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Lisfranc Injury: a Comprehensive Analysis of Long-Term Outcomes – the Oswestry Experience

Poranění Lisfrancova kloubu: komplexní analýza dlouhodobých výsledků – zkušenost Oswestry

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ABSTRACT

PURPOSE OF THE STUDY

Lisfranc is a challenging injury both diagnostically and surgically, with sparse long-term literature evidence of surgical practice. We aim to review our long-term specialist orthopaedic institutional experience of Lisfranc injuries and the surgical management of this complex injury, specifically considering surgical outcomes as per radiological and clinical assessment.

MATERIAL AND METHODS

We present data from a prospectively maintained institutional database, reviewing patients who underwent operative fixation for Lisfranc injury between April 2014 and August 2020. Patients were referred to our institution from hospitals across the country. We included all operatively managed Lisfranc injuries, primary procedures, and patients over the age of 16. Revision procedures, open injuries, polytrauma patients, patients under the age of 16, and those with multiple foot injuries were excluded. We assessed post-operative results as per the Wilpulla radiographic and clinical criteria.

RESULTS

We treated 27 patients across the study period, of mean age 37.5 (SD 18.3), 55% male and 45% female. 33.3% of our patients were obese as defined by body mass index >30. As per the Myerson classification, we had 2 category A, 24 category B, and 1 category C injuries. Time to operation was median 14 days (range 0–116), with 2 delayed presentations following failure of conservative treatment. Our median length of stay was 1 day (range 0–16). We had 3 complications: 2 wound infections and 1 re-operation for non-union. Post-operative assessment as per Wilpulla demonstrated 74% of good, 18.5% fair and 7% poor fixation results.

CONCLUSIONS

In our institutional experience, partial congruity lateral displacement injuries were the majority of surgical referrals. Surgical treatment through open reduction and internal fixation delivers good clinical and radiographically anatomical results. Further to conventional mechanisms of injury, we propose obesity to be an important risk factor for indirect, low-energy injuries that may help identify this injury.

Key words: Lisfranc injury, long-term, orthopaedic surgery, obesity.

INTRODUCTION

Lisfranc injury refers to a disruption of the tarsometatarsal (TMT) joint where one or more of metatarsals are displaced from the tarsal bones, representing a spectrum of injury from pure ligamentous to involvement of osseous and articular structures (41). Jacques Lisfranc de St Martin (1790–1847) an army surgeon and gynaecologist who served during the Napoleonic Era has been accredited with the eponym for this pathology (6). Interestingly he never directly referred to the injury or the mechanism of injury, rather it was his account of amputation at the level of the tarsal-metatarsal joints in a soldier who fell from his horse sustaining a mid-foot injury and obtained reference through association (6).

The Lisfranc complex is polyarticular system that refers to the collection of skeletal and non-skeletal elements which include the bony elements of tarsal and metatarsals, articular capsule, ligaments, and tendons that collectively provide stability to the TMT joints (7, 26, 30). The Lisfranc joint is composed of 3 types of articulations – the tarsometatarsal, intermetarsal and anterior intertarsal joints (Table 1). Metatarsals 1–3 articulate with a cuneiform, and metatarsals 4 and 5 articulate with the cuboid bone. What confers stability to the Lisfranc joint is the configuration of these bones, and the ligament complex. The cuneiforms can be seen in the coronal view to form a Roman Arch construct, the keystone of which is the 2nd metatarsal base, which confers stability to the arch in this plane.

The mechanism of injury may be described as direct or indirect. Direct injury encompasses higher energy trauma such as motor vehicle crash, crush injury and fall from height. These were considered the most common mechanisms of injury, whereby impact to the dor-

Table 1. The columns of the midfoot and their articulations. Adapted from Coetzee (2008) (7)

Column	Articulation	TMTJ range of motion
Medial	Medial cuneiform and 1st metatarsal base	5–10°
Middle/Intermediate	Middle and lateral cuneiforms, and 2nd and 3rd metatarsal base	minimal
Lateral	Cuboid and 4th and 5th metatarsal base	10–20°

sum of the foot may render the joint unstable following the disruption of plantar structures (10, 22, 41). Indirect injury refers to the trauma sustained at lower-energy mechanisms with the foot in hyper-plantarflexion, excessive pronation and supination and associated axial loading, which has been widely reported in sports including horse riding, football, and gymnastics (12, 13, 35, 37). A 2020 Norwegian study examining radiology assessed tarsometatarsal joint injuries and correlated them with stability of the Lisfranc joint clinically found that intraarticular fractures in the two lateral tarsometatarsal joints, female gender and shorter second tarsometatarsal joint height increase the risk of sustaining an unstable injury of the Lisfranc joint (38).

Diagnosis may be elusive due to the range of both high and low energy mechanisms associated to the injury, indeed it is suggested that 20–40% of cases are misdiagnosed which may result in severe sequalae and morbidity (17, 21). The infrequent presentation of the injury such that it reflects only 0.2% of all fractures or 1 in 55,000 people per annum, it is possible to see why the diagnosis may not be evident (22, 26).

We aim to review our long-term specialist orthopaedic institutional experience of Lisfranc injuries and the surgical management of this complex injury, specifically considering surgical outcomes as per radiological and clinical assessment.

MATERIAL AND METHODS

We collected data from a prospectively maintained database of electronic patient records, reviewing all patients who underwent operative intervention for Lisfranc injury between April 2014 and August 2020. We included all operatively managed Lisfranc injuries, primary procedures, and patients over the age of 16. Revision procedures, open injuries, polytrauma patients, patients under the age of 16, and those with adjacent foot injuries were excluded.

This study was carried out at our tertiary specialist orthopaedic hospital, Robert Jones and Agnes Hunt

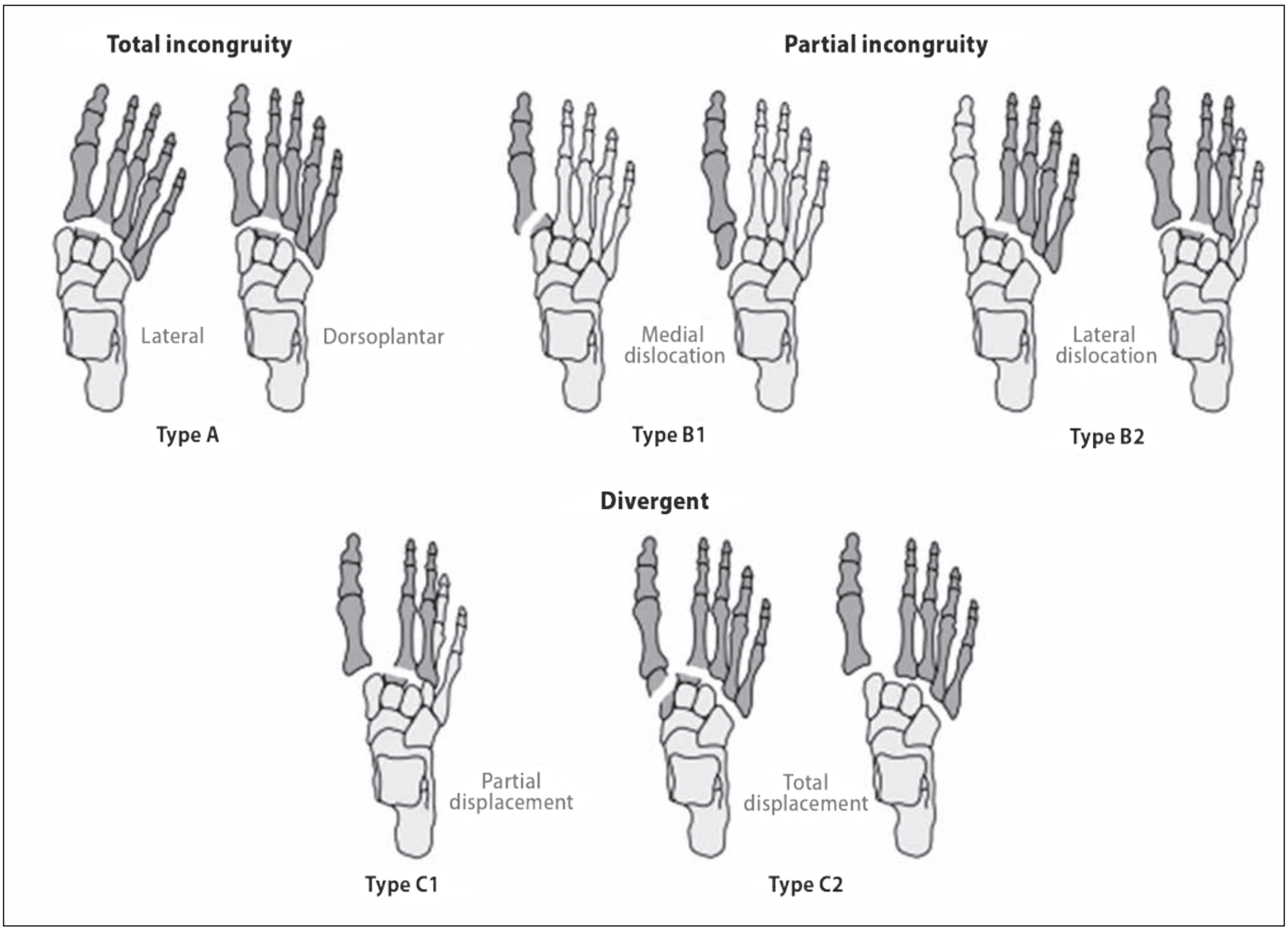

Fig. 1. Illustration of Hardcastle & Myerson classification of Lisfranc injury (26).

Table 2. Lisfranc injury patient demographics and injury classification between 2014 and 2020.

Patient demographics			Total
Gender (percentage)	Male 15(55%)	Female 12(45%)	27
Age, years Mean, (SD), range	44.0 (16.6), 18–70	33.0 (18.4) 18–87	37.5 (18.3), 18–87
		p-value	0.031
Charlson Comorbidity Index			
Overall Score	Mode 0		
	1 patient with congestive cardiac failure	1 patient with COPD	2 comorbid patients
Obesity (Body Mass Index>30)	patients		
Myerson Classification	Total	Direct	Indirect
A	2	1	1
B1	3	2	1
B2	21	10	11
C1	1	1	0
C2	0	0	0

Orthopaedic Hospital (RJAH). RJAH provides multi-specialty orthopaedic care including foot and ankle surgery, however patients are not received for emergency care as direct admissions rather accepted as tertiary referrals from other hospitals. All surgery was undertaken by senior specialist foot and ankle surgeons experienced in complex foot surgery. All surgical patients received a pre-operative computer tomography (CT) scan to further delineate the anatomy of the injury. CT scans were assessed by and reported by specialist musculoskeletal consultant radiologists as well as the foot and ankle consultant of care. Pre-operative and follow-up radiographs were assessed by the authorship to confirm ascribed injury type and post-operative classifications. All patient underwent venous thromboembolism assessment as part of their surgical care, taking into account operative risk, comorbidities, age and anticipated immobility; following which they would receive a suitable low molecular weight heparin as a prophylactic daily dose throughout the period of non-weight-bearing or immobilisation. Usual post-operative follow-up includes two-week wound check, six weeks clinical assessment and radiograph, three months and six months follow-up for clinical assessment. Many of the patients treated at our institute have travelled from across the region and country, so although routine follow-up has always been provided in the post-operative period there is variable attendance.

Data parameters include baseline demographics of age, gender, Charlson Comorbidity Index (CCI) score (9), body mass index and mechanism of injury. Recorded injury type was classified as per Myerson et al. system (26), time to surgery, surgical intervention, post-operative Wilppula anatomical results (43), length of stay and any complications. We specifically considered complications such as wound infection, deep-vein thrombosis, compartment syndrome, and revision procedures.

The Myerson classification is based on the pattern of displacement of the metatarsals (26). Type A injuries involve complete incongruity of the tarsals and metatarsals, which can displace laterally, or in a dorsoplantar fashion. Type B injuries are of partial incongruity, and are divided into medial (B1, of the first ray alone) and lateral (B2, of the 4 lesser rays) dislocations. Type C injuries are divergent pattern injuries in which the 1st and 2nd ray are partially (C1) or fully (C2) displaced. Currently, no classification exists to correlate mechanism of injury and type of fracture, and subsequent prognosis of the different types of Lisfranc injuries, but the findings of Myerson's original study suggested that direct injuries lead to poorer clinical outcomes due to the higher severity of soft tissue injury *(Fig. 1)*.

Wilppula described three types of anatomical outcomes based on radiographic and clinical assessment, considering the diastasis of the 1st and 2nd metatarsal and level of deformity. Good outcome referred to a good total foot shape with diastasis <5 mm, fair as 6–9 mm with moderate arthrosis, and poor with marked deformity and diastasis >10 mm (43).

Descriptive statistics were utilised to present means, standard deviations (SD) and ranges. Continuous data with normal distribution was analysed by parametric testing using t-test was performed and is presented as means with confidence intervals(CI) set at 95%. Non-parametric data was assessed by Wilcoxon-rank test and presented using the median and range, and chi-squared test was used for categorical data. Significance was set at $p < 0.05$ as for all the tests as per convention. Statistical analysis was performed using R 3.4.3 (Core Team, Austria).

Table 3. Lisfranc surgery – time to operation, length of stay, post-operative Wilppula assessment and complications

Time to operation from diagnosis, days				
Median, range	14	0–116		
Length of stay, days				
Median, range	1	0–16		
Wilppula Classification		Good	Fair	Poor
A	Direct	0	1	0
	Indirect	0	1	0
B1	Direct	0	1	0
	Indirect	0	2	0
B2	Direct	10	0	0
	Indirect	10	0	1
C1	Direct	0	0	1
	Indirect	0	0	0
Total		20	5	2
Complications	n			
Wound Infection	2			
Deep Vein Thrombosis	0			
Compartment Syndrome	0			
Re-operation	1	Non-union		

RESULTS

The management of Lisfranc injury at our institute was based on the operative treatment of patients who did not satisfy conservative management. Of these patients we have had a greater percentage of male compared to female attendances, and a statistically significant preponderance of older male population (Table 2). We maintained a record of our patients' comorbidities, which are referenced through the Charlson Comorbidity Index and the associated score. The majority of our patient group were fit and healthy adults, with only two patients suffering comorbidities, both relating to cardiorespiratory disease. As part of our pre-operative assessment, basic measurements were recorded including body mass index scores which help identify obese patients, with obesity being a recognised comorbidity and prevalent a third of our patients. Further subgroup analysis identified that this obese population of patients were all involved in indirect injuries and low energy mechanisms.

Radiographic assessment of the injury patterns identified that patients experienced the range of Myerson injury patterns, except for type C2 which is total displacement. Patients who underwent operative intervention came from both direct and indirect populations with a slightly higher undertaking for those with high energy direct injuries. The vast majority of injuries both direct and indirect followed type B2 pattern, which describes partial congruity lateral dislocation. Only one type C1 injury was seen and this was for a direct injury following a large set of boxes crushing the foot.

There are a wide range of times to operation from the diagnosis, however the median time of 14 days is representative of the preoperative timeline (Table 2) . Two particular patients underwent a trial of conservative management thereby providing the wide range. Both of those patients were initially managed at external hospitals. Unfortunately, one of the patients failed to meet follow-up appointments repeatedly until they deteriorated and became significantly symptomatic and represented, at which stage they were referred onwards to RJAH, prolonging the timeline from diagnosis to operation to 108 days. The second patient seemingly succeeded in initial conservative management, but they were also referred to RJAH when they also became symptomatic delaying time to operation to 116 days.

Most patients were treated as day cases requiring only one day of inpatient admission, as often preoperative assessment, surgical and theatre planning was all arranged in advance as semi-elective cases. Again, to patients required more prolonged inpatient stays, as they sustained high energy direct injuries, and were transferred from other regions to undergo operative care. One patient fell from a ladder at height, with significant soft tissue swelling, such that it precluded operative intervention till six days postdate of injury and required a total of 12 days of inpatient stay. The second patient was involved in an RTC in a distant region, transferred to RJAH, and also sustained significant soft tissue swelling that again required 10 days of rest and elevation prior to surgery, with a total of 16 days of inpatient care.

Post-operative Wilppula assessment of the surgical fixation was based on the first post-operative radiograph, and clinical assessment of any foot deformity. The majority of patients received good and anatomic reduction and fixation of the injury. Type A patients obtained fair fixations, and there were two instances of poor fixation: one in the B2 indirect group and the C1 group (Table 3).

We saw very few post-operative complications in our surgical population, with two instances of wounds infections that were slow to heal and managed with wound dressing care and antibiotics (Table 3). There was also one patient to require re-operation arthrodesis due to non-union as assessed at the six-month follow-up.

DISCUSSION

This fascinating injury which was not originally described by an orthopaedic surgeon but rather accredited to a military surgeon and a gynaecologist, still proves one of the most elusive and difficult diagnosis in modern day foot and ankle orthopaedic surgery. Lisfranc injuries have been discussed at length throughout literature, yet they remain an infrequent and often challenging diagnosis. A significant challenge in diagnosis comes with the variability in presentation, a wide range of radiographic signs which may corroborate clinical suspicion, and vast spectrum of mechanisms from which the injury may be sustained. Lisfranc injury has been widely attributed to both low and high energy injuries, also described as direct and indirect injuries, further developing a tangled web of aetiology which does not lend to straightforward detection. Oversight may lead to disastrous outcomes, with significant compromise of foot architecture and severely impaired mobility. Here we explored our long-term institutional experience as a specialist orthopaedic hospital, with a dedicated foot and ankle subspecialty service.

The patient demographics most commonly associated to this injury are the physically active adult population, both male and female, with the majority of cases seen in those between the ages of 30 to 50 years old (4, 14, 20, 23, 24, 32, 34). The biomechanics of the injury are reliant upon sufficient force and disruption of the Lisfranc is complex, and therefore would be in keeping with this patient population, who are freely mobile and those likely to undertake activities which would result in the necessary mechanisms. The more elderly population are unlikely to be undertaking physical activities which would routinely predispose the Lisfranc injury as compared to osteoporotic fractures such as hip and distal radius fractures.

In concordance with the young population who are affected by this injury, we see that few patients have baseline comorbidities. Naturally with increasing age we would expect increasing comorbidities, yet our patient group have limited healthcare issues that would be registered significant on any scoring system, such as the CCI. One particular comorbidity, obesity, as diagnosed as body mass index >30 featured heavily in our patient population. Interestingly this was also the group of patients who were associated with low energy mechanisms of injury, such that they fell from standing height having twisted their feet. Traditionally we consider this low energy mechanism to be associated more with sporting injuries. Hyper-plantarflexion, with axial loading and excessive pronation or supination would result in injury within the low energy of injury or indirect group. One would correlate this with a fit and active group of individuals, who would be capable of undertaking fast and rapid movement in order to generate the forces required to sustain the injury, as widely documented in literature (12, 13, 35, 37).

Obesity is currently a worldwide pandemic that was considered to be a western phenomenon, and we can now see the profound effects on public health that includes the ever-increasing list of affiliated diseases, of which musculoskeletal disease and injury are increasingly prevalent (16, 28). Obesity also impacts bone metabolism, through a process of chronic low- grade inflammation, where pro-inflammatory cytokines TNF-a, IL-1, IL-6, and NF-kB impair common haematopoietic progenitor differentiation of osteoblasts and whilst stimulating osteoclast activity through upregulation of RANKL pathway (5). Indeed the relationship between increased body mass and bone mineral density may appear to provide protection, however evidence also suggests that obesity is a risk factor for fractures (2, 16).

Lower limb fractures in particular are increasing in prevalence when associated with obesity, and although the increased padding from adiposity and improved bone mineral density may protect against hip fractures, a multitude of studies evidence the risk for low energy injuries and fractures as a result of high BMI (2, 3, 8, 11, 29, 31, 37). A large systematic review and meta-analysis of almost 380,000 patients highlighted the increased challenges in treating obese patients throughout their surgical care pathway, with increased post-operative complications including non-union, wound problems, metalwork failure, mortality, deep vein thrombosis and mortality (19). A cross-sectional study of 42,304 patients also presented the increased risk of musculoskeletal injury in the obese population, and almost 50% higher for the BMI>40 category (15). Interestingly although one may expect obesity to contribute to the risk of fracture non-union within foot and ankle fractures, the evidence remains equivocal (39, 40).

In our institutional experience for the surgical management of Lisfranc injuries, we have recognised this trend, where low energy mechanisms of injuries have been mainly sustained within the obese patient population. With the obesity pandemic progressing exponentially around the world, we suggest that this is taken seriously as a significant risk factor for patients who may sustain foot injuries, and thereby indirect Lisfranc injury. Despite being a very infrequent diagnosis, the consistency with which the demographic of patient has presented with this injury pattern further emphasises the potential risk.

Injury classification has evolved from the original Quenu and Kuss in 1909, to Hardcastle, and Myerson (18, 27, 33), yet literature does not suggest that one classification system is superior to another. We utilised the Myerson classification system, and assigned type based on pre-operative radiographs and CT assessment. 78% of our patients sustained a B2 type injury, which is a partial congruity lateral dislocation. This describes a lesser displaced injury when compared to the type at A and C groups which reflect homolateral and divergent patterns. The crucial articulation of the medial cuneiform to the second metatarsal forms the cornerstone from which the midfoot architecture derives stability. Therefore, initial disruption at this point will serve as a catalyst from which the cascade of greater deforming injuries to the tarsometatarsal and intermetatarsal joints, starting with partial loss of congruence as seen in type B, progressing to either the patterns present in type A or C.

Most of our patients had surgical treatment a few weeks after the initial injury, which is consistent with the fact that they were referred from other regional centres. This provided enough time for further radiological investigations and pre-operative planning. An additional benefit was that patients attended to operation with adequate time to allow for soft tissues to decrease in swelling and oedema. There is significant controversy throughout literature as to the timing of surgery within lower-extremity injuries and relationship with wound complications, where traditional teaching supports delay till skin wrinkling and others suggest that only high BMI, smoking and heel-pad oedema influence the wound outcome (36). Interestingly the B1 patients who were initially managed non-operatively, subsequently took longer to heal. Despite what was in effect a protracted period of rest without soft tissue disruption from an operation, these patients would still experience pain, inflammation and swelling, a chronic process which may result in impaired keratinocyte function, impeding the progress through the normal stages of wound healing (25).

We have a uniform venous thromboembolism (VTE) assessment protocol for all surgical patients in RJAH, considering, patient and operative risk factors. This helps us to ensure appropriate protective prophylaxis is delivered to patients and thereby reduce the risk for VTE. As such this intervention was successful and we did not observe any incidence within our patient population through follow-up.

CONCLUSIONS

Lisfranc injury is a challenging diagnosis with considerable morbidity when overlooked. In our institutional experience, partial congruity lateral displacement injuries were the majority of surgical referrals. Surgical treatment through open reduction and internal fixation delivers good and anatomical outcomes in the majority of cases, as assessed by post-operative radiographic and clinical assessment. Further to conventional mechanisms of injury, we propose obesity to be an important risk factor for indirect, low-energy injuries that may help identify this injury.

References

1. Anandacoomarasamy A, Caterson I, Sambrook P, Fransen M, March L. The impact of obesity on the musculoskeletal system. Int J Obes (Lond). 2008;32:211–222. doi: 10.1038/sj.ijo.0803715.
2. Beck TJ, Petit MA, Wu G, LeBoff MS, Cauley JA, Chen Z. Does obesity really make the femur stronger? BMD, geometry, and fracture incidence in the women's health initiative-observational study. J Bone Miner Res. 2009;24:1369–1379. doi: 10.1359/jbmr.090307.
3. Bergkvist D, Hekmat K, Svensson T, Dahlberg L. Obesity in orthopedic patients. Surg Obes Relat Dis. 2009;5:670–672. doi: 10.1016/j.soard.2009.05.014.
4. Blanco RP, Merchán CR, Sevillano RC, Martínez LM. Tarsometatarsal fractures and dislocations. J Orthop Trauma. 1988;2:188–194. doi: 10.1097/00005131-198802030-00003.
5. Cao JJ. Effects of obesity on bone metabolism. J Orthop Surg Res. 2011;6:30. doi: 10.1186/1749-799X-6-30.
6. Cassebaum WH. Lisfranc fracture-dislocations. Clin Orthop Relat Res. 1963;30:116–129.
7. Castro M, Melão L, Canella C, Weber M, Negrão P, Trudell D, Resnick D. Lisfranc joint ligamentous complex: MRI with anatomic correlation in cadavers. AJR Am J Roentgenol. 2010;195:W447–W455. doi: 10.2214/AJR.10.4674.
8. Chan MY, Frost SA, Center JR, Eisman JA, Nguyen T V. Relationship between body mass index and fracture risk is mediated by bone mineral density. J Bone Miner Res. 2014;29:2327–2335. doi: 10.1002/jbmr.2288.
9. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40:373–383. doi: 10.1016/0021-9681(87)90171-8.
10. Coetzee JC. Making Sense of Lisfranc injuries. Foot Ankle Clin. 2008;13:695–704. doi: 10.1016/j.fcl.2008.07.001.
11. Compston JE, Watts NB, Chapurlat R, Cooper C, Boonen S, Greenspan S, Pfeilschifter J, Silverman S, Díez-Pérez A, Lindsay R, Saag KG, Netelenbos JC, Gehlbach S, Hooven FH, Flahive J, Adachi JD, Rossini M, Lacroix AZ, Roux C, Sambrook PN, Siris ES; Glow Investigators. Obesity is not protective against fracture in postmenopausal women. GLOW. Am J Med. 2011;124:1043–1050. doi: 10.1016/j.amjmed.2011.06.013
12. Curtis MJ, Myerson M, Szura B. Tarsometatarsal joint injuries in the athlete. Am J Sports Med. 1993;21:497–502. doi: 10.1177/036354659302100403.
13. DeOrio M, Erickson M, Usuelli FG, Easley M. Lisfranc injuries in sport. Foot Ankle Clin. 2009;14:169–186. doi: 10.1016/j.fcl.2009.03.008
14. Dubois-Ferrière V, Lübbeke A, Chowdhary A, Stern R, Dominguez D, Assal M. Clinical outcomes and development of symptomatic osteoarthritis 2 to 24 years after surgical treatment of tarsometatarsal joint complex injuries. J Bone Joint Surg Am. 2016;98:713–720. doi: 10.2106/JBJS.15.00623.
15. Finkelstein EA, Chen H, Prabhu M, Trogdon JG, Corso PS. The relationship between obesity and injuries among U.S. adults. Am J Heal Promot. 2007;21:460–468. doi: 10.4278/0890-1171-21.5.460.
16. Gonnelli S, Caffarelli C, Nuti R. Obesity and fracture risk. Clin Cases Miner Bone Metab. 2014;11:9–14. doi: 10.11138/ccmbm/2014.11.1.009.
17. Goossens M, De Stoop N. Lisfranc's fracture-dislocations: etiology, radiology, and results of treatment. A review of 20 cases. Clin Orthop Relat Res. 1983;176:154–162.

18. Hardcastle PH, Reschauer R, Kutscha-Lissberg E, Schoffmann W. Injuries to the tarsometatarsal joint. Incidence, classification and treatment. J Bone Joint Surg Br. 1982;64:349–356. doi: 10.1302/0301-620X.64B3.7096403.
19. Kinder F, Giannoudis P V, Boddice T, Howard A. Clinical Medicine The effect of an abnormal BMI on orthopaedic trauma patients: a systematic review and meta-analysis. J Clin Med. 2020;9:1302. doi: 10.3390/jcm9051302.
20. Kirzner N, Zotov P, Goldbloom D, Curry H, Bedi H. Dorsal bridge plating or transarticular screws for Lisfranc fracture dislocations: a retrospective study comparing functional and radiological outcomes. Bone Joint J. 2018;100-B: 468–474. doi: 10.1302/0301-620X.100B4.BJJ-2017-0899.R2.
21. Krause F, Schmid T, Weber M. Current Swiss Techniques in management of Lisfranc injuries of the foot. Foot Ankle Clin. 2016;21:335–350. doi: 10.1016/j.fcl.2016.01.006.
22. Lau S, Bozin M, Thillainadesan T. Lisfranc fracture dislocation: a review of a commonly missed injury of the midfoot. Emerg Med J. 2017;34:52–56. doi: 10.1136/emermed-2015-205317.
23. Pirro M, Fabbriciani G, Leli C, Callarelli L, Manfredelli MR, Fioroni C, Mannarino MR, Scarponi AM, Mannarino E. High weight or body mass index increase the risk of vertebral fractures in postmenopausal osteoporotic women. J Bone Miner Metab. 2010;28:88–93. doi: 10.1007/s00774-009-0108-0.
24. Macmahon A, Kim P, Levine DS, Burket J, Roberts MM, Drakos MC, Deland JT, Elliott AJ, Ellis SJ. Return to sports and physical activities after primary partial arthrodesis for Lisfranc injuries in young patients. Foot Ankle Int. 2016;37:355–362. doi: 10.1177/1071100715617743.
25. Marín-Peña OR, Recio FV, Gómez TS, Garijo RL. Fourteen years follow up after Lisfranc fracture-dislocation: functional and radiological results. Injury. 2012;43(Suppl 2):S79–S82. doi: 10.1016/S0020-1383(13)70185-2.
26. Mustoe TA, O'Shaughnessy K, Kloeters O. Chronic wound pathogenesis and current treatment strategies: a unifying hypothesis. Plast Reconstr Surg. 2006;117(7 Suppl):35S0–41S. doi: 10.1097/01.prs.0000225431.63010.1b.
27. Myerson MS, Fisher RT, Burgess AR, Kenzora JE. Fracture dislocations of the tarsometatarsal joints: end results correlated with pathology and treatment. Foot Ankle. 1986;6:225–242. doi: 10.1177/107110078600600504.
28. Palma L De, Santucci A, Sabetta SP, Rapali S. Anatomy of the Lisfranc joint complex. Foot Ankle Int. 1997;18:356–364. doi: 10.1177/107110079701800609.
29. Pantalone KM, Hobbs TM, Chagin KM, Kong SX, Wells BJ, Kattan MW, Bouchard J, Sakurada B, Milinovich A, Weng W, Bauman J, Misra-Hebert AD, Zimmerman RS, Burguera B. Prevalence and recognition of obesity and its associated comorbidities: cross-sectional analysis of electronic health record data from a large US integrated health system. BMJ Open. 2017;7:e017583. doi: 10.1136/bmjopen-2017-017583.
30. Preidler KW, Wang YC, Brossmann J, Trudell D, Daenen B, Resnick D. Tarsometatarsal joint: anatomic details on MR images. Radiology. 1996;199:733–736.
31. Premaor MO, Pilbrow L, Tonkin C, Parker RA, Compston J. Obesity and fractures in postmenopausal women. J Bone Miner Res. 2010;25:292–297. doi: 10.1359/jbmr.091004.
32. Qiao Y Sen, Li JK, Shen H, Bao HY, Jiang M, Liu Y, Kapadia W, Zhang HT, Yang HL. Comparison of arthrodesis and non-fusion to treat Lisfranc injuries. Orthop Surg. 2017;9:62–68. doi: 10.1111/os.12316.
33. Quénu ÉAVA, Küsss G. Étude sur les luxations du métatarse (luxations métatarso-tarsiennes) du diastasis entre le 1 er et le 2 e métatarsien. F. Alcan, 1909.
34. Reinhardt KR, Oh LS, Schottel P, Roberts MM, Levine D. Treatment of lisfranc fracture-dislocations with primary partial arthrodesis. Foot Ankle Int. 2012;33:50–56. doi: 10.3113/FAI.2012.0050.
35. Renninger CH, Cochran G, Tompane T, Bellamy J, Kühn K. Injury characteristics of low-energy lisfranc injuries compared with high-energy injuries. Foot Ankle Int. 2017;38:964–969. doi: 10.1177/1071100717709575.
36. Riedel MD, Parker A, Zheng M, Briceno J, Staffa SJ, Miller CP, Kaiser PB, Wu JS, Zurakowski D, Kwon JY. Correlation of soft tissue swelling and timing to surgery with acute wound complications for operatively treated ankle and other lower extremity fractures. Foot Ankle Int. 2019;40:526–536. doi: 10.1177/1071100718820352.
37. Singh SK, George A, Kadakia AR, Hsu WK. Performance-based outcomes following Lisfranc injury among professional american football and rugby athletes. Orthopedics. 2018;41:e479–e482. doi: 10.3928/01477447-20180424-03.
38. Stødle AH, Hvaal KH, Enger M, Brøgger H, Madsen JE, Ellingsen Husebye E. Lisfranc injuries: incidence, mechanisms of injury and predictors of instability. Foot Ankle Surg. 2020;26:535–540. doi: 10.1016/j.fas.2019.06.002.
39. Thevendran G, Wang C, Pinney SJ, Penner MJ, Wing KJ, Younger ASE. Nonunion risk assessment in foot and ankle surgery. Foot Ankle Int. 2015;36:901–907. oi: 10.1177/1071100715577789.
40. Thorud JC, Mortensen S, Thorud JL, Shibuya N, Maldonado YM, Jupiter DC. Effect of obesity on bone healing after foot and ankle long bone fractures. J Foot Ankle Surg. 2017;56:258–262. doi: 10.1053/j.jfas.2016.11.010.
41. Vuori JP, Aro HT. Lisfranc joint injuries: trauma mechanisms and associated injuries. J Trauma. 1993;35:40–45. doi: 10.1097/00005373-199307000-00007.
42. Welck MJ, Zinchenko R, Rudge B. Lisfranc injuries. Injury. 2015;46:536–541. doi: 10.1016/j.injury.2014.11.026.
43. Wilppula E. Tarsometatarsal fracture-dislocation: late results in 26 patients. Acta Orthop. 1973;44:335–345. doi: 10.3109/17453677308988700.

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