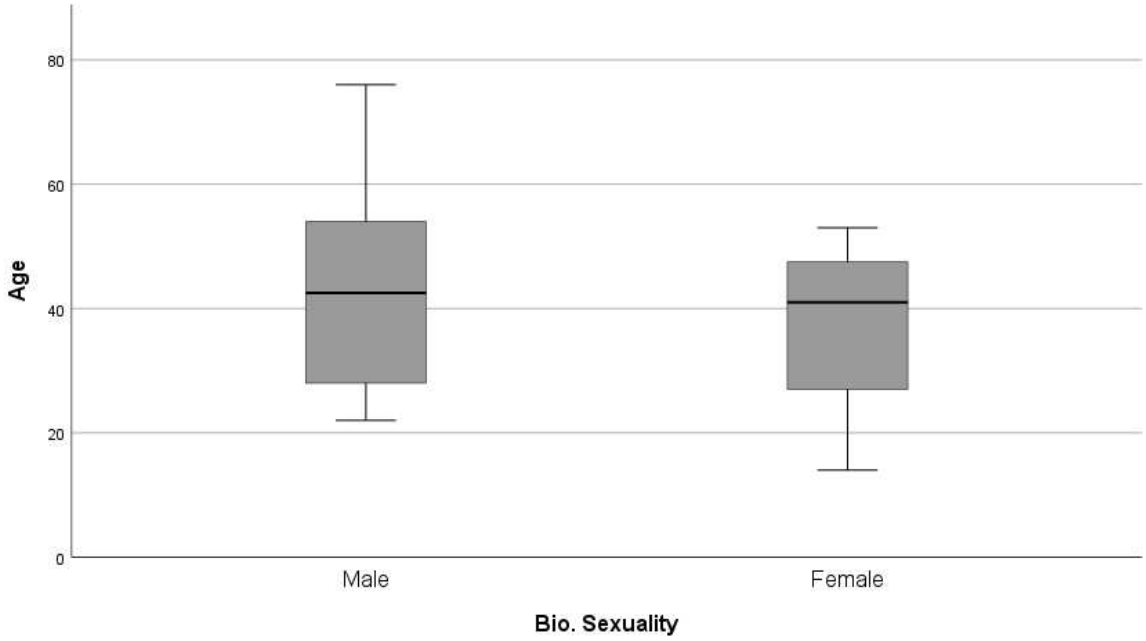


Table 7 Boxplot of age stratified by sex.

Intraosseous calcaneous lipomas had an average diameter of 2.5 cm (IQR 1.5-3.0 cm). The smallest documented lipoma was 0.7 cm in size, and the largest 5 cm.

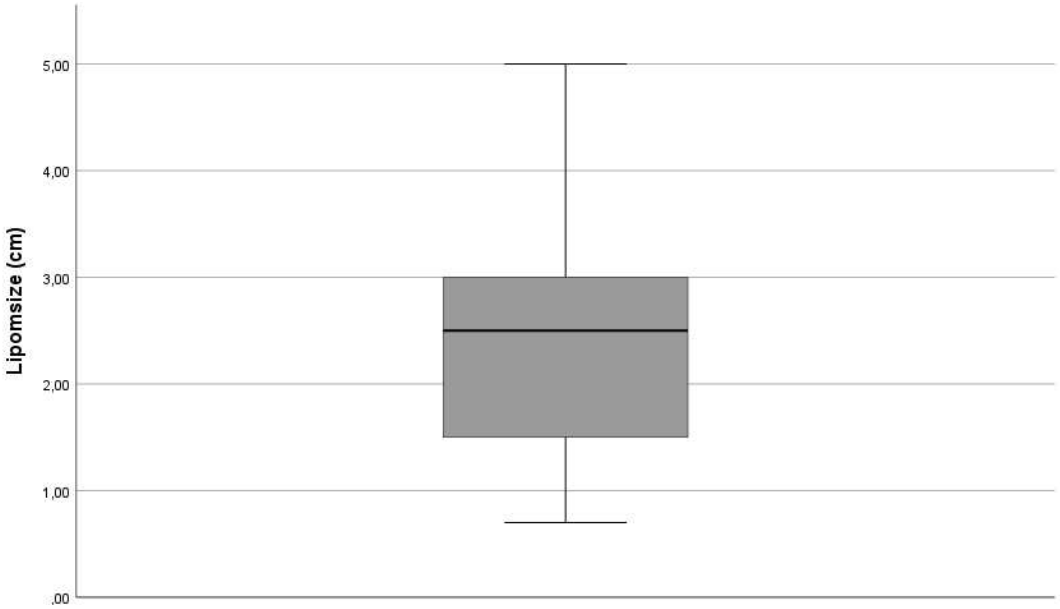


Table 8 Boxplot showing the median size of the intraosseous calcaneal lipomas.

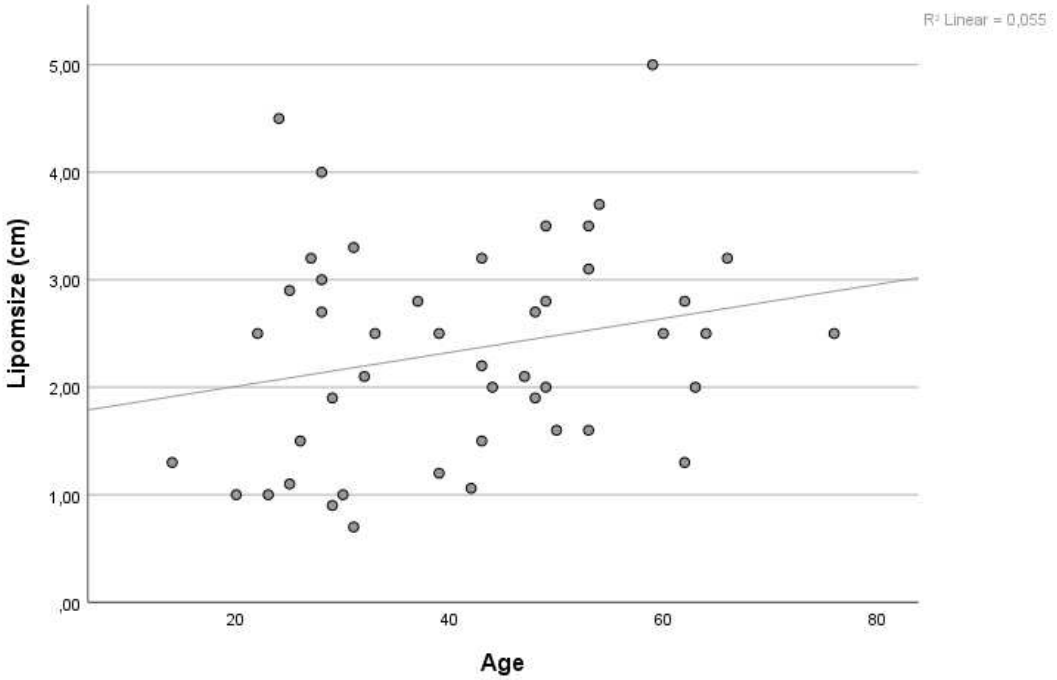


Table 9 Scatterplot showing correlation between lipoma size and patient age.

The linear regression demonstrates an R-squared value of 0.055, and thus does not show a good correlation between age and the size of calcaneus lipomas (Table 9).

Lesion size was greater in males (median 2.5 cm [IQR 1.9–3.2 cm]) compared to females (median 1.8 cm [IQR 1.2–2.3 cm]; p = 0.030). No significant sex-related differences were observed regarding age (p = 0.388), side (p = 0.122), contrast enhancement (p = 0.818), incidental detection (p = 1.000), Milgram staging (p = 0.357), or the presence of multilocular lesions (p = 1.000; Table 6).

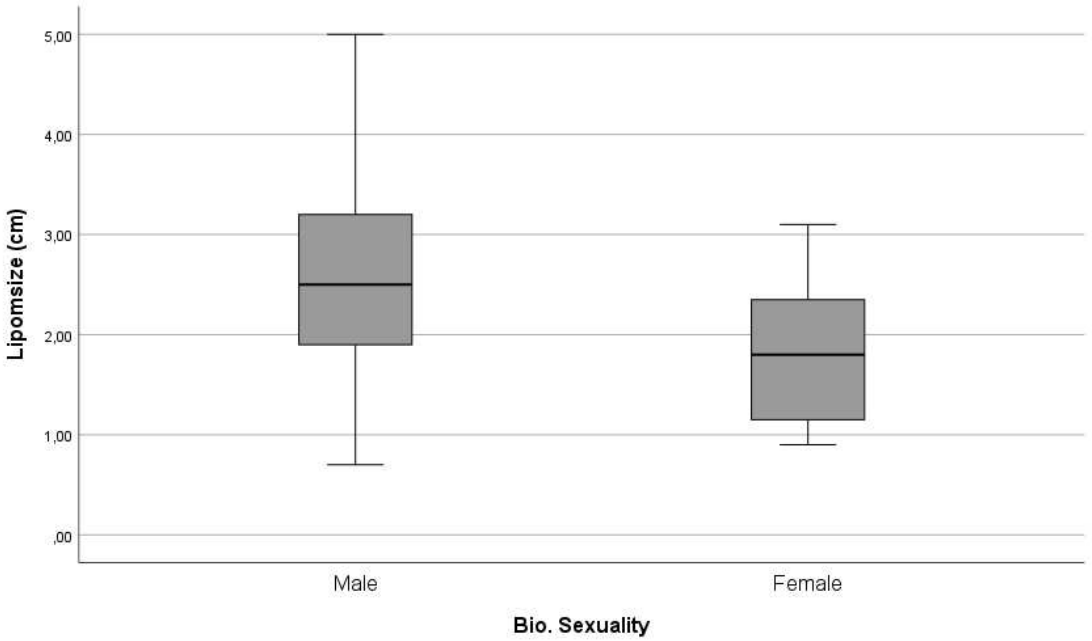


Table 10 Boxplot showing lipoma size stratified by sex.

Among the 21 patients, calcaneal lipomas were discovered incidentally during MRI examinations. These scans were performed primarily after traumatic events (n=14), while a smaller number were related to degenerative changes (n=6) or following medical interventions (n=1). In 20 cases, patients were referred to MRI due to a suspected lesion in the calcaneus. Additionally, two patients were examined because of generalized pain, and another two due to swelling. For one patient, the reason for the MRI referral could not be determined (Table 11).

	All patients (n=45*) (n/N [%])
Incidental finding (n=21)	
Preceding trauma	14/45 (31.1)
Degenerative changes	6/45 (13.3)
Postinterventional changes	1/45 (2.2)
Non-incidental finding (n=24)	
Calcaneal cyst	20/45 (44.4)
Unspecific pain	2/45 (4.4)
Unspecific swelling	2/45 (4.4)

Table 11 Reasons for referral to MRI Scan.

4 Discussion

4.1 Answering the research questions

4.1.1 Prevalence

The main aim of this study was to estimate the prevalence of the intraosseous calcaneus lipomas, due to the fact that no previous studies have investigated their prevalence. As far as the authors are aware, this study represents the most extensive investigation to date on the prevalence of calcaneal lipomas.

Furthermore, previous studies have focused on intraosseous lipomas in general (i.e. any anatomical region), rather than specifically on intraosseous calcaneus lipomas. The study by Campbell et al. also addressed intraosseous lipomas in general, in a study population of 206 patients. (3) The present study involves a 74 times larger study population, and focusses on intraosseous calcaneus lipomas in particular.

The study covers a period of nearly 11-year time period and over 18 000 MRI scans. During this time period, intraosseous calcaneus lipomas were diagnosed in 46 MRI scans. The resulting prevalence was 0.30%. Other uncommon bone tumors demonstrate similar or slightly higher prevalence rates, with enchondromas reported at 0.39% in the shoulder (33) and up to 1.45% in the knee (34), while osteochondromas occur in approximately 0.44% of cases (35). These findings provide a valuable insight into the overall prevalence, given the large number of MRI scans examined.

4.1.2 Epidemiology

The largest number of intraosseous calcaneus lipomas examined so far can be found in the study by Campbell et al. (3) In that study, patient age ranged of from 13 to 60 years with a mean age of 37 years. In their literature review, the author describes an age range of 12 to 66 years, with a mean of 42 years, deriving from a population with 39 intraosseous calcaneus lipomas. (3) These values can be reconciled with the findings of the present study. The age range in this study is 14 to 76 years, with a mean value of 42.5 (IQR 28.3–52.3).

In terms of gender distribution, both the study by Campbell et al. and this study show a higher objected frequency in men. While Campbell et al. described a male frequency of 66%, the one in the present study is even higher at 74%. A significantly higher prevalence was observed in males (0.44%) than in females (0.16%; p = 0.001).
A definitive reason for this sex-related difference is lacking, since the underlying cause of calcaneal lipomas remains unknown.

4.1.3 Further parameters

The absence of bilateral cases in this study suggests exclusive unilateral involvement. However, it cannot be ruled out that intraosseous calcaneus lipomas may occur in individuals both at the right and left side. (29, 30, 31)
The study by Yildiz et al reports on three bilateral cases and presents a case in which a 34-year-old woman is affected on both calcanei. (29)
Notably, all intraosseous calcaneus lipomas occurred in the area of Ward's triangle.
In 43.5% of cases (n = 20/46) the left calcaneus was involved showing a prevalence of 0.27%, while the right calcaneus was affected in 56.5% (n = 26/46) with a prevalence of 0.32%. Notably, also Ulucay et al. observed a slight right dominant occurrence, although they did not address prevalence, but only the absolute number. (31)
A key strength of this investigation is the analysis of a large-scale MRI database, consisting of over 18,000 ankle scans collected across almost 11 years, which facilitated an accurate assessment of the prevalence of calcaneal lipomas.

4.2 Limitations/Restrictions on content and method

Some limitations have to be considered when interpreting the results. One limitation of the study is the search process to identify the intraosseous calcaneus lipomas, whereby all radiological findings within the defined anatomical regions were screened for predefined keywords. The informative value of this study is therefore only as good as the ability of the radiologists to diagnose an intraosseous calcaneus lipoma with one of the keywords used.

Another limitation relates to age at diagnosis. The age distribution should be treated with caution due to the fact that the intraosseous calcaneus lipomas are usually asymptomatic and therefore found incidentally. Thus, conclusions on age distribution based on the time of detection should be made bearing this limitation in mind. (2) Another limitation of this study arises from the chosen database search strategy, which was deliberately restricted to lipomatous terms in order to identify lesions that were explicitly described as lipomas in radiological reports. As a consequence, Milgram stage III lesions may be underrepresented, since these more advanced lesions are frequently reported using nonspecific terminology rather than being cleary described as lipomas. To identify those lesions retrospectively would necessitate a comprehensive reevaluation of imaging studies and histopathological data.

4.3 Clinical Practice

The results of this study have implications for clinical practice, particularly for radiologists and orthopedic surgeons. Intraosseous calcaneus lipomas are often asymptomatic, and while the risk of malignant transformation remains uncertain, clinicians should be able to recognize their characteristic features to avoid unnecessary treatments and follow-ups.

In this study, almost half of the patients were found to have calcaneal lipomas incidentally on MRI scans (Table 11).

The consistent location in the Ward triangle suggests that the presence of a lesion in this region could be a strong indicator of an intraosseous calcaneus lipoma, helping clinicians differentiate it from other bone lesions or abnormalities that may appear in different areas of the calcaneus. (32)

Orthopedic surgeons can generally advise towards a conservative approach (i.e. watch-and-wait) and counsel patients towards the benign nature of their diagnosis. Should symptoms develop or should there be concerns regarding malignant transformation, re-evaluation of the subsequent therapeutic approach should be implemented. Future long-term studies could help clarify the risk of malignant transformation of intraosseous calcaneus lipomas and inform treatment decisions.

4.4 Conclusion

This study entails the largest MRI imaging database so far on the prevalence of intraosseous calcaneus lipomas. The prevalence of intraosseous calcaneus lipomas was 0.30% over a nearly 11-year period in total. A male predominance, as well as occurrence on the right side constitute interesting findings that add to scientific knowledge. The results indicate that asymptomatic calcaneal lipomas occur at a substantially higher rate than previously documented.

4.5 Future

It remains of interest to ascertain the etiology of intraosseous calcaneus lipomas, as the approach used in this study does not answer this question.

Longitudinal studies are of significance in the advanced understanding of intraosseous calcaneus lipomas, as they would ease the monitoring of their progression over time. While this study provides valuable insights in the prevalence and distribution of intraosseous calcaneus lipomas, it does not offer a comprehensive picture of their potential growth or alterations in size over the years.

Such a study could determine whether these lesions increase in size, remain stable, or undergo alterations in characteristics over time. Additionally, these could enhance identification of complications or co-morbidities associated with intraosseous calcaneus lipomas that are currently poorly understood.

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