# Incidence and Epidemiology of Foot Fractures

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## Abstract

Baggrund: Formålet med dette epidemiologiske studie, var at give opdateret viden omkring incidensen af frakturer i foden, i en større velkendt befolkningsgruppe, der inkluderede alle aldersgrupper og dækkede i en 6-års periode. Derudover var målet, at angive klassifikationen af frakturer, traume mekanisme og patient demografien.

Metode: Retrospektivt kohortestudie af alle patienter i Region Nord, diagnosticeret med én eller flere frakturer i foden i perioden fra 1. januar 2005 til 31. december 2010. Der blev foretaget manuelt opslag af alle patienters journal og billeddiagnostik. Studiet blev tilrettelagt efter STROBE[1] retningslinjer med brug af tjekliste for kohortestudier.

Resultater: 5.912 frakturer i foden blev konstateret blandt 4.938 patienter. Incidensen var 142,3/100.000/år (hunkøn 130,2/100.000/år, hankøn 185,1/100.000/år), med gennemsnitsalder på 36,1 år (hunkøn 41,3 år, hankøn 31,3 år). Incidensen var omkring 50% højere i sommermånederne juni, juli & august, når sammenlignet med vintermånederne december, januar & februar. Begge køn havde højeste incidens i aldersgruppen 10-19 år, med 201,4/100.000/år for hunkøn og 296,9/100.000/år for hankøn. For hunkøn fandtes en bimodal fordeling med et andet, dog mindre, toppunkt omkring aldersgruppen 60-69 år (148,9/100.000/år), men incidensen for hankøn var næsten konstant faldende efter 20-års alderen. De hyppigste frakturer var i 5. metatars og 1. tå. Langt de fleste frakturer skyldtes lav energi traumer.

Konklusion: Dette studie viser en incidens på 142,3/100.000/år for frakturer i foden i en veldefineret kendt befolkning over en 6 års periode. 5. Metatars havde den højeste individuelle incidens, og langt de fleste frakturer skyldtes lavenergi traumer. Incidensen af frakturer viste lav år til år variation.

## Introduction

Foot fractures are some of the most common fractures, representing 40% of all fractures in the lower extremity[2]. The literature on the epidemiology of fractures of the foot is varied. Recent studies reports incidence rates of foot fractures, between 210 and 223 pr. 100.000 persons/year[3, 4].

One group of studies aim to describe the fractures in regards to trauma mechanism [5-9]. One article includes all ages [3], while others exclude non-adults [4, 5, 10] and some focus on non-adults[9, 11-13]. The reporting of incidences is based on uncertain populations[7, 10, 13], a Danish study from 2016 states that even with sound knowledge of the background population retrospective studies underestimate the incidences[4]. Furthermore some studies focus on only one bone or part of the foot[11, 14-16] while others present incidences for the whole foot, without detailing further[3, 5].

Evidently, there is available literature, but basic knowledge on the incidence, classification and trauma mechanisms for the individual bones in the foot is spread over several studies, making it difficult to gain a comprehensive understanding of the epidemiology. Foot fractures represent a significant burden both in terms of workload in the emergency department[5, 17]. Valid epidemiological data, including trauma mechanisms is essential in estimating the economic burden on individuals and society. Furthermore, sound data can establish which fractures that may warrant further studies, for example in regards to choice of treatment and outcome[17].

As such, there is a need for a large scale epidemiological study, based on accurate population data, including age groups and fracture types spanning several years. Additionally, information on trauma mechanism and fracture classification, based on large scales cohorts is needed for understanding the nature of the common fractures.

The primary aim of this study was to report the incidence of foot fractures in a complete and well defined population. Furthermore, the study aims to report both fracture classification and the mechanism of trauma leading to fracture.

## Methods

This study is a retrospective cohort study providing epidemiological data on fractures in the foot. It was performed on medical data from the northern region of Denmark from January 1st 2005 to December 31st 2010. All patients treated in the region and diagnosed with one or more fracture(s) in the foot (ICD-10 S 92)[18] were initially included in the study. Patients who had a Danish social security number and resided in the region at the time of fracture were included, while foreigners and misclassifications were excluded.

The obtained medical records and corresponding x-rays were reviewed manually. In addition to clinical and radiological information on the fracture(s), baseline characteristics and information regarding date of injury, trauma mechanism were obtained. Trauma mechanism was divided in low- and high-energy incidents. Low energy included: distorsion, fall from >1 meter, fall – not during sports, bicycle related (including fall), sports, incident while driver of vehicle, hit by vehicle (including while on foot or bicycle), hit by object and other. High energy included: high speed accident (> 65 km/h or vehicle deformation > 0,5 meter), jammed/trapped in vehicle, person hit or run over by truck/bus/train, pedestrian/cyclist hit by vehicle (not truck/bus/train) travelling more > 50 km/h, motorcycle accident > 50 km/h, fall >4 meters or other. If the journal was unclear in regards to trauma mechanism, it was recorded as unknown.

All fractures were classified according to the pre-planned classification system. Both X-rays, computer tomography and procedural notes were used when available. If no X-rays/CTs/procedural notes were available, the fracture was classified only as being present if mentioned in medical records, but not in terms of severity.

Fractures of the Talus were classified using Hawkins classification [19] or osteochondral. Calcaneus fractures were classified using Sanders classification[20] or other. Mid- and forefoot fractures were classified individually as simple, dislocated or complex (including comminute). Fractures of the phalanxes of the 2., 3., 4., or 5. toe were simply counted[21]. Fracture(s) in or adjoining the midfoot was also evaluated in regards to Choparts or Lisfranc damage[14].

For analysis the individual bones were grouped in Hind-, Mid- and Forefoot, the Hind Foot included Calcaneus and Talus, the Mid Foot consisting of Naviculare, Cuboideum and the Cuneiforme bones, and the Fore Foot being the Metatarsals and digits. Because of a low number of fractures in the Cuneiforme bones, they were grouped as one for some of the statistical analysis.

The 6 year incidences was calculated for the total, seasonal, bone specific and by age group. Seasonal variations were reported in four seasons (Winter: December-February, Spring: March-May, Summer: June-August, Fall: September-November). Age group incidence were reported in 10-year increments.

This study was conducted in accordance with the ethical principles of the 1975 Declaration of Helsinki. The study was approved by the Danish Data Protection Agency(J.nr.2010-41-4354).

The study was designed and reported using the STROBE guidelines[1].

Mean values and standard deviation (SD) are presented for continuous variables. With categorical data percentages (%) and frequencies are given. The statistical analysis was performed by STATA 15, StataCorp, 4905 Lakeway Drive, College Station, Texas 77845 USA.

# RESULTS

A total of 4,938 patients sustained 5,912 fractures of the foot between January 1st 2005 to December 31st 2010. 491 (8.3%) fractures occurred in the Hind Foot, 280 (4.7%) in the Mid Foot and 5,151 (87.0%) in the Fore Foot (Table 1).

The mean age was 36.1 (21.7 SD) years. Female mean age was 41.3 (23.4 SD) and male 31.3 (19.1 SD) years. The gender distribution was 2,253 (45.7%) females and 2,685 (54.3%) males. Baseline characteristics for all patients and groups are presented in Table 1.

The population of North Region Denmark varied between 576,807 people (year 2006) and 580,515 (year 2010) in the period between January 1st 2015 to December 31st. The average population was 578,340 people. Figure 1 shows the average population of North Region Denmark from 1st 2005 to 31st 2010, divided in 10-year age-groups.

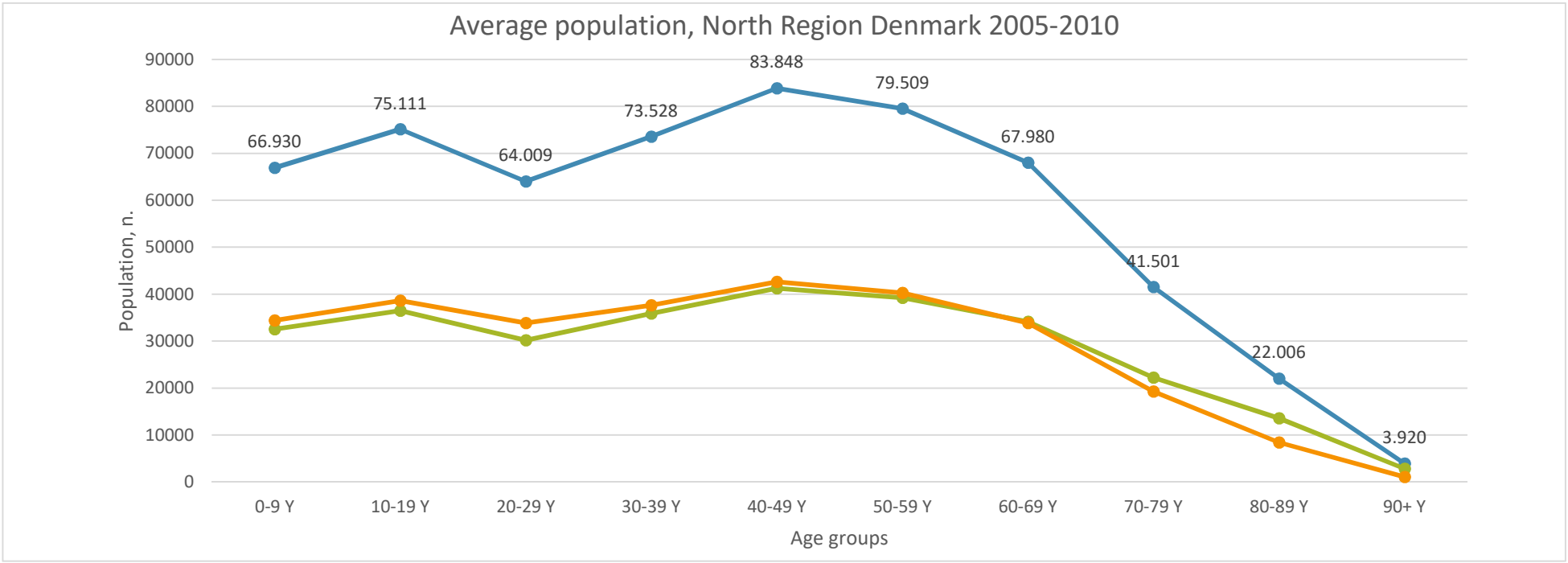


Figure 1. Average population, North Region Denmark 2005-2010: blue – total, orange – male, green – female.

## Incidence

The overall incidence of foot fractures was 142.3/100,000/year. Female incidence was 130.2/100,000/year and male incidence was 185.1/100,000/year. The incidences show a peak in the age group 10-19 year with a male predominance. After the age of 20 the male incidence decline. In contrast, the females experience a second increase after the age of 50 with a peak at age 60-69. Patients under the age of 30 represented 43.9% of all fractures (Figure 2 & 3) and (Table 1).

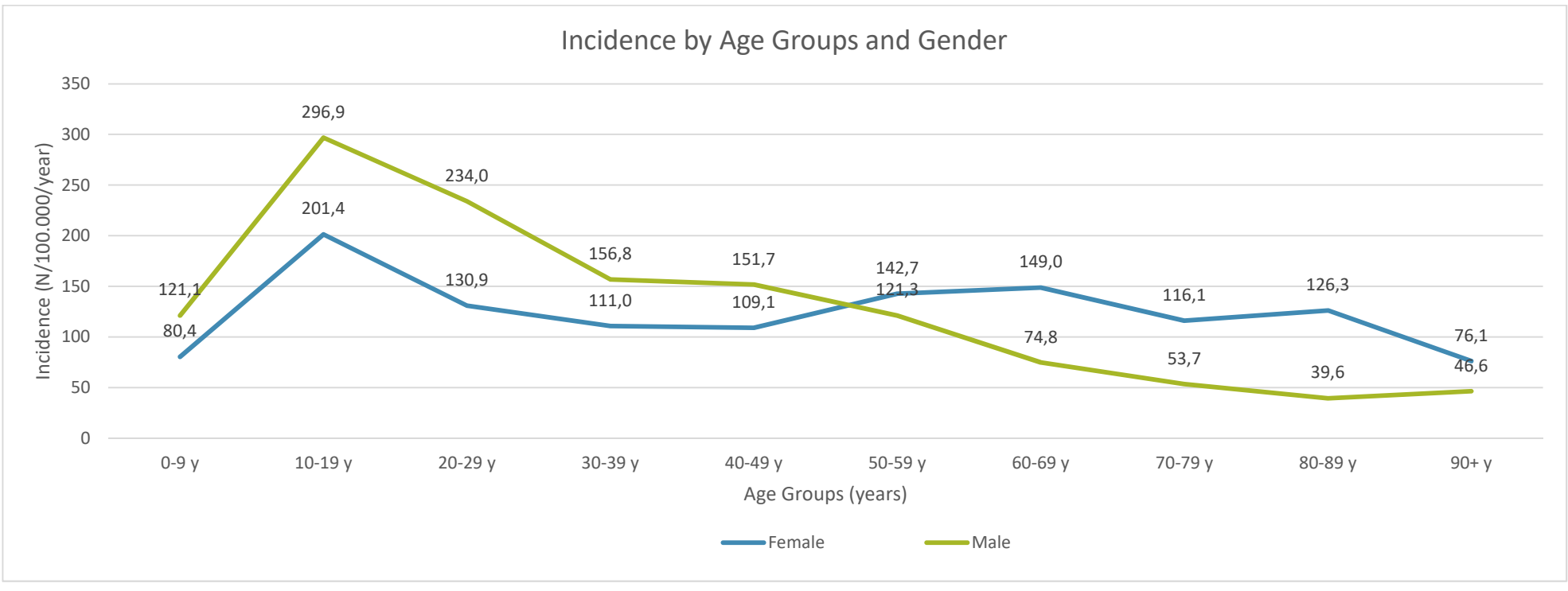


Figure 2. Incidence by age group, 2005-2010.

| Bone | Fractures (n) | Patients (n) | Mean age(SD) | F/M (n) | Mean age F:MA(SD)/M:MA(SD) | Incidence F/M | Incidence Patients | Incidence Fractures |
|---|---|---|---|---|---|---|---|---|
| Calcaneus | 354 | 340 | 47(20.4) | 108/323 | 57.7(20.1)/42.2(18.5) | 6.2/16 | 9.8 | 10.2 |
| Talus | 137 | 137 | 36.4(17.6) | 63/74 | 40.0(19.0)/33.5(15.9) | 3.6/5.1 | 3.9 | 3.9 |
| Naviculare | 117 | 117 | 38.7(20.6) | 53/64 | 42.6(23.5)/35.5(15.3) | 3.1/4.4 | 3.4 | 3.4 |
| Cuboideum | 75 | 75 | 39.0(18.3) | 25/50 | 41.3(22.4)/37.9(16.1) | 1.4/3.4 | 2.2 | 2.1 |
| Cunaiforme medialis | 43 | 43 | 38.8(18.2) | 16/27 | 44.2(19.4)/35.5(17.1) | 0.9/1.9 | 1.2 | 1.2 |
| Cunaiforme interm. | 17 | 17 | 47.6(15.4) | 4/13 | 59.2(18.6)/44.1(13.1) | 0.2/0.9 | 0.5 | 0.5 |
| Cunaiforme laterale | 28 | 28 | 40.0(17.1) | 6/22 | 46.1(15.7)/38.5(17.4) | 0.3/1.5 | 0.8 | 0.8 |
| 1. Metatarsal | 345 | 345 | 24.4(22.0) | 129/216 | 28.1(24.1)/22.3(20.4) | 7.5/14.9 | 9.9 | 9.9 |
| 2. Metatarsal | 465 | 465 | 37.3(23.4) | 191/274 | 44.2(26.8)/32.5(19.3) | 11.1/18.9 | 13.4 | 13.4 |
| 3. Metatarsal | 487 | 487 | 37.9(24.7) | 216/271 | 47.6(26.1)/30.2(20.4) | 12.5/18.7 | 14.0 | 14.0 |
| 4. Metatarsal | 457 | 457 | 40.1(25.5) | 217/240 | 51.3(25.9)/30.0(20.5) | 12.5/16.5 | 13.2 | 13.2 |
| 5. Metatarsal | 1,716 | 1,716 | 39.4(22.7) | 921/795 | 44.7(23.9)/33.3(19.4) | 53.2/54.8 | 49.5 | 49.5 |
| 1. Digit | 1,304 | 1,304 | 33.2(19.5) | 517/787 | 36.4(21.0)/31.2(18.2) | 29.9/54.2 | 37.6 | 37.6 |
| 2.-5. Digiti | 367 | 367 | 34.0(19.6) | 209/158 | 36.9(20.5)/30.3(17.9) | 12.1/10.9 | 10.6 | 10.6 |
| Hind Foot | 491 | 477 | 44.0(20.2) | 171/306 | 51.2(21.5)/40.1(18.3) | 9.9/21.1 | 13.7 | 14.2 |
| Mid Foot | 280 | 227 | 38.3(19.6) | 97/132 | 42.6(22.6)/35.3(16.5) | 5.6/9.1 | 6.5 | 8.1 |
| Fore Foot | 5,141 | 4,298 | 35.2(21.8) | 2007/2291 | 40.5(23.4)/30.6(19.1) | 116.0/158.0 | 123.9 | 148.2 |
| Chopars | 3 | 3 | 29.1(23.5) | 2/1 | | 0.12/0.07 | 0.086 | 0.086 |
| Lisfranc | 65 | 65 | 38.9(20.0) | 30/35 | 42.7(22.8)/35.6(16.9) | 1.7/2.4 | 1.9 | 1.9 |
| Total | 5,980 | 4,938 | 36.1(21.7) | 2253/2685 | 41.3(23.4)/31.3(19.1) | 130.2/185.1 | 142.3 | 172.3 |

| Bone | Fracture (n) | Classification (n fractures/classification) | | | | | | | Energy | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 99 | High Energy | Low Energy | Unknown |
| Calcaneus | 354 | 43 | 37 | 65 | 55 | 28 | 6 | 120 | 22 | 316 | 2 |
| Talus | 137 | 16 | 12 | 4 | 0 | | | 105 | 12 | 125 | 0 |
| Naviculare | 117 | 103 | 7 | 1 | | | | 6 | 7 | 110 | 0 |
| Cuboideum | 75 | 57 | 4 | 7 | | | | 7 | 4 | 71 | 0 |
| Cunaiforme medialis | 43 | 35 | 3 | 2 | | | | 3 | 1 | 42 | 0 |
| Cunaiforme interm. | 17 | 15 | 0 | 1 | | | | 1 | 1 | 16 | 0 |
| Cunaiforme laterale | 28 | 25 | 1 | 0 | | | | 2 | 0 | 28 | 0 |
| 1. Metatarsal | 345 | 280 | 14 | 16 | | | | 35 | 6 | 339 | 0 |
| 2. Metatarsal | 465 | 333 | 75 | 20 | | | | 37 | 9 | 465 | 0 |
| 3. Metatarsal | 487 | 345 | 83 | 16 | | | | 43 | 12 | 474 | 1 |
| 4. Metatarsal | 457 | 322 | 78 | 18 | | | | 39 | 12 | 444 | 1 |
| 5. Metatarsal | 1,716 | 1,257 | 230 | 50 | | | | 179 | 9 | 1,707 | 0 |
| 1. Digit | 1,304 | 1,007 | 74 | 75 | | | | 148 | 3 | 1,301 | 0 |
| 2.-5. Digiti | 367 | 313 | 46 | 5 | 2 | | | | 1 | 366 | 0 |
| Hind Foot | 491 | | | | | | | | 34 | 441 | 2 |
| Mid Foot | 280 | | | | | | | | 8 | 221 | 0 |
| Fore Foot | 5,141 | | | | | | | | 21 | 4,276 | 1 |
| Total | 5,912 | | | | | | | | | | |
| Lisfranc | 65 | | | | | | | | 5 | 60 | 0 |
| Chopars | 3 | | | | | | | | 0 | 3 | 0 |

Explanations:

Calcaneus: 1 Sanders 1, 2 – Sanders 2a, 3 – Sanders 2b, 4 – Sanders 3a, 5 – Sanders 3b, 6 – Sanders 4 + 99 - other.

Talus: Hawkins Classification (1-4) + osteochondral damage (99).

Mid- & Forefoot: 1 - Simple fracture, 2 – Dislocated fracture, 3 - Complex fracture, 99 – No Radiology.

Digiti 2-5: Count of number of fractures.

Table 1. Fractures of the foot, epidemiology. n = number, mean age (MA) and standard diviation (SD) is expressed in years, F = female, M = male, Incidence: n/100,000/year

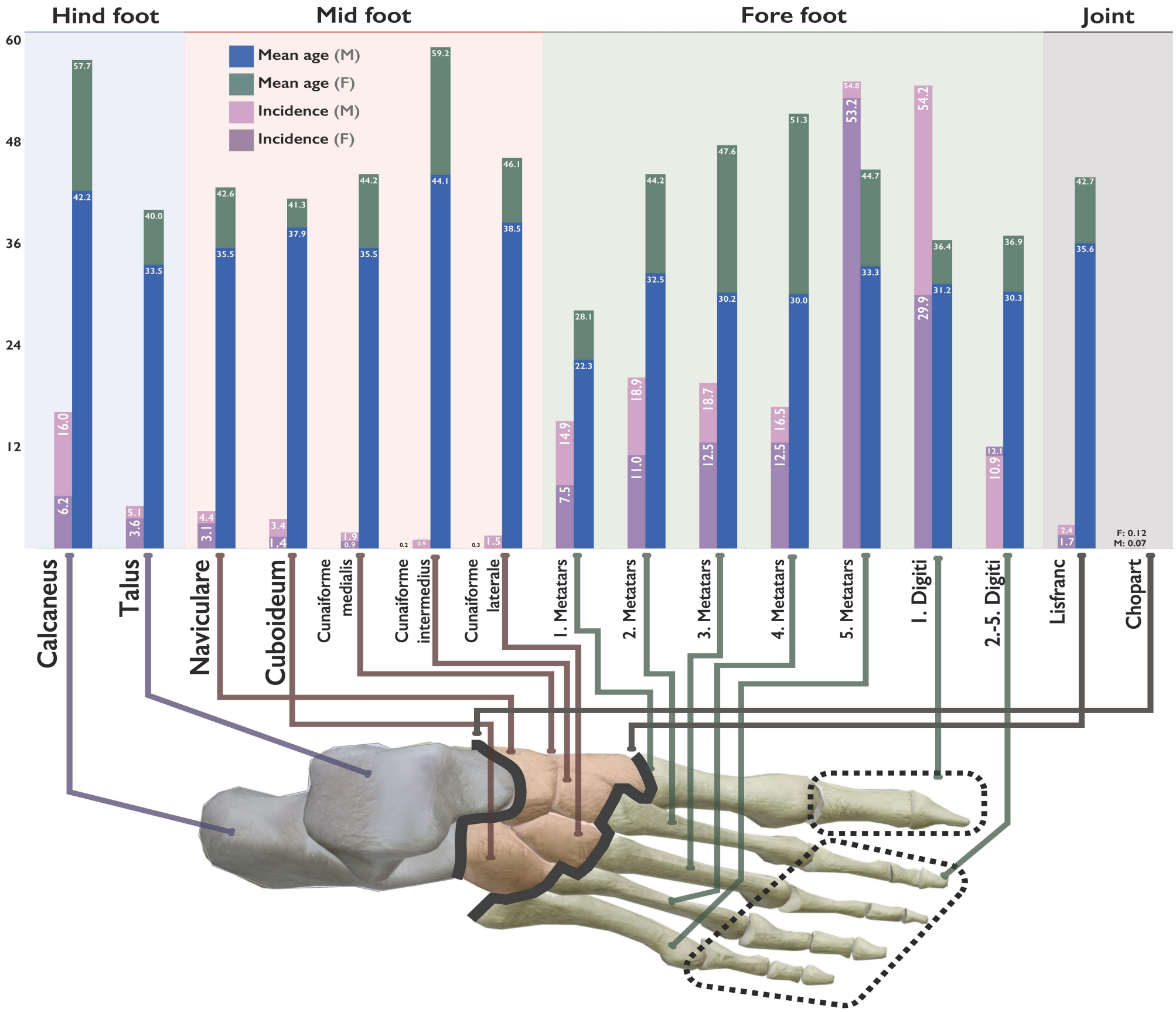


Figure 3. Gender distribution of Incidences (n/100,000/year) and mean age in years. M(male), F(female). Y-axis: numerical.

## Year-to-year variation

The incidence varies between 136.3/100,000/year and 156.0/100,000/year, indicating a low year-to-year variation (Appendix, Figure A1).

## Seasonal variation

The incidence was considerably higher in the forefoot compared to the mid and Hind Foot in all seasons. Fractures of the Fore- and Hind Foot had approximately 50% higher incidences in the summer compared to the winter. The incidence for the Mid Foot fractures was approximately 40% higher in the summer compared to the winter. Fall and spring showed almost no variation when compared to each other (Figure 4).

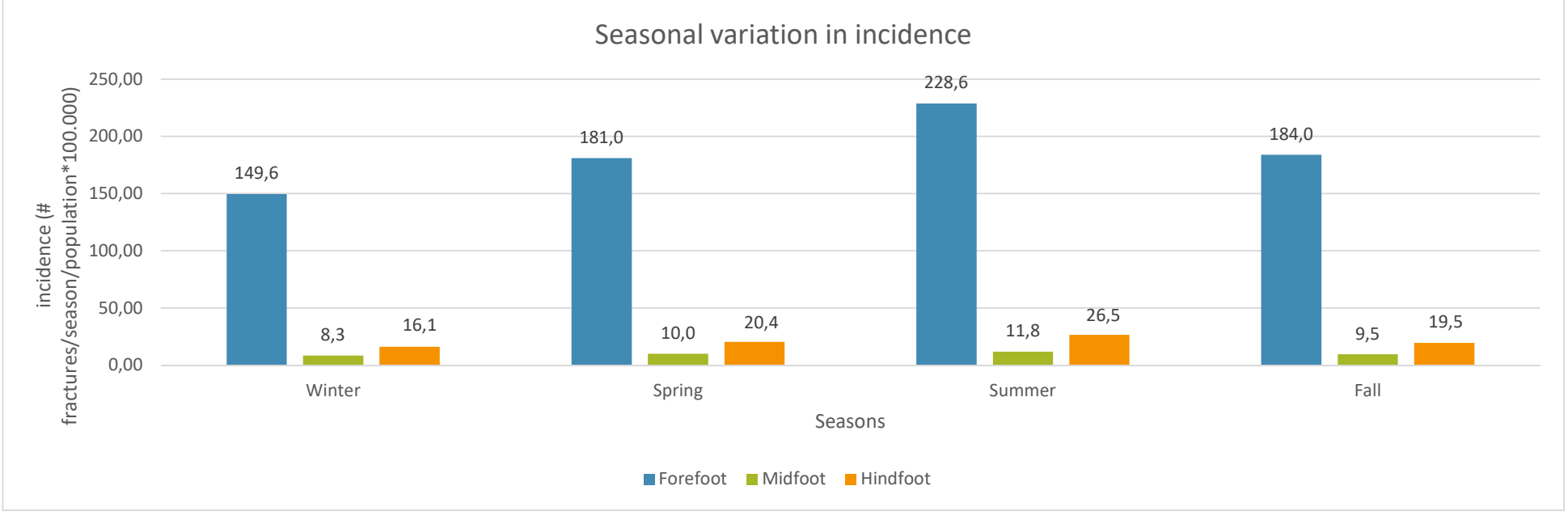


Figure 4. Seasonal Variation in incidence

## Trauma mechanism

Most frequent mode of injury were due to low energy trauma (99.2%). The predominant low-energy trauma was distortion (18.4%) and sport (16.6%). The predominant high-energy trauma was fall from > 4 meter (45% of all high-energy traumas) and high-speed accident (28% of all high energy traumas), (Appendix, Figure A2 & A3).

## Fractures, Classification and Trauma Mechanisms in the Hind- Mid- and Fore Foot

### Hind Foot fractures, classification and trauma mechanism

We report 491 fractures in the Hind Foot of 477 patients, 12 had bilateral calcaneal fractures. The incidence was 13.7/100,000/year (9.9/100,000/year for females and 21.1/100,000/year for males), the mean age 44 years (SD 20.6 years). 171 were females, 306 were males.

Highest incidence was in the Calcaneus. Calcaneus had the 3rd highest difference in mean age between the genders in the entire foot (Table 1) and (Figure 3), with females on average being 15.5 years older. Injury to Chopart´s joint was rare (n=3). It had the overall lowest incidence of all fractures in the foot (Table 1, fig 3).

Classification distribution of Calcaneus was most frequent in the category other (33.9%), followed by Sander type 2b (18.4%), Sander type 3a (15.5%); Sander type 1 (12.1%); Sander type 2a (10.4%); Sander type 3b (7.9%) and Sander type 4 (1.7%), (Table 1). Most common type of fracture in Talus, was osteochondral lesion (76.6%) followed by the Hawkins type 1 (11.7%); Hawkins type 2 (8.8%) and Hawkins type 3 (2.9%), (Table 1).

The predominant mode of injury in the Hind Foot fractures was low energy trauma (93.5%) with the majority being the results of a fall > 1 m (46.8%). Compared to the Mid- and Fore Foot, the Hind Foot had a higher frequency of high-energy traumas (6.5%). Most frequent high-energy trauma was fall > 4m (n=16), (Figure 5). Calcaneal fracture was associated with fall > 1 m (60.6%), fall while walking, not sports (9.1%) and sports (4.4%), (Appendix Table A6). Talar fracture was associated with distorsion (19%), Fall while walking, not sport (13.9%) and fall > 1 meter (12.4%), (Appendix Table A7).

| Trauma Mechanism, Hind Foot | Age Group | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-9 y | 10-19 y | 20-29 y | 30-39 y | 40-49 y | 50-59 y | 60-69 y | 70-79 y | 80-89 y | 90+ y | Total |
| **Fall > 1 m** | 8 | 14 | 35 | 24 | 44 | 40 | 41 | 12 | 2 | 3 | 223 |
| **Fall while walking, not sports** | 0 | 2 | 7 | 6 | 5 | 10 | 9 | 4 | 6 | 1 | 50 |
| **Sport** | 3 | 12 | 9 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 31 |
| **Distorsion** | 0 | 3 | 6 | 3 | 6 | 6 | 6 | 0 | 0 | 0 | 30 |
| **Fall > 4 m (HE)** | 0 | 1 | 4 | 4 | 5 | 1 | 1 | 0 | 0 | 0 | 16 |
| **Hit by object** | 1 | 1 | 3 | 1 | 2 | 3 | 0 | 0 | 2 | 0 | 13 |
| **Driver, vehicle** | 0 | 1 | 3 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 11 |
| **High speed accident (HE)** | 0 | 0 | 4 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 9 |
| **Hit by vehicle** | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 7 |
| **Cycle** | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 4 |
| **Motorcycle (HE)** | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 4 |
| **Trapped (HE)** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Hit by truck, train or bus (HE)** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Other (HE)** | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Unknown** | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 3 |
| **Other** | 2 | 7 | 16 | 8 | 7 | 9 | 9 | 9 | 5 | 0 | 72 |
| **Total** | 14 | 43 | 90 | 56 | 82 | 75 | 69 | 28 | 16 | 4 | 477 |

Figure 5. Trauma mechanism in the Hind Foot. HE = high energy, y = years.

### Mid Foot Fractures, Classification and trauma Mechanism

280 fractures in the Mid Foot was demonstrated in 227 patients, giving an incidence of 6.6/100,000/year (5.6/100,000/year for females and 9.1/100,000/year for males), the mean age was 38.3 years (SD 19.6 years). 95 patients were female, 132 male (Table 1).

Fractures of the Mid Foot had an overweight of males (57.6%). Highest incidence was in Naviculare and the lowest in Cuneiforme intermedius. Highest mean age for all fractures in the entire foot was seen in Cuneiforme medialis (59.2 years), (Table 1, Figure 3).

The classification of Mid Foot Fractures showed that simple fracture was most frequent, varying between 76% in Cuboideum and 88% in Naviculare. Complex fractures were highest in Cuboideum (9%) and lowest in Naviculare (1%). Dislocated fractures was almost similar and varied around 5-6% (Table 1).

Trauma mechanism in the Mid Foot was most frequent in distorsion (17%), fall while walking not sport (14.1%) and sport (11.0%), (Figure 6).

| Trauma Mechanism, Mid Foot | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0-9 y | 10-19 y | 20-29 y | 30-39 y | 40-49 y | 50-59 y | 60-69 y | 70-79 y | 80-89 y | Total |
| **Distorsion** | 3 | 4 | 6 | 3 | 9 | 8 | 5 | 1 | 0 | 39 |
| **Fall while walking, not sports** | 0 | 1 | 5 | 4 | 6 | 5 | 7 | 3 | 1 | 32 |
| **Sport** | 1 | 11 | 2 | 5 | 3 | 1 | 1 | 1 | 0 | 25 |
| **Hit by object** | 1 | 4 | 6 | 0 | 5 | 6 | 2 | 0 | 0 | 24 |
| **Fall > 1 m** | 1 | 0 | 4 | 2 | 4 | 5 | 2 | 0 | 0 | 18 |
| **Hit by vehicle** | 1 | 2 | 2 | 0 | 2 | 0 | 3 | 0 | 0 | 10 |
| **Driver, vehicle** | 0 | 2 | 3 | 1 | 2 | 1 | 0 | 0 | 0 | 9 |
| **Cycle** | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 7 |
| **Fall > 4 m (HE)** | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 4 |
| **High speed accident (HE)** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Motorcycle (HE)** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Other (HE)** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Other** | 5 | 9 | 9 | 8 | 5 | 12 | 3 | 2 | 2 | 55 |
| **Total** | 14 | 37 | 38 | 28 | 37 | 39 | 24 | 7 | 3 | 227 |

Figure 6. Trauma mechanism in the Mid Foot. HE = high energy, y = years.

## Fore Foot Fractures, Classification and Trauma Mechanism

We report 5,141 fractures in 4,298 patients, with an incidence of 123.9/100,000/year (116/100,000/year for females and 158/100,000/year for males). The mean age was 35.2 years (SD 21.8 years), 2,007 were females, 2,291 males.

Fracture of the forefoot had the highest incidence (Table 1). With the 5$^{th}$ Metatarsal and 1$^{st}$ Digit having considerably higher incidences than any other bone in the foot, (Table 1, Figure 3). Fractures of digiti 1$^{st}$ was most frequent in the age group 10-19 years (fig 5). Fractures of 5$^{th}$ Metatarsals and 2.-5. digiti had a gender distribution with a small overweight of females 53.2% and 56.9% respectively, (Table 1).

In terms of classification, the category (simple) fracture varied between 70-81% and complex fractures varied between 3-5%. Dislocated fracture was lowest in 1$^{st}$ Metatarsal, (Table 1).

The most frequent trauma mechanisms were sport (16.7%), hit by object (16%), distorsion (15.7%) and fall while walking (15.7%), (Figure 7).

| Trauma Mechanism, Fore Foot | Age Group | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-9 y | 10-19 y | 20-29 y | 30-39 y | 40-49 y | 50-59 y | 60-69 y | 70-79 y | 80-89 y | 90+ y | Total |
| **Sport** | 37 | 383 | 152 | 74 | 38 | 16 | 12 | 4 | 0 | 0 | 716 |
| **Hit by object** | 71 | 78 | 109 | 103 | 131 | 109 | 69 | 14 | 5 | 0 | 689 |
| **Distorsion** | 28 | 148 | 72 | 74 | 113 | 121 | 73 | 33 | 14 | 0 | 676 |
| **Fall while walking, not sports** | 43 | 95 | 71 | 71 | 95 | 91 | 84 | 62 | 54 | 8 | 674 |
| **Fall > 1 m** | 44 | 19 | 10 | 10 | 10 | 5 | 13 | 4 | 1 | 0 | 116 |
| **Driver, vehicle** | 5 | 24 | 12 | 7 | 5 | 4 | 3 | 1 | 1 | 0 | 62 |
| **Hit by vehicle** | 2 | 12 | 3 | 6 | 3 | 8 | 5 | 4 | 1 | 1 | 45 |
| **Cycle** | 2 | 8 | 1 | 1 | 3 | 6 | 7 | 2 | 0 | 0 | 30 |
| **Fall > 4 m (HE)** | 1 | 1 | 0 | 5 | 1 | 0 | 1 | 0 | 0 | 0 | 9 |
| **High speed accident (HE)** | 0 | 2 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 6 |
| **Motorcycle (HE)** | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| **Trapped (HE)** | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Other (HE)** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Other** | 150 | 285 | 156 | 166 | 154 | 163 | 103 | 60 | 29 | 3 | 1269 |
| **Total** | 383 | 1057 | 589 | 519 | 555 | 523 | 371 | 184 | 105 | 12 | 4298 |

Figure 7. Trauma mechanism in the Fore Foot. HE = high energy, y = year.

## Lisfranc´s joint.

65 patients suffered Lisfranc injury, the incidence was 1.8/100,000/year (1.7/100,000/year for females and 2.4/100,000/year for males). The mean age was 38.9 years (SD 20 years). Injury to Lisfranc´s joint was almost similar distributed between females (n = 30) and males (n = 35). Frequent trauma mechanism were distortions (13.1%) and fall >1 m (13.8%), (Appendix, Table A34).

# Discussion

## General

This study reports the overall incidence of foot fractures to be 142.3/100,000/year (female 130.2/100,000/year, male 185.1/100,000/year). To the authors knowledge, this is the first study to report an overview of all foot fractures based on an accurate and well defined population in combination with manually reviewed charts and x-rays of all patients.

In contrast, Beerekamp et al. showed a slightly higher incidence of 226/100,000/year of foot fractures in 2012 in the Netherlands[3]. This variation in incidence may be due to differences in methods between the two studies. The main reason is likely the exclusion of children below the age of 16 in the study by Beerkamp et al. excluding the patient group experiencing the highest incidence of foot fractures in the study. Moreover, this study includes all emergency departments and a manual review of all medical records and x-rays. This is in contrast to Beerekamp et al. and Dreissen et al. where data is derived from registries without manual review of data[3, 4].

The highest incidence of foot fractures was observed in the age group 10-19 years, with an incidence of 251/100,000/year. The incidence for the age-group 0-19 years was 180/100,000/year. A Norwegian study reporting fractures in children (0-18 years) reports an incidence of 329/100,000/year[13]. These differences are likely to be the result of a low number of participants in the Norwegian study and difference in methology[13].

For the age group 10-19 years the female and male incidences were 201.4/100.000/year and 296.9/100,000/year respectively. Another Danish study reports these incidences to be 260/100,000/year and 350/100,000/year respectively[4]. This may be explained by Driessen et al. using register data alone[4], and our study confirming the fractures by manual review.

For women a bimodal age distribution was observed, where the early peak was followed by a second lesser peak of 149/100,000/year for the age group 60-69 years. This was in contrast to males showing an almost constant decline in fracture incidence after the age of 20. These results are supported by several studies [2, 4].

A Low year-to-year variation in incidences between 156.1/100,000/year in 2005 and 136.3/100,000/year in 2009 was found in the present study. This is supported by Beerekamp et al., reporting approximately 20% year-to-year variations in foot fractures between 2004 and 2012 with no clear trends [3]. Similar low year-to-year variation is reported in other studies of the lower extremity[22], while other studies report considerable variation[23, 24]. As such, we cannot determine a clear trend for the lower extremity as a whole.

## Hind Foot

This study reported an incidence of 9.8/100,000/year for calcaneal fractures (female 6.2/100,000/year, male 15.9/100,000/year). Our data show that on average females are 15 years older (mean ages: female 57.7y, males 42.2y) than males at the time of calcaneal fracture. We have been unable to find comparable data. Among calcaneal fractures, 3.5% were bilateral, this is markedly different from other data that report 19.2%[16] and 31.3%[2] bilateral fractures. Our study and Court-Brown et al.[2] agree that the male incidence is twice as large as the female, while Leite et al. reports a male-female ration of 5.5:1[16]. This may be explained by differences in method, with Leite et al. only including hospitalised patients in a single institution. All three studies agree that the majority of calcaneal fractures are the result of falls.

The incidence of talar fractures was 3.9/100,000/year, with a female mean age of 40.0 years and a male mean age of 33.5 years. A Brasilian study focused only on talar fractures that underwent surgical treatment, stating that these are primarily male, but provide no incidences[15]. Mollehoff et al. reported that 2.4 % of patients that experienced supination trauma had talar fractures, but do not specify the classification[25]. Shiboya et al. and Court-Brown et al. also finds Calcaneal fractures to have the highest incidences of fracture in the Hind Foot[2, 26]. The differences in inclusion criteria may well explain the different results, and makes further comparison very difficult.

We reported that the majority of hindfoot fractures were due to falls > 1 m,  this is in contrast to Court-Brown et al. where talar fractures are associated with sport- and motorcycle accidents, and calcaneal fractures with pedestrians being hit by vehicles[2]. Jeffers et al. found a high frequency of Metatarsal fracture in motorcycle related foot fractures (49.1%), but also many talar (26.4%) and calcaneal fractures (13.2%)[27]. The difference between our study and Jeffers may be due to different methods, where we included patients from a trauma center as well as regional hospitals, Jeffers focused on patients initially treated in a trauma center following motorcycle accidents. This difference in scope leading to different results is pointed out by Court-Brown et al., and supports the claim that comparable results are difficult to achieve[2].

## Mid Foot

Fractures of the Mid Foot had an incidence of 6.6/100,000/year (female 5.6/100,000/year, male 9.1/100.000/year), a mean age of 38.3 years (female 42.6y, male 35.3y) and 42.3% were female. The overweight of males is supported by Court-Brown et al., who also find comparable incidences, female 4/100,000/year and male 7/100,000/yearl[2]. Ponkilainen et al. reports an incidence of 12.1/100,000/year, but includes chopars and Lisfranc injuries[28], so at least part of the difference is due to variation in reporting. We have been unable to find literature that specified the incidences of the different bones in the Mid Foot, so comparison at that level of detail could not be made.

The trauma mechanism in Mid Foot fractures was widely distributed, but with distorsion, fall while walking  (not sport) and sport being the most frequent. Court-Brown found Mid Foot fractures associated with sport- and motorcycle accidents[2]. Wood et al. finds an incidence of sport related fractures in adolescents of 563/100,000/year, but there is no mention of Mid Foot fracture in their article, only hind- and Fore Foot[6]. Aitken et al. found that in general 14.5% of fractures were due to incidents in sports, with the highest frequency being among males aged 15 to 19 years[7]. There is no obvious explanation for the discrepancy between our study and Court-Brown/Aitken, but it shows the difficulty in categorising accidents.

## Lisfranc (and Chopars) injury

Lisfranc injury had a low incidence of 1.9/100,000/year (female 1.7/100,000/year, male 2.4/100,000/year), this is corroborated by other studies[2, 26]. We report that 40% are female, with a mean age of 38.9 years (female 42.7y, male 35.6y). Damage to the Lisfranc joint is not common, and easily missed[14]. These low incidences may well represent an underestimation because of under- or misdiagnosis[14, 26, 29]. This study reports injury to the Chopart joint to be very rare, with just three cases, and will not discuss it further.

Males tends to be younger when sustaining Lisfranc injury (female 42.7y, male 35.6y) with almost equal gender distribution, and the vast majority arising from low energy trauma. Sobrado et al. found that among those sustaining Lisfranc injuries, young men involved in motor vehicle accidents were more frequent, and that approximately one third of all Lisfranc injuries were sustained in low energy traumas[29]. The difference in gender distribution and low vs. high energy trauma may be explained by differences in methods, with Sobrado et al. reporting on cases from a single institution and our study having a more varied uptake. This study reports that 92% of the injuries were correlated to low energy traumas. In contrast Benirschke et al. describes that in approximately one third of the Lisfranc injuries the trauma mechanism is low energy[14]. This could be because extremity fractures, including those in the foot may be under diagnosed in severely injured patient

following high energy trauma. It is also possible that the injury is found and treated, but not assigned an ICD-10 code, simply because the patient has a multitude of injuries. Also, recognising that Benirschke et al. is based on US data, and assuming that the Danish system of tax-funded health care brings almost all persons with distressing injury (as Lisfranc injury is) to seek help, the difference in association with trauma mechanism, may at least in part be explained by differences in threshold for seeking medical attention. Furthermore the markedly higher female mean age in combination with high correlation to low energy trauma may suggest that Lisfranc injury is associated with fragility.

## Fore Foot

The incidence of 5$^{th}$ Metatarsal fracture was the highest for an individual bone in the foot with 49.5/100,000/year (female 53.2/100,000/year, male 54.8/100,000/year), a mean age of 39.4 years (female 44.7y, male 33.3y) and 53.6% being females. Court-Brown et al. also finds females to be older at time of fracture[2]. This may be another example of a fragility fracture. Our study reports that the 5$^{th}$ Metatarsal accounted for 49.5% of fractures of the Metatarsals. Zhao et al. support our data, reporting that it accounted for 42.45% of Metatarsal fractures[30]. As mentioned earlier a Norwegian study does not include Metatarsal fractures and Driessen et al. does not specify which Metatarsal bones are fractured[4, 13], making comparison difficult at best.

We report the incidence of fractures in the 1$^{st}$ toe to be 37.6/100,000/year (female 29.8/100,000/year, male 54.2/100,000/year). For both genders, fracture of the 1$^{st}$ Metatarsal had the lowest mean age 33.2 years (female 36.4y, male 31.2y), with 55.3% of the fractures occurring in patients aged 19 or younger. This is supported by Court-Brown et al. [2].Despite being a clinical diagnosis, we found 367 patients (F219/M158) with one or more fractures in the 2$^{nd}$ to 5$^{th}$ toes, among these, 72 patients had other fractures. If the initial suspicion is 2$^{nd}$-5$^{th}$ digital fracture, it can be claimed that referring the patients to X-ray and ED represents an undue burden on the secondary sector[21]. Our incidence of 10.6/100,000/year (female 12.1/100,000/year, male 10.9/100,000/year) is marked contrast to Court-Brown et al. who reports a female incidence of 37.3/100,000/year and male incidence of 59.8/100,000/year[2]. This difference may be explained by more fractures being diagnosed (without X-ray) and treated in the Danish primary sector, and not referred to emergency departments. It is tempting to claim that the majority of these fractures must be treated in the primary sector, just as intended.

We found that the fractures in the Fore Foot are associated with distortions, fall while walking and sports. Wood et al. report a rather low frequency of Fore Foot fractures in relation to sports, with 12 Metatarsal fractures among 209 injured athlete with fracture[6]. Court-Brown reports that Fore Foot fractures are associated with distortions, sports and motorcycle accidents[2]. Despite different methods the studies seem to agree that distortions and sports are associated with fractures in the Fore Foot.

## Strengths and Limitations

A strength of this study is the accuracy in the population and the inclusion of all age groups in a non-selected population, because it gives the necessary background population for reporting incidences. The data from DNPR and our, albeit time consuming, manual review of medical records and X-rays provides a precise patient population for reporting incidences. With our manual review we have reduced the amount of inter observer variability from several hundred to just three observers.

Our study was limited by an initial selection bias because the patients who have been treated for a fracture in the foot, but assigned an erroneous ICD-10 code never reach our attention; likewise, those who do not seek medical attention are never diagnosed and coded.

Another limitation is the categorisation of trauma mechanisms, with our “other” category ending up accounting for many and varied mechanisms. For future epidemiological studies, that aim at reporting trauma mechanism we would recommend pilot studies on a sub-population. This would allow early adjustment and strengthen then study. Information bias could have limited the studies because medical record were used for categorising the trauma mechanism.

# Conclusion

This study shows an overall incidence of foot fractures to be 142.3/100,000/year. The Hind Foot incidence is 13.7/100,000/year, the Mid Foot incidence 6.5/100,000/year and the Fore Foot incidence 123.9/100,000/year. Both gender show a peak incidence in the age group 10-19 years with a male predominance, the females having a bimodal distribution and males near constant decline after the initial peak. Low energy trauma was the most common mode of injury (98.7%).

# Conflict of interest.

The authors declare no conflicts of interest.

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