Adult Acquired Flatfoot Deformity: Incidence, treatment and outcomes

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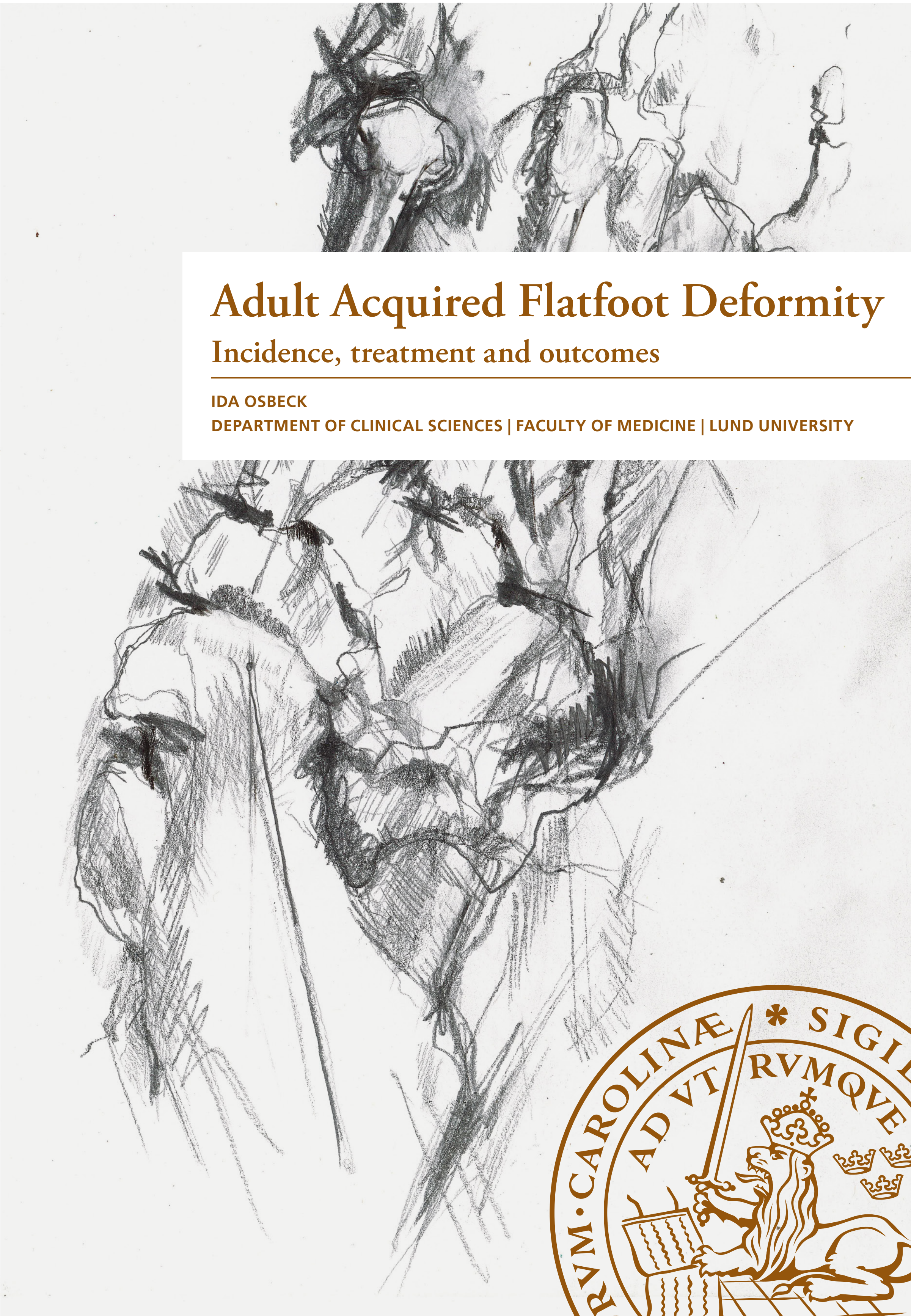
Osbeck, Ida

2026



Adult Acquired Flatfoot Deformity

Incidence, treatment and outcomes

IDA OSBECK

DEPARTMENT OF CLINICAL SCIENCES | FACULTY OF MEDICINE | LUND UNIVERSITY

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Ida Osbeck

LUND UNIVERSITY

DOCTORAL DISSERTATION
Doctoral dissertation for the degree of Doctor of Philosophy (PhD) at the Faculty of Medicine at Lund University will be publicly defended on 12 June at 09:00 in the Belfrage Hall, BMC, Lund

Faculty opponent
Adrian Kendal, Honorary Senior Lecturer, University of Oxford

Organization: LUND UNIVERSITY

Document name: Doctoral Dissertation | **Date of issue:** 2026-06-12

Author: Ida Osbeck | **Sponsoring organization:**

Title and subtitle: Adult Acquired Flatfoot Deformity: Incidence, treatment and outcomes

Abstract: Adult acquired flatfoot deformity (AAFD) is a disabling condition involving multiple deformities in the foot. Despite increasing clinical awareness, knowledge regarding epidemiology of AAFD and the outcomes of commonly used surgical procedures remains limited.

The aims of this doctoral thesis were to improve understanding of AAFD, the affected patient population, and the burden of the disease, as well as describe and compare surgical interventions in order to promote more standardized treatment.

This thesis is based on four studies. Study I was an epidemiological study using the Swedish National Patient Register (2007-2018) to estimate the incidence of AAFD referred to specialist care. Studies II and III analyzed data from the Swedish National Quality Register for Foot and Ankle Surgery (Swefoot) to describe patient characteristics, surgical procedures, and postoperative outcomes using patient-reported outcome measures (PROMs). Study IV is an ongoing multicenter randomized controlled trial (RCT) comparing medial displacement calcaneal osteotomy (MDCO) with or without sinus tarsi implant in patients with flexible AAFD.

The incidence of AAFD referred to specialist care was 23.0 per 100,000 person-years and was nearly twice as high in women as in men, with the highest incidence among individuals aged 61–75 years. Considerable regional variation in incidence was found across Sweden. Patients undergoing surgery reported low preoperative function and health-related quality of life. Surgical treatment resulted in statistically significant and clinically important improvements in PROMs at 1 year postoperatively. There were large regional variations regarding the type of surgical treatment used. No statistically significant difference in outcomes was observed between calcaneal osteotomy and hindfoot arthrodesis.

AAFD requiring specialist care is relatively common and predominantly affects older women. Surgical treatment improves function and quality of life, although substantial regional variations exist in both incidence and surgical treatment. The ongoing RCT may provide further evidence regarding the role of using the sinus tarsi implant as an adjunctive procedure in the treatment of flexible AAFD.

Key words: Adult Acquired Flatfoot Deformity, Progressive Collapsing Foot Deformity, National Quality Register, Incidence, Surgical Treatment, Outcomes, PROM, QoL, SEFAS, EQ-5D

Classification system and/or index terms (if any) | Supplementary bibliographical information

Language: English | **Number of pages**: 104

ISSN and key title: 1652-8220,
Lund University, Faculty of Medicine Doctoral Dissertation Series 2026:96

ISBN: 978-91-8021-894-8

Recipient's notes | Price | Security classification

Signature | Date 2026-04-28

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Coverphoto by Marita Flisbäck

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Orthopaedics

ISBN 978-91-8021-894-8
ISSN 1652-8220

Printed in Sweden by Media-Tryck, Lund University
Lund 2026

Printed matter
3041 0903

Media-Tryck is a Nordic Swan Ecolabel certified provider of printed material. Read more about our environmental work at www.mediatryck.lu.se

MADE IN SWEDEN

*To my family and friends, whose support has carried me,
whose curiosity has inspired me, and whose conversations
continue to draw me towards the bigger questions of life.*

*"The human foot is a masterpiece of engineering
and a work of art."
– Leonardo da Vinci*

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Incidence of adult acquired flatfoot deformity referred to specialist care in Sweden.

Journal of Foot and Ankle Research 2025;18(1):e70042.

Study II

Osbeck I, Cöster M, Montgomery F, Atroshi I.

Surgically treated adult acquired flatfoot deformity: register-based study of patient characteristics, health-related quality of life and type of surgery according to severity.

Foot and Ankle Surgery 2023;29:367-372.

Study III

Osbeck I, Cöster M, Atroshi I.

1-year results after surgery for flexible adult-acquired flatfoot deformity: a cohort study based on 190 patients from the Swedish Foot and Ankle Surgery Register

Acta Orthopaedica 2026;97:279-285.

Study IV

Osbeck I, Cöster M, Montgomery F, Atroshi I.

The sinus tarsi implant as an adjuvant procedure to medial displacement calcaneal osteotomy for flexible adult acquired flatfoot deformity: protocol for a randomized controlled trial.

Manuscript.

The Thesis at a Glance

Study I

Incidence of adult acquired flatfoot deformity referred to specialist care in Sweden.

Research question: What is the incidence rate (IR) of adult acquired flatfoot deformity (AAFD) referred to specialist care in the Swedish general population, and are there age-, sex- and region-related differences?

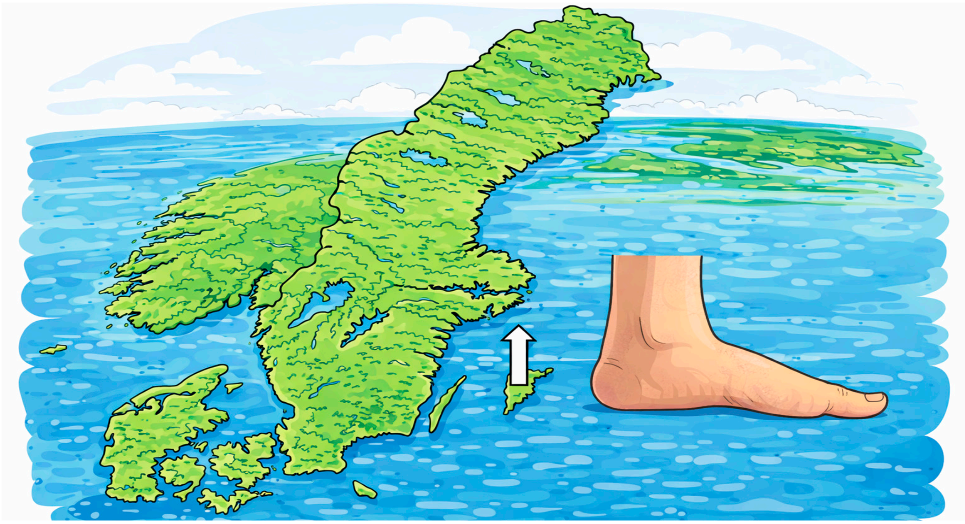
Data from years: 2007-2018

Study population: Patients aged ≥16 years, with a first-time diagnosis of AAFD (ICD-10 code M214) registered at a doctor visit to a secondary or tertiary healthcare facility and recorded in the Swedish National Patient Register (n=21,766 feet).

Main result: The IR of referred AAFD was 23 per 100,000 person-years, almost twice as high in women as in men, with the highest IR in individuals aged 61-75 years. Substantial regional variation in IR were observed across Sweden.

Clinical perspective: AAFD requiring specialist care is relatively common and predominantly affects older women. The regional variations suggest potential differences in disease recognition, referral patterns, or underlying risk factors.

Year of publication: 2025



Study II

Surgically treated adult acquired flatfoot deformity: register-based study of patient characteristics, health-related quality of life and type of surgery according to severity.

Research question: What are the characteristics, preoperative health-related quality of life, and types of surgical procedures used for patients undergoing surgery for AAFD in Sweden?

Data from years: 2014-2021

Study population: Patients aged ≥16 years, registered in the Swedish National Quality Register for Foot and Ankle Surgery (Swefoot) who underwent primary surgery for AAFD (n=625 feet).

Main result: Patients undergoing surgery had low preoperative foot function and health-related quality of life. Surgical procedures generally followed current treatment principles but large regional variations in the choice of surgical interventions were observed.

Clinical perspective: Patients considered for AAFD surgery have substantial functional impairment. The variation in surgical procedures highlights limited evidence guiding treatment decisions.

Year of publication: 2023

Study III

1-year results after surgery for flexible adult-acquired flatfoot deformity: a cohort study based on 190 patients from the Swedish Foot and Ankle Surgery Register

Research question: What are the 1-year postoperative patient-reported outcomes after surgical treatment of flexible AAFD, and do outcomes of calcaneal osteotomy (CO) differ from those of hindfoot arthrodesis (HFA)?

Primary outcome: Self-Reported Foot and Ankle Score (SEFAS).

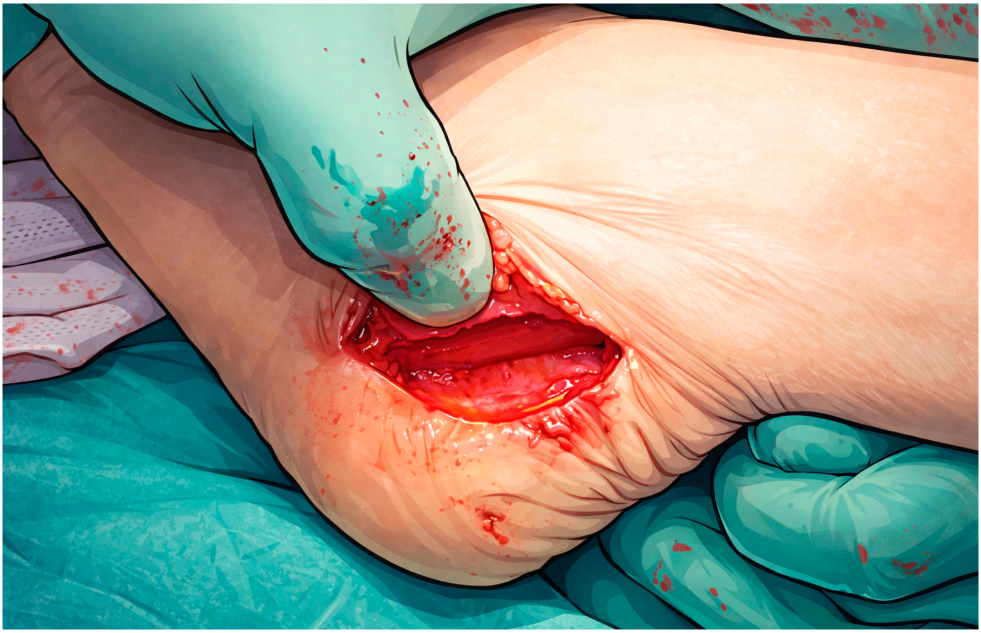
Data from years: 2017-2022

Study population: Patients with grade II (flexible) AAFD undergoing primary surgery, registered in Swefoot, with complete preoperative and postoperative patient-reported outcomes data (n=190 feet).

Main result: Surgical treatment resulted in statistically significant and clinically important improvements in the SEFAS score at 1 year postoperatively. No statistically significant difference in the degree of improvement in SEFAS score was observed between patients treated with CO and those treated with HFA.

Clinical perspective: Surgical treatment of AAFD improves symptoms and function, but postoperative function rarely returns to normal. More evidence is needed to guide procedure selection.

Year of publication: Accepted for publication.



Study IV

The sinus tarsi implant as an adjuvant procedure to medial displacement calcaneal osteotomy for flexible adult acquired flatfoot deformity: Protocol for a randomized controlled trial.

Research question: Does the addition of the sinus tarsi implant (a device placed in the subtalar joint to limit excessive pronation) to medial displacement calcaneal osteotomy (MDCO) improve deformity correction in patients with flexible AAFD?

Primary outcome: Change in Meary's angle (radiograph) at 1 year postoperatively.

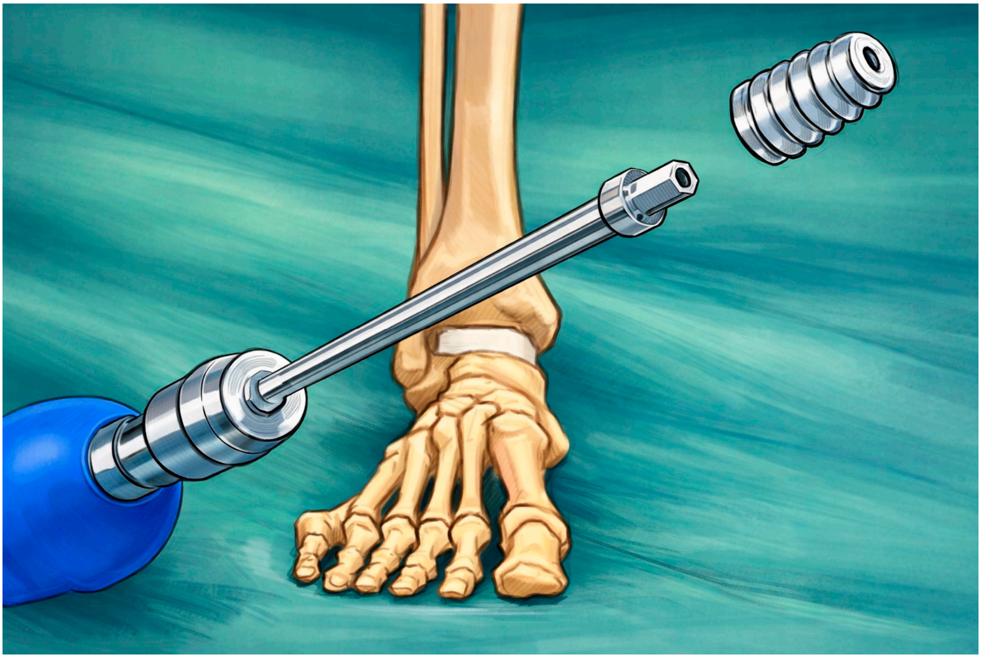
Data from years: Ongoing study

Study population: Patients aged 16-75 years with stage II (flexible) AAFD, eligible for surgical treatment at participating orthopedic units in Sweden (planned enrollment of 130 patients).

Main result: Not available (study protocol of ongoing trial).

Clinical perspective: This trial can provide evidence on whether, in flexible AAFD, adjuvant sinus tarsi implant can improve radiographic correction after MDCO.

Year of publication: Manuscript



Abstract

Adult acquired flatfoot deformity (AAFD) is a disabling condition involving multiple deformities in the foot. Despite increasing clinical awareness, knowledge regarding the epidemiology of AAFD and the outcomes of commonly used surgical procedures remains limited.

The aims of this doctoral thesis were to improve understanding of the epidemiology of AAFD, the affected patient population, and the burden of the disease, and to describe and compare the outcomes of commonly used surgical interventions, in order to promote more standardized treatment.

This thesis is based on four studies. Study I was an epidemiological study using the Swedish National Patient Register (2007-2018) to estimate the incidence of AAFD referred to specialist care. Studies II and III analyzed data from the Swedish National Quality Register for Foot and Ankle Surgery (Swefoot) to describe patient characteristics, the surgical procedures used, and postoperative outcomes measured using patient-reported outcome measures (PROMs). Study IV is an ongoing multicenter RCT comparing medial displacement calcaneal osteotomy (MDCO) with or without sinus tarsi implant in patients with flexible AAFD.

In Sweden, the incidence of AAFD referred to specialist care was 23.0 per 100,000 person-years and was nearly twice as high in women as in men, with the highest incidence among individuals aged 61-75 years. Considerable regional variation in incidence was found across Sweden. Patients undergoing surgery reported low preoperative function and health-related quality of life. Surgical treatment resulted in statistically significant and clinically important improvements in patient-reported outcomes at 1 year postoperatively. There were large regional variations in the type of surgical procedures used in flexible AAFD. No statistically significant difference in outcomes was observed between calcaneal osteotomy and hindfoot arthrodesis.

AAFD requiring specialist care is relatively common and predominantly affects older women. Surgical treatment improves function and quality of life, although substantial regional variations exist in both incidence and surgical treatment. The ongoing RCT may provide further evidence regarding the role of the sinus tarsi implant as an adjunctive procedure in the treatment of flexible AAFD.

Populärvetenskaplig sammanfattning

Förvärvad plattfothet är ett tillstånd med flera olika felställningar i foten, där fotens form och funktion gradvis förändras. I början av sjukdomsförloppet upplever många patienter smärta och svullnad längs med fotens insida och bakom den inre fotknölen, utan någon synlig felställning. Med tiden kan dock fotvalvet sjunka ned mot underlaget, vilket lättast noteras genom att det naturliga "hålrummet" under hålfoten försvinner när man gör ett fotavtryck. Samtidigt ses även felställningar i bakfoten och framfoten. Den viktigaste konsekvensen av dessa förändringar är smärta och ett förändrat belastningsmönster i foten. Detta kan leda till minskad kraft och stabilitet i foten samt påverka gångförmågan.

Tillståndet kan behandlas icke-kirurgiskt med skoinlägg, fysioterapi och smärtstillande läkemedel. Långvarig felställning kan dock leda till inflammation och artrosutveckling i fotens leder. Vid fortsatta påtagliga besvär trots adekvat icke-kirurgisk behandling övervägs kirurgi. Det finns en stor mängd olika kirurgiska interventioner att tillgå, vilka syftar till att korrigera olika typer av felställningar i foten.

Förvärvad plattfothet är ett välkänt tillstånd inom ortopedisk specialistsjukvård. Trots detta saknas studier som beskriver hur vanligt tillståndet är i befolkningen, vilka patienter som drabbas eller vilka kirurgiska metoder som används i Sverige och internationellt. Det saknas också kunskap om hur patienterna upplever resultaten efter såväl icke-kirurgisk som kirurgisk behandling. För att kunna bedriva en vård baserad på vetenskapligt underlag och för att kunna garantera en likvärdig vård runt om i landet är det viktigt att en kartläggning görs avseende sjukdomens förekomst, vilka patienter som drabbas, hur de mår, hur de behandlas samt hur de upplever resultaten av den behandling de erhållit.

Denna avhandling består av fyra delprojekt som syftar till att kartlägga dessa aspekter och öka kunskapen om förvärvad plattfothet i Sverige. I delprojekt I har förekomsten av plattfothet inom svensk specialistsjukvård kartlagts med hjälp av data från det nationella patientregistret. I delprojekt II och III användes data från det svenska kvalitetsregistret för fot och fotledskirurgi (Riksfot, internationellt känt som Swefoot). Med hjälp av registerdata har vi, i delprojekt II, beskrivit patientgruppen som behandlas kirurgiskt för förvärvad plattfothet i Sverige, hur de mår och vilka ingrepp som utförs i dag. I delprojekt III har vi beskrivit resultaten efter kirurgisk behandling av förvärvad plattfothet samt jämfört resultaten vid ledbevarande kirurgi och steloperation av vissa leder i bakfoten. Delprojekt IV är ett studieprotokoll för en pågående klinisk studie där vi undersöker effekten av en skruv, kallad sinus tarsi-implantat, som tilläggsbehandling vid plattfotsoperationer.

Sammanfattningsvis visar avhandlingen att förvärvad plattfothet är ett vanligt tillstånd inom specialistvården i Sverige och förekomsten har ökat mellan 2007–2012 till 2013–2018. De patienter som drabbas är oftast äldre och överviktiga kvinnor. Före kirurgisk behandling har patienter som regel uttalad smärta, nedsatt funktion i foten och en låg livskvalitet. Efter kirurgi förbättras patienterna tydligt vad gäller smärta, funktion och livskvalitet. När resultaten ett år efter kirurgi jämfördes mellan ledbevarande kirurgi och steloperation hos patienter med förvärvad plattfothet kunde ingen signifikant skillnad påvisas i funktion eller livskvalitet.

Abbreviations

AAFD – Adult Acquired Flatfoot Deformity
AN – Accessory Navicular
AP – Anteroposterior
ATL – Achilles Tendon Lengthening
AOFAS – American Orthopaedic Foot and Ankle Society

CC – Calcaneocuboid
CO – Calcaneal Osteotomy

EQ-5D – EuroQol 5-Dimensions
EQ-5D-3L – 3-level version of EuroQol 5-Dimensions
EQ-VAS – EuroQol Visual Analog Scale

FAO – Foot and Ankle Offset
FAOS – Foot and Ankle Outcome Score
FDL – Flexor Digitorum Longus

GC – Gastrocnemius–Soleus Complex
GR – Gastrocnemius Recession

HFA – Hindfoot Arthrodesis
HR-QoL – Health-Related Quality of Life

ICD-10 – International Classification of Diseases, 10th Revision
IR – Incidence Rate

LCL – Lateral Column Lengthening

MDCO – Medial Displacement Calcaneal Osteotomy
MOXFQ – Manchester-Oxford Foot Questionnaire
MRI – Magnetic Resonance Imaging

NC – Naviculocuneiform
NPR – National Patient Register
NSAID – Nonsteroidal Anti-Inflammatory Drug

PCFD – Progressive Collapsing Foot Deformity
PL – Peroneus Longus
PROMs – Patient-Reported Outcome Measures
PTT – Posterior Tibial Tendon
PTTD – Posterior Tibial Tendon Dysfunction

QoL – Quality of Life

RCT – Randomized Controlled Trial

SEFAS – Self-Reported Foot and Ankle Score
SFI – Subfibular Impingement
SJ – Subtalar Joint
SL – Spring Ligament
STI – Sinus Tarsi Implant

TC – Talocalcaneal
TMT – Tarsometatarsal
TN – Talonavicular

VAS – Visual Analog Scale
WBCT – Weight-Bearing Computed Tomography

Chapter I: Background

The normal and pathological anatomy and biomechanics of the foot

The human foot is a complex structure composed of 26 bones, numerous ligaments, muscles, and tendons that together provide both stability and flexibility during gait. Its anatomical architecture enables the foot to support body weight, absorb shock, adapt to uneven surfaces, and efficiently transmit forces during forward motion. Central to these functions is the medial longitudinal arch that plays a key role in load distribution and energy transfer during stance and push-off (1).

The medial column consists of the talus, navicular, medial cuneiform and the first metatarsal bone. This column contributes substantially to the maintenance of the medial longitudinal arch and to the controlled transmission of forces during gait. The stability of the medial arch depends on the coordinated interaction between static stabilizers, such as ligaments and joint capsules, and dynamic stabilizers, including several muscles and tendons.

The static stabilizers of the medial column include the spring ligament (SL), talocalcaneal (TC) and deltoid ligaments, the talometatarsal joint complex and the plantar fascia. During gait, the first metatarsophalangeal joints are dorsally extended, which causes tension in the plantar fascia that stabilizes the Chopart's joint and reduces midfoot mobility. This mechanism is referred to as the Windlass effect (2). Degeneration of the talocalcaneal ligament has been associated with hindfoot valgus and subsequent development of subfibular impingement (SFI) (3).

Among the dynamic stabilizers, the posterior tibial muscle and posterior tibial tendon (PTT) play particularly important roles. The PTT contributes to inversion of the foot, assists in plantarflexion, and provides dynamic support to the medial longitudinal arch (4). Degeneration of the PTT has been associated with hindfoot valgus, excessive pronation and altered subtalar joint alignment, leading to sinus tarsi impingement (3). The flexor digitorum longus (FDL), flexor hallucis longus (FHL), peroneus longus (PL), and gastrocnemius-soleus complex (GC), through the connections to the plantar fascia, are also important dynamic stabilizers. During loading, the intrinsic muscles of the foot can sense local deformation and provide stabilization in that area (1).

In the normal gait cycle, the heel rise is initiated by the Achilles tendon. Just prior to toe-off, the axes of the transverse tarsal joint become nonparallel, resulting in joint "locking", which stabilizes the medial arch. The triceps surae then generates a forward propulsion force that is transmitted through the medial arch to the metatarsal heads. At initial contact during heel strike, the peritalar joints move into eversion. The posterior tibial muscle acts eccentrically at this stage, functioning as a dynamic stabilizer by controlling arch collapse and limiting excessive eversion of the foot. During the subsequent stance phase, this eversion leads to forefoot abduction and flattening of the medial arch. The axes between the transverse tarsal joints become parallel, and the joints thereby unlocked. As the gait cycle progresses from midstance to toe-off, the hindfoot gradually inverts and transitions into a varus position, restoring rigidity to facilitate efficient push-off (5).

Adult Acquired Flatfoot Deformity (AAFD)

Adult Acquired Flatfoot Deformity (AAFD) is a three-dimensional deformity affecting multiple structures of the foot, including hindfoot valgus, forefoot supination and abduction, and progressive collapse of the medial longitudinal arch (6). Historically, the term posterior tibial tendon dysfunction (PTTD) has been used synonymously with AAFD, and the stages were described as a continuum of PTTD (Figure 1) (7-9). However, more recent research has expanded our understanding of this complex condition, which involves many structures of the foot and ankle.

Figure 1. Rupture of the posterior tibial tendon

Strain or rupture of the SL (Figure 2) leads to rotation, plantar tilting, and anterior translation of the talar head. The resulting internal rotation of the talus contributes to collapse of the medial arch. Huang et al. showed that the SL was the third most important contributor to arch stability; the most important structure was the plantar fascia, followed by the plantar ligaments (10).

Cadaveric studies investigating the stability of the medial column have demonstrated that sectioning the SL results in greater medial column mobility than sectioning either the PTT or the FDL, regardless of the order of sectioning. This finding highlights the importance of the SL, rather than the PTT, and suggests that the PTTD may, in some cases, be a consequence of SL elongation or rupture rather than the primary cause of the deformity (11). Degeneration of the superomedial, and particularly the inferior, aspect of the SL is correlated with loss of normal alignment between the talus and calcaneus (3).

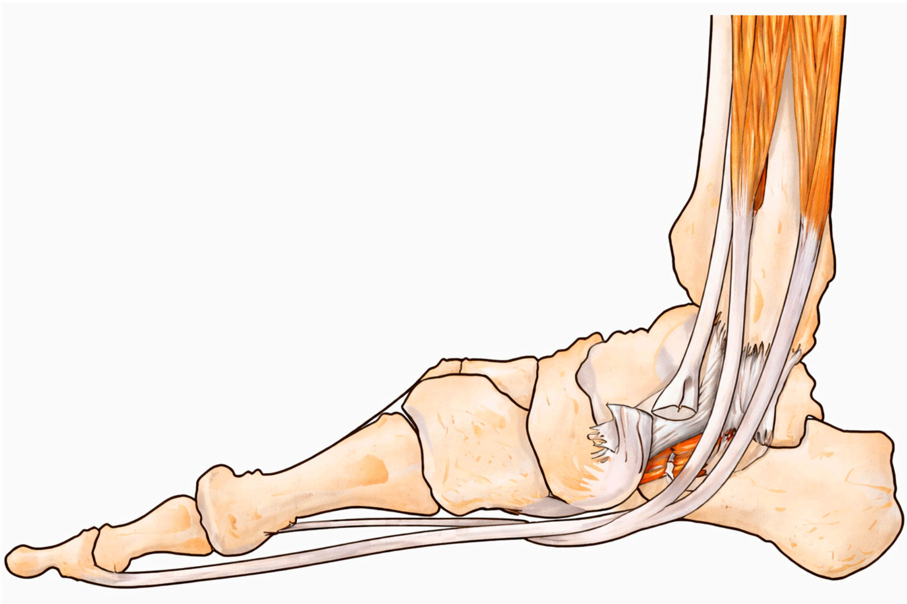


Figure 2. Spring ligament rupture visualized under dissected posterior tibial tendon

These changes in alignment are often referred to as subtalar joint subluxation. Another frequently used term is peritalar subluxation, which refers to a three-dimensional malalignment of the talus relative to the surrounding hindfoot and midfoot bones, including the calcaneus, navicular, and cuboid. Unlike isolated subtalar subluxation, it reflects a global loss of congruency around the talus across multiple joints. An early indicator of peritalar subluxation is subluxation at the middle facet of the subtalar joint (12).

The progressive failure of the stabilizing structures of the medial longitudinal arch initiates a cascade of biomechanical changes within the foot. During gait, the triceps surae, via the Achilles tendon, provides a powerful dynamic arch-supporting force that contributes to midfoot alignment. The repetitive loading of the midfoot contributes to further collapse over time. As the medial arch collapses, the hindfoot drifts into valgus alignment, which alters the mechanical axis of the Achilles tendon (AT). This lateralization increases the valgus force acting on the calcaneus and places additional strain on the already compromised medial structures.

Consequently, the forefoot is driven into abduction (Figure 3), supination, and relative elevation in an attempt to maintain ground contact (5). Compared with a normally aligned foot, the flatfoot is subjected to increased eversion (deforming) forces acting on the medial longitudinal arch, as well as increased hindfoot and forefoot mobility (13).

Figure 3. Foot with prominent forefoot abduction

Simultaneously, increased subtalar joint mobility reduces the functional requirement for ankle dorsiflexion during gait. This may contribute to adaptive shortening and contracture of the GC, further exacerbating deformity. The combined effect of ligamentous insufficiency, tendon dysfunction, and muscular imbalance results in disruption of both passive and active stabilization mechanisms.

Although instability of the medial column is a key feature of AAFD, the condition may involve the entire foot. Tightness of the GC may also contribute to premature heel rise during gait and thereby prolonged metatarsophalangeal (MTP) loading. This, in turn, leads to instability of the lateral column (LC), comprising the calcaneus, cuboid, and fourth and fifth metatarsals. Such instability may interfere with the smooth transition of the axis of rotation from the ankle to the MTP joints (2).

In patients with unilateral AAFD, the dorsal sagittal motion of the LC in the affected foot has been shown to be nearly twice that of the unaffected foot. The PL tendon acts as a sling beneath the cuboid and supports the height of the lateral arch. Dorsiflexion instability at the base of the fifth metatarsal may cause overload of the PL; this is counteracted by increased plantarflexion force (2).

Together, these changes establish a self-perpetuating cycle in which altered alignment and loading further weaken the supporting structures, resulting in progressive deformity. This interplay between structure and function underlies the pathomechanics of AAFD and helps explain its typically progressive nature. However, much remains unknown about the exact mechanisms and underlying risk factors that initiate these deformities.

Clinical findings and symptoms

Clinical examination includes inspection and palpation of the posterior tibial tendon (PTT) as well as evaluation of foot alignment. An early finding in AAFD can be tenderness and swelling along the PTT together with a gradual collapse of the medial, longitudinal, and transverse arches. Pain usually increases during prolonged standing and may affect gait pattern (4). Altered foot posture leads to increased strain on the medial soft tissue structures such as the PTT and the spring ligament (SL), which may result in elongation and eventual rupture. The function of the PTT can be further assessed using the “single heel-rise test” in which the patient elevates the heel of the affected foot while keeping the knee extended. Inability to actively invert the heel can indicate PTT dysfunction (PTTD), and patients with severe dysfunction may be unable to perform the test altogether (Figure 4).

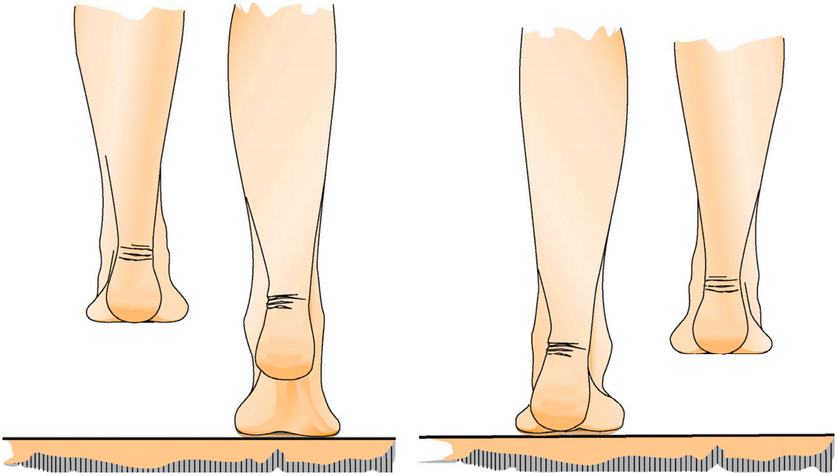


Figure 4. The “single heel-rise test”: the left image shows adequate inversion of the right heel during heel rise; the right image shows hindfoot valgus of the left foot during standing.

Increased hindfoot valgus and forefoot abduction can be assessed using the “too many toes sign”, where a greater number of toes are visible laterally when the foot is observed from behind (Figure 5).

Figure 5. Image of hindfoot valgus and the “too many toes sign” of the left foot

Tightness of the GC can be evaluated using the Silfverskiöld test in which the ankle is passively dorsiflexed with and without knee flexion. If ankle dorsiflexion increases when the knee is flexed, the test is considered positive (14). It is important to passively correct heel valgus to eliminate motion through the transverse tarsal joint when assessing ankle range of motion (Figure 6).

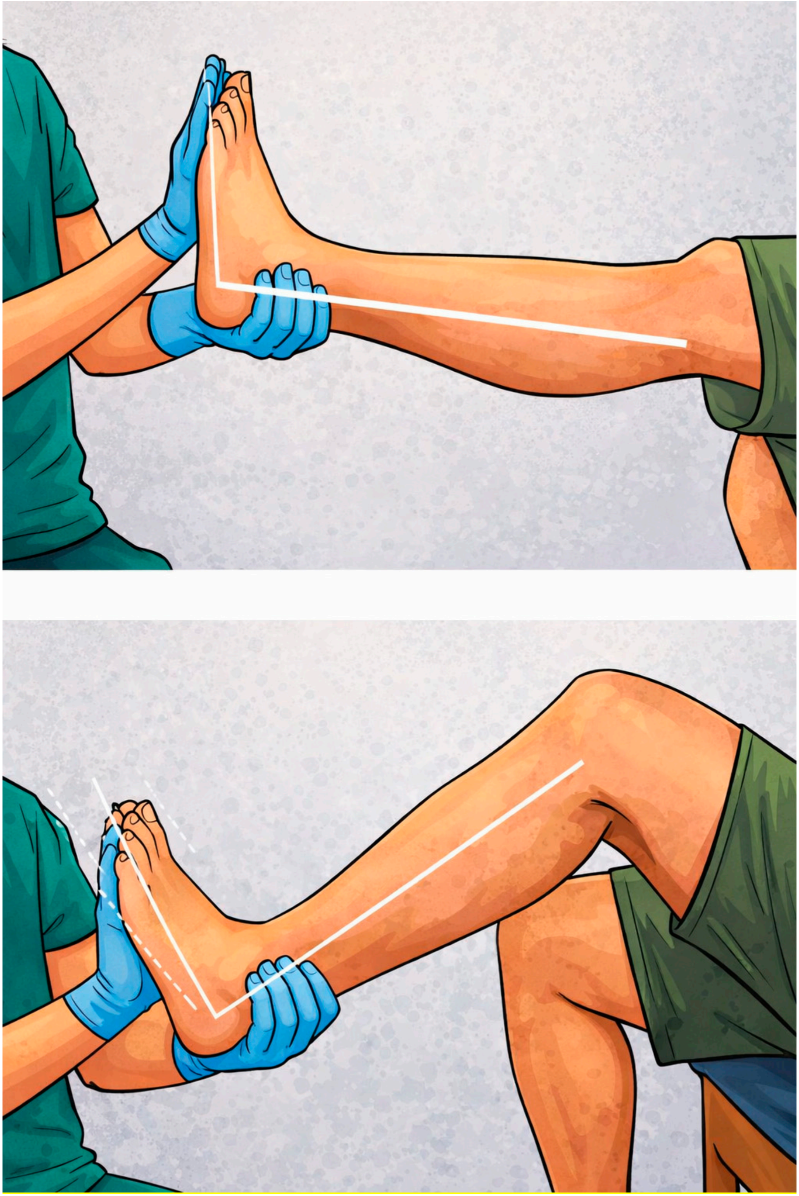


Figure 6. The Silfverskiöld test demonstrating increased ankle dorsiflexion upon knee flexion

Klaue's criteria are used to assess medial column instability at the tarsometatarsal (TMT) joint. According to Klaue, first-ray hypermobility is defined as dorsal displacement of the first metatarsal >8-10 mm when a dorsiflexion force is applied to the first metatarsal head. This test is called the "first metatarsal rise test", in which the patient is seated and non-weightbearing with the ankle in a neutral position (Figure 7). The examiner manually stabilizes the second through fifth metatarsals and uses the other hand to apply a dorsally directed force under the head of the first metatarsal. If the first metatarsal head translates dorsally relative to the second metatarsal head, particularly if it rises above the plane of the lesser metatarsal heads or demonstrates a soft or poorly defined endpoint, the test is considered positive (15).

Figure 7. The "First metatarsal rise test": the first metatarsal head is dorsally translated upon dorsally directed force

By asking the patient to actively plantarflex the first ray while manually stabilizing the second through fifth metatarsals, the examiner can also evaluate the strength and status of the peroneus longus (PL) tendon. This assessment is clinically relevant because the PL acts as an active stabilizer of the first ray and the medial column, and dysfunction may contribute to medial arch collapse (16).

The SL can be examined in isolation using the “neutral heel lateral push test” in which the ankle is held in a neutral position and the calcaneus is stabilized. A lateral force is then applied to the first metatarsal (Figure 8). Increased lateral translation of the midfoot relative to the hindfoot, compared with the contralateral side, suggests SL laxity or rupture (11).

Figure 8. Neutral heel lateral push test.

In the early stages of AAFD, the deformity is typically flexible and can be corrected manually. Later findings include lateral impingement and pain, as well as osteoarthritis resulting in a more rigid deformity that can no longer be corrected manually. Determining whether the deformity is flexible or rigid is essential, as this has important implications for treatment decisions (6).

Radiographic findings

Plain radiographs

Several imaging modalities are available for the assessment of AAFD. Plain radiographs are inexpensive, accessible and helpful when selecting an appropriate intervention. Radiographs should be obtained under weight-bearing conditions, as a flexible deformity may not be visible on non-weight-bearing images (1).

Figure 9. Lateral radiograph demonstrating AAFD with an obliterated longitudinal arch

On lateral views, changes in the longitudinal arch can be evaluated (Figure 9). The angle between the longitudinal axis of talus and the first metatarsal, known as Meary's angle, is approximately 0° in normally aligned feet, and increases as the medial arch collapses (Figure 10). Other commonly used metrics include the calcaneal inclination angle (calcaneal pitch), talar declination angle, calcaneal-fifth metatarsal angle, and the distance between the medial cuneiform and the floor (1).

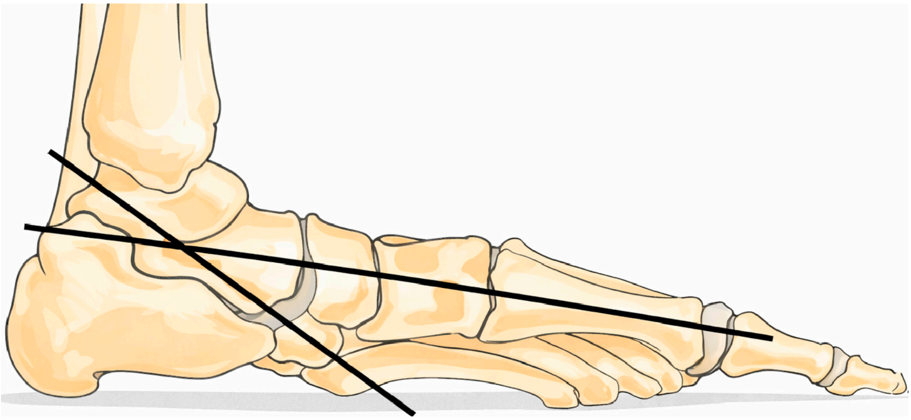


Figure 10. Increased Meary's angle as the medial arch has collapsed and the talar head is tipped towards the floor.

Figure 11. Radiograph demonstrating forefoot abduction

On the anteroposterior (AP) view (Figure 11), midfoot and forefoot abduction can be assessed by measuring the angle between the talus and the first or second metatarsal, the talo-calcaneal (Kite) angle, the talonavicular uncoverage (defined as the portion of the talar head not covered by the navicular bone), and the talar coverage angle (Figure 12) (1). The angle between the first and second metatarsals (the intermetatarsal angle) may also be increased as a sign of pronation and forefoot varus, most commonly seen in hallux valgus (17).

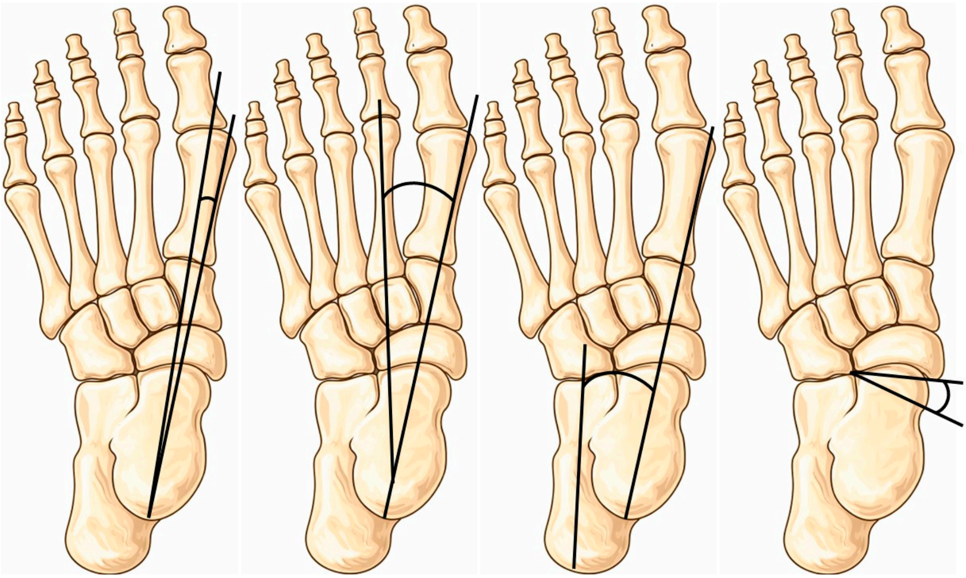


Figure 12. Angles from the left: talo-first metatarsal, talo-second metatarsal, talo-calcaneal, and talonavicular uncoverage

The hindfoot alignment view, also known as the Saltzman view, enables assessment of hindfoot valgus by measuring the angle between the tibial weight-bearing line and the most distal point of the calcaneus (Figure 13-14) (18).

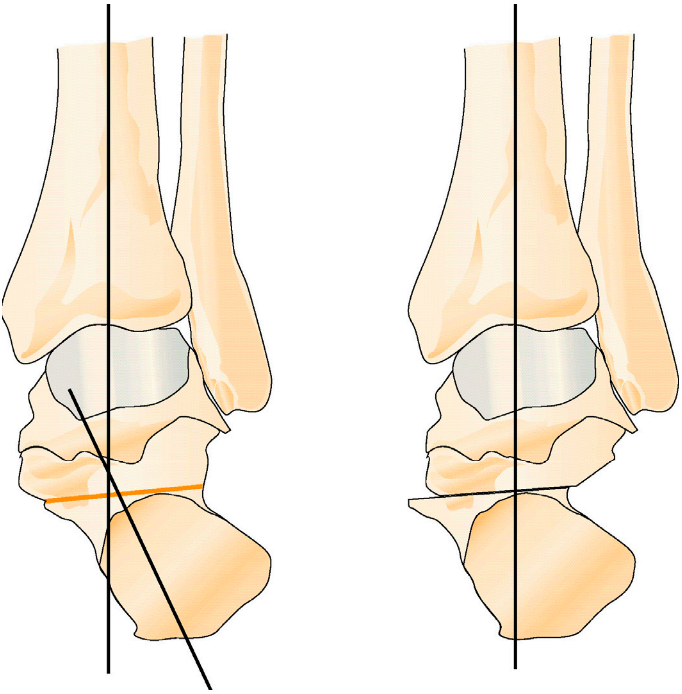


Figure 13. Hindfoot valgus and medial displacement calcaneal osteotomy that corrects the angle between longitudinal axis of the tibia and the hindfoot

Figure 14. Radiograph demonstrating corrected hindfoot alignment

Magnetic Resonance Imaging (MRI)

MRI can be used to evaluate the SL and the PTT; a longitudinal split is sometimes visualized. MRI is more sensitive in detecting intramural degeneration of the PTT than intraoperative inspection and can also detect bone edema as a sign of impingement. In addition, MRI can help rule out other causes of medial compartment pain, such as tarsal tunnel syndrome and os tibiale externum (OTE), as outlined in section 1.5.2.5 (19, 20).

Degenerative changes of the PTT observed on MRI have been associated with sinus tarsi impingement, whereas subfibular impingement (SFI) has been associated with degeneration of the talocalcaneal interosseus ligament. Degeneration of the superomedial and particularly the inferior aspect of the SL has been associated with subtalar joint (STJ) subluxation (3).

Weight-Bearing Computed Tomography (WBCT)

The increased use of weight-bearing CT (WBCT) has led to a paradigm shift in foot and ankle surgery in general, and particularly in the diagnosis of AAFD and understanding of its progression (21). Measuring angles and distances on plain radiographs introduces a risk of error because radiographs represent a two-dimensional projection of a three-dimensional structure. Because AAFD is a three-dimensional deformity, it can be visualized more accurately using WBCT, and important aspects of disease development have become better understood (20). One such aspect is the concept of subtalar joint instability, in which the subtalar middle facet has been identified as the center of rotation, and subtalar joint uncoverage as an early marker in AAFD (21).

At present, interpretation of WBCT data can be challenging and often relies on clinical experience. The examiner must be able to select the appropriate plane on which two-dimensional measurements should be performed. However, extensive research is being conducted on the development of computational models to assist with this evaluation (21). One such parameter is the Foot and Ankle Offset (FAO) in which landmarks of the weight-bearing tripod are manually selected using dedicated software (21).

These landmarks are the weight-bearing points of the first and fifth metatarsal heads and the calcaneus. The computer then calculates a midline passing through the calcaneus and between the first and fifth metatarsal heads. Another landmark, representing the center of the ankle joint (at the middle of the uppermost point of talus), is then manually selected. The computer calculates the distance between the virtual midline of the foot (where the ground force is applied) and the center of the ankle joint (where body weight is applied). This distance is then divided by foot length to create a comparable value independent of foot size. FAO represents the torque lever arm applied to the foot and ankle complex at each step during gait (20, 22).

The FAO has demonstrated good interobserver and intraobserver reliability, as well as good correlation with several established radiographic measurements, including the talonavicular coverage angle, Kite’s angle, and hindfoot moment arm (23).

Although WBCT is less expensive than conventional CT and exposes the patient to approximately ten times less radiation, it is still not widely available, particularly in Sweden. Therefore, plain weight-bearing radiographs combined with clinical examination remain the primary methods for evaluating AAFD in Sweden.

Classification

Johnson and Strom

In 1989, Johnson and Strom introduced a three-stage classification system for PTTD based on the condition of the PTT, hindfoot position, and deformity flexibility (Table 1). In stage I, PTT length was normal. In stage II, the PTT was elongated and the hindfoot deformity remained flexible; in stage III the PTT was elongated and the hindfoot deformity had become rigid. In their original article, the authors also described a fourth stage of PTTD in which the hindfoot becomes fixed in eversion, leading to valgus tilt of the talus and lateral tibiotalar degeneration. However, the fourth stage was not officially included in their classification system (24).

Table 1. Classification of posterior tibial tendon dysfunction by Johnson and Strom 1989
FDL; flexor digitorum longus, PTT; posterior tibial tendon (24)

Variable	Stage I – mild, medial pain	Stage II – moderate, medial pain	Stage III – severe, medial and lateral pain
Examination: swelling and tenderness	Mild swelling and tenderness along PTT	Moderate swelling and tenderness along PTT	Not much swelling but marked tenderness along PTT
Heel-rise test	Mild weakness	Marked weakness	Marked weakness
"Too many toes" sign	Absent	Present	Present
Deformity	Absent	Present (flexible)	Present (fixed)
Pathological features	Normal tendon length, paratendinitis	Elongated with longitudinal tears	Disrupted with visible tears
Images	No changes	Gross deformity	Deformity and diffuse arthritic changes
Treatment	Conservative, tenosynovectomy	FDL transfer	Triple arthrodesis

Bluman-Myerson

The Johnson and Strom Classification system was later refined by other authors, including Myerson et al., who formally added the fourth stage of the deformity (1, 6, 9, 24). Stage IV was described as a valgus deformity of the ankle associated with deltoid ligament insufficiency and sometimes lateral tibiotalar arthritis. Deland et al. published a similar classification in 2006 (25). Bluman et al. further revised the four-stage classification system in 2007 and introduced subgroups—most notably within stage II—which have important implications for surgical treatment (26). The four-stage classification system remains the most commonly used in clinical practice and in the literature (Table 2) (4, 8, 27).

Table 2. Simplified Bluman-Myerson Classification (1, 6, 9, 24)

Stage	Deformity	Clinical / Radiological Findings
I	None	Mild pain and swelling. Posterior tibial tendon tendinosis/tenosynovitis but functionally intact tendon. Able to perform a single heel rise, although weakness may occur with repeated attempts.
II	Flexible	Moderate pain with or without lateral pain. Dysfunctional posterior tibial tendon, involvement of the spring ligament. Inability to perform a single heel rise.
IIA	Flexible – moderate	>30–40% talar head coverage by the navicular.
IIB	Flexible – severe	Forefoot abduction, <30–40% talar head coverage by the navicular.
III	Rigid	Severe pain. Tendon and ligament insufficiency. Lateral hindfoot impingement. Subtalar arthritis. Inability to perform a single heel rise.
IV	Ankle involvement	Lateral talar tilt.
IVA	Flexible tibiotalar valgus	Deltoid ligament insufficiency.
IVB	Rigid tibiotalar valgus	Deltoid ligament insufficiency with ankle osteoarthritis.

The Rearfoot, Ankle and Midfoot (RAM)

The traditional classification systems have, however, been criticized for lack of validation, low interobserver and intraobserver reliability, and exclusion of important anatomical aspects of AAFD, such as the SL, deltoid ligament, and the NC and TMT joints. Advances in imaging technology have improved understanding of the condition and revealed additional anatomical factors that should be considered during surgical planning.

Consequently, several newer, more comprehensive classification systems have been proposed. In 2012, Raikin et al. introduced an entirely new classification system, the RAM classification, which divides the deformity into anatomic locations: rearfoot (R), ankle (A), and midfoot (M), highlighting that deformities involving these locations should be assessed independently. By assessing these aspects of the foot separately, a patient-specific surgical treatment plan can be formulated (Table 3) (28).

Table 3. RAM classification of AAFD 2012 (28)

Stage	Rearfoot	Ankle	Midfoot
Ia	Tenosynovitis of PTT	Neutral alignment	Neutral alignment
Ib	PTT tendonitis without deformity	Mild valgus (<5°)	Mild flexible midfoot supination
IIa	Flexible planovalgus (<40% talar uncoverage, <30° Meary angle, incongruency angle 20° to 45°)	Valgus with deltoid insufficiency (no arthritis)	Midfoot supination without radiographic instability
IIb	Flexible planovalgus (>40% talar uncoverage, >30° Meary angle, incongruency angle >45°)	Valgus with deltoid insufficiency with tibiotalar arthritis	Midfoot supination with midfoot instability—no arthritis
IIIa	Fixed/arthritic planovalgus (<40% talar uncoverage, <30° Meary angle, incongruency angle 20°-45°)	Valgus secondary to bone loss in the lateral tibial plafond (deltoid normal)	Arthritic changes isolated to medial column (navicular-medial cuneiform or first tarso-metatarsal joints)
IIIb	Fixed/arthritic planovalgus (>40% talar uncoverage, >30° Meary angle, incongruency angle >45°), not correctable through triple arthrodesis	Valgus secondary to bone loss in the lateral tibial plafond and with deltoid insufficiency	Medial and middle column midfoot arthritic changes (usually with supination and/or abduction of the midfoot)

In 2020, a consensus statement by Myerson et al. marked a paradigm shift in the understanding of the condition. A new nomenclature and classification system were proposed. In contrast to earlier concepts that described the condition as varying degrees of PTTD leading to other deformities in a continuous and predetermined pattern, Myerson et al. highlighted the fact that several deformities observed in AAFD can arise independently and that the pattern of disease development can differ substantially between patients. For example, increased mobility of the TMT and NC joints may occur following rupture of the SL, plantar fascia and/or the deltoid ligament, while the PTT may remain intact (8).

The new classification system was based on deformity flexibility as well as the type and location of the deformity (Table 4). Because the original stage I included no deformity (only PTT tendinosis), it was not included in the new system. In the new classification system, anatomic locations and associated deformities are assessed separately, represented by letters A-E and classified as either flexible (stage I) or rigid (stage II) deformities. The locations/deformities evaluated are hindfoot valgus (A), midfoot/forefoot abduction (B), forefoot varus or medial column instability (C), peritalar subluxation (D), and ankle instability (E) (8).

The authors also proposed replacing the term Adult Acquired Flatfoot Deformity with Progressive Collapsing Foot Deformity (PCFD). The terms “PTTD” and “flatfoot” were intentionally omitted from the new nomenclature because PTTD is not an obligate finding and “flatfoot” refers to only one aspect of this complex three-dimensional deformity. The word “adult” was also omitted, allowing inclusion of younger patients, and the word “progressive” was added to more accurately describe the natural history of the disorder (8).

Table 4. Myerson Classification 2020 (8)

Consensus Group Classification of Progressive Collapsing Foot Deformity		
Stage of deformity		
Stage I (flexible)	Stage II (rigid)	
Types of deformities		
(classes – isolated or combined)	**Deformity type/location**	**Consistent clinical/radiographic findings**
Class A	Hindfoot valgus deformity	Hindfoot valgus alignment Increased hindfoot moment arm, hindfoot alignment angle, foot and ankle offset
Class B	Midfoot/forefoot abduction deformity	Decreased talar head coverage Increased talonavicular coverage angle Presence of sinus tarsi impingement
Class C	Forefoot varus deformity/medial column instability	Increased talus–first metatarsal angle Plantar gapping first TMT joint/NC joints Clinical forefoot varus
Class D	Peritalar subluxation/dislocation	Significant subtalar joint subluxation/subfibular impingement
Class E	Ankle instability	Valgus tilting of the ankle joint

In Sweden, however, the term AAFD and different versions of the four-stage classification system are still commonly used. In the Swedish National Quality Register for Foot and Ankle Surgery (Swefoot), surgeons record the grade as: (1) no deformity, (2a) flexible deformity without forefoot abduction, (2b) flexible deformity with forefoot abduction, or (3) rigid deformity. Because ankle surgery is captured in a separate national quality register in Sweden (Swedankle), ankle involvement (stage 4) is not included in Swefoot.

When describing the different forms of AAFD, it can be argued that the term “grade” should be used instead of “stage”, because staging implies a predictable continuum of the disease progression. In contrast, the natural development of AAFD is not fully understood and progression between the described forms has not been clearly established.

Pathogenesis and related conditions

Risk factors for development of PTTD

Although the pathogenesis of AAFD is not fully understood, several risk factors have been associated with the disorder. The condition is more common in women than in men, with an approximate prevalence ratio of 2:1. It most commonly affects individuals later in life (Figure 15). Seronegative arthropathy, obesity, hypertension, trauma and corticosteroid injections have been associated with PTTD (29, 30). Smoking has also been linked to tendinopathy (31).

Figure 15. A patient with typical characteristics for adult acquired flatfoot deformity: woman, older and overweight

Increased body weight leads to greater mechanical loading of the foot, whereas metabolic syndrome contributes to systemic inflammation. Both factors may increase the risk of foot and ankle tendinopathies, including PTTD.

The higher prevalence in older individuals may be explained by the time required for degenerative changes to develop, as well as age-related decline in tendon quality. Activity level and footwear habits may also influence the overall load applied to the foot. These factors may also differ between sexes, as women and men may have different activity patterns and footwear habits. Furthermore, symptomatic hypermobility is more common in women, suggesting that generalized joint hypermobility may be an additional factor contributing to disease development (32).

Other risk factors for the development of tendinosis and tendon rupture include hypovascularity, matrix metalloproteinase (MMP) polymorphisms, particularly MMP-1 and MMP-8 (33-35).

Other conditions leading to pes planus

Pes planus (flatfoot) may arise from conditions other than PTTD, SL insufficiency and medial column instability. In some cases the cause of flatfoot and how it should be classified are uncertain.

Hypermobility

Patients with generalized joint hypermobility may exhibit excessive pronation during weight bearing, resulting in a form of "functional flatfoot". However, in these individuals, the medial longitudinal arch may reappear under non-weight-bearing conditions, and they can also actively elevate the arch by contracting intrinsic and extrinsic foot muscles. Symptoms may include discomfort or fatigue during prolonged standing or walking, although many individuals remain asymptomatic. These patients may benefit from insoles or physiotherapy.

Pediatric flatfoot

There is no universally accepted definition of pediatric flatfoot even though the condition is common. A low medial arch and hindfoot valgus are generally accepted features. Normally, infants have flexible flatfoot and gradually develop a normal medial longitudinal arch during the first decade of life because of growth and osseous remodeling.

The reported prevalence of pediatric flatfoot varies considerably across studies, ranging from less than 1% to 78%. This wide variation is likely attributable to differences in study populations, age distributions, definitions, and assessment methods.

When assessing a flatfoot in a young individual, the clinician must first determine whether the deformity is flexible (physiologic) or rigid (pathologic) (36, 37).

Most pediatric flatfeet are asymptomatic. Important factors that contribute to the development of physiologic flatfoot include age, sex, weight, hypermobility, and footwear habits. The question of when pediatric flatfoot should be considered pathologic is debated. However, features such as pain, rigidity, progression of the deformity, or functional limitation warrant further examination and consideration.

Nonphysiologic factors associated with pediatric flatfoot can be categorized into neurologic, muscular, genetic and collagen-related. The difficulty in distinguishing between physiologic and pathologic flatfeet, and determining appropriate treatment for each individual case, has led to the development of assessment tools including the Foot Posture Index (FPI-6), Flat Foot Proforma (FFP), and pediatric Flat Foot Proforma (p-FFP).

Most cases of pediatric flexible flatfoot are asymptomatic and represent a normal developmental variant that requires no treatment. In nonphysiological flatfoot, the first line of treatment is nonsurgical. Footwear modification, orthoses, and physiotherapy are commonly used, although the evidence supporting these interventions remains limited and inconsistent. When nonsurgical treatment fails, surgery may be considered to improve alignment and relieve symptoms.

A range of surgical procedures is available to treat pediatric flatfoot, including subtalar arthroereisis, soft-tissue reconstruction, and osteotomies; the choice of procedure is guided by deformity characteristics and patient factors. However, the overall quality of evidence for surgical interventions remains limited (36).

Figure 16. Feet of an adult and a child walking in the sand

Tarsal coalition

Tarsal coalition is defined as an abnormal connection between two or more tarsal bones. The condition is most commonly congenital and inherited in an autosomal-dominant pattern.

It arises from incomplete segmentation of the mesenchymal anlage of adjacent tarsal bones during embryonic development (38). Tarsal coalitions may also be acquired through degenerative joint disease, such as inflammatory arthritis, or in association with conditions including fibular hemimelia, Apert syndrome, arthrogryposis, and Nievergelt-Pearlman syndrome (39).

Coalitions may be fibrous, cartilaginous, or osseous. The most common types of coalitions are the calcaneonavicular (CN) and talocalcaneal (TC), which together account for approximately 90% of cases. Less common variants include talonavicular, calcaneocuboid, naviculocuneiform, and cubonavicular coalitions (39).

Estimated prevalence ranges between 1% and 13% and is equally distributed between sexes (38, 40). However, many cases remain asymptomatic, and the true prevalence is therefore uncertain.

The coalition usually becomes symptomatic during adolescence, at the onset of ossification, which causes rigidity. Initial symptoms typically include pain; later findings include reduced range of motion, particularly subtalar inversion and eversion. The condition may also progress to painful pes planovalgus, recurrent ankle sprains and osteoarthritis. Diagnostic imaging includes plain radiographs (anteroposterior and lateral views), weight-bearing 45° internal-oblique view, and a Harris axial view.

There is no evidence that asymptomatic coalitions lead to future problems. As in AAFD, first-line treatment in symptomatic cases is nonsurgical and may include NSAID or orthoses. If nonsurgical treatment fails, surgical resection of the coalition is usually recommended. Selective or triple arthrodesis can be performed when degenerative changes are present (39).

Lisfranc injury

The Lisfranc joint complex comprises the articulation between the five metatarsals, the cuboid and the three cuneiform bones that are linked by capsule-ligamentous structures. Between the medial and lateral cuneiforms lies the base of the second metatarsal, where it acts as a keystone that provides inherent stability to the joint complex.

A Lisfranc injury may result from either direct or indirect trauma but the extent of the injury can vary from mild subluxations to severe fracture-dislocations of the tarsometatarsal joints, and could easily be overlooked (41). A common clinical finding of Lisfranc injury is plantar hematoma (Figure 17).

Missed or inadequately treated Lisfranc injuries may lead to instability and progressive collapse of the medial longitudinal arch, resulting in a flatfoot deformity with symptoms and a need for surgical treatment.

Figure 17. Plantar hematoma, a common clinical finding of Lisfranc injury

Accessory Navicular (AN)

The accessory navicular (AN) bone is one of the most common accessory bones of the foot and is generally considered a normal anatomical variant. It is also referred to as os tibiale externum, os naviculare secundarium, os naviculare accessorium, os scaphoidea accessoria, and prehallux. Estimated prevalence in children is 10-12% (42). Three different types of AN have been described: Type 1, a sesamoid bone within the PTT insertion; Type 2, a secondary ossification center adjacent to the navicular bone, connected to the navicular tuberosity by a synchondrosis at the PTT insertion; and Type 3, a fusion of the secondary ossification center with the navicular bone (43).

Compression, excessive motion, or torsional stress at the AN can provoke symptoms. As the PTT inserts partly into the navicular bone and the AN is often embedded into the tendon, mechanical irritation may occur which can lead to inflammation and PTTD.

Symptoms most commonly present during adolescence or early adulthood and may resemble early stages of AAFD, typically worsening with physical activity. Mechanical irritation and inflammation increase the risk of PTT rupture, which can lead to medial arch collapse, and 35% of individuals with an AN also exhibit flatfoot deformity (45). The presence of type 2 or type 3 AN increases the risk for PTT tendinopathy and tear (44). Type 2 AN accounts for approximately 70% of symptomatic cases (46).

A painful AN can be treated nonsurgically with NSAIDs, braces, orthoses or insoles. However, results of nonsurgical treatment have been moderate to poor, especially in athletes (47, 48). When nonsurgical treatment fails, the AN can be surgically excised using various techniques described below, which may reduce inflammation and tendinosis and thereby prevent progression to tendon rupture and flatfoot deformity.

Epidemiology

Epidemiologic data on the incidence and prevalence of AAFD in the general population are limited. Using a combination of survey and clinical assessment, a study from England estimated the prevalence of flatfoot pathology among women aged 40 years or older registered at a county general practice, to be 6.6%, with symptomatic flatfoot reported by 3.3% of the participants (49).

In Spain, a population-based study using podoscopic examination in randomly selected women and men, from a single municipality, estimated the prevalence of AAFD in individuals aged 40 years or older to be 19% (50).

In the United States, a study involving 185 acute-care and ambulatory surgical units in South Carolina reported that the incidence rate of corrective surgery for AAFD increased from 0.26 per 100,000 individuals in 1996 to 3.04 per 100,000 in 2014 (51).

Treatment

Nonsurgical

There are multiple treatment options for AAFD, and first-line management is usually nonsurgical. Physiotherapy can help strengthen the foot and ankle and stretch the GC. Orthoses can help reduce loading of medial structures and improve the positioning of the foot. Nonsteroidal anti-inflammatory drugs can be used to reduce inflammation and pain.

Surgical

Soft-tissue procedures

Tenosynovitis of the PTT can be treated with synovectomy. If the PTT is elongated or ruptured, its function can be restored by transferring the flexor digitorum longus tendon (FDL) to the navicular bone, a procedure known as FDL transfer (Figure 18) (1).

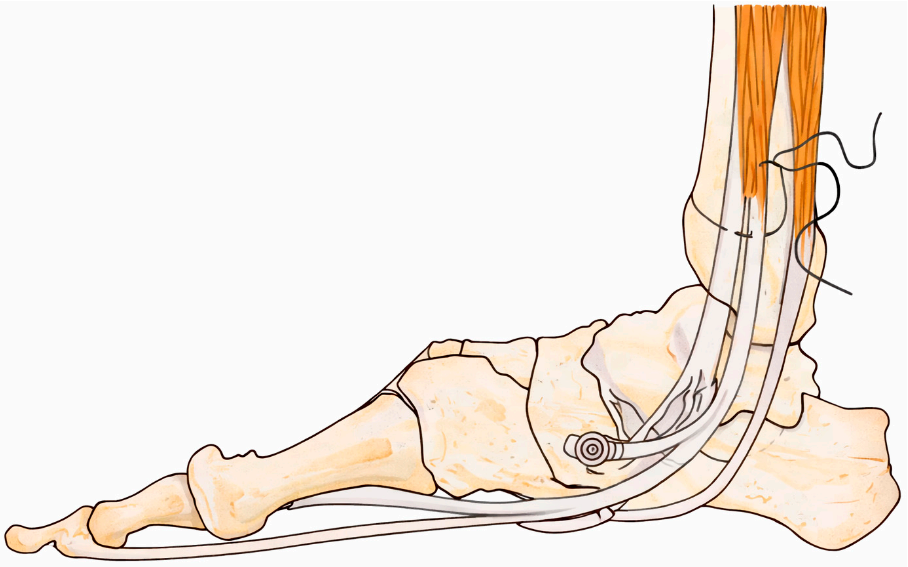


Figure 18. Flexor digitorum longus transfer.

Occasionally, tendinosis resulting from an AN requires surgical treatment. One of the most commonly used procedures is the Kidner procedure, in which the AN is excised and the PTT is repaired, reconstructed or advanced into the remaining navicular bone. In a young individual without flatfoot deformity, excision of the AN and plication of the PTT is usually sufficient. However, if flatfoot is present, the PTT may need to be rerouted through the navicular bone to increase tension in the tendon, and bony procedures may be necessary as described below. In adult patients with symptomatic AN, with or without a flatfoot deformity, the AN can be excised and the PTT sutured or anchored to the side of the medial aspect of the navicular bone. If hypertrophy of the medial navicular is present, this can be resected or osteotomized to reduce pressure on this area (45, 47, 52, 53).

An elongated or ruptured SL can be repaired by suturing or reconstruction through tendon transfers, allografts or synthetic augmentation (54). Tightness of the gastrocnemius-soleus complex can be surgically addressed with a gastrocnemius recession or a more distal procedure such as Achilles tendon lengthening (ATL). Several gastrocnemius-recession techniques exist; one of the most commonly used is the Strayer's procedure, which involves isolated release of the gastrocnemius tendon at the gastrocnemius musculotendinous junction (55).

Bony procedures

Several bony procedures are available for the surgical treatment of AAFD.

To correct hindfoot valgus, a commonly used procedure is medial displacement calcaneal osteotomy (MDCO), also known as Koutsogiannis osteotomy. In this procedure the posterior calcaneal tuberosity is osteotomized and translated medially, typically by 1.0-1.5 cm, thereby shifting the Achilles tendon lever arm medially and improving hindfoot alignment (Figure 19) (56, 57).

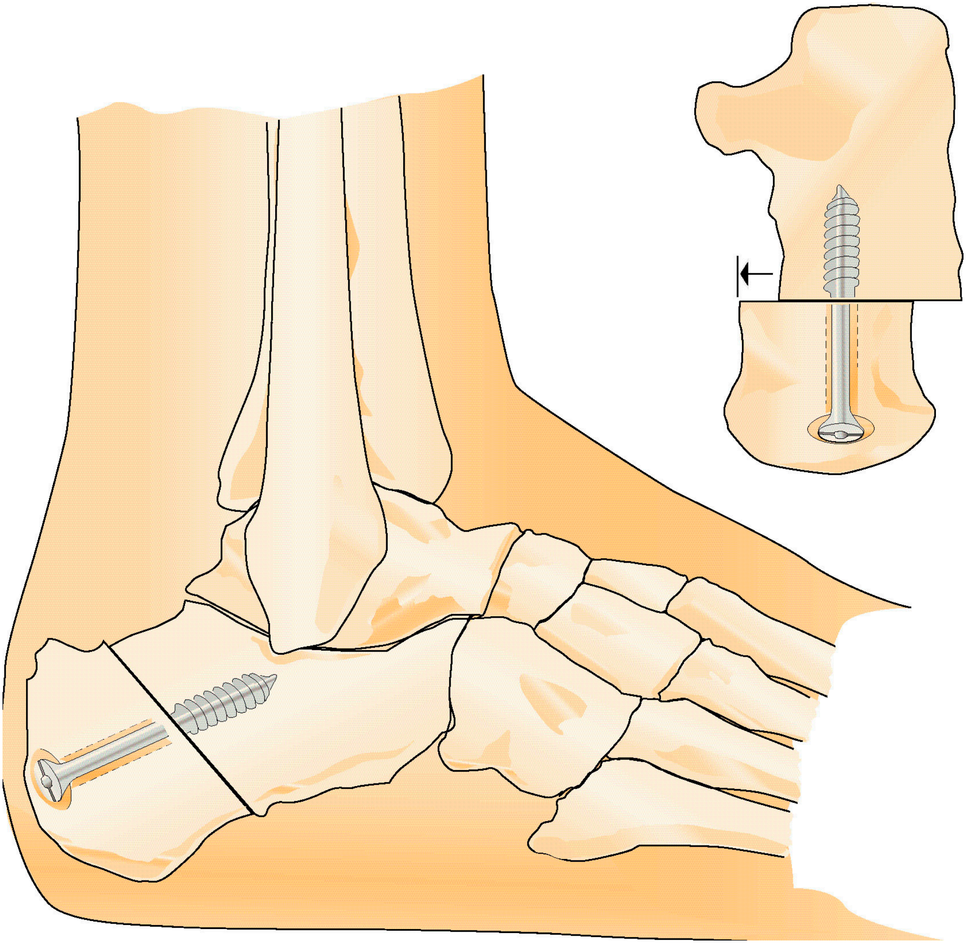


Figure 19. Medial displacement calcaneal osteotomy

If significant forefoot abduction is present, it can be addressed with lateral column lengthening (LCL). One of the most common LCL procedures is Evan’s osteotomy in which a lateral opening-wedge osteotomy is performed approximately 1 cm proximal to the calcaneocuboid joint. The resulting gap is distracted and filled with, for example, a tricortical bone graft (Figure 20) (58).

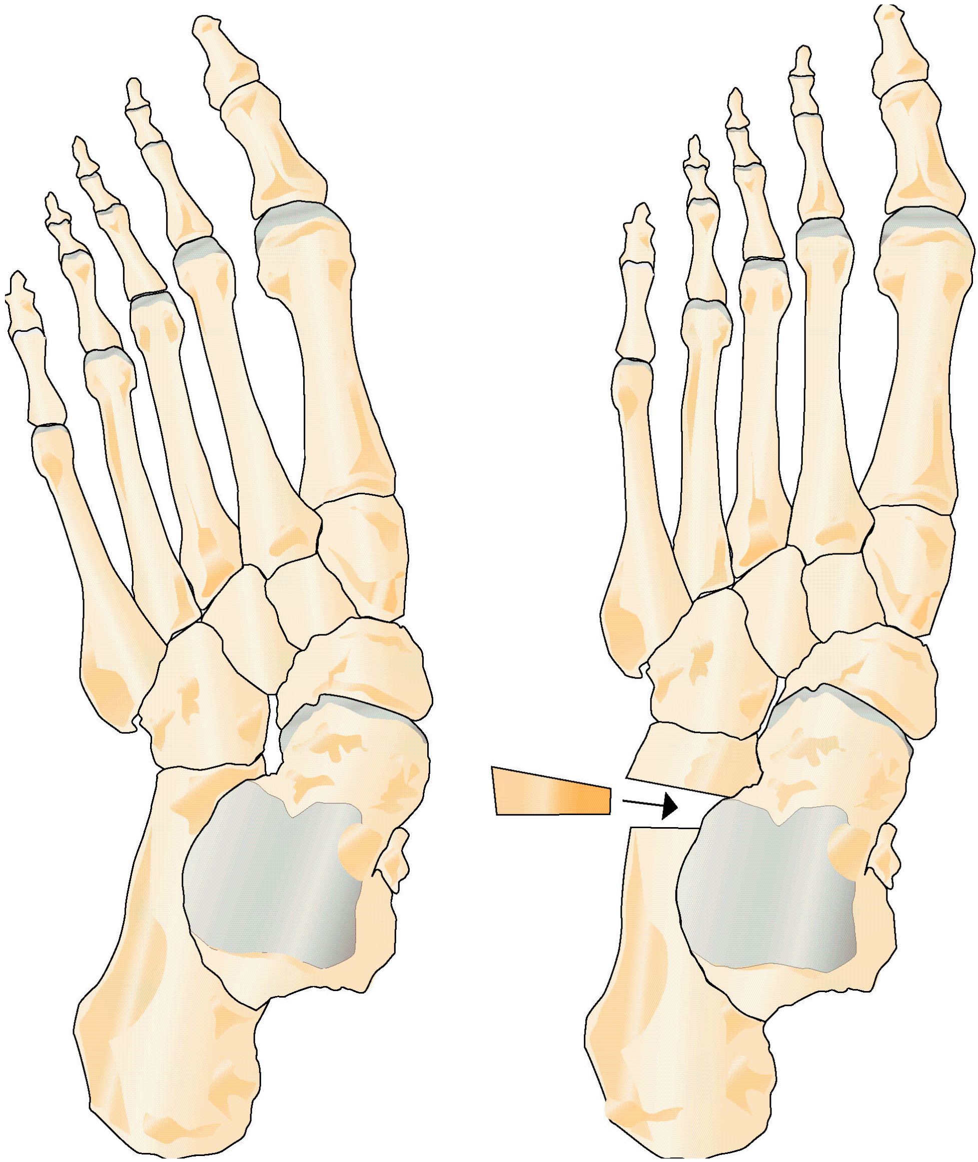


Figure 20. Lateral column lengthening

The medial column of the foot is often unstable, which may lead to forefoot supination. This deformity and instability can be addressed with arthrodesis of the naviculocuneiform (NC) joint or first tarsometatarsal joint (TMT I) (Figure 21). Other procedures include an opening-wedge osteotomy of the medial cuneiform (Cotton osteotomy), or a plantarflexion osteotomy of the first metatarsal.

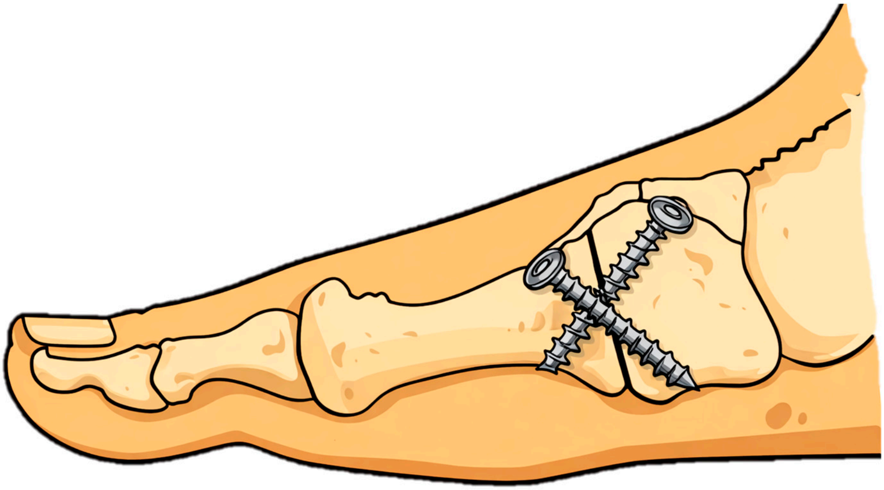


Figure 21. Arthrodesis of the first tarsometatarsal joint

When osteoarthritis is present, arthrodesis of the hindfoot joints may be required, including the talocalcaneal (TC), talonavicular (TN), and calcaneocuboid (CC) joints. Triple arthrodesis refers to arthrodesis of all three joints, whereas diple arthrodesis typically refers to arthrodesis of the TN and TC joints (Figure 22-23).

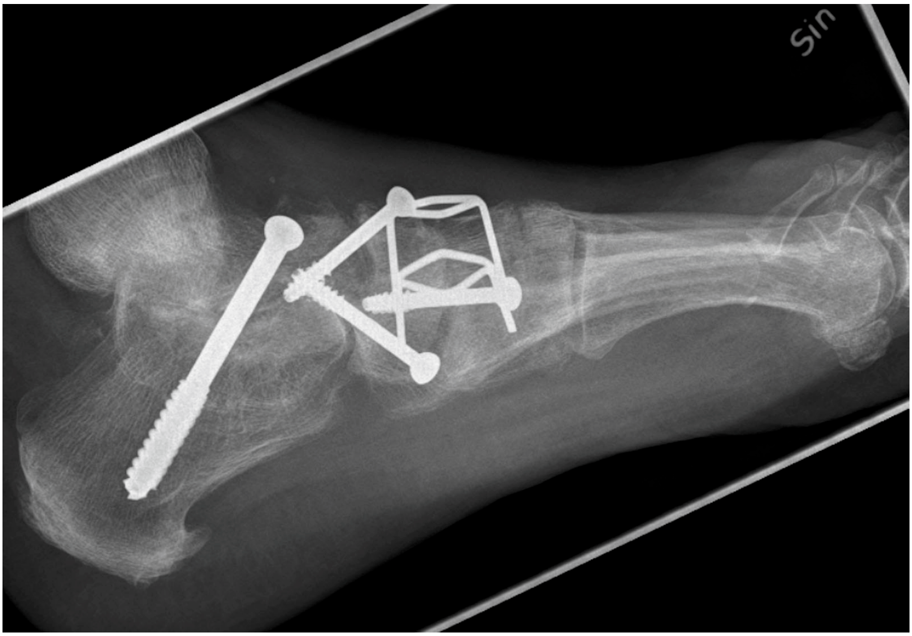


Figure 22. Radiograph demonstrating arthrodesis of multiple hindfoot joints

Figure 23. Radiograph demonstrating arthrodesis of multiple hindfoot joints

To block hyperpronation of the calcaneus, limit plantar tilting of the talar head and reduce lateral impingement, an extra-osseus implant can be placed in the sinus tarsi, a procedure known as subtalar arthroereisis or insertion of a sinus tarsi implant (STI) (Figure 24). In adults with flexible AAFD, it is often performed adjunctive to procedures such as MDCO and FDL transfer, and has shown favorable functional and radiographic results (59, 60). However, evidence remains limited, and no prospective studies have compared outcomes of STI as an adjunctive procedure with those of conventional surgical treatment without STI.

Subtalar arthroereisis is performed by palpating the soft spot inferior to the distal tip of the fibula and making a 15-mm skin incision over the sinus tarsi. The intermediate dorsal cutaneous branch of the superficial peroneal nerve is preserved, and subcutaneous tissue is spread gently. A guide pin is inserted into the canal, in the direction following the axis of the sinus tarsi joint, until it protrudes through the medial skin above the synovial sheath of the PTT. The soft tissue is spread, and a lever is introduced in the sinus tarsi to correct the tilted talus and restore subtalar-joint congruency. Implant size is determined by inserting sizers starting with the smallest. Passive range of motion of the talonavicular joint is assessed with the foot in dorsiflexion for each sizer. Implant position is assessed on anteroposterior and lateral views using a C-arm. The appropriate sizer is then replaced with the implant. Implant position and range of motion are assessed, the guidewire is removed, and the incision is closed. The need for additional procedures is then assessed (61).

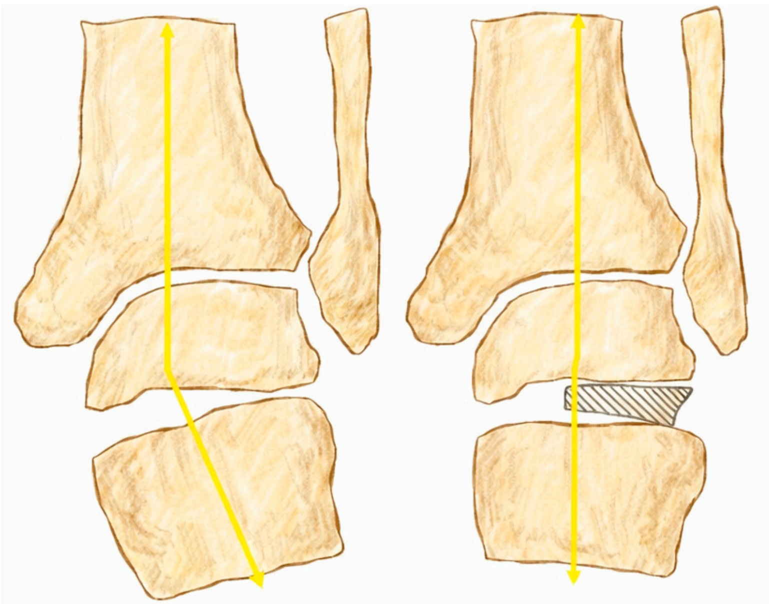


Figure 24. From the left: valgus alignment of the hindfoot, corrected hindfoot alignment with a sinus tarsi implant

Patient-reported outcome measures (PROMs)

A patient-reported outcome measure (PROM) is an outcome assessment instrument based on information reported directly by the patient (Figure 25). PROMs are typically designed as questionnaires consisting of carefully selected items with standardized response options, often using ordinal categories such as none, mild, moderate, and severe. Responses to the individual items are subsequently aggregated into a summary score or index, which can then be used to evaluate the status of a disease or condition. PROMs can also be used to compare health status between different patient groups or to assess changes in health status within the same patient over time. PROMs have the advantage of capturing the patient's perception of health rather than relying solely on clinical or radiographic findings, which may not fully reflect the patient's experience.

Figure 25. Demonstration of a patient-reported outcome measure

Several types of PROMs exist, evaluating different features of health. Generic PROMs assess overall health and can be used across many disorders and treatment settings. However, if a PROM assesses too many aspects of a patient's health, it may dilute the impact of a specific disease or condition of interest. Conversely, a PROM that is too specific to one disease or disorder can create interpretation difficulties, because fewer comparative data are available for contextualizing scores.

Another important aspect to consider is PROM quality. Measurement properties of a PROM must be evaluated before implementation in research studies (62-64). Standardized assessment tools are used to evaluate PROM quality, a process referred to as validation. Four main measurement properties should be evaluated: (1) validity, the degree to which the instrument measures what it purports to measure; (2) reliability, the degree to which an instrument is free from random error; (3) responsiveness, the instrument's ability to detect change over time; and (4) interpretability, the degree to which one can assign easily understood meaning to the instrument's quantitative scores (65). Not all PROMs have been fully validated and even fewer have been validated with desirable results, i.e. with good measurement properties. These aspects must be carefully considered when designing a study and selecting an appropriate PROM.

Generic PROMs

Generic PROMs are appropriate when the aim of a study is to describe the general health of a patient. However, when a study aims to evaluate the symptoms and functional limitations related to a specific region of the body, generic outcome measures are less sensitive.

EuroQol-5-Dimensions (EQ-5D)

The EQ-5D is a generic PROM that assesses five aspects of health-related quality of life (HR-QoL): (1) mobility, (2) self-care, (3) usual activities, (4) pain/discomfort, and (5) anxiety/depression. In the 3-level version of EQ-5D (EQ-5D-3L), each dimension has three levels: (1) no problems, (2) some problems, and (3) severe problems/unable to do. Different combinations of responses generate different possible EQ-5D states; in total there are 243 possible states.

The summary score of the EQ-5D is the EQ-5D index, which is a weighted value calculated using preference weights that account for population differences in health-state valuations. Different national and regional tariffs are available; in Sweden the United Kingdom tariff is commonly used. The EQ-5D index can be used across a wide range of conditions and treatments.

The highest possible EQ-5D index (1) represents full health whereas 0 represents the worst possible health. The EQ-5D also includes a visual analog scale (EQ-VAS) on which patients rate their general health from 0 to 100.

Sex-, country- and age-specific normative values are available for the EQ-5D, allowing comparison between the general population and populations with specific diseases. In addition, the EQ-5D has been thoroughly validated and is considered to have good measurement properties (66-69).

Figure 26. A patient filling out a patient reported outcome measure form

Disease-specific PROMs

PROMs can also be region-specific, dimension-specific, or disease-specific. These PROMs are usually more responsive to clinical change and often contain fewer questions, which makes them easier and faster to complete than a generic PROM. Depending on the anatomic region of interest, many different region-specific PROMs are available (72).

Foot and ankle specific PROMs

American Orthopedic Foot and Ankle Society (AOFAS)

The AOFAS score is widely used in the foot- and ankle-related literature. However, the instrument is not fully validated, is not available in Swedish, and not strictly a PROM because it includes clinician-assessed components (71, 73-75).

Foot and Ankle Outcome Score (FAOS)

The FAOS was developed in Sweden based on the Knee Injury and Osteoarthritis Outcome Score (KOOS) (76). Although FAOS is used in foot and ankle research, it is less widely used than the AOFAS. FAOS is a fully patient-reported instrument, initially validated in patients after ankle-ligament reconstruction and more recently for foot disorders, such as hallux valgus, hallux rigidus and AAFD. These studies indicate acceptable psychometric properties; however, several limitations remain. Moreover, the questionnaire is relatively extensive, with 42 items, which may reduce usability (77-79). To our knowledge, FAOS currently lacks age-, sex-, and country-specific normative values.

Manchester-Oxford Foot Questionnaire (MOXFQ)

The MOXFQ was developed from the Manchester Foot Pain and Disability Index (MFPDI) and was designed specifically to assess foot and ankle disorders. The MOXFQ has been extensively evaluated and is considered a high-quality PROM (80-83). However, it contains many items, and it has not been translated into Swedish.

Self-Reported Foot and Ankle Score (SEFAS)

SEFAS is a 12-item foot and ankle-specific PROM used in Swefoot. It is based on the New Zealand total ankle questionnaire (NZAQ), and the Swedish version has been developed according to a standardized cross-cultural adaption process.

The PROM includes multiple dimensions including pain, function, and activity limitations. Each item is scored 0 to 4 and summarized into a total score in which 0 represents the most severe disability and 48 represents normal function. A scoring approach has also been developed to handle missing or incorrectly completed items, which is an important advantage when using SEFAS in research because fewer questionnaires must be excluded.

SEFAS has been thoroughly evaluated and is considered a high-quality PROM for foot and ankle disorders. Age- and sex-specific normative values have been established for the Swedish population. In addition, minimal important change (MIC) values are available for SEFAS. MIC represents the smallest change in score that reflects a clinically meaningful improvement in health status. Having a MIC value along with normative values for a reference population facilitates interpretation of results from studies using SEFAS.

Chapter II: Aims

General aims of the thesis

The aims of this thesis were to improve understanding of and knowledge about Adult Acquired Flatfoot Deformity (AAFD), the affected patient population, and the burden of the disease, as well as to describe and compare current surgical interventions in order to promote more standardized treatment.

This was addressed through the following aims:

- Determine the incidence of AAFD referred to orthopedic specialist care in Sweden.
- Determine characteristics in patients undergoing surgical treatment for AAFD, including demographic and clinical features.
- Describe the surgical interventions used in the treatment of AAFD and evaluate potential regional variations in practice.
- Assess the relationship between patient characteristics, type of surgical intervention, and postoperative outcomes, including patient-reported measures of pain, function and health-related quality of life.
- Evaluate whether the stage of AAFD deformity correlates with preoperative symptoms, function, and quality of life as measured by patient-reported outcome measures.
- Compare outcomes of commonly used surgical procedures for flexible AAFD, including calcaneal osteotomy and hindfoot arthrodesis.
- Investigate whether the addition of a sinus tarsi implant as an adjunctive procedure to calcaneal osteotomy improves outcomes compared with calcaneal osteotomy without a sinus tarsi implant, in patients with flexible AAFD.

Chapter III: Patients and methods

The National Patient Register

The Swedish National Board of Health and Welfare manages a number of registers including the National Patient Register (NPR). The primary aim of the NPR is to support equitable distribution of healthcare resources and to ensure that healthcare provision is of high quality, and consistent across the country. This is achieved by monitoring long-term health trends in the population, contributing to disease prevention and treatment, supporting the development of healthcare, and monitoring the quality of healthcare services (84).

Reporting

The NPR contains comprehensive data including a personal identity number (unique for every resident in Sweden), healthcare provider, county, diagnoses (primary and secondary diagnoses), and dates of healthcare visits (84). Diagnoses are coded according to the Swedish version of the International Statistical Classification of Diseases and Related Health Problems (ICD-10-SE).

Data are reported monthly to the National Board of Health and Welfare from all publicly funded healthcare providers in the 21 county councils, as well as from private providers. Reporting to the NPR is mandatory for all county councils and, since 1987, the NPR has included all inpatient care in Sweden. However, the National Board of Health and Welfare cannot compel private organizations to report to the NPR.

Since 2001, all outpatient physician visits, including day surgery, have been included in the NPR. Data on primary care or patients treated only by nonphysician healthcare professionals in nonpsychiatric outpatient care are not included in NPR (84).

Coverage and quality

NPR coverage is generally considered high, but it is not possible to confirm this because of a lack of comparative data. There is no comprehensive nationwide register of all healthcare providers in Sweden, and therefore no definitive list of providers obliged to report to the NPR. Private healthcare providers are estimated to constitute a significant proportion of non-reporting providers. Reporting of inpatient care has been ongoing for a longer period and is considered high (84).

In contrast, outpatient-care coverage was initially lower but gradually improved to a high level. One indicator of this improvement is the increase in the number of encounters recorded over time.

The Swedish Association of Local Authorities and Regions (SALAR) provide annual statistics on physician encounters in specialist outpatient care financed by the regions. These data are used as benchmarks to assess NPR coverage by comparing the number of encounters recorded in each source. In 2005, comparisons showed substantially fewer encounters in NPR than in SALAR. Over time, this discrepancy has diminished, and by 2021, the NPR recorded approximately 7% more encounters than SALAR. However, this comparison has limitations, because the NPR also includes privately financed healthcare not captured by SALAR, making it an approximate reference for evaluating changes in NPR coverage over time.

Frequent quality and validity controls of the NPR are conducted throughout the data-collection and reporting process. Data are extracted from healthcare providers' medical record systems and reported electronically to the National Board of Health and Welfare, either through the 21 regional healthcare authorities or directly by private providers. Extracted information, such as diagnoses, procedures, and relevant drug codes is regulated by national legislation and reporting standards. Since 2015, automated delivery controls have been applied to all submitted data. These include technical, logical, and nonresponse checks. Some errors trigger a complete stoppage of the entire data delivery, requiring the provider to correct and resubmit the data, whereas less severe issues generate warnings. Following each submission, a feedback file summarizing detected discrepancies is sent to the reporting provider to support correction and improvement of data quality (84).

The Swedish national quality register for foot and ankle surgery, Swefoot

Swefoot was founded in 2014 and is a part of the Swedish system of national quality registers. It prospectively collects data through a web-based platform in which operating surgeons enter procedure-related variables. The aim of Swefoot is to improve the quality of foot and ankle surgery in Sweden, allowing comparisons between surgical units, regions, and over time.

The register includes 16 different diagnoses, and approximately 15,000 foot and ankle procedures are potentially eligible for inclusion each year. Data are collected from both the surgeon and the patient. To be included in the register, the patient must be 16 years of age or older, have a permanent Swedish personal identity number, and undergo surgery for one of the 16 foot and ankle conditions covered by the register (85).

Surgeon-reported data

Immediately after surgery, the surgeon reports data in a web-based system. The report includes data on comorbidities related to the condition, the diagnosis and its grading/severity, preoperative and perioperative findings, and revision-surgery status. Additional variables include the type of anesthesia used and the postoperative regimen, including external fixation and weightbearing. Surgeons also report where and when the surgery was performed as well as their competence level, categorized as: (1) resident physician, (2) orthopedic specialist (<15 forefoot and/or 5 hindfoot procedures per year), or (3) foot and ankle surgeon specialist (≥15 forefoot and/or 5 hindfoot procedures per year). Other data recorded in the register include the type of procedure and whether implants or internal fixation were used (and, if so, which type).

Patient-reported data

Patients complete questionnaires preoperatively and at 1 and 2 years postoperatively. The questionnaires can be completed on paper or electronically via the register platform, depending on the surgical unit and the patient's preference. Follow-up questionnaires were previously sent by email with a direct link or by mail. Currently, the questionnaire is distributed through the Swedish Healthcare Guide (1177), a nationwide digital and telephone-based health information service provided by the Swedish healthcare system.

The questionnaire includes questions on baseline characteristics, such as sex, height, weight, smoking habits, and comorbidities. It also includes two types of PROMs, as well as additional questions about foot appearance, footwear habits, foot strength, forefoot pain, and overall satisfaction with the surgery. The PROMs used in Swefoot are EQ-5D-3L and SEFAS.

Quality, coverage and completeness

Swefoot performs continuous data validation, for example by comparing registry entries with medical records and the NPR, identifying and removing duplicate registrations, and excluding deceased patients. Illogical surgery dates are corrected and nonresponse in PROM follow-up is analyzed.

Coverage in Swefoot refers to the proportion of eligible surgical units connected to the register. By the end of 2024, 74 units were connected, corresponding to coverage of 87%. Of the 21 regions in Sweden, 20 were represented. However, only 69 units were actively registering by the end of 2024 (86).

Completeness refers to the proportion of performed surgical procedures that are recorded in the register, typically estimated by comparison with the NPR. Although completeness has improved substantially in recent years, completeness of AAFD registration has remained relatively low, at 58%. Completeness varies considerably between diagnoses, regions and surgical units and is generally higher in units with well-established registration routines (86).

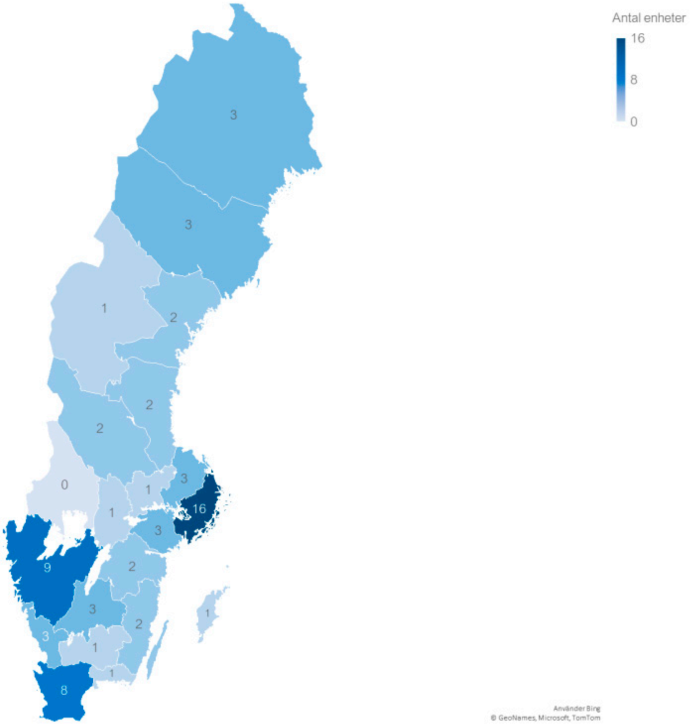


Figure 27. Number of units connected to Swefoot in the different regions of Sweden

Research Electronic Data Capture (REDCap)

REDCap is a secure, web-based application designed for building and managing online databases and surveys. It can be used by researchers to create customized electronic case report forms and questionnaires accessible through a secure login system.

The platform includes features such as data validation, branching logic, calculated fields, and automated export to common statistical software packages such as SPSS, Stata, and R. In addition, REDCap maintains audit trails that track data entry and modification, which support data integrity and transparency in research data management.

At Lund University, REDCap is provided as a secure data management platform with regular system backups and access control to support compliant storage and handling of research data. The system allows the principal investigator to assign different levels of access to members of the research team. REDCap also supports scheduling and tracking of study-related events, such as patient visits and follow-up assessments, which facilitates efficient data collection and management in clinical research projects (87).

Study I

Study design and inclusion

Study I is a population-based study using data from the NPR.

Data on all patient visits to a medical doctor in secondary and tertiary healthcare facilities from January 1, 2007, through December 31, 2018, in which the ICD-10-SE code M214 and M768 were registered, were extracted. The dataset included demographic variables (age, sex, country of birth, and citizenship), clinical data with diagnoses coded according to the Swedish version of the International Classification of Diseases 10th Revision (ICD-10-SE; up to 30 codes per visit, including a designated main diagnosis), and procedure codes (up to 30 per visit) with corresponding dates.

Additional variables included diagnosis-related group (DRG) codes, anesthesia and medication codes (ATC codes), and organizational information on the hospital, unit, and specialty. Healthcare utilization was captured using visit dates as well as length of stay; dates were available in both numeric and calendar formats.

Patients aged 16 years or older with a first-time diagnosis of M214 (AAFD) were included. Because the diagnosis code M768 is used for PTTD and several other conditions, records with M768 were excluded.

A total of 54,964 patient visits were registered during the study period, and 21,766 of these were first-time registrations among patients ≥16 years (Figure 28).

Statistical analysis

Incidence rates (IRs), expressed as the number of cases per 100,000 person-years with 95% confidence intervals (CIs), were calculated using annual population data from Statistics Sweden. Changes in incidence rate over time (2007–2012 and 2013–2018) were analyzed and compared using a Poisson test.

County-, age-, and sex-adjusted incidence rates were also calculated, as well as incidence rate ratios (IRRs). The at-risk population was standardized with weights from the Swedish general population based on data from Statistics Sweden.

IBM SPSS Statistics v 28 was used, and statistical significance was defined as a p-value <0.05.

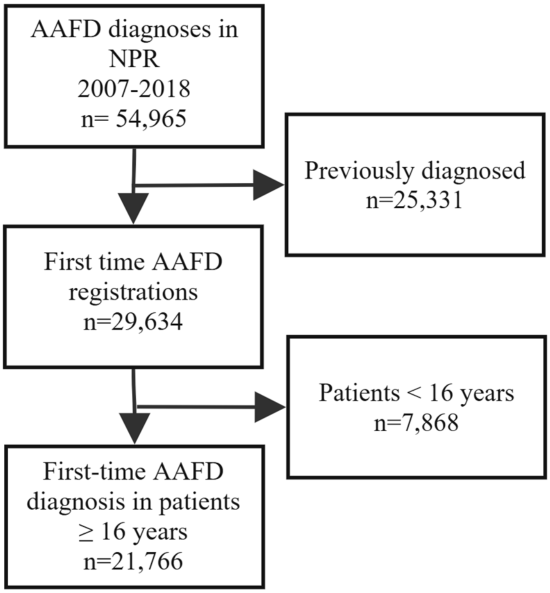


Figure 28. Flowchart of inclusion process, Study I

Study II-III

Study design and inclusion

Study II and III are nationwide, register-based studies using data from Swefoot.

Study II: Data on all patients registered in Swefoot for primary AAFD surgery from January 2014 through July 2021 were retrieved. Patients with previous surgery for AAFD on the same foot were excluded. Data included preoperative patient characteristics, surgeon-reported clinical data, and PROMs. Preoperative variables included age, sex and other baseline characteristics. Clinical variables included diagnosis, surgical procedures, and perioperative details recorded by the operating surgeon. Postoperative outcomes were not analyzed, as a new data extraction was planned once additional postoperative data became available.

During the study period, there were 725 feet surgically treated for AAFD in Swefoot. Of these, 84 feet were excluded due to previous ipsilateral AAFD surgery and 16 were excluded due to lack of data regarding previous surgery. The remaining 625 feet were included in the analyses. Of the 625 feet, 385 had complete patient-reported data (Figure 29).

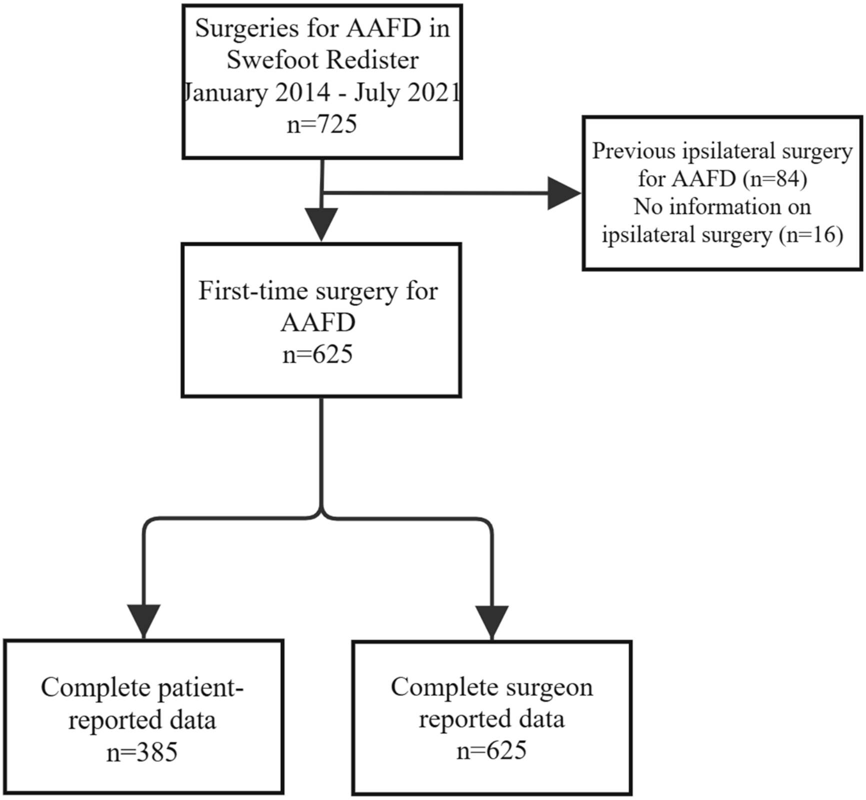


Figure 29. Flowchart of inclusion process, Study II

Study III: Data on all patients with flexible flatfoot (AAFD grade II), registered in Swefoot for primary AAFD surgery from February 2017 through May 2022, were retrieved. Patients with previous ipsilateral surgical treatment, AAFD grade I or III, or absent data about the surgery were excluded. The same variables from Study II were abstracted in Study III, but in Study III postoperative results were analyzed. During the study period, 798 feet were registered for surgical treatment of AAFD in Swefoot, and 646 of these feet had a flexible deformity (grade II). Of these, 567 had primary AAFD surgery, and 190 feet had complete preoperative and postoperative PROMs (Figure 30).

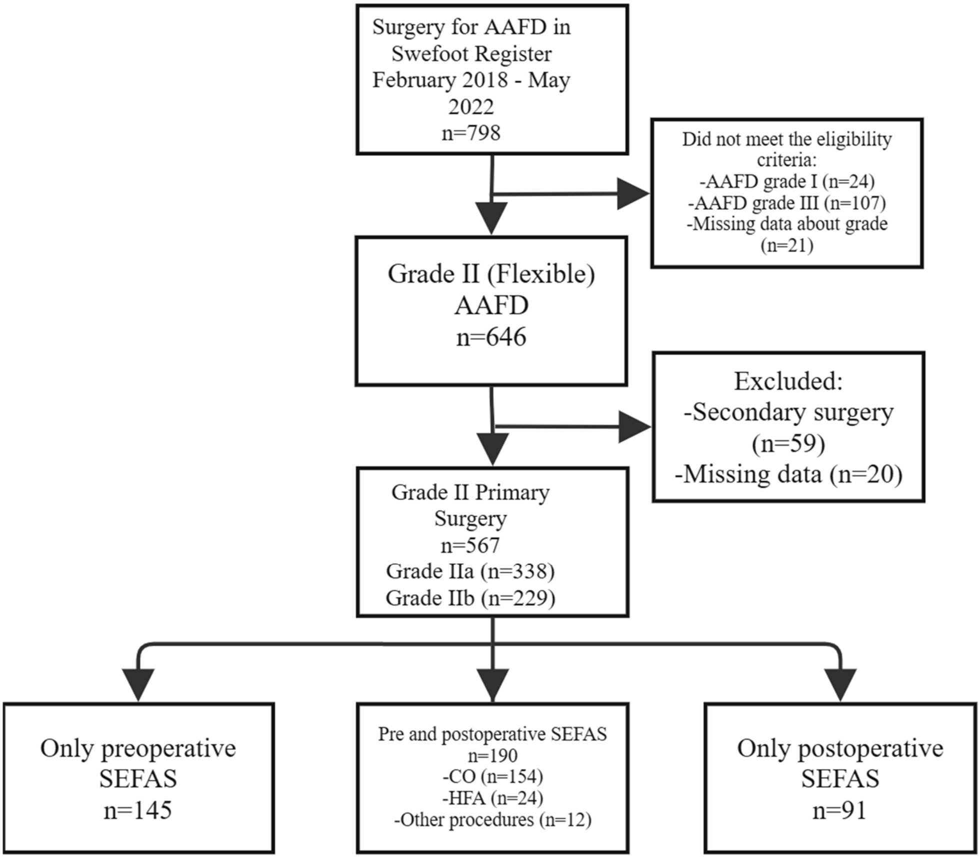


Figure 30. Flowchart of inclusion process, Study III

Interventions

Study II: The soft tissue procedures analyzed were FDL transfer, SL repair and ATL (lengthening of the AT or gastrocnemius recession).

The bony procedures were classified into 3 concepts:

1. MDCO, without LCL or HFA
2. LCL, with or without MDCO, and without HFA
3. HFA (arthrodesis of one or more of the TC, TN, CC, or NC joint), with or without osteotomy (MDCO or LCL)

Study III: The same procedures, as in Study II, were analyzed, but two treatment methods were compared:

1. CO (MDCO and/or LCL)
2. HFA (arthrodesis of one or more of TC, TN, or CC joints) with or without osteotomy (MDCO or LCL)

In addition to the procedures described in Study II, tenosynovectomy and TMT-1 arthrodesis were presented. NC arthrodesis was not included in the HFA, since it is a midfoot and not hindfoot joint, as inaccurately described in Study II.

Statistical analyses

Study II-III: Data were shown as mean and SD, median and quartiles, or numbers and proportions as appropriate. To describe preoperative HR-QoL and function, the mean EQ-5D index and SEFAS score were presented in tables. IBM SPSS Statistics 25 (28 in Study III) was used for handling the data and statistical analyses. All statistical tests were 2-sided and statistical significance was defined as a p-value of <0.05.

Study II: To investigate whether there was an association between AAFD grade, patient characteristics and patients' HR-QoL and/or function, a multivariate linear regression was performed. The regression coefficient (B) with 95% CI was calculated.

Types of surgical procedure according to AAFD grade were analyzed. For flexible flatfeet surgical treatments according to AAFD grade and surgical unit were also presented to explore regional variations.

Study III: The primary outcome was change in SEFAS score from baseline to 1 year postoperatively. The secondary outcomes were changes in EQ-5D index, EQ-5D VAS score, satisfaction with foot appearance, footwear options, foot strength and satisfaction with the result of surgery at 1 year postoperatively.

Changes in SEFAS score, EQ-5D index and VAS score, according to grade, were analyzed with the paired-samples t-test. The McNemar test was used to analyze change in satisfaction with appearance of the foot, footwear options and foot strength from preoperatively to 1 year postoperatively.

To assess the relationship between surgical procedure (CO vs HFA) and postoperative SEFAS score, analysis of covariance (ANCOVA) was used, adjusting for sex, age, BMI, rheumatic disease, baseline score, and concomitant procedures. Least square means, with standard errors and 95% CI, and the between-group differences were calculated. Because there were 3 individuals with bilateral surgery in the CO group a sensitivity analysis excluding these patients was performed.

Study IV

Study design and inclusion

Study IV is a multicenter randomized controlled trial.

The study is conducted at ten orthopedic units in Sweden. The participating units are Hässleholm hospital, Skåne University Hospital in Malmö, Capio Ortho Center in Malmö and Gothenburg, Sahlgrenska University hospital in Mölndal, Uppsala University Hospital, Falun Hospital, Östersund Hospital, Eksjö Hospital and Växjö Hospital.

Patients with flexible AAFD referred to the orthopedic units involved in this study are invited to participate if they fulfil the trial's eligibility criteria. In total, 130 patients who provide informed consent will be randomized to either MDCO with STI or MDCO without STI (65 patients in each group). The inclusion criteria are shown in Table 5.

Table 5. Inclusion and exclusion criteria, Study IV

Inclusion criteria	Exclusion criteria
AAFD grade II	Previous ipsilateral surgery for AAFD
Age 16–75	General hypermobility (Beighton score > 6)
Failed nonsurgical treatment including 3 months of physiotherapy	Osteoarthritis in the hindfoot joints, ankle joint or first tarsometatarsal joint
	Rheumatoid arthritis
	Inability to answer PROMs due to language difficulties or cognitive disorder
	Current smoker
	Current pregnancy
	Severe medical illness
	Known abuse of drugs and/or alcohol
	Previous ipsilateral hindfoot fracture including Lisfranc injury

Intervention and comparator

On the day of the scheduled surgery, the patients will be randomized to either Group A or Group B. The interventions performed in the two trial arms are shown in Table 6.

Table 6. Comparison of trial arm A and trial arm B

Group A: STI + MDCO	Group B: MDCO
Strayer procedure if gastrocnemius-soleus tightness (<5° dorsiflexion)	Strayer procedure if gastrocnemius-soleus tightness (<5° dorsiflexion)
Insertion of sinus tarsi implant	-
Medial displacement calcaneal osteotomy with screw fixation	Medial displacement calcaneal osteotomy with screw fixation
Flexor digitorum longus transfer to navicular bone	Flexor digitorum longus transfer to navicular bone
Spring ligament assessed; reconstructed if ruptured, otherwise tightened	Spring ligament assessed; reconstructed if ruptured, otherwise tightened
Cotton osteotomy if indicated	Cotton osteotomy if indicated

Randomization

The patient is randomized on the day of the surgery. The allocation sequence is computer-generated by an independent statistician, using block randomization, stratified by sex.

Assessment

Assessments are performed preoperatively and at 4-5 months, 1 year and 2 years postoperatively. The included patients are clinically and radiographically examined. The radiographic assessment includes weight-bearing radiographs (anteroposterior, lateral, and Saltzman view). The clinical examination includes single heel-rise test using the CalfRaise App. Patients also fill out a form that includes Self-Reported Foot and Ankle Score (SEFAS), Euro-QoL 5 Dimensions (EQ-5D), questions regarding pain, satisfaction with the appearance of the foot, foot strength, and footwear. The same form is filled out postoperatively with added questions regarding satisfaction with surgery and the length of sick leave.

Outcomes

Changes in the alignment of the foot are assessed with weight-bearing radiographs measuring specific angles and positions described below. Patient's experience is evaluated using PROMs (SEFAS and EQ-5D). The peak height and total work at repeated single heel-rise test are assessed by a physiotherapist using the Calf Raise App. The endpoints are listed in Table 7.

Table 7. Primary and secondary endpoints, Study IV

Endpoint
Primary
Change in Meary's angle from baseline to 12 months postoperatively
Secondary
Change in Meary's angle from baseline to 4–5 and 24 months postoperatively
Change in calcaneal inclination angle from baseline to 4–5, 12 and 24 months postoperatively
Change in talar declination angle from baseline to 4–5, 12 and 24 months postoperatively
Change in talar-2nd metatarsal angle from baseline to 4–5, 12 and 24 months postoperatively
Change in talar coverage angle from baseline to 4–5, 12 and 24 months postoperatively
Change in talar uncoverage from baseline to 4–5, 12 and 24 months postoperatively
Change in height of the medial cuneiform bone to the floor from baseline to 4–5, 12 and 24 months postoperatively
Changes in the angle between tibial and calcaneal midline on Saltzman view from baseline to 4–5, 12 and 24 months postoperatively
Change in SEFAS score from baseline to 4–5, 12 and 24 months postoperatively
Change in EQ-5D index from baseline to 4–5, 12 and 24 months postoperatively
Satisfaction assessment compared between the two groups
Change in pain on VAS from baseline to 4–5, 12 and 24 months postoperatively
Number of adverse events at 12 and 24 months postoperatively
Change in single heel-rise peak height (cm) and endurance from baseline to 4–5, 12 and 24 months postoperatively
Duration of postoperative sick leave (weeks)

Blinding

Treatment allocation is neither conveyed to the patient by the surgeon nor written in the patient files because these are accessible to the patients. Follow-up clinical examinations are performed by blinded assessors by placing steristrips in front of lateral malleolus, covering the scars from the surgical procedures and corresponding area in patients who do not have scars, prior to examination. The radiographic measurements are performed by two external radiologists who are blinded to group allocation. Prior to radiographic assessment, the radiographs will be masked by a person not involved in the assessment, using a computer program covering the location where an STI could be placed (provided it does not interfere with accurate measurement of Meary's angle). All statistical analyses will be performed by a statistician blinded to group allocation.

Statistical analyses

The primary outcome is change in Meary's angle from baseline to 1 year postoperatively. In previous studies investigating the degree of correction in Meary's angle from baseline to 1 year after MDCO in patients with AAFD stage II, a mean correction of 10 degrees has been reported. Assuming a mean correction of Meary's angle of 10 degrees (SD 10) after MDCO and 15 degrees (SD 10) after MDCO with an adjuvant STI, 80% power and $p<0.05$, a sample size of 63 patients in each trial arm will be required. We aim to recruit 130 patients (65 in each treatment group) to account for potential dropouts.

For continuous endpoints (radiographic measurements, SEFAS score, EQ-5D index, heel-rise height and endurance, duration of sick leave) mean values and standard deviations will be calculated. For categorical variables, such as adverse events, and satisfaction assessment, proportions will be calculated. The statistical tests will be performed according to the intention-to-treat principle. An as-treated exploratory analysis will also be performed. Both hypothesis-generating and confirmatory testing will be performed, the latter for the primary endpoints.

Primary analysis: The mean change in Meary's angle (degrees) from baseline to 12 months postoperatively (primary outcome) will be compared using the paired-samples t-test. Secondary analyses: mean change in the other radiographic measurements, SEFAS score and EQ-5D index, clinical tests, and sick-leave duration will be investigated using the paired-samples t-test. Adverse events and satisfaction assessment results will be presented in tables.

Chapter IV: Results

Study I

During the study period, there were 21,766 first-time registrations of AAFD in patients 16 years or older. In 14,547 (67%) of the registrations, the patients were female.

The incidence rate (IR) was 23.0 (95% CI 22.7-23.3) per 100,000 person-years. The IR was 30.4 (95% CI 29.9-30.8) in women and 15.4 (95% CI 15.1-15.8) in men, with an incidence rate ratio (IRR) of 1.99 (95% CI 1.93-2.04). The IR increased after 45 years in both men and women (Figure 31). The highest IRs were observed in the age group 61-75 years with IRs of 51.8 (95% CI 50.4-53.3) in women and 22.5 (95% CI 21.5-23.5) in men. The IR increased significantly from 19.7 (95% CI 19.3-20.1) during 2007-2012 to 26.2 (95% CI 25.7-26.6) during 2013-2018, with an IRR of 1.33 (95% CI 1.30-1.37).

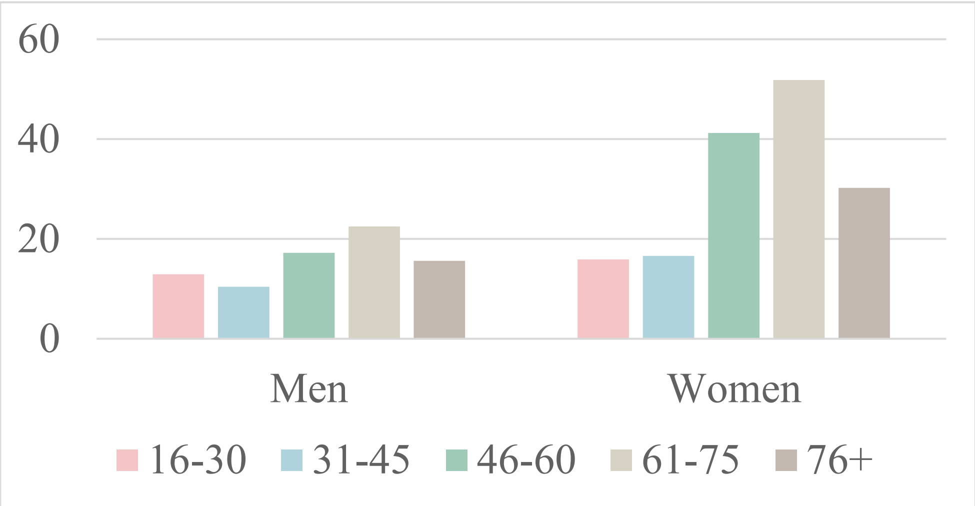


Figure 31. Incidence distribution of adult acquired flatfoot deformity in men and women of different age categories

Large variations in IR across the Swedish regions were observed, ranging from 8.3 (95% CI 7.2-9.4) in Västerbotten and 8.6 (95% CI 7.5-9.6) in Värmland to 38.7 (95% CI 37.8-39.5) in Stockholm, and 69.1 (62.4-75.8) in Gotland (Figure 32). The increase in IR from 2007-2012 to 2013-2018 was significant in 9 of 21 Swedish regions, but in 4 regions, there was a statistically significant decrease.

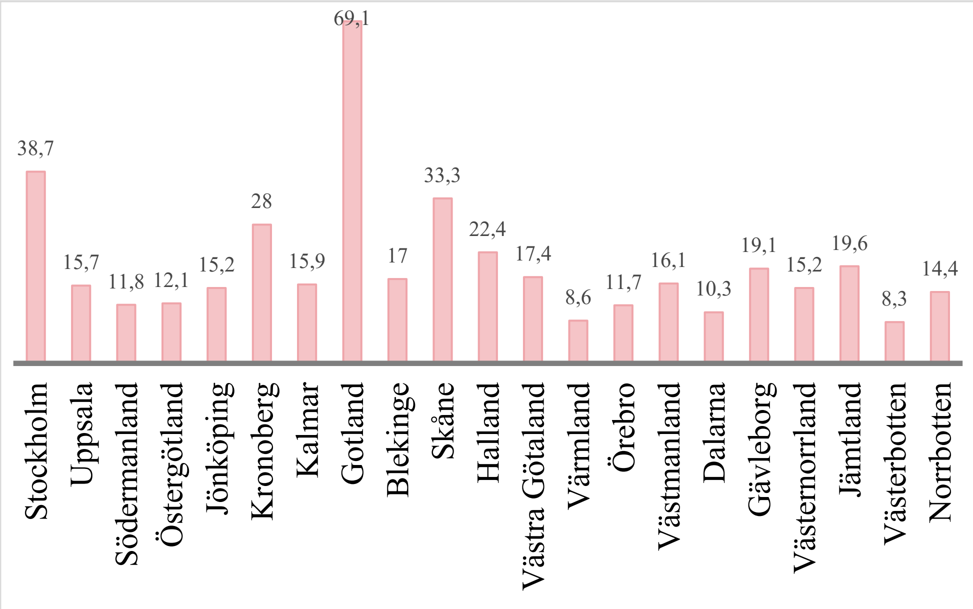


Figure 32. Incidence of adult acquired flatfoot deformity across the regions of Sweden

Study II

There were 625 feet that had undergone primary surgical treatment for AAFD with complete surgeon-reported data, and 385 of these patients had complete preoperative patient-reported data including co-morbidities and smoking status. 400 (64%) were women and the median age was 60 (range 16-83). AAFD grade IIa was the most common grade, constituting 319 (51%) of all feet. The mean BMI was 28.4 (range 17.3-45.0). 28 (7%) had diabetes, 31 (8%) had rheumatic disease, and 345 (95%) were not smokers.

At baseline, mean SEFAS score was 18.6 (SD 7.3), and mean EQ-5D index was 0.45 (SD 0.30). Patients with grade IIb had the worst mean SEFAS score (18.2, SD 7.4) and patients with grade III had the worst mean EQ-5D index (0.37, SD 0.29). Baseline characteristics with statistically significant associations with worse preoperative mean SEFAS score were higher BMI (B 0.49, 95% CI 0.32-0.66), female sex (B 2.2, 95% CI 0.6-3.7), and rheumatic disease (B 4.0, 95% CI 1.2-6.8). The same characteristics had statistically significant associations with worse preoperative EQ-5D index: higher BMI (B 0.01, 95% CI 0.002-0.02), female sex (B 0.09, 95% CI 0.02-0.169), rheumatic disease (B 0.13, 95% CI 0.003-0.25). There was no statistically significant association between worse preoperative SEFAS score and higher AAFD stage (B 0.05, 95% CI -1.0-1.1). However, there was a statistically significant association between worse preoperative SEFAS score and worse EQ-5D index (B 0.06, 95% CI 0.01-0.11).

The most common bony procedures were MDCO (n=311, 50%), HFA (n=140, 23%), and LCL (n=133, 21%). The most common soft-tissue procedures were FDL transfer (n=370, 59%), ATL (n=147, 24%), and SL repair or reconstruction (n=175, 28%). The dominant bony procedure used in the treatment of AAFD grade IIa was MDCO (n=249, 78%). In grade IIb, LCL was the most common procedure (n=118, 52%) and HFA was the second most common (n=48, 21%). In grade III, HFA was the most common procedure (n=55, 83%) (Figure 33a-b, Figure 34a-b).

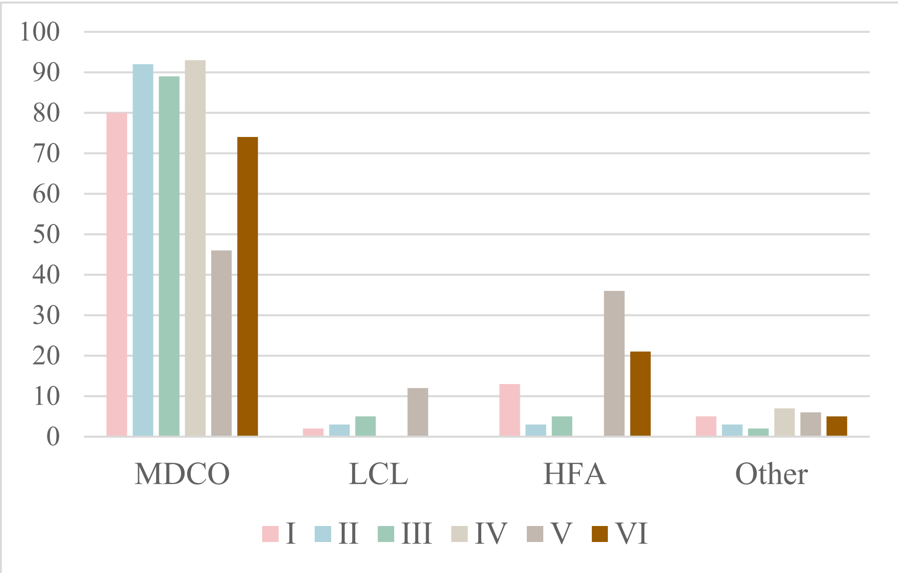


Figure 33a. Percentage distribution of total bony procedures, by procedure type, across surgical units, in patients with adult acquired flatfoot deformity grade IIa

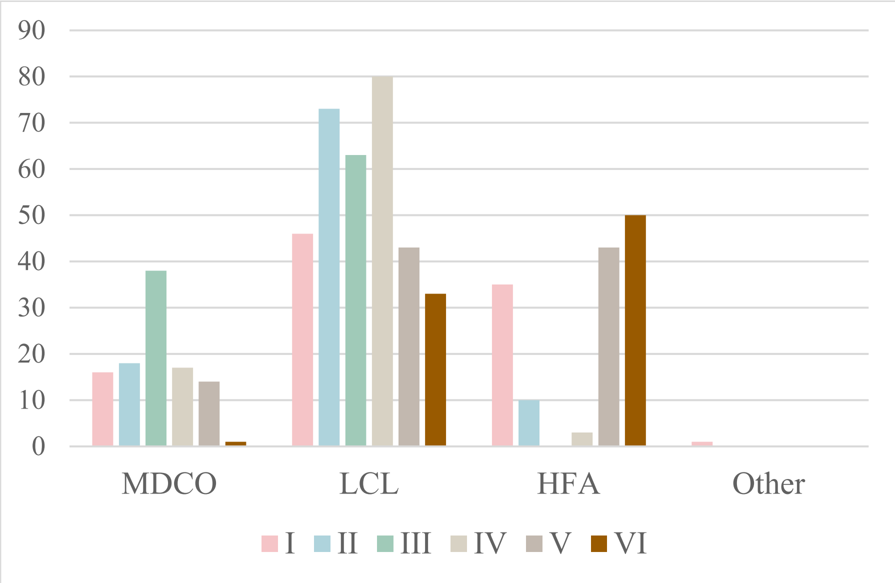


Figure 33b. Percentage distribution of total bony procedures, by procedure type, across surgical units, in patients with adult acquired flatfoot deformity grade Iib
I, Capio Movement Halmstad; II, Capio Orthopedic House Stockholm; III, Skåne University Hospital; IV, Hässleholm Hospital; V, Falun Hospital, VI, Piteå-Sunderby Hospital.

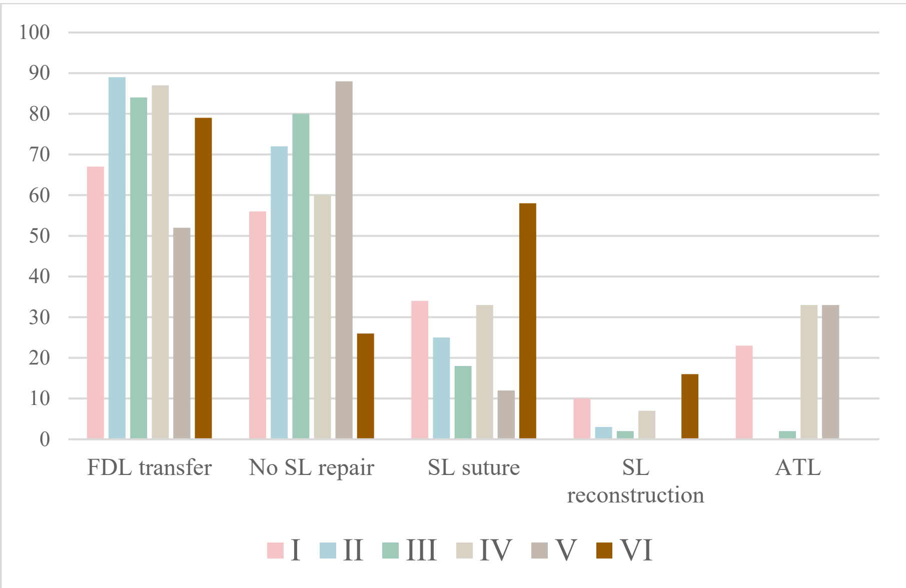


Figure 34a. Percentage distribution of total soft-tissue procedures, by procedure type, across surgical units, in patients with adult acquired flatfoot deformity grade IIa

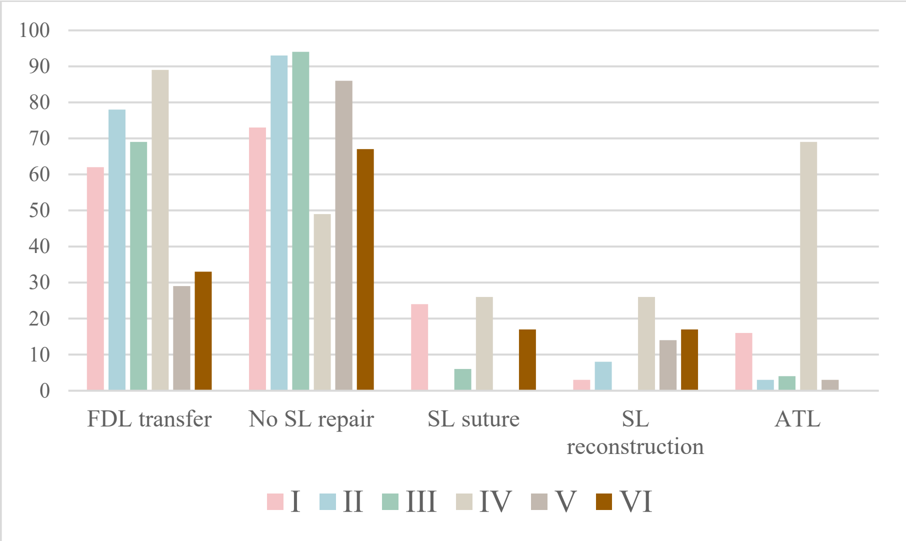


Figure 34b. Percentage distribution of total soft-tissue procedures, by procedure type, across surgical units, in patients with adult acquired flatfoot deformity grade Iib
I, Capio Movement Halmstad; II, Capio Orthopedic House Stockholm; III, Skåne University Hospital; IV, Hässleholm Hospital; V, Falun Hospital, VI, Piteå-Sunderby Hospital.

Of the 625 feet, 386 were treated at one of the six units with the largest numbers of AAFD surgeries in Sweden, and 349 had flexible AAFD (grade IIa-b). The median age ranged from 57 to 62 years. The proportion of women varied from 43% to 81%. MDCO was the most common intervention in the treatment of AAFD grade IIa, across all units, but two units used other procedures frequently. LCL was used in up to 12% of cases and HFA was used in up to 36%. At four units, LCL was the most common intervention in the treatment of grade IIb, whereas HFA was more common at two units.

There were large differences regarding the use of ATL, especially in grade IIb, with surgical rates ranging from 0% to 69%. In most cases, both in IIa and IIb, the SL was not repaired but the surgical rate ranged from 6% to 74% across units.

Study III

During the study period, 567 feet had primary surgery for flexible AAFD and 190 of these had complete pre and postoperative SEFAS scores. Characteristics of the non-responder patients were generally similar to those with complete responses.

The most frequently used soft-tissue procedures in both grade IIa and IIb were PTT repair and FDL transfer (Figure 35), performed in over 60% of the feet. MDCO was the most common bony procedure in grade IIa (74%) and LCL was the most common in grade IIb (51%). HFA was performed in 11% of the feet in grade IIa and 13% of the feet in grade IIb. Other interventions used in grade IIa were SL repair (34%), ATL (17%). TMT-1 arthrodesis (16%), and tenosynovectomy (13%).

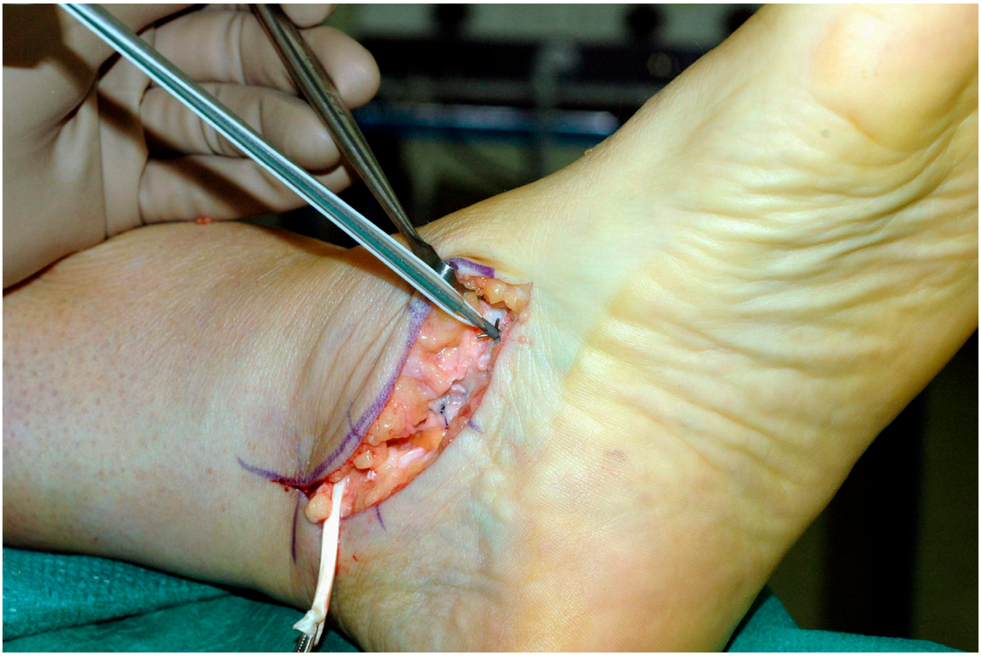


Figure 35. Peroperative picture of flexor digitorum longus transfer

Among the 190 feet with complete preoperative and postoperative SEFAS scores, 119 (63%) feet were grade IIa and 71 (37%) were IIb. No important differences regarding patient characteristics were observed between the groups.

The mean preoperative SEFAS score was 18 (SD 7) in both grade IIa and IIb, and the mean postoperative score was 30 (SD 9) and 28 (SD 10), respectively. The mean preoperative EQ-5D index was 0.44 (SD 0.32) in grade IIa and IIb, and the mean postoperative index was 0.71 (SD 0.23) and 0.68 (SD 0.30), respectively.

There were statistically significant improvements in PROMs in both grade IIa and IIb from preoperatively to 1 year postoperatively. Mean change in SEFAS score was 12 (95% CI 10-13) in grade IIa and 10 (95% CI 8-12) in grade IIb. Mean change in EQ-5D index was 0.27 (95% CI 0.20-0.34) in grade IIa and 0.23 (95% CI 0.15-0.31) in grade IIb. A significantly higher percentage of patients were satisfied with foot appearance, strength and footwear at 1 year postoperatively, than before surgery.

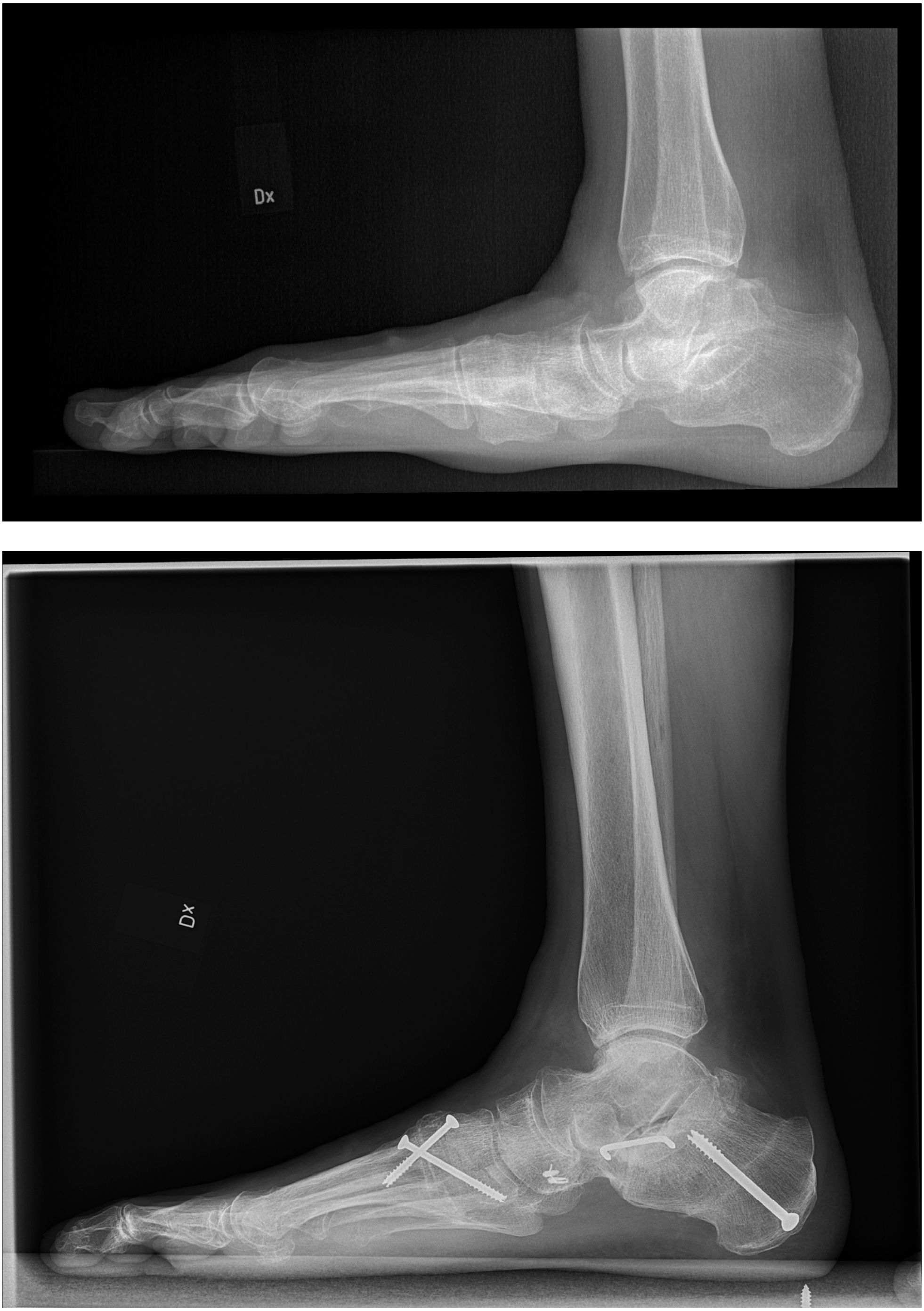


Figure 36. Radiographs of a flatfoot before and after surgical correction

Among 178 feet with complete SEFAS scores, the surgical treatment used was either CO (n=154) or HFA (n=24; including 6 patients with concomitant CO). The mean preoperative SEFAS score was 19 (SD 7) in the CO group and 16 (SD 6) in the HFA group, and the mean score change was 11 (95% CI 10-13) and 10 (95% CI 5-15), respectively. The mean changes in SEFAS score, EQ-5D index, and EQ-5D VAS did not differ significantly between the two groups. In the multivariable ANCOVA analysis, CO was associated with a higher adjusted postoperative SEFAS score compared to HFA (mean difference 2.7, 95% CI -1.2-6.5), but this difference was not statistically significant. The sensitivity analysis excluding the 3 patients with bilateral surgery gave similar results.

Figure 37. Demonstration of the equal postoperative results after surgical treatment with calcaneal osteotomy (CO) and hindfoot arthrodesis (HFA)

Study IV

Study IV is an ongoing trial, and no final results are yet available. Three of 10 units have initiated patient recruitment. As of April 2026, 12 patients have been included in the study, of whom 8 have been randomized and surgically treated. Six patients have undergone 4–5 months postoperative assessment, and 4 have undergone 12-month postoperative assessment.

Chapter V: Discussion

Epidemiology

Study I demonstrates that AAFD is a relatively common foot condition encountered at the orthopedic units in Sweden and that there are clear age- and sex-related differences in incidence. National-level studies investigating the prevalence or incidence of AAFD are scarce. However, other epidemiological studies have estimated the prevalence of different foot and ankle disorders. In a systematic review and meta-analysis, the overall pooled prevalence of hallux valgus was estimated to be 19% (95% CI 13%-25%) (88). Although that prevalence estimate is not directly comparable to incidence data in Study I, it nevertheless indicates that hallux valgus is considerably more common in the general population compared to AAFD.

Previous studies estimating the prevalence of AAFD have applied questionnaire-based screening methods to age-defined populations within geographically limited regions, which limits comparability with our nationwide register-based study.

In a Spanish study, both women and men aged 40 years and older were screened, and those reporting symptoms suggestive of AAFD underwent subsequent clinical examinations including podoscopic assessment. In contrast, an English study included only women aged 40 years or older, and clinical examination did not incorporate podoscopic analysis. Using these differing methodologies, the estimated prevalence of AAFD was 19% in Spain and 3.3% in England (49, 50). The higher estimated prevalence in the Spanish cohort including both men and women compared with the English cohort consisting only of women, is unexpected, given that our study consistently demonstrated a higher incidence among women than among men, in all age groups.

Study I further demonstrates an increasing incidence over time which can have several possible explanations. Age and sex differences do not explain these differences because the incidence rate ratios were adjusted for both age and sex. An increased prevalence of underlying risk factors such as higher BMI and diabetes could not be ruled out. However, increased knowledge about AAFD among the general population, and importantly primary healthcare providers could have contributed to an increased referral rate rather than an actual increase in disease incidence.

Classification and nomenclature

The heterogeneity in classification systems and nomenclature used to describe AAFD substantially affects how research is conducted, how studies are compared, and the conclusions that can be drawn.

The terminology and classification systems have also implications on how the condition is understood, disease development, and how it should be treated.

The traditional idea of AAFD as a continuum in which one stage eventually progresses to the next has recently been questioned (8). Even though one stage would be the chronological continuum of a previous stage, it does not automatically translate to greater symptoms as the condition progresses. It is therefore not surprising that no statistically significant association between AAFD stage and preoperative SEFAS score could be shown in Study II.

However, there was a statistically significant association between EQ-5D index and AAFD stage. There are no established MIC values for EQ-5D in populations with foot and ankle disorders. However, MIC value of 0.05 has often been used, which suggests that a higher AAFD stage may lead to clinically relevant decline in HR-QoL (89).

Diagnostic coding presents additional challenges. In Sweden, orthopedic surgeons commonly use standardized guidance when selecting ICD-10 codes to report at a doctor visit or at surgery. In this, the code M214 is generally used for AAFD, whereas the code M768 is used for PTT tendinosis/tendinitis. However, M768 is also used for anterior tibial tendon tendinosis, adductor tendinosis/tendinitis of the hip, and medial tibia syndrome. This makes the usability of M768 as an indicator of AAFD questionable. M768 was not included in Study I for this reason, and it was not possible to determine the extent to which this code was used instead of M214. This could result in an underestimation of the AAFD incidence.

In Study I, M214 was also recorded in young patients, including infants, which was interpreted as miscoding. Therefore, inclusion criterion of 16 years or older was applied. At the age of 16 years, many patients are skeletally mature, and this age is usually used to separate children from adults in orthopedic settings. In an infant, the medial arch of the foot is naturally flat and not considered pathologic, and in young children, one could argue that most of the registrations of M214 should more appropriately have been classified as Q66.6 (congenital pes planovalgus). But it raises the question of when AAFD can be considered acquired. If a 14-year-old boy presents with painful unilateral collapse of the medial arch that has not been present before, it should probably not be considered congenital. However, should such case be classified as the same disorder as the degenerative condition usually affecting older, overweight women, in whom PTTD and spring ligament rupture are often present?

If the underlying reason for the collapsed medial arch is a traumatic Lisfranc injury, and not degeneration of the PTT, should that really be considered AAFD? This exemplifies how the nomenclature and classification system are intertwined in the perception of the condition and its underlying pathogenesis, which makes it hard to know what is really being described and what is being studied.

The lack of uniform classification systems also reduces comparability between studies. To strengthen the evidence base for both surgical and nonsurgical interventions, a more stringent and widely accepted terminology and classification system is required. Such standardization would improve comparability, facilitate literature searches, and enhance the interpretability and generalizability of future research.

The updated classification and nomenclature proposed by Myerson et al. offer several advantages and are likely to gain broader acceptance (8). However, the system is somewhat more complex than the Bluman-Myerson classification, which limits its practicality for use in large-scale settings such as national quality registers. In addition, the limited number of prior studies applying this classification makes comparisons with existing literature more challenging.

Patient population

In Study I, the incidence rate in women was almost twice as high as that in men and the highest incidence rate was observed in the age group 61-75 years.

In Study II-III, the patient population was predominantly female and the median age was approximately 60 years. This is consistent with previous literature and theories regarding underlying risk factors such as inflammation, and degenerative changes that develop over time (6, 30, 90, 91).

Still, a large number of younger patients were registered with AAFD, as described above, and the questions regarding the pathogenesis of their deformity remain uncertain.

It would be interesting to specifically study this younger patient population in future studies. Trauma, higher BMI, diabetes and diseases of the connective tissue could possibly contribute to disease development in these cases. It cannot be ruled out that the younger patients included in Study II had congenital flatfoot with later symptom debut or worsening, or that they were simply misclassified.

In Study II, the mean BMI was slightly above the normal range. This is all consistent with previous research linking higher BMI to AAFD. However, the prevalence of diabetes was not higher in Study II than in the general population, and most of the patients were not smokers. Previous studies have described an association between

AAFD and diabetes (6, 30). Tendinopathy has been linked to both smoking and diabetes (31). It is important to note that the populations in Studies II–III consisted exclusively of surgically treated patients. In many Swedish orthopedic units, elective surgery requires smoking cessation, which introduces a selection bias. Many orthopedic units prefer a relatively healthy patient and hesitate to operate on patients with poorly controlled diabetes or significant comorbidities. Perhaps this could also exclude some patients with severe diabetes.

Surgical interventions

In Study II, the surgical interventions used for the different stages of AAFD were mostly consistent with international recommendations. However, there were discrepancies regarding surgical interventions used in the treatment of flexible (stage II) deformity. Most units performed calcaneal osteotomies (CO) primarily, including medial displacement calcaneal osteotomy (MDCO) or lateral column lengthening (LCL). Nevertheless, some units used hindfoot arthrodesis (HFA) despite the absence of rigidity or osteoarthritis in this stage and contrary to current recommendations (6, 8).

In some cases, it can be argued that the deformity is too severe to be adequately corrected by an isolated CO and, therefore, addition of an HFA would be necessary even though the deformity is flexible. A confounding factor is the fact that in Study II, NC arthrodesis was incorrectly classified as an HFA, which may have contributed to an overestimation of the number of patients in this category. However, only a small number of patients underwent isolated NC arthrodesis without other types of HFA (9 of 37 HFA in stage IIa and 4 of 48 HFA in stage IIb). In Study III, NC arthrodesis was not classified as HFA. Consequently, the proportion of patients classified as having undergone HFA in stage IIb, in Study III, was nearly half of that reported in Study II. Conversely, the proportion of patients with stage IIb, treated with MDCO was more than twice the observed in Study II.

Substantial variation was also observed regarding spring ligament (SL) repair. Despite the importance of the SL in stabilizing the medial column, SL repair was uncommon (10, 11).

Study II also demonstrated substantial variation in the use of adjunctive Achilles tendon lengthening (ATL). Although not all patients with AAFD present with gastrocnemius-soleus complex (GC) shortening, the proportion of patients receiving the adjunctive procedure would be expected to be relatively consistent across units. Instead, substantial variation was observed. Currently, there is no high-level evidence supporting the routine use of ATL as an adjunctive procedure in the treatment of AAFD (92).

Tightness of the GC is frequently described as a contributing factor to hindfoot valgus, but this effect may be diminished by an MDCO, which medializes the axis of pull of the AT. Nevertheless, a shortened GC may still contribute to AAFD through compensatory mechanisms and increased subtalar joint hypermobility when ankle dorsiflexion is restricted. Considering this, the wide variation in the use of adjunctive ATL is notable. However, given the absence of high-level evidence demonstrating improved outcomes, the decision not to perform adjunctive ATL in the surgical management of AAFD remains difficult to question.

In Study IV, the added effect of a sinus tarsi implant (STI) to MDCO is assessed. STI was initially developed and used in pediatric patients with flexible flatfoot (93). Surgeons subsequently started to use it as a standalone procedure or as an adjunctive procedure in patients with AAFD.

The use of STI continues worldwide, although its adoption varies considerably between regions. A survey of the members of the American Orthopedic Foot and Ankle Society showed that nearly half of the respondents had performed the procedure, but only about one third continued to use it in current practice. Notably, there were clear geographical differences; of the US respondents 24% reported current STI use compared to 53% of the non-US respondents (94).

Previous studies have shown good radiographic correction after surgical treatment with STI, as well as improved load distribution in the foot (95-99). However, many of the previously conducted studies are limited to retrospective methodology. The lack of well-designed, prospective and randomized studies has fueled ongoing debate about the use of STI and its implications in the adult population. Therefore, the findings of Study IV could have a substantial impact on current knowledge and clinical practice regarding the use of STI.

One of the current discussion points is whether the STI should be used as an adjunctive or standalone procedure in the treatment of AAFD. Most surgeons argue that the STI is not able to address transverse plane deformities and should first and foremost be used adjunctive to other procedures but what other procedures should be used is also under debate (95-97, 100, 101). Gastrocnemius recession is often recommended, as STI treatment has been shown to increase Achilles tendon tension (102-105). Other suggested adjunctive procedures are FDL, LCL, MDCO and stabilizing procedures of the medial column (100).

In Study IV, the selected adjunctive procedures are MDCO, FDL, SL repair and potentially Cotton's osteotomy and Strayer's procedure. The possibility of performing Cotton's osteotomy and Strayer's procedure in all patients was discussed within the research group and with the surgeons at the participating surgical units. However, it was concluded that performing these procedures in cases with a negative Silfverskiöld test and stable medial column was unnecessary and therefore could not be ethically justified.

One of the most commonly reported STI-related events is the relatively high postoperative removal rate. The most common reason for surgical removal is postoperative pain and discomfort, reported in 7-46% (97, 106). Other complications include talar cysts, implant migration, overcorrection or under correction, infection/wound problems, psychogenic reactions, wearing of nonmetallic implants, unremitting and unresolving pain, avascular necrosis of the talus, talar fracture, talar neck fracture, and in situ subtalar fusion.

Complications are most commonly related to inadequate surgical technique, inappropriate patient selection, and insufficient preoperative clinical assessment (97, 106). Contraindications for STI are sinus tarsi joint arthritis, peroneal muscle spasm, rigid deformity, and excessive ligamentous laxity (61). For this reason, Study IV uses clear eligibility criteria, and surgeons at the participating centers received lectures and cadaveric training before the study was initiated.

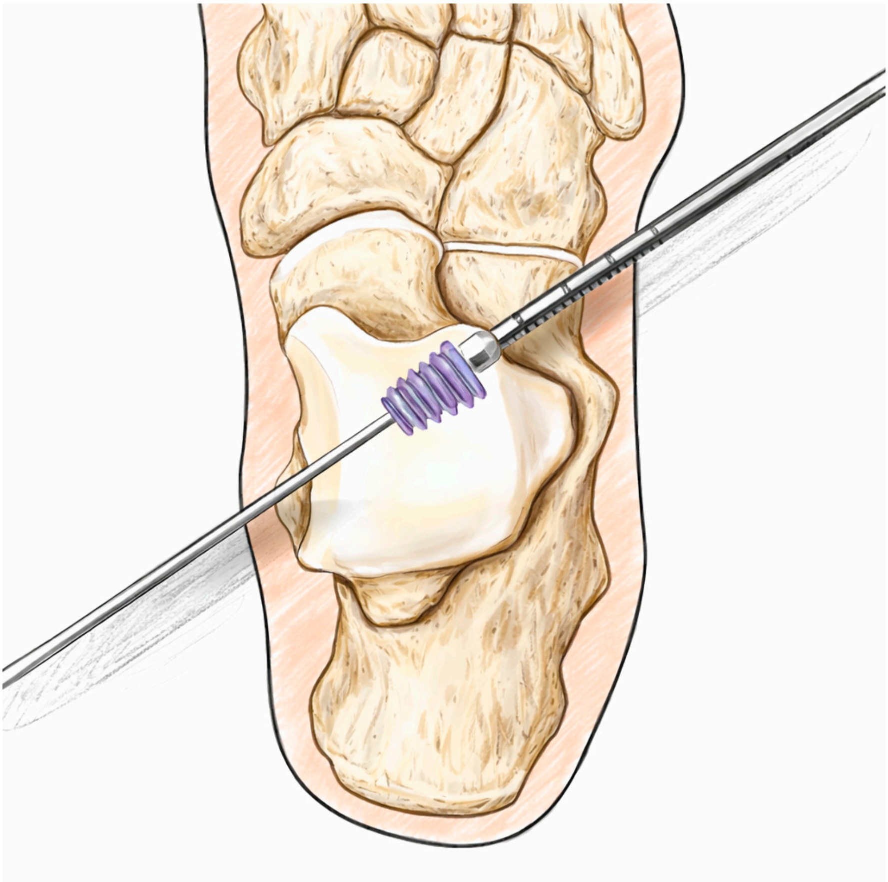


Figure 38. Sinus tarsi implant at insertion

In Study IV, removal of the STI does not constitute study dropout. The implant may be removed no earlier than 4-5 months postoperatively, by which time the first follow-up has been completed and soft tissues have healed. Previous studies have demonstrated that implant removal results in relief of discomfort and pain without loss of correction. However, in many of the studies removal was performed after longer period, often around 20 months postoperatively, when symptoms typically developed. However, in Study IV it was considered ethically inappropriate to delay removal in patients experiencing possible STI-related pain early in the postoperative period. Radiographic assessment at both 4-5 months and 12 months postoperatively enables detection of possible loss of correction following implant removal.

There are several types of implants in different shapes and materials. The sinus tarsi is conically shaped. A conic shape of the implant can offer more accurate fit into the sinus tarsi and narrower trailing end, which can reduce the risk of pain and irritation (107). A blunt-thread design may offer a softer fit into the sinus tarsi with potentially less irritation and risk of postoperative synovitis. The implant used in Study IV is therefore the ProStop® Subtalar Arthroereisis Screw (Arthrex Inc., Naples, FL, USA) and was the implant used during the cadaveric training.

Patient-reported outcomes

Study III showed that surgical treatment of AAFD leads to statistically significant and clinically important improvement regarding HR-QoL, as well as foot function and pain, at 1 year after surgery. The mean improvement in SEFAS score exceeded twice the minimal important change (MIC) value of 5 in both stage IIa and IIb (108). Similarly, the mean improvement in EQ-5D index approached 5 times the MIC value of 0.05 in both groups (89).

In the age groups 50-59 and 60-69 years the reported normal mean values for women are 42 and 40, respectively. The corresponding values for men are 46 and 44, respectively (109). This indicates that the SEFAS scores of patients treated surgically for AAFD remained substantially below age- and sex-matched reference values. This suggests that although surgery leads to clinically important improvement, patients have not fully regained normal foot function at one year. Usually, the rehabilitation after surgical treatment of AAFD is long and a longer follow-up time could reveal further improvement and even better results than could be shown in Study III. The mean preoperative SEFAS score was 18 (SD 7) in both grade IIa and IIb and the mean postoperative score was 30 (SD 9) and 28 (SD 10), respectively. The mean preoperative EQ-5D index was 0.44 (SD 0.32) in grade IIa and IIb and the mean postoperative index was 0.71 (SD 0.23) and 0.68 (SD 0.30), respectively. In addition, a significantly higher percentage of patients reported that they were satisfied with foot appearance and strength and footwear at 1 year postoperatively, than before surgery. The questions regarding patient satisfaction serve as a valuable complement to standard PROMs, as they capture the patient's overall perception of treatment success and expectations.

Patients treated with HFA had slightly worse mean preoperative SEFAS score and EQ-5D index than those treated with CO. Postoperatively, CO was associated with marginally higher mean SEFAS score, but no statistically significant differences were observed in mean change scores between CO and HFA for either SEFAS or EQ-5D.

Interpretation of these findings must consider several factors. As previously described, the rehabilitation period is usually long, and the outcomes may therefore be more appropriately assessed after longer follow-up time, preferably at least 2 years postoperatively. Once full rehabilitation has been achieved after both HFA and CO, a greater difference in outcomes may potentially be revealed. Another confounding factor is that the surgical bony procedures are rarely performed in isolation, but rather in combination with additional bony and/or soft-tissue procedures. This makes it difficult to establish comparable groups in a study evaluating the outcomes of two specific interventions.

Figure 39. An older woman with high functional demands

Regional variations

The most notable finding in Study I was the substantial regional variations in incidence. Underlying differences in risk factors cannot be ruled out considering that the pathogenesis of AAFD remains incompletely understood. Age and sex differences cannot explain the observed regional variance because incidence was adjusted for these factors. Possible variations in underlying risk factors, such as diabetes and overweight, were explored using data from the Public Health Agency in Sweden. The incidence of referred AAFD was exceptionally high in the region Gotland, and this region had a concurrent high prevalence of overweight and diabetes. However, in the Region Värmland, the prevalence of overweight and diabetes was even higher than in Gotland, but the incidence of AAFD was exceptionally low (110, 111). These potential correlations warrant further investigation but are unlikely to fully explain the observed variations.

Inequalities in healthcare access may exist within the Swedish healthcare system. Geographic proximity to secondary and tertiary referral units varies considerably across Sweden and between regions, which may influence both referral patterns and patients' willingness to seek specialist care, considering the associated time and economic burden. In addition, the availability of foot and ankle surgeons and surgical units that perform reconstructive procedures for AAFD differs across regions. In some areas, this may result in patients not being referred further or being informed that no surgical options are available locally. Furthermore, awareness and diagnostic recognition of AAFD by primary care providers may differ geographically, potentially contributing to delayed or inconsistent referral.

As shown in Study II, considerable variation also existed in the choice of surgical procedures for the same AAFD grade despite the availability of international guidelines recommending procedure selection based on AAFD grade (6, 8). Foot and ankle surgery remains a relatively young and evolving subspecialty, in which established methods are continually reassessed, and new techniques introduced.

In Sweden, where relatively few surgeons perform hindfoot surgery, individual surgeon preference, training background and local tradition may have substantial influence on treatment choice, particularly in smaller units with only one or two specialized surgeons.

Fewer patients with AAFD diagnosis were identified in secondary and tertiary care facilities in northern Sweden. This may reduce local clinical exposure to the condition but could also reflect delayed referral, with patients presenting at a more advanced stage of the deformity. In such cases, CO alone may be insufficient, necessitating HFA even though the deformity is not rigid yet.

This further highlights the limitations of currently used classification systems. Grade II AAFD encompasses a broad spectrum of deformities, and even with subclassifications, it remains difficult to formulate surgical treatment guidelines applicable to such a heterogeneous population. For this reason, an additional subclassification has been suggested, AAFD IIC, where the hindfoot is fully flexible but the forefoot has a fixed supination (112). However, this classification system has not been widely adopted in the literature.

The use of HFA in cases where it may not be strictly indicated could reduce foot mobility which could negatively impact the patient with high functional demands. However, because currently there is no clear evidence demonstrating inferior outcomes following HFA compared with CO, these treatment decisions remain difficult to challenge. Further research through high-quality prospective studies is therefore essential to establish robust, evidence-based guidelines and to support the delivery of standardized care nationwide.

Chapter VI: Limitations and strengths

Study I

To our knowledge, this is the first study to describe incidence of AAFD referred to specialist care on a national level. The large variations in incidence across the different regions may imply inequalities in referral patterns, which needs further investigation.

These findings are also important for resource allocation in healthcare as well as the planning and implementation of future studies. Furthermore, baseline data are essential for evaluating the impact of potential changes in referral policies.

Methodology used in Study I has several limitations. Although data on registered diagnosis codes, age, sex, comorbidities, consultation dates, and healthcare units could be analyzed, individual medical records and information on the examining physician's expertise level were not available. Therefore, it was not possible to determine how the diagnosis was established (clinically or radiographically), or whether the examining physician was resident or specialist (and if so which specialty).

As previously described, the classification and nomenclature of AAFD are complex, which entails limitations regarding reliability of the diagnosis particularly if the physician is not specialized in foot and ankle surgery. Additionally, the diagnosis code M768 was excluded, which is sometimes used for AAFD but also for several other conditions, thereby limiting its specificity.

Primary care is not included in the NPR, and therefore patients who were not referred to specialist care were not captured. This may lead to underestimation of the incidence and limit our knowledge about the patient group managed in primary care without referral to specialist care.

Study II

To date, surgical interventions used in the treatment of AAFD on a national level have not been comprehensively described. The use of register-based data is a strength, as it reflects real-world clinical practice of a larger number of surgeons and surgical units that could be included in other types of studies. Furthermore, the population registered in Swefoot is more heterogeneous and representative of routine clinical populations than those typically included in randomized controlled trials and other cohort studies. This enhances the generalizability of the findings.

This study highlights considerable variations regarding surgical treatment strategies, but also the need for stringent national guidelines, and high-quality studies to provide the evidence base for such recommendations.

The incomplete coverage and completeness of the Swefoot register introduce limitations. However, the largest units that perform AAFD surgery report to the register. Another limitation is that patient-reported data were available in less than two-thirds of the registered feet. Nevertheless, the characteristics of patients with complete patient-reported data were similar to those without patient-reported data, reducing the risk of selection bias.

Study III

Register-based data also enable longitudinal monitoring of treatment outcomes and provide a comprehensive overview of routine care across regions. With continued collection of data in Swefoot, more complete 2-year postoperative outcomes will become available. Future comparison with 2-year postoperative results may help to further elucidate the longer-term effectiveness and durability of CO and HFA.

The limitations of Study III are similar to those in Study II regarding the coverage and completeness of Swefoot, as discussed in the Background section. In Study III, there were missing data, but like in Study II, the characteristics of patients with and without missing responses were similar.

The relatively small sample size of patients with grade II treated with either CO or HFA represents another limitation. As highlighted in the Discussion, grade II includes a large variety of deformities and analyzing them as a single group may not be optimal when attempting to determine the most appropriate surgical intervention.

As previously described, follow-up time of 1 year is also not optimal when assessing the results after CO and HFA, since the rehabilitation time associated with both methods is usually long. However, further subclassification and division of analyses would create smaller sample sizes. In Swefoot, 2-year postoperative data are collected, and the number of responses at this time point would have been even lower than the 1-year postoperative responses resulting in insufficient statistical power for meaningful analysis.

Swefoot is a relatively young register, and for most registers, registration rates in the beginning are often low. These low registration rates during the initial years continue to impact the completeness estimates despite continuous improvements each year (86).

Achieving high completeness in PROM data collection remains difficult and is often limited by logistic challenges in register-based data collection, such as variability in follow-up methods, reliance on different platforms (paper, electronic, telephone), and diverse clinical workflows across institutions. As a result, both the frequency and consistency of patient responses vary substantially. The International Society of Arthroplasty Registries Working Group has recognized these challenges and proposed a realistic completeness threshold of 60% for PROM data in arthroplasty registers (82).

Study IV

This is the first RCT evaluating STI as an adjunctive procedure in the surgical treatment of AAFD, thereby providing high-quality evidence. The randomized design and prospective data collection strengthen internal validity and allow causal interpretation of treatment effects. Comparable patient groups were sought in both trial arms.

However, procedures such as Strayer's and Cotton's are not indicated in all patients. Consequently, it was not feasible to standardize these interventions across all participants. Excluding all patients requiring these procedures would have reduced the number of patients eligible for the trial.

In the study, blinding is applied whenever possible. Physiotherapists performing the physical tests are blinded to treatment allocation. It will not be possible to blind the surgeon. The participants are not informed which of the two treatments they receive, and it is not documented in the patient-accessible medical records. Participants receiving treatment with STI will have an additional scar and may therefore be able to determine which treatment they have received. Furthermore, some participants may develop STI-related symptoms that necessitate implant removal; in these cases, blinding is no longer possible. These factors may introduce reporting bias in the PROMs, as participants may hold preconceived beliefs regarding the superiority of one treatment. This risk is mitigated by informing participants at trial inclusion that clinical equipoise exists, and that the relative effectiveness of the treatment remains uncertain. In addition, PROMs are not the primary outcome.

The assessors of the radiographs, on which the primary outcome is based, are blinded. However, masking of the STI could potentially interfere with the landmarks used for radiographic measurements. In those cases, masking cannot be performed and blinding of the radiographic assessor would not be possible.

Another limitation is the relatively short follow-up time for the primary endpoint. The chosen duration was a pragmatic compromise to maintain feasibility, as longer follow-up would have substantially extended the study period. However, a 2-year follow-up is included as a secondary endpoint to capture differences that may become apparent after longer rehabilitation.

Chapter VII: Conclusions

Adult acquired flatfoot deformity (AAFD) is a complex and heterogeneous condition commonly encountered in orthopedic practice, yet its population-level occurrence remains unclear. This thesis provides complementary insights into its epidemiology, patient characteristics, surgical management, and outcomes, contributing to a broader understanding and highlighting key knowledge gaps.

- AAFD is a common and disabling condition with substantial impact on function and quality of life.
- Patients referred to specialist care because of AAFD represent a group with advanced disease and marked impairment.
- The incidence of AAFD requiring specialist care, in Sweden, is high and has increased over time.
- Women are affected approximately two to three times as often as men, and incidence peaks around 60-75 years of age.
- Large regional variations in incidence of AAFD exist, which could suggest differences in healthcare access, referral patterns, or awareness of the condition.
- Patients undergoing surgery for AAFD have substantially reduced preoperative function and quality of life, particularly women and those with higher BMI or rheumatic disease.
- Surgical management of AAFD is generally grade-adapted, but shows considerable variation between surgical units, potentially reflecting limited evidence guiding treatment choices.
- Despite statistically significant and clinically relevant improvement following surgical treatment of AAFD, full recovery is uncommon, indicating persistent functional limitations after surgical treatment.
- No significant differences in outcomes were observed between calcaneal osteotomy and hindfoot arthrodesis at 1 year postoperatively, but longer follow-up is needed.

In summary, AAFD represents a prevalent and clinically important condition characterized by significant disability and variation in management strategies. Although surgical treatment improves patient-reported outcomes, it rarely restores normal function. The observed variations in incidence and treatment approaches, together with the absence of clear superiority between surgical techniques, emphasize the need for more high-quality comparative studies with long follow-up as well as more standardized treatment guidelines and care pathways.

Chapter VIII: Future perspectives

The studies presented in this thesis may contribute to current knowledge about AAFD and provide a foundation for future research, with several areas warranting further investigation.

First, the substantial regional variation in incidence rates of AAFD referred to specialist care in Sweden, observed in Study I, should be explored in greater depth. Comparative analysis of other foot and ankle disorders across regions may help determine whether these differences primarily reflect variation in referral patterns, diagnostic awareness and access to specialist care, or true epidemiological differences.

Improved nationwide knowledge and harmonization of clinical practice are therefore important goals for the future care of AAFD. One possible approach to improving referral rates in regions with low incidence rates is the implementation of coordinated educational initiatives, such as lectures or written guidance outlining clear referral criteria.

To better define the population-level burden of AAFD, future studies should include both primary and specialist care. A nationwide design similar to Study I, that would also include AAFD managed exclusively at primary care, would allow estimation of the incidence of doctor-diagnosed AAFD in the general population. Such studies may combine questionnaire-based screening with clinical examination, although the latter would require substantial resources.

Further research is needed to determine long-term outcomes after surgical treatment. Extended follow-up of the patients in Study III, with a minimum of two years, may show whether differences between hindfoot arthrodesis and calcaneal osteotomy become more evident after full rehabilitation. If clinically meaningful differences are identified, this could support the development of evidence-based national guidelines and contribute to more standardized and equitable care. In addition, the varying use of adjunctive Achilles tendon lengthening should be investigated, for example through a randomized trial or possibly register-based study that compares the outcomes of calcaneal osteotomy with and without tendon lengthening.

Important knowledge gaps remain regarding patients with grade I and III AAFD. Future studies should evaluate treatment patterns and potential regional variations as well as outcomes for these groups. In grade I, it would also be valuable to compare surgical with nonsurgical treatment.

Finally, additional basic research is needed to improve understanding of the pathogenesis of AAFD. Epidemiological studies have demonstrated associations between AAFD and factors such as female sex, increasing age, higher BMI, smoking, and diabetes. However, the biological mechanisms underlying these associations remain unclear. Further research is needed to determine how mechanical loading, metabolic factors, vascular changes, and alterations in connective tissue contribute to the development and progression of the deformity.

It is also important to consider whether AAFD represents a single disease entity or a spectrum of conditions with different underlying etiologies. Refinement of current classification and nomenclature may therefore be necessary to better reflect disease heterogeneity and severity.

As outlined in Study III, patients undergoing surgical treatment for flexible AAFD show significant improvement at 1 year postoperatively. However, level of pain and function remains inferior to those of the general population of similar age. The addition of STI to MDCO is intended to provide temporary mechanical support to maintain a more favorable alignment of the calcaneus and talus during the healing phase and reduce strain on medial structures. This may improve radiographic alignment, patient-reported outcomes, and potentially contribute to more durable correction and better functional outcomes.

Acknowledgments

I would like to express my sincere gratitude to all those who have supported and inspired me throughout this work.

I am deeply grateful to my main supervisor, *Isam Atroshi*, for his exceptional breadth of knowledge in research methodology, study design, planning and scientific writing. His thoroughness, attention to detail, and patience have been invaluable. I am also thankful that he took me on as a medical student and believed in me throughout the process.

I would also like to thank my co-supervisor, *Maria Cöster*, for her extensive expertise in foot and ankle surgery and for being a constant source of inspiration. Her guidance has been important to me from my master's thesis through to my PhD, and I am especially grateful for her support and understanding during more challenging periods.

I am especially grateful to my mother, *Christina Osbeck*, who first inspired my interest in research through her enthusiasm and dedication. Many of my earliest memories of research are the hours we spent studying together at weekends, at her workplace or in front of the fireplace at the lake house. Her support, encouragement, and ability to help me structure my time have meant a great deal.

I would also like to thank my aunt, *Marita Flisbäck*, for her support and inspiration, and for creating the cover image of this thesis.

I am grateful to *Nigel* and *Amanda Fancourt*, who kindly hosted me during my research exchange in Oxford, where my interest in research truly began.

I would also like to thank *My von Friesendorff* for her support and inspiration. Throughout my life, she has inspired me because of her positivity, strength and kindness, and continues to inspire me as a friend, researcher, clinician and colleague.

I am thankful to my friends *Sanni Värelä* and *Caroline Antgren Hellsten* for their support, for listening to my presentations and providing feedback, for valuable discussions about research and about life. I also thank *Alexandra Antgren Hellsten* for contributing to our research sessions with her knowledge of statistics and mathematics and through her contagiously positive energy.

Finally, I would like to thank *Lisa Åselius* and *Mikael Kindt*. Lisa has been a close friend since medical school and always brings perspective and humour when it is most needed. Mikael has been a valued mentor, friend, and colleague, always willing to discuss difficult cases or go for a run around Pildammsparken.

Lastly, I would like to thank all my family, friends, and colleagues for their support, encouragement, and belief in me throughout this journey.

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Printed by Media-Tryck, Lund 2026 NORDIC SWAN ECOLABEL 3041 0903

LUND UNIVERSITY

FACULTY OF MEDICINE

Orthopaedics
Department of Clinical Sciences

Lund University, Faculty of Medicine
Doctoral Dissertation Series 2026:96
ISBN 978-91-8021-894-8
ISSN 1652-8220