THE EPIDEMIOLOGY, MANAGEMENT AND OUTCOME OF ACUTE FRACTURES IN TEAM SPORTS

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Declaration

This thesis and its composition are entirely my own work. The contributions and assistance of others in data collection and analysis have been appropriately acknowledged. I confirm that the work within this thesis and its composition is my own and that it has not been submitted for any other degree or professional qualification.

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Abstract

Introduction

Acute fractures are among the most serious injuries incurred by athletes. Of all sports, team sports cause the highest proportion of fracture injuries, accounting for up to 69% of all acute sport-related fractures.

Despite the importance of this injury type, the literature describing sport-related fractures has remained limited.

Aim

The aims were: to describe the epidemiology, management and outcome of acute team-sport related fractures, focussing on the three most common team sports in the Lothian region (football, rugby, hockey); and to ascertain if the outcome of these injuries can be optimised.

Methods

The thesis is based on a data-mining collective of six descriptive epidemiological papers and one retrospective cohort study, which: describes the epidemiology (Papers I, II, III, V, VI), management trends (Papers I, II, III, V, VI), outcome (Papers I, II, III) of team sport-related fractures (specifically football, rugby, hockey); and assesses whether the outcome of these injuries can be optimised through the judicious choice of management (Papers IV, VII).

Patients who experienced a sport-related fracture injury at the Edinburgh Orthopaedic Trauma Unit from the Lothian Population, over the time period January 1995 to December 2009, had pre-determined outcome variables recorded.

Outcomes comprised: patient demographic data; fracture demographic data; treatment selection data; sporting outcome by fracture type; and symptom-profile post fracture management.

Results

The incidence of football-related fractures was 0.71/1000 adult population; 0.28/1000 adult population for rugby-related fractures; and 0.04/1000 adult population for hockey-related fractures.

Within the adult population: 20% of football-related fractures were treated surgically; 17% of rugby-related fractures were treated surgically; 21% of hockey-related fractures were treated surgically.

Eighty-six percent of football-related fractures returned to football; 87% of rugby-related fractures returned to rugby; 89% of hockey-related fractures returned to hockey.

Primary surgical management of undisplaced unstable fractures (tibial diaphyseal fractures, scaphoid waist fractures) can improve return rates and return times to sport over conservative management.

Conclusion

This thesis provides the first comprehensive description of the epidemiology, management and outcome of acute team-sport related fractures in the current literature.

With a world-wide interest in sport, this data provides key clinical information on the management and prognosis of sport-related fractures, and serves as the most comprehensive resource on the topic at present.

Published papers upon which this thesis is based

The Epidemiology, Morbidity and Outcome of Soccer-Related Fractures in a Standard Population

Robertson GA, Wood AM, Bakker-Dyos J, Aitken SA, Keenan AC, Court Brown CM. Published in the American Journal of Sports Medicine. 2012 Aug; 40(8):1851-7.

Impact factor: 6.06

Citation Count: 30

Appendix I

Novel question: What is the incidence of football-related fractures within a standard adult population? Who is most likely to sustain these and what are the common fracture locations? What are the trends in management of these injuries? When can athletes expect to return to football following these?

Original finding: Within a standard adult population, the incidence of football-related fractures was 0.71 per 1000 population. These were most common in young (mean age, 27 years), male (98% male: 2% female) non-professional (95% non-professional: 5% professional) football players. 68% of the fractures were recorded in the in the upper limb, with 32% recorded in the lower limb: the most common fracture types were finger phalanx (21%), distal radius (20%) and ankle (13%). 80% of fractures were managed conservatively, with 20% managed surgically. From the cohort, the mean return rate to football was 86%; and the mean return time to football was 15 weeks.

The Epidemiology, Morbidity and Outcome of Fractures in Rugby Union from a Standard Population

Robertson GA, Wood AM, Heil K, Aitken SA, Court Brown CM.

Published in Injury 2014 Apr;45(4):677-83.

Impact factor: 2.20

Citation Count: 15

Appendix II

Novel question: What is the incidence of rugby-related fractures within a standard adult population? Who is most likely to sustain these and what are the common fracture locations? What are the trends in management of these injuries? When can athletes expect to return to rugby following these?

Original finding: Within a standard adult population, the incidence of rugby-related fractures was 0.28 per 1000 population. These were most common in young (mean age, 22 years), male (94% male: 6% female) non-professional (93% non-professional: 7% professional) rugby players. 83% of the fractures were recorded in the in the upper limb, with 17% recorded in the lower limb: the most common fracture types were finger phalanx (28%), metacarpal (19%) and clavicle (17%). 83% of fractures were managed conservatively, with 17% managed surgically. From the cohort, the mean return rate to rugby was 87%; and the mean return time to rugby was 16 weeks.

The Epidemiology, Management and Outcome of Field Hockey Related Fractures in a Standard Population

Robertson GA, Wood AM, Aitken SA, Court Brown CM.

Published in the Archives of Trauma Research 2017 Oct;6(4):76-81.

Impact factor: N/A

Citation Count: 0

Appendix III

Novel question: What is the incidence of field hockey-related fractures within a standard adult population? Who is most likely to sustain these and what are the common fracture locations? What are the trends in management of these injuries? When can athletes expect to return to field hockey following these?

Original finding: Within a standard adult population, the incidence of field hockey-related fractures was 0.04 per 1000 population. These were most common in young (mean age, 25 years), male (53% male: 47% female) non-professional (95% non-professional: 5% professional) field hockey players. 89% of the fractures were recorded in the in the upper limb, with 11% recorded in the lower limb: the most common fracture types were finger phalanx (42%), metacarpal (37%) and ankle (5%). 79% of fractures were managed conservatively, with 21% managed surgically. From the cohort, the mean return rate to field hockey was 89%; and the mean return time to field hockey was 11 weeks.

The Epidemiology, Management and Outcome of Sport-Related Ankle Fractures in a Standard UK Population

Robertson GA, Wood AM, Aitken SA, Court Brown CM.

Published in Foot and Ankle International 2014 Nov;35(11):1143-52

Impact factor: 2.65

Citation Count: 16

Appendix IV

Novel question: What is the incidence of sport-related ankle fractures within a standard adult population? Who is most likely to sustain these and what are the common causative sports? What are the trends in management of these injuries? When can athletes expect to return to sport following these? What is the optimal mode of management?

Original finding: Within a standard adult population, the incidence of sport-related ankle fractures was 0.19 per 1000 population. These were most common in young (mean age, 28 years), male (83% male: 17% female) non-professional (95% non-professional: 5% professional) athletes. The most common causative sports were football (51%) and rugby (16%). 54% of fractures were managed conservatively, with 46% managed surgically. From the cohort, the mean return rate to sport was 94%; and the mean return time to sport was 26 weeks. Ankle fractures suitable for conservative management had superior return rates (100% vs 87%) and return times (20 weeks vs 35 weeks) than those managed surgically.

The Epidemiology of Sports-Related Fractures in Adolescents

Wood AM, Robertson GA, Rennie L, Caesar BC, Court Brown CM.

Published in Injury 2010 Aug; 41(8):834-8.

Impact factor: 2.20

Citation Count: 37

Appendix V

Novel question: What is the incidence of sport-related fractures within a standard adolescent population? Who is most likely to sustain these? What are the common fracture locations? What are the common causative sports?

Original finding: Within a standard adolescent population, the incidence of sport-related fractures was 5.63 per 1000 population. These were most common in male (87% male: 13% female) non-professional (100% non-professional: 0% professional) athletes. 84% of the fractures were recorded in the in the upper limb, with 16% recorded in the lower limb: the most common fracture types were finger phalanx (29%), distal radius (23%) and metacarpal (13%). The most common causative sports were football (36%) and rugby (16%).

The Epidemiology of Open Fractures in Sport: One Centre's 15-year Retrospective Study

Wood AM*, Robertson GA*, MacLeod K, Porter A, Court Brown CM. (*Joint First Authors)

Published in the World Journal of Orthopaedics 2017 Jul 18;8(7):545-552.

Impact factor: 2.88

Citation Count: 2

Appendix VI

Novel question: What is the incidence of open sport-related fractures within a standard adult population? Who is most likely to sustain these? What are the common fracture locations? What are the common causative sports? What are the trends in management of these injuries?

Original finding: Within a standard adult population, the incidence of open sport-related fractures was 0.01 per 1000 population. These were most common in young (mean age, 29 years) male (83% male: 17% female) non-professional (98% non-professional: 2% professional) athletes. 59% of the fractures were recorded in the in the upper limb, with 40% recorded in the lower limb: the most common fracture types were finger phalanx (35%), tibial diaphysis (22%) and ankle (8%). The most common causative sports were football (22%) and rugby (11%). 45 (53%) fractures were Gustillo Grade 1; 28 (33%) fractures Grade 2; 8 (9%) fractures Grade 3a; and 4 (5%) fractures Grade 3b. Due to the nature of the injury, all fractures required surgical management: however only 8% of fracture required plastic surgical intervention.

The Management of Sport-Related Fractures: Operative versus Non-Operative Management

Robertson GA, Aitken SA, Wood AM.

Published in Trauma Monthly 2018 Jul;23(4):1-9.

Impact factor: 0.79

Citation Count: 0

Appendix VII

Novel question: What is the optimal method of treating sport-related fractures to maximise return rates and minimise return times and morbidity for athletes?

Original finding: Operatively managed fractures of the Ankle (42 weeks vs 22 weeks), Metacarpus (18 weeks vs 5 weeks) and Distal Radius (14 weeks vs 9 weeks) took longer to return to sport than non-operatively managed fractures; while operatively managed fractures of the Tibial Diaphysis took shorter to return to sport (35 weeks vs 45 weeks). However, operatively managed fractures consistently showed increased rates of post-operative symptoms compared to non-operatively managed fractures: Ankle (57% vs 22%), Tibial Diaphysis (89% vs 50%), Scaphoid (80% vs 60%), Clavicle (50% vs 31%), Metacarpus (67% vs 40%) and Distal Radius (50% vs 18%).

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b) Meta-Analysis Comparison of Return Times to Sport for Conservative versus Surgical Management of Metacarpal Fractures

Abbreviations

AO	Arbeitsgemeinschaft fur Osteosynthesefragen
CRISP-DM	Cross Industry Standard Process for Data Mining
Ex-Fix	External Fixation
F	Female
FIFA	The Federation Internationale de Football Association
IM Nail	Intra-Medullary Nail
IOC	The International Olympic Committee
K-Wire	Kirschner Wire
M	Male
MOI	Mechanism of Injury
MUA	Manipulation under Anaesthetic
NCAA	National Collegiate Athletic Association
NHS	National Health Service
ORIF	Open Reduction Internal Fixation
PA	Pronation-Abduction
PER	Pronation External Rotation
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised controlled trial
SA	Supination Adduction
SD	Standard Deviation
SEMMA	Sample Explore Modify Model Assess
SER	Supination External Rotation
UEFA	The Union of European Football Associations
UK	United Kingdom
US	United States of America
YR	Year

Chapter One: Background

Section One: General Introduction

1.1 The evolution of this commentary into determining the epidemiology, management and outcome of acute fractures in team sports

The Edinburgh Orthopaedic Trauma Unit is a single Orthopaedic Centre for a fixed population of 517,555 people(1). This allows clear demographic data on orthopaedic trauma injuries to be collected and analysed (2-4).

The researchers in the Edinburgh Orthopaedic Trauma Unit have collated a number of prospective databases recording information on fracture epidemiology(2-9). Within these databases, fractures are labelled by their mode of injury: this has allowed sport-related fractures to be cohorted for analysis(10, 11).

The author of this thesis has focussed on sport-related fractures, to determine their epidemiology, establish trends in their management, and define their outcome. Within this research, there has been a focus on team-related sports, given their significant role in modern society(12-16). From the collation of the published papers, it has been possible to provide a structured narrative on the Epidemiology, Management and Outcome of Acute Fractures in Team Sports within the Lothian Population.

1.2 Background

Between one and sixteen percent of all sporting injuries are acute fractures(17-37), and ten percent of all acute fractures are sport-related(10). However, research and the associated literature on acute fractures in sport remains limited(10, 38). The reasons for this are multi-fold, and include difficulties in achieving follow-up of these injuries, variations in geographical trauma care often preventing orthopaedic trauma centres from providing accurate epidemiological information of such injuries, and limited funding for fracture research(2, 10, 39).

The lack of information on these injuries is a significant oversight in the current scientific literature(38).

Until the late 2000s, research on this topic was limited to cohort studies, focussing either on specific fracture types(40-43), representing fractures as a sub-cohort of sporting injuries(18-27, 30, 44, 45), or providing a heterogeneous cohort of sport-related fractures(46).

The first comprehensive overview of sport-related fractures in the adult recorded an incidence of 1.42 per 1000 in the Lothian population, and found sport-related fractures comprised 13% of all fractures(10). The authors found the most common causative sports were football, rugby, skiing, snowboarding, hockey and basketball; and the most common fracture types were finger phalanx, distal radius, metacarpus, clavicle, ankle and carpus(10). Of the 761 recorded fractures, 69% (n=526) occurred during team sports, with the three most common team sports being football, rugby and hockey(10).

An overview of sport-related fractures in the paediatric patient (0-16 years) also recorded an incidence of 2.44 per 1000 in the Lothian population, and found sport-related fractures comprised 12% of all paediatric fractures(3). They found the most common causative sports were football, rugby, skiing, basketball, snowboarding and sledging; and the most common fracture types were finger phalanx, distal radius, clavicle, metacarpus and tibial diaphysis(3).

Similar to this, Swenson et al (2010) reported on the Epidemiology of US High School Sports-Related fractures from 2005 to 2009(29). From an estimated population of 7.5 million, 568 177 fractures were recorded(29). The most common causative sports were American Football, football, volleyball and basketball(29). The most common fracture sites were hand/finger (28.3%), wrist (10.4%), lower leg (9.3%), forearm (8.2%) and foot/toe (7.4%)(29).

Court Brown et al (2012) provided a brief synopsis of open sport-related fractures in the adult(4). Within the Lothian population, 3.6% of all open fractures occurred due to sports, recording 85 sport-related open fractures over a 15-year period(4). The average age of incidence was 29.2 years and the gender ratio was 82:18 (male:female)(4). The most common fracture types were Finger phalanges, Tibia Diaphysis and Ankle(4). Fourteen percent of the fractures were Gustillo Type III (severe soft tissue injury damage)(4).

However, none of these studies provided an in-depth analysis of team-sport related fractures, nor did they provide information on management and outcome of these injuries(3, 4, 10, 29).

1.3 Fractures in Team Sport: Epidemiology

1.3.1 General

Team sports comprise 15% of recorded sporting activity in the adult UK population and 84% in the adolescent UK population(47, 48). Despite the low proportional participation in the adult population, team sports account for 69% of all adult (acute) fractures sustained during sports(10), and 60% of all adolescent (acute) fractures sustained during sports(11).

The study by Court Brown et al (2008) provided the first comprehensive insight into the epidemiology of team sport-related fractures in a UK population(10). Using a prospective database, which charted all adult sport-related fractures in the Lothian population in 2000, the authors recorded of a total of 761 sport-related fractures over the one year study period, of which 526 occurred during team sports(10). The main causative team sports were: football, rugby, hockey, basketball and cricket; with the three most common team sports (football, rugby, hockey) comprising 90% of all team sport-related fractures(10). However, the incidence of fracture types within each sport was not described, nor was data provided on the management and outcome of these injuries(10).

Rennie et al (2007) also provided a brief overview of team-sport related fractures in the paediatric patient (0-16 years)(3). Using a retrospective database, which charted all paediatric fractures in the Lothian population in 2000, the authors recorded of a total of 2198 fractures, of which 266 were sports-related(3). The most common causative team sports were football (32% of fractures), rugby (12% of fractures) and basketball (5% of fractures), with these three sports comprising half of all sport-related fractures(3). Further information on team sports was not provided(3).

1.3.2 Football

Reports from the English Football Association, the UEFA Champions League Injury Study, the Football World Cup, FIFA, and the Olympic Games have found that fractures comprise 1-6% of all football-related injuries(18, 31-37, 44, 45). In a number of studies recording the incidence of sport-related fractures, football has been found to be the most common causative sport, both within UK and Asia populations, accounting for 45 to 63% of all sport-related fractures(10, 46). The exception to this is the US, where American Football has been found to be the most common cause of sport-related fracture: football, however, is the second commonest cause, accounting for 13% of all sport-related fractures(28).

Regarding the epidemiology of adult football-related fractures, previous studies have found these to occur at an incidence of 0.64 per 1000 population within the UK population(10). From this data, the mean age of occurrence of this injury type was 25.6 years, the male:female ratio was 96:4, and the upper limb:lower limb ratio was 66:34(10). The three most common fracture locations recorded were distal radius (19%), finger phalanx (18%) and ankle (11%)(10).

Regarding specific fracture types, Court Brown et al (1995) found that, within the Lothian population, 80% of all sport-related tibial fractures were sustained during football, with football-related tibial diaphyseal fractures accounting for 25% of all tibial diaphyseal fractures(5, 49). Data from other epidemiology studies from the Lothian population have found that football accounts for 50% of all sport–related distal radial fractures(50), 75% of all sport-related ankle fractures(6), 33% of all sport-related clavicle fractures(7), 44% of all sport-related carpal fractures(51), 33% of all sport-related metacarpal fractures(51) and 36% of all sport-related finger phalanx fractures(51).

Previous studies investigating the epidemiology of paediatric football-related fractures (0-16 years) have found these to occur at an incidence of 0.77 per 1000 population within the UK population(3). From this data, the mean age of occurrence of this injury type was 12.6 years, the male:female ratio was 94:6, and the upper limb:lower limb ratio was 75:25(3). Data on the epidemiology of football-related adolescent fractures(28, 29) and football-related open fractures(4) remains limited.

1.3.3 Rugby

Reports from the Scottish Rugby Union, the English Rugby Union and the Rugby World Cup have found that fractures comprise 3-14% of all rugby-related injuries (19-25, 52). In a number of studies recording the incidence of sport-related fractures, rugby has been found to be one of most common causative sports, both within UK (2nd most common) and Asia (4th most common) populations, comprising 4 to 15% of all sport-related fractures(10, 46).

Regarding the epidemiology of adult rugby-related fractures, previous studies have found these to occur at an incidence of 0.21 per 1000 population within the UK population(10). From this data, the mean age of occurrence of this injury type was 22.1 years, the male:female ratio was 94:6, and the upper limb:lower limb ratio was 85:15(10). The three commonest fracture locations were finger phalanx (26%), metacarpus (23%) and clavicle (19%)(10).

For specific fracture types, epidemiological cohort studies from the Lothian population have found that rugby accounts for 7% of all sport–related distal radial fractures(50), 11% of all sport-related ankle fractures(6), 39% of all sport-related clavicle fractures(7), 13% of all sport-related carpal fractures(51), 21% of all sport-related metacarpal fractures(51) and 16% of all sport-related finger phalanx fractures(51).

Regarding the epidemiology of paediatric rugby-related fractures (0-16 years), previous studies have found this injury type to occur at an incidence of 0.30 per 1000 population within the UK population(3). From this data, the mean age of occurrence was 13.5 years, the male:female ratio was 97:3, and the upper limb:lower limb ratio was 76:24(3). Data on the epidemiology of rugby-related adolescent fractures(28, 29) and football-related open fractures remains(4) limited.

1.3.4 Hockey

Reports from the National Collegiate Athletic Association (NCAA) and the Canadian Hockey Leagues have found that fractures comprise 15 to 16% of all field hockey-related injuries(26, 27), with fractures comprising 44% of all hand injuries, and 61% of all hand fractures involving the phalanges(53). In a number of studies recording the incidence of sport-related fractures, hockey has been found to be the fifth, seventh and eighth most common causative sport, within UK, Asia and US populations respectively, accounting for 2 to 3% of all sport-related fractures(10, 28, 46).

Regarding the epidemiology of adult hockey-related fractures, previous studies have found these to occur at an incidence of 0.05 per 1000 population within the UK population(10). From this data, the mean age of occurrence of this injury type was 25.0 years, the male:female ratio was 60:40, and the upper limb:lower limb ratio was 100:0(10). The three most common fractures recorded were Finger Phalanx (48%), Metacarpus (24%) and Clavicle (16%)(10).

Regarding specific fracture locations, epidemiological cohorts from the Lothian populations have found that hockey accounts for 3% of all sport-related carpal fractures(51), 6% of all sport-related metacarpal fractures and 7%(51) of all sport-related finger phalanx fractures(51).

Data on the epidemiology of hockey-related paediatric fractures(3), hockey-related adolescent fractures(28, 29) and football-related open fractures(4) remains limited.

1.4 Fractures in Team Sports: Management

1.4.1 General Principles of Orthopaedic Trauma

Fracture management concords with the established principles of orthopaedic trauma osteosynthesis which comprises accurate fracture reduction, stable fracture immobilisation and timely rehabilitation(39). The exact management of the fracture injury is dependent on three main factors: the location of the fracture (upper limb or lower limb; the location of the fracture within the affected bone), the nature of the fracture (undisplaced or displaced; comminuted or non-comminuted; intra-articular or extra-articular) and the functional level of the patient involved(39). A combined analysis of these three factors allows fracture management to be stratified into conservative (non-operative) management and surgical (operative) management(39).

With regards to fractures in the athletic patient, undisplaced fractures can be further differentiated by the ‘stability’ of the fracture (i.e. the likelihood of delayed displacement) (38): some undisplaced fractures are deemed inherently stable (Weber A ankle fractures) and can be rehabilitated immediately with no concern of further fracture displacement; other undisplaced fractures are deemed potentially unstable (tibial diaphyseal fractures, scaphoid waist fractures), and immobilisation is accompanied by protective restrictions to reduce the risk of fracture displacement, postponing the commencement of rehabilitation(38).

1.4.2 Conservative Management

As a general rule, most undisplaced fractures in the athletic patient can be considered for conservative management(38, 39). The exceptions to this are undisplaced proximal femoral and neck of femur fractures, which are routinely fixed to avoid the requirement for prolonged bed rest and allow for early mobilisation(39, 54). There are also certain ‘unstable’ undisplaced fracture types, which can be considered for primary surgical fixation in the athletic patient to facilitate early rehabilitation and avoid the adverse effects of prolonged immobilisation: these include undisplaced tibial diaphyseal fractures, undisplaced scaphoid waist fractures and undisplaced fifth metatarsal ‘Jones’ fractures(38). The significant proportion of undisplaced fractures in the athletic patient are, however, managed conservatively(38, 39).

Most displaced fractures in the athletic patient are not suitable for conservative management, given the close relationship between anatomical reduction and functional outcome in the highly active individual(38, 39). The exception to this are displaced middle-third clavicle fractures, which can often unite and provide satisfactory functional outcome with conservative management(38, 39, 55, 56).

Displaced extra-articular non-comminuted fractures, predominantly of the upper limb (distal radius, finger phalanx, metacarpal), can be considered for closed reduction (manipulation under anaesthetic) and casting with serial follow-up to assess for maintenance of satisfactory fracture alignment(38, 39). This treatment method is considered to be non-surgical(38, 39).

1.4.3 Surgical Management

As a general rule, most displaced fractures require surgical management(38, 39). The exceptions to this are discussed in 1.4.2.

Undisplaced fractures which are routinely fixed include the undisplaced proximal femoral and neck of femur fractures(39, 54). There are also certain 'unstable' undisplaced fracture types (tibial diaphyseal, scaphoid waist and fifth metatarsal 'Jones' fractures), which can be considered for primary surgical fixation in the athletic patient to facilitate early mobilisation and avoid the adverse effects of prolonged immobilisation(38).

The main surgical techniques available are: Manipulation under Anaesthetic (MUA) and Kirschner Wiring; Percutaneous Reduction and Internal Fixation; Open Reduction and Internal Fixation; Intra-Medullary Nail Fixation; and External Frame Fixation(39).

The choice of surgical fixation is guided by the location and nature of the fracture: however, this can also vary based on surgeon preference, operator expertise and resources available in certain centres(39).

1.5 Fractures in Team Sports: Outcome

The literature on the outcome of team sport-related fractures remains limited(38).

The available studies comprise either generalised cohorts of sporting injuries, of which fractures form a sub-cohort, or specific sport-related fracture cohorts(38).

1.5.1 Football

Of the available cohorts of football-related injuries, data from UEFA has found that, from 16 football-related fractures, prospectively recorded from eleven top clubs in five European countries, throughout the season of 2001–2002, 1 was classified as a slight injury (≤ 3 day absence from sport), 1 as a minor injury (4-7 days absence from sport), 3 as moderate injuries (8-28 days absence from sport) and 11 as major injuries (>28 days absence from sport)(44).

Of the fracture type cohorts, Lawson et al (1995) found that from 65 football-related distal radial fractures, 53 (82%) returned to pre-injury level football at follow-up(50). Boden et al (1999) found that from 26 football-related tibial diaphyseal fractures (with 16 treated conservatively and 10 treated with IM Nail), 25 (96%) returned to football at mean time of 38 (8-130) weeks(57). Chang et al (2007) found that from 24 football-related tibial diaphyseal fractures (with 11 treated conservatively, 11 with IM Nail, and 2 with ORIF), the mean return time to sport was 25 weeks, with mean return times of 28 weeks for conservative management and 23 weeks for surgical management(58). Fankhauser et al (2004) found that from 20 football-related tibial diaphyseal fractures (all treated with IM Nail), 14 (70%) returned to football at a mean of 40.9 (22-103) weeks(59). Shaw et al found (1997) that from 74 football-related tibial diaphyseal fractures (with 29 treated conservatively, 24 with IM Nail, 8 with External Fixation, and 13 with treatment type not documented), 69 (93%) returned to football at mean of 40 weeks, with mean return times of 48 weeks for those treated with IM Nail and 55 weeks for those with External Fixation(49). Hens et al (1990) found that from 10 surgically-treated football-related fifth metatarsal (Jones) fractures, 10 (100%) returned to pre-injury level football at mean of 3 months post-procedure(60).

1.5.2 Rugby

Of the available cohort studies on rugby-related injuries, data from the English Premiership Rugby Union, during the seasons 2002-2004, has found that: lateral malleolar fractures took a mean of 118 days to return to rugby(61); patella fractures a mean of 74 days to return(62); arm fractures a mean of 62 days to return(24); hand and wrist fractures a mean of 43 days to return(24); and foot fractures a mean of 44 days to return(24).

Garraway et al (1995) from the Scottish Rugby Union, during the season 1993-1994, found that rugby-related upper limb fractures (n=21) took a mean of 55.8 days to return to rugby, and rugby-related lower limb fractures (n=9) took a mean of 112.8 days to return to rugby(19).

Kerr et al (2008) found that from the Collegiate Rugby Union Leagues in New England, USA, during the season 2005-2006: male players sustained 36 match-related fractures, of which 3 required ‘no time’ off sport, 5 required ‘1 to 7 days’ off sport, and 28 required ‘over 7 days’ off sport; and female players sustained 50 match-related fractures, of which 2 required ‘no time’ off sport, 12 required ‘1 to 7 days’ off sport and 36 required ‘over 7 days’ off sport(63).

1.5.3 Hockey

The only study which provides outcome data for hockey-related fractures is that by Dick et al (2007)(27). From a cohort of female hockey players from the NCAA in the USA, during the seasons 1988–1989 to 2002–2003, the authors recorded 56 game-related finger fractures (6.5% of all injuries), of which 17 were recorded as severe injuries (return time greater than 10 days)(27).

1.6 Fractures in Team Sports: Optimising Outcome

Until recently, limited attention has been paid to the topic of individualising the management of sport-related fractures, in order to provide athletes with the opportunity to return to sport as rapidly as possible, with the lowest morbidity possible(38). For the main part, the management of sport-related fractures concords to the standard principles of orthopaedic trauma as discussed above(38, 39). However, in certain cases, it is being recognised that deviations from this, can, in certain cases, facilitate an earlier return to sport(38). These are as follows:

1) Primary surgical management of undisplaced unstable fractures (undisplaced tibial diaphyseal fractures, undisplaced scaphoid waist fractures, undisplaced fifth metatarsal (Jones) fractures) to facilitate return to early weightbearing with the affected limb, avoiding the need for post-treatment immobilisation and facilitating an accelerated return to sport(38, 43, 64).
2) The judicious selection of surgical treatments, where one method enables an earlier return to activities compared to the other e.g. the use of ORIF over MUA and K-Wire for hand metacarpal fractures(38, 65).
3) Primary surgical management of displaced fractures which are routinely managed with conservative management (e.g. displaced middle third clavicle fractures)(38, 66). This provides immediate stable fixation of the fracture site, to facilitate an earlier return to sporting activities(38, 66).

The available evidence for each of these scenarios is analysed by systematic review and meta-analysis in the results section of the thesis.

1.7 Injury Surveillance in Sport

1.7.1 General Principles and Methods

Injury Surveillance in Sport is the process of ongoing and systematic collection of sports injury data, with its associated analysis, interpretation, dissemination and subsequent public health response(17, 67-69).

The aims of injury surveillance systems in sports are to: detect trends in incidence; identify risk factors and causes; develop preventive and control measures; and evaluate the impact of prevention(17, 67-69).

Such systems can capture data from all active players within their targeted population, or can record injury data from a convenience sample or random stratified sample of their target population(67).

Injury surveillance in sport is often performed in the sports environment, with only a limited proportion of athletes requiring formal hospital assessment and treatment for their injury(17, 67-69). As such, the definition of what constitutes an injury in the sporting environment is a key factor in this process, in order to consistently record the relevant events(17, 67-69). Some surveillance systems employ injury definitions relating to time loss from participation in sport, other systems use definitions relating to the requirement of medical-attention, and some systems use both definitions(17, 67-69).

Similarly, the personnel who detect and confirm these injuries is another key factor in this process, as their training, medical knowledge and experience can vary, often influencing the diagnoses(17, 67-69). Some systems utilise team doctors and physiotherapists to record such data, while other use certified athletic trainers or non-medically trained technical personnel(17, 67-69).

These issues have been addressed by consensus statements to specify the recommended methods and modalities to collect such data collection(68, 69).

There are 15 official active injury surveillance systems in sport(67). Eleven of these record data on elite or professional athletes, and four record data on non-professional athletes(67). The sports covered by each of the systems comprise: football (n=3); rugby (n=1); American Football (n=1); Australian Football (n=1); baseball (n=1); skiing and snowboarding (n=1); cricket (n=1); and multiple sports (n=6) (67). Seven of the systems define injury by time loss from sport; three systems define injury by the requirement for medical-attention; two systems define injury by both time loss and medical attention; and two systems record all occurring injuries(67). Injury data is recorded by: team doctors or physiotherapists in eight systems; certified athletic trainers in six systems (all US based); and non-medically trained technical personnel in one system(67).

All types of sports injury are included in these systems, ranging from muscle sprains to head injury(23, 24, 27-29, 31, 34, 36, 37, 67, 70, 71). Fracture data is often provided as a sub-cohort of injuries(23, 24, 27-29, 31, 34, 36, 37, 70, 71). While fracture injuries have a definite method of diagnosis (radiological imaging), many of these programmes record ‘fracture’ cohorts, which combine acute and stress fractures, and combine fractures from all body regions (i.e. grouping facial fractures with limb fractures)(23, 24, 27-29, 31, 34, 36, 37, 70-72). Thus, analysis of the acute orthopaedic-relevant fracture data can be difficult(23, 24, 27-29, 31, 34, 36, 37, 70-72).

1.7.2 Injury Surveillance in Football.

There are three active injury surveillance programmes, specifically focussed on football: the UEFA Champions League Injury Study(34); the FIFA surveillance system(36, 37); and the Norwegian professional football league (Tippeligaen) surveillance system(73).

There are three other active surveillance programmes which record football injuries, as part of multiple sport surveillance programmes: the IOC injury surveillance system for multi-sports events(31, 68); the National High School Sports- Related Injury Surveillance System(28, 29, 70); and the NCAA Injury Surveillance System(71).

Fracture-related injury data is reported by all the systems(27-29, 31, 34, 36, 37, 68, 70, 71, 73).

1.7.3 Injury Surveillance in Rugby

This is one active injury surveillance programme, specifically focussed on rugby: the England Professional Rugby Injury Surveillance Project(23, 24).

There is also a programme which records rugby injuries, as part of a multiple sport surveillance programme: the IOC injury surveillance system for multi-sports events(23, 24, 31, 68).

Fracture-related injury data is reported by all the systems(31, 68).

1.7.4 Injury Surveillance in Hockey

There are three active injury surveillance programmes, which record hockey injuries, as part of multiple sport surveillance programmes: the IOC injury surveillance system for multi-sports events(31, 68); the National High School Sports- Related Injury Surveillance System(28, 29, 70); and the NCAA Injury Surveillance System(27, 71).

Fracture-related injury data is reported by all the systems(27-29, 31, 68, 70, 71).

Section Two: Research Question and Aims

1.7 Research question

Generic Question:

What is the Epidemiology, Management and Outcome of Team Sport-Related Fractures in Lothian Population – focussing on the three main team sport in the region (football, rugby, hockey)?

Specific Questions:

1) a) What is the epidemiology of acute fractures in the adult Lothian population in the three main team sports?

   b) What is the epidemiology of acute fractures in the adolescent Lothian population in the three main team sports?

   c) What is the epidemiology of acute open fractures in the adult Lothian population in the three main team sports?

2) a) What are the management trends for the acute fractures in the adult Lothian population in the three main team sports?

   b) What are the management trends for the acute fractures in the adolescent Lothian population in the three main team sports?

   c) What are the management trends for the acute open fractures in the adult Lothian population in the three main team sports?

3) What is the sporting outcome for the acute fractures in the adult Lothian population in the three main team sports?

4) Can the management of acute sport-related fractures be adjusted to improve the outcome for patients?

1.8 Aims

1. The principle aim of the thesis was to define the epidemiology, management and outcome of acute team-sport related fractures in the three most common causative team sports (football, rugby, hockey) in the Lothian Population.
2. For the ‘Epidemiology’ section, the aims were: to provide an overview of the incidence of acute fractures from each of the three sports in the adult and adolescent populations in the Lothian region; and to provide an overview of the incidence of open fractures from each of the three sports.
3. For the ‘Management’ section, the aims were: to provide an overview of the management of acute fractures from each of the three sports in the adult and adolescent populations in the Lothian region; and to provide an overview of the management of open fractures from each of the three sports.
4. For the ‘Outcome’ section, the aim was: to provide an overview of the outcome of acute fractures from each of the three sports in the adult population in the Lothian region.
5. For the ‘Optimising Outcome’ section, the aim was: to assess the effect of treatment selection on the outcome of these injuries. This was to be performed: through cohort analysis of the outcome data for the five fractures types with the highest rates of surgical intervention (ankle, tibial diaphysis, clavicle, scaphoid, metacarpal); in conjunction with systematic review and meta-analysis of the available literature on the topic.

Chapter Two: Methods

2.1 Methodology

The thesis is divided into four parts, each of which has a different research design: the ‘Epidemiology’ section, the ‘Management’ section, the ‘Outcome’ section and the ‘Optimising Outcome’ section.

The ‘Epidemiology’ section is formed from the adult, adolescent and open fracture databases. The research data is obtained from retrospective review of the prospectively collated databases. The research data provides comprehensive epidemiological information of all adult fractures, adolescent fractures and open fractures sustained during football, rugby and hockey in the Lothian Population over the relevant time periods.

The ‘Management’ section is formed from the adult, adolescent and open fracture databases. The research data is obtained from retrospective review of the patient case notes, as well as from retrospective review of the prospectively collated databases. The research data provides comprehensive information on the management techniques employed for the adult, adolescent and open fractures sustained during football, rugby and hockey in the Lothian Population over the relevant time periods.

The ‘Outcome’ section is formed from the adult fracture database. The research data is obtained from telephone questionnaire follow-up of the patients. The research data provides comprehensive information on the outcome of all adult fractures sustained during football, rugby and hockey in the Lothian Population over the relevant time period.

The ‘Optimising Outcome’ section is formed through retrospective cohort comparative analyses of the Outcome Data. This focuses specifically on the five fracture types with the highest rates of surgical intervention (Ankle Fractures, Tibial Diaphyseal Fractures, Clavicle Fractures, Scaphoid Fractures and Metacarpal Fractures), to assess the variations in outcome between conservative and surgical management for these injuries. These retrospective cohort comparative analyses are supplemented by systematic review and meta-analysis of the available literature, which reports on return to sport for the five fracture types.

During the time periods of the thesis, all recorded rugby fractures occurred during rugby union, and all recorded hockey fractures occurred during field hockey. Thus the sporting terms are used interchangeably throughout the thesis and the papers.

The aim of the first two sections of the thesis was to define the epidemiology and management of acute team-sport related fractures within the Lothian Population. Given the nature of this information, it was felt best to use descriptive epidemiology studies (i.e. observational studies) to obtain this. These studies employed a combination of prospective database collations, followed by retrospective database review and data-mining.

The aim of the third section of the thesis was to define the outcome of team-sport related fractures within the adult Lothian Population. This required collection of the relevant follow-up information, and, given the resources available and the sizes of the cohorts involved, this was felt best performed through telephone questionnaires.

Lastly, the aim of the fourth section was to perform analysis of the outcome data, through cohort analysis, to provide information on the optimal management methods for these fractures. Given the nature of this information, it was felt best to present this through an observational analytic cohort study.

The gold standard method of comparing the outcome of different treatment methods is through randomised control trial. However, due to the limited numbers within the study cohorts and the retrospective nature of the review process, this was not possible. The data presented in the included study provides an insight into the value of certain treatment processes for fracture management in the athletic patient, providing direction for future research. Future randomised controlled trails are to be recommended in this area. To further strengthen the quantity and quality of evidence on this topic, the authors supplemented their observational analytical cohort study with systematic review and meta-analysis of the available literature in this field. The authors adhered to the PRISMA guidelines when performing these reviews, maximising the quality of the analysis process and limiting the effects of study heterogeneity on the overall results. This enabled optimisation of the quantity and quality of outcome data in this area, providing the most comprehensive contemporary conclusions on the optimal methods for managing these injuries.

2.2 Study Design

2.21 Descriptive Epidemiology Studies

Paper I: The Epidemiology, Morbidity and Outcome of Soccer-Related Fractures in a Standard Population.

Paper II: The Epidemiology, Morbidity and Outcome of Fractures in Rugby Union from a Standard Population.

Paper III: The Epidemiology, Management and Outcome of Field Hockey Related Fractures in a Standard Population.

Paper IV: The Epidemiology, Management and Outcome of Sport-Related Ankle Fractures in a Standard UK Population.

Study Design: For each of these four papers: the epidemiology section was formed through retrospective review of a prospectively collated database; the management section was formed through retrospective review of patient case notes; the outcome section was formed through telephone questionnaire follow-up of the patients.

Paper V: The Epidemiology of Sports-Related Fractures in Adolescents

Study Design: For this paper, the epidemiology and management sections were formed through retrospective review of a prospectively collated database.

Paper VI: The Epidemiology of Open Fractures in Sport: One Centre's 15-year Retrospective Study

Study Design: For this paper: the epidemiology section was formed through retrospective review of a prospectively collated database; and the management section was formed through retrospective review of patient case notes.

2.22 Retrospective Comparative Cohort Study.

Paper VII: The Management of Sport-Related Fractures: Operative versus Non-

Operative Management

Study Design: The data from this paper was formed through a combination of retrospective review of a prospectively collated database, retrospective review of patient case notes, and telephone questionnaire follow-up of patients. The data was stratified into the relevant cohorts, allowing retrospective cohort comparisons to be made.

2.3 Databases (Figure 1)

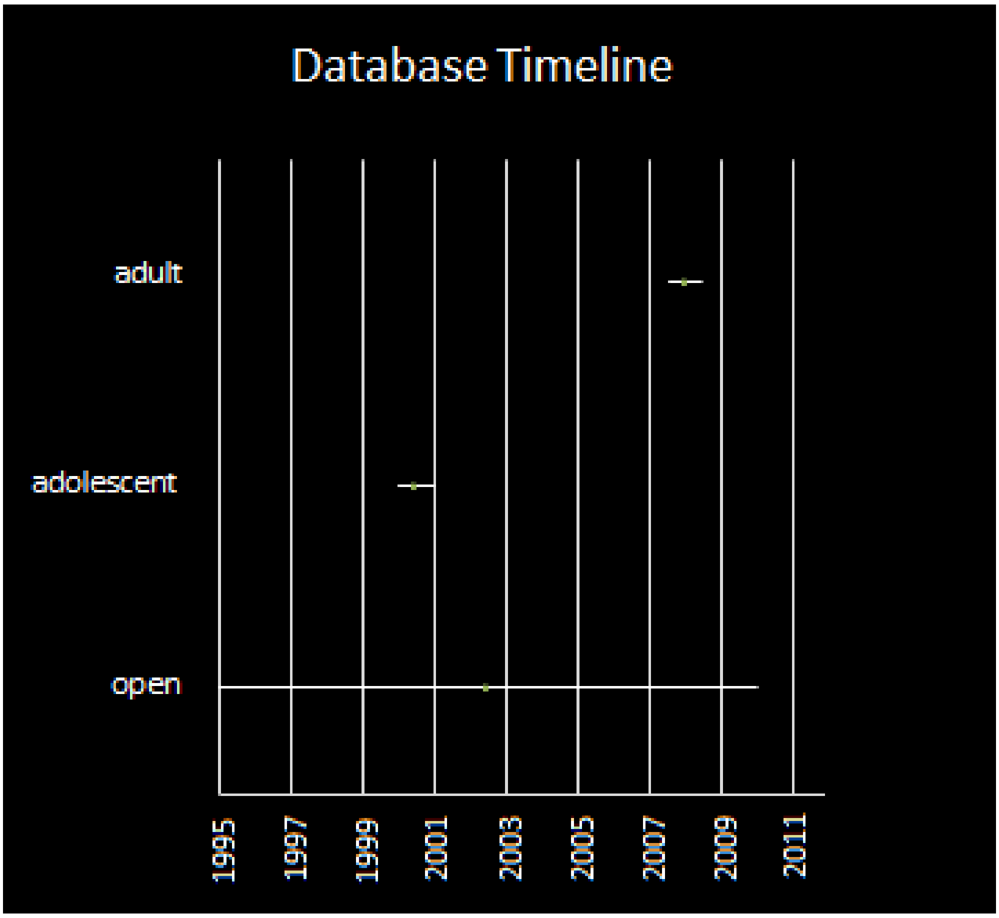
The data for the thesis papers was obtained from three prospective databases, which recorded epidemiological fracture data from the Edinburgh, Mid-Lothian and East Lothian Populations (collectively termed the Lothian Population). This population is covered by a unified Orthopaedic Service, which covers both the adult and the paediatric populations. The adult patients are treated at the Edinburgh Orthopaedic Trauma Unit, Royal Infirmary of Edinburgh. The paediatric patients are treated at the Royal Hospital for Sick Children, Edinburgh. This set-up allows accurate capture of the fracture epidemiology data for the region. The databases were set-up and managed by the SORT-IT Research Team under the leadership of Professor Charles Court Brown. Each of the databases represent the most recent data for the relevant populations in our region.

The adult data was obtained from a prospective database which recorded all sport-related fractures in the Adult (age 15+) Lothian Population (Edinburgh, Mid-Lothian and East-Lothian) from July 2007 to June 2008. The person count from this population, over the designated study period, as per the General Register Office for Scotland, was 517 555(1). This database recorded a total of 6871 adult fractures over the one-year study period. Of these, 992 were sport-related fractures (occurring in 990 patients), of which 572 were team-sport related fractures (occurring in 570 patients).

The adolescent data was obtained from a prospective database which recorded all sport-related fractures in the Adolescent (age 10-19) Lothian Population (Edinburgh, Mid-Lothian and East-Lothian) from January 2000 to December 2000. The person count from this population, over the designated study period, as per the General Register Office for Scotland, was 72 405(74). This database recorded a total of 1707 adolescent fractures over the one-year study period. Of these, 408 were sport-related fractures (occurring in 406 patients), of which 244 were team-sport related fractures (occurring in 242 patients).

The open fracture data was obtained from a prospective database which recorded all sport-related open fractures in the Adult (age 15+) Lothian (Edinburgh, Mid-Lothian and East-Lothian) Population from January 1995 to December 2009. The mean annual person count from this population, over the designated study period, as per the General Register Office for Scotland, was 539 858(75). A prolonged database was required for this cohort, as the incidence of sport-related open fractures is low, thus data from several years was necessary to provide appreciable numbers. This database recorded a total of 2386 adult open fractures over the fifteen-year study period. Of these, 85 were sport-related fractures, (occurring in 84 patients), of which 43 were team-sport related fractures (occurring in 42 patients).

Figure 1 – Timeline for the Three Databases used in the Thesis (Adult / Adolescent / Open Fractures)



2.4 Outcome Measures

The Outcome Measures used in each of the Papers are presented in Table 1.

Table 1: Outcome Measures used in Thesis

Outcome Measure	Definition	Database	Papers
Return Rates to Sport	The number of fractures who returned to sport / The total number of fractures	Adult	I,II,III,IV,VII
Return Rates to Pre-Injury Level Sport	The number of fractures who returned to pre-injury level sport / The total number of fractures	Adult	I,II,III,IV,VII
Return Times to Training	The time taken to return to a training level of sport, recorded in weeks post-fracture.	Adult	I,II,III,IV,VII
Return Times to Play	The time taken to return to full level sport, recorded in weeks post-fracture.	Adult	I,II,III,IV,VII
Persisting Symptoms	The presence of symptoms related to the fracture site at the time of follow-up.*	Adult	I,II,III,IV,VII
Persisting Symptoms Impairing Sporting Ability	The presence of symptoms related to the fracture site which impaired sporting ability at the time of follow-up.*	Adult	I,II,III,IV,VII

*(symptom categories comprised: fracture site pain; associated joint stiffness; metalwork related pain; scar related pain; nerve related symptoms; weakness; loss of tendon function; malalignment; psychological)

2.5 Data Collection

2.51 Database Set-Up

The data for the Adult Fracture Database was prospectively collated by the SORT-IT Research Team from July 2007 to June 2008 at the Edinburgh Orthopaedic Trauma Unit. This data was collected from all patients aged 15 and above who sustained an acute fracture in the Lothian Population from July 2007 to June 2008.

The data for the Adolescent Fracture Database was prospectively collated by the SORT-IT Research Team from January 2000 to December 2000 at the Edinburgh Orthopaedic Trauma Unit and the Royal Hospital of Sick Children Edinburgh. This data was collected from all patients aged 10 to 19 who sustained an acute fracture in the Lothian Population from January 2000 to December 2000.

The data for the Open Fracture Database was prospectively collated by the SORT-IT Research Team from January 1995 to December 2009. This data was collected from all patients aged 15 and above who sustained an acute open fracture in the Lothian Population from January 1995 to December 2009.

The SORT-IT Research Team comprised a team of dedicated full-time research workers who were based at the Edinburgh Orthopaedic Trauma Unit and the Royal Hospital of Sick Children Edinburgh, under the leadership of Professor Charles Court Brown: this included a full-time trauma research fellow who was a trainee Orthopaedic Surgeon, two full-time research nurses and a full-time research physiotherapist.

For inpatients, the data was gathered from the details of the admission history from the Emergency Department and from in-patient and out-patient hospital records; where details were absent from these sources, patients were contacted either on the ward or at clinic, during the initial management period of their injury, to complete this. For outpatients, the data was gathered from the details of the admission history from the Emergency Department and from out-patient hospital records; where details were absent from these sources, patients were contacted at clinic, during the initial management period of their injury, to complete this.

For all three datasets, the information recorded onto the database during this process included: the date of the injury; the age of the patient; the gender of the patient; the address and the postcode of the patient; the occupation of the patient (where relevant); the smoking status and alcohol intake of the patient (where relevant); the mode of injury; the date of hospital admission (where relevant); the date of treatment; whether management was as an in-patient or out-patient; the site of the fracture; the AO classification of the fracture; further site-specific classifications of the fracture; whether the fracture was open or closed; and associated injuries. Open fractures were classified using the Gustilo classification(76).

The adolescent database also recorded whether the fracture was managed conservatively or surgically.

The open fractures database also recorded: the Gustilo Grading of each fracture; the Injury Severity Score; and the management method used for each fracture (and associated soft tissue injury), recording both Orthopaedic and Plastic Surgical procedures.

For the Gustilo Classification of the injuries, the grading of this classification was based on the intra-operative findings after surgical debridement.

For the sport-related fractures on the databases, the specific sport that was being played at the time of the injury was noted accordingly.

For the adult and adolescent databases, each fracture radiograph was reviewed by the orthopaedic trauma research fellow during this process to confirm the injury and to determine the fracture classification. For the open fracture database, each fracture radiograph and each designated Gustilo Grading was reviewed by the senior author, Professor Charles Court Brown, to confirm the injury, to determine the fracture classification and to validate the Gustilo Grading.

Patients living outside the catchment area were excluded to allow accurate epidemiological analysis. Patients from the Lothian Population who sustained fractures in other regions and were followed-up in the Edinburgh Orthopaedic Trauma Unit or the Royal Hospital for Sick Children Edinburgh were included in the database, with the relevant information for the database obtained during clinic visits. Stress fractures were not included in the database.

2.52 Data Mining

Data mining is a process which involves the semi-automatic or automatic analysis of large sets of data to discover new patterns, with a view to predict future events(77-79).

The commonly defined stages of the data-mining process are(77-79):

1) Data Selection – selecting the data to be analysed;
2) Pre-Processing of Data - assembling the target data, to ensure it is large enough for analysis but concise enough to be mined; and cleaning the dataset of observations containing noise and those with missing data;
3) Data Transformation – transforming the data into the format which can be fed into the data mining model.
4) Data Mining – semi-automatic or automatic analysis of the data to extract previously unknown, interesting patterns.
5) Interpretation / Evaluation – assessing the validity and applicability of the results achieved, and reviewing the complexity and repeatability of the process.

Data mining is performed to fulfil one of several different clinical paradigms(77-79):

- Anomaly detection – identifying unusual data records that require further investigation.
- Association rule learning – searching for relationships between variables.
- Clustering – discovering groups and structures in the data that are similar.
- Classification – finding whether certain facts fall into predefined groups.
- Forecasting - discovering patterns in data that can lead to reasonable predictions.
- Regression – finding functions which model the data with the least error, to estimate the relationships among data.
- Sequence or Path analysis - finding patterns where one event leads to a future event.
- Summarization – providing a more compact representation of the data set.

There are two recognised methods for Datamining: Cross Industry Standard Process for Data Mining (CRISP-DM) and SEMMA (Sample, Explore, Modify, Model, and Assess)(80, 81).

The key stages for each are:

- CRISP-DM: business understanding; data understanding; data preparation; modelling; evaluation; deployment(80).
- SEMMA: sample; explore; modify; model; assess(81).

However, the most simplified method of datamining comprises the stages: pre-processing; data mining; and results validation(77-79, 82-84).

Given the basic nature of our data, this simplified method was utilised within our studies(77-79, 82-84).

With relevance to the thesis studies, the key phases for the datamining process were performed as follows:

The pre-processing stage comprised assembly of the relevant study data onto an excel sheet under the specified sub-headings. With this, it was necessary to ensure the sample size was sufficient for the relevant cohort analyses, and to ensure the data was concisely presented and labelled, so the analysis process was possible. It was also necessary to ensure that patients with missing data and patients with outlying results were identified and appropriately stratified during the analyses(77-79, 82-84).

The data mining stage comprised simple analysis of the datasets to provide key results for each of the cohorts, and to enable comparative analysis between the relevant categorical and continuous variables. This was done: to provide predicted reference values for future similar cohorts (forecasting); to provide information on relationships between the relevant variables (association rule learning); and to present the data in a more concise manner (summarisation) (77-79, 82-84).

The results validation stage comprised repeating the analyses to ensure the results were reproducible; and comparing our results, both between sub-cohorts, and with the existing literature, to ensure that the data was within the expected limits(77-79, 82-84).

For the purpose of the papers within the thesis, all fractures sustained during football, rugby and hockey were identified from the respective databases, to allow data analyses. All sport-related ankle fractures from the adult database were also identified for a further study assessing the ‘Epidemiology, Management and Outcome of Sport-Related Ankle fractures’ within the Lothian population: the data from this study is used in the ‘Optimising Outcome’ section of the Results Section. Table 2 lists: the relevant database that each paper used; and the data variables that were extracted from each database for each of the studies.

Table 2: Databases and Data Variables used for Each Paper

Paper	Database	Data Variables
I	Adult	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; Gustilo classification of fracture (if open); associated injuries.
II	Adult	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; Gustilo classification of fracture (if open); associated injuries.
III	Adult	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; Gustilo classification of fracture (if open); associated injuries.
IV	Adult	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; ankle specific fracture classifications; Gustilo classification of fracture (if open); associated injuries.
V	Adolescent	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; Gustilo classification of fracture (if open); associated injuries; management of fracture.
VI	Open	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; Gustilo classification of fracture (if open); associated injuries; management of fracture.
VII	Adult	Date of injury; age of patient; gender of patient; mode of injury; in-patient or out-patient care; site of fracture; AO classification of fracture; Gustilo classification of fracture (if open); associated injuries.

2.53 Additional Data

To obtain the required data on management and outcome from the adult database, all fractures sustained during football, rugby and hockey, and all sport-related ankle fractures were further identified.

For the each cohort, a retrospective review of patients' inpatient and fracture clinic notes, held in the Electronic Case Note System of the Edinburgh Orthopaedic Trauma Unit, was conducted to identify mechanism of injury, the limb dominance, treatment methods used and associated complications. The reviews were performed in: August 2010 for the football cohort; February 2012 for the rugby cohort; September 2010 for the hockey cohort; and February 2011 for the ankle cohort.

2.6 Treatment Centres

For the adult patients in Lothian, initial presentation of suspected acute fractures was through the Emergency Department at the Royal Infirmary of Edinburgh or the Minor Injuries Department at the Western General Hospital Edinburgh. Inpatient Fracture Care was performed on the Orthopaedic Wards, of the Edinburgh Orthopaedic Trauma Unit, and Out-Patient Fracture Care was performed in the Orthopaedic Outpatient Department of the Edinburgh Orthopaedic Trauma Unit. Patients from the region, who sustained fractures out-with the region, underwent follow-up of their injuries in the Orthopaedic Outpatient Department of the Edinburgh Orthopaedic Trauma Unit on return to Lothian.

For the paediatric patients in Lothian, initial presentation of suspected acute fractures was through the Emergency Department at the Royal Hospital for Sick Children Edinburgh. Inpatient Fracture Care was performed on the Orthopaedic

Ward, in the Royal Hospital for Sick Children Edinburgh, and Out-Patient Fracture Care was performed in the Orthopaedic Outpatient Department of the Royal Hospital for Sick Children Edinburgh. Patients from the region, who sustained fractures out-with the region, underwent follow-up of their injuries in the Orthopaedic Outpatient Department of the Royal Hospital for Sick Children Edinburgh on return to Lothian.

2.7 Management Methods

The Management Methods were categorised as ‘Conservative’ and ‘Surgical’(32).

Treatments within the Conservative Cohort included: cast immobilisation; orthotic immobilisation; splint immobilisation; finger ‘buddy’ strapping; closed reduction (MUA) with casting or splinting(32).

Treatments within the Surgical Cohort included: MUA and K-Wiring; Open Reduction Internal Fixation; Percutaneous Reduction Internal Fixation; Intra-Medullary Nail Fixation; and External Frame Fixation(32).

During the respective study periods, the clinical decision-making in the Edinburgh Orthopaedic Trauma Unit was encouraged to follow a set of standardised principles which have been published by the senior consultants in the internationally-recognised textbook(32)

2.8 Clinical Follow-Up

Clinical follow-up to obtain outcome data was performed for the three cohorts (football, rugby and hockey) from the adult database. This was also performed for the adult ‘sport-related ankle fracture’ cohort.

Patients in each cohort were contacted by telephone to obtain retrospective follow-up data by asking a standardised set of questions. The telephone interviews were performed in: August 2010 for the football cohort; February 2012 for the rugby cohort; September 2010 for the hockey cohort; and February 2011 for the ankle cohort. (Appendix VIII-XI). The mean duration of follow-up for each cohort was: 30 (24-36) months post-injury for the football cohort; 50 (44-56) months post-injury for the rugby cohort; 31 (25-37) months post-injury for the hockey cohort; 36 (30-42) months post-injury for the ankle cohort.

This process involved the same clinician (GR) performing each of the telephone interviews, with each patient being asked a consistent set of interview questions (Appendix VIII-XI). In order to offset inaccuracies with retrospective event re-call, GR reviewed the patient’s fracture clinic notes immediately prior to communicating with the patient, in order to be able to provide the patient with the time-frame of clinic discharge post-injury, as well as the recorded level of function at this stage. GR also noted the date of the injury, to help orientate the patient within the injury process.

2.9 Systematic Review and Meta-Analysis

Systematic Reviews were performed on the available literature for the five fracture types in the ‘Optimising Outcome’ Section (Ankle, Tibial Diaphysis, Clavicle, Scaphoid, Metacarpal) in order to identify all studies which reported on return rates to sport and return times to sport for each of the fracture types. Each systematic review was performed by a comprehensive literature search using

Medline (PubMED), EMBASE, CINHAL, Cochrane Collaboration Database, Web of Science, Physiotherapy Evidence Database (PEDro), Sports Discus, Scopus and Google Scholar. This was to identify articles published in English in peer-reviewed journals, reporting data and information on return to sports for each of the fracture types, without any distinction for type and severity of fracture, or level and type of sports activity. There was no limit for year of publication.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines were followed(85). Two authors independently reviewed the abstract of each publication, and deemed it suitable for inclusion on the basis of its content. Literature reviews, case reports, biomechanical reports, expert opinions, instructional courses and technical notes were excluded unless they contained relevant patient data. When exclusion was not possible based on the abstract, the full-text versions were downloaded. The reference lists of the selected articles were also reviewed to identify articles not included at the electronic search.

Data on patient demographics, location and type of fracture, conservative and surgical management techniques, rate of return to sports, time to return to sports, rate of fracture union, time to fracture union, complications and predictive factors for return to sports were recorded. Primary outcome measures were rate of return to sport and time to return to sport. Secondary outcome measures were rate of return to pre-injury level of sport, rate of fracture union, time to fracture union and associated complications.

Where possible, synthesis cohorts were formed from the available data; when the synthesis cohorts were of sufficient size, meta-analysis comparisons were performed.

2.10 Statistical Analysis

2.10.1 Statistical Software

The datasets were analysed using SPSS 19.0 (SPSS, Chicago, *Illinois*, USA), for the standard statistical tests. The meta-analysis comparisons were performed using RevMan Version 5.3 (The Cochrane Group).

2.10.2 Categorical Data

For categorical data: uni-variate comparisons between parametric data were performed with the Chi Squared Test (using Fisher's exact test with n<5); uni-variate comparisons between non-parametric data were performed with the Chi Squared Test (using Fisher's exact test with n<5).

2.10.3 Continuous Data

For continuous data: uni-variate comparisons between parametric data were performed with the Student t-test; uni-variate comparisons between non-parametric data were performed with the Mann Whitney U Test.

2.10.4 Data Normality Testing

Assessment of Normality of Datasets was performed using the Shapiro-Wilk Test.

2.10.5 Survival Analyses

Survival analyses for return to sport were performed using the Kaplan Meier Estimator, with the Hazard Function. Sub-group analyses were performed for age of patient (<30 years vs >30 years) to assess the effect of age on return to sport.

2.10.6 Meta-Analysis Comparisons

Meta-analysis comparisons were performed on synthesis cohorts (of sufficient size) using the outcome measures: return rates to sport, return times to sport and return rates to pre-injury level of sport. For dichotomous data, odds ratios (ORs) were selected for comparison assessment, using a random effects model. For continuous data, mean differences (MDs) were selected for comparison assessment, using a random effects model. Cohort heterogeneity was analysed using the I^2 statistic; this was deemed to be significant with $I^2>50\%$.

2.10.7 Statistical Significance Level

The significance level for all statistical tests was set at $p<0.05$.

2.11 Ethical Approval

Ethical Approval for the collation of data in the thesis studies was discussed with our regional Research Ethics Service (South East of Scotland Research Ethics Service) through the SORT-IT Research Committee. The Regional Research Ethics Service concluded that the process of data collection in our studies was classified as Clinical Audit and Service Evaluation, not Research (Appendix XII). Given the regulations of the Regional Research Ethics Service, formal Ethical Approval was not required for this.

Chapter Three: Results

3.1 Results

This section describes the results of the Epidemiology, Management and Outcome of acute fractures in the three main team sports in the Lothian Population: Football, Rugby and Hockey. This section also assesses whether the Outcome of these injuries can be further optimised, through comparative analyses of the Outcome of the Fractures, as well as through Systematic Review and Meta-Analyses on this topic.

3.2 Epidemiology

3.2.1 Football

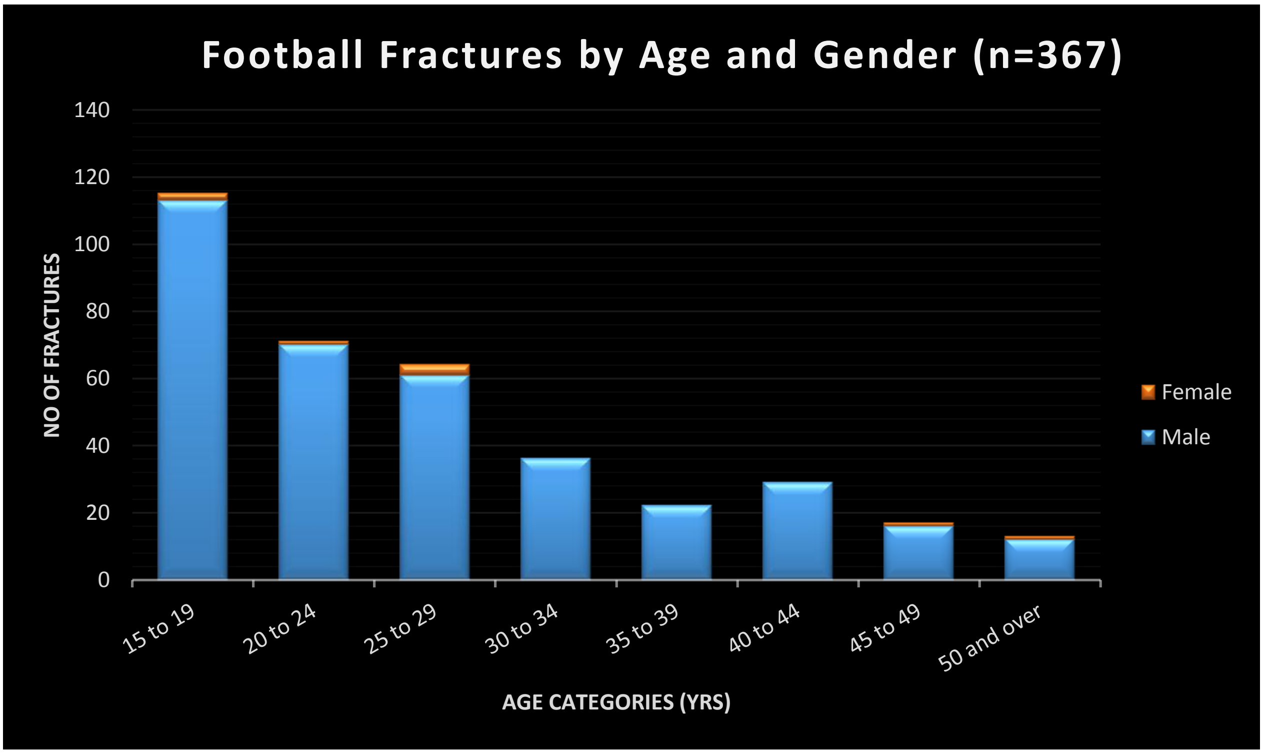
3.2.1.1 Adult Fracture Database

Over the one-year study period, 367 adult football-related fractures were recorded in 357 patients (Table 3). This gave an incidence of 0.71/1000 adult population, with football-related fractures comprising 37.0% of all adult sport-related fractures.

Table 3: General Adult Fracture Demographics		
Total Fractures	6871	
Sport-Related Fractures	992 (14.4%)	
Team-Sport Related Fractures	572 (57.7%)	
Football Fractures	367 (37.0%)	
Number of Patients	357	Mean Age: 26.9 years
Male	349 (97.8%)	Mean Age: 26.8 years
Female	8 (2.2%)	Mean Age: 32.1 years
In-Patient Fractures	76 (20.7%)	
Out-Patient Fractures	291 (79.3%)	
Conservatively Managed Fractures	295 (80.4%)	
Surgically Managed Fractures	72 (19.6%)	
Fractures with Full Follow-Up Data	312 (85.0%)	
Patients with Full Follow-Up Data	303 (84.9%)	Mean Age: 26.8 years
Rugby Fractures	145 (14.6%)	
Number of Patients	143	Mean Age: 21.8 years
Male	135 (94.4%)	Mean Age: 21.8 years
Female	8 (5.6%)	Mean Age: 22.4 years
In-Patient Fractures	29 (20.0%)	
Out-Patient Fractures	116 (80.0%)	
Conservatively Managed Fractures	120 (82.8%)	
Surgically Managed Fractures	25 (17.2%)	
Fractures with Full Follow-Up Data	117 (80.6%)	
Patients with Full Follow-Up Data	115 (80.4%)	Mean Age: 22.2 years
Hockey Fractures	19 (1.9%)	
Number of Patients	19	Mean Age: 24.7 years
Male	10 (52.6%)	Mean Age: 26.4 years
Female	9 (47.4%)	Mean Age: 22.9 years
Out-Patient Fractures	15 (78.9%)	
In-Patient Fractures	4 (21.1%)	All Day Case Procedures.
Conservatively Managed Fractures	15 (78.9%)	
Surgically Managed Fractures	4 (21.1%)	
Fractures with Full Follow-Up Data	18 (94.7%)	
Patients with Full Follow-Up Data	18 (94.7%)	Mean Age: 24.9 years

Of the fractures, 359 occurred in male athletes; 8 occurred in female athletes (Figure 2).

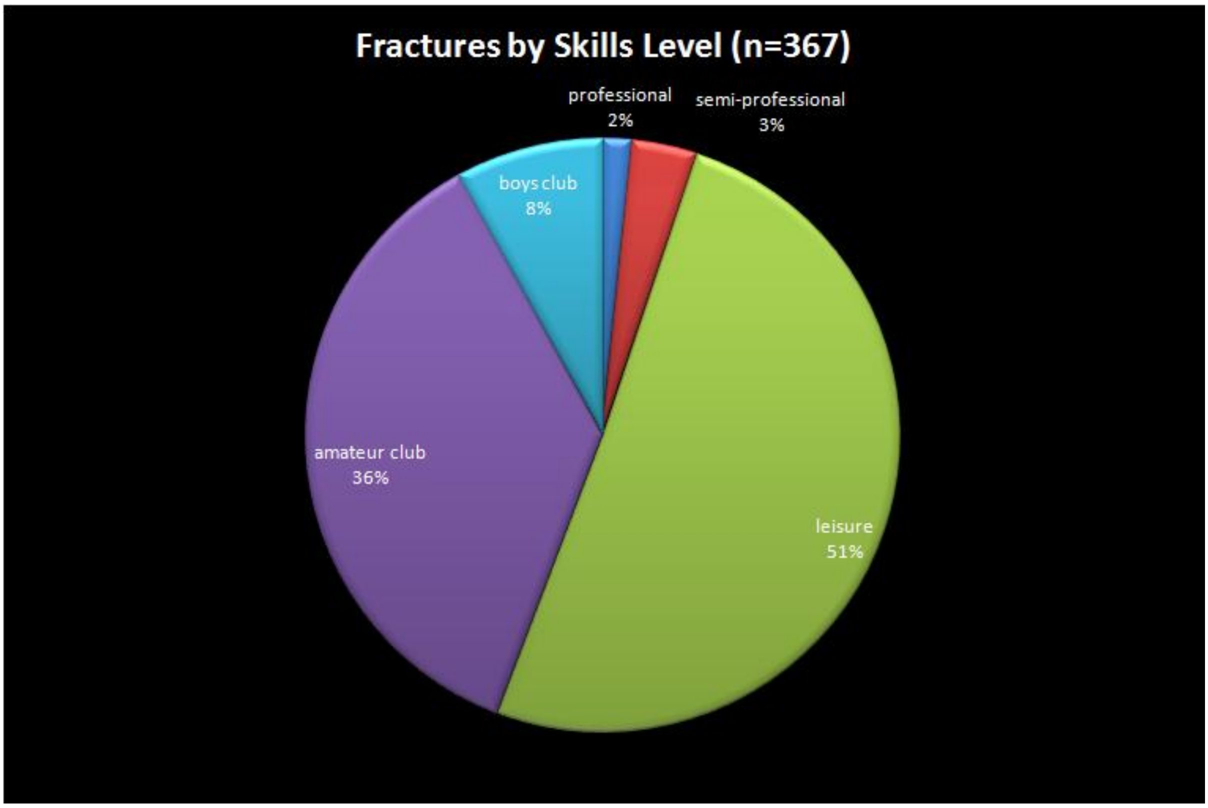
Figure 2 – The Age and Gender Distributions of the Adult Football-Related Fractures



The mean age of the patients was 26.9 years (range, 15-76 years).

The distribution of athletes by pre-injury skill level is shown in Figure 3.

Figure 3 – The Pre-Injury Distribution of Skill Level of the Adult Football-Related Fracture Patients



Two-hundred and fifty of the fractures were upper limb fractures (68.1%); 117 of the fractures were lower limb fractures (31.9%) (Table 4).

Table 4: Adult Football Fracture Demographics

Type	Number	Mean Age (yr)	M:F Ratio	Surgically Managed	In-Patient	Main MOI
Upper Limb Fracture Demographics						
Upper Limb	250	27.2	243:7	28 (11.2%)	26 (10.4%)	Fall (51%)
Finger Phalanx	76	28.3	73:3	4 (5.3%)	5 (6.6%)	Goals (39%)
Distal Radius	73	27.4	70:3	7 (9.6%)	8 (11.0%)	Fall (59%)
Metacarpal	27	22.5	27:0	3 (11.1%)	3 (11.1%)	Goals (37%)
Carpus	26	26.1	26:0	6 (23.1%)	2 (7.7%)	Fall (81%)
Clavicle	20	27.6	19:1	4 (20.0%)	3 (15.0%)	Fall (85%)
Proximal Radius	17	27.0	17:0	1 (5.9%)	0 (0%)	Fall (88%)
Proximal Humerus	2	46.5	2:0	0 (0%)	0 (0%)	Fall (100%)
Radial Diaphysis	2	15.0	2:0	0 (0%)	1 (50.0%)	Goals (100%)
Radius & Ulna	2	17.0	2:0	2 (100.0%)	2 (100.0%)	Fall (100%)
Ulna Diaphysis	2	53.0	2:0	0 (0%)	0 (0%)	Goals (100%)
Lower Limb Fracture Demographics						
Lower Limb	117	26.3	116:1	44 (37.6%)	50 (42.7%)	Tackle (54%)
Ankle	49	26.6	48:1	25 (51.0%)	26 (53.1%)	Tackle (53%)
Metatarsal	23	25.0	23:0	0 (0%)	0 (0%)	Tackle (39%)
Tibial Diaphysis	18	23.9	18:0	12 (66.7%)	16 (88.9%)	Tackle (83%)
Toe	8	21.1	8:0	0 (0%)	2 (25.0%)	Tackle (50%)
Distal Tibia	4	44.3	4:0	3 (75.0%)	3 (75.0%)	Twist (75%)
Fibula	4	37.3	4:0	0 (0%)	0 (0%)	Tackle(100%)
Talus	3	26.3	3:0	0 (0%)	0 (0%)	Twist (67%)
Midfoot	2	19.5	2:0	0 (0%)	0 (0%)	Tackle (50%)
Patella	2	35.5	2:0	2 (100.0%)	2 (100.0%)	Fall (50%)
Proximal Tibia	2	26.0	2:0	2 (100.0%)	1 (50.0%)	Tackle (50%)

Two of the fractures were open: Finger Phalanx (n=1, Gustilo Grade 1); Toe Phalanx (n=1, Gustilo Grade 1).

3.2.1.2 Adolescent Fracture Database

Over the one-year study period, 147 adolescent football-related fractures were recorded in 147 patients (Table 5). This gave an incidence of 2.03/1000 adolescent population, with football-related fractures comprising 36.0% of all adolescent sport-related fractures.

Table 5: Adolescent Football Fracture Demographics						
Fracture	**No.**	**%**	**Age (years)**	**M/F (%)**	**Surgically Managed (%)**	**Inpatient (%)**
Upper Limb Fracture Demographics						
Upper Limb	111	75.5	14.9	95/5	10 (9%)	12 (11%)
Distal radius	45	30.6	14.3	96/4	6 (13%)	8 (18%)
Finger phalanx	32	22.6	14.9	91/9	0 (0%)	0 (0%)
Metacarpal	20	13.6	15.0	100/0	3 (15%)	3 (15%)
Clavicle	8	5.5	15.5	100/0	0 (0%)	0 (0%)
Radius & ulna diaphysis	3	2.0	17.0	100/0	0 (0%)	0 (0%)
Distal humerus	1	0.7	19.0	100/0	1 (100%)	1 (100%)
Proximal humerus	1	0.7	14.0	100/0	0 (0%)	0 (0%)
Proximal radius & ulna	1	0.7	17.5	100/0	0 (0%)	0 (0%)
Lower Limb Fracture Demographics						
Lower Limb	36	24.5	15.5	92/8	12 (33%)	12 (33%)
Ankle	14	9.5	15.9	93/7	4 (29%)	4 (29%)
Metatarsal	8	5.5	15.2	88/12	0 (0%)	0 (0%)
Tibial diaphysis	7	4.8	15.2	100/0	5 (71%)	5 (71%)
Distal tibia	2	1.4	14.1	100/0	1 (50%)	1 (50%)
Toe phalanx	2	1.4	15.1	100/0	0 (0%)	0 (0%)
Patella	1	0.7	18.0	100/0	1 (100%)	1 (100%)
Proximal femur	1	0.7	16.0	100/0	0 (0%)	0 (0%)
Talus	1	0.7	17.0	0/100	1 (100%)	1 (100%)

Of the fractures, 138 occurred in male athletes; 9 occurred in female athletes.

The mean age of the patients was 15.1 years (range 10 to 19 years).

One hundred and eleven of the fractures were upper limb fractures (75.5%), thirty-six of the fractures were lower limb fractures (24.4%).

There was one open fracture: tibial diaphysis (Gustilo Grade 1).

3.2.1.3 Open Fracture Database

Over the fifteen-year study period, 19 open football-related fractures were recorded in 19 patients (Table 6). This gave an incidence of 0.002/1000 adult population, with football-related fractures comprising 22.4% of all adult open sport-related fractures.

Of the fractures, 18 occurred in male athletes; 1 occurred in female athletes.

Table 6: Adult Open Fracture Demographics						
Type	**Number**	**Mean Age (yr)**	**M:F Ratio**	**Surgically Managed**	**In-Patient**	**Main MOI**
Football Fracture Demographics						
Football Fractures	19	29.6	18:1	19 (100.0%)	13 (68.4%)	Tackle (58%)
Tibial Diaphysis	9	26.6	9:0	9 (100.0%)	9 (100.0%)	Tackle (100%)
Finger Phalanx	3	40.3	2:1	3 (100.0%)	0 (0.0%)	Fall (67%)
Toe Phalanx	3	28.3	3:0	3 (100.0%)	0 (0.0%)	Stubbing Injury (67%)
Ankle	1	31.0	1:0	1 (100.0%)	1 (100.0%)	Tackle (100%)
Distal Humerus	1	32.0	1:0	1 (100.0%)	1 (100.0%)	Wall Collision (100%)
Distal Tibia	1	31.0	1:0	1 (100.0%)	1 (100.0%)	Tackle (100%)
Radius & Ulna Diaphysis	1	24.0	1:0	1 (100.0%)	1 (100.0%)	Fall (100%)
Rugby Fracture Demographics						
Rugby Fractures	9	26.3	9:0	9 (100.0%)	6 (67.0%)	Tackle (67%)
Ankle	3	30.7	3:0	3 (100.0%)	3 (100.0%)	Tackle (67%)
Finger Phalanx	2	24.5	2:0	2 (100.0%)	0 (0.0%)	Tackle (100%)
Metacarpal	1	21.0	1:0	1 (100.0%)	0 (0.0%)	Kick (100%)
Patella	1	16.0	1:0	1 (100.0%)	1 (100.0%)	Fall (100%)
Proximal Tibia	1	42.0	1:0	1 (100.0%)	1 (100.0%)	Tackle (100%)
Tibial Diaphysis	1	17.0	1:0	1 (100.0%)	1 (100.0%)	Tackle (100%)
Hockey Fracture Demographics						
Hockey Fractures	8	19.8	3:5	8 (100.0%)	0 (0.0%)	Ball (75%)
Finger Phalanx	8	19.8	3:5	8 (100.0%)	0 (0.0%)	Ball (75%)

The mean age of the patients was 29.6 years (range, 16 to 62 years).

One of the fractures occurred in a professional athlete; eleven in amateur athletes; one in a school level athlete; and six in recreational athletes.

Five of the fractures were upper limb fractures (26.3%), 14 of the fractures were lower limb fractures (73.7%).

Of the fractures, seven were Gustilo 1 (finger phalanx (n=3); toe phalanx (n=3), tibial diaphysis (n=1)), seven were Gustilo 2 (tibial diaphysis (n=4), ankle (n=1), distal humerus (n=1), radius and ulna (n=1)) and four were Gustilo 3a (tibial diaphysis (n=4)) and one was Gustilo 3b (distal tibia (n=1)).

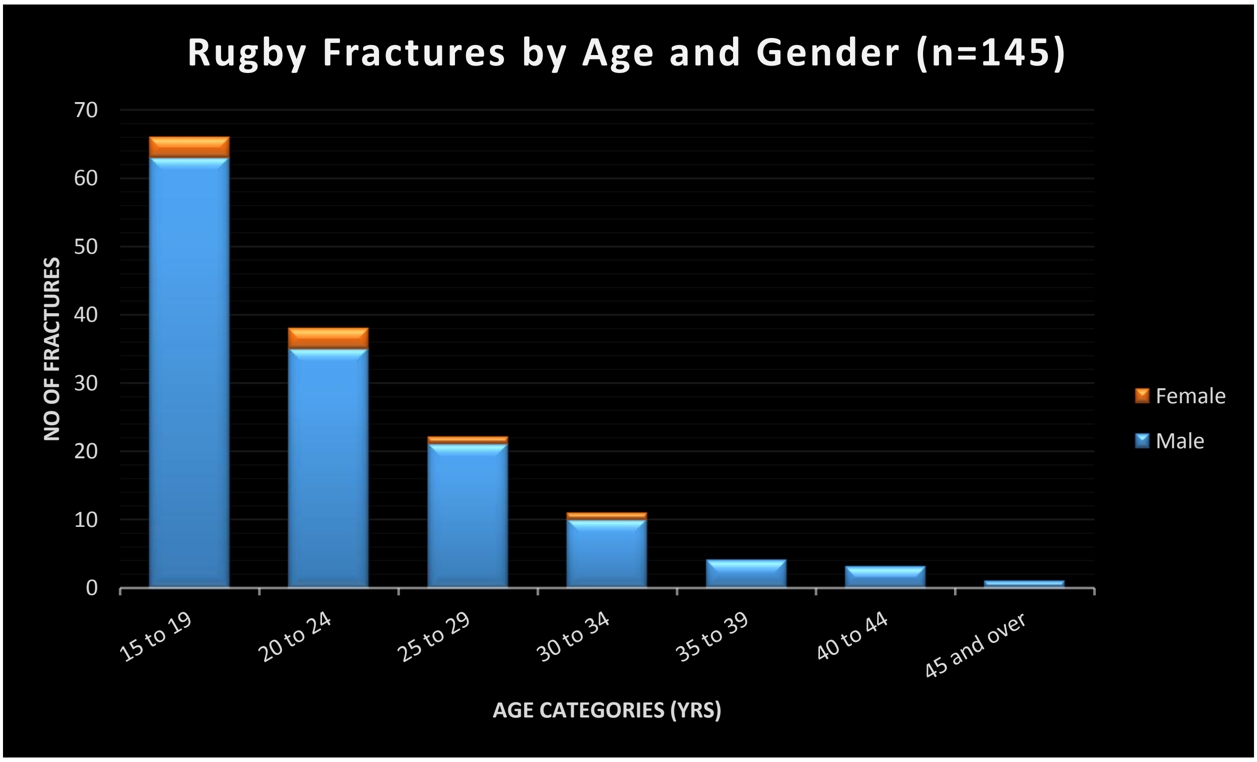
3.2.2 Rugby

3.2.2.1 Adult Fracture Database

Over the one-year study period, 145 adult rugby-related fractures were recorded in 143 patients (Table 3). This gave an incidence of 0.28/1000 adult population, with rugby-related fractures comprising 14.6% of all adult sport-related fractures.

Of the fractures, 137 occurred in male athletes; 8 occurred in female athletes (Figure 4).

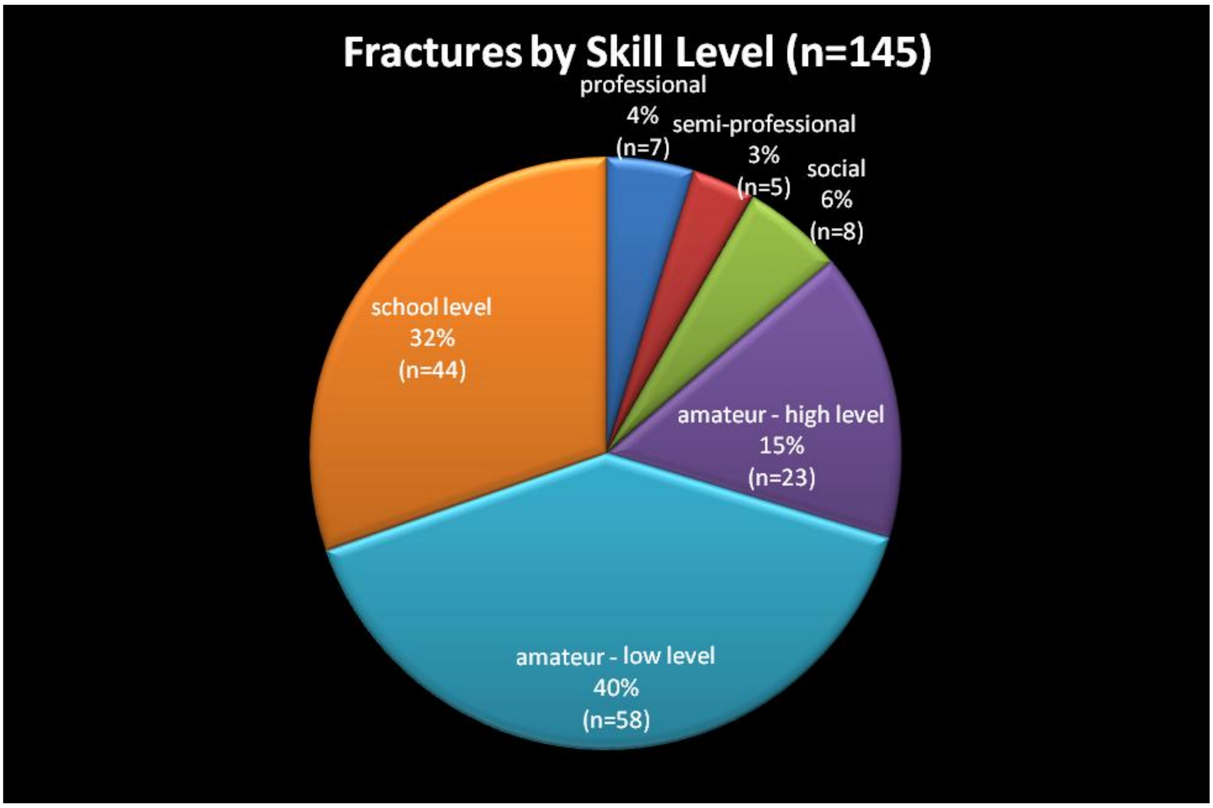
Figure 4 – The Age and Gender Distributions of the Adult Rugby-Related Fractures



The mean age of the patients was 21.8 years (range 15–46 years).

The distribution of athletes by pre-injury skill level is shown in Figure 5.

Figure 5 – The Pre-Injury Distribution of Skill Level of the Adult Rugby-Related Fracture Patients



One-hundred and twenty of the fractures were upper limb fractures (82.8%), 25 of the fractures were lower limb fractures (17.2%) (Table 7).

Table 7: Adult Rugby Fracture Demographics						
Type	**Number**	**Mean Age (yr)**	**M:F Ratio**	**Surgically Managed**	**In-Patient**	**Main MOI**
Upper Limb Fracture Demographics						
Upper Limb	120	21.5	113:7	14 (11.7%)	17 (14.2%)	Tackle (45%)
Finger Phalanx	40	22.8	37:3	3 (7.5%)	3 (7.5%)	Tackle (50%)
Metacarpal	27	23.8	24:3	5 (18.5%)	6 (22.2%)	Tackle (37%)
Clavicle	24	17.3	24:0	2 (8.3%)	3 (12.5%)	Tackle (54%)
Distal Radius	11	18.8	10:1	1 (9.1%)	2 (18.2%)	Fall (45%)
Proximal Humerus	5	28.0	5:0	0 (0%)	0 (0%)	Tackle (60%)
Scaphoid	3	21.0	3:0	0 (0%)	0 (0%)	Fall (67%)
Distal Ulna	2	20.0	2:0	0 (0%)	0 (0%)	Lineout (50%)
Radius & Ulna	2	15.0	2:0	0 (0%)	0 (0%)	Lineout (50%)
Radial Diaphysis	2	23.0	2:0	2 (100%)	2 (100%)	Ruck (50%)
Distal Humerus	1	24.0	1:0	0 (0%)	0 (0%)	Tackle (100%)
Humeral Diaphysis	1	16.0	1:0	0 (0%)	0 (0%)	Tackle (100%)
Proximal Radius	1	22.0	1:0	0 (0%)	0 (0%)	Fall (100%)
Proximal Ulna	1	21.0	1:0	1 (100%)	1 (100%)	Tackle (100%)

Lower Limb Fracture Demographics						
Lower Limb	25	23.5	24:1	11 (44.0%)	11 (44.0%)	Tackle (40%)
Ankle	15	22.3	14:1	6 (40.0%)	6 (40.0%)	Tackle (53%)
Tibial Diaphysis	3	25.0	3:0	3 (100%)	3 (100%)	Tackle (67%)
Metatarsal	3	21.0	3:0	0 (0%)	0 (0%)	Ruck (100%)
Fibula	2	31.5	2:0	0 (0%)	0 (0%)	Twist(100%)
Distal Tibia	1	26.0	1:0	1 (100%)	1 (100%)	Tackle(100%)
Talus	1	26.0	1:0	1 (100%)	1 (100%)	Tackle(100%)

There were no open fractures.

3.2.2.2 Adolescent Fracture Database

Over the one-year study period, 64 adolescent rugby-related fractures were recorded in 64 patients (Table 8). This gave an incidence of 0.88/1000 adolescent population, with rugby-related fractures comprising 15.7% of all adolescent sport-related fractures.

Table 8: Adolescent Rugby Fracture Demographics

Fracture	No.	%	Age (years)	M/F (%)	Surgically Managed (%)	Inpatient (%)
Upper Limb Fracture Demographics						
Upper Limb	52	81.2	15.2	96/4	7 (14%)	7 (14%)
Clavicle	20	31.1	14.7	95/5	0 (0%)	0 (0%)
Finger phalanx	10	15.6	15.0	100/0	2 (20%)	2 (20%)
Metacarpal	9	14.1	15.9	100/0	0 (0%)	0 (0%)
Distal radius	7	10.9	15.7	86/14	4 (57%)	4 (57%)
Carpus	2	3.1	18.0	100/0	1 (50%)	1 (50%)
Radius & ulna diaphysis	2	3.1	15.0	100/0	0 (0%)	0 (0%)
Distal Humerus	1	1.6	13.0	100/0	0 (0%)	0 (0%)
Proximal radius & ulna	1	1.6	14.0	100/0	0 (0%)	0 (0%)
Lower Limb Fracture Demographics						
Lower Limb	12	18.8	14.5	100/0	4 (33%)	4 (33%)
Tibial diaphysis	4	6.2	16.0	100/0	4 (100%)	4 (100%)
Metatarsal	4	6.2	13.2	100/0	0 (0%)	0 (0%)
Ankle	3	4.7	15.0	100/0	0 (0%)	0 (0%)
Patella	1	1.6	12.4	100/0	0 (0%)	0 (0%)

Of the fractures, 62 occurred in male athletes; 2 occurred in female athletes.

The mean age of the patients was 15.2 years (range 10 to 19 years).

Fifty-two of the fractures were upper limb fractures (81.2%), twelve of the fractures were lower limb fractures (18.8%).

There was one open fracture: finger phalanx (Gustilo Grade 1).

3.2.2.3 Open Fracture Database

Over the fifteen-year study period, 9 open rugby-related fractures were recorded in 9 patients (Table 7). This gave an incidence of 0.001/1000 adult population, with rugby-related fractures comprising 10.6% of all adult open sport-related fractures

Of the fractures, all 9 occurred in male athletes.

The mean age of the patients was 26.0 years (range, 16 to 42 years).

One of the fractures occurred in a professional athlete; three in amateur athletes; three in school level athletes; and two in recreational athletes.

Three of the fractures were upper limb fractures (33.3%), six of the fractures were lower limb fractures (66.7%).

Of the fractures, three were Gustilo 1 (finger phalanx (n=2); metacarpal (n=1)), five were Gustilo 2 (ankle (n=2), tibial diaphysis (n=1), proximal tibia (n=1), patella (n=1)) and one was Gustilo 3a (ankle (n=1)).

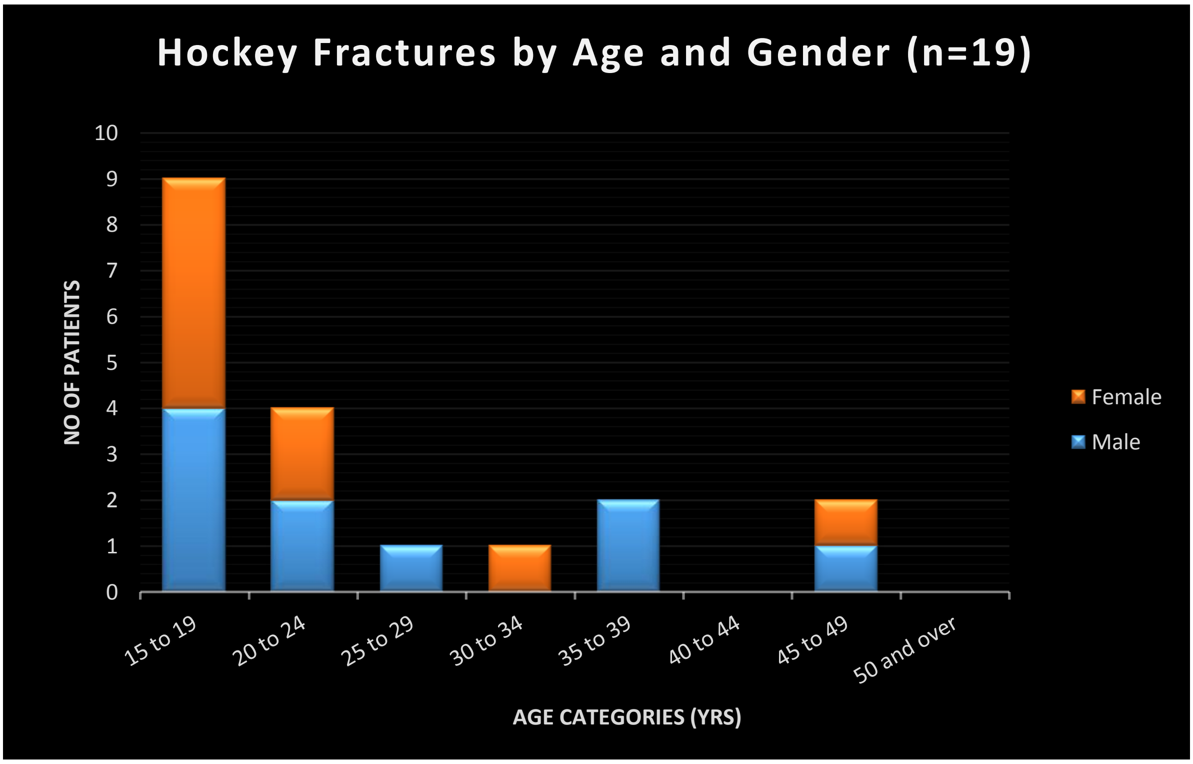
3.2.3 Hockey

3.2.3.1 Adult Fracture Database

Over the one-year study period, 19 adult hockey-related fractures were recorded in 19 patients (Table 3). This gave an incidence of 0.04/1000 adult population, with hockey-related fractures comprising 1.9% of all adult sport-related fractures.

Of the fractures, 10 occurred in male athletes; 9 occurred in female athletes (Figure 6).

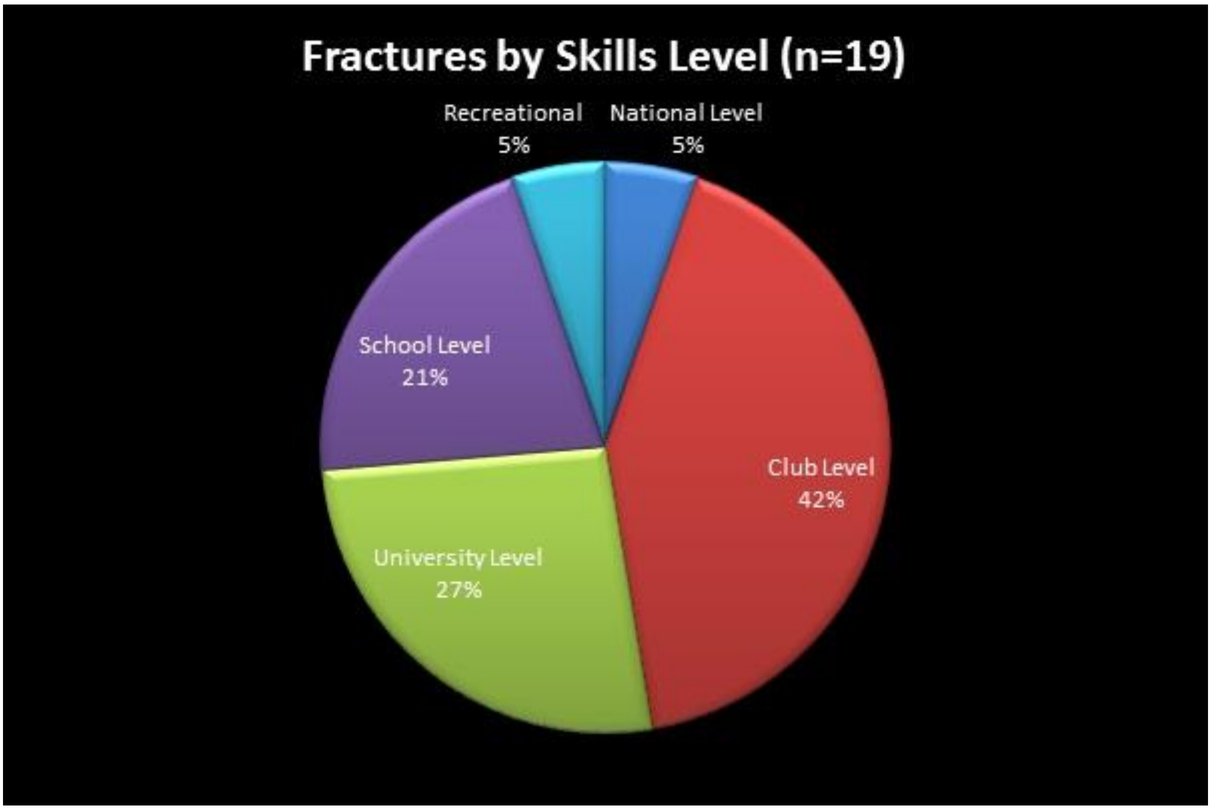
Figure 6 – The Age and Gender Distributions of Adult Hockey-Related Fractures



The mean age of the patients was 24.7 years (range: 15–47 years).

The distribution of athletes by pre-injury skill level is shown in Figure 7.

Figure 7 – The Pre-Injury Distribution of Skill Level of the Adult Hockey-Related Fracture Patients



Seventeen of the fractures were upper limb fractures (89.5%), two of the fractures were lower limb fractures (10.5%) (Table 9).

Table 9: Adult Hockey Fracture Demographics						
Type	**Number**	**Mean Age (yr)**	**M:F Ratio**	**Surgically Managed**	**In-Patient**	**Main MOI**
Total	19	24.7	10:9	4 (21.1%)	4 (21.1%)	Stick (53%)
Upper Limb	17	25.8	10:7	3 (17.6%)	3 (17.6%)	Stick (59%)
Finger Phalanx	8	25.8	6:2	1 (12.5%)	1 (12.5%)	Stick (63%)
Metacarpal	7	27.4	3:4	2 (28.6%)	2 (28.6%)	Stick (57%)
Clavicle	1	18.0	0:1	0 (0%)	0 (0%)	Ball (100%)
Distal Ulna	1	22.0	1:0	0 (0%)	0 (0%)	Stick (100%)
Lower Limb	2	16.0	0:2	1 (50.0%)	1 (50.0%)	Ball (50%)
Ankle	1	15.0	0:1	1 (100.0%)	1 (100.0%)	Twist (100%)
Patella	1	17.0	0:1	0 (0%)	0 (0%)	Ball (100%)

There was one open fracture: finger phalanx (Gustilo Grade 2).

3.2.3.2 Adolescent Fracture Database

Over the one-year study period, nine adolescent hockey-related fractures were recorded in nine patients (Table 10). This gave an incidence of 0.12/1000 adolescent population, with hockey-related fractures comprising 2.2% of all adolescent sport-related fractures.

Table 10: Adolescent Hockey Fracture Demographics						
Fracture	**No.**	**%**	**Age (years)**	**M/F (%)**	**Surgically Managed (%)**	**Inpatient (%)**
Upper Limb Fracture Demographics						
Upper Limb	9	100.0	14.0	78/22	1 (11%)	1 (11%)
Finger phalanx	3	33.3	13.3	33/67	0 (0%)	0 (0%)
Metacarpal	3	33.3	14.0	100/0	0 (0%)	0 (0%)
Clavicle	2	22.2	15.5	100/0	0 (0%)	0 (0%)
Radius & ulna diaphysis	1	11.1	16.0	100/0	1 (100%)	1 (100%)

Of the fractures, seven occurred in male athletes; two occurred in female athletes.

The mean age of the patients was 14.0 years (range 10 to 16 years).

All nine of the fractures were upper limb fractures (100.0%) (Table 10).

There were no open fractures recorded.

3.2.3.3 Open Fracture Database

Over the fifteen-year study period, 8 open hockey-related fractures were recorded in 8 patients (Table 6). This gave an incidence of 0.001/1000 adult population, with hockey-related fractures comprising 9.4% of all adult open sport-related fractures.

Of the fractures, three occurred in male athletes; five occurred in female athletes.

The mean age of the patients was 19.8 years (range, 16 to 25 years).

Five of the fractures occurred in amateur athletes; three occurred in school level athletes.

All eight fractures were upper limb fractures (100.0%).

Of the fractures, seven were Gustilo 1 (finger phalanx (n=7); metacarpal (n=1)), and one was Gustilo 2 (finger phalanx (n=1)).

3.3 Management

3.3.1 Football

3.3.1.1 Adult Database

For the total cohort, 295 of the fractures were treated conservatively (80.4%); 72 were treated surgically (19.6%) (Table 3).

For the upper limb cohort, 222 of the fractures were treated conservatively (88.8%); 28 were treated surgically (11.2%).

For the lower limb cohort, 73 of the fractures were treated conservatively (62.4%); 44 were treated surgically (37.6%).

3.3.1.2 Adolescent Database

For the total cohort, 125 of the fractures were treated conservatively (85.0%); 22 were treated surgically (15.0%).

For the upper limb cohort, 101 of the fractures were treated conservatively (91.0%); 10 were treated surgically (9.9%).

For the lower limb cohort, 24 of the fractures were treated conservatively (66.7%); 12 were treated surgically (33.3%).

3.3.1.3 Open Fracture Database

For the total cohort, all of the fractures were treated surgically, as all required surgical wound debridement.

3.3.2 Rugby

3.3.2.1 Adult Database

For the total cohort, 120 of the fractures were treated conservatively (82.8%); 25 were treated surgically (17.2%) (Table 3).

For the upper limb cohort, 106 of the fractures were treated conservatively (88.3%); 14 were treated surgically (11.7%).

For the lower limb cohort, 14 of the fractures were treated conservatively (56.0%); 11 were treated surgically (44.0%).

3.3.2.2 Adolescent Database

For the total cohort, 53 of the fractures were treated conservatively (82.8%); 11 were treated surgically (17.2%).

For the upper limb cohort, 45 of the fractures were treated conservatively (86.5%); 7 were treated surgically (13.5%).

For the lower limb cohort, eight of the fractures were treated conservatively (66.7%); four were treated surgically (33.3%).

3.3.2.3 Open Fracture Database

For the total cohort, all of the fractures were treated surgically, as all required surgical wound debridement.

3.3.3 Hockey

3.3.3.1 Adult Database

For the total cohort, 15 of the fractures were treated conservatively (78.9%); four were treated surgically (21.1%) (Table 3).

For the upper limb cohort, 14 of the fractures were treated conservatively (82.4%); three were treated surgically (17.6%).

For the lower limb cohort, one of the fractures was treated conservatively (50.0%); one was treated surgically (50.0%).

3.3.3.2 Adolescent Database

For the total cohort (all upper limb fractures), eight of the fractures were treated conservatively (88.9%); one was treated surgically (11.1%).

3.3.3.3 Open Fracture Database

For the total cohort (all upper limb fractures), all of the fractures were treated surgically, as all required surgical wound debridement.

3.4 Outcome

3.4.1 Football

3.4.1.1 Adult Database

For the total cohort, follow-up data was achieved in 312 of the 367 fractures (85.0%).

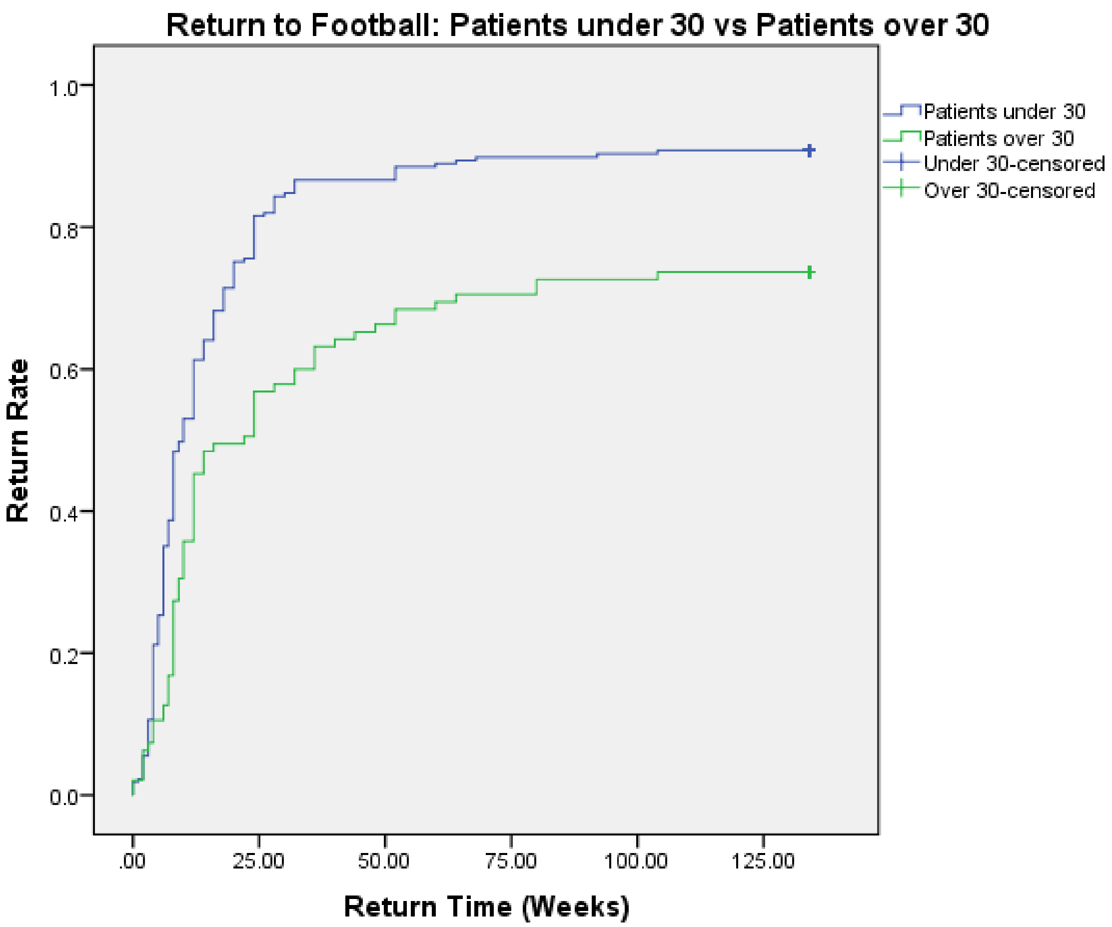
Of the 312 fractures, 267 returned to football (return rate 85.6%) (Table 11). For the upper limb cohort, 178 of the 209 fractures returned to football (return rate 85.2%). For the lower limb cohort, 89 of the 103 fractures returned to football (return rate 86.4%). The difference in return rates between the upper limb and lower limb cohorts was not significant (p=0.769).

For the surgically-managed cohort, 48 of the 59 fractures returned to football (return rate 80.6%). For the conservatively-managed cohort, 219 of the 253 fractures returned to football (return rate 86.6%). The difference in return rates between the surgically-managed and conservatively-managed cohorts was not significant (p=0.305).

Table 11: Adult Football Fracture Follow-up Data						
Type	**Follow-Up**	**Return to Football**	**Return to Same Level or Higher**	**Time to Football (wks) [SD]**	**Persisting Symptoms**	**Persisting Symptoms Affecting Football**
Upper Limb Fracture Follow-up Data						
Total Cohort	312 (85%)	267 (86%)	258 (83%)	15.0 [16.6]	123 (39%)	24 (8%)
Upper Limb	209 (84%)	178 (85%)	175 (84%)	9.2 [8.3]	76 (36%)	10 (5%)
Finger Phalanx	62 (82%)	59 (95%)	58 (94%)	6.6 [3.4]	26 (42%)	1 (2%)
Distal Radius	62 (85%)	49 (79%)	48 (77%)	8.9 [4.1]	13 (21%)	1 (2%)
Metacarpal	23 (85%)	20 (87%)	20 (87%)	6.7 [3.8]	10 (43%)	1 (9%)
Carpus	22 (85%)	20 (91%)	19 (86%)	14.4 [5.1]	13 (59%)	4 (18%)
Clavicle	17 (85%)	13 (76%)	13 (76%)	18.1 [8.3]	6 (35%)	1 (6%)
Proximal Radius	14 (82%)	12 (86%)	12 (86%)	7.8 [3.2]	5 (36%)	1 (7%)
Proximal Humerus	2 (100%)	1 (50%)	1 (50%)	6.0 [n/a]	1 (50%)	0 (0%)
Radial Diaphysis	2 (100%)	1 (50%)	1 (50%)	8.0 [n/a]	1 (50%)	0 (0%)
Radius & Ulna	2 (67%)	1 (50%)	1 (50%)	16.0 [n/a]	1 (50%)	0 (0%)
Ulna Diaphysis	2 (100%)	1 (50%)	1 (50%)	28.0 [n/a]	0 (0%)	0 (0%)
Lower Limb Fracture Follow-up Data						
Total Cohort	312 (85%)	267 (86%)	258 (83%)	15.0 [16.6]	123 (39%)	24 (8%)
Lower Limb	103 (88%)	89 (86%)	96 (81%)	26.5 [22.1]	47 (46%)	14 (14%)
Ankle	44 (90%)	42 (95%)	39 (89%)	31.2 [15.3]	17 (39%)	6 (14%)
Metatarsal	21 (91%)	20 (95%)	18 (86%)	11.5 [4.5]	8 (38%)	3 (14%)
Tibial Diaphysis	15 (83%)	12 (80%)	11 (73%)	38.2 [20.8]	11 (73%)	4 (27%)
Toe Phalanx	6 (75%)	3 (50%)	3 (30%)	7.0 [2.8]	3 (50%)	0 (0%)
Distal Tibia	4(100%)	3 (75%)	3 (75%)	65.3 [25.4]	3 (75%)	0 (0%)
Fibula	4 (100%)	3 (75%)	3 (75%)	11.0 [4.4]	2 (50%)	0 (0%)
Talus	3 (100%)	2 (67%)	2 (67%)	29.0 [26.9]	1 (33%)	0 (0%)
Proximal Tibia	2 (100%)	1 (50%)	1 (50%)	32.0 [n/a]	1 (50%)	0 (0%)

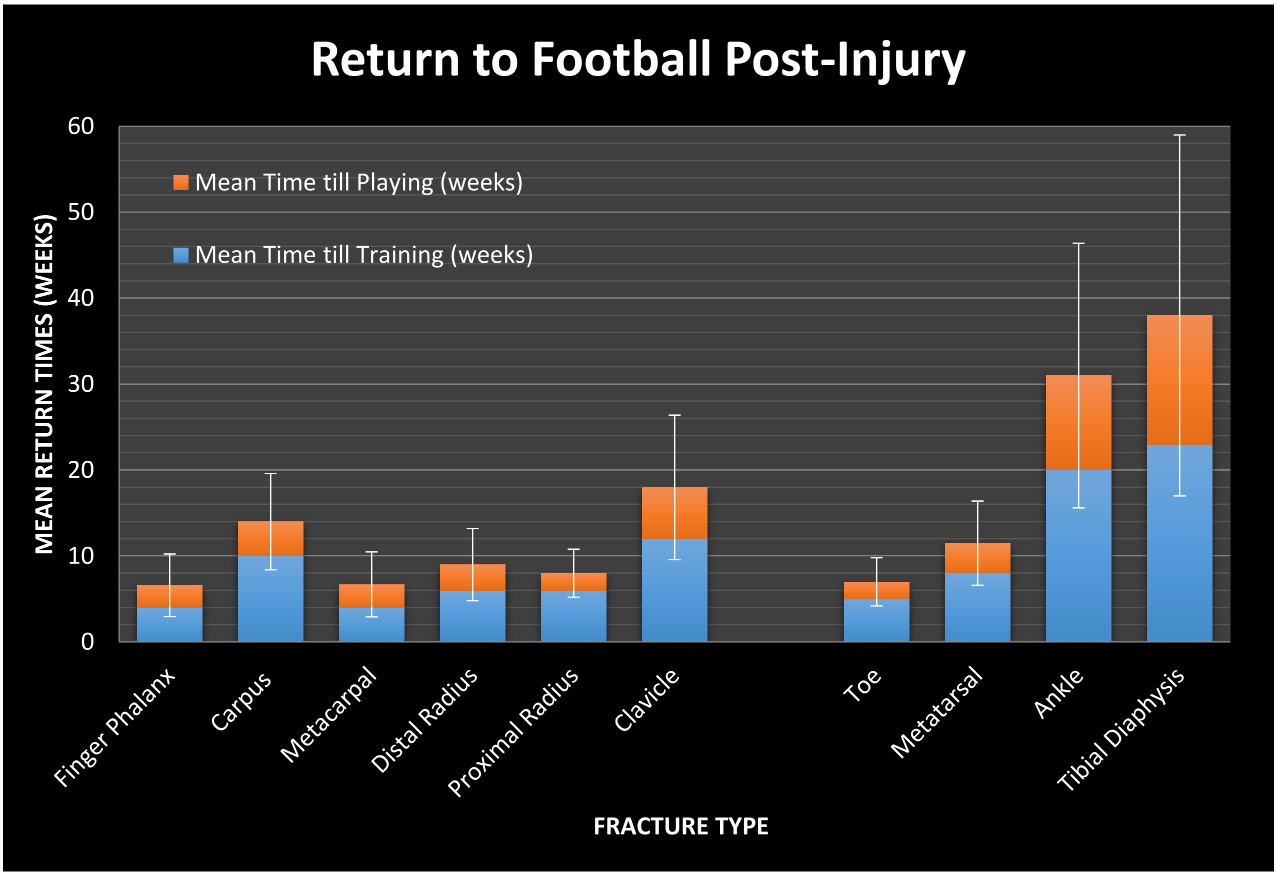
For the total cohort, 45 (14.4%) of the 312 fractures did not return to football. The fracture types with the highest rates of no return were: clavicle (24%), distal radius (21%), and tibial diaphysis (20%). The cause of no return was symptom-related reasons in 13 patients and personal-related reasons in 32 patients. There was a higher incidence of personal reasons for quitting in upper limb fractures (26/31, 84%) compared with lower limb fractures (8/14, 57%). Patients over 30 years (no-return rate, 26.3%) were 2.9 times more likely to quit soccer than those under 30 years (no-return rate, 9.2%) ($p<0.001$). (Figure 8)

Figure 8 – Return to Football Post-Injury: Patients under 30 vs Patients over 30 (Kaplan-Meier Hazard Function)



For the total cohort, the mean return time to full-level football was 15.0 (0-104) weeks (Table 11 and Figure 9).

Figure 9 – The Duration taken for Return to Training and Full-Level Football for the Different Fracture Types. (Error Bars represent +/- 1 Standard Deviation).



For the upper limb cohort, the mean return time to full-level football was 9.2 (0-64) weeks. For the lower limb cohort, the mean return time to full-level football was 26.5 (4-104) weeks. The difference in return times to full-level football between the upper limb and lower limb cohorts was significant. ($p<0.001$: 95%CI 12.47 to 22.09).

For the surgically-managed cohort, the mean return time to full-level football was 33.9 (6-104) weeks. For the conservatively-managed cohort, the mean return time to full-level football was 10.8 (0-104) weeks. The difference in return times to full-level football between the surgically-managed and conservatively-managed cohorts was significant ($p<0.001$: 95%CI 15.98 to 30.11).

For the total cohort, the rate of non-union was 1.3% (4/312) and the rate of mal union was 3.8% (12/312).

The rate of non-union was 1.2% (3/253) for the conservatively-managed cohort and 1.7% (1/59) for the surgically-managed cohort ($p=0.570$).

The rate of mal-union was 4.0% (10/253) for the conservatively-managed cohort and 3.4% (2/59) for the surgically-managed cohort ($p=1.000$).

From the surgically-managed cohort, six patients (8%) suffered complications from their surgery and ten patients (14%) required secondary surgery.

For the total cohort, 123 of the 312 fractures had persisting symptoms at follow-up (rate 39.4%) (Table 11). These included fracture site pain (n=75), stiffness of an adjacent joint (n=35), and metalwork-related pain (n=9).

For the upper limb cohort, 76 of the 209 fractures (36.4%) had persisting symptoms at follow-up. For the lower limb cohort, 47 of the 103 fractures (45.6%) had persisting symptoms at follow-up. The difference in persisting symptoms rates between the upper limb and lower limb cohorts was not significant ($p=0.139$).

For the surgically-managed cohort, 40 of the 59 fractures (67.8%) had persisting symptoms at follow-up. For the conservatively-managed cohort, 83 of the 253 fractures (32.8%) had persisting symptoms at follow-up. The difference in persisting symptoms rates between the surgically-managed and conservatively-managed cohorts was significant ($p<0.001$).

For the total cohort, 24 of the 312 fractures (7.7%) had persisting symptoms which impaired footballing ability at follow-up (Table 11). These included fracture site pain (n=16) and stiffness of an adjacent joint (n=6) and metalwork-related pain (n=2).

For the upper limb cohort, 10 of the 209 fractures (4.8%) had persisting symptoms which impaired footballing ability at follow-up. For the lower limb cohort, 14 of the 103 fractures (13.6%) had persisting symptoms which impaired footballing ability at follow-up. The difference in persisting symptoms rates which impaired footballing ability between the upper limb and lower limb cohorts was significant ($p<0.024$).

For the surgically-managed cohort, 10 of the 59 fractures (16.9%) had persisting symptoms which impaired footballing ability at follow-up. For the conservatively-managed cohort, 14 of the 253 fractures (5.5%) had persisting symptoms which impaired footballing ability at follow-up. The difference in persisting symptoms rates which impaired footballing ability between the surgically-managed and conservatively-managed cohorts was significant ($p<0.003$).

3.4.2 Rugby

3.4.2.1 Adult Database

For the total cohort, follow-up data was achieved in 117 of the 145 fractures (80.7%).

Of the 117 fractures, 102 returned to rugby (return rate 87.2%) (Table 12).

For the upper limb cohort, 83 of the 95 fractures returned to rugby (return rate

87.4%). For the lower limb cohort, 19 of the 22 fractures returned to rugby (return rate 86.4%). The difference in return rates between the upper limb and lower limb cohorts was not significant ($p=1.000$).

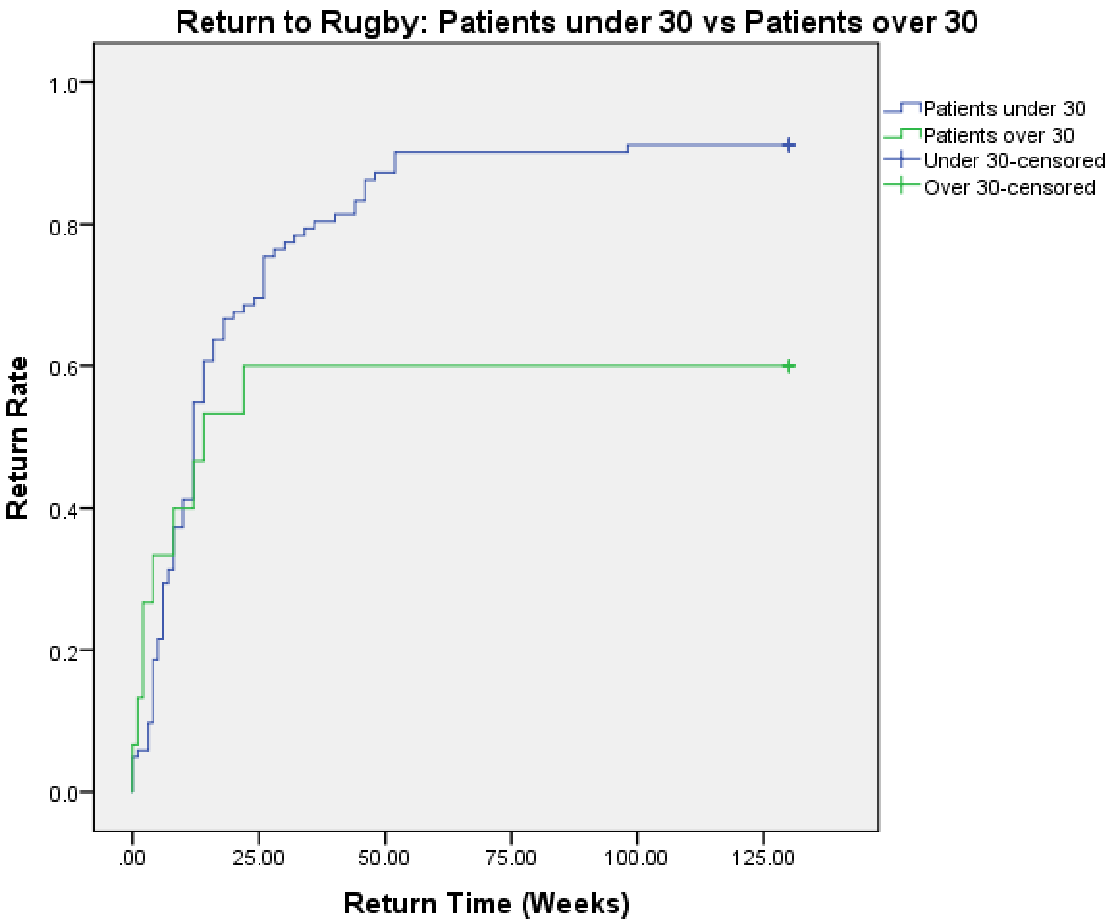
For the surgically-managed cohort, 16 of the 22 fractures returned to rugby (return rate 72.7%). For the conservatively-managed cohort, 86 of the 95 fractures returned to rugby (return rate 90.5%). The difference in return rates between the surgically-managed and conservatively-managed cohorts was significant ($p<0.036$).

Table 12: Adult Rugby Fracture Follow-up Data

Type	Follow-Up	Return to Rugby	Return to Same Level or Higher	Time to Rugby (wks) [SD]	Persisting Symptoms	Persisting Symptoms Affecting Rugby
Total Cohort	117 (81%)	102 (87%)	100 (85%)	15.5 [15.8]	37 (32%)	11 (9%)
Upper Limb	95 (79%)	83 (87%)	81 (85%)	12.9 [14.9]	25 (26%)	9 (9%)
Finger Phalanx	33 (83%)	29 (88%)	27 (82%)	7.3 [4.2]	11 (33%)	5 (15%)
Metacarpal	22 (81%)	20 (91%)	20 (91%)	8.2 [4.0]	4 (18%)	2 (9%)
Clavicle	19 (79%)	18 (95%)	18 (95%)	24.0 [11.4]	3 (16%)	0 (0%)
Distal Radius	10 (91%)	9 (90%)	9 (90%)	12.2 [4.8]	2 (20%)	1 (10%)
Proximal Humerus	3 (60%)	0 (0%)	0 (0%)	n/a [n/a]	2 (67%)	-
Scaphoid	2 (67%)	2(100%)	2(100%)	4.0 [0.0]	0 (0%)	0 (0%)
Distal Ulna	2(100%)	2(100%)	2(100%)	38.0 [28.3]	1 (50%)	1 (50%)
Radial Diaphysis	2(100%)	1 (50%)	1 (50%)	50.0 [n/a]	2(100%)	0 (0%)
Humeral Diaphysis	1(100%)	1(100%)	1(100%)	12.0 [n/a]	0 (0%)	0 (0%)
Proximal Radius	1(100%)	1(100%)	1(100%)	5.0 [n/a]	0 (0%)	0 (0%)
Lower Limb	22 (88%)	19 (86%)	19 (86%)	26.9 [15.1]	12 (55%)	2 (9%)
Ankle	12 (80%)	10 (83%)	10 (83%)	30.4 [17.1]	7 (58%)	1 (8%)
Metatarsal	3 (100%)	3(100%)	3(100%)	11.3 [4.7]	0 (0%)	0 (0%)
Tibial Diaphysis	3 (100%)	2 (67%)	2 (67%)	49.0 [19.4]	0 (0%)	1 (33%)
Fibula	2 (100%)	2(100%)	2(100%)	11.0 [4.2]	0 (0%)	0 (0%)
Distal Tibia	1 (100%)	1(100%)	1(100%)	28.0 [n/a]	1 (100%)	0 (0%)
Talus	1 (100%)	1(100%)	1(100%)	26.0 [n/a]	1 (100%)	0 (0%)

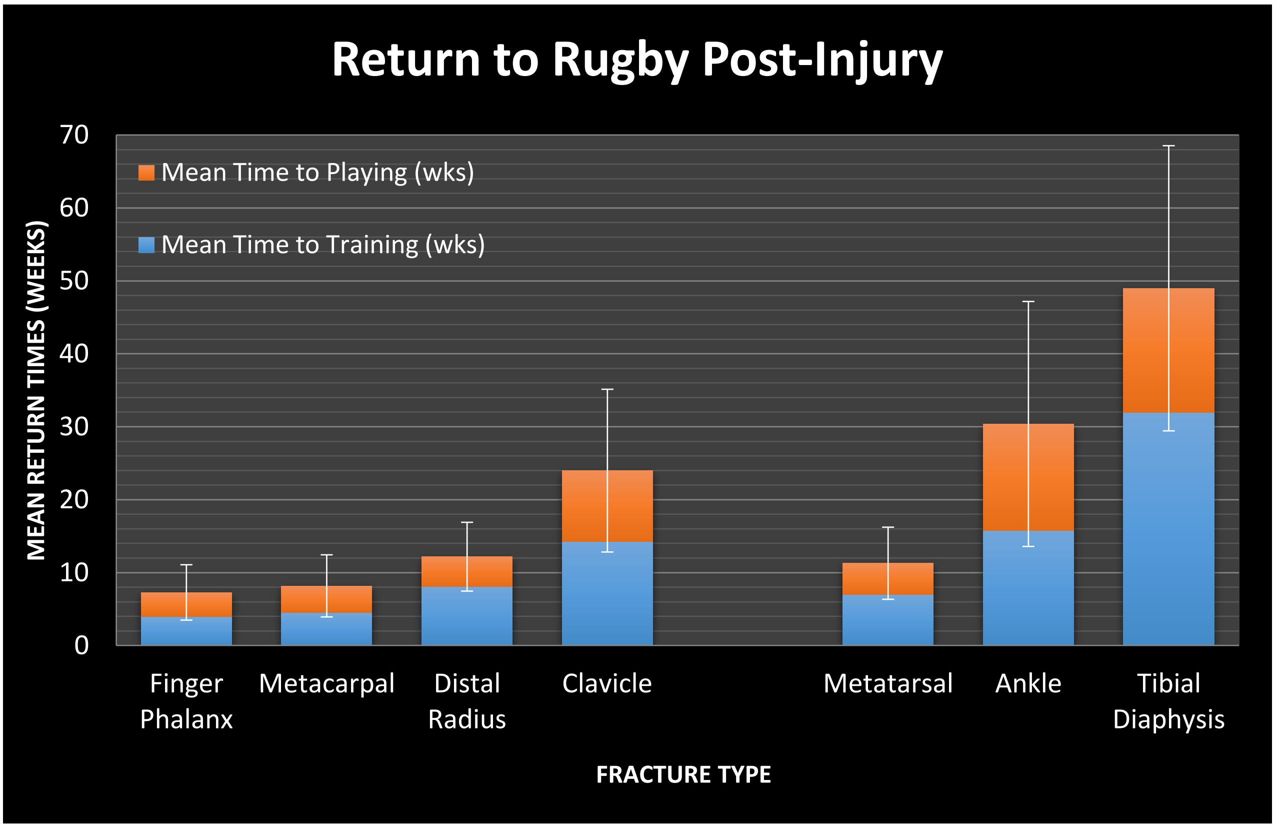
For the total cohort, 15 (12.8%) of the 117 fractures did not return to rugby. The fracture types with the highest rates of no return were: tibial diaphysis (33%), ankle (17%), and finger phalanx (12%). The cause of no return was symptom-related reasons in three patients and personal-related reasons in twelve patients. There was a higher incidence of personal reasons for quitting in upper limb fractures (10/12, 83%) compared with lower limb fractures (2/3, 67%). Patients over 30 years (no-return rate, 40.0%) were 4.5 times more likely to quit rugby than those under 30 years (no-return rate, 8.8%) ($p<0.001$). (Figure 10)

Figure 10 – Return to Rugby Post-Injury: Patients under 30 vs Patients over 30 (Kaplan-Meier Hazard Function)



For the total cohort, the mean return time to full-level rugby was 15.5 (0-98) weeks (Table 12 and Figure 11).

<u>Figure 11 – The Duration taken for Return to Training and Full-Level Rugby for the Different Fracture Types. (Error Bars represent +/- 1 Standard Deviation).</u>



For the upper limb cohort, the mean return time to full-level rugby was 12.9 (0-98) weeks. For the lower limb cohort, the mean return time to full-level rugby was 26.9 (7-52) weeks. The difference in return times to full-level rugby between the upper limb and lower limb cohorts was significant. ($p<0.001$: 95%CI -21.50 to -6.46).

For the surgically-managed cohort, the mean return time to full-level rugby was 25.1 (5-52) weeks. For the conservatively-managed cohort, the mean return time to full-level rugby was 13.7 (0-98) weeks. The difference in return times to full-level rugby between the surgically-managed and conservatively-managed cohorts was significant ($p<0.008$: 95%CI -19.67 to -3.12).

For the total cohort, the rate of non-union was 1.7% (2/117) and the rate of mal-union was 4.2% (5/117).

The rate of non-union was 2.1% (2/95) for the conservatively-managed cohort and 0.0% (0/22); for the surgically-managed cohort (p=1.000).

The rate of mal-union was 4.2% (4/95) for the conservatively-managed cohort and 4.5% (1/22) for the surgically-managed cohort (p=1.000).

From the surgically-managed cohort, one patient (5%) suffered a complication from his surgery and five patients (23%) required secondary surgery.

For the total cohort, 37 of the 117 fractures (31.6%) had persisting symptoms at follow-up (Table 12). These included fracture site pain (n=18), stiffness of an adjacent joint (n=17), and metalwork-related pain (n=3).

For the upper limb cohort, 25 of the 95 fractures (26.3%) had persisting symptoms at follow-up. For the lower limb cohort, 12 of the 22 fractures (54.5%) had persisting symptoms at follow-up. The difference in persisting symptoms rates between the upper limb and lower limb cohorts was significant (p<0.020).

For the surgically-managed cohort, 15 of the 22 fractures (68.2%) had persisting symptoms at follow-up. For the conservatively-managed cohort, 22 of the 95 fractures (23.2%) had persisting symptoms at follow-up. The difference in persisting symptoms rates between the surgically-managed and conservatively-managed cohorts was significant (p<0.001).

For the total cohort, 11 of the 117 fractures (9.4%) had persisting symptoms which impaired rugby ability at follow-up (Table 12). These included fracture site pain (n=8) and stiffness of an adjacent joint (n=5) and weakness of grip (n=3).

For the upper limb cohort, 9 of the 95 fractures (9.5%) had persisting symptoms which impaired rugby ability at follow-up. For the lower limb cohort, 2 of the 22 fractures (9.1%) had persisting symptoms which impaired rugby ability at follow-up. The difference in persisting symptoms rates which impaired rugby ability between the upper limb and lower limb cohorts was not significant (p=1.000).

For the surgically-managed cohort, 4 of the 22 fractures (18.2%) had persisting symptoms which impaired rugby ability at follow-up. For the conservatively-managed cohort, 7 of the 95 fractures (7.4%) had persisting symptoms which impaired rugby ability at follow-up. The difference in persisting symptoms rates which impaired rugby ability between the surgically-managed and conservatively-managed cohorts was not significant (p=0.215).

3.4.3 Hockey

3.4.3.1 Adult Database

For the total cohort, follow-up data was achieved in 18 of the 19 fractures (94.7%).

Of the 18 fractures, 16 returned to hockey (return rate 88.9%) (Table 13).

For the upper limb cohort, 14 of the 16 fractures returned to hockey (return rate 87.5%). For the lower limb cohort, 2 of the 2 fractures returned to hockey (return rate 100.0%). The difference in return rates between the upper limb and lower limb cohorts was not significant (p=1.000).

For the surgically-managed cohort, 4 of the 4 fractures returned to hockey (return rate 100.0%). For the conservatively-managed cohort, 12 of the 14 fractures returned to hockey (return rate 85.7%). The difference in return rates between the surgically-managed and conservatively-managed cohorts was not significant (p=1.000).

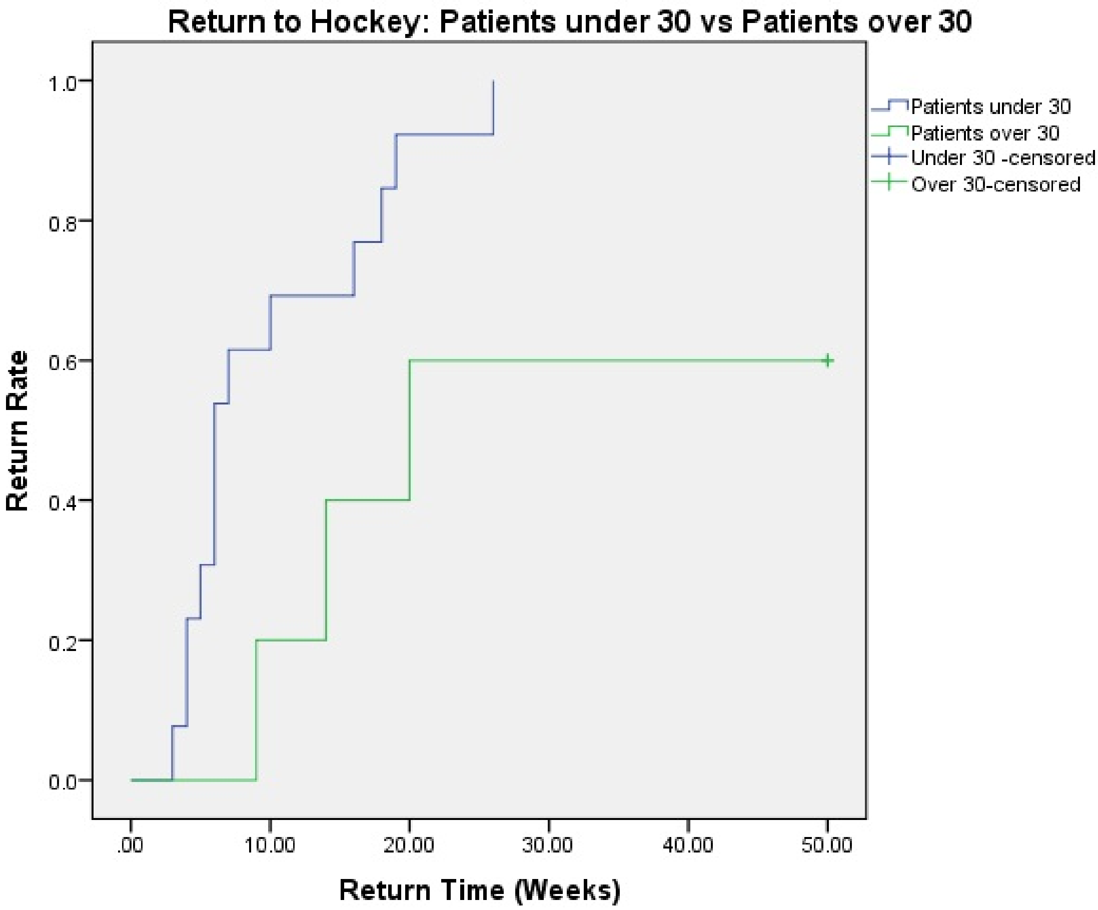
Table 13: Adult Hockey Fracture Follow-up Data

Type	Follow-Up	Return to Hockey	Return to Same Level or Higher	Time to Hockey (wks) [SD]	Persisting Symptoms	Persisting Symptoms Affecting Hockey
Total Cohort	18 (95%)	16 (89%)	14 (78%)	10.8 [7.1]	9 (50%)	3 (17%)
Upper Limb	16 (94%)	14 (88%)	13 (81%)	9.2 [5.7]	7 (44%)	2 (13%)
Finger Phalanx	8 (100%)	7 (88%)	7 (88%)	8.4 [5.5]	3 (38%)	1 (13%)
Metacarpal	7 (100%)	6 (86%)	5 (71%)	8.5 [3.3]	3 (43%)	1 (14%)
Clavicle	1 (100%)	1 (100%)	1 (100%)	19.0 [n/a]	1 (100%)	0 (0%)
Distal Ulna	0 (0%)	-	-	-	-	-
Lower Limb	2 (100%)	2 (100%)	1 (50%)	22.0 [5.7]	2 (100%)	1 (50%)
Ankle	1 (100%)	1 (100%)	0 (0%)	26.0 [n/a]	1 (100%)	1 (100%)
Patella	1 (100%)	1 (100%)	1 (100%)	18.0 [n/a]	1 (100%)	0 (0%)

For the total cohort, 2 (11.1%) of the 18 fractures did not return to hockey. The fracture types with the highest “no return” rates were: metacarpal (14%) and finger phalanx (13%). The cause of no return was symptom-related reasons in both patients. Both patients had suffered an upper limb fracture, and both were over 30 years old (mean age 41.5 years: Range: 38–45 years; SD 4.9 years) (Figure 12).

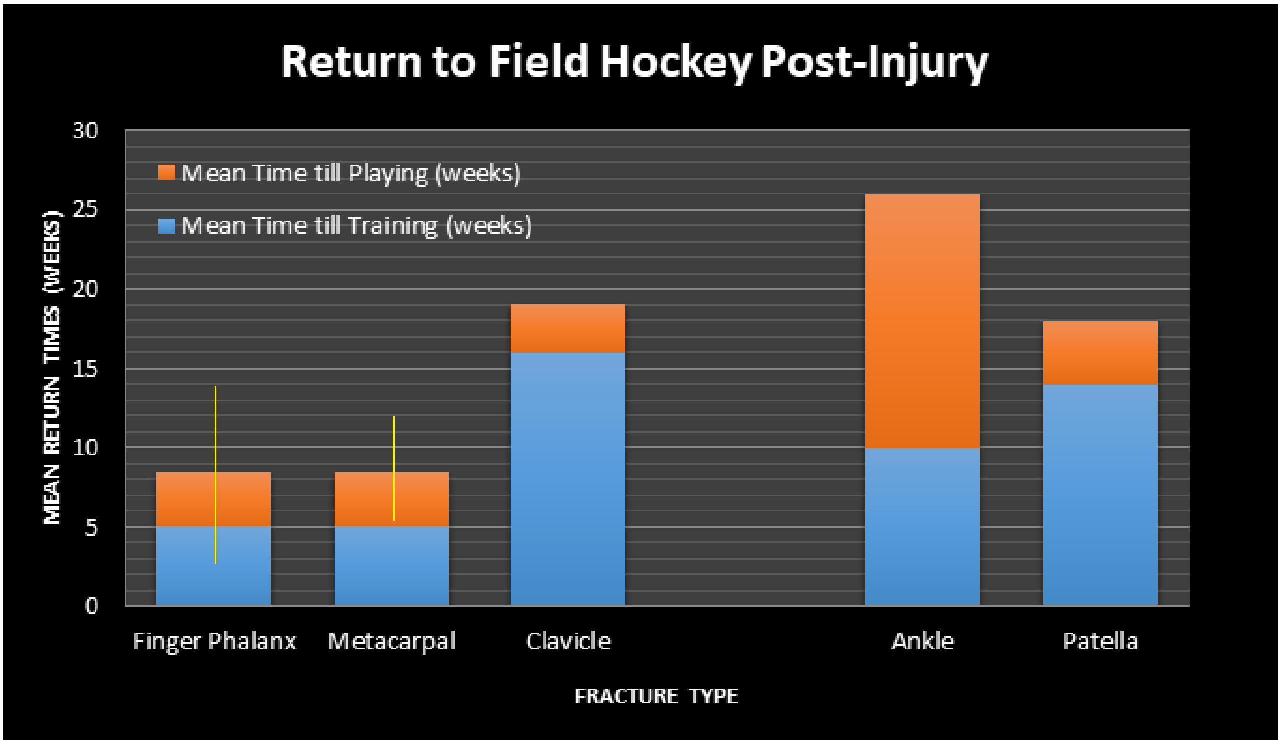
Figure 12 – Return to Hockey Post-Injury: Patients under 30 vs Patients over 30

(Kaplan-Meier Hazard Function)



For the total cohort, the mean return time to full-level hockey was 10.8 (3-26) weeks (Table 13 and Figure 13).

Figure 13 – The Duration taken for Return to Training and Full-Level Hockey for the Different Fracture Types. (Error Bars represent +/- 1 Standard Deviation).



For the upper limb cohort, the mean return time to full-level hockey was 9.2 (3-20) weeks. For the lower limb cohort, the mean return time to full-level hockey was 22.0 (18-26) weeks. The difference in return times to full-level hockey between the upper limb and lower limb cohorts was significant. ($p<0.011$; 95%CI -22.08 to -3.49).

For the surgically-managed cohort, the mean return time to full-level hockey was 16.5 (10-26) weeks. For the conservatively-managed cohort, the mean return time to full-level hockey was 8.9 (3-20) weeks. The difference in return times to full-level hockey between the surgically-managed and conservatively-managed cohorts was not significant ($p=0.069$: 95%CI -15.51 to 0.56).

For the total cohort, the rate of non-union was 0.0% (0/18) and the rate of mal-union was 5.6% (1/18).

The rate of non-union was 0.0% (0/14) for the conservatively-managed cohort

and 0.0% (0/4) for the surgically-managed cohort (p=1.000).
The rate of mal-union was 7.1% (1/14) for the conservatively-managed cohort and 0.0% (0/4) for the surgically-managed cohort (p=1.000).
From the surgically-managed cohort, no patient (0%) suffered a complication from their surgery and one patient (25%) required secondary surgery.

For the total cohort, 9 of the 18 fractures (50.0%) had persisting symptoms at follow-up (Table 13). These included fracture site pain (n=6), stiffness of an adjacent joint (n=4), and metalwork-related pain (n=1).
For the upper limb cohort, 7 of the 16 fractures (43.8%) had persisting symptoms at follow-up. For the lower limb cohort, 2 of the 2 fractures (100.0%) had persisting symptoms at follow-up. The difference in persisting symptoms rates between the upper limb and lower limb cohorts was not significant (p=0.471).
For the surgically-managed cohort, 3 of the 4 fractures (75.0%) had persisting symptoms at follow-up. For the conservatively-managed cohort, 6 of the 14 fractures (42.9%) had persisting symptoms at follow-up. The difference in persisting symptoms rates between the surgically-managed and conservatively-managed cohorts was not significant (p=0.577).

For the total cohort, 3 of the 18 fractures (16.6%) had persisting symptoms which impaired hockey ability at follow-up (Table 13). These included fracture site pain (n=3) and stiffness of an adjacent joint (n=1) and metal-work related pain (n=1).
For the upper limb cohort, 2 of the 16 fractures (12.5%) had persisting symptoms which impaired hockey ability at follow-up. For the lower limb cohort,

1 of the 2 fractures (50.0%) had persisting symptoms which impaired hockey ability at follow-up. The difference in persisting symptoms rates which impaired hockey ability between the upper limb and lower limb cohorts was not significant (p=0.314).

For the surgically-managed cohort, 2 of the 4 fractures (50.0%) had persisting symptoms which impaired hockey ability at follow-up. For the conservatively-managed cohort, 1 of the 14 fractures (7.1%) had persisting symptoms which impaired hockey ability at follow-up. The difference in persisting symptoms rates which impaired hockey ability between the surgically-managed and conservatively-managed cohorts was not significant (p=0.108).

3.5 Optimising Outcome

3.5.1 Ankle Fractures

3.5.1.1 Adult Football Cohort

From the adult football cohort, of the 49 ankle fractures, follow-up was achieved in 44. Twenty-one were managed surgically (all displaced – treated with ORIF); twenty-three were managed conservatively (all undisplaced). For the surgical cohort, the return rate was 90.5% (19/21); the mean return time was 42.0 (16-104) weeks. For the conservative cohort, the return rate was 100% (23/23); the mean return time was 22.2 (5-52) weeks. The difference in return rates was not significant (p=0.222), but the difference in mean return times was significant (p<0.002: 95%CI 7.79 to 31.77).

For the conservatively-managed ankle fractures, the rate of ‘persisting symptoms’ was 21.7% (5/23); the rate of ‘persisting symptoms impairing football ability’ was 4.3% (1 / 23). For the surgically-managed ankle fractures, the rate of ‘persisting symptom’ was 57.1% (12/21); the rate of ‘persisting symptoms impairing football ability’ was 23.8% (5/21). The difference between the rate of ‘persisting symptoms’ (p=0.065) and the difference between the rate of ‘persisting symptoms impairing football ability’ (p=0.088) both neared statistical significance.

3.5.1.2 Systematic Review on Sport-Related Ankle Fractures

Following a systematic literature search on the topic of return to sport following ankle fractures, the thesis author noted an existing systematic review on the topic(86).

This was published in 2013, with the literature search being performed in October 2012.

The authors reviewed 781 abstracts, and 31 articles(86).

Seven studies were included in the review(87-93), of which five reported on return to sport following acute ankle fractures(87-91). This provided a combined cohort of 337 ankle fractures(86).

All studies comprised of cohorts of surgically-managed ankle fractures(86).

The recorded sports included American Football, baseball, football, softball, wrestling, gymnastics, motocross, rock climbing, rodeo, rugby and volleyball(86).

The reported return rates to sport were: 96% by 7 months post-injury(88); 25%

at 1 year follow-up (88% for recreational athletes; 12% for competitive athletes)(87); 100%(90); 100%(89); and 100%(91).
The reported return times to sport were limited with only one study recording recovery of activity for all patients between 3 and 4 months(91).

The authors' conclusion was that 'the general principles were to undertake open reduction and internal fixation of acute fractures' 'to obtain early and full return to sports'(86). This however, is in contrast to the data from our football cohort, where conservative management of undisplaced ankle fractures provided statistically significant improved return times when compared to surgical management of displaced ankle fractures.

3.5.1.3 Sport-Related Ankle Fracture Study

The thesis author performed a further study on the Epidemiology. Management and Outcome of Sport-Related Ankle Fractures from the Adult Fracture Database. A total of 96 sport-related ankle fractures were included in the study.

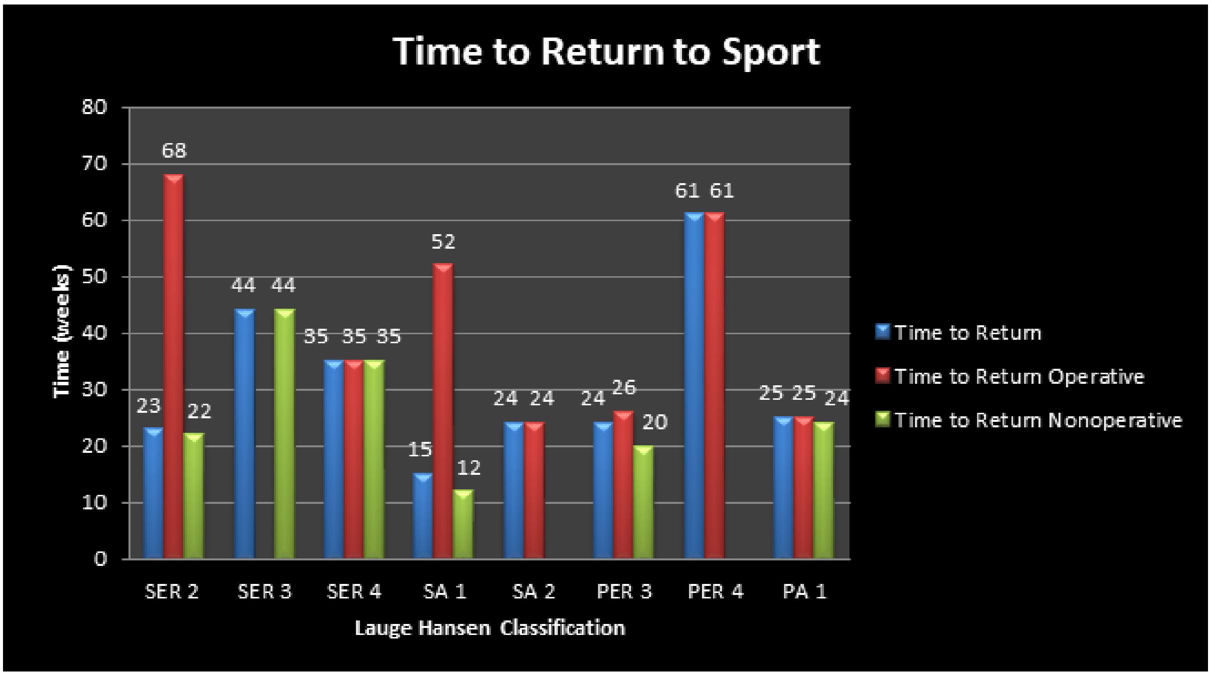
The recorded sports included soccer (n=49), rugby (n=15), running (n=5), and ice skating (n=3), basketball (n=2), golf (n=2), netball (n=2), skateboarding (n=2) and trampolining (n=2). Forty-two of the fractures were undisplaced; fifty-four were displaced. Forty-four of the fractures were treated surgically (all displaced fractures and two undisplaced trimalleolar ankle fracture); fifty-two were treated conservatively.

Follow-up was achieved for 84 fractures. Thirty-eight fractures were managed surgically (all ORIF); forty-six were managed conservatively. For the surgical cohort, the return rate was 86.8% (33/38); the mean return time was 35 (8-104) weeks. For the conservative cohort, the return rate was 100.0% (46/46); the mean return time was 20 (4-52) weeks. Comparing the surgical and conservative cohorts, the difference in return rates ($p<0.016$) and the difference in mean return times ($p<0.001$: 95%CI 7.72 to 23.69) were both significant.

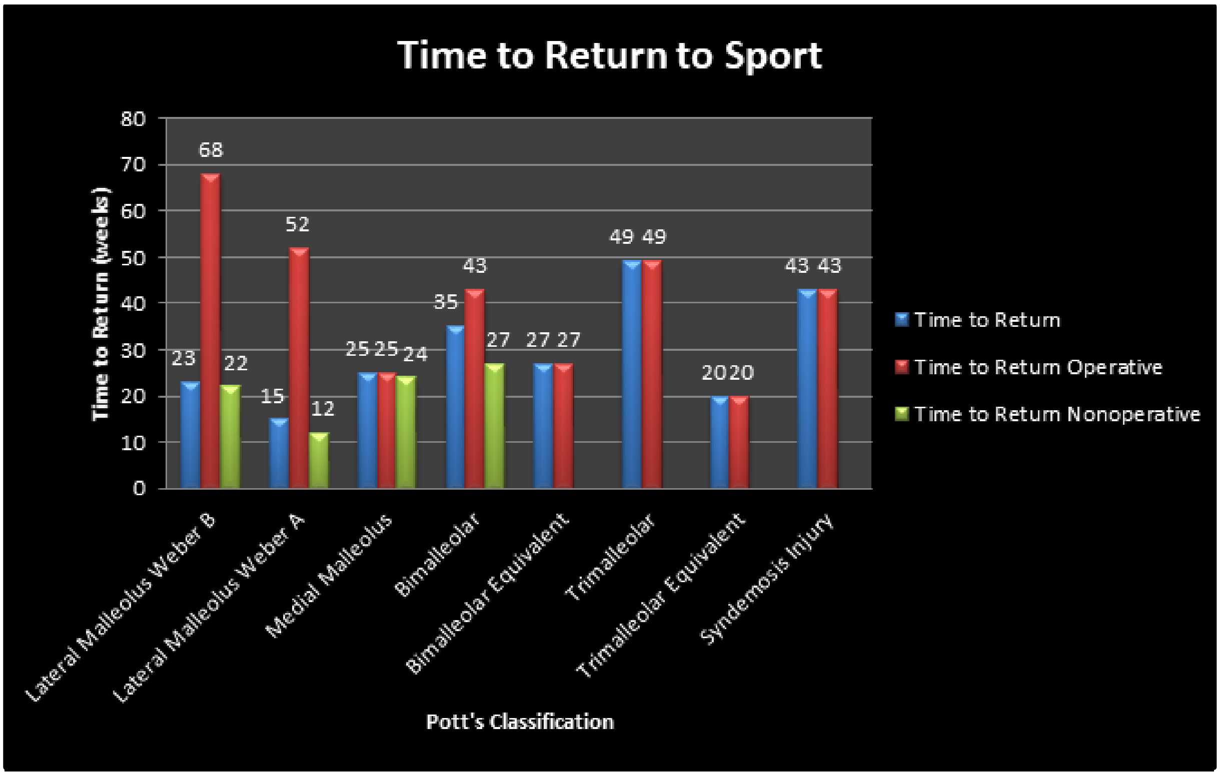
The ankle fractures are divided by the Lauge Hansen classification in Figure 14a and by the Potts classification in Figure 14b. The mean return times for each of the classification sub-groups are provided in the Figures, along with the mean return times for the conservative and surgical sub-cohorts. This shows that, for all fracture types, when conservative management is possible, due to the fracture being undisplaced, this provided improved return times to sport over surgical management.

Figure 14 – Sport-Related Ankle Fractures Outcome: Study Analysis

a) Time to Return to Sport: Lauge-Hansen Classification



b) Time to Return to Sport: Pott's Classification



Of the 38 patients managed surgically, 27 (71%) were found to have persisting symptoms at follow-up, and 8 (21%) had symptoms that interfered with their sporting ability. Of the 46 patients managed conservatively, 8 (17%) were found to have persisting symptoms at follow-up, and 0 (0%) had symptoms that interfered with their sporting ability. Persisting symptom rates ($p<0.001$) and persisting symptoms affecting sporting ability rates ($p<0.001$) were significantly greater in the surgical cohort.

From the study results, the thesis author concludes that conservative management should form the first-line treatment for undisplaced ankle fractures, and surgical management the first-line treatment of displaced ankle fractures.

3.5.2 Tibial Diaphyseal Fractures

3.5.2.1 Adult Football Cohort

From the adult football cohort, of the 18 tibial diaphyseal fractures, follow-up was achieved in 15. Nine were managed surgically (all displaced – treated with IM Nail); six were managed conservatively (all undisplaced). For the surgical cohort, the return rate was 88.9% (8/9); the mean return time was 35.0 (18-64) weeks. For the conservative cohort, the return rate was 66.7% (4/6); the mean return time was 44.5 (20-104) weeks. Due to the cohort size, neither the difference in return rates ($p=0.525$), nor the difference in mean return times ($p=0.557$: 95%CI -44.33 to 25.33) achieved statistical significant.

For the conservatively-managed tibial diaphyseal fractures, the rate of ‘persisting symptoms’ was 50.0% (3/6); the rate of ‘persisting symptoms impairing football ability’ was 33.3% (2/6). For the surgically-managed tibial diaphyseal fractures, the rate of ‘persisting symptom’ was 88.9% (8/9); the rate of ‘persisting symptoms impairing football ability’ was 22.2% (2/9). Neither the difference between the rate of ‘persisting symptoms’ (p=0.235) and nor the difference between the rate of ‘persisting symptoms impairing football ability’ (p=1.000) was significant.

2.5.2.2 Meta-Analysis of Sport-Related Tibial Diaphyseal Fractures

The thesis author performed a systematic review and meta-analysis on the topic of return to sport following tibial diaphyseal fractures(40).

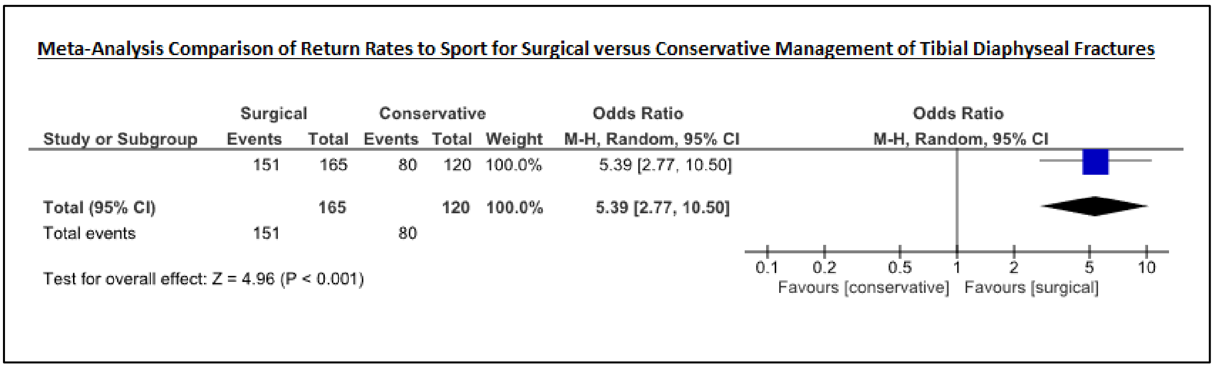
A systematic literature search on the topic was performed in February 2015, and the article was published in 2016(40).
The authors reviewed 46847 titles, 152 abstracts, and 49 articles(40).
Sixteen studies were included in the review, all of which reported on return to sport following acute tibial diaphyseal fractures(49, 57-59, 94-105). This provided a combined cohort of 889 tibial diaphyseal fractures, with sporting follow-up data achieved for 782 of the fractures(40).
Fourteen studies reported on surgical management of tibial diaphyseal fractures ($n_{follow\text{-}up}$=568) (49, 57-59, 94-98, 100, 102-105); eight studies reported on conservative management ($n_{follow\text{-}up}$=201) (49, 57, 58, 94, 99-102).
The recorded sports included football, rugby, skiing, gaelic football and

skiing(40).

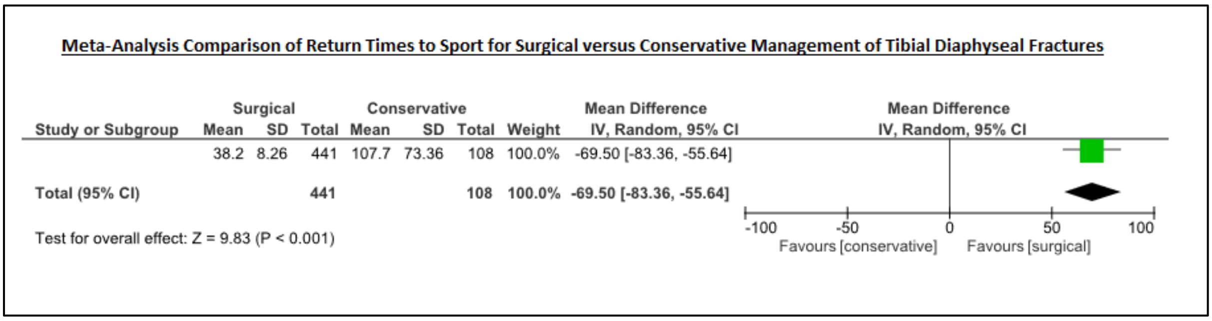
For the surgical ‘synthesis’ cohort, the return rate to sport was 91.5% (151/165) and the mean return time to sport was 38.2 (12-55) weeks(40). For the conservative ‘synthesis’ cohort, the return rate to sport was 66.7% (80/120) and the mean return time to sport was 107.7 (27.6-182) weeks(40). Comparing the surgical ‘synthesis’ cohort to the conservative ‘synthesis’ cohort, the difference between the return rates to sport (OR, 5.39; 95%CI, 2.77 to 10.50; p<0.001: I^2=0%, p=0.65) (Figure 15a) and the difference between the mean return times to sport (MD, 69.5 weeks; 95%CI, –83.36 to –55.64; p<0.001) (Figure 15b) were both significant(40).

Figure 15 – Sport-Related Tibial Diaphyseal Fractures: Meta-Analysis of Outcome Data

a) Meta-Analysis Comparison of Return Rates to Sport for Conservative versus Surgical Management of Tibial Diaphyseal Fractures



b) Meta-Analysis Comparison of Return Times to Sport for Conservative versus Surgical Management of Tibial Diaphyseal Fractures



The data suggests that primary surgical intervention of undisplaced tibial diaphyseal fractures may result in higher return rates and quicker return times to sport over conservative management(40). Surgical management remains the first-line treatment of displaced tibial diaphyseal fractures(40).

3.5.3 Clavicle Fractures

As the management of clavicle fractures is dependent on the location of the fracture (mid-shaft, lateral, medial) and the displacement of the fracture, analysis of the management and outcome of these injuries requires the cohort to be sub-divided by fracture location.

3.5.3.1 Adult Football Cohort

From the adult football cohort, of the 20 clavicle fractures, follow-up was achieved in 17. These comprised 10 mid-shaft fractures and 7 lateral fractures. Of the mid-shaft fractures: 5 were undisplaced and treated conservatively; 5 were displaced, of which 4 were treated conservatively and 1 was treated surgically (ORIF). Of the lateral fractures: 4 were undisplaced and treated conservatively; 3 were displaced and treated surgically (ORIF).

For the mid-shaft fractures, the return rate was 70.0% (7/10): undisplaced conservative - 80.0% (4/5); displaced conservative - 50.0% (2/4); displaced surgical - 100.0% (1 / 1). For the mid-shaft fractures, the mean return time to football was 18.9 (10-38) weeks: undisplaced conservative - 12.5 (10-16) weeks: displaced conservative - 29.0 (20-38) weeks; displaced surgical - 24.0

weeks.

For the lateral fractures, the return rate was 85.7% (6/7): undisplaced conservative - 100.0% (4/4); displaced surgical - 66.7% (2/3). For the lateral fractures the mean return time to football was 17.2 (6-24) weeks: undisplaced conservative -15.0 (6-24) weeks; displaced surgical - 21.5 (19-24) weeks.

For the mid-shaft clavicle fractures, the rate of ‘persisting symptoms’ was 30.0% (3/10) (undisplaced conservative - 20.0% (1/5); displaced conservative - 25.0% (1/4); displaced surgical - 100% (1/1)), and the rate of ‘persisting symptoms impairing football ability’ was 10.0% (1/10) (undisplaced conservative - 20.0% (1/5); displaced conservative – 0.0% (0/4); displaced surgical - 0.0% (0/1)).

For the lateral fractures, the rate of ‘persisting symptoms’ was 42.9% (3/7) (undisplaced conservative - 50.0% (2/4); displaced surgical 33.3% (1/3)), and the rate of ‘persisting symptoms impairing football ability’ was 0.0% (0/7) (undisplaced conservative - 0.0% (0/4); displaced surgical – 0.0% (0/3)).

3.5.3.2 Adult Rugby Cohort

From the adult rugby cohort, of the 24 clavicle fractures, follow-up was achieved in 19. These comprised 17 mid-shaft fractures and 2 lateral fractures. Of the mid-shaft fractures: 11 were undisplaced and treated conservatively; 6 were displaced, of which 4 were treated conservatively and 2 were treated surgically (ORIF). Of the lateral fractures: 2 were undisplaced and treated conservatively.

For the mid-shaft fractures, the return rate was 94.1% (16/17): undisplaced conservative - 100.0% (11/11); displaced conservative - 100.0% (4/4); displaced surgical - 50.0% (1/2). For the mid-shaft fractures, the mean return time to rugby was 23.7 (14-36) weeks: undisplaced conservative - 21.5 (14-36) weeks: displaced conservative – 28.5 (23-33) weeks; displaced surgical - 29.0 weeks.

For the lateral fractures, the return rate was 100.0% (2/2): undisplaced conservative - 100.0% (2/2); For the lateral fractures, the mean return time to rugby was 26.0 (23-29) weeks: undisplaced conservative - 26.0 (23-29) week.

For the mid-shaft clavicle fractures, the rate of 'persisting symptoms' was 17.6% (3/17) (undisplaced conservative - 9.1% (1/11); displaced conservative - 25.0% (1/4); displaced surgical – 50.0% (1/2)), and the rate of 'persisting symptoms impairing rugby ability' was 0.0% (0/17) (undisplaced conservative - 0.0% (0/11); displaced conservative – 0.0% (0/4); displaced surgical - 0.0% (0/2)).

For the lateral fractures, the rate of 'persisting symptoms' was 0.0% (0/2) (undisplaced conservative - 0.0% (0/2)), and the rate of 'persisting symptoms impairing rugby ability' was 0.0% (0/2) (undisplaced conservative - 0.0% (0/2)).

3.5.3.3 Meta-Analysis of Sport-Related Clavicle Fractures

The thesis author performed a systematic review and meta-analysis on the topic of return to sport following clavicle fractures(41).

A systematic literature search on the topic was performed in August 2015, and the article was published in 2016(41).

The authors reviewed 14755 titles, 223 abstracts, and 148 articles(41). Twenty-three studies were included in the review, all of which reported on return to sport following acute clavicle fractures(66, 102, 103, 106-125). This provided a combined cohort of 589 clavicle fractures, with sporting follow-up data achieved for 555 of the fractures(41).

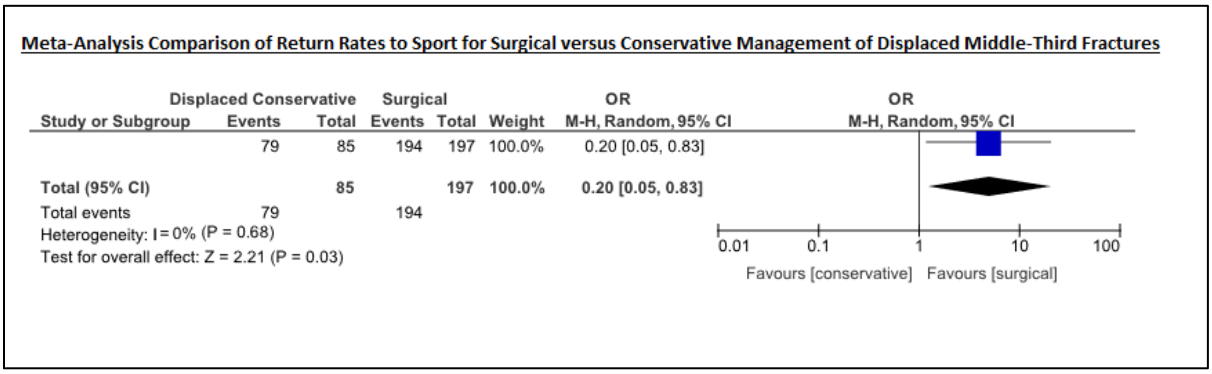
Ten studies reported on mid-shaft clavicle fractures ($n_{follow\text{-}up}$=304) (66, 102, 103, 106-112); fourteen studies reported on lateral clavicle fractures ($n_{follow\text{-}up}$=210) (102, 103, 113-124). The most common recorded sports included American Football, football, rugby, cycling, motorcycling, horse riding, skiing, snowboarding and running(41).

In the mid-shaft 'synthesis' cohort: for the conservatively-managed undisplaced fractures, the return rate to sport was 95.5% (21/22) and the mean return time to sport was 10.6 (10-13) weeks; for the conservatively-managed displaced fractures, the return rate to sport was 92.9% (79/85) and the mean return time to sport was 21.5 (12-78) weeks; for the surgically-managed displaced fractures, the return rate to sport was 98.5% (194/197) and the mean return time to sport was 9.4 (2-24) weeks(41). For the displaced mid-shaft fractures, comparing the surgical 'synthesis' sub-cohort to the conservative 'synthesis' sub-cohort, the difference between the return rates to sport (OR 0.20: 95%CI

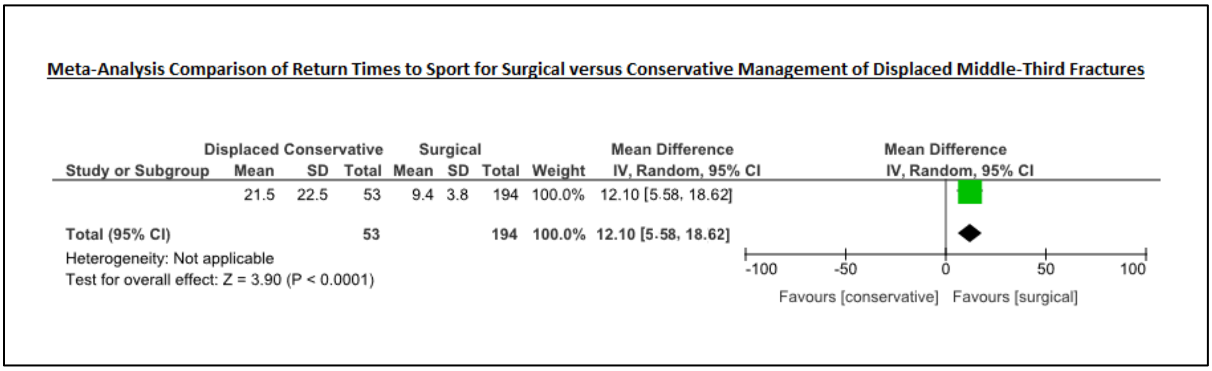
0.05–0.83, p<0.027; I^2=0%, p=0.68) (Figure 16a) and the difference between the mean return times to sport (MD 12.1 weeks: 95%CI 5.58–18.62, p<0.001) (Figure 16b) were both significant(41). However, comparing the ‘undisplaced conservatively managed’ fracture ‘synthesis’ sub-cohort to the ‘displaced surgically managed’ fracture ‘synthesis’ sub-cohort, the difference between the return rates to sport (OR 0.32: 95%CI 0.03–3.26, p=0.339; I^2=12%, p=0.32) and the difference between the mean return times to sport (MD 1.2 weeks: 95%CI 0.53–1.87, p=0.151) were not significant(41).

Figure 16 – Sport-Related Clavicle Fractures: Meta-Analysis of Outcome Data

a) Meta-Analysis Comparison of Return Rates to Sport for Conservative versus Surgical Management of Displaced Middle Third Fractures



b) Meta-Analysis Comparison of Return Times to Sport for Conservative versus Surgical Management of Displaced Middle Third Fractures



In the lateral ‘synthesis’ cohort: for the conservatively-managed undisplaced fractures, the return rate to sport was 100.0% (6/6) and the mean return time to sport was 14.7 (14-15) weeks; for the surgically-managed displaced fractures, the return to sport rate was 85.3% (174/204) and the mean return time to sport was 19.4 (11-36) weeks(41).

The meta-analysis data confirms that the recommended treatment methods of conservative management for undisplaced mid-shaft clavicle fractures, conservative management for undisplaced lateral clavicle fractures and surgical management for displaced lateral clavicle fractures all provide satisfactory results(41). For displaced mid-shaft clavicle fractures, surgical management can provide significantly improved return rates and return times to sport compared to conservative management(41).

3.5.4 Scaphoid Fractures

3.5.4.1 Adult Football Cohort

From the adult football cohort, of the 24 scaphoid fractures, follow-up was achieved in 20. Two of these were managed with acute surgical fixation (both undisplaced); three were managed with delayed surgical fixation (all undisplaced) following development of non-union; 15 were managed conservatively (all undisplaced). For the ‘acute’ surgical cohort, the return rate was 100.0% (2/2); the mean return time was 8.5 (8-9) weeks. For the ‘delayed’ surgical cohort, the return rate was 66.7% (2/3); the mean return time was 40.0 (20-60) weeks. For the conservative cohort, the return rate was 93.3% (14/15); the mean return time was 12.7 (6-24) weeks. Comparing the ‘acute’ surgical cohort to the conservative cohort, due to the cohort sizes, neither the difference in return rates (p=1.000), nor the difference in mean return times (p=0.343: 95%CI -4.99 to 13.42) achieved statistical significant.

For the scaphoid fractures managed conservatively, the rate of ‘persisting symptoms’ was 60.0% (9/15); the rate of ‘persisting symptoms impairing football ability’ was 20.0% (3/15). For the scaphoid fractures managed with ‘acute’ surgical fixation, the rate of ‘persisting symptom’ was 100.0% (2/2); the rate of ‘persisting symptoms impairing football ability’ was 0.0% (0/2). For the scaphoid fractures managed with ‘delayed’ surgical fixation, the rate of ‘persisting symptom’ was 66.7% (2/3); the rate of ‘persisting symptoms impairing football ability’ was 33.3% (1/3). Comparing the conservative cohort to the ‘acute’ surgical cohort, neither the difference between the rate of ‘persisting symptoms’ (p=0.515) and nor the difference between the rate of ‘persisting symptoms impairing football ability’ (p=1.000) was significant.

3.5.4.2 Meta-Analysis of Sport-Related Scaphoid Fractures

The thesis author performed a systematic review and meta-analysis on the topic of return to sport following scaphoid fractures(126).

A systematic literature search on the topic was performed in August 2018, and the article was published in February 2019(126).
The authors reviewed 29683 titles, 131 abstracts, and 46 articles(126).
Eleven studies were included in the review, all of which reported on return to sport following acute scaphoid fractures(64, 102, 127-135). This provided a

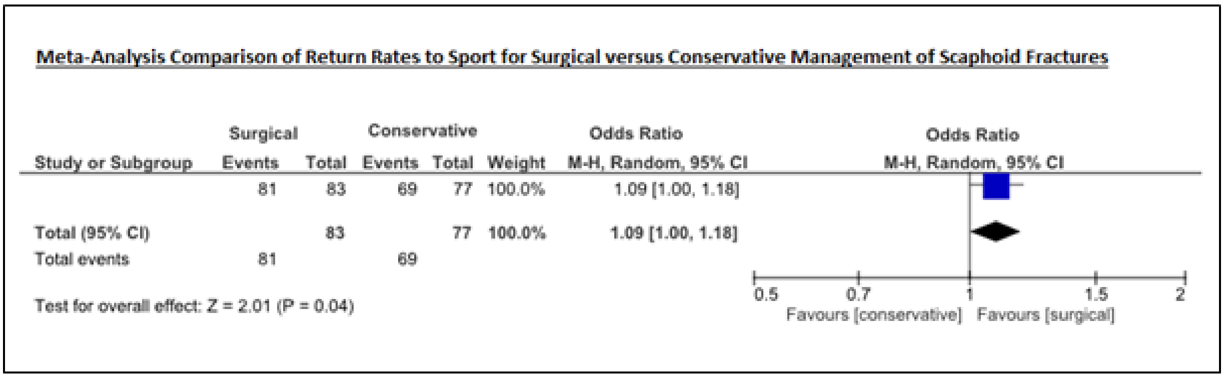
combined cohort of 170 acute scaphoid fractures, with sporting follow-up data achieved for 160 of the fractures(126).

Eight studies reported on surgical management of acute scaphoid fractures ($n_{follow\text{-}up}$=83) (64, 102, 128-132, 134); seven studies reported on conservative management ($n_{follow\text{-}up}$=77)(64, 102, 127, 128, 132, 133, 135). The recorded sports included football, American football, rugby, basketball swimming, squash, athletics, baseball and archery(126).

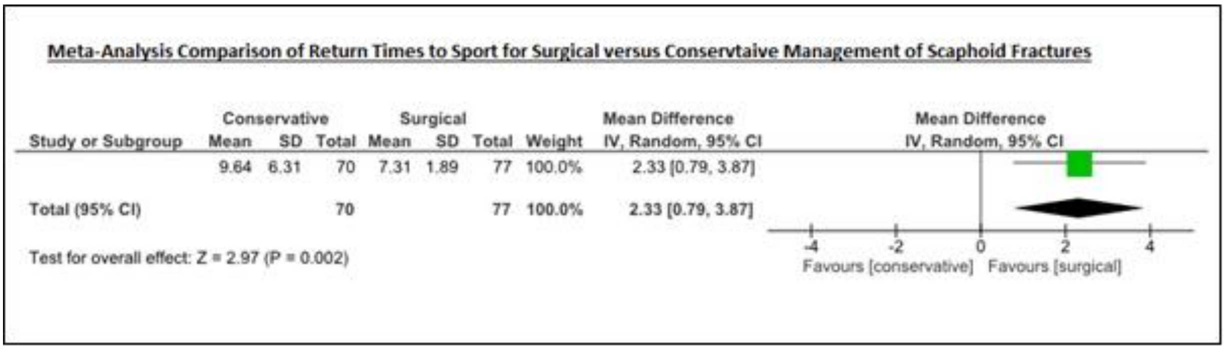
For the surgical 'synthesis' cohort, the return rate to sport was 97.6% (81/83) and the mean return time to sport was 7.3 (6-11) weeks(126). For the conservative 'synthesis' cohort, the return rate to sport was 89.6% (69/77) and the mean return time to sport was 9.6 (0-16) weeks(126). Comparing the surgical 'synthesis' cohort to the conservative 'synthesis' cohort, the difference between the return rates to sport (OR, 1.09; 95%CI, 1.00 to 1.18; $p<0.045$: I^2=0%, $p=0.78$) (Figure 17a) and the difference between the mean return times to sport (MD 2.3 weeks; 95%CI, 0.79 to 3.87; $p<0.002$) (Figure 17b) were both significant(126).

Figure 17 – Sport-Related Scaphoid Fractures: Meta-Analysis of Outcome Data

a) Meta-Analysis Comparison of Return Rates to Sport for Conservative versus Surgical Management of Scaphoid Fractures



b) Meta-Analysis Comparison of Return Times to Sport for Conservative versus Surgical Management of Scaphoid Fractures



The data suggests that primary surgical intervention of undisplaced scaphoid fractures may result in higher return rates and quicker return times to sport over conservative management(126). Surgical management remains the first-line treatment of displaced scaphoid fractures(126).

3.5.5 Metacarpal Fractures

3.5.5.1 Adult Football Cohort

From the adult football cohort, of the 27 metacarpal fractures, follow-up was achieved in 23. Three were managed surgically (all displaced); twenty were managed conservatively (all undisplaced). Of those managed surgically, one was treated with ORIF; two with MUA and K-Wire. For the surgical cohort, the return rate was 100.0% (3/3); the mean return time was 18.3 (12-24) weeks. For the conservative cohort, the return rate was 85.0% (17/20); the mean return time was 4.6 (2-10) weeks. The difference in return rates was not significant (p=0.525), but the difference in mean return times was statistically significant (p<0.001: 95%CI -18.79 to -8.59).

For the surgical cohort: those treated with MUA and K-Wiring had a return rate of 100.0% (2/2) and a mean return time of 21.5 (19-24) weeks; those treated with ORIF had a return rate of 100.0% (1/1) and a mean return time of 12 (12-12) weeks.

For the conservatively-managed metacarpal fractures, the rate of ‘persisting symptoms’ was 40.0% (8/20); the rate of ‘persisting symptoms impairing football ability’ was 5.0% (1/20). For the surgically-managed metacarpal fractures, the rate of ‘persisting symptom’ was 66.7% (2/3); the rate of ‘persisting symptoms impairing football ability’ was 0.0% (0/3). Neither the difference between the rate of ‘persisting symptoms’ (p=0.560) and nor the difference between the rate of ‘persisting symptoms impairing football ability’ (p=1.000) was significant.

3.5.5.2 Adult Rugby Cohort

From the adult rugby cohort, of the 27 metacarpal fractures, follow-up was achieved in 22. Four were managed surgically (all displaced); eighteen were managed conservatively (all undisplaced). All of the surgically managed fractures were treated with MUA and K-Wire. For the surgical cohort, the return rate was 100.0% (4/4); the mean return time was 15.8 (5-22) weeks. For the conservative cohort, the return rate was 88.9% (16/18) and the mean return time was 6.3 (1-12) weeks. The difference in return rates was not significant ($p=1.000$), but the difference in mean return times was statistically significant ($p<0.001$: 95%CI -14.99 to -3.89).

For the conservatively-managed metacarpal fractures, the rate of ‘persisting symptoms’ was 16.7% (3/18); the rate of ‘persisting symptoms impairing rugby ability’ was 5.6% (1/18). For the surgically-managed metacarpal fractures, the rate of ‘persisting symptom’ was 25.0% (1/4); the rate of ‘persisting symptoms impairing rugby ability’ was 25.0% (1/4). Neither the difference between the rate of ‘persisting symptoms’ ($p=1.000$) and nor the difference between the rate of ‘persisting symptoms impairing rugby ability’ ($p=0.338$) was significant.

3.5.5.3 Meta-Analysis of Sport-Related Metacarpal Fractures

The thesis author performed a systematic review and meta-analysis on the topic of return to sport following metacarpal fractures(65, 102, 133, 135-140).

A systematic literature search on the topic was performed in August 2018. The authors reviewed 35672 titles, 106 abstracts, and 41 articles.
Nine studies were included in the review, all of which reported on return to sport following acute metacarpal fractures(65, 102, 133, 135-140). This provided a combined cohort of 195 metacarpal fractures, with sporting follow-

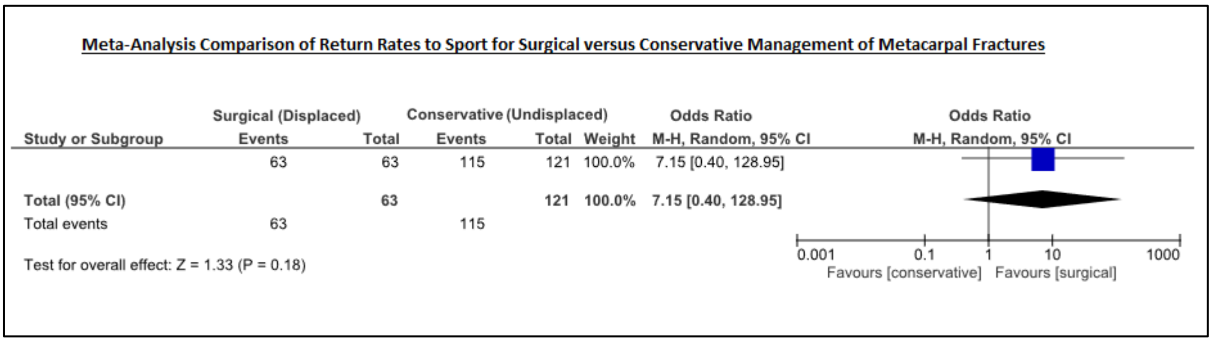
up data achieved for 184 of the fractures.

Eight studies reported on surgical management of metacarpal fractures ($n_{follow-up}$=63) (65, 102, 133, 135-137, 139, 140); six studies reported on conservative management ($n_{follow-up}$=121) (65, 102, 133, 135, 138, 140). The recorded sports included American football, football, rugby, Australian football, baseball, basketball, hockey, wrestling and skiing.

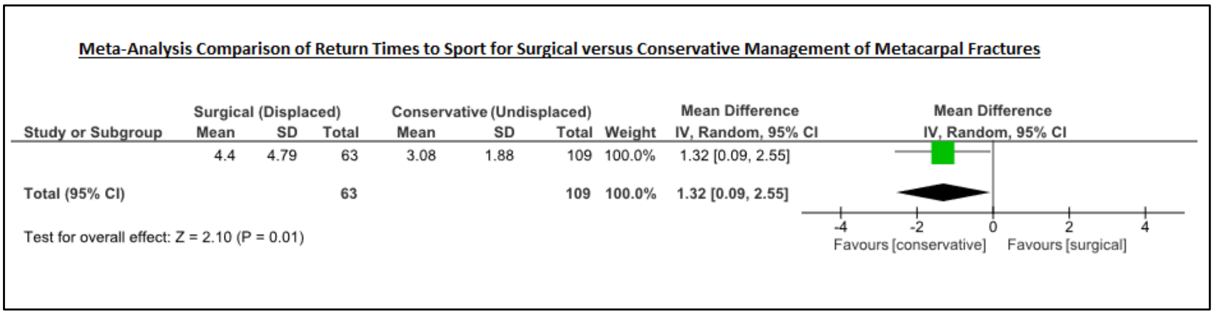
For the surgical 'synthesis' cohort, the return rate to sport was 100.0% (63/63) and the mean return time to sport was 4.4 (1.0–18.3) weeks(65, 102, 133, 135-137, 139, 140). For the conservative 'synthesis' cohort, the return rate to sport was 95.0% (115/121) and the mean return time to sport was 3.1 (1.7–6.8) weeks(65, 102, 133, 135, 138, 140). Comparing the surgical 'synthesis' cohort to the conservative 'synthesis' cohort, there was no significant difference between the return rates to sport (OR, 7.15; 95% CI, 0.40 to 128.95; p=0.183: I^2=0%, p=1.00) (Figure 18a), however the conservative 'synthesis' cohort had significantly quicker mean return times to sport (MD 1.3 weeks; 95%CI, 0.09 to 2.55; p<0.011) (Figure 18b).

Figure 18 – Sport-Related Metacarpal Fractures: Meta-Analysis of Outcome Data

a) Meta-Analysis Comparison of Return Rates to Sport for Conservative versus Surgical Management of Metacarpal Fractures



b) Meta-Analysis Comparison of Return Times to Sport for Conservative versus Surgical Management of Metacarpal Fractures



Within the surgical ‘synthesis’ cohort: for fractures treated with ORIF, the return rate to sport was 100.0% (50/50) and the mean return time to sport was 2.6 (2.0–12.0) weeks(65, 102, 136, 137, 139); for fractures treated with MUA and K-Wire, the return rate to sport was 100.0% (13/13) and the mean return time to sport was 11.4 (1.0–21.5) weeks(65, 102, 133, 135, 140). Comparing the ORIF ‘synthesis’ sub-cohort to the MUA and K-Wire ‘synthesis’ sub-cohort, there was no difference between the return rates to sport (OR, 1.00; 95%CI, 0.90 to 1.11; p=1.000: I^2=0%, p=1.00), however the mean return times to sport for ORIF were significantly quicker than those for MUA and K-Wire (MD 8.8 weeks; 95%CI, 4.84 to 12.68; p<0.001).

The data confirms that conservative management is the recommended first-line treatment for undisplaced and minimally displaced metacarpal fractures;

and surgical management is the recommended first-line treatment for displaced metacarpal fractures. Regarding the choice of surgical management, ORIF can offer improved return times to sport over MUA and K-Wire.

Chapter Four: Discussion, strengths and limitations, clinical relevance and future research

4.1 Main Findings

4.1.1 Epidemiology

4.1.1.1 Football

The main findings were that the incidence of football-related fractures for the adult population was 0.71/1000, and for the adolescent population was 2.03/1000. The incidence of open football-related fractures was 0.002/1000 population. For all three populations, there was a male dominance in gender. For the adult and adolescent populations there was a significant predominance of upper limb fractures; for the open fracture cohort, there was a higher representation of lower limb fractures.

The gender and age distribution is accounted for by the current football population within the Lothian population, with the significant majority being young male athletes(47). In the UK as a whole, data from the Football 2006 Worldwide: Official FIFA Survey17 shows that 89% of all UK football players are male(141).

4.1.1.2 Rugby

The main findings were that the incidence of rugby-related fractures for the adult population was 0.28/1000, and for the adolescent population was 0.88/1000. The incidence of open rugby-related fractures was 0.001/1000 population. For all three populations, there was a male dominance in gender. For the adult and adolescent populations there was a significant predominance of upper limb fractures; for the open fracture cohort, there was a higher representation of lower limb fractures.

The gender and age distribution is accounted for by the current rugby population within the Lothian population, with the significant majority being young male athletes(47). The available data for the Scottish Rugby Union shows that during 2007-2008, for the adult rugby-playing population, there were 2504 registered male players and only 242 registered female players(47, 135).

For both the football and the rugby cohorts, the predominance of upper limb fractures in the closed fracture cohorts is in keeping with the most common reported injury mechanisms (fall and goals for football; tackle and fall for rugby): such injury mechanisms commonly affect the upper limb more than the lower limb(142-146). The higher rate of upper limb fractures in rugby, compared to football, again is representative of the increased upper limb involvement in this sport(142-145). Lower limb fractures tend to occur from more high energy injury mechanisms, as so occur less often, in both sports(142-146). However, due to the high energy of injury involved in the lower limb fractures, and the fact that open fractures represent a high energy injury type, lower limb fractures represent a higher proportion of the open fracture cohort in both sports(4, 142-144, 146).

4.1.1.3 Hockey

The main findings were that the incidence of hockey-related fractures for the adult population was 0.04/1000, and for the adolescent population was 0.12/1000. The incidence of open hockey-related fractures was 0.001/1000 population. For all three populations, there was a higher female proportion than the other two sports.

For the adult, adolescent and open fracture populations there was a significant predominance of upper limb fractures.

The more balanced gender distribution in hockey, compared to the other two sports, is accounted for by the increased proportion of female hockey players in the Lothian region(47). Hockey forms a major school sport for school-girls in this region, and within Scotland, there are four national female hockey leagues and 10 regional female hockey leagues(147).

The predominance of upper limb fractures in the closed fracture cohorts is in keeping with the most common reported injury mechanisms (stick and ball contact): these commonly affect the upper limb more than the lower limb(27). Such mechanisms can have significant energy associated with them, and this explains why there is a significant proportion of upper limb fractures in the open fracture cohort(4, 27).

4.1.2 Management

For the Management section, the main findings were that: within the adult populations, the rates of surgical intervention ranged 17 to 21%; and within the adolescent populations, the rates of surgical intervention ranged 11 to 17%. Within the open fracture population: all fractures were treated surgically, due to the requirement for wound debridement of the associated soft tissue injury.

For all the adult and adolescent cohorts, upper limb fractures had lower rates of surgical intervention than lower limb fractures.

4.1.3 Outcome

4.1.3.1 Football

The main findings from the outcome section in the football cohort were that 86% of football-related fractures returned to football, with a mean return time of 15 weeks. There was no significant difference in return rates between the upper limb cohort and the lower limb cohort. There was also no significant difference in the return rates between the surgically-managed cohort and the conservatively-managed cohort.

The upper limb cohort had significant quicker mean return times to full-level football than the lower limb cohort. The conservatively-managed cohort also had significant quicker mean return times to full-level football than the surgically-managed cohort.

4.1.3.2 Rugby

The main findings from the outcome section in the rugby cohort were that 87% of rugby-related fractures returned to rugby, with a mean return time of 16 weeks. There was no significant difference in return rates between the upper limb cohort and the lower limb cohort. The difference in the return rates between the surgically-managed cohort and the conservatively-managed cohort was however significant, with the surgical cohort having a significantly lower rate of return. The upper limb cohort had significant quicker mean return times to full-level rugby than the lower limb cohort. The conservatively-managed cohort also had significant quicker mean return times to full-level rugby than the surgically-managed cohort.

4.1.3.3 Hockey

The main findings from the outcome section in the hockey cohort were that 89% of hockey-related fractures returned to hockey, with a mean return time of 11 weeks. There was no significant difference in return rates between the upper limb cohort and the lower limb cohort. There was also no significant difference in the return rates between the surgically-managed cohort and the conservatively-managed cohort.

The upper limb cohort had significant quicker mean return times to full-level hockey than the lower limb cohort. The difference in the return times to full-level hockey for the conservatively-managed cohort compared to the surgically-managed cohort neared statistical significance.

For all three cohorts, the difference in mean return times for the upper limb cohort and the lower limb cohort can be explained by the lower limb fractures more often comprising higher energy injuries, with increased rates of displacement and requirement for surgery, as well as prolonged rehabilitation(27, 142-146). The difference in mean return times for the conservatively-managed cohort and the surgically-managed cohort can also be explained by the conservatively-managed cohort being largely comprised of low energy, upper limb fractures which can be rehabilitated quicker; by comparison the surgically-managed cohort comprised a greater proportion of higher energy, lower limb fractures which take longer to rehabilitate(142-146).

4.1.4 Optimising Outcome

The main findings from the Optimising Outcome section were that: primary surgical management of undisplaced unstable fractures (undisplaced tibial diaphyseal fractures, undisplaced scaphoid waist fractures) can improve return rates and return times to sport over conservative management; and primary conservative management of stable undisplaced fractures (undisplaced ankle fractures, undisplaced metacarpal fractures) provides the optimal return rates and times to sport for these injuries. In the case of primary surgical management of the undisplaced unstable fractures, this exposes the patient to the risk of surgical complications, and so must be accompanied by a detailed discussion of both conservative and surgical treatment options, outlining the risks and benefits of each. Surgical management remains the gold standard treatment for displaced fractures, with restoration of anatomical alignment and stable fixation required to facilitate an optimal return to function.

4.2 Strengths

The research presents a number of strengths. The first is that this is a unique collection of prospectively-collated data, of which there is nothing similar in the current literature. This relates to the epidemiology, management and outcome sections, as well as the analyses of the optimising outcome section. As such, the thesis forwards the topic of ‘epidemiology, management and outcome of acute fractures in team sports’ considerably.

Not only is the data unique, it is also comprehensive, providing a robust capture of epidemiology, management and outcome data of acute fractures in team sport for the set time periods of the thesis studies. This is possible due to the well-defined set-up of Orthopaedic Trauma in our region. Similarly, our well-established Orthopaedic record database, provides accurate, easily-accessible data on all our patients, allowing access to comprehensive management data, as well as contact details to obtain follow-up data.

Other notable strengths from our data are that all radiographs were reviewed by a trained Orthopaedic Surgeon to provide accurate information regarding fracture location and classification. This allows the authors to be confident of the fracture diagnoses recorded in the studies.

Further strengths from the data is the unified management principles that were adopted by the treating surgeons from the Edinburgh Orthopaedic Trauma Unit, allowing for consistent fracture management throughout the cohort. This allowed for stratified analyses of the outcome data, with useful conclusions, given the similar treatment methods adopted.

Further positive aspects of the data include the robust method by which the follow-up data was obtained. Each patient was contacted by the same clinician via telephone and asked a standardised questionnaire to obtain uniform data for each case. The patients' records were reviewed immediately prior to contacting the patient, in order to allow the clinician to orientate himself more accurately to the expected time-frame of the patient's response, and so avoid recall bias, which can cause significant inaccuracies to the study results.

Lastly, in order to amass the relevant literature to assess the Optimisation of Outcome of the chosen fracture types, a standardised and accepted comprehensive technique was adopted to systematically review the relevant literature, and provide all the available studies for the topic of interest. This then allowed for the most accurate and contemporary analysis and meta-analysis of the literature, providing the most clinically relevant conclusions on the optimal management methods of the chosen fracture types.

4.3 Limitations

4.3.1 Patient Cohort

While the set-up of Orthopaedic Trauma in our region allows all fracture patients to be identified, there are limitations regarding diagnosis from the patient cohorts.

The first relates to an inability to ensure that all fractures have been identified during the study period. There is likely to be a sub-cohort of patients who sustained fracture injuries, and either did not seek medical attention or did not undergo radiographic assessment to diagnose these during medical treatment. However, due the appreciable pain associated with fracture injuries, it is very unlikely that such sub-cohorts comprised a significant number of patients.

There is also likely to be a sub-cohort of patients in our region who sustained minor fracture injuries (5^{th} metacarpal neck fractures, radial head fractures) that were assessed and managed at centres out with the region, with no follow-up required in our Orthopaedic Outpatient service. Again, the size of such sub-cohort is likely to be minimal, and so the overall effect on the total study cohorts is unlikely to be significant.

4.3.2 Data

A further limitation from the thesis is that three different databases were used for the three different populations. While each database provided a comprehensive description of the fracture injuries from each population, the three databases were based over different time-periods and had minor variations in the information contained.

This is because each database represented the most recent fracture epidemiology data for the relevant populations. Thus while the databases were recorded in different time periods, they represent the most recent available fracture epidemiology data for the relevant cohorts in our population.

Similarly, while the information contained in each database was slightly different, each database shared the same key information that allowed a transparent comparison between them.

As such, the use of the three separate databases was necessary to provide the most recent data available from our region. Despite their difference, in combination, they provide the most contemporary comprehensive dataset on this topic in the current literature.

4.3.3 Method of Follow-Up

Further limitations reside in the modality and timing of patient follow-up. The ideal method would have been to have regular clinical reviews over 2 to 4 years post injury, allowing for regular physical examination and prospective follow-up data. However, the majority of fracture patients are discharged from clinic by 6 to 12 weeks post-injury. This is a globally-accepted practice, and prolonged follow-up would not be sustainable, with the resources available(39). As such, patient follow-up was obtained for our studies by standardised telephone questionnaires, performed by the same clinician, at a mean of 30 to 50 months post-injury. This enabled the authors to obtain consistent, accurate follow-up information from each of the patients interviewed, to provide the desired outcome information for the study.

A key limitation of the retrospective telephone questionnaire follow-up is the potential for recall inaccuracies, particularly regarding return times to sport. To limit such effects, the interviewing clinician reviewed the patient’s medical records prior to contacting the patient. This provided the clinician and the patient with information regarding the time and nature of the injury, the duration of clinic follow-up, and the recorded functional status on discharge from clinic. Through this, the authors feel they achieved sufficiently accurate follow-up data from each of the patients.

4.3.4 Assumptions

There are a number of assumptions made in the study designs.
The first of these is that all fracture injuries, occurring in the population of our region, were detected during the study periods. This assumes that all patients who sustained a fracture injury sought medical attention, and all patients who underwent medical review for suspected fractures had the relevant injury radiographed and

diagnosed. Given the pain associated with fracture injuries, it is unlikely that there was a significant number of fracture injuries missed due to these reasons, and therefore this is a valid assumption from our study.

The second assumption is that all fractures sustained out-with the region, by residents from the Lothian population, were followed-up through the NHS Lothian Orthopaedic Outpatient Services. Over the time periods of each database, most fracture types routinely required a minimum of six weeks clinic follow-up. Thus, it is likely that the vast majority of all such fractures were referred back for review in our Orthopaedic service, and so would have been entered into the relevant databases.

The last assumptions relates to the fact that all patients returned to sport as soon as their symptoms allowed. This will be true for the professional and semi-professional athletes. In contrast, for the amateur and recreational athletes, it is likely that a number of these delayed return due to personal and work-related reasons. However, our data provides an overall representation of the practice of return to sport following fracture injuries in a standard population: such delays in return to sport, due to personal and work-related reasons, are intrinsic factors within the overall process. Thus the presence of such factors in the data is an accepted consequence of recording data from a standard population: this then allows the data to be extrapolated more realistically to other standard populations.

4.3.5 Publication Errors and Editorial Amendments

There are no publication errors or editorial amendments to declare.

4.4 Comparison with the Available Literature

4.4.1 Epidemiology

4.4.1.1 Football

For the adult population, data from the same population around 10 years earlier shows that the incidence of adult football-related fractures is increasing (0.64 per 1000 population then to 0.71 per 1000 population with the current data)(10). This likely represents an increased participation in the sport, due to continued increased global popularity of football(141). The age (mean age 25.6 years vs 26.9 years) and gender distribution (96% male vs 98% male) of the cohorts were similar, again reflecting a similar cohort of the population participating in football i.e. young male athletes(10, 47, 141). The fracture location proportions were also similar (66% upper limb vs 68% upper limb), again representing similar injury mechanisms present within the two cohorts(10).

For the adolescent population, from a US high school cohort, the gender ratio of football-related fractures was 63% male to 37% female(28). The increased female proportion in this cohort represents the increased female participation in football in the US population compared to the UK population(28, 141). Despite this. the US population similarly found that 72% of the football-related fractures occurred in the upper limb, representing similar injury mechanisms between the two cohorts(28).

There is no similar data on the epidemiology of football-related open fractures, with which to compare our data(4).

4.4.1.2 Rugby

For the adult population, data from the same population around 10 years earlier shows that the incidence of adult rugby-related fractures is increasing (0.21 per 1000 population then to 0.28 per 1000 population with the current data)(10). This likely represents an increased participation in the sport, due to continued increased global popularity of rugby(142, 143). The age (mean age 22.1 years vs 21.8 yrs) and gender distribution (94% male vs 94% male) of the cohorts were similar, again reflecting a similar cohort of the population participating in rugby i.e. young male athletes(10, 47, 135). The fracture location proportions were also similar (85% upper limb vs 83% upper limb), again representing similar injury mechanisms persisting between the two cohorts(10).

There is no similar data on the epidemiology of rugby fractures in adolescent populations(28, 29), nor of rugby-related open fractures(4), with which to compare our data.

4.4.1.3 Hockey

For the adult population, data from the same population around 10 years earlier shows that the incidence of adult hockey-related fractures has remained similar (0.05 per 1000 population then to 0.04 per 1000 population with the current data)(10). This represents a well-established and continued interest in this sport, within our population(47, 147). The age (mean age 24.7 years vs 25.0 years) and gender distribution (53% male vs 60% male) of the cohorts were similar, reflecting a similar cohort of population participating in hockey i.e. young male and female athletes(10, 47). The fracture location proportion were also similar (89% upper limb vs 100% upper limb), again representing similar injury mechanisms present within the two cohorts(10).

There is no similar data on the epidemiology of hockey fractures in adolescent populations(28, 29), nor of hockey-related open fractures(4), with which to compare our data.

4.4.2 Management

The only available study to report on the management of a combined cohort of sport-related fractures is that by Hon et al (2001)(46). The authors found that from 113 sport-related fractures, 90 (79.6%) were treated conservatively with 23 (20.4%) treated surgically(46). There was a similar upper limb:lower limb fracture ratio as our cohorts (76:33)(46). Understandably such findings will be influenced by the upper limb:lower limb ratio of fractures, as well as the rate of fracture displacement in the cohort: both of these can be influenced by the causative sports of the cohort(10, 39, 46). Nevertheless, it would appear that for most comprehensive sport-related fracture cohorts, one would predict around four fifths of fractures will be managed conservatively and one fifth of fractures will be managed surgically(11, 46, 102, 135, 140).

4.4.3 Outcome

4.4.3.1 Football

The available outcome-related literature remains limited to cohorts of football injuries, of which acute fractures form a sub-cohort(18, 31-37, 44, 45, 72, 148), or to fracture-type cohorts in football players(40, 49, 50, 57-59).

Assessing the thesis results, it is the data from the fracture-type cohorts which provide the most useful comparisons(40, 49, 50, 57-59). The two fracture types, for which there is comparative data, are the tibial diaphysis(40, 49, 57-59) and the distal radius(50).

The tibial diaphyseal fractures have the most outcome-related evidence(40). There are four available studies(49, 57-59), with three reporting on both conservative and surgical management(49, 57, 58), and one reporting on surgical management(59). The return rates varied from 70%(59) to 96%(57) and the mean return times varied from 25 weeks(58) to 41 weeks(59). In comparison our data found return rates of 80%, and mean return times of 38 weeks. Such results are clearly influenced by the nature of the fracture and the choice of treatment, and this is discussed in detail below in the Optimising Outcome Section(40). However, in general, it would appear that around four fifths of football-related tibial diaphyseal can be expected to return to sport post-injury at around 6 to 10 months post-fracture. This is a lower return rate and higher return time than most fracture types: this however reflects the extent of the injury, with tibial diaphyseal fractures being one of the most severe limb injuries that a footballer player can sustain(38, 40, 49, 57-59).

From within the Lothian Population 20 years earlier, Lawson et al (1995) found that, from 65 football-related distal radial fractures, 53 (82%) returned to pre-injury level football at follow-up(50). This is similar to our data with 79% of our cohort returning to football and 77% retuning to pre-injury level of football. It would appear that around four-fifths of sport-related distal radial fractures can be expected to return to football post-injury(50, 102). This is a lower proportion than a number of the other fracture types, particularly from the upper limb cohort(102): this can explained by the fact that this injury is more prone to occur in an older 'recreational' athlete: and so, when this occurs, this can often prompt a non-return to sport for personal-related reasons, such as fear of re-injury and not wanting further time from work(50, 102, 149).

4.4.3.2 Rugby

The literature on this topic again is limited to cohorts of rugby-related injuries, of which fractures forms a sub-cohort(38).

Of the available studies, that by Garraway et al (1995), from the Scottish Rugby Union, provides the most comparable data(19). From the season 1993-1994, they found that rugby-related upper limb fractures (n=21) took a mean of 8.0 weeks to return to rugby, while rugby-related lower limb fractures (n=9) took a mean of 16.1 weeks days to return to rugby(19). These return times are marginally quicker than our data, and this can be explained by the fact that Garraway et al (1995) recorded time to return to training or playing(19), while our times represent time to return to full-level rugby.

Other cohort data from the English Premiership Rugby Union, during the seasons 2002-2004, has found that ankle fractures took a mean of 16.9 weeks to return to rugby(61), patella fractures a mean of 10.6 weeks to return to rugby(62), arm fractures a mean of 8.9 weeks to return to rugby(24), hand and wrist fractures a mean of 6.1 weeks to return to rugby(24), and foot fractures a mean of 6.3 weeks to return to rugby(24). Again, these return times are quicker than our data, and this can also be explained by the fact that the authors recorded time to return to training, while our times represent time to return to full-level rugby(24, 61, 62). Similarly, this data records return times in professional athletes, which are often accelerated compared to amateur athletes, due to the focussed rehabilitation in professional sport(24, 61, 62): our cohort was predominantly amateur athletes.

4.4.3.3 Hockey

The only study to compare our data against is that by Dick et al. (2007) who found that, from a cohort 56 game-related finger fractures in female hockey players from the US NCAA (seasons 1988–1989 to 2002–2003), 17 were recorded as severe injuries (return time greater than 10 days)(27). With a mean return time of 8 weeks for our finger phalanx cohort, and a minimum return time of 3 weeks, our return times appear longer. However, this again can be explained by the fact that Dick et al (2007) recorded time to return to all ‘sports participation’, while our study recorded time to return to full-level hockey(27). Similarly, given the higher level of hockey played by the US NCAA players, there would have been a greater pressure to return to sport earlier in their cohort, compared to our cohort(27). Given the limited data, further studies are required to better define the outcome of hockey-related fractures(27).

4.4.4 Optimising Outcome

The theory underlying the relevant findings in this section demonstrates clear logic in the management planning of sport-related fractures(38, 39).

Undisplaced unstable fractures, which are treated conservatively, require a prolonged period of cast immobilisation and restricted use to allow the fracture to unite (upper limb 6-12 weeks, lower limb 6 to 16 weeks)(38, 39). Surgical management of such injuries, however, provides solid internal fixation across the fracture, converting it to a stable injury, and so allowing progressive return to sport almost immediately post-operatively(38, 39). Due to the reduced period of convalescence, this also reduces the non-return rates seen with such fractures, as prolonged rehabilitation and associated deconditioning, can often direct the less competitive athlete to quit the sport, for fear of having to go through a similar process in the future(38, 39).

Primary surgical management does come with the risk of surgical complications, and the patient should be adequately counselled on this prior to deciding treatment method(38, 39). However, given the favourable biomechanical situation provided by primary surgical management, this can have significant benefits for the patient post-operatively in terms of return to sport(38, 39).

In a similar perspective, displaced middle-third clavicle fractures, were historically treated conservatively, with the belief that these healed to provide similar function to those treated surgically(39, 55, 56). However, during the healing phase, these fracture are ‘unstable’, with significant risk of ‘re-fracture’, particularly if sport is re-commenced too early, prior to the fracture adequately uniting(41, 66). Thus, primary surgical management provides an immediate stable environment for the fracture, allowing for accelerated return to sporting activities significantly quicker than with conservative management(38, 41, 66).

For stable undisplaced fractures, these are stable injuries from the outset, and do not benefit from surgical management to reduce immobilisation and enable early rehabilitation(38, 39, 150). Thus surgical management in such cases does not improve the situation: instead, the surgical insult, with the subsequent scarring and retained metalwork, can result in an increased adverse symptom profile, and so is not recommended(38, 39, 150).
As per established Orthopaedic Trauma Management Principles, surgical management remains the first-line treatment for the vast majority of displaced fractures in the athletic patient, as this provides anatomical reduction and stable fracture fixation, allowing restoration of function and timely rehabilitation(38, 39).

Given that this area is an emerging principle of fracture management, there is limited data with which to compare(38). Roche and Calder (2013) assessed the management of 'Jones-type' 5th Metatarsal fractures in the athletic patient(43). These fractures occur in the proximal metaphyseal-diaphyseal of the 5th metatarsal, where a precarious blood supply renders such injuries at a high risk of delayed union and non-union(43). From a systematic review of 17 studies, the authors found that, given the 'unstable' nature of such injuries, even when undisplaced, surgical management provided improved return times to sport (mean return times 4 to 18 weeks), over conservative management (mean return times 9 to 22 weeks) (43). This again supports the concept of primary surgical management for undisplaced unstable fractures types, to provide fracture stability, allowing earlier mobilisation and rehabilitation, and subsequent improved return to sport(38, 39).

4.5 Clinical Relevance

Fractures have one of the longest return times to sport of all injuries(19, 38, 40, 41, 61, 151). The importance of such injuries, relates to their financial burden on the sports industry in professional athletes, and their economic burden to society in amateur athletes(13, 38, 102, 135). The thesis provides novel information on four key areas of this topic (Epidemiology, Management, Outcome and Optimising Outcome), with each area providing beneficial developments for clinical practice.

The information on the Epidemiology of Acute Team Sport-Related Fractures provides the first comprehensive dataset describing the incidence of fractures in the three most common team sports (football, rugby and hockey) within the Lothian population. While this data will be most relevant for a UK population(10, 47, 48), football remains the most participated team sport in the world(18, 141, 152), with field hockey and rugby regularly recorded in the top ten most participated team sports in the world(14, 16). Thus such data provides value both on a national and a global scale(10, 14, 16, 18, 47, 48, 141, 152). The data provides useful epidemiological information for each of the three sports, enabling sport coaches, sport physicians and sports surgeons managing such athletes, to plan accordingly for the expected fracture injuries per season, creating treatment protocols for these, to allow consistent evidence-based management of these injuries(38). However, the true strength of the data lies with the ability of clinicians to assess the injury patterns by mode of injury and playing position, within each of the three sports, in order to determine potential injury prevention strategies for these fractures(153).

The key area for injury prevention in football cohorts lies in the role of shin-guards for preventing tibial diaphyseal fractures(58, 144, 146, 153, 154). This is particularly relevant given that football accounts for 25% of all tibial diaphyseal fractures, and 83% of all football-related tibial fractures occurring due to tackle-related injuries(5, 49). Biomechanical studies have found shin-guards to reduce tackle impact forces by up to 17% and strain forces by up to 51%, compared with the unguarded leg(154). It has been hypothesised that the introduction of shin guards, and their subsequent design improvements, may explain the decreasing incidence of football-related tibial fractures seen in the available literature(58) (25% of all tibial fractures in 1988-1990(49); 18% of all tibial fractures in 1990-1994(155); 10% of all tibial fractures in 1997-2001(58)). Given such findings, it would appear the use of shin guards in footballing activities should be recommended(58, 154). Other areas of injury prevention consideration include the influence of stud type, football boot design and playing surface on the incidence of ankle and metatarsal fractures, and the design of goalkeeping gloves to reduce the incidence of hand-related fractures(144-146, 153, 156, 157). The evidence on these topics however remains limited, so further research is required prior to recommendation of such equipment(144-146, 153, 156, 157).

The key area for injury prevention in rugby cohorts is the role of shoulder pads to reduce the incidence of clavicle fractures, given their significant proportion during rugby(142, 143, 151). However, despite the theoretical benefits, these have not been found to significantly reduce such injuries in rugby players(151). The most comprehensive study to-date found no difference in the incidence of shoulder injuries between wearers and non-wearers of shoulder pads(151). Thus, further research is required to define their value in the sport(151). Other areas of interest include the role of shin guards in preventing tibial diaphyseal fractures, the role of hand and wrist gear in the protection against hand and wrist fractures and the influence of rugby boot design and playing surface on the incidence of ankle and metatarsal fractures(142, 143, 153). The evidence these topics remains limited, so further research is required prior to recommendation of such equipment(142, 143, 153).

The key area for injury prevention in the hockey cohort is the role protective hand gear to reduce the incidence of hand–related fractures, given the high proportion of hand fractures in the sport(26, 27, 53). While the use of such hand-gear is not routinely recommended in hockey, it has been shown to be protective against hand injuries in similar sports (e.g. lacrosse), where this is routinely used, with limited adverse effect on player dexterity(53). Given such findings the authors feel the use of protective hand-gear in hockey should be routinely recommended(53).

The information on the Management of Acute Team Sport-Related Fractures provides an interesting overview of the treatment practices of the Edinburgh Orthopaedic Trauma Unit. While, the majority of fracture patterns follow uniform treatment plans, the data allow us to identify developing concepts in the field of sport-related fracture management (e.g. surgical management of undisplaced scaphoid waist fractures, surgical management of displaced middle third clavicle fractures)(38, 39). This enables both an assessment of the frequency of use of these emerging management principles, as well as cohort comparisons of the outcome data(38, 39). Such information provides clinicians with an early indicator to the value of these techniques for sport-related fractures, allowing further randomised controlled trials to be developed to further validate this practice(38, 39).

The information on the Outcome of Acute Team Sport-Related Fractures provides sports coaches, sport physicians and sport surgeons predicted return rates and return times to sport, with which they can inform the injured athletes(38). This also allows affected sports teams to plan appropriately following such injuries, being able to realistically consider both the likelihood of return to play post-injury, and the expected duration till return: such information can enable coaches to re-organise teams accordingly, and to consider drafting new players if appropriate(38). Lastly, with an improved understanding of the time required to return to sport following such injuries, sports physicians, sports surgeons and sports physiotherapists can best modify rehabilitation programmes, to optimise recovery and return to function, with an aim to reduce return times in the future(38).

The information on Optimising Outcome of Acute Team Sport-Related Fractures provides Sport Surgeons with the most up-to-date evidence on the optimal management principles for the five common sport-related fracture types with the highest rates of surgical intervention – ankle, tibial diaphysis, clavicle, scaphoid and metacarpal(38). This then provides Sport Surgeons with evidence-based guidance to allow them to select the optimal management method (conservative versus surgical management) for each of these five fractures types, stratifying for fracture location and displacement, to provide the affected athletes with the best possibility of returning to sport, as rapidly as possible, with the optimal side-effect profile(38). As shown from the examples above (e.g. surgical management of undisplaced tibial diaphyseal fractures), review of such evidence not only allows development and validation of innovative treatment principles to optimise the management of these injuries, but also can considerably transform the return rates and return times to sport following such fractures(38). This, in essence, translates to improved clinical care of the affected athletes(38).

4.6 Future research

The areas for future research from this topic can be again be divided into the four sections of the thesis: Epidemiology, Management, Outcome and Optimising Outcome.

For the ‘Epidemiology’, ‘Management’ and ‘Outcome’ Sections, a future long-term combined adult and adolescent database, covering both populations, over a five to ten year period, recording prospective follow-up data for all participated sports in the region, would provide the highest quality data possible on sport-related fractures.

Further developments from our current data include the future integration of injury prevention programmes within our regions, having identified the key potential areas for intervention: the use of shin guards as protection against tibial diaphyseal fractures in football players(58, 144, 146, 153, 154); the use of shoulder pads as protection against clavicle fractures in rugby players(142, 143, 151); and the use of hand-gear as protection against hand fractures in hockey players(26, 27, 53). By integrating this protective equipment through a controlled programme within our region, and then assessing the effect this has on the epidemiology on such injuries, it would be possible to determine the true effect that such ‘protective’ equipment has on the incidence of these fractures.

For the ‘Optimising Outcome’ Section, future well-designed randomised controlled trials, comparing the available treatment options in high-functioning athletic individuals, with clear recording of sporting outcomes (return rates and return times to sport), should be organised, to provide the highest quality evidence on the value of these emerging treatment principles and methods in the field of sport-related fractures(38). In addition to this, all surgeons who manage sport-related fractures, should be encouraged to record sporting outcome data for these injuries(38). This will allow the formation and analysis of further cohort data, which again will add to the available evidence in this field(38).

4.7 Conclusion

This thesis provides a comprehensive overview of the epidemiology, management and outcome of acute fractures in three most common team sports in the Lothian region (football, rugby, hockey).

These injuries are a relatively common condition, with recorded incidences ranging from 2.03/1000 adolescent population for football-related fractures, to 0.04/1000 adult population for hockey-related fractures. The majority of these fractures were of the upper limb, comprising 68% to 100% of all recorded fractures within the cohorts.

Around one fifth of these injuries required operative management, with surgical intervention rates ranging from 11 to 21% from the recorded cohorts. Return rates to sport for the three sports ranged 86 to 89%, with return times to sport varying depending on the location of the fracture, the nature of the fracture and the sport played.

Review of the outcome of these injuries, in conjunction with systematic review and meta-analysis of the relevant literature, found there is a developing role for primary surgical management of undisplaced, unstable fractures (tibial diaphysis, scaphoid waist) in the athlete, to facilitate improved return rates and return times to sport. Conservative management forms the recommended treatment for undisplaced, stable fractures (ankle, metacarpal), and surgical management remains the gold standard treatment for displaced fractures.

The information collated for this thesis allows sports teams and sport-related health-care professionals: to develop effective treatment protocols for these fractures, which can allow for optimisation of the management and outcome of these injuries; and to enable injury prevention programmes to be developed, which can potentially reduce the future incidence of these fractures.

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Appendix I:

Paper 1:

The Epidemiology, Morbidity and Outcome of Soccer-Related Fractures in a Standard Population.

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The Epidemiology, Morbidity, and Outcome of Soccer-Related Fractures in a Standard Population

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Background: Soccer is the most common cause of sporting fracture, but little is known about patient outcome after such fractures.

Purpose: To describe the epidemiological characteristics of soccer-related fractures, their outcomes, and the likelihood of return to soccer after injury in a known United Kingdom population at all skill levels.

Study Design: Descriptive epidemiology study.

Methods: All soccer fractures during 2007-2008 in the Lothian population were prospectively collected, with the diagnosis confirmed by an orthopaedic surgeon when patients attended the only adult orthopaedic service in Lothian. Patients living outside the region were excluded from the study. Patients were contacted in August 2010 to ascertain their progress in returning to soccer.

Results: A total of 367 fractures were recorded over the study period in 357 patients; 312 fractures (85%) in 303 patients (85%) were followed up, with a mean interval of 30 months (range, 24-36 months). The mean time for return to soccer from injury was 15 ± 17 weeks (range, 0-104 weeks). For patients with lower limb injuries, the mean time was 26 ± 22 weeks (range, 4-104 weeks) compared with 9 ± 8 weeks for patients with upper limb injuries (range, 0-64 weeks). Fourteen percent of the whole cohort did not return to soccer; 83% returned to soccer at the same level or higher. Thirty-nine percent had ongoing related problems; however, only 8% had impaired soccer ability because of these problems. Fractures with the highest morbidity in not returning to soccer were to the clavicle (24%), distal radius (21%), and tibial diaphysis (20%).

Conclusion: Most patients sustaining a fracture while playing soccer will return to soccer at a similar level. While over one third of them will have persisting symptoms 2 years after injury, for the majority, this will not impair their soccer ability.

Keywords: soccer; fracture; epidemiology; morbidity; return

Soccer is the most popular sport worldwide.[17] This popularity has substantial financial implications, particularly for professional soccer. The economic revenue of leading professional soccer leagues has been reported to exceed $3 billion.[20] Thus, accurate knowledge of morbidity and outcome of soccer-related injuries is vital to predict the availability of players and to appropriately plan rehabilitation.

Soccer has previously been demonstrated to be the most common cause of sporting fracture within a standard United Kingdom (UK) population.[5] Fractures are estimated to comprise around 10% of all soccer injuries.[7,12] There is significant research on the morbidity and outcome of soccer-related soft tissue injuries[9,11,21-24]; however, the published data on the morbidity and outcome of soccer-related fractures are either limited to small fracture-specific cohorts[1,2,6,13,14,16,19] or involve follow-up of a large number of sports in a small group of patients.[10]

These injuries represent a unique set of fractures, being medium- to high-impact trauma, in a young, highly active population with a significant potential for rapid healing and rehabilitation.[5] However, within the overall epidemiology of fractures, they represent a minority group, with sport-related fractures comprising just over 10% of all fractures and soccer-related fractures just over 5%.[5] Thus, unsurprisingly, the vast majority of current fracture research focuses on the more common low-impact osteoporotic fractures of the middle aged and elderly,[3] with very limited data on sport-related or soccer-related fractures.[5] Given the considerable difference between the epidemiology and expectations of the 2 patient groups, as well as variations in fracture patterns and locations, extrapolation

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of the pre-existing research on osteoporotic fractures into sport-related fractures is not feasible.[1,2,5,10,14,16] Thus, given the significance of soccer-related fractures, both to professional soccer teams as well as to society as a whole, greater knowledge on the morbidity and outcome of these injuries is urgently required. Such information would be invaluable to all medical staff working with soccer teams as well as to those caring for the population as a whole.[2,9]

We present a study that defines the epidemiology of adult fractures sustained during soccer in a known UK population at all skill levels, describes the morbidity for these patients, and demonstrates the likelihood of returning to soccer for these patients.

MATERIALS AND METHODS

Study Design

All acute fractures sustained by patients aged 15 years and above in the Lothian population from July 2007 to July 2008 were prospectively recorded in a database. The population figure for this cohort was 517,555. The database contained information on the age, gender, address, postcode and occupation of the patient, the mode of injury, the date of treatment, whether management was as an inpatient or outpatient, the site of the fracture, the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification of the fracture, and whether the fracture was open or closed. The mode of injury was recorded from the details of the admission history as well as from inpatient and outpatient hospital records. When the mode of injury was not clear from these sources, patients were contacted either on the ward or at the clinic during the initial management period of their injury. With sport-related fractures, the specific sport that was being played at the time of injury was noted accordingly. A record of whether this was played at an indoor or outdoor facility was not made in the initial database. Each fracture type was confirmed through examination of the relevant radiographs by an orthopaedic surgeon. Stress fractures were not included in the analysis. Patients living outside the catchment area were excluded to allow accurate epidemiological analysis. Open fractures were classified using the Gustilo and Anderson classification.[8]

All fractures sustained during soccer were then identified from the database. Patients were contacted by telephone in August 2010 to obtain retrospective follow-up data by asking a standardized set of questions (see the Appendix, available in the online version of this article at http://ajs.sagepub.com/supplemental/). This was a mean duration of 30 months after injury (range, 24-36 months). A retrospective review of patients' inpatient and fracture clinic notes was also conducted in August 2010 to identify the mechanism of injury, limb dominance, management, and complications.

Statistical Analysis

Collected data were analyzed by descriptive statistics using SPSS 19.0 (SPSS Inc, Chicago, Illinois). Univariate statistical comparisons between continuous variables were performed using the Student t test. Univariate statistical comparisons between categorical variables were performed using the χ^2 test (with Fisher exact test as required). The significance level was set at $P < .05$.

TABLE 1
General Fracture Demographics

Demographics	n (%)
Sports fractures	992
Soccer fractures	367 (37.0)
No. of patients (mean age, 26.9 y)	357
Male (mean age, 26.8 y)	349 (97.8)
Female (mean age, 32.1 y)	8 (2.2)
Inpatient fractures	76 (20.7)
Outpatient fractures	291 (79.3)
Nonsurgically managed fractures	295 (80.4)
Surgically managed fractures	72 (19.6)
Fractures with full follow-up data	312 (85.0)
Patients with full follow-up data (mean age, 26.8 y)	303 (84.9)
Male (mean age, 26.6 y)	296 (97.7)
Female (mean age, 32.6 y)	7 (2.3)

RESULTS

Of a total 6871 fractures sustained during the study period in 6325 patients, 367 fractures (5.3%) were soccer related, occurring in 357 patients (5.6%) (Table 1). There were 250 (68.1%) upper limb fractures (Table 2) and 117 (31.9%) lower limb fractures (Table 3). The annual incidence of soccer-related fractures was 0.71 per 1000 of the general population per year. Figure 1 shows the age-related incidence of both male and female patients.

The mean age of the cohort was 27 years (range, 15-76 years). The gender ratio of the cohort by fractures was 349:8 (male:female). Figure 2 shows the level of soccer that the players were competing before injury. Over 95% of the fractures occurred in nonprofessional athletes.

The demographics of the soccer fracture population are shown in Table 1. Twenty percent of the fractures required surgical management. Surgical intervention included open reduction internal fixation (65%), intramedullary nailing (17%), external fixation (8%), and K-wire fixation (6%).

Table 2 shows the demographics for upper limb fractures. Fractures with high (nonsurgical) manipulation rates included the distal radius (16%) and finger phalanx (13%). Table 3 shows the demographics for the different types of lower limb fractures. Eight patients with tibial diaphyseal fractures had concomitant fibula fractures. Of the metatarsal fractures (n = 23), 12 were of the fifth metatarsal, of which 5 were in zone 1, 2 in zone 2, 3 in zone 3, and 2 in zone 4.[4]

Full follow-up data were obtained for 312 (85%) of the fractures, with the mean age of this cohort being 27 years. Of these, 267 (86%) returned to soccer (mean age, 26 years), with 258 (83%) returning to the same level or higher (mean age, 26 years). Patients returned to training at a mean duration of 10 ± 12.5 weeks (range, 0-88 weeks),

TABLE 2
Upper Limb Fracture Demographics

Type	n	Mean Age, y	Male:Female Ratio	Surgically Managed, n (%)	Inpatient, n (%)	Main Mode of Injury
Total	250	27.2	243:7	28 (11.2)	26 (10.4)	Fall (51%)
Finger phalanx	76	28.3	73:3	4 (5.3)	5 (6.6)	Goals (39%)
Distal radius	73	27.4	70:3	7 (9.6)	8 (11.0)	Fall (59%)
Metacarpal	27	22.5	27:0	3 (11.1)	3 (11.1)	Goals (37%)
Carpus	26	26.1	26:0	6 (23.1)	2 (7.7)	Fall (81%)
Clavicle	20	27.6	19:1	4 (20.0)	3 (15.0)	Fall (85%)
Proximal radius	17	27.0	17:0	1 (5.9)	0 (0)	Fall (88%)
Proximal humerus	2	46.5	2:0	0 (0)	0 (0)	Fall (100%)
Radial diaphysis	2	15.0	2:0	0 (0)	1 (50.0)	Goals (100%)
Radius and ulna	2	17.0	2:0	2 (100.0)	2 (100.0)	Fall (100%)
Ulna diaphysis	2	53.0	2:0	0 (0)	0 (0)	Goals (100%)

TABLE 3
Lower Limb Fracture Demographics

Type	n	Mean Age, y	Male:Female Ratio	Surgically Managed, n (%)	Inpatient, n (%)	Main Mode of Injury
Total	117	26.3	116:1	44 (37.6)	50 (42.7)	Tackle (54%)
Ankle	49	26.6	48:1	25 (51.0)	26 (53.1)	Tackle (53%)
Metatarsal	23	25.0	23:0	0 (0)	0 (0)	Tackle (39%)
Tibial diaphysis	18	23.9	18:0	12 (66.7)	16 (88.9)	Tackle (83%)
Toe	8	21.1	8:0	0 (0)	2 (25.0)	Tackle (50%)
Distal tibia	4	44.3	4:0	3 (75.0)	3 (75.0)	Twist (75%)
Fibula	4	37.3	4:0	0 (0)	0 (0)	Tackle (100%)
Talus	3	26.3	3:0	0 (0)	0 (0)	Twist (67%)
Midfoot	2	19.5	2:0	0 (0)	0 (0)	Tackle (50%)
Patella	2	35.5	2:0	2 (100.0)	2 (100.0)	Fall (50%)
Proximal tibia	2	26.0	2:0	2 (100.0)	1 (50.0)	Tackle (50%)

while return to the preinjury level of soccer occurred at a mean duration of 15 ± 16.6 weeks (range, 0-104 weeks).

The "return" rates for the different preinjury competition levels were 100% for the professional cohort (100% to the same level), 100% for the semiprofessional cohort (91% to the same level), 90% for the amateur league cohort (84% to the same level), 96% for the boys' club cohort (92% to the same level), and 79% for the leisure cohort (79% to the same level). While professional-level soccer players (professional and semiprofessional) demonstrated a higher "return" rate (100% vs 85%) and a higher "return to same level" rate (94% vs 82%) compared with the nonprofessional-level soccer players (amateur, boys' club, and leisure), these differences were not statistically significant (comparison of "return" rates, P = .141; comparison of "return to same level" rates, P = .323).

Of those patients managed surgically, 6 (8%) suffered complications from surgery. Eight patients (10%) required repeat surgery. Of the whole cohort, 123 (39%) of the fractures were found to have persisting symptoms at 2 years after injury (mean age, 30 years), the most common being fracture site pain (61%), stiffness of an adjacent joint (28%), and metalwork-related pain (7%). However, only 24 (8%) of all the fractures were found to have persisting symptoms that affected their ability to play soccer (mean age, 26 years), the most common being fracture site pain (67%) and stiffness of an adjacent joint (25%).

For the patients who were managed operatively, the mean time to return to soccer was 34 ± 24 weeks (range, 6-104 weeks), and the return rate was 81%. Patients managed nonoperatively returned to soccer at a mean time of 11 ± 11 weeks (range, 0-104 weeks), and the return rate was 87%. Those who underwent surgery took significantly longer to return to soccer ($P < .001$; 95% confidence interval, 15.98-30.11), but there was no difference in the return rate (P = .305). Figure 3 illustrates the time to return to training and soccer for the common fracture types.

Sixty-eight percent of patients treated operatively were found to have persisting symptoms, and 17% had symptoms that interfered with their ability to play soccer. Of those treated nonoperatively, 33% had ongoing symptoms, and 6% had symptoms that interfered with their soccer playing. "Persisting symptom" rates ($P < .001$) and "persisting symptoms affecting soccer ability" rates ($P < .003$) were significantly greater in the operative cohort.

Overall, 45 (14%) of the fracture patients had not returned to soccer at 2 years after injury. Eleven had been treated operatively (no-return rate, 19%) and 34

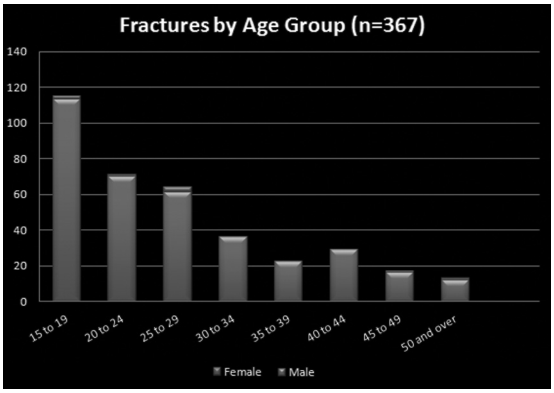

Figure 1. The incidence of fractures by age and gender.

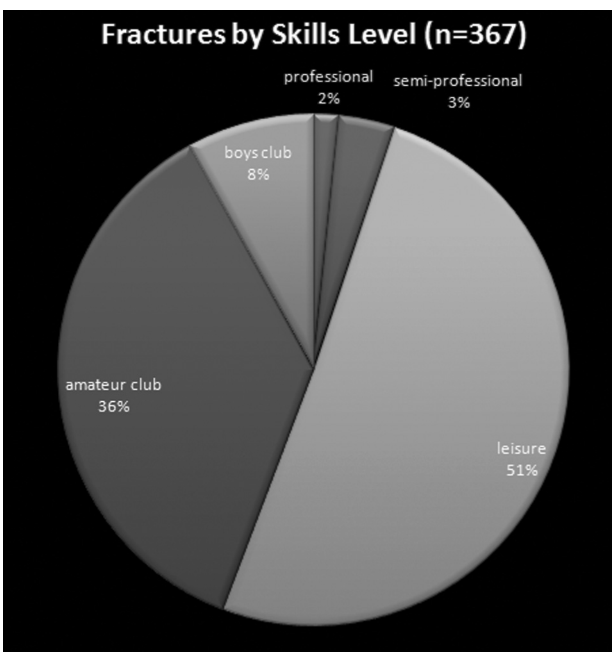

Figure 2. The preinjury distribution of skill level of the patients.

nonoperatively (no-return rate, 13%) (P = .305). Fractures of the clavicle (24%), distal radius (21%), and tibial diaphysis (20%) showed the highest no-return rates.

Over two thirds of the cohort (32/45) reported they had quit soccer for personal reasons. Twenty-four of these played soccer for leisure, and 8 played at an amateur level. Common reasons included fear of reinjury (27%), not wanting to take more time off work (18%), change of sport (9%), and being banned by the spouse (9%). There was a higher incidence of personal reasons for quitting in upper limb fractures (26/31, 84%) compared with lower limb fractures (8/14, 57%). Patients over 30 years (no-return rate, 26.3%) were 2.9 times more likely to quit soccer than those under 30 years (no-return rate, 9.2%) (P < .001).

Table 4 shows the outcome data for the upper limb fractures. Eighty-four percent follow-up was achieved for the

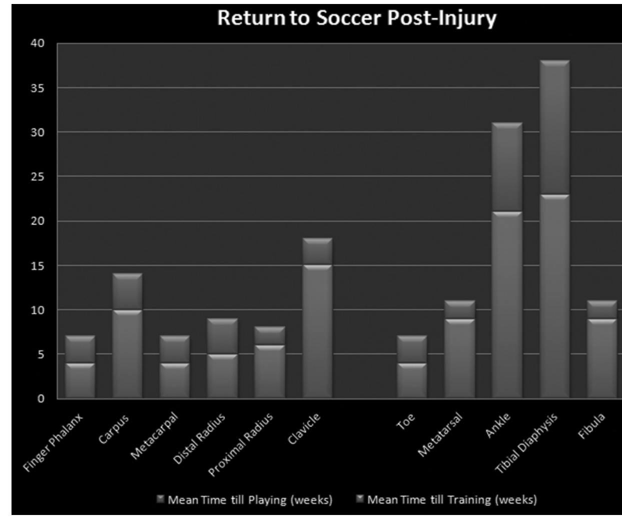

Figure 3. Duration taken for returning to training and full-level soccer for the different fracture types.

upper limb cohort. Of these, 85% returned to soccer, and 84% returned to the same level or higher. The highest return rate is seen in finger phalanx (95%) and carpal (91%) fractures and the lowest in distal radius (79%) and clavicle (76%) fractures. Patients with clavicle fractures took the longest to return to soccer (mean, 18 weeks), while those with finger phalanx and metacarpal fractures took the shortest times (mean, 7 weeks for both). The highest rate of persisting symptoms 2 years after injury was seen for carpal fractures (59%) and the lowest rate for distal radius fractures (21%). Only 5% of all upper limb fractures had persisting symptoms at 2 years that impaired soccer ability.

Table 5 shows the outcome data for the lower limb fractures. Eighty-eight percent follow-up was achieved for the lower limb cohort. Of these, 86% returned to soccer, and 81% returned to the same level or higher. The highest return rate was seen after ankle (95%) and metatarsal (95%) fractures and the lowest after toe (50%) and tibial diaphyseal (80%) fractures. Patients with tibial diaphyseal fractures took the longest to return to soccer (mean, 38 weeks), while those with toe fractures took the shortest times (mean, 7 weeks). The presence of an associated fibular fracture with tibial diaphyseal fractures had no effect on the time to return to soccer (38 weeks). For the 9 tibial diaphyseal fractures treated surgically, 89% (n = 8) of patients returned to the same level of soccer or higher, with a mean return to soccer time of 35 weeks (mean return to training time, 25 weeks). For the 21 ankle fractures treated surgically, 76% (n = 16) of patients returned to the same level of soccer or higher, with a mean return to soccer time of 43 weeks (mean return to training time, 28 weeks). Patients with upper limb injuries returned to activity significantly quicker than those with lower limb injuries (mean, 9.2 weeks vs 26.5 weeks; P < .001; 95% confidence interval, 12.47-22.09), but there was no significant difference in return rates to sport between the 2 groups (P = .769).

TABLE 4
Upper Limb Fracture Follow-up Data[a]

Type	Follow-up	Return to Soccer	Return to Same Level or Higher	Time to Soccer, wk	Persisting Symptoms	Persisting Symptoms Affecting Soccer
Total cohort	312 (85)	267 (86)	258 (83)	15.0	123 (39)	24 (8)
Upper limb	209 (84)	178 (85)	175 (84)	9.2	76 (36)	10 (5)
Finger phalanx	62 (82)	59 (95)	58 (94)	6.6	26 (42)	1 (2)
Distal radius	62 (85)	49 (79)	48 (77)	8.9	13 (21)	1 (2)
Metacarpal	23 (85)	20 (87)	20 (87)	6.7	10 (43)	1 (9)
Carpus	22 (85)	20 (91)	19 (86)	14.4	13 (59)	4 (18)
Clavicle	17 (85)	13 (76)	13 (76)	18.1	6 (35)	1 (6)
Proximal radius	14 (82)	12 (86)	12 (86)	7.8	5 (36)	1 (7)
Proximal humerus	2 (100)	1 (50)	1 (50)	6.0	1 (50)	0 (0)
Radial diaphysis	2 (100)	1 (50)	1 (50)	8.0	1 (50)	0 (0)
Radius and ulna	2 (67)	1 (50)	1 (50)	16.0	1 (50)	0 (0)
Ulna diaphysis	2 (100)	1 (50)	1 (50)	28.0	0 (0)	0 (0)

[a]Values are presented as n (%) unless otherwise indicated.

TABLE 5
Lower Limb Fracture Follow-up Data[a]

Type	Follow-up	Return to Soccer	Return to Same Level or Higher	Time to Soccer, wk	Persisting Symptoms	Persisting Symptoms Affecting Soccer
Total cohort	312 (85)	267 (86)	258 (83)	15.0	123 (39)	24 (8)
Lower limb	103 (88)	89 (86)	96 (81)	26.5	47 (46)	14 (14)
Ankle	44 (90)	42 (95)	39 (89)	31.2	17 (39)	6 (14)
Metatarsal	21 (91)	20 (95)	18 (86)	11.5	8 (38)	3 (14)
Tibial diaphysis	15 (83)	12 (80)	11 (73)	38.2	11 (73)	4 (27)
Toe	6 (75)	3 (50)	3 (30)	7.0	3 (50)	0 (0)
Distal tibia	4 (100)	3 (75)	3 (75)	65.3	3 (75)	0 (0)
Fibula	4 (100)	3 (75)	3 (75)	11.0	2 (50)	0 (0)
Talus	3 (100)	2 (67)	2 (67)	29.0	1 (33)	0 (0)
Proximal tibia	2 (100)	1 (50)	1 (50)	32.0	1 (50)	0 (0)

[a]Values are presented as n (%) unless otherwise indicated.

DISCUSSION

We believe this to be the first article to provide a comprehensive description of both the epidemiology of soccer-related fractures in a known general population and the subsequent morbidity and likely return to soccer for each fracture type. While the epidemiological characteristics of sport-related fractures have been well reported,[5] the literature on returning to sporting activity after fractures is of poor quality, either focusing on one fracture type,[1,2,6,13,14,16,19] having limited follow-up, or following a large number of sports in a small group of patients.[10]

Despite soccer being the most popular sport in the world, with a vast economic revenue,[2,9] most of the soccer injury research focuses on soft tissue injuries,[9,11,21-24] overlooking fractures. Indeed soft tissue injuries are more common than fractures in soccer,[9,11,21,22] with fractures being reported to comprise just 10% of all soccer-related injuries.[7,12] However, the published evidence[5,10,13,19] suggests that not only is soccer the most common cause of sport-related fractures, but the incidence of fractures in soccer is also considerable.[5,9] Recent reported incidences include 63.5 per year per 1000 of the general population[5] and 140 per year per 1000 professional soccer players.[9] In comparison, our incidence is similar at 70.9 per year per 1000 of the general population. In keeping with the previous soccer-related fracture cohorts,[2,5,10,16,19] we also found a significant male dominance, a distinct age-related unimodal incidence of sport-related fractures (Figure 1), and a vast majority of nonprofessional athletes (Figure 2). Without definite epidemiology data on the active soccer players in our population, it is difficult to be certain of the cause of these trends. However, data from the Football 2006 Worldwide: Official FIFA Survey[17] show that within our country, 89% of all soccer players are male and 99% of all soccer players play at a nonprofessional level. Thus, it is very likely that our epidemiological findings are a reflection of the fact that the majority of soccer players in our region tend to be young male athletes playing at a nonprofessional level.

When we assess specific fracture cohorts and compare them against much earlier data within the same population,[13,16] there are some notable decreases in certain fracture types. Our reported incidence for soccer-related tibial diaphyseal fractures was 18 per year, while in the same population 13 years earlier, Shaw et al[16] reported an incidence of 43 per year. Similarly, our reported incidence for soccer-related distal radial fractures was 73 per year, while within the same population 15 years earlier, Lawson et al[13] reported an incidence of 112 soccer-related distal radial fractures.

This decreasing incidence has been previously documented by Chang et al,[2] who equated it to the introduction of shin guards. While we must accept the limited evidence for this,[1] this cannot account for the decrease in distal radial fractures. Lawson et al[13] reported that falls on synthetic pitches were by far the most common cause for their fractures, and we believe the introduction and enhancement of specifically suited boots to artificial surface pitches have had a reducing effect on the incidence of falls and thus fracture incidence.[9,13,15,18] Despite changes in incidences, mechanisms of injury appear to have changed little with time. Tackles remain the dominant cause of tibial diaphyseal fractures,[1,2,16] and falls are the dominant cause of distal radial fractures.[13]

Our results demonstrate that upper limb fractures are more common than lower limb fractures, with a ratio of 68:32 (upper limb:lower limb). This is in keeping with recent evidence, suggesting that upper limb fractures are much more common than previously accounted for, with reported upper limb:lower limb ratios of 65:35[10] and 67:33.[5] However, in keeping with traditional views,[2,5] our lower limb fractures were found to have considerably higher rates of surgery, increased duration to return to soccer, and increased rates of persisting symptoms than our upper limb fractures.

Our results also demonstrate that there is a significantly increased duration in the time to return to soccer and increased symptom rates associated with surgical management of soccer-related fractures. In a similar manner, Hon and Kock[10] found surgically treated sports fractures had a 3-fold increase in residual disabilities compared to non–surgically treated sports fractures.[2,10] This may reflect the severity of these injuries, and further research is required to ascertain whether similar fracture classifications have a better return to sport rate when treated nonoperatively compared with operatively.

We reported a return to soccer figure for our whole cohort of 86%, with a return to the same level or higher in 83% with a mean duration of return to soccer of 15 weeks. Given the limited literature available on follow-up of soccer-related fractures, it is hard to make general comparisons with other studies. The only similar study found that in a cohort of 113 sport-related fractures (of which soccer was the most common), 90 (79.6%) had returned to a preinjury sporting level by a mean of 13 weeks.[10] This correlates well with our results.

In terms of individual fracture types, for our tibial diaphysis series, we found a return rate of 80% (73% to the same level or higher) and a mean duration for return to soccer of 38 weeks. Figures from the available literature include 93% return to full-level soccer by a mean duration of 40 weeks,[16] 54% return to competitive soccer (44% to the previous level of competition) by a mean duration of 11.6 months (range, 6-18 months),[14] and 100% return rate by a mean of 35 weeks.[1] This obviously demonstrates considerable variability within the available evidence. However, within nonprofessional cohorts, this is the realistic pattern with a return to soccer often influenced by personal factors as much as function.[1]

For the upper limb fractures, our cohort of distal radial fractures reported a 79% return rate (77% to the same rate or higher), with a mean duration of return to soccer of 9 weeks. This correlates with the published results of Lawson et al,[13] who found that 82% of their patients made a full return to soccer.

In terms of reasons for not returning, we found 71% of nonreturners did so because of personal reasons, with 27% stating fear of reinjury as the main cause. This was similar to Lenehan et al,[14] who found that 55% of nonreturns were done so for personal reasons (27% because of fear of reinjury). Lawson et al[13] also found that fear of reinjury was the most common cause for stopping. It seems that personal factors, especially in players over 30 years of age, play a significant role in return to sport.

It was interesting to note that professional-level soccer players had higher return rates than the nonprofessional soccer players. The reason for this would appear to be the considerable proportion of nonprofessional players who quit soccer secondary to personal reasons, as none of the professional players were noted to do this.

Persisting symptoms were not the most common reason for quitting soccer, but they still had a significant incidence in our cohort, with 39% of patients reporting persisting symptoms 2 years after injury and 8% of patients reporting symptoms that interfered with their soccer ability. Reported incidences of persisting symptoms include 53% for stiffness of the adjacent joint,[10] 12% for limb pain,[10] and 25%[6] and 35%[10] for fracture site difficulties. Reported incidences of subsequent impaired performance secondary to symptoms include 20%[10] and 26%.[16]

There are several limitations to our study. The first of these relates to the accuracy of fracture type diagnosis from radiograph examination. To mitigate this, all radiographs were reviewed by an orthopaedic surgeon, who was performing full-time research on the epidemiology and classification of fractures to confirm the diagnosis. In a situation of uncertainties or complex cases, advice was sought from the senior author, who was the supervisor of the research. He is a professor of orthopaedic trauma surgery and has published extensively in the epidemiology and classification of fractures. The second limitation centers on the accuracy of follow-up data obtained via telephone communication. Understandably, questionnaire and clinic follow-up would have provided more comprehensive, and possibly more accurate, information. However, to communicate with the significant number within our cohort, we believe that a telephone interview was the optimal mode. By performing a consistent set of interview questions that was asked by the same clinician, we were able to obtain the relevant information from each case, thus avoiding further more time-consuming methods of follow-up. Again, the retrospective nature of our follow-up may be considered a limitation to the data. We agree that prospective follow-up data would have been ideal, but given the standard duration of follow-up for most fracture types, this was not possible. Lastly, some may believe the reporting of our follow-up data as a whole cohort provides inaccuracies, as it fails to differentiate between injuries incurred at different playing levels. Some may believe that the pattern and severity of fractures may vary among such groups. In our defense, we did not notice such a difference while performing our analyses, and given that our professional and semiprofessional cohorts were so small, we failed to appreciate the value in representing them separately.

In conclusion, we present the first comprehensive study into the epidemiology of soccer-related fractures in a known general UK population and their subsequent morbidity and return to sport. As soccer is the most popular sport in the world, we believe this information will be useful to medical staff managing soccer teams as well as those looking after the general population.

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Appendix II:

Paper 2:

The Epidemiology, Morbidity and Outcome of Fractures in Rugby Union from a Standard Population

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The epidemiology, morbidity and outcome of fractures in rugby union from a standard population

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ABSTRACT

Background: Rugby union is the second commonest cause of sporting fracture in the UK, yet little is known about patient outcomes following such fractures.
Objective: To describe the epidemiology of fractures in rugby union, their morbidity and the likelihood of return to rugby post-injury in a known UK population at all skill levels.
Methods: All rugby union fractures sustained during 2007–2008 in the Edinburgh, Mid and East Lothian populations were prospectively recorded, when patients attended the only adult orthopaedic service in Lothian. The diagnosis was confirmed by an orthopaedic surgeon. Patients living outside the region were excluded from the study. Patients were contacted by telephone in February 2012 to ascertain their progress in return to rugby.
Results: A total of 145 fractures were recorded over the study period in 143 patients. The annual incidence of rugby-related fractures was 0.28/1000 of the general population and 29.86/1000 of the adult registered rugby playing population. 120 fractures were of the upper limb and 25 were of the lower limb. 117 fractures (81%) in 115 patients (80%) were followed up at a mean interval of 50 months (range 44–56 months). 87% of the cohort returned to rugby post-injury (87% of upper limb fractures and 86% of lower limb fractures), with 85% returning to rugby at the same level or higher. Of those who returned, 39% did so by 1 month post-injury, 77% by 3 months post-injury and 91% by 6 months post-injury. For those who returned following upper limb fractures, 48% did so by 1 month post-injury, 86% by 3 months post-injury and 94% by 6 months post-injury. In patients who returned following lower limb fractures, 0% did so by 1 month post-injury, 42% by 3 months post-injury and 79% by 6 months post-injury. From the whole cohort, 32% had ongoing fracture related problems, yet only 9% had impaired rugby ability secondary to these problems.
Conclusions: Most patients sustaining a fracture playing rugby union will return to rugby at a similar level. While one third of them will have persisting symptoms 4 years post-injury, for the majority this will not impair their rugby ability.

Introduction

Rugby union is one of the most popular team contact sports in the world [1–5] with one of the highest recorded injury rates of all sports [6]. It is estimated that over 5 million people participate in rugby union worldwide [2,7], and the Rugby World Cup is now the third largest sporting event in the world [7]. Whilst rugby union is the seventh most popular sport by participation in England [8], it was recorded as the second highest cause of sporting fractures in a UK population [9]. The epidemiology and outcome of rugby union injuries has been described extensively [3,5,10–19]. However, research on the epidemiology and outcome of fractures sustained during rugby union is sparse, and data are limited to small patient cohorts [3,10,11,13–15,17–22].

Accurate knowledge of the morbidity and outcome of rugby-related fractures is vital, to fully council and plan appropriate rehabilitation for the individual players and to allow team managers to predict availability of players. This information would also provide essential reference material for sports physicians, orthopaedic surgeons and general health practitioners who provide healthcare for rugby playing populations.

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We present a study that defines the epidemiology of adult fractures sustained during rugby union in a known UK population at all skill levels. We describe the morbidity for these patients, and demonstrate their likelihood of return to rugby.

Materials and methods

Study design

All acute fractures sustained by patients aged 15 years and above in the Edinburgh, Mid and East Lothian populations (numbering 517,555) from July 2007 to June 2008 were prospectively recorded. This was performed as part of a routine census of all acute fractures within our region, carried out every 3 years for research purposes. Recorded fractures were limited to those of the appendicular skeleton and the spine, excluding maxillo-facial and rib fractures. There are no other specialist centres in our region to refer to for fracture management, so this provides a definite capture of all fractures presenting to hospital in this region. Data on patient demographics, the circumstances surrounding injury, and the specific fracture type and classification were noted. The mode of injury was recorded from the details of the admission history as well as from in-patient and out-patient hospital records. Where the mode of injury was not clear from these sources, patients were contacted either on the ward or at clinic, during the initial management period of their injury. With sport-related fractures, the specific sport that was being played at the time of the injury was noted accordingly. Each fracture type was confirmed through examination of the relevant radiographs by an orthopaedic surgeon. Stress fractures were not included in the analysis. Patients living outside the catchment area were excluded but Lothian residents injured elsewhere and followed up at our institution were included. Open fractures were classified using the Gustilo classification [23].

All fractures sustained during rugby union were identified from the database. The formal rugby season in our region runs from September to June with pre-season training running from July to August [24]. Patients were contacted by telephone in February 2012 to obtain retrospective follow-up data by asking a standardised set of questions (see Annex 1). This was a mean duration of 50 months post-injury (range 44–56 months). Given the duration between injury and follow-up, we made reference to patients' fracture clinic records during telephone calls, as required, to help orientate patients to the timing of their injury within the season and their level of function by discharge from fracture clinic. To improve the accuracy of follow-up data, we categorised return to rugby times to by 1 month, 3 months, 6 months and 12 months post-injury. For analysis purposes, we divided amateur level rugby players into high level rugby players (Scottish RBS Premiership, National and Championship Leagues – 11 teams) and low level rugby players (Scottish Regional Leagues – 68 teams) [24]. There is one professional team in the region and 98 registered youth teams for players aged 15 years and above [24]. The epidemiology of the adult rugby playing population of the region (aged 19 years and above) for the season 2007–2008 was obtained from collation of data from the 2007 to 2008 Regional Annual Rugby Reports from the City of Edinburgh, Mid Lothian and East Lothian Rugby Management Committees, obtained directly from the Scottish Rugby Union (see Annexes 2–4). This data did not provide numbers for the registered players aged 15–18 years old specifically so it was not possible to provide incidence figures for these groups. When collating incidence figures for the registered rugby population, fractures sustained during 'social' rugby were excluded.

Supplementary data related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2013.06.006.

A retrospective review of patients' inpatient and fracture clinic notes was conducted in February 2012 to identify mechanism of injury, the limb dominance, management and complications. Recorded mechanism of injury was a combination of information from the patients' notes and patients' response from telephone interview.

Ethical Approval for the study was requested from the South East Scotland Research Ethics Service but this body deemed that formal ethical approval was not necessary (Annex 5).

Supplementary material related to this article found, in the online version, at http://dx.doi.org/10.1016/j.injury.2013.06.006.

Statistical analysis

Collected data were analysed by descriptive statistics using SPSS 19.0 (SPSS, Chicago, IL, USA). Univariate statistical comparisons between categorical variables were performed using the Chi square test (with Fisher's exact test as required). The significance level was set at $p < 0.05$.

Results

Out of a total 6871 fractures (from the upper limb, lower limb and spine) sustained during the study period, 145 fractures (2.1%) were rugby-related, and occurred in 143 patients (2.3%) (Table 2).

There were 120 (82.8%) upper limb fractures (Table 3) and 25 (17.2%) lower limb fractures (Table 4). There were no spinal fractures recorded over the period. The annual incidence of rugby-related fractures was 0.28 per 1000 of the general population and 29.86 per 1000 of the registered rugby playing population of the region. Fig. 1 shows the age- and gender-related incidences. Table 1 lists the epidemiology of the registered adult rugby playing population of the region (aged 19 years and above) for the season 2007–2008 as well as the annual incidence of rugby-related fractures for the registered rugby playing population of the region. The total number of fractures recorded in the registered adult rugby playing population of the region (excluding those sustained during 'social' rugby) was 82.

The mean age of the cohort was 22 years (range 15–46 years). The gender ratio of the cohort by fractures was 137:8 (Male:Female). Fig. 2 shows the level of rugby that the players were competing at pre-injury. Over 90% of the fractures occurred in non-professional athletes. One hundred and seven (74%) of the fractures were sustained during a match, 29 (20%) during training and 9 (6%) during social rugby.

The demographics of the rugby fracture population are shown in Table 2. Seventeen percent of the fractures required surgical management, including open reduction internal fixation (48%), K-wire fixation (28%) and intra-medullary nailing (20%).

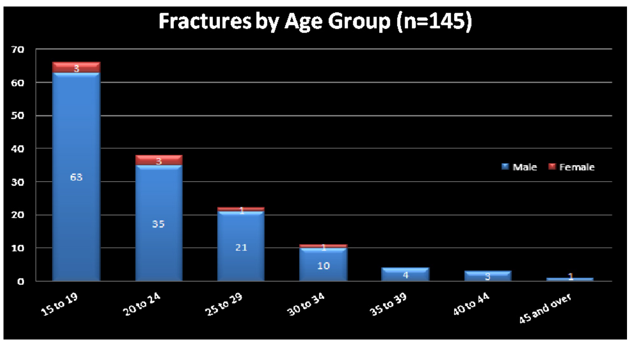

Fig. 1. The incidence of fractures by age and gender.

Table 1
Epidemiology and incidence of fractures in the registered rugby playing population aged 19 and above in Edinburgh, Mid and East Lothian (Annexes 2–4).

Age group	Total players	Total fractures	# Incidence per 1000 players	Female players	# Incidence per 1000 ♀ players	Male players	# Incidence per 1000 ♂ players	Teams
Adult (≥19)	2746	82	29.86	242	8.26	2504	31.95	80

Table 2
General fracture demographics.

Total fractures	6871	
Sports fractures	992 (14.4%)	
Rugby fractures	145 (14.6%)	
Number of patients	143	Mean age: 21.8 years
Male	135 (94.4%)	Mean age: 21.8 years
Female	8 (5.6%)	Mean age: 22.4 years
In-patient fractures	29 (20.0%)	
Out-patient fractures	116 (80.0%)	
Conservatively managed fractures	120 (82.8%)	
Surgically managed fractures	25 (17.2%)	
Fractures with full follow-up data	117 (80.6%)	
Patients with full follow-up data	115 (80.4%)	Mean age: 22.2 years
Male	109 (94.8%)	Mean age: 22.2 years
Female	6 (5.2%)	Mean age: 21.8 years

Table 3 shows the demographics for upper limb fractures. Fractures with high (non-surgical) manipulation rates included distal radius (36%) and finger phalanx (8%).

Table 4 shows the demographics for the different types of the lower limb fractures. Table 5 shows the fractures distributed by playing position. Fig. 3 demonstrates the mechanism of injuries for the fractures, illustrating the ratio of upper limb to lower limb fractures for each mechanism. The tackle was the most common mechanism of injury resulting 44% of all fractures.

Full follow-up data was obtained for 117 (81%) of the fractures. Of these, 102 (87%) returned to rugby (mean age 22 years), with 100 (85%) returning to the same level or higher (mean age 21 years).

Of the fracture cohort who returned to rugby, 39% had returned to full level rugby by 1 month post-injury, 77% by 3 months post-injury, 91% by 6 months post-injury and 99% by 12 months post-injury. Fig. 4 illustrates the time to return to full level rugby for the common fracture types.

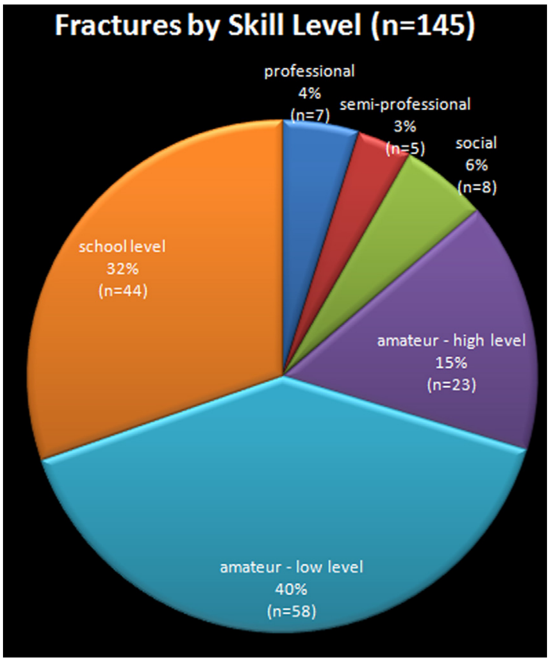

Fig. 2. The pre-injury distribution of skill level of the patients.

The 'return' rates for the different pre-injury competition levels were 100% for the professional cohort (86% to same level), 100% for the semi-professional cohort (100% to same level), 91% for the amateur high level cohort (91% to same level), 78% for the amateur low level cohort (78% to same level), 93% for the school-boy cohort (91% to the same level) and 100% for the social cohort (100% to the same level). While professional rugby players (professional and semi-professional) demonstrated a higher 'return' rate (100% vs 87%) and higher 'return to same level' rate (92% vs 86%) compared to the non-professional rugby players (amateur, school-boy and social), these differences were not statistically significant (difference between 'return' rates – $p = 0.356$; difference between 'return to same level' rates – $p = 1.000$).

Of the whole cohort, 37 (32%) of the fractures were found to have persisting symptoms 4 years post-injury (mean age 25 years), the most common being fracture site pain (49%), stiffness of an adjacent joint (46%) and metalwork related pain (8%). However only 11 (9%) of all the fractures were found to have persisting symptoms which impacted upon their ability to play rugby (mean age 25 years), the most common being fracture site pain (72%), stiffness of an adjacent joint (45%) and weakness of grip (27%).

For the patients who were managed operatively, the return rate was 73%. Of those who returned, 13% did so by 1 month post-injury, 50% by 3 months post-injury, 81% by 6 months post-injury and 100% by 12 months post-injury. For patients managed conservatively, the return rate was 91%. Of those who returned, 44% did so by 1 month post-injury, 83% by 3 months post-injury, 93% by 6 months post-injury and 99% by 12 months post-injury. The difference between the return rates of the operative cohort and the conservative cohort was statistically significant ($p < 0.036$). Comparing the time to return rates between the operative and conservative cohorts, the differences in the 'return by 1 month' rates ($p < 0.001$) and the 'return by 3 months' rates ($p < 0.008$) were statistically significant.

Sixty-eight percent of patients treated operatively were found to have persisting symptoms and 18% had symptoms which interfered with their ability to play rugby. Of those treated conservatively, 23% had ongoing symptoms and 7% had symptoms which interfered with their rugby. 'Persisting symptom' rates ($p < 0.001$) were significantly greater in the operative cohort but the difference in 'persisting symptoms affecting rugby ability' rates was not statistically significant ($p = 0.215$).

Overall, 15 (13%) of the fracture patients had not returned to rugby 4 years post-injury. The mean age of this cohort was 27 years. Twelve had upper limb fractures, three had lower limb fractures. Ten were backs, four were forwards, and one we failed to record the position played. Six were from the Operative Cohort (no-return rate 27%) and 9 were from the Conservative Cohort (no-return rate 9%). This difference was statistically significant ($p < 0.036$).

Eighty percent of those who did not return to rugby (12/15) reported they had quit secondary to personal reasons (i.e. not related to symptoms from the injury) with the other twenty percent (3/15) citing persisting symptoms as their reason for stopping. The recorded personal reasons included fear of re-fracture (42%), advancing age (33%), responsibilities of young children (25%), not wanting to take more time off work (17%) and

Table 3
Upper limb fracture demographics.

Type	Number	Mean age (years)	M:F ratio	Surgically managed	In-patient	Main MOI
Total	120	21.5	113:7	14 (11.7%)	17 (14.2%)	Tackle (45%)
Finger phalanx	40	22.8	37:3	3 (7.5%)	3 (7.5%)	Tackle (50%)
Metacarpal	27	23.8	24:3	5 (18.5%)	6 (22.2%)	Tackle (37%)
Clavicle	24	17.3	24:0	2 (8.3%)	3 (12.5%)	Tackle (54%)
Distal radius	11	18.8	10:1	1 (9.1%)	2 (18.2%)	Fall (45%)
Proximal humerus	5	28.0	5:0	0 (0%)	0 (0%)	Tackle (60%)
Scaphoid	3	21.0	3:0	0 (0%)	0 (0%)	Fall (67%)
Distal ulna	2	20.0	2:0	0 (0%)	0 (0%)	Lineout (50%)
Radius and ulna	2	15.0	2:0	0 (0%)	0 (0%)	Lineout (50%)
Radial diaphysis	2	23.0	2:0	2 (100%)	2 (100%)	Ruck (50%)
Distal humerus	1	24.0	1:0	0 (0%)	0 (0%)	Tackle (100%)
Humeral diaphysis	1	16.0	1:0	0 (0%)	0 (0%)	Tackle (100%)
Proximal radius	1	22.0	1:0	0 (0%)	0 (0%)	Fall (100%)
Proximal ulna	1	21.0	1:0	1 (100%)	1 (100%)	Tackle (100%)

Table 4
Lower limb fracture demographics.

Type	Number	Mean age (years)	M:F ratio	Surgically managed	In-patient	Main MOI
Total	25	23.5	24:1	11 (44.0%)	11 (44.0%)	Tackle (40%)
Ankle	15	22.3	14:1	6 (40.0%)	6 (40.0%)	Tackle (53%)
Tibial Diaphysis	3	25.0	3:0	3 (100%)	3 (100%)	Tackle (67%)
Metatarsal	3	21.0	3:0	0 (0%)	0 (0%)	Ruck (100%)
Fibula	2	31.5	2:0	0 (0%)	0 (0%)	Twist (100%)
Distal Tibia	1	26.0	1:0	1 (100%)	1 (100%)	Tackle (100%)
Talus	1	26.0	1:0	1 (100%)	1 (100%)	Tackle (100%)

Table 5
Fractures by playing position.

Position	*n*	Main MOI	Upper limb:lower limb	Most common fracture (*n*)	2nd most common (*n*)	3rd most common (*n*)
Forwards	54	Tackle (35%)	45:9	Finger phalanx (13)	Clavicle (9)	Metacarpal (9)
Back row	23	Tackle (43%)	20:3	Finger phalanx (8)	Clavicle (4)	Distal radius (3)
Front row	19	Tackle (32%)	14:5	Metacarpal (4)	Finger phalanx (3)	Distal radius (3)
2nd row	12	Line-out (50%)	11:1	Clavicle (4)	Metacarpal (3)	Finger phalanx (2)
Backs	65	Tackle (45%)	56:9	Finger phalanx (20)	Metacarpal (15)	Clavicle (11)
Winger	19	Tackle (42%)	17:2	Finger phalanx (7)	Clavicle (3)	Metacarpal (3)
Centre	18	Tackle (18%)	16:2	Metacarpal (8)	Finger phalanx (6)	Tibia diaphysis (1)
Scrum-half	10	Tackle (40%)	7:3	Clavicle (4)	Finger phalanx (1)	Ankle (1)
Full back	10	Tackle (40%)	9:1	Finger phalanx (4)	Clavicle (2)	Distal radius (2)
Stand-off	8	Tackle (50%)	7:1	Clavicle (2)	Metacarpal (2)	Finger phalanx (2)

(*Position Data was not available for 18 of the players playing organised rugby and was not applicable for the 8 players playing rugby socially

change of sport (17%). Patients over 30 (40.0% no return rate) were 4.5 times more likely to quit rugby than those under 30 (8.8% no return rate) ($p < 0.004$).

Table 6 shows the outcome data for the common fractures types. There was no difference in the 'return' rates between upper limb injuries and lower limb injuries ($p = 1.000$). For those who returned to rugby from the upper limb injuries and lower limb injuries, the difference in return rates by 1 month ($p < 0.001$) and 3 months ($p < 0.001$) was statistically significant but the difference in return rates by 6 months ($p = 0.060$) and 12 months ($p = 1.000$) was not. Lower limb fractures had a significantly greater frequency of persisting symptoms at follow-up compared to upper limb fractures ($p < 0.010$).

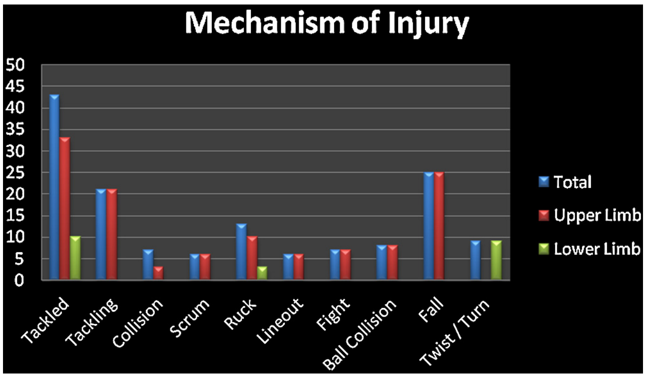

Fig. 3. Mechanism of injury.

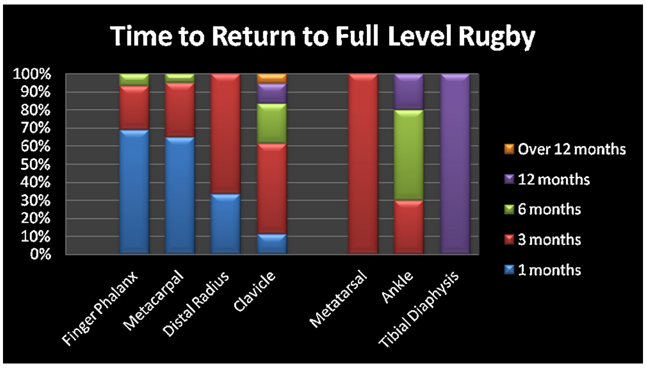

Fig. 4. Duration taken for return to full level rugby for the different fracture types.

Table 6
Fracture follow-up data.

Type	Follow-up	Return to rugby	Return to same level or higher	Return by 1 month post-injury	Return by 3 months post-injury	Return by 6 months post-injury	Return by 12 months post-injury	Persisting symptoms	Persisting symptoms affecting rugby
Total cohort	117 (81%)	102 (87%)	100 (85%)	40 (39%)	79 (77%)	93 (91%)	101 (99%)	37 (32%)	11 (9%)
Upper limb	95 (79%)	83 (87%)	81 (85%)	40 (48%)	71 (86%)	78 (94%)	82 (99%)	25 (26%)	9 (9%)
Finger phalanx	33 (83%)	29 (88%)	27 (82%)	20 (69%)	27 (93%)	29 (100%)	29 (100%)	11 (33%)	5 (15%)
Metacarpal	22 (81%)	20 (91%)	20 (91%)	13 (65%)	19 (95%)	20 (100%)	20 (100%)	4 (18%)	2 (9%)
Clavicle	19 (79%)	18 (95%)	18 (95%)	2 (11%)	11 (61%)	15 (83%)	17 (94%)	3 (16%)	0 (0%)
Distal radius	10 (91%)	9 (90%)	9 (90%)	3 (33%)	9 (100%)	9 (100%)	9 (100%)	2 (20%)	1 (10%)
Proximal humerus	3 (60%)	0 (0%)	0 (0%)	-	-	-	-	2 (67%)	-
Scaphoid	2 (67%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	0 (0%)	0 (0%)
Distal ulna	2 (100%)	2 (100%)	2 (100%)	0 (0%)	1 (50%)	1 (50%)	2 (100%)	1 (50%)	1 (50%)
Radial diaphysis	2 (100%)	1 (50%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)	1 (100%)	2 (100%)	0 (0%)
Humeral diaphysis	1 (100%)	1 (100%)	1 (100%)	0 (0%)	1 (100%)	1 (100%)	1 (100%)	0 (0%)	0 (0%)
Proximal radius	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0 (0%)	0 (0%)
Lower limb	22 (88%)	19 (86%)	19 (86%)	0 (0%)	8 (42%)	15 (79%)	19 (100%)	12 (55%)	2 (9%)
Ankle	12 (80%)	10 (83%)	10 (83%)	0 (0%)	3 (30%)	8 (80%)	10 (100%)	7 (58%)	1 (8%)
Metatarsal	3 (100%)	3 (100%)	3 (100%)	0 (0%)	3 (100%)	3 (100%)	3 (100%)	0 (0%)	0 (0%)
Tibial diaphysis	3 (100%)	2 (67%)	2 (67%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	1 (33%)
Fibula	2 (100%)	2 (100%)	2 (100%)	0 (0%)	2 (100%)	2 (100%)	2 (100%)	0 (0%)	0 (0%)
Distal tibia	1 (100%)	1 (100%)	1 (100%)	0 (0%)	0 (0%)	1 (100%)	1 (100%)	1 (100%)	0 (0%)
Talus	1 (100%)	1 (100%)	1 (100%)	0 (0%)	0 (0%)	1 (100%)	1 (100%)	1 (100%)	0 (0%)

Discussion

This is the first paper to provide a comprehensive description of the epidemiology of rugby union related fractures in a known population. We have reported the subsequent morbidity and likely return to rugby for these patients.

The incidence and outcome of rugby union injuries at professional [5,10–15], amateur [3,18,20] and schoolboy level [16,17,19,25] has been well reported. However, the majority of this research focuses on soft tissue and head and neck injuries, with non-head and neck fractures being overlooked [1,25–27]. This is despite the fact that fractures result in the greatest morbidity and absence from work of all rugby injuries [14,18,19].

Fractures are a minority injury type in rugby union [3,5,10,11,13–15,17,28,29] comprising between 5% and 14% of all rugby injuries [1,3,13–15,17–19,28]. However, not only is rugby union the second most common cause of sport-related fracture [9], comprising 15% of all sport-related fractures [9], the incidence of fractures in rugby union is considerable [9,13,14,17–19]. Reported incidences include 0.21 per year per 1000 of the population in a standard UK population [9], 113.6 per year per 1000 professional rugby players [13,14], 28.2 per year per 1000 amateur rugby players [18], and 10.6–19.4 per year per 1000 schoolboy rugby players [17,19]. Our incidence of rugby-related fractures from our general population correlates well with that from the literature. Similarly, our incidence within our registered rugby population correlates well with reported incidences among amateur rugby players, representative of the mainstay of the rugby playing population in our region.

We found a significant pre-dominance of rugby-related fractures in young men and non-professional athletes (Figs. 1 and 2), both a reflection of the playing population of the region (Annexes 2–4) as well the higher incidence of fractures found in the male population (Table 1). These findings are not reflective of the literature, as fracture incidence within rugby has been shown to increase with seniority and professionalism [13,14,17–19], and the incidence of fractures within female rugby players has been shown to be twice that of equivalent male counterparts [3]. We are unsure the exact reason for our findings but it may relate to an under-detection of minor fractures in previous studies or variations in intensity of play among different populations.

It was interesting to note the considerably low incidence within the adult female population. Again it is hard to be certain of the nature of such findings but may related to a lesser intensity of play within our female cohort.

In our study, as in previous studies [7], tackle was the most common cause of fracture, accounting for 44% of injuries. We found that those being tackled were at higher risk of sustaining a fracture than those tackling, with a ratio of 2:1 for tackled to tackling. Risk of injury during a tackle is felt to be a multi-factorial situation, encompassing the nature and direction of the tackle and the speed and role of the players [30], so offering specific injury advice based on our findings is difficult. However we would advise sports doctors and coaches to have higher index of suspicion of fracture in the tackled player who presents with significant pain.

Our data demonstrate that all lower limb fractures from tackles were sustained by the tackled player. Such a difference in the distribution and location of fracture between the tackler and the ball carrier is likely due to the differing direction and points of application of energy during the tackle [30]. Further research to define methods of contact that are most vulnerable for lower limb fractures would help players be aware of methods of contact to avoid [30].

Positions with high reported rates of fracture included scrum-halves, full backs and wingers, though no one position showed a notably increased rate of fracture. We did find that 2nd Row Forwards had a high rate of clavicle fractures, sustained from falls during line-outs. This may represent an area for improvement in injury prevention.

We found that 74% of fractures occurred during matches with 20% occurring during training. Reported match to training ratios include 18:3 for amateur players [20], 43:16 for professional players [13,14] and 5:1 for American collegiate players [3]. It would appear that players are at a substantially greater risk of sustaining a fracture during a match than during training.

Our results demonstrate that upper limb fractures are more common than lower limb fractures with a ratio of 120:25. This is in keeping with available evidence, with reported upper limb:lower limb ratios of 85:15 [9], 22:10 [18], 28:5 [19] and 15:6 [20]. However, we found a surprisingly low incidence of scaphoid fractures (2%) compared to other reports of sport fractures (5%) [9,31]. This is likely a reflection of the soft ground of the rugby terrain acting as a protective factor against this type of fracture.

We reported a return to rugby figure for our whole cohort of 87% with a return to the same level or higher in 85%. Of those who returned, 39% had returned to full level rugby by 1 month post-injury, 77% by 3 months and 91% by 6 months. Around half of those who returned to rugby following upper limb fractures had returned by one month post-injury. Around half of those who returned to rugby following lower limb fractures had returned by three month post-injury. By comparison, Garraway and MacLeod reported that upper limb fractures took a mean of 56 days to return to rugby and lower limb fractures a mean of 113 days [18]. Brooks et al. reported that upper limb fractures sustained during matches took a mean of 51 days to return to rugby, while lower limb fractures took a mean of 85 days to return [9].

Our results demonstrated that there was a significantly increased duration in the time to return to rugby and increased symptom rates associated with surgical management of rugby-related fractures. Similar findings have been reported in other sport fracture cohorts [22,32]. This is likely to reflect the severity of these injuries, such that fractures with greater displacement and comminution often require surgical intervention. However, further research is required to ensure that these fractures are managed optimally to allow as rapid a return to rugby as possible.

In terms of reasons for not returning, we found 80% of non-returners did so because of personal reasons with 42% stating fear of re-injury as the main cause. There is no specific data within the rugby fracture literature to compare against, but similar finding have been reported in the sport fracture literature [21,32].

It was interesting to note that professional rugby players had higher return rates than the non-professional rugby players. Financial incentives likely play a significant influence, with professional players having a financial incentive to return to play, while non-professional players have a financial incentive not to become injured again, as they are less able to work [15]. Other factors which may influence this finding include the fact that professional players in our region often receive privatised medical and rehabilitation services while the amateur players regularly receive such resources through public health care. Lastly professional players are often at better base level of fitness facilitating a faster and more complete return to play.

There are several limitations to our study. Epidemiological fracture studies rely upon accurate fracture ascertainment, and the researchers' ability to identify all fracture cases for a given population. We accept that many players suffering minor fractures may not have chosen to seek medical advice, however we cannot accurately estimate a figure that this may comprise. Additionally, some fractures may be difficult to identify on plain radiographs. It is important to note that all radiographs were examined by a dedicated trauma fellow for the duration of the study.

Secondly, the use of the Scottish Rugby Union Annual Regional Reports to derive incidence figures provides limitations in that it does not account for wide variations in exposure and intensity levels for different levels of players, which have significant influence on injury risks. Unfortunately, this is the only available record of the rugby playing population in our region at this time, and so we are restricted to use of this resource.

Thirdly, we appreciate that retrospectively derived outcome data are limited by accurate patient recall. However, by presenting patients with a consistent set of interview questions, administered by the same clinician, we were able to obtain the relevant information from each case. The mean follow-up period was significant and this may have diminished the patients' accurate recollection of their recovery. However, prior to communicating with the patient, we reviewed their fracture clinic notes to provide the patient with the time frame of clinic discharge post-injury as well as the recorded level of function at this stage. We also noted the dates of the injury, to help orientate the patient within the relevant rugby season.

Fourthly, we did not address the effect of protective equipment in our study, but note with interest that previous reports have suggested such equipment may be of limited usefulness [26].

Lastly, our patient cohort represented a diverse group of amateur, semi-professional and professional players whose relatively small numbers precluded a detailed analysis of the effect of playing level on injury patterns or indeed outcome.

Conclusion

We present the first study into the epidemiology of rugby-related fractures in a known general UK population and their subsequent morbidity and return to sport. This shows that most patients sustaining a fracture playing rugby union will return to rugby at a similar level. While one third of them will have persisting symptoms 4 years post-injury, for the majority this will not impair their rugby ability. As rugby is one of the most popular sports in the world, we believe this information will allow medical staff managing rugby teams to council players appropriately regarding the likely outcome of their injury, plan rehabilitation schedules accordingly and inform team managers about the likely availability of players.

Conflict of interest

There are no conflicts of interest to declare.

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Appendix III:

Paper 3:

The Epidemiology, Management and Outcome of Field Hockey Related Fractures in a Standard Population

Original Article

The Epidemiology, Management, and Outcome of Field Hockey-related Fractures in a Standard Population

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Abstract

Background: Field hockey is one of the most popular sports in the world, yet little is known about patient outcome following fracture injuries sustained during this sport. **Objectives:** The aim of this study is to describe the epidemiology, management, and outcome of field hockey-related fractures in a known UK population at all skill levels. **Materials and Methods:** All fractures sustained during field hockey from 2007 to 2008 within the adult Lothian population were prospectively recorded and confirmed by an orthopedic surgeon during treatment at the sole adult orthopedic center in the region. Nonresident individuals were not included in the study. Follow-up data were obtained in September 2010 to determine return rates and times to field hockey. **Results:** Nineteen fractures were recorded over the study period in 19 patients. Seventeen (89%) of the fractures were recorded in the upper limb, with 15 (79%) recorded in hand. Eighteen fractures (85%) in 18 patients (95%) were followed up at a mean interval of 31 months (range: 25–37 months; standard deviation [SD] 2.1 months). The mean time for return to field hockey from injury was 10.8 weeks (range: 3–26 weeks; SD 7.1 weeks). For patients with upper limb injuries, the mean time was 9.2 weeks (range: 3–20 weeks; SD 5.7 weeks), compared to 22 weeks (range: 18–26 weeks; SD 5.7 weeks) for patients with lower limb injuries. Eleven percent of the cohort did not return to field hockey. Seventy-eight percent of the cohort returned to field hockey at the same level or higher. Fifty percent had ongoing related problems, yet only 17% had impaired field hockey ability because of these problems. Fractures with the highest morbidity in not returning to field hockey were as follows: Metacarpal 14% and finger phalanx 13%. **Conclusions:** The significant majority of field hockey-related fractures are sustained in the upper limb, notably the hand. Around ninety percent of patients sustaining a fracture during field hockey will return to this sport at a similar level. While half of these will have persisting symptoms 2 years postinjury, only one-third of symptomatic patients will have impaired field hockey ability because of this.

Keywords: Epidemiology, fracture, hockey, management, outcome

Introduction

Field hockey is one of the most participated sports in the world.[1] Within the UK, between 2 and 5/1000 of the adult population participate in this sport at least once a week,[2,3] and over the past 5 years, participation numbers for this sport in the UK have risen by 5%.[3]

Due to the contact nature of the sport, the lack of protective clothing for the outfield players and the potential for collision with both the hockey stick and the hockey ball, there is a high risk for injury in this sport, particularly fractures.[4-9] Previous studies have recorded an injury incidence within field hockey of 8/1000 match exposures and 4/1000 practice exposures,[5] with fractures comprising around 15% of all field hockey-related injuries.[4]

Despite the frequency of such injuries, there has been limited research into the epidemiology, management and outcome of field hockey-related fractures.[4-12] Previous studies have either provided an overview of the injury patterns in the sport, restricting fractures to a subcohort within this,[4-6] or have focused on a particular region of the body,[6,7] failing to provide a comprehensive description of the epidemiology, management, and outcome of such fractures.

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Such data are important as it allows players and teams to plan rehabilitation schedules, based on expected recovery times, as well as enabling sports doctors and surgeons to define and provide the optimal management for these injuries.[4-6] Such information also allows the development and design of realistic injury prevention methods and equipment.[4-6,13] This in whole enables optimization of the return rates and times to field hockey for the players, as well as reducing the incidence of such injuries in the future.[4-6,13]

The aim of this study was to provide a comprehensive overview of the epidemiology, management and outcome of fracture injuries sustained during field hockey over a year period in a standard UK population.

Materials and Methods

Study design

All acute fractures sustained within the Edinburgh, Mid and East Lothian populations from July 2007 to 2008 in patients aged 15 years and over were prospectively recorded in a database. The population count for Edinburgh, Mid and East Lothian was 517,555. Information contained within the database included age, gender, mode of injury, site of the fracture, date of treatment, whether orthopedic treatment was as an in-patient or out-patient, and whether the fracture was open or closed. Fracture classification was performed using the Arbeitsgemeinschaft fuer Osteosynthesefragen classification, by individual review of each presenting radiograph by an orthopedic surgeon. The Gustilo classification was used to classify open fractures.[14] For fractures sustained during sport, the specific sport participated in at the time of the injury was recorded in the database. The database did not record stress fractures. Nonresident individuals were excluded from the database to allow accurate epidemiological analysis.

The mode of injury was recorded from the details of the admission history as well as from in-patient and out-patient hospital records and was confirmed with patients either on the ward or at the clinic, during the initial management period of their injury.

All patients who sustained a fracture during field hockey were identified from the database and telephoned in September 2010 to complete a standardized questionnaire. This provided a mean follow-up of 31 months postfracture (range: 25–37 months; standard deviation [SD] 2.1 months).

All the case notes of the patient cohort were retrospectively reviewed in September 2010 to determine the mechanism of injury, fracture treatment modalities and subsequent complications.

Statistical analysis

Analysis of the cohort data was performed using SPSS 19.0 (SPSS, Chicago, Illinois, USA). For the continuous (nonparametric) data, univariate comparisons were performed with the Mann–Whitney U-test. For the categorical (nonparametric) data, univariate comparisons were performed with the Chi-squared test (using Fisher's exact test if necessary). The Kaplan–Meier estimator, with the hazard function, was used to perform survival analyses for return to field hockey between: patients treated operatively versus patients treated conservatively; and patients below the age of 30 years versus patients over 30 years of age. These groups were chosen to illustrate the effect of treatment and age on sporting outcome. The significance level was $P < 0.05$.

Results

Out of a total 6871 fractures sustained during the study period in 6325 patients, 19 fractures (0.3%) were field hockey-related occurring in 19 patients (0.3%) [Table 1].

There were 17 (89.5%) upper limb fractures and 2 (10.5%) lower limb fractures [Table 2]. The annual incidence of field hockey-related fractures was 0.04/1000 of the general population per year.

The mean age of the cohort was 24.7 years (range: 15–47 years: SD 10.33 years). The gender ratio of the cohort was 10:9 (Male:Female). Of the fractures, eight occurred during club level hockey, five during university-level hockey, four during school level hockey, one during national level hockey and one during recreational hockey. Thirteen of the fractures occurred during competition; six occurred during practice. None of the patients had previously fractured the affected areas. None of the patients suffered multiple fractures.

The demographics of the field hockey fracture population are shown in Table 1. Twenty-one percent of the fractures required surgical management ($n = 4$). Surgical intervention included manipulation of the thumb metacarpal fracture with K-wire fixation ($n = 2$), syndesmosis screw fixation of a Weber C ankle fracture ($n = 1$), and washout and reduction of open fracture dislocation of a thumb metacarpal-phalangeal joint ($n = 1$). The mean duration of hospitalization for the fractures was 0.3 days (range: 0–2 days; SD 0.6 days).

Table 2 shows the demographics for upper limb and lower limb fractures. For the finger phalanx fractures, two involved the

Table 1: General fracture demographics

	n (%)	
Sports fractures	992	
Field hockey fractures	19 (1.9)	
Number of patients	19	Mean age: 24.7 years
Male	10 (52.6)	Mean age: 26.4 years
Female	9 (47.4)	Mean age: 22.9 years
Out-patient fractures	15 (78.9)	
In-patient fractures	4 (21.1)	All day case procedures
Conservatively managed fractures	15 (78.9)	
Surgically managed fractures	4 (21.1)	
Fractures with full follow-up data	18 (94.7)	
Patients with full follow-up data	18 (94.7)	Mean age: 24.9 years
Male	9 (50.0)	Mean age: 26.9 years
Female	9 (50.0)	Mean age: 22.9 years

Table 2: Fracture demographics

Type	Number	Mean age (year)	Male:female ratio	Surgically managed (%)	In-patient (%)	Main MOI (%)	Mean duration of hospitalisation (days)
Total	19	24.7	10:9	4 (21.1)	4 (21.1)	Stick (53)	0.3
Upper limb	17	25.8	10:7	3 (17.6)	3 (17.6)	Stick (59)	0.2
Finger phalanx	8	25.8	6:2	1 (12.5)	1 (12.5)	Stick (63)	0.1
Metacarpal	7	27.4	3:4	2 (28.6)	2 (28.6)	Stick (57)	0.3
Clavicle	1	18.0	0:1	0	0	Ball (100)	0
Distal ulna	1	22.0	1:0	0	0	Stick (100)	0
Lower limb	2	16.0	0:2	1 (50.0)	1 (50.0)	Ball (50)	1
Ankle	1	15.0	0:1	1 (100.0)	1 (100.0)	Twist (100)	2
Patella	1	17.0	0:1	0	0	Ball (100)	0

MOI: Mechanism of Injury

thumb, five the index finger and one the little finger. For the metacarpal fractures, three involved the thumb, two the middle finger, one the ring finger, and one the little finger. Fractures with high (nonsurgical) manipulation rates included finger phalanx (12.5%). There was one recorded open fracture: an open fracture dislocation of a thumb metacarpal-phalangeal Joint.

Figure 1 demonstrates the mechanism of injury for the cohort. Figure 2 demonstrates the location of the fractures by the playing positions of the cohort.

Full follow-up data were obtained for 18 (95%) of the fractures, with the mean age of this cohort being 25 years (range: 15–47 years; SD 10.6 years). Of these, 16 (89%) returned to field hockey (mean age 23 years: Range: 15–47 years; SD 9.2 years), with 14 (78%) returning to the same level or higher (mean age 22 years: Range: 17–38 years; SD 6.8 years). Patients returned to training at a mean duration of 7 weeks (range 1–16 weeks; SD 4.8 weeks), and return to preinjury level of field hockey at a mean duration of 11 weeks (range 3–26 weeks: SD 7.1 weeks). Figure 3 demonstrates the return times for the fracture types.

The "return" rates for the different preinjury competition levels were 100% for the national level cohort (100% to same level), 86% for the club level cohort (71% to same level), 100% for the university level cohort (100% to same level), 100% for the school level cohort (75% to the same level) and 0% for the recreational cohort (0% to the same level).

Of those patients managed surgically, none suffered complications. One required repeat surgery, which comprised of delayed removal of an ankle syndesmosis screw.

Of the whole cohort, 9 (50%) of the fractures were found to have persisting symptoms 2 year postinjury (mean age 27 years: Range 15–47 years; SD 12.9 years), the most common being fracture site pain (67%), stiffness of an adjacent joint (44%), and metalwork-related pain (11%). However, only 3 (17%) of all the fractures were found to have persisting symptoms which impacted on their ability to play field hockey (mean age 33 years: Range 15–47 years; SD 16.5 years), the most common symptoms being fracture site pain (100%), stiffness of an adjacent joint (33%) and metalwork-related pain (33%).

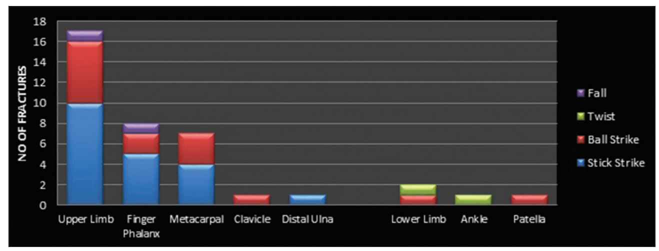

Figure 1: Mechanism of injury by fracture type

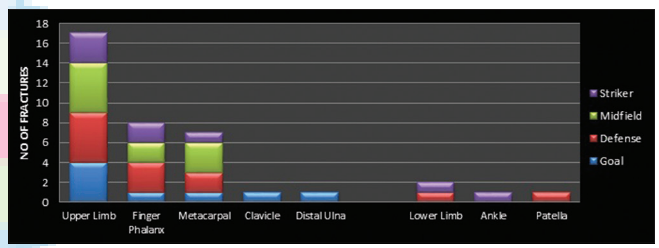

Figure 2: Location of fracture by position of play

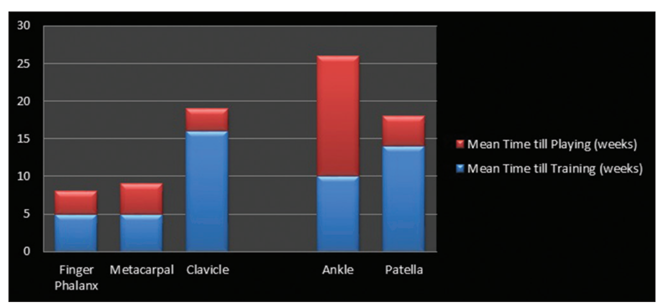

Figure 3: Return times to field hockey

For the patients who were managed operatively, the mean time to return to field hockey was 17 weeks (median 15 weeks; range 10–26 weeks; SD 6.8 weeks) and the return rate was 100%; for those managed conservatively, the mean return time was 9 weeks (median 6 weeks; range: 3–20 weeks; SD 6.3 weeks) and the return rate was 86%. The difference in return times to field hockey for operative compared to conservative management neared statistical significance (P = 0.07); there was, however, no difference noted in the return rates (P = 1.00) [Figure 4].

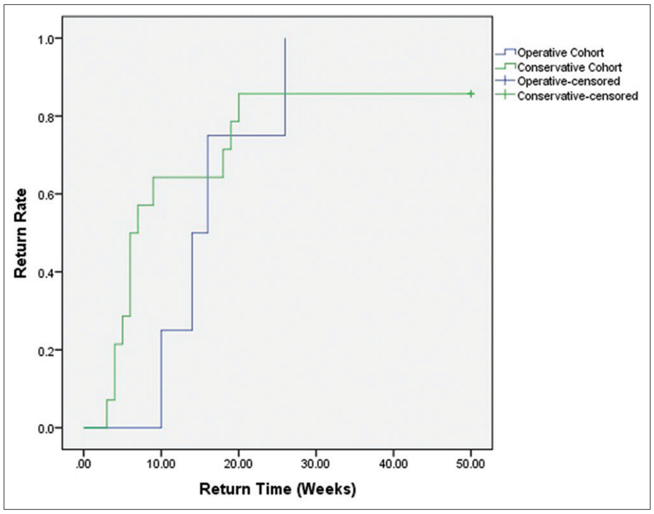

Figure 4: Return to field hockey: operative cohort versus conservative cohort (Kaplan–Meier Hazard Function)

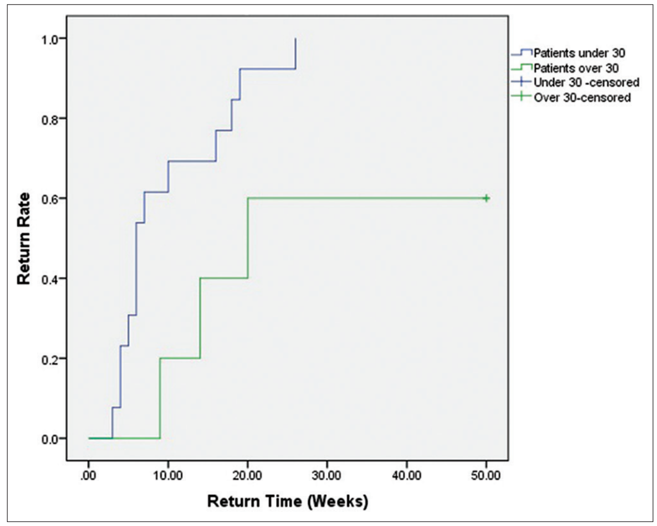

Figure 5: Return to field hockey: patients under 30 versus patients over 30 (Kaplan–Meier Hazard Function)

For patients over 30 years of age (mean age 40.4 years: Range 34–47 years; SD 5.4 years), the mean return time was 14.3 weeks (median 14 weeks; range 9–20 weeks; SD 5.5 weeks) and the return rate was 60%; for patients under 30 years of age (mean age 19.1 years: Range 15–26 years; SD 3.3 years), the mean return time was 10 weeks (median 6 weeks; range 3–26 weeks; SD 7.3 weeks) and the return rate was 100%. The difference in return rates to field hockey between the two groups neared statistical significance ($P = 0.06$); there was, however, no difference noted in the return times ($P = 0.20$) [Figure 5].

Seventy-five percent of patients treated operatively were found to have persisting symptoms at follow-up, with 50% of patients having symptoms which interfered with their ability to play field hockey. Of those treated conservatively, 43% had ongoing symptoms, and 7% had symptoms which interfered with their field hockey. The difference in "persisting symptom" rates ($P = 0.58$) and "persisting symptoms affecting field hockey ability" rates ($P = 0.11$) was not statistically significant.

Overall, two (11%) of the fracture patients had not returned to field hockey 2 years postinjury. None were from the operative cohort (no-return rate 0%), with both from the conservative cohort (no-return rate 14%) ($P = 1.00$) [Figure 4]. Fractures of the metacarpal (14%) and finger phalanx (13%) showed the highest "no return" rates.

Both patients who did not return to hockey stated they had done so for personal reasons. Both were over 30 years old (mean age 41.5 years: Range: 38–45 years; SD 4.9 years), and both reported they did not want to suffer a reinjury, necessitating more time off work.

Table 3 shows the outcome data for the upper limb and lower limb fractures.

Ninety-five percent follow-up was achieved for the upper limb cohort. Of these, 88% returned to field hockey, and 81% returned to the same level or higher. The highest return rates were seen in the clavicle (100%) and finger phalanx (88%) fractures, with the lowest seen in the metacarpal fractures (86%). Clavicle fractures took longest to return to hockey (mean 19 weeks: range 19 weeks; SD n/a) while finger phalanx and metacarpal fractures took the shortest times (finger phalanx: Mean 8.4 weeks: Range 3–20 weeks, SD 6.7 weeks; Metacarpal: Mean 8.5 weeks: Range 5–14 weeks, SD 3.3 weeks). For finger phalanx fractures, those of the thumb took a mean of 11 weeks (range 6–16 weeks; SD 7.1 weeks) to return to hockey, while those of the other digits took 7 weeks (range 3–20 weeks; SD 7.1 weeks) to return to hockey ($P = 0.32$). For metacarpal fractures, those of the thumb took a mean of 12 weeks (range 10–14 weeks; SD 2.8 weeks) to return to hockey, while those of the other digits took 7 weeks (range 5–9 weeks; SD 1.7 weeks) to return to hockey ($P = 0.06$). The highest rate of persisting symptoms 2 years postinjury was seen in clavicle (100%) and the lowest rate in the finger phalanx (38%). Only 13% of all upper limb fractures had persisting symptoms at 2 years, which impaired field hockey ability.

Complete follow-up was achieved for the lower limb cohort. Of these, all returned to field hockey, and 50% returned to the same level or higher. Both the lower limb patients were noted to have persisting symptoms 2 year postinjury, though only the ankle patient had persisting symptoms which impaired her ability to play hockey.

Upper limb injuries returned to activity significantly quicker than lower limb injuries ($P < 0.05$), but there was no significant difference in return rates between the two groups ($P = 1.00$).

Discussion

We believe this study provides the first comprehensive overview of the epidemiology, management and outcome of field hockey-related fractures in a known general population.

Table 3: Fracture follow-up data

Type	Follow-up (%)	Return to hockey (%)	Return to same level or higher (%)	Time to hockey (weeks)	Persisting symptoms (%)	Persisting symptoms affecting hockey (%)
Total cohort	18 (95)	16 (89)	14 (78)	10.8	9 (50)	3 (17)
Upper limb	16 (94)	14 (88)*	13 (81)	9.2**	7 (44)	2 (13)
Finger phalanx	8 (100)	7 (88)	7 (88)	8.4	3 (38)	1 (13)
Metacarpal	7 (100)	6 (86)	5 (71)	8.5	3 (43)	1 (14)
Clavicle	1 (100)	1 (100)	1 (100)	19.0	1 (100)	0
Distal ulna	0	-	-	-	-	-
Lower limb	2 (100)	2 (100)*	1 (50)	22.0**	2 (100)	1 (50)
Ankle	1 (100)	1 (100)	0	26.0	1 (100)	1 (100)
Patella	1 (100)	1 (100)	1 (100)	18.0	1 (100)	0

Statistical comparisons: *Upper limb versus lower limb return rates (P=1.00), **Upper limb versus lower limb return time (P<0.05)

The study reported an incidence of field hockey-related fractures of 0.04/1000 population. This is in keeping with previous studies within the same population which noted an incidence of 0.05/1000 population.[9] In contrast to reports from other sports,[15-17] we found an even gender distribution among our fracture cohort. This is reflective of the significant female participation in the sport.[2,3,9] We recorded a unimodal distribution of these injuries with a mean age of 24.7 years for our cohort. This is in keeping with previous reports which noted a mean age of 25 years for their cohort,[9] reflective of the young age group of participation in this sport in our region.[2,3] The SD for our age range was 10 years. this is indicative of the injuries being predominantly recorded in patients aged 15–35 years and is similar to previous reports of sport-related fractures.[9,15-17]

We found a significantly greater upper limb to lower limb ratio in this cohort, compared to reports from other sports.[7-9,15,16] Similar findings have been noted by previous reports on field hockey fracture epidemiology.[9] This high incidence of upper limb fractures is reflective of the upper limb involvement of the sport, with significant potential for injury from both the hockey stick and the hockey ball.[5] This provides clear guidance regarding focus for injury prevention strategies in the sport.[4]

Regarding fracture types, we found finger phalanx fractures to have an incidence of 0.02/1000 population and metacarpal fractures to have an incidence of 0.01/1000 population. This reflects a similar incidence to previous studies, with field hockey noted to be the sixth most common cause of sport-related finger phalanx fractures and the fifth most common cause of sport-related metacarpal fractures.[7] Regarding the mechanism of injury, we found that stick and ball contact provided the highest cause of fracture, again in keeping with the common modes of injury reported by previous studies.[5] Such information provides valuable direction for the planning of injury prevention equipment in the sport.[13]

We recorded a return to field hockey rate of 89% for our whole cohort, with a return to the same level or higher in 78% and a mean duration of return to field hockey of 11 weeks. In comparison to previous studies on other sports, this represents a reduction in return time to the sport (13–15 weeks).[15,17] This is likely a reflection of the high proportion of upper limb injuries within our cohort, which have been well documented to take a shorter time to return to sport compared to lower limb injuries.[15-17]

Regarding our survival analyses, we found that the operatively-managed fractures had prolonged return times compared to the conservatively-managed fractures, though with comparable return rates. Similar findings have been reported in previous studies, with operatively-managed fractures being recorded to take three times longer to return to the sport than conservatively-managed fractures.[15] Such prolonged return times are often a consequence of the more severe injuries requiring surgical intervention, as well as the effects of postoperative rehabilitation restrictions. Conversely, we found that patients over 30 years of age had lower return rates than those under 30 years, although with similar return times. This again is in keeping with previous studies, who found that patients over 30 years of age had a 3–5 times increased chance of no return compared those <30 years.[15,16] It would appear advancing age is a key factor in deciding to stop sport postinjury.

Regarding the distribution of fractures among the different play positions, we found these were distributed evenly through all four positions. To note, goalkeepers have previously been recorded to have the highest rate of injuries.[4] However, they also have been recorded to have lower rates of hand fractures than other players due to the use of gloves.[6] The study results are reflective of this, with goalkeepers having lower rates of hand fractures than the other positions, but having higher rates of other fractures; this then results in a similar overall fracture incidence among the positions. This shows the benefit of protective handwear against such injuries and should be considered in future injury prevention programs.[6,13]

There are several limitations to our study. The first involves the limited number of patients: this reflects the frequency of participation in this sport in our region; given our study covered a 1-year period, we feel the cohort provides a sufficient representation of the fracture patterns in this sport within our region. The second limitation relates to the follow-up process. While clinical review could have provided more reliable information, the authors have successfully performed a number of similar studies using preformed telephone questionnaires.[15,16] A further limitation relates to the retrospective follow-up data. While prospective follow-up data would have been preferred, the standard clinical follow-up for the majority of the fracture types in the study was not sufficient to allow for this.

Conclusions

We present the first comprehensive study into the epidemiology, management, and outcome of field hockey-related fractures in a known general UK population. While field hockey related fractures represent a limited portion of all sport-related fractures, they comprise a significant proportion of all field hockey-related injuries, resulting in one of the longest return times to the sport. Accurate knowledge of their epidemiology, management, and the outcome is vital to medical staff managing field hockey teams, to allow optimization of these injuries. Future injury prevention programs are likely to reduce the incidence of such injuries, particularly the use of protective handwear.

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Conflicts of interest

There are no conflicts of interest.

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Appendix IV:

Paper 4:

The Epidemiology, Management and Outcome of Sport-Related Ankle Fractures in a Standard UK Population.

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Epidemiology, Management, and Outcome of Sport-Related Ankle Fractures in a Standard UK Population

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Abstract

Background: The literature on the outcome of sport-related ankle fractures has focused on operatively managed fractures, despite a large proportion being treated nonoperatively. We describe the epidemiology, management, and outcome of acute sport-related ankle fractures in a UK population.

Methods: All sport-related ankle fractures sustained during 2007 to 2008 in the Lothian Population were prospectively collected when patients attended the only adult orthopaedic service in Lothian. Fractures were classified using the Lauge Hansen and the Pott's Classification. The presence of fracture displacement was also recorded. Patients were contacted in February 2011 to ascertain their progress in return to sport.

Results: Ninety-six sport-related ankle fractures were recorded in 96 patients. Eighty-four fractures (88%) were followed up at a mean interval of 36 months (range, 30-42). Most common associated sports were soccer (n = 49), rugby (n = 15), running (n = 5), and ice skating (n = 3). The mean time for return to sport was 26 weeks (range, 4-104), the return rate to sport 94%, and the persisting symptom rate 42%. Fifty-two fractures (all nondisplaced) were managed nonoperatively—43 isolated lateral malleolar (30 Weber B, 13 Weber A), 2 isolated medial malleolar, 7 bimalleolar. Forty-four fractures were managed operatively—42 were displaced (2 isolated lateral malleolar, 3 isolated medial malleolar, 18 bimalleolar equivalent, 9 bimalleolar, 3 trimalleolar equivalent, 7 trimalleolar), 2 were un-displaced (2 trimalleolar). The mean times for return to sport were 20 weeks (range, 4-52) for the nonoperative cohort (NOC) and 35 weeks (range, 8-104) for the operative cohort (OC) ($P < .001$), the return rates to sport were 100% for NOC and 87% for OC ($P < .016$), and the persisting symptom rates were 17% for NOC and 71% for OC ($P < .001$).

Conclusions: Nondisplaced ankle fractures in athletes were successfully managed with nonoperative care. They had greater return rates to sport, quicker return times, and lower persisting symptom rates but had less severe injuries.

Level of Evidence: III, retrospective comparative study.

Keywords: ankle, fracture, sport, epidemiology, management, outcome

Introduction

Ankle fractures comprise 7% of all acute sport-related fractures and occur at an incidence of 0.11 per 1000 of the adult population.[5] The literature on the outcome of acute sport-related ankle fractures is limited, focusing exclusively on operatively managed fractures.[6] A recent review of outcome in acute sport-related ankle fractures suggested that all such injuries should be managed with operative fixation,[6] despite previous studies reporting half of these injuries are managed nonoperatively.[19,20] Given that such fractures remain a common serious injury, with a significant time to return to sport and a significant rate of persisting symptoms,[19,20] appropriate knowledge of optimal management of these injuries is important.

Variation in management of ankle fractures is well recognized, and reasons for this include difference in clinician preference and experience, difference in availability of resources, and variation in patient desires and expectations.[4] Historically, success of fracture management was assessed by radiological and clinical measures of non-union and mal-union, lowering the threshold for operative fixation to provide a stable construct for healing.[4] Evidence has shown

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that operative fixation of ankle fractures provides faster healing times.[11]

However, recent studies on the outcome and management of fractures in athletic populations have shown that operative management of fractures is associated with significantly prolonged duration until return to sport as well as a significantly increased rate of persisting symptoms.[9,19,20] Yet these studies are limited to large-scale analysis of heterogeneous fracture types,[9,19,20] failing to differentiate return to sport times and persisting symptoms rates by fracture location or severity, so it remains difficult to draw conclusions from such evidence. As young athletic patients often have good quality bone with significant potential for fracture healing,[15,16] whether managed operatively or nonoperatively, clear evidence should be available to direct optimal management of fractures in athletes to allow as rapid a return to sport as possible with the lowest side effect profile.

This study analyzes a cohort of acute sport-related ankle fractures sustained during sporting activities, at all levels, within a standard UK population, over a year, detailing epidemiology, management, and outcome.

Methods

Study Design

All acute fractures sustained by patients aged 15 years and above in the Edinburgh, Mid and East Lothian populations from July 2007 to July 2008 were prospectively recorded on a database. The population figure for this cohort was 517 555. The database contained information on the age, gender, and address of the patient; mode of injury; date of treatment; whether management was as an inpatient or outpatient; site of the fracture; AO (Arbeitsgemeinschaft fuer Osteosynthesefragen) classification of the fracture; and whether the fracture was open or closed. Open fractures were classified using the Gustilo classification.[8] The mode of injury was recorded from the details of the admission history as well as from inpatient and outpatient hospital records. Where the mode of injury was not clear from these sources, patients were contacted either on the ward or at clinic during the initial management period of their injury. With sport-related fractures, the specific sport that was being played at the time of the injury was noted accordingly. Each fracture type was confirmed and classified through examination of the relevant radiographs by an orthopaedic surgeon. Stress fractures were not included in the analysis. Patients living outside the catchment area were excluded to allow accurate epidemiological analysis.

All ankle fractures sustained during sport were then identified from the database. Patients were contacted by telephone in February 2011 to obtain retrospective follow-up data by asking a standardized set of questions (appendix) at a mean of 36 months (range, 30-42) post injury.

A retrospective review of patients' inpatient and fracture clinic notes was also conducted in February 2011 to identify mechanism of injury, management, and complications, including clinical and radiological evidence of non-union or mal-union.

Similarly, a retrospective review of the patient radiographs was performed to classify the ankle fractures by the Pott's Classification[4,14] and the Lauge Hansen Classification,[13] as well as to determine if fracture displacement was present. Fracture displacement was considered present if talar shift was noted (a medial clear space of the tibiotalar joint greater than or equal to 5 mm or greater than the superior clear space)[26] or if there was articular surface incongruency greater than 2 mm.[1]

Fractures grouped into the "operatively managed" cohort were those who underwent either open reduction and internal fixation or syndesmotic stabilization. Fractures grouped into the "nonoperatively managed" cohort were those who did not undergo an operative procedure. The indications for operative management were: (1) evidence of fracture displacement on radiographs[4] (defined as the presence of talar shift[26] or articular surface incongruency greater than 2 mm[1]), (2) evidence of syndesmotic injury on radiographs[4] (defined as the presence of syndesmotic widening on stress testing[2]), or (3) a posterior malleolar fracture fragment greater than one-third of the articular surface.[4] When none of the aforementioned indications were present, fractures were considered suitable for nonoperative management.

Operative fixation methods included: combined small fragment lag screw and tubular plate fixation for displaced lateral malleolar fractures, small fragment lag screw fixation for displaced medial and posterior malleolar fractures, and suprasyndesmotic screw fixation of syndesmotic injuries. The posterior malleolus was operatively stabilized if the fragment was greater than one-third of the joint surface or if it remained displaced after fixation of the lateral and medial malleoli. Syndesmotic stabilization was performed if there was obvious medial widening or if there was widening on stress radiograph after fixation of the lateral and medial malleoli. One screw was placed across the syndesmosis for fixation. Soft tissue structures were not repaired unless they prevented intraoperative fracture reduction.

Patients were immobilized in a below-knee partial circumferential cast for 48 hours post surgery, followed by conversion to below knee full circumferential cast immobilization for 6 weeks post surgery. Unless there was significant concern regarding the stability of operative fixation, patients were progressed to crutch-assisted full weightbearing status as soon as able. When concern regarding the stability of surgical fixation was present, patients were kept toe-touch weightbearing for 6 weeks. Clinic follow-up with accompanying radiographs was performed at 1, 2, 4, 6, and 12 weeks

Table 1. General Fracture Demographics.

Total fractures	6871	
Sports fractures	992 (14.4%)	
Ankle fractures	96 (9.7%)	
Number of patients	96	Mean age: 28 years
Male	80 (83.3%)	Mean age: 27 years
Female	16 (16.7%)	Mean age: 36 years
Inpatient fractures	44 (45.8%)	
Outpatient fractures	52 (54.2%)	
Operatively managed fractures	44 (45.8%)	Mean age: 28 years
Nonoperatively managed fractures	52 (54.2%)	Mean age: 29 years
Fractures with full follow-up data	84 (87.5%)	
Patients with full follow-up data	84 (87.5%)	Mean age: 28 years
Male	72 (90.0%)	Mean age: 26 years
Female	12 (75.0%)	Mean age: 38 years
Operatively managed fractures	38 (86.4%)	Mean age: 27 years
Nonoperatively managed fractures	46 (88.5%)	Mean age: 29 years

post injury. Following cast removal, physiotherapy was commenced, with progression to full weightbearing as pain levels permitted, under the care of the physiotherapists. Patients who underwent syndesmotic fixation were managed nonweightbearing for 6 weeks postoperatively with progression to full weightbearing under the care of the physiotherapists following this. If symptomatic, syndesmotic screws were removed between 6 to 8 weeks postoperatively.

Nonoperative management consisted of below-knee partial circumferential cast immobilization for 48 hours post injury, followed by conversion to below-knee full circumferential cast immobilization for 6 to 12 weeks post injury, depending on clinical and radiographic evidence of healing. Patients were progressed to crutch-assisted full weightbearing status as soon as pain levels permitted, under the care of the physiotherapists. Crutch-assisted full weightbearing was continued until removal of the cast. Clinic follow-up with accompanying radiographs was performed at 1, 2, 4, 6, and 12 weeks post injury. Following cast removal, physiotherapy was commenced, with progression to full weightbearing as pain levels permitted, under the care of the physiotherapists.

Statistical Analysis

Collected data were analyzed by descriptive statistics using SPSS 19.0 (SPSS, Chicago, IL). Univariate statistical comparisons between continuous variables were performed using the Student *t* test between 2 groups. Univariate statistical comparisons between categorical variables were performed using the chi-square test (with Fisher's exact test as required). The significance level was set at $P < .05$.

Results

Epidemiology

Of a total of 992 sport-related acute fractures sustained over the study period, 96 were ankle (malleolar) fractures, occurring in 96 patients (Table 1). The annual incidence of sport-related ankle fractures was 0.19 per 1000 of the general population. The most common associated sports were soccer (n = 49), rugby (n = 15), running (n = 5), and ice skating (n = 3) (Table 2). Figure 1 shows the age- and gender-related incidences. The mean age of the cohort was 28 years (range, 15-81). The male to female ratio of the cohort was 5:1. Figure 2 shows the level of sport that the patients were competing at pre-injury.

The fractures are divided by the Lauge Hansen Classification[13] in Table 3, with data presented on management, time to return to athletic activity, return rate to athletic activity, and persisting symptom rates. Similarly, the fractures are divided by the Pott's Classification[4,14] in Table 4, with data presented on management, time to return to athletic activity, return rate to athletic activity, and persisting symptom rates. All fractures were closed injuries.[8]

Treatment

Forty-four of the 96 fractures (46%) were managed operatively. The operations performed included lateral malleolus ORIF in bimalleolar equivalent fracture (n = 15), bimalleolar ORIF in bimalleolar fracture (n = 8), bimalleolar ORIF for trimalleolar fracture (no posterior malleolar ORIF) (n = 4), isolated medial malleolus ORIF (n = 3), lateral malleolus ORIF and syndesmosis screw in bimalleolar equivalent fracture (n = 3), bimalleolar ORIF and

Table 2. Sport.

Type	N	Mean Age (yr)	M:F Ratio	Level of Sport	Professional	Amateur	Schoolboy	Leisure
Soccer	49	26.6	48:1		3	26	5	15
Rugby	15	22.3	14.1		1	8	3	3
Running	5	30.0	3:2		0	1	0	4
Ice skating	3	30.3	1:2		0	0	0	3
Basketball	2	23.0	1:1		0	1	0	1
Golf	2	70.5	1:1		0	0	0	2
Netball	2	31.5	0:2		0	0	0	2
Skateboarding	2	19.0	2:0		1	0	0	1
Trampolining	2	28.5	1:1		0	0	0	2
Badminton	1	42.0	0:1		0	0	0	1
Caving	1	47.0	1:0		0	0	0	1
Climbing	1	27.0	0:1		0	0	0	1
Go-karting	1	35.0	1:0		0	0	0	1
Hockey	1	5.0	0:1		0	0	1	0
Horseriding	1	52.0	0:1		0	0	0	1
Martial arts	1	21.0	1:0		0	1	0	0
Motocross	1	66.0	1:0		0	1	0	0
Mountain biking	1	29.0	1:0		0	0	0	1
Skiing	1	62.0	0:1		0	0	0	1
Sledging	1	26.0	1:0		0	0	0	1
Snowboarding	1	28.0	1:0		0	0	0	1
Tennis	1	27.0	1:0		0	0	0	1
Windsurfing	1	22.0	1:0		0	0	0	1
Total	96	28.3	80:16		5	38	9	44

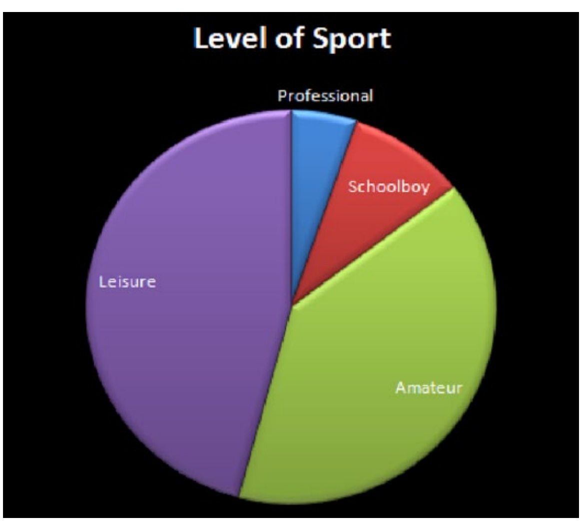

Figure 1. Fractures by age group.

syndesmosis screw for trimalleolar fracture (no posterior malleolar ORIF) (n = 3), lateral malleolus ORIF for trimalleolar equivalent (no posterior malleolar ORIF) (n = 3), isolated lateral malleolus ORIF (n = 2), trimalleolar ORIF and syndesmosis screw (n = 1), trimalleolar ORIF (n = 1), bimalleolar ORIF and syndesmosis screw in bimalleolar fracture (n = 1).

Complications from the surgery included 1 wound infection and 3 cases of malreduction that required revision (1 medial side and 2 lateral side—1 index procedure was performed at another center). Six cases required removal of symptomatic hardware (4 were syndesmosis screws).

Forty-two of the fractures were noted to have fracture displacement. All of these were managed operatively. The remaining 54 fractures were noted to be nondisplaced, and 2 of these (both trimalleolar fractures) were managed operatively. Of the 52 fractures managed nonoperatively, none required delayed operative fixation for fracture displacement.

The mean age of patients managed operatively was 28 years (range, 15-52), with the mean age of patients managed nonoperatively being 29 years (range, 15-81) (P = .420, 95% confidence interval [CI], –3.57 to 8.46).

Return to Sport

Full follow-up data were obtained for 84 (88%) of the 96 fractures.

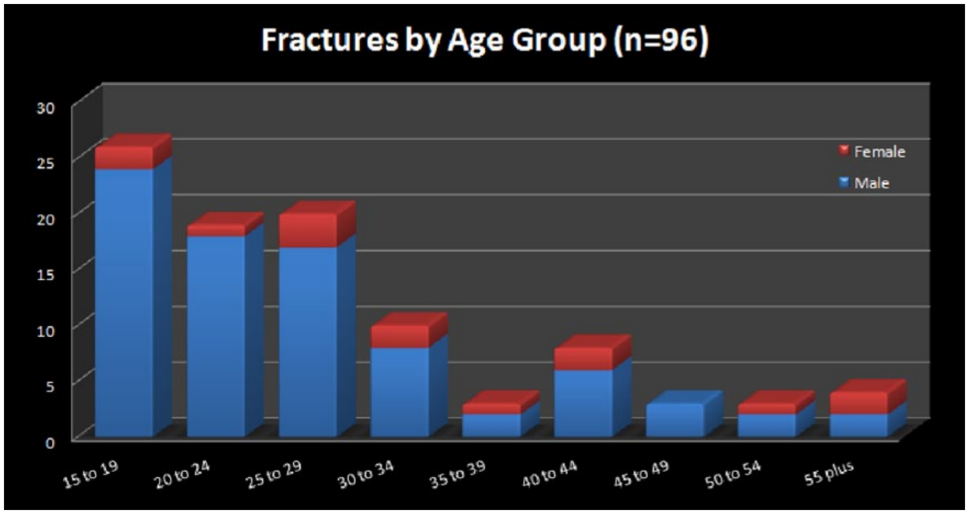

Figure 2. Level of sport pre injury.

Table 3. Lauge Hansen Classification.[13]

Type	N (follow-up)	Time to Return (wks)	Displaced (follow-up)	Undisplaced (follow-up)	Operative (displaced)	Nonoperative (undisplaced)	Return Operative	Return Nonoperative	Persisting Symptoms Operative	Persisting Symptoms Nonoperative
SER 2	31 (27)	23.3	1 (1)	30 (26)	1 (1)	30 (30)	1/1 (100%)	26/26 (100%)	0/1 (0%)	5/26 (15%)
SER 3	1 (1)	44.0	0 (0)	1 (1)	0 (0)	1 (1)	—	1/1 (100%)	—	0/1 (0%)
SER 4	25 (22)	35.1	21 (18)	4 (4)	23 (21)	2 (2)	17/20 (85%)	2/2 (100%)	15/20 (75%)	1/2 (50%)
SA 1	14 (12)	14.9	1 (1)	13 (11)	1 (1)	13 (13)	1/1 (100%)	11/11 (100%)	1/1 (100%)	1/11 (9%)
SA 2	3 (1)	24.0	3 (1)	0 (0)	3 (3)	0 (0)	1/1 (100%)	—	0/1 (0%)	—
PER 3	13 (12)	23.5	9 (8)	4 (4)	9 (9)	4 (4)	7/8 (88%)	4/4 (100%)	5/8 (63%)	0/4 (0%)
PER 4	4 (4)	60.7	4 (4)	0 (0)	4 (4)	0 (0)	3/4 (75%)	—	4/4 (100%)	—
PA1	5 (5)	24.8	3 (3)	2 (2)	3 (3)	2 (2)	3/3 (100%)	2/2 (100%)	2/3 (67%)	1/2 (50%)

Abbreviations: SER, supination external rotation; SA, supination adduction; PER, pronation external rotation; PA, pronation abduction.

Of these, 94% (79/84) returned to sport (96%, 76/79, to pre-injury level) with a mean time to return to sport of 26 weeks (range, 4-104; SD = 19). For patients managed operatively, follow-up data were achieved in 38 (86%) of the 44 fractures. Of these, 33 (87%) returned to sport (91%, 30/33, to pre-injury level), with a mean time to return to sport of 35 weeks (range, 8-104; SD = 23). For patients managed nonoperatively, follow-up data were achieved in 46 (89%) of the 52 fractures. Of these, all 46 (100%) returned to sport (all to pre-injury level), with a mean time to return to sport of 20 weeks (range, 4-52; SD = 14).

Those managed operatively took significantly longer to return to sport ($P < .001$, 95% CI, 6.90-23.18) and had a significantly lower return rate ($P < .016$).

Those with a syndesmotic injury who returned to sport (n = 5) took a mean time to return to sport of 43 weeks (range, 16-104; SD = 37) while those without a syndesmotic injury who returned to sport (n = 74) took a mean time to return to sport of 25 weeks (range, 4-92; SD = 17) ($P < .05$, 95% CI, 0.01-34.88).

The mean times to return and return rates for the professional cohort were 38 weeks (range, 20-60; SD = 18) and 100% (100% to same level); for the amateur cohort, 27 weeks (range, 5-68; SD = 17) and 91% (85% to same level); for the schoolboy cohort, 26 weeks (range, 8-52; SD = 17) and 100% (88% to the same level); and for the leisure cohort, 20 weeks (range, 4-88; SD = 18) and 95% (95% to the same level). While the professional cohort demonstrated a higher return rate (100% vs 94%) ($P = 1.000$) and a longer return to sport time (38 weeks vs 26 weeks) ($P = .172$, 95% confidence interval, –5.28 to 29.08) compared to the non-professional cohort (amateur, schoolboy, and leisure), with the numbers available, these differences were not statistically significant.

Figure 3 presents the time taken for return to sport for the ankle fractures divided by the Lauge Hansen Classification.[13]

Table 4. Pott's Classification.[4,14]

Type	N (follow-up)	Time to Return (wks)	Displaced (follow-up)	Undisplaced (follow-up)	Operative (displaced)	Nonoperative (undisplaced)	Return Operative	Return Nonoperative	Persisting Symptoms Operative	Persisting Symptoms Nonoperative
Isolated lateral malleolus	45 (39)	20.7	2 (2)	43 (37)	2 (2)	43 (43)	2/2 (100%)	37/37 (100%)	1/2 (50%)	6/37 (16%)
Weber A	14 (12)	14.9	1 (1)	13 (11)	1 (1)	13 (13)	1/1 (100%)	11/11 (100%)	1/1 (100%)	1/11 (9%)
Weber B	31 (27)	23.3	1 (1)	30 (26)	1 (1)	30 (30)	1/1 (100%)	26/26 (100%)	0/1 (0%)	5/26 (15%)
Isolated medial malleolus	5 (5)	24.8	3 (3)	2 (2)	3 (3)	2 (2)	3/3 (100%)	2/2 (100%)	2/3 (67%)	1/2 (50%)
Bimalleolar	16 (14)	35.4	9 (7)	7 (7)	9 (9)	7 (7)	7/7 (100%)	9/9 (100%)	4/7 (57%)	1/7 (14%)
With synesmotic injury	1 (1)	52.0	1 (1)	0 (0)	1 (1)	0 (0)	1/1 (100%)	—	1/1 (100%)	—
Bimalleolar equivalent	18 (16)	27.1	18 (16)	0 (0)	18 (18)	0 (0)	13/16 (81%)	—	11/16 (69%)	—
With synesmotic injury	3 (3)	20.0	3 (3)	0 (0)	3 (3)	0 (0)	2/3 (67%)	—	3/3 (100%)	—
Trimalleolar	9 (8)	49.0	7 (6)	2 (2)	9 (8)	0 (0)	6/8 (75%)	—	7/8 (88%)	—
With synesmotic injury	4 (3)	61.0	4 (3)	0 (0)	4 (4)	0 (0)	2/3 (67%)	—	3/3 (100%)	
Trimalleolar equivalent	3 (2)	20.0	3 (2)	0 (0)	3 (3)	0 (0)	2/2 (100%)	—	2/2 (100%)	—
Syndesmotic injury	8 (7)	42.8	8 (7)	0 (0)	8 (8)	0 (0)	5/7 (71%)	—	7/7 (100%)	—

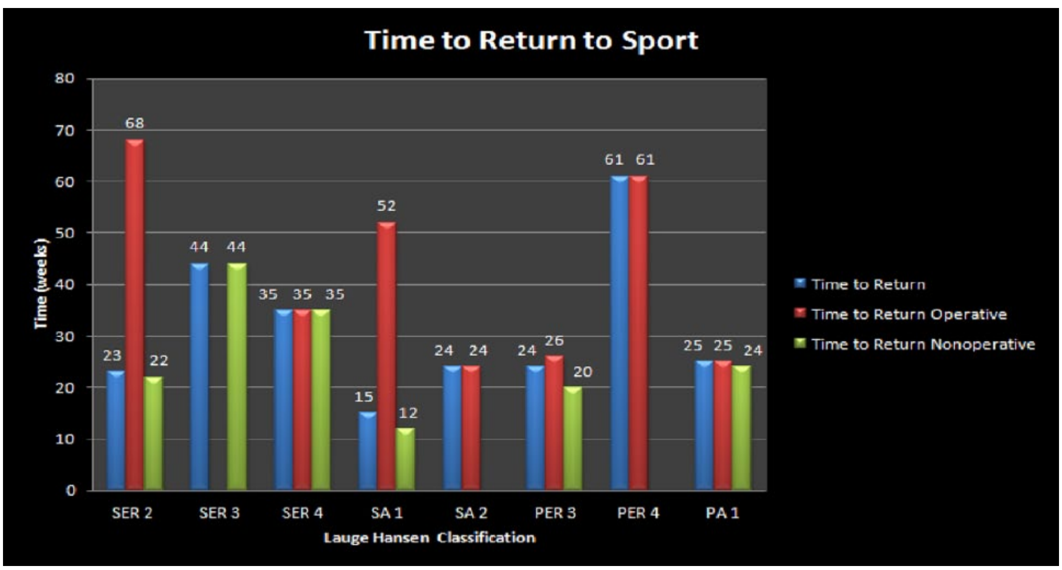

Figure 3. Time to return to sport: Lauge Hansen Classification.

Figure 4 presents the time taken for return to sport for the ankle fractures divided by the Pott's Classification.[4,14] For both figures, the results are further subdivided into operative and nonoperative categories.

Persisting Symptoms

Of the whole cohort, 35 of the 84 fractures (42%) were found to have persisting symptoms 2 years post injury (mean age 30 years), the most common being fracture site pain (27/35, 77%), stiffness of an adjacent joint (7/35, 20%), and hardware-related pain (6/35, 17%). However, only 8 (23%) of the 35 patients were found to have persisting symptoms that impacted upon their sporting ability (mean age 25 years).

Of the 38 patients managed operatively, 27 (71%) were found to have persisting symptoms at follow-up, and 8 (21%) had symptoms that interfered with their sporting ability. Of the 46 patients managed nonoperatively, 8 (17%) were found to have persisting symptoms at follow-up, and 0 (0%) had symptoms that interfered with their sporting ability. Persisting symptom rates ($P < .001$) and persisting symptoms affecting sporting ability rates ($P < .001$) were significantly greater in the operative cohort.

Of the 5 patients who did not return to sport following injury, the mean age was 30 years (range, 21-37; SD = 6). Of the 79 patients who returned to sport following injury, the mean age was 28 years (range, 15-81; SD = 13). With the numbers available, we found no significant association between age and return rates ($P = .745$, 95% confidence

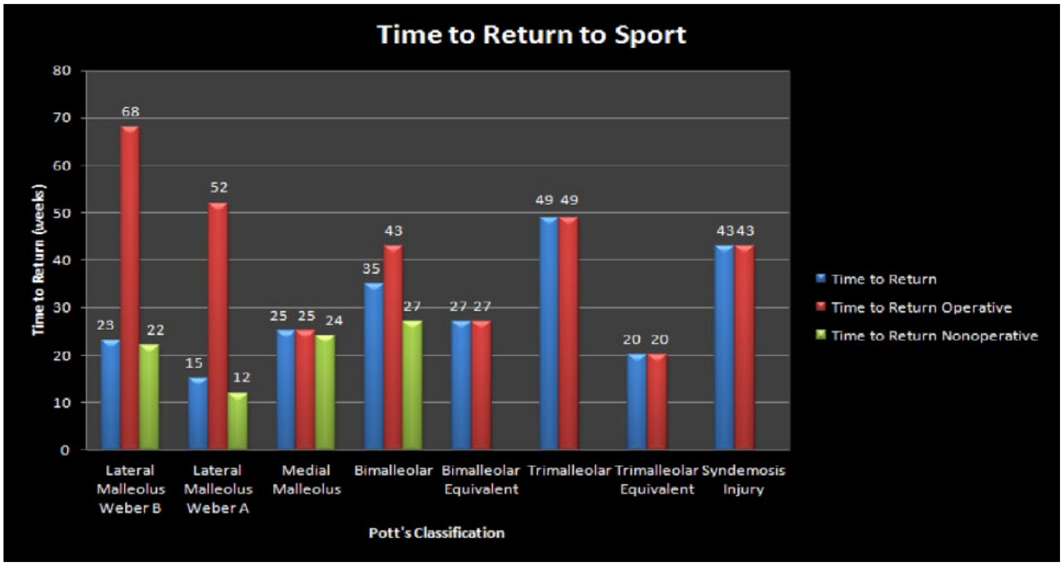

Figure 4. Time to return to sport: Pott's Classification.

interval, –9.93 to 13.83). Of the 5 patients who did not return to sport following injury, 3 did so because of symptom-related reasons (all pain related), 1 because of fear of reinjury, and 1 because of age-related reasons. For the whole cohort, the rate of non-union was 0% and the rate of mal-union was 0%.

Discussion

We describe the first comprehensive series of acute sport-related ankle fractures, sustained over a fixed time period, in a set population, with a focus on operative and nonoperative management and subsequent return to sport. While a number of previous studies describe the outcome of sport-related ankle fractures,[2,6,7,10,18,25] these focus on operatively managed fractures, providing a limited description of this injury. Our findings show that ankle fractures comprise 10% of acute sport-related fractures. Court Brown et al[5] similarly noted ankle fractures comprised 7% of sport-related fractures in the same population 5 years previously. However, they recorded an annual total of 55 sport-related ankle fractures, with a total of 761 sport-related fractures, around two-thirds our figure.[5] This difference is likely due to an increase in the population of the area,[17] with a resultant increase in the sporting population.[24]

We found a predominance of sport-related ankle fractures in young male nonprofessional athletes (Figures 1 and 2), a reflection of the sporting population of the region.[21-24] Similar findings have been noted in the sport ankle fracture literature, however such studies are not true epidemiology studies.[2,6,18] Nevertheless, it would appear that young male athletes are most likely to suffer this injury, both due to the nature and intensity of sport they undertake and their increased participation in sport.

Soccer was the most common sport of injury in our study, in keeping with it being the most participated sport in our region.[24] However, other studies based in the US report American football as the most common sport of injury.[7,18,25] It would appear the main sport of injury remains region specific with the most participated sport likely representing the main risk.

We found the most common fracture patterns were supination external rotation and isolated lateral malleolar. This is in contrast to the literature, in which bimalleolar,[10,18] trimalleolar,[2,10] and pronation external rotation fractures[7] are reported as the main injuries. However these papers are not true epidemiology studies, focusing specifically on operatively managed fractures.[2,7,10,18] Both supination external rotation[12,13] and isolated lateral malleolar fractures[3] have been shown to be the most common ankle fractures in previous general ankle fracture epidemiology studies. Our findings suggest that the epidemiology of sport ankle fracture patterns reflect that of standard ankle fracture patterns.

On average, our patients took 26 weeks to return to sport, with a return rate of 94%. Those treated operatively took 35 weeks with a return rate of 87% and those treated nonoperatively took 20 weeks with a 100% return rate. When matched for fracture type, patients managed nonoperatively showed similar or quicker return times to sport than those managed operatively, with higher return rates and fewer persisting symptoms. Nonoperative management was limited to patients with nondisplaced fractures. With a return rate to sport of 100%, we demonstrated that nonoperative management is an acceptable treatment modality for nondisplaced ankle fractures in the athlete.

Comparison with the available outcome data is difficult as this is limited to operatively managed fractures, with heterogenous fracture types.[6]

Porter et al[18] noted a return rate of 96% to same level of competition in a series of 27 operatively managed ankle fractures with all those who returned having done so by 7 months post injury. In comparison, in a series of 33 operatively managed bi- and trimalleolar fractures, Hong et al[10] reported that only 9 were able to return to their pre-injury level of sporting activities with no difficulties at 1 year, with 6 unable to do sports activities at all. This was likely related to a high persisting symptoms rate as over half had residual pain and just under two-thirds had residual stiffness. Colvin et al[2] found that in 243 operatively managed ankle fractures, 3% had returned by 3 months, 14% by 6 months, and 25% at 1 year, with 88% of recreational athletes having returned to full sport at 1 year in comparison to 12% of competitive athletes. Smaller case series of operatively managed ankle fractures[7,25] reported 100% return to competitive levels, without reference to the timeframe of return. It would appear that the majority of athletes can expect to return to sport post fracture, however the timeframe for this is variable and can be prolonged.

We found a persisting symptom rate at 3 years of 42% with the most common reported symptoms being fracture site pain, stiffness of an adjacent joint, and hardware-related pain. Persisting symptom rates were noted to be 17% for nonoperative patients and 71% for operative patients. Again, it is difficult to make comparisons with the available literature, as it is limited to operatively managed patients.[6] Hong et al[10] reported that 55% of their cohort had residual pain, 62% stiffness, and 45% ankle swelling 1 year post injury, yet most regained good function and had good to excellent Olerud and Molander scores. In contrast, 2 years post surgery, Porter et al[18] reported mean scores of the lower limb core modules of 94.6 for function and 98.0 for pain with function reported at 96% that of preoperative level. It appears that a significant proportion of sport ankle fracture patients will experience symptoms up to 2 years post injury, though mostly these will not impair function or sporting ability.

We propose the higher symptom rate observed following operative management is largely related to the surgical insult given that such differences are observed between operatively and nonoperatively managed fractures of similar severity. Fracture displacement, with the associated increased degree of soft tissue damage, may also contribute to this. We feel that the increased persisting symptom rate in operatively managed fractures has a considerable influence on return to sport so lower rates of return are observed in the operative cohort.

We found that professional athletes took longer to return to full-level sport than nonprofessional athletes, a reflection of the higher level of sport required for the professional athletes to achieve. We also found that syndesmotic injuries had significantly longer times to return to sport than nonsyndesmotic injuries, likely a consequence of the more restrictive rehabilitation program used for these injuries. Both findings have been previously documented.[2]

From our study, we acknowledge that cases of displaced unstable fractures in the athlete require fixation, as restoration of articular congruency is a key factor to optimum outcome in sporting ability.[1] However, with stable nondisplaced ankle fractures, namely, isolated malleolar fractures,[4] we feel these can be managed conservatively and show very acceptable outcome in terms of return to sport and symptom profile. Regarding cases of nondisplaced "unstable" ankle fractures, namely, bimalleolar fractures,[2] we feel these may be considered for nonoperative treatment and can show very acceptable outcomes in terms of return to sport and symptom profile. However, such decisions must be made in conjunction with the patient, with the benefits and risks of both treatment modalities discussed. If nonoperative management is decided upon, regular dedicated follow-up is required with repeat radiographic review to confirm the fracture remains nondisplaced.

There are several limitations to our study. Epidemiological fracture studies rely upon accurate fracture diagnosis and the researchers' ability to identify all fracture cases for a given population. We accept that many athletes suffering minor ankle fractures may not have sought medical advice, however we cannot accurately estimate a figure that this may comprise. Additionally, some fractures may be difficult to identify on plain radiographs. It is important to note that all radiographs were examined by a dedicated trauma fellow for the duration of the study. Second, and possibly most significantly, with a mean follow-up period of 3 years post injury, the retrospective nature by which our outcome data were collected has the real potential to create inaccuracy and bias in our results, due to inconsistent and incorrect patient recall. Ideally we would have had prospective follow-up data on which to establish our outcome measures, particularly our return times to athletic activity. Yet, given the standard duration of follow-up for ankle fractures within our health service, this was not possible. To note, however, the authors have previously performed retrospective follow-up studies on sport fracture cohorts and as such were able to optimize the method used to provide as accurate a process as possible. This involved presenting patients with a clear consistent set of interview questions, administered by the same clinician, to allow collection of the relevant information from each case. To augment this, the patients' fracture clinic notes were reviewed prior to the telephone interview to provide the patient with the date of injury, the timing of clinic discharge post injury, and the recorded level of function at that stage, in order to orientate the patient as best as able with their treatment and rehabilitation. Thus, while our retrospective method has potential for significant inaccuracies, we have tried to minimize this as much as possible. Third, despite uniform treatment protocols, patients likely had varied rehabilitation programs, influencing recovery and function. However, this study was reflective of a normal population with sport ankle fractures, and thus this is representative of management within a normal population. Fourth, our study was unable to provide radiological and functional score outcome data at final follow-up. This is a significant limitation, though a consequence of our decision to undertake telephone follow-up. Indeed, clinic follow-up would have provided more comprehensive, and possibly more accurate, information. However, the aim of this study was to provide clear figures on return rates to sport, times to return to sport, and persisting symptoms following treatment, and this was possible through our methodology.

Conclusion

Nondisplaced ankle fractures in the athlete show very acceptable return rates to sport, return times to sport, and symptom profile when managed nonoperatively. Displaced ankle fractures managed by open reduction and internal fixation continue to show acceptable figures for return to sport and return times to sport but demonstrate high rates of persisting symptoms post surgery. We believe this information will allow medical staff managing athletes to counsel patients appropriately regarding management and outcome of their injury, plan rehabilitation schedules accordingly, and inform team managers about the likely availability of players.

Appendix

Telephone Questionnaire

Patients were asked about:

1. A) The level of sport that the patient was playing at prior to injury.
   B) The club or school that they played for prior to injury.
   C) The team within the club or school they played for prior to injury.
2. The mechanism of injury with specific regards to the type of sport incident that the injury occurred.
3. The level of sport that the patient returned to after the injury.
4. If they did not return, the reason for not returning.
5. The length of time (weeks) it took to return to noncontact sports
6. The length of time (weeks) it took to return to a training level of sport (ie, being able to run and play sport leisurely).
7. The length of time (weeks) it took to return to full level sport.
8. If playing competitively, then the length of time (weeks) it took for return to full team sport.
9. The presence of any persisting symptoms from the fracture at follow-up.
10. A) The presence of any persisting symptoms from the fracture at follow-up that impaired their ability to play sport.
    B) How these symptoms affected their ability to play sport.

Declaration of Conflicting Interests

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Appendix V:

Paper 5:

The Epidemiology of Sports-Related Fractures in Adolescents

Injury, Int. J. Care Injured 41 (2010) 834–838

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The epidemiology of sports-related fractures in adolescents

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ABSTRACT

Objective: To examine the epidemiology of sports-related fractures in adolescents aged 10–19 years.
Methods: All fractures in adolescents presenting to the Royal Hospital for Sick Children and the Royal Infirmary of Edinburgh in a one-year period were prospectively documented and all sports-related fractures retrospectively examined. These two hospitals have a defined population facilitating epidemiological studies.
Results: There were 408 adolescent sports-related fractures giving an overall incidence of 5.63/1000/year. The gender ratio was 87/13% male/female and 84% were upper limb fractures. Thirty sports produced 22 different fracture types. Football, rugby and skiing accounted for 66.2% of the fractures. The commonest fractures were in the finger phalanges (28.7%), distal radius and ulna (23.0%) and metacarpus (12.7%).
Conclusions: Sport-related fractures are common in adolescents, particularly in males. They tend to be low-energy injuries affecting the upper limb in particular. Few require operative treatment although their frequency means that they impose significant demands on orthopaedic surgeons and health systems.

Sports injuries are an important cause of fractures in adolescents but there is very little known about their epidemiology. This is not only because few hospitals in the United Kingdom have a well defined population that allows fracture epidemiology to be studied but also because most large hospitals treat children or adults with the cut-off age usually being 14 or 16 years of age. Thus it is very difficult to collect appropriate data for a population ranging from 10 to 19 years of age.

We have previously analysed the epidemiology of sports-related fractures in children[12] and adults[4] but we believe that the adolescent group is important because interest in sports is high in this section of the population and sports activities are encouraged in many secondary schools. Indeed it seems likely that sporting activities may increase with increasing affluence and leisure time and orthopaedic surgeons may well be called on to treat an increasing number of sports-related fractures in adolescents.

We have analysed the epidemiology of adolescent sports-related fractures in a defined population over a one-year period. We understand that sports vary in different parts of the world and we accept that we are unable to provide information about fractures, caused by baseball, American football and other sports mainly played in North America but many of the sports that are popular in Scotland are popular worldwide and we believe that our results will be applicable in many countries in the world.

Methods

A retrospective study of all patients presenting with fractures to the Royal Hospital for Sick Children and the Edinburgh Royal Infirmary in the year 2000 was undertaken. These two hospitals are the only hospitals treating orthopaedic trauma in the City of Edinburgh, East Lothian and Midlothian and therefore accurate epidemiological analysis is possible. Both hospitals keep prospective databases of all in-patient and out-patient fractures and these were analysed to review all patients aged 10–19 years who had sustained their fractures as a result of sport. Those patients injured within our referral area but domiciled without the area were excluded from analysis but those injured elsewhere but who lived within our area were included.

The parameters that were recorded included age, gender, date of injury, mechanism of injury and site of fracture. All in-patient X-rays were reviewed by a consultant orthopaedic surgeon and all out-patient X-rays by a consultant or senior trainee. Each case was re-reviewed by one of the authors with LR reviewing the X-rays

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from the Royal Hospital for Sick Children and BC the X-rays from the Edinburgh Royal Infirmary. Fracture incidence was calculated from the 2001 Census.[2]

Results

A review of the 2001 Census[2] showed that there were 72,405 adolescents aged 10–19 years in the referral area with a gender ratio of 50/50% male to female. During the year 2000 there were 408 sports-related fractures in 406 patients giving an incidence of 5.63/1000/year. Overall 23.9% of the adolescent fractures were caused by sport. The gender ratio was 87/13% male to female with the incidence of sports-related fractures in males being 9.28/1000/year with 1.86/1000/year being recorded in females.

The overall average age was 14.5 years with 14.6 years being recorded in males and 13.7 years in females. A review of the fracture locations showed that 83.6% of the fractures were in the upper limb and 16.2% were in the lower limb. There was one (0.2%) pelvic fracture from skiing. Only 2 patients presented with more than one fracture. Both presented with two finger phalangeal fractures, one from skiing and one from ice skating. There were four (1%) open fractures. All were Gustilo I[7] in severity. There was one open tibial diaphyseal fracture from football, one finger phalangeal fracture from rugby, one ankle fracture from running and one radius and ulnar diaphyseal fracture from basketball.

Tables 1 and 2 show that there were 22 different fracture types caused by sport. Table 1 lists the fractures that had a prevalence of more than 1%. These 10 fracture types comprised 94.8% of the sports-related adolescent fractures. The remaining 12 fractures shown in Table 2 occurred very infrequently and there were insufficient numbers to adequately analyse them. Tables 3 and 4 list the 30 sports that were associated with adolescent fractures during the study year. Table 3 shows the epidemiological data for those sports associated with a fracture prevalence of at least 1%. These 16 sports caused 90.7% of the adolescent fractures seen in the study year. It shows that football, rugby and skiing caused 66.2% of all the fractures and because of the importance of these sports more complete epidemiological information is presented in Tables 5–7. Table 3 also lists the common fractures associated with the other sports with a fracture prevalence of more than 1%. Table 4 shows the 14 sports that were infrequently associated with fractures and where further analysis was impossible.

Table 3 highlights the importance of finger phalangeal fractures and metacarpal fractures in adolescent sport. Together they accounted for 41.7% of all the fractures in the study year. Table 8 shows the prevalence of fractures in each ray of the hand with the metacarpal and phalangeal fractures being combined. The overall results are shown together with the results for football, rugby and skiing.

Table 1
The epidemiology of the 10 fracture types with a prevalence of $<1\%$. The number, prevalence, average age and gender ratio are shown. % (*B*) refers to the percentage of that fracture type that was caused by sport.

Fracture	No.	% (*A*)	Age (years)	M/F	% (*B*)
Finger phalanges	117	28.7	14.1	75/25	37.3
Distal radius and ulna	94	23.0	14.2	84/16	20.1
Metacarpal	52	12.7	14.6	94/6	18.1
Clavicle	47	11.5	14.8	91/9	47.5
Ankle	19	4.7	15.6	95/5	22.6
Tibia and fibular diaphyses	17	4.2	14.9	88/12	45.9
Metatarsal	15	3.7	14.6	87/13	16.0
Radius and ulnar diaphyses	14	3.4	14.5	72/28	31.1
Proximal radius and ulna	7	1.7	16.6	100/0	17.9
Toe phalanges	5	1.2	14.6	60/40	7.9

Table 2
The fractures associated with a prevalence of $\leq 1\%$. The numbers of fractures are shown.

Fracture	No.
Carpus	4
Distal tibia and fibula	3
Proximal humerus	3
Distal humerus	2
Patella	2
Proximal femur	1
Femoral diaphysis	1
Distal femur	1
Pelvis	1
Proximal tibia and fibula	1
Scapula	1
Talus	1

The distribution of sports-related fractures in each year of adolescence is shown in Fig. 1a. The curve shows that the prevalence of fractures is maximal between 13 and 14 years of age. Fig. 1b shows that the curves for males and females are somewhat different with the highest number of sports-related fractures in adolescent females being between 11 and 12 years of age compared with 13–14 years for males. Fig. 1c shows the same curves for football, rugby and skiing and given the lower average age for skiing fractures shown in Table 3 it is not surprising that the curves for the three sports are different. Skiing fractures tend to occur at a younger age. However comparison between football and rugby also shows a difference with the highest number of adolescent football fractures occurring about 14 years of age compared with 15–17 years for rugby fractures.

Discussion

We are not aware of a previous study of the epidemiology of sports-related fractures in adolescents. The importance of this group is highlighted by the very high incidence of sports-related fractures in adolescent males. We have used the epidemiological data collected in 2000[3,4,12] to estimate the incidence of sports-related fractures at different ages. The results are shown in Table 9. Between 0 and 9 years the incidence of sports-related fractures is low. We accept that it is sometimes difficult to define sporting activities in this age group but our data suggests an overall incidence of 0.49/1000/year with a similar incidence in males and females. If all adults aged 20 years or more are assessed the overall incidence of sports-related rises to 0.98/1000/year with the incidence in males being about 4 times that in females. If however one restricts the assessment of incidence to adults between 20 and 34 years of age the overall incidence rises to 2.25/1000/year, the incidence in males being 5 times that of females. Table 9 shows the very high incidence of sports-related fractures in adolescent males but the overall proportion of male and female fractures is similar to that seen in adults. It is interesting to note that the overall fracture incidence for all causes in males in 2000 in Edinburgh was 11.67/1000/year[3] highlighting the high figure for male adolescent sports fractures.

One of the reasons why the high incidence of sports-related fractures may not be fully appreciated is because the apex of the distribution curve of these fractures is about 13–14 years this being the age that many hospitals transfer the care of paediatric fractures to adult hospitals. This means that the considerable number of sports-related fractures is distributed between paediatric and adult hospitals.

Our results clearly show that the majority of adolescent sports-related fractures are low-energy injuries occurring mainly in males which predominantly affect the upper limb. Table 2 shows that surgeons will see some fractures that one might expect to follow

Table 3
The epidemiology of sports associated with a fracture prevalence of ≥1%. The number and prevalence of each fracture is shown together with the average age, gender ratio and ratio of upper and lower limb fractures. The common fractures associated with each sport are shown.

Sport	No.	%	Age (years)	M/F	U/L	Commonest fracture types
Football	147	36.0	15.1	94/6	75/25	See Table 5
Rugby	64	15.7	15.2	97/3	81/19	See Table 6
Skiing	59	14.5	14.0	81/19	88/12	See Table 7
Snowboarding	22	5.4	15.0	86/14	95/5	Finger phalanges 40.9% Distal radius/ulna 36.4%
Basketball	18	4.4	14.1	61/39	100/0	Finger phalanges 88.9%
Horseriding	11	2.7	13.9	9/91	91/9	Finger phalanges 27.2% Distal radius/ulna 27.2% Clavicle 27.2%
Gymnastics	11	2.7	13.7	45/55	91/9	Distal radius/ulna 45.5% Finger phalanges 27.2%
Hockey	9	2.2	14.0	78/22	100/0	Metacarpal 33.3% Finger phalanges 33.3%
In-line skating	9	2.2	13.9	100/0	100/0	Distal radius/ulna 88.9%
Karate	8	2.0	14.5	62/38	100/0	Finger phalanges 50.0% Metacarpal 37.5%
Running	7	1.7	14.3	86/14	86/14	Distal radius/ulna 42.8%
Ice skating	7	1.7	12.8	50/50	100/0	Finger phalanges 42.7% Metacarpal 28.5%
Skateboarding	5	1.2	14.6	100/0	100/0	Clavicle 40.0% Metacarpal 40.0%
Sledging	4	1.0	11.6	75/25	75/25	Proximal humerus 50.0%
Boxing	4	1.0	16.2	75/25	100/0	Metacarpal 75.0%
Trampolining	4	1.0	13.7	0/100	75/25	Distal radius/ulna 50.0%

Table 4
The sports associated with a fracture prevalence of <1%. The numbers of fractures are shown.

Sport	No.
Mountain biking	3
Mountainboarding	2
Cricket	2
Motorcross	2
American football	1
Badminton	1
Curling	1
Cycling	1
Golf	1
Judo	1
Netball	1
Shinty	1
Swimming	1
Tennis	1

Table 5
The epidemiology of fractures caused by football. The number and prevalence of each fracture is shown together with the average age and gender ratio.

Fracture	No.	%	Age (years)	M/F (%)
Distal radius	45	30.6	14.3	96/4
Finger phalanges	32	22.6	14.9	91/9
Metacarpal	20	13.6	15.0	100/0
Ankle	14	9.5	15.9	93/7
Metatarsal	8	5.5	15.2	88/12
Clavicle	8	5.5	15.5	100/0
Tibial and fibular diaphyses	7	4.8	15.2	100/0
Radius and ulnar diaphyses	3	2.0	17.0	100/0
Distal tibia and fibula	2	1.4	14.1	100/0
Toe phalanges	2	1.4	15.1	100/0
Distal humerus	1	0.7	19.0	100/0
Patella	1	0.7	18.0	100/0
Proximal femur	1	0.7	16.0	100/0
Proximal humerus	1	0.7	14.0	100/0
Proximal radius and ulna	1	0.7	17.5	100/0
Talus	1	0.7	17.0	0/100

higher energy injuries but they are very rare. However it is important to point out that the fractures of the pelvis, femoral diaphysis and proximal tibia all followed skiing injuries.

Table 1 shows that in adolescence sports injuries are, in fact, the commonest cause of certain fractures. This is true of finger phalangeal fractures, clavicle fractures, tibia and fibular fractures and radius and ulnar diaphyseal fractures. The commonest fracture to be seen in adolescents is the distal radial fractures and while 20.1% of these were caused by sport another 49% were caused by a fall from a standing height. The overall distribution of adolescent sports fractures shown in Table 1 is not dissimilar to the distribution seen in paediatric sports fractures[12] although there are some differences from adult fractures.[4] In adults there is also a high prevalence of distal radial, finger phalangeal and forearm diaphyseal fractures in sports-related upper limb fractures but in the study year 24.5% of adult carpal fractures were caused by sport. This is relevant as the four carpal fractures listed in Table 2 occurred in patients with an average age of 17.5 years with two occurring in rugby, one in boxing and one in ice skating. In adult lower limb fractures 25.2% of tibial diaphyseal fractures were caused by sport and adults also had a higher prevalence of sports-related proximal tibial, distal tibial and ankle fractures than are seen in adolescents.

We examined sports fractures of the hand in more detail as together finger phalangeal and metacarpal fractures comprise 41.2% of adolescent sports fractures. Table 8 shows that overall

Table 6
The epidemiology of fractures caused by rugby. The number and prevalence of each fracture is shown together with the average age and gender ratio.

Fracture	No.	%	Age (years)	M/F (%)
Clavicle	20	31.1	14.7	95/5
Finger phalanges	10	15.6	15.0	100/0
Metacarpal	9	14.1	15.9	100/0
Distal radius/ulna	7	10.9	15.7	86/14
Tibia and fibular diaphyses	4	6.2	16.0	100/0
Metatarsal	4	6.2	13.2	100/0
Ankle	3	4.7	15.0	100/0
Carpus	2	3.1	18.0	100/0
Radius and ulnar diaphyses	2	3.1	15.0	100/0
Patella	1	1.6	12.4	100/0

Table 7
The epidemiology of fractures caused by skiing. The number and prevalence of each fracture is shown together with the average age and gender ratio.

Fracture	No.	%	Age (years)	M/F (%)
Finger phalanges	30	50.8	13.0	76/24
Distal radius	9	15.3	12.8	78/22
Metacarpal	6	10.2	14.4	83/17
Clavicle	4	6.8	13.7	100/0
Tibia and fibular diaphyses	4	6.8	13.3	100/0
Radius and ulnar diaphyses	2	3.4	13.0	100/0
Femoral diaphysis	1	1.7	10.0	100/0
Distal tibia and fibula	1	1.7	12.0	100/0
Proximal tibia and fibula	1	1.7	11.0	100/0
Pelvis	1	1.7	16.0	0/100

Table 8
The prevalence of metacarpal and phalangeal fractures in different rays of the hand. The overall prevalances together with those for football, rugby and skiing are shown.

	Metacarpal and finger phalangeal fractures (%)				
	Thumb	Index	Middle	Ring	Little
All sports	24.8	11.2	17.8	13.0	33.1
Football	16.6	10.4	13.3	6.2	54.2
Rugby	31.6	10.5	10.5	31.6	15.8
Skiing	0	29.4	23.5	23.5	23.5

fractures of the first and fifth rays of the hand are most common but this obviously varies in different sports. In football 55.8% of the fractures affected the fifth ray whereas in skiing it was the first ray that was most commonly affected. In rugby the first and fourth rays were most affected. These findings are not dissimilar to those seen in adults[1] and they probably merely reflect the different activities undertaken in different sports. As football is meant to be a non-contact sport the high prevalence of 5th ray injuries probably relates to falls on the pitch. Football also has a high rate of distal radial fractures and it has been previously established that distal radial fractures are not uncommon in adolescent goal-keepers.[9] We assume that the high prevalence of thumb injuries in skiers relates to the use of ski-poles.

Table 3 shows that the sport with the highest prevalence of finger phalangeal fractures is basketball where 88.9% of the fractures involved the fingers. This contrasts with only one (5.5%) metacarpal fracture. A further analysis of these fractures shows that there were no thumb fractures and that 12 of the 16 (75%) finger phalangeal fractures affected the middle phalanges. If one ignores the thumb fractures in football, rugby and skiing the

Table 9
The incidence of sports-related fractures in adolescents compared with children of less than 10 years, adults between 20 and 34 years and all adults over 20 years.

Fracture incidence (X/1000/year)			
Age	All	Males	Females
0–9 years	0.49	0.55	0.43
10–19 years	5.61	9.28	1.86
20–34 years	2.25	3.82	0.75
20+ years	0.98	1.65	0.39

prevalence of middle phalangeal fractures is 29.6%, 0% and 31.2% respectively. We are not sure why this is the case but it may relate to the method of striking the ball in basketball.

As with paediatric and adult fractures in Edinburgh the three main sports associated with fractures are football, rugby and skiing. Football is the world's most popular sport and it has been estimated that there are 10–35 injuries per 1000 game hours.[6] It has also been estimated that fractures account for 10–12% of football injuries with muscle strains, ligament sprains and contusions being more common.[6,10] Kujala et al.[10] drew attention to the fact that fractures of the fingers, palm and wrist were actually the commonest fractures resulting from football, ice hockey, volleyball, basketball, judo and karate. Our figures suggest that this is the case in adolescents as well and also show that fractures of the fingers, palm and wrist are also the commonest fractures caused by hockey, boxing, cricket, gymnastics, horseriding, ice-skating, in-line skating, rugby, skate-boarding, skiing and snowboarding.

In rugby it has been estimated that fractures account for 8–27% of all rugby injuries.[5,8,11] Lower limb soft tissue injuries are relatively common[5,11] but in adults the upper/lower limb fracture ratio was 85/15% and Table 3 shows that the adolescent ratio is very similar. In adults we found that finger phalangeal and metacarpal fractures were commoner than clavicle fractures but Table 6 shows that this is not true of adolescents.

Skiing and snowboarding have been extensively studied in adults with Sasaki et al.[13] showing that the incidence of injuries in snowboarding was three times that of skiing and that the wrist was commonly involved. There are however more skiers than snowboarders and surgeons will tend to see more skiing injuries. Most skiing injuries involve the hand and wrist but Table 7 shows that higher energy injuries may be seen although they are rare in adolescents. Fig. 1c shows that skiing injuries occur at a younger age and it seems likely that these low-energy injuries occur during the learning phase and that higher energy skiing injuries more commonly occur in adulthood when more risks are taken.

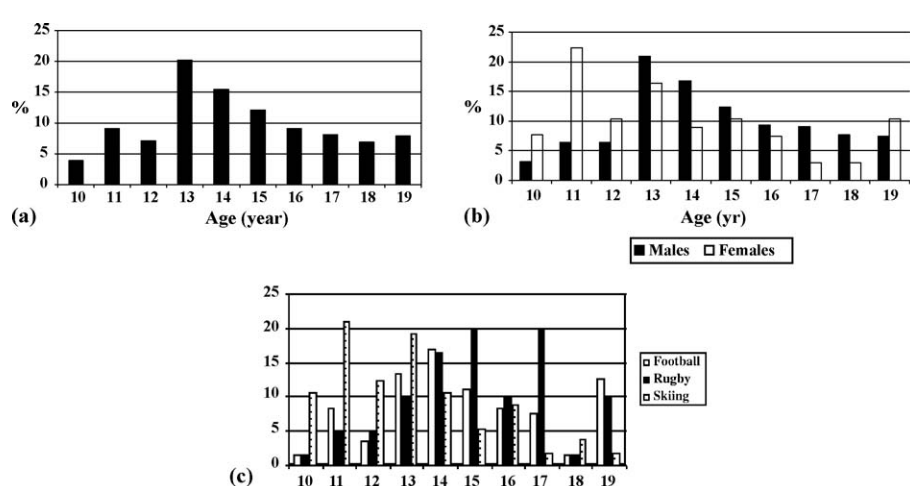

Fig. 1. The distribution curves for all adolescent sports-related fractures (a), male and female adolescents (b) and for the three commonest sports to cause fractures (c).

Our results show that adolescent sports fractures are common, particularly in young males. Of the 408 fractures in this series only 59 (14.5%) were treated operatively but their frequency imposes significant demands on orthopaedic surgeons and it seems likely that these demands will grow in the future.

The authors wished to analyse the fractures further but despite the X-rays being reviewed by both orthopaedic staff and research fellows it proved impossible to agree on fracture classification and this may well be considered to be a limitation of this study.

Conflict of interest

None of the authors has any conflict of interest regarding this paper.

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Appendix VI:

Paper 6:

The Epidemiology of Open Fractures in Sport: One Centre's 15-year Retrospective Study

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ORIGINAL ARTICLE

Retrospective Study

Epidemiology of open fractures in sport: One centre's 15-year retrospective study

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Author contributions: Wood AW, Robertson GAJ and Court-Brown CM performed data collection; Wood AW, Robertson GAJ, Porter A and Court-Brown CM performed data analysis; Wood AW, Robertson GAJ, Porter A and Court-Brown CM wrote and edited the manuscript.
* denotes Joint First Author.

Institutional review board statement: The study was reviewed and approved by the "Scottish Orthopaedic Research Trust into Trauma" Review Board.

Informed consent statement: The study involved review of patient case notes and entering of relevant data onto a data set. The data was anonymised and there was no patient intervention or involvement required in the research process. As such informed patient consent was not required for the study, in accordance with the "Scottish Orthopaedic Research Trust into Trauma" Institutional Review Board.

Conflict-of-interest statement: The authors have no conflict of interests.

Data sharing statement: No additional data are available.

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Abstract

AIM
To describe the epidemiology of sport-related open fractures from one centre's adult patient population over a 15-year period.

METHODS
A retrospective review of a prospectively-collected database was performed: The database contained information all sport-related open fractures, sustained from 1995 to 2009 in the Edinburgh, Mid and East Lothian Populations.

RESULTS
Over the 15-year period, there were 85 fractures recorded in 84 patients. The annual incidence of open sport-related fractures was 0.01 per 1000 population. The mean age at injury was 29.2 years (range 15-67). There were 70 (83%) males and 14 females (17%).

The 6 most common sports were soccer (*n* = 19, 22%), rugby (*n* = 9, 11%), cycling (*n* = 8, 9%), hockey (*n* = 8, 9%); horse riding (*n* = 6, 7%) and skiing (*n* = 6, 7%). The five most common anatomical locations were finger phalanges (*n* = 30, 35%); tibial diaphysis (*n* = 19, 23%); forearm (*n* = 12, 14%); ankle (*n* = 7, 8%) and metacarpals (*n* = 5, 6%). The mean injury severity score was 7.02. According to the Gustilo-Anderson classification system, 45 (53%) fractures were grade 1; 28 (33%) fractures were grade 2; 8 (9%) fractures were grade 3a; and 4 (5%) fractures were grade 3b. Out of the total number of fractures, 7 (8%) required plastic surgical intervention as part of management. The types of flaps used were split skin graft (*n* = 4), fascio- cutaneous flaps (*n* = 2); and adipofascial flap (*n* = 1).

CONCLUSION

We analysed the epidemiology of open fractures secondary to sport in one centre over a 15-year period. Soccer and rugby were the most common causative sports while fractures of the finger phalanx and of the tibial diaphysis were the most common sites. Open fractures are uncommon in sport; however, when they are sustained they usually occur on muddy sport fields or forest tracks and therefore must be treated appropriately. It is important that clinicians and sports therapists have knowledge of these injuries, in order to ensure they are managed optimally.

Key words: Open; Fracture; Sport; Epidemiology; Injury; Trauma

Core tip: We reviewed all open sport-related fractures presenting to our trauma centre over a 15-year period to provide comprehensive epidemiological data on this injury type. Open sport-related fractures occurred at an annual incidence of 0.01/1000 population. The mean age at injury was 29.2 years; the gender ratio was 7.4:1 (male:female). The most common causative sports were soccer and rugby. The most common fracture locations were finger phalanx and tibial diaphysis. Fourteen percent of the fractures were Gustilo- Grade 3; 8% required plastic surgical intervention. Open fractures in sport are a rare, but significant, injury; awareness and education is necessary among clinicians to optimize outcome.

Wood AM, Robertson GAJ, MacLeod K, Porter A, Court-Brown CM. Epidemiology of open fractures in sport: One centre's 15-year retrospective study. *World J Orthop* 2017; 8(7): 545-552 Available from: URL: http://www.wjgnet.com/2218-5836/full/ v8/i7/545.htm DOI: http://dx.doi.org/10.5312/wjo.v8.i7.545

INTRODUCTION

Open fractures are uncommon in the United Kingdom sporting population, however they have a high morbidity, which makes the patient group significant. This institution has previously published work looking at the epidemiology of open fractures and found an incidence of 30.7 per 100000 per year[1].

Sports and exercise is ever increasing in popularity, particularly team sports and multi-sport endurance[2]. This is due to the impact of social and cultural influences, such as easier access to sporting facilities and social media. The epidemiology of acute sporting fractures has been described by Court-Brown *et al*[3] 2008. The authors describe sports-related fractures as having a Type C distribution with unimodal peaks in both young males and females[3]. They also noted a clear preponderance towards upper limb fractures in sports, the majority of which involve the finger phalanges, metacarpus or distal radius[3]. Lastly they recorded an open fracture rate of 1.7% among sport-related fractures, with an annual incidence for open sport-related fractures of 0.02 per 1000 population. Court-Brown *et al*[1] 2012 also described the epide- miology of open fractures, they conclude that 3.6% of all open fractures are a result of sport.

In order to obtain accurate epidemiological data, when the incidence of open fractures is this low, it is necessary to perform a long-term study of these fractures within a large population group[3]. Thus, while there has been an increasing cohort of literature of the epidemiology of sport-related fractures, the literature describing the epidemiology of open fractures in sport remains minimal[1,3].

We aim to provide the first long-term study descri- bing the epidemiology of sport-related open fractures from one centre's adult patient population. This infor- mation will be useful for medical professionals treating patients participating in sport and sport governing bodies.

MATERIALS AND METHODS

All acute fractures presenting to the Royal Infirmary of Edinburgh, Orthopaedic Trauma Unit from the residents of Edinburgh, Mid and East Lothian, over the period of 1995 to 2009, were prospectively recorded on a database. This included all patients from the region, who were injured elsewhere, but were followed up under the Edinburgh Orthopaedic Trauma Unit: This was to provide accurate epidemiological data. Conversely, all non-resident patients who were injured within the region were excluded from the database. The mean population count for the region over the study period was 539858 (Population Count in 2000, *n* = 534715[3]; Population Count in 2007, *n* = 545000[4]).

The database was retrospectively reviewed in 2016, and all open fractures, sustained over the 15-year period (1995 to 2009), were identified. Subsequently, a subgroup, in which the injury was secondary to a sporting activity, was identified. Sporting activity was defined as participation in an athletic game or activity

Table 1 Total number of sport-related open fractures, divided by causative sport and the 5 most common fracture locations

Sport	Number	Percentage of the whole cohort (%)	Finger phalanx	Tibial diaphysis	Forearm	Ankle	Metacarpal
Soccer	19	22	3	9	1	1	0
Rugby	9	11	2	1	0	3	1
Cycling	8	9	3	1	2	0	0
Hockey	8	9	8	0	0	0	0
Horse riding	6	7	1	1	2	1	0
Skiing	6	7	3	1	2	0	0
Mountain bike	4	5	0	0	2	0	0
Quad bike	4	5	0	2	1	1	0
Basketball	3	4	2	0	1	0	0
Shinty	3	4	3	0	0	0	0
Sledging	3	4	0	2	0	1	0
Motorcross	2	2	0	0	0	0	2
Badminton	1	1	1	0	0	0	0
Bowling	1	1	1	0	0	0	0
Cricket	1	1	1	0	0	0	0
Golf	1	1	0	0	0	0	1
Snowboarding	1	1	0	1	0	0	0
Squash	1	1	1	0	0	0	0
Surfboard	1	1	1	0	0	0	0
Trampolining	1	1	0	0	1	0	0
White water rafting	1	1	0	1	0	0	0
Unknown	1	1	0	0	0	0	1
Totals	85	100	30	19	12	7	5

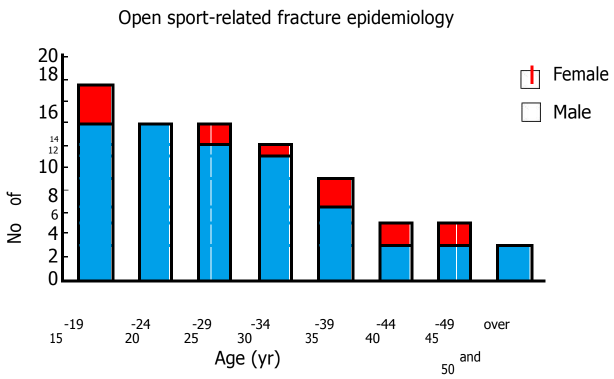

Figure 1 Open sport-related fracture epidemiology.

at time of injury. The Gustilo-Anderson classification[5] was used to describe the extent of soft tissue injury associated with the fracture: For all the fractures, the grading of this classification was based on the intra-operative findings after surgical debridement.

The database contained information on patient age and gender, site of the fracture, mode of injury, sport participated at time of injury, Gustilo grading for each fracture, and required treatment, including both Orthopaedic and Plastic Surgical procedures. Review of each presenting radiograph, as well as confirmation of the designated Gustilo grading[4], was performed by the senior author, a Professor of Orthopaedic Trauma Surgery.

For analysis purposes, niche sporting activities, of a very similar nature, were grouped to allow for more meaningful interpretation of the data: Grouping however was only performed if the sports were considered to be suitably similar. For instance road cycling and track cycling were combined as cycling; however, mountain biking, was considered a separate sport.

RESULTS

Epidemiology

There were 85 fractures sustained by 84 people over the 15-year period. The annual incidence of open sport-related fractures was 0.01 per 1000 population. Of the 84 patients, 70 (83%) were male and 14 (17%) were female (Figure 1). The mean age of the total cohort was 29.2 (range 15-67; SD 11.75; 95%CI: 2.5). The mean age of the female population was 31.93 years and the mean age of the male population was 28.62 years. Forty fractures occurred during competitive sport, nine during training for competitive sport and thirty-six during recreational sport. Two fractures were sustained by professional athletes and eighty-three fractures were sustained by recreational athletes.

Causative sports

The 6 most common sports were soccer (*n* = 19, 22%), rugby (*n* = 9, 11%), cycling (*n* = 8, 9%), hockey (*n* = 8, 9%); horse riding (*n* = 6, 7%) and skiing (*n* = 6, 7%) (Figure 2). Other common sports were mountain biking (*n* = 4, 5%), quad biking (*n* = 4, 5%), basketball (*n* = 3, 4%), shinty (*n* = 3, 4%) and sledging (*n* = 3, 4%). Table 1 shows the total number of fractures, divided by sport, and by fracture location.

Fracture location

The top 5 fracture locations were finger phalanges, 35% (*n* = 30); tibial diaphysis 22% (*n* = 19); forearm 14% (*n* = 12); ankle 8% (*n* = 7) and metacarpals 6%

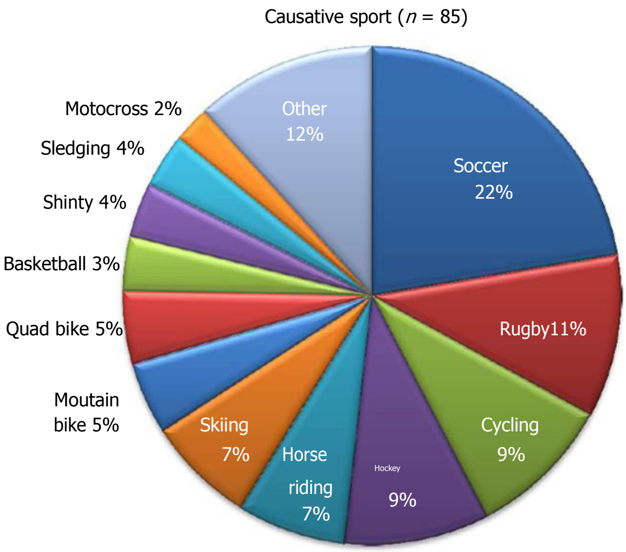

Figure 2 Causative sports for open sport-related fractures.

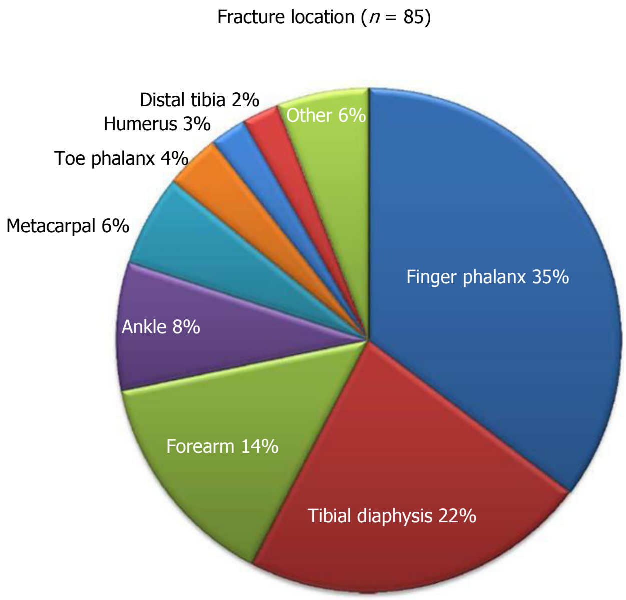

Figure 3 Fracture location for open sport-related fractures.

(*n* = 5) (Figure 3). Of the forearm fractures, four were of the distal radius, four were of the proximal ulna, three were of the combined radial and ulna diaphysis and one was of the ulnar diaphysis. Other fracture sites included toe phalanges (*n* = 3); humerus (*n* = 2); distal tibia (*n* = 2); pelvis (*n* = 1); clavicle (*n* = 1); femur (*n* = 1); patella (*n* = 1) and talus (*n* = 1). The fractures involving finger phalanges, included 5 of the little finger; 6 of the ring finger; 3 of the middle finger; 4 of the index finger; 10 of the thumb and in 2 cases the finger involved was unknown. Of all the fractures, 59% (50/85) were of the upper limb. Table 2 shows the fracture locations for the top 6 sports.

Injury severity

According to the Gustilo-Anderson classification

Table 2 The six most common causative sports and their anatomical distribution

Anatomical ocation	Soccer	Rugby	Cycling	Hockey	Horse riding	Skiing
Ankle	1	3	0	0	1	0
Clavicle	0	0	1	0	0	0
Distal radius	0	0	0	0	2	0
Distal humerus	1	0	0	0	0	0
Femur	0	0	1	0	0	0
Finger phalanx	3	2	3	8	1	3
Metacarpal	0	1	0	0	0	0
Patella	0	1	0	0	0	0
Distal tibia	1	1	0	0	0	0
Proximal ulna	0	0	2	0	0	1
Radius and ulna	1	0	0	0	0	1
Talus	0	0	0	0	1	0
Tibial diaphysis	9	1	1	0	1	1
Toe phalanx	3	0	0	0	0	0
Ulna	0	0	0	0	0	0
Total	19	9	8	8	6	6

system[5], 45 (53%) fractures were Grade 1; 28 (33%) fractures were Grade 2; 8 (9%) fractures were Grade 3a; and 4 (5%) fractures were Grade 3b (Figure 4).

The mean Injury Severity Score was 7.02 (SD 4.33; 95%CI: 0.92). There were 2 deaths during the 15-year period; 1 road-cyclist who had an open proximal ulna fracture; and 1 soccer player, who sustained a grade 3a open tibia fracture.

Primary orthopaedic management

Regarding the primary index procedures: Twenty-two fractures were treated with wound management and cast/splint application; twenty-six fractures with wound management and open reduction internal fixation; eighteen fractures with wound management and intra-medullary nailing; eleven fractures with wound management and kirschner-wire fixation; five fractures with wound management and external fixator application; and three fractures with wound management and tension band wire fixation (Table 3).

Plastic surgical intervention

There were 7 fractures (8%) that required plastic surgical intervention as part of their management. The types of flaps used were split skin graft (*n* = 4), fasciocutaneous flaps (*n* = 2); and adipofascial flap (*n* = 1) (Table 4).

DISCUSSION

The aim of this study was to describe the epidemiology of sport-related open fractures. The main findings were that sport-related open fractures demonstrated a uni-modal incidence of injury, with an annual incidence of 0.01 per 1000 population, a mean age at injury of 29.2 years and a male to female ratio of 7.4:1. Ninety-eight percent of these injuries were sustained by non-professional athletes. Over half of all fractures were

Table 3 Orthopaedic management of the open fractures

Fracture location	Wound management + splint/cast	Wound management + ORIF	Wound management + intra-medullary nail	Wound management + K-wire fixation	Wound management + external fixator	Wound management + tension band wire
Finger phalanx	20	3	-	6	1	-
Tibial diaphysis	-	2	17	-	-	-
Ankle	-	7	-	-	-	-
Metacarpal	-	2	-	3	-	-
Distal radius	-	2	-	-	2	-
Proximal ulna	-	1	-	-	-	3
Radius and ulna	-	3	-	-	-	-
Toe phalanx	1	-	-	2	-	-
Distal humerus	-	2	-	-	-	-
Distal tibia	-	1	-	-	1	-
Ulna diaphysis	-	1	-	-	-	-
Clavicle	1	-	-	-	-	-
Pelvis	-	1	-	-	-	-
Patella	-	1	-	-	-	-
Femur	-	-	1	-	-	-
Talus	-	-	-	-	1	-
Total	22	26	18	11	5	3

ORIF: Open reduction internal fixation; K-wire: Kirschner wire.

Table 4 Sport-related open fractures requiring plastic surgical intervention

Sport	Gustilo grade	Procedure	Injury
Soccer	2	SSG	Tibial diaphysis
Soccer	3a	Adipofascial flap	Tibial diaphysis
Soccer	3a	SSG	Tibial diaphysis
Soccer	3b	Fasciocutaneous flap	Distal tibia
Quad bike	3b	SSG	Ankle
Quad bike	2	Fasciocutaneous flap	Tibial diaphysis
Sledging	3b	SSG	Ankle

SSG: Split skin graft.

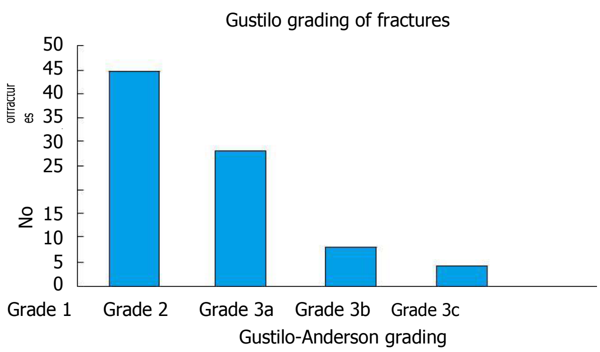

Figure 4 Gustilo-Anderson grading for open sport-related fractures.

located in the upper limb, with finger phalanx fractures the most common fracture location. Soccer was the most common causative sport, accounting for over one fifth of all injuries. Regarding injury severity, 14% were Gustilo-Anderson Grade 3 classification, with only 8% of all fractures requiring plastic surgical intervention.

This is in keeping with existing literature on sport-related fractures[3,6]. Court-Brown *et al*[3,6] previously reported that 12.8% of all fractures are sustained during sporting activities. These injuries were noted to present in a uni-modal distribution, with a mean age at injury of 25.6 years and a gender ratio of 7.5:1[3]. Upper limb sport-related fractures were also noted to be more common than lower limb sport-related fractures, with 77% of all sport-related fractures occurring within the upper limb fractures[3,6]. One point seven percent (1.7%) of these sport-related fractures were open, providing an annual incidence of open sport-related fractures of 0.02 per 1000 population[3,6]. Robertson *et al*[7,8] also noted that between 96% to 98% of all sport-related fractures occur in non-professional athletes.

In comparison of both studies, regarding the increased mean age observed with our cohort, which specifically relates to open fractures, we feel this reflects a greater proportion of elderly athletes who sustain an open fracture during sport[1]. Age has previously been identified as a risk factor for sustaining an open fracture: This is felt to be secondary both to the weakening effects of aging on the skin, as well as to the decreased levels of proprioception seen in the elderly, which predispose to more severe injury[1,9]. Regarding the increased proportion of lower limb fractures in our cohort, we feel this is secondary to an increased proportion of tibial diaphyseal and ankle fractures, among the open fracture cohort. Both fractures have been noted to be at high risk of open injury with tibial diaphysis the second most common recorded open fracture and ankle fracture the fifth most common recorded open fracture[1]. This provides a higher proportion of lower limb fractures among sport-related open fractures[1].

Regarding the severity of injury within our study, the proportion of Gustilo-Anderson grade 3 fractures was slightly lower than that within previous studies[9].

Court-Brown *et al*[1] reported a series of 2386 open fractures, within the general population, and 27% were Grade 3 grading. The difference between proportions is likely explained by the younger mean age of our “athletic” cohort at 29.2 years, with the mean age from Court-Brown *et al*[1] being 45.5 years. Age has been noted to be a risk factor to sustain a more serious grade of open fracture, due to the deleterious effects it has on the surrounding soft tissues and skin[1,9]. This will also account for our marginally decreased requirement for plastic surgical intervention at 8%, compared to 13% from their data[1,10].

In our study, soccer was the most common sport (22%) and within this category, the most common fracture was tibia diaphysis (47%). Soccer accounted for 4 of the 7 cases requiring plastic surgery intervention: 3 out of the 9 soccer-related tibial fractures were Gustilo-Anderson Grade 3. This represents the severity of these injuries. Robertson *et al*[7] have previously reported on soccer-related fractures. Similar to Court-Brown *et al*[1], they found that the majority of soccer-related fractures were of the upper limb (68%). In contrast, we found 74% of our soccer-related fractures were of the lower limb. Within our cohort, this reflects a high proportion of tibial diaphyseal, ankle and toe phalanx fractures, which have previously been documented as being high risk for open fractures[1]. This contrast is likely explained by the higher energy “mechanism of injury” required to sustain an open fracture compared to a closed fracture[1]: Within soccer, such higher energy “mechanisms of injury” most often involve high-speed collisions between players; with soccer being predominantly a lower limb sport, this then increases the likelihood of soccer-related open fractures being sustained in the lower limb[1,3,7].

Rugby accounted for 11% of the open fractures secondary to sport. This is similar to the figures reported by Robertson *et al*[8] in their paper describing the epidemiology of rugby-related fractures, with rugby accounting for 17% of all sport-related fractures. To note in the present study, six of the nine rugby-related fractures were of the lower limb, with fractures of the ankle comprising half of the lower limb injuries. In contrast, both Robertson *et al*[8] and Garraway *et al*[11] reported that the upper limb was most at risk of fracture (83% and 42% of injuries respectively); however, as detailed above, there is an increased proportion of lower limb fractures in open fracture cohorts, due to higher proportions of tibial diaphyseal and ankle fractures[1]. Indeed, Garraway and MacLeod[11] did record that the lower limb was at greatest risk of dislocations and soft tissue injuries.

Cycling (including road cycling and track cycling) accounted for 9% of all fractures seen in the 15-year period. Mountain Biking accounted for only 5% and this may be a reflection of the protective equipment used in this sport, as road cyclists appear at a higher risk of open fracture compared to their mountain biking counterparts. Both sports showed a preponderance for upper limb injuries, with cycling recording 3 finger phalanx fractures and 3 forearm fractures (out of a total of 6 fractures) and mountain biking recording 2 forearm fractures. This pattern of injury reflects the findings of Aitken *et al*[12], who reported that upper limbs fractures occurred 10 times more commonly than lower limb fractures during mountain biking. To note, mountain biking is increasing in popularity, and with our trauma centre being located close to Scotland’s largest mountain biking centre (Glentress), one may expect to detect a significant incidence of injuries from this sport. However, Aitken *et al*[12], in their comprehensive study on recreational mountain biking injuries 2011, noted a trend away from serious injury in this sport, as a result of the use of personal protective equipment. This likely accounts for the low incidence observed in our study period.

Similarly, hockey accounted for 9% of all open sport-related fractures. This sport also demonstrated a preponderance for upper limb injuries, with all such fractures occurring within the finger phalanx. Court-Brown *et al*[13] have already shown that fractures of the finger phalanx is common in hockey, comprising half of all such fractures in the sport[3] Furthermore, Aitken *et al*[13] found that while field hockey only accounted for 7% of all sport-related finger phalanx fractures, it was the cause of 50% of all of the open sport-related finger phalanx fractures. Comparatively, this study found that hockey accounted for 40% of all open fractures of the finger. Aitken *et al*[13] went on to reason that such injuries are likely due to accidental contact between the hand and either a hockey stick or a hockey ball travelling at speed, and this may be further explained by the pattern of grip around the stick. Players often hold the stick low to the ground during tackles thus increasing the chance of contact with the ball or entrap- ment with another player’s stick[13-15]. This continues to be an area where increased protection may benefit participants and decrease the incidence of these injuries[13-15].

Horse riding accounted for 7% of the open fractures sustained. The mechanism by which injuries are sustained during horse riding are usually high energy - a fall from height at high speed - therefore, there is a clear potential for an open fracture to be sustained as a result of this mechanism[16,17]. It is important to note that these fractures are often farmyard injuries and have a high risk of contamination[16,17]. Therefore these fractures should be managed appropriately in line with BOAST guidelines[18]. Previous studies on horse riding injuries, have shown that sprains are the most prevalent injury type (42%), followed by lacerations and bruises (40%), and then fractures and dislocations (33%)[16]. There was a near equal proportion of upper and lower limb fractures in the current series (3 upper limb and 2 lower limb open fractures), and while our paper was specifically looking at open fractures, this finding is reflected in other studies. A retrospective study from the United States looking at horse riding injuries, showed that the lower extremity was injured

22.2% of the time and the upper extremity 21.5%, with the remaining injuries being to the head, chest and abdomen[17].

Skiing accounted for 7% of all sporting-related open fractures. The majority of these were upper limb fractures (5 of 6), with 1 recorded ankle fracture. The low prevalence of open fractures secondary to skiing may reflect our institution's urban geographical location. However, it should be noted that there is an artificial ski slope on the outskirts of the city.

Within skiing, 50% of fractures were in the hand: This may be linked to the composition of the dry-ski slope material, with a high propensity to entrap fingers.

Anatomically, the most common location of fracture was the finger phalanx comprising 35% of all fractures. This again is in keeping with the findings from Court-Brown *et al*[3], who found the most common location for sport-related fractures was the finger phalanx, followed by distal radius, metacarpals, clavicle and ankle[3]. Similar findings have been reported by Aitken *et al*[4] in another comprehensive series of sport-related fractures. In contrast, the current study found the next most common fracture locations for sport-related open fractures to be tibial diaphysis, forearm, ankle and metacarpal. This is in keeping with the incidence of open fractures within the general population, with the five most common fracture locations being finger phalanx, tibial diaphyseal, distal radius, toe phalanx and ankle[1]. It would appear there is a difference between the common presenting locations for sport-related open fractures and sport-related closed fractures[1,3,4,6]. The exact reasons behind this are difficult to fully define, though it appears that certain fracture locations (tibial diaphysis and ankle) are at an increased risk of open fractures: This is likely due to a combination of the common fracture patterns observed at these sites as well as the volume of surrounding soft tissue cover in these regions[1]. As such, these fracture locations are more likely to be present within observational open fracture cohorts[1]. Nevertheless, the number of fractures described in this series are low, and, while this reflects a low incidence of this injury type, we would recommend further large-scale studies on this topic, to better define the epidemiology of open fractures in sport[1,3,4,6]. Similarly, as with previous papers from our institution, our study reflects the experience of our region: It is likely that the incidence of such fractures will vary in other centres, according to the types of sports that predominate in the studied area[1,3,4,6].

Regarding further limitations of our study, patient outcomes were not obtained, and this certainly could be an area for future work. Obtained information on the time taken to return to sport or work after injury would be of significant relevance for sporting regulators: A high incidence of injuries requiring long periods of rehabilitation may lead to a review of rules and personal protective equipment: This can serve to reduce the economic impact of such injuries in professional and recreational sport[1,3,4,6,15].

In conclusion, the epidemiology of sport-related open fractures from one orthopaedic trauma centre over a 15-year period was reviewed. Soccer and rugby were the most common causative sports, while the finger phalanx and tibial diaphysis were the most common fracture locations. Only 14% of fractures were Gustilo Grade 3 and only 8% required plastic surgical intervention. While open fractures in sport are uncommon, they frequently occur on muddy sport fields or forest tracks and must be treated appro- priately. A robust set of guidelines is in place from the British Orthopaedic Association and British Association of Plastic Reconstructive and Aesthetic Surgeons to enable this to be achieved, and these should followed accordingly. Furthermore, a good understanding of the range and variety of sport-related open fractures is beneficial for clinicians and sports therapists, as this allows planning for treatment protocols, rehabilitation and injury prevention.

COMMENTSCOMMENTS

Background

Open fractures are uncommon in the United Kingdom sporting population, accounting for less than 2% of all sport-related fractures. However they have a high morbidity, which makes the patient group significant. Currently there is limited evidence in the literature describing the epidemiology of open fractures in sport.

Research frontiers

Despite comprising less than 2% of all sport -related fractures, open fractures in sport represent a very significant injury for the athlete, often resulting from a high energy mechanism and being sustained in an environment with high risk of wound contamination. However, due to the limited incidence of this fracture type, minimal research has been previously performed regarding its epidemiology. Given the potential significant morbidity associated with such injuries, an accurate understanding of the range and variety of sport-related open fractures will allow clinicians and sports therapists to better plan treatment protocols, rehabilitation and injury prevention methods for these fractures.

Innovations and breakthroughs

In the study, the authors analysed the epidemiology of open fractures in sport within our population over a 15 -year period. Open sport -related fractures occurred at an annual incidence of 0.01/1000 population. The mean age at injury was 29.2 years; the gender ratio was 7.4:1 (male:female). Soccer and rugby were the most common causative sports while fractures of the finger phalanx and of the tibial diaphysis were the most common sites. 14% of the fractures were Gustilo-grade 3; 8% required plastic surgical intervention. This is the first study to provide a comprehensive description of the epidemiology of this injury type.

Applications

A comprehensive understanding of the predicted patterns of injury and most common causative sports, with this fracture type, can allow sports teams and medical personnel to appropriately plan for such injuries, producing treatment protocols and instigating injury prevention measures. This allows both optimization of the management and outcome of these injuries, as well as potential reduction in their future incidence.

Terminology

An open fracture is a fracture with an associated skin wound which allows the external environment to communicate with the fracture. The Gustilo-Anderson Classification is a classification system which grades the severity of open fractures into three grades, based on the wound size, the underlying damage to the peri-osteal and neuro-vascular structures, and the ability to achieve direct wound closure. Please refer to the provided reference for the formal classification. A Split Skin Graft is a skin graft which comprises the epidermis and a portion of the dermis: the full thickness of the dermis is not excised in this graft type. An Adipofascial Flap is a portion of adipose and fascial tissue that is based on a perforating artery. This is dissected and elevated from its native location, maintaining the perforator blood supply, and transferred locally to the damage area requiring soft tissue coverage. A Fasciocutaneous Flap is a portion of skin, subcutanoues tissue and fascial tissue that is based on a perforating artery. This is dissected and elevated from its native location, maintaining the perforator blood supply, and transferred locally to the damage area requiring soft tissue coverage.

Peer-review

It is very interesting finding.

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Appendix VII:

Paper 7:

The Management of Sport-Related Fractures: Operative versus Non-Operative Management

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Management of Sport-Related Fractures: Operative Versus Non-Operative Management

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Abstract

Background: Fractures are the most serious injury suffered by athletes, resulting in the greatest time recuperating from Such injuries.
Objectives: To describe the difference in outcome for non-operative versus operative management of site-specific soccer-related fractures.
Methods: All fractures sustained during soccer from 2007 to 2008 within the Lothian population were prospectively recorded. Patients were followed up in August 2010, via telephone, to determine return rates and times to soccer. High incidence fractures with significant rates of surgery (Tibial Diaphysis, Ankle, Scaphoid, Clavicle, Metacarpus Distal Radius) were identified and classified according to the AO system. Outcomes of similar fracture classifications with contrasting management were compared.
Results: Of 367 fractures identified during the study period, 20% were managed operatively. The rates of surgery for the six fractures cohorts were Tibial Diaphyseal 67%, Ankle 51%, Scaphoid 25%, Clavicle 20%, Metacarpal 11% and Distal Radial 10%. Operatively managed fractures of the Distal Radius (14 weeks vs. 9 weeks: $P < 0.031$), Ankle (42 weeks vs. 22 weeks: $P < 0.004$) and Metacarpus (18 weeks vs. 5 weeks: $P < 0.001$) took longer to return to soccer than non-operatively managed fractures, while operatively managed fractures of the Tibial Diaphysis took shorter to return (35 weeks vs. 45 weeks: $P = 0.673$). Operatively managed fractures of the Ankle (57% vs. 22%: $P < 0.029$), Tibial Diaphysis (89% vs. 50%: $P = 0.683$), Scaphoid (80% vs. 60%: $P = 0.613$), Clavicle (50% vs. 31%: $P = 0.584$), Distal Radius (50% vs. 18%: $P = 0.234$) and Metacarpus (67% vs. 40%: $P = 0.537$) had higher rates of persisting symptoms at follow-up than non-operatively managed fractures.
Conclusions: The role of operative management in the treatment of soccer-related fractures is specific to the location and nature of the fracture. The effect of operative management on return times to sport is fracture specific, though invariably this is associated with higher rates of persisting symptoms. The decision regarding the choice of non-operative versus operative management requires clinical judgment on an individual basis, based on the fracture location and configuration.

Keywords: Fracture, Sport, Soccer, Return, Time, Operative, Non-Operative

1. Background

Fractures remain one of the most serious injuries suffered by athletes, resulting in considerable time away from sport, with significant rates of persisting symptoms post-treatment (1-5). Despite their significant morbidty, there remains considerable variation in their management, due to various factors such as clinician preference and experience, difference in availability of resources and variation in patient desires and expectations (6, 7). Given the significant adverse economic and social implications these injuries can have, both from professional and amateur sport, appropriate knowledge of the optimal management strategies for sport-related fractures is a key factor in modern day sports medicine (1-5).

The management of sport-related fractures is guided the standard treatment principles of orthopaedic trauma, based on fracture location, configuration and displacement (8). There is however a growing body of literature that promotes a tailored choice of fracture management based on the activity level of the patient (9-13). Athletic patients with undisplaced 'unstable' fractures may benefit from primary surgical management to avoid the deconditioning associated with cast management and to promote earlier return to sporting activities (9-13). Such examples include surgical management of undisplaced scaphoid waist fractures, undisplaced tibial shaft fractures and undisplaced 5th metatarsal base fractures (9-13). These principles, however, are site-specific, with other undisplaced 'stable' fractures, such as those of the ankle, being better managed with orthotic immobilisation and early rehabilitation, (5, 9). The literature guiding such principles remains limited, and further evidence is required in this field to optimise practice (9). As young athletic patients often have good quality bone with significant potential for fracture healing, when managed either operatively or non-operatively (14, 15), clear guidelines should be available to direct optimal management on individual fracture types to allow rapid return to sport as possible with the lowest side effect profile.

2. Objectives

This study analyses a cohort of fractures sustained by soccer players, at all levels, within a standard UK population, over the period of a year. Fractures are divided by body part and then by AO fracture classification as well as by mode of management (operative vs. non-operative). Comparisons are made between return times and rates to soccer and persisting symptoms at follow-up for similar fracture types managed operatively and non-operatively.

3. Methods

3.1. Study Design

All acute fractures sustained within the Edinburgh, Mid and East Lothian populations from July 2007 to July 2008 in patients aged 15 years was prospectively recorded in a database. The population count for Edinburgh, Mid and East Lothian was 517,555. Information contained within the database included age, gender, mode of injury, and site and nature of the fracture. Fracture classification was performed using the AO (Arbeitsgemeinschaft fuer Osteosynthesefragen) classification, by individual review of each presenting radiograph by an orthopaedic surgeon. The Gustilo classification was used to classify open fractures (16). For fractures sustained during sport, the type of sport performed was recorded in the database. The database did not record stress fractures. Non-resident individuals were excluded from the database.

All patients who sustained a fracture during soccer were identified from the database and telephoned in August 2010 to complete a standardised questionnaire. This provided mean follow-up of 30 months post-fracture (range 24 to 36 months).

All the case notes of the patient cohort were retrospectively reviewed in August 2010 to determine fracture treatment modalities and subsequent complications, particularly noting the development of non-union or mal-union.

The six fracture locations with the highest rates of surgery (tibial diaphysis, ankle, scaphoid, clavicle, distal radius and metacarpal) were categorised by the AO Classification to differentiate the site and type of these fractures. Operative management was defined as fractures requiring surgical fixation while non-operative management was defined as not requiring surgical fixation. Manipulation under anaesthetic (MUA) and casting was considered non-operative management. Comparisons were made between similar fracture types that were managed operatively or non-operatively with a focus on time and rate of return to soccer, persisting symptoms post-injury, non-union and mal-union.

3.2. Statistical Analysis

Analysis of the cohort data was performed using SPSS 22.0 (SPSS, Chicago, Illinois, USA). For continuous data, uni-variate comparisons were performed with the Student t-test and multivariate comparisons with the ANOVA. For categorical data, uni-variate comparisons were performed with the Chi Squared Test (using Fisher's exact test if necessary). The significance level was $P < 0.05$.

4. Results

Over the study period, 367 soccer-related fractures were recorded in 357 patients.

Twenty percent of the fractures required surgical management (n = 72). Surgical intervention included Open Reduction Internal Fixation (65%), Intra-Medullary Nailing (17%), External Fixation (8%) and K-Wire Fixation (6%). The common fracture locations with the highest rates of surgery were tibial diaphysis (67%), ankle (51%), scaphoid (25%), clavicle (20%), metacarpal (11%) and distal radius (10%).

Of the 250 upper limb fractures, 11% were managed surgically (Table 1). Of the 117 lower limb fractures, 38% were managed surgically (Table 2). The percentage of surgery for each fracture type is shown in Tables 1 and 2.

Fractures with high rates of MUA and casting included distal radius (16%) and finger phalanx (13%).

All surgically managed tibial diaphyseal fractures were treated with IM Nail (n = 12). All surgically managed ankle fractures were treated with ORIF (n = 25); 10 of those required syndesmosis screw fixation. Of the four surgically managed clavicle fractures, one (mid-shaft) was treated with plate fixation and three (all lateral) were treated with open endobutton fixation. Of the three surgically managed metacarpal fractures, one was treated with plate fixation and two with MUA and K-Wiring. From the distal radial cohort, three fractures were managed with volar plate fixation and four with Non-Bridging External Fixation. From the scaphoid cohort, two acute fractures were managed with Percutaneous Screw fixation and four delayed unions underwent ORIF (3 requiring bone graft).

Of the patients managed operatively (n = 72), six (8%) suffered complications from surgery. These included three

Table 1. Upper Limb Fracture Outcome Data[a]

Type	No.	Follow-Up	Surgically Managed	Return Surgical	Return Non Surgical	Time to Return Surgical, wks	Time to Return Non Surgical, wks
Total	250	209 (84)	23 (11.0)	18 (78.3)	160 (86)	19.7[b]	8.0[b]
Finger Phalanx	76	62 (82)	2 (3.2)	2 (100)	57 (95)	13.0[b]	6.4[b]
Distal Radius	73	62 (85)	6 (9.7)	4 (66.7)	45 (80)	14.0[b]	8.5[b]
Metacarpal	27	23 (85)	3 (13.0)	3 (100)	17 (85)	18.3[b]	4.6[b]
Scaphoid	24	20 (83)	5 (25)	4 (80)	14 (93.3)	Acute: 8.5, Delayed: 40	12.7
Clavicle	20	17 (85)	4 (23.5)	3 (75)	10 (76.9)	22.3	16.8
Proximal Radius	17	14 (82)	1 (7.1)	1 (100)	11 (84.6)	7.0	7.9
Proximal Humerus	2	2 (100)	0 (0)	-	1 (50)	-	6.0
Radial Diaphysis	2	2 (100)	0 (0)	-	1 (50)	-	8.0
Ulna Diaphysis	2	2 (100)	0 (0)	-	1 (50)	-	28.0
Radius and Ulna	2	1 (50)	1 (100)	1 (50)	-	16.0	-
Distal Humerus	1	1 (100)	1 (100)	1 (100)	-	6.0	-
Humeral Diaphysis	1	1 (100)	0 (0)	-	1 (100)	-	24.0
Proximal Ulna	1	0 (0)	-	-	-	-	-
Capitate	1	1 (100)	-	-	1 (100)	6.0	-
Triquetrum	1	1 (100)	-	-	1 (100)	6.0	-

[a]Values are expressed as No. (%).
[b]$P < 0.05$

Table 2. Lower Limb Fracture Outcome Data[a]

Type	No.	Follow-Up	Surgically Managed	Return Rate Surgical	Return Rate Non Surgical	Time to Return Surgical, wks	Time to Return Non Surgical, wks
Total	117	103 (88)	36 (35.0)	30 (83.3)	59 (88.1)	42.3[b]	18.4[b]
Ankle	49	44 (90)	21 (47.7)	19 (90.5)	23 (100.0)	42.0[b]	22.2[b]
Metatarsal	23	21 (91)	0(0)	-	20 (95)	-	11.5
Tibial Diaphysis	18	15 (83)	9 (60.0)	8 (88.9)	4 (66.7)	35.0	44.5
Toe	8	6 (75)	0(0)	-	3 (50)	-	7.0
Distal Tibia	4	4 (100)	3 (75.0)	2 (66.7)	1 (100.0)	80.0	36.0
Fibula	4	4 (100)	0 (0)	-	3 (75)	-	11.0
Talus	3	3 (100)	0 (0)	-	2 (67)	-	29.0
Midfoot	2	2 (100)	0 (0)	-	1 (50)	-	32.0
Proximal Tibia	2	2 (100)	2 (100)	1 (50)	-	32.0	-
Patella	2	1 (50)	1 (100)	0 (0)	-	-	-
Sesamoid	2	2 (100)	0(0)	-	2 (100)		6.0

[a]Values are expressed as No. (%).
[b]$P < 0.05$

post-operative compartment syndromes (all tibial diaphyseal fractures), two post-operative wound infections following (one ankle fracture, one scaphoid fracture), and one bilateral pulmonary emboli (tibial diaphyseal fracture).

Ten patients (14%) required secondary surgery, which included post-operative fasciotomies for tibial diaphyseal fractures (n = 3), exchange nail for tibial non-union (n = 1), removal of metalwork from prominent locking screws in a tibial nail (n = 1), removal of symptomatic clavicle plate (n

= 1), removal of symptomatic patella cerclage wire (n = 1), removal of infected scaphoid screw (n = 1), revision ankle fixation for initial malreduction (n = 1), removal of symptomatic ankle syndesmosis screw (n = 1).

Full follow-up data was obtained for 312 (85%) of the fractures. Of these, 267 (86%) returned to soccer. Patients returned to pre-injury level of soccer at mean duration of 15 weeks (range 0 - 104 weeks; SD 16.6 weeks). Table 3 shows the return times to soccer for the six major fracture locations, comparing outcome by displacement of fracture, comminution of fracture and age of patient.

Regarding the location of ankle fractures, Weber A fractures (n = 9) took a mean of 22.8 weeks to return to full level soccer (operatively managed (n = 2), mean time to return 38 weeks: non-operatively managed (n = 7), mean time to return 18 weeks), Weber B fractures (n = 23) a mean of 32.9 weeks to return to full level soccer (operatively managed (n = 10), mean time to return 46 weeks: non-operatively managed (n = 13), mean time to return 24 weeks) and Weber C fractures (n = 10) a mean of 34.9 weeks to return to full level soccer (operatively managed (n = 7), mean time to return 38 weeks: non-operatively managed (n = 3), mean time to return 23 weeks). Comparison between time to return for Weber A, B and C fractures was not significant (P = 0.412).

Regarding the location of clavicle fractures: mid shaft fractures (n = 7) took a mean of 18.9 weeks to return to full level soccer (undisplaced non-operatively managed (n = 4), mean time to return 12.5 weeks: displaced non-operatively managed (n = 2), mean time to return 29.0 weeks; displaced operatively managed (ORIF) (n = 1), mean time to return 24 weeks); lateral fractures (n = 6) took a mean of 17.2 weeks to return to full level soccer (displaced operatively managed (open endobutton fixation) (n = 2), mean time to return 21.5 weeks: undisplaced non-operatively managed (n = 4), mean time to return 15 weeks).

For scaphoid fractures, those treated with acute percutaneous fixation had a return time of 8.5 weeks (n = 2); those treated with casting had a return time of 12.7 weeks (n = 14); those treated with casting, who later developed non-union and required ORIF had a return time of 40 weeks (n = 2).

For distal radial fractures, those treated with cast alone had a return time of 8.3 weeks (n = 42); those requiring MUA and Cast had a return time of 11.7 weeks (n = 3). Those managed surgically had a return time of 14 weeks (n = 4); those who underwent immediate surgery had a return time of 12 weeks (n = 3); those who underwent delayed surgery following displacement with initial cast management had a return time of 16 weeks (n = 1). Those treated with ORIF had a return time of 10.7 weeks (n = 3); those with Non-Bridging External Fixation had a return time of 24 weeks (n = 1).

For metacarpal fractures, those treated with MUA and K-Wiring had a return time of 21.5 weeks (n = 2); those treated with ORIF had a return time of 12 weeks (n = 1).

Figure 1A to 1F shows the Ankle, Tibial Diaphyseal, Clavicle, Distal Radial, Metacarpal and Scaphoid Fracture cohorts respectively divided by AO Classification, with each subgroup divided into those managed operatively and non-operatively.

From the six cohorts, Salter Harris Fracture Patterns were observed within two of these (Distal Radial and Ankle). There were seven cases within the Distal Radial cohort (1 Salter Harris I, 5 Salter Harris II, 1 Salter Harris III) and three cases within the Ankle cohort (1 Salter Harris I, 1 Salter Harris II, 1 Salter Harris IV).

Table 4 shows the rate of persisting symptoms for the six major fracture types by displacement of fracture, comminution of fracture and age of patient. Higher rates of persisting symptoms were seen in the operative cohorts of all the fractures types.

Overall, 45 (14%) of the fracture patients had not returned to soccer two years post-injury. The return rates for each of the fracture types, by surgical and non-surgical treatment, is shown in Tables 1 and 2.

For the whole cohort, the rate of non-union was 1.3% (4/312) and the rate of mal union was 3.8% (12/312). The rates of non-union, mal-union and delayed union for the six fracture cohorts are listed in Table 5.

5. Discussion

We believe this is the first paper to provide a comprehensive description of the variation in management of soccer-related fractures and the effect this has on return to sport and persisting symptoms. Despite the massive global interest in the sport, and the substantial monetary value associated with it (17, 18), there remains very little published evidence on management of soccer-related fractures and subsequent function (18-23). Given the importance of such outcomes, this data would prove very useful in guiding management of injured soccer players.

The currently available literature analyses combined cohorts of sport and soccer fractures, failing to take account of the influence of fracture site and severity on outcome (3, 24). The evidence suggests that operatively managed fractures take longer to return to full level sport and have higher rates of persisting symptoms but this is likely influenced more severe fractures and lower limb fractures having higher rates of surgery (3). Such injuries often have prolonged rehabilitation and higher likelihood of persisting problems given the greater nature of structural damage involved (3, 8). An in-depth assessment of site-specific

Table 3. Time to Return by Severity of Fracture and Patient Age (wks)

Type	Time to Return Displaced	Time to Return Non-Displaced	Time to Return Comminuted	Time to Return Non-Comminuted	Time to Return Over 30	Time to Return Under 30
Upper Limb						
Clavicle	25.0[a]	13.8[a]	24.0	17.6	30.3[a]	12.7[a]
Distal Radius	13.0[a]	8.3[a]	12.7[a]	8.4[a]	11.4[a]	8.1[a]
Metacarpal	18.3[a]	4.6[a]	5.3	6.9	7.0	6.7
Scaphoid	-	15.3	-	15.3	22.4	12.5
Lower Limb						
Ankle	42.0[a]	22.2[a]	38.4[a]	21.5[a]	44.7[a]	27.5[a]
Tibial Diaphysis	35.0	44.5	40.0	38.0	40.0	38.0

[a] $P < 0.05$.

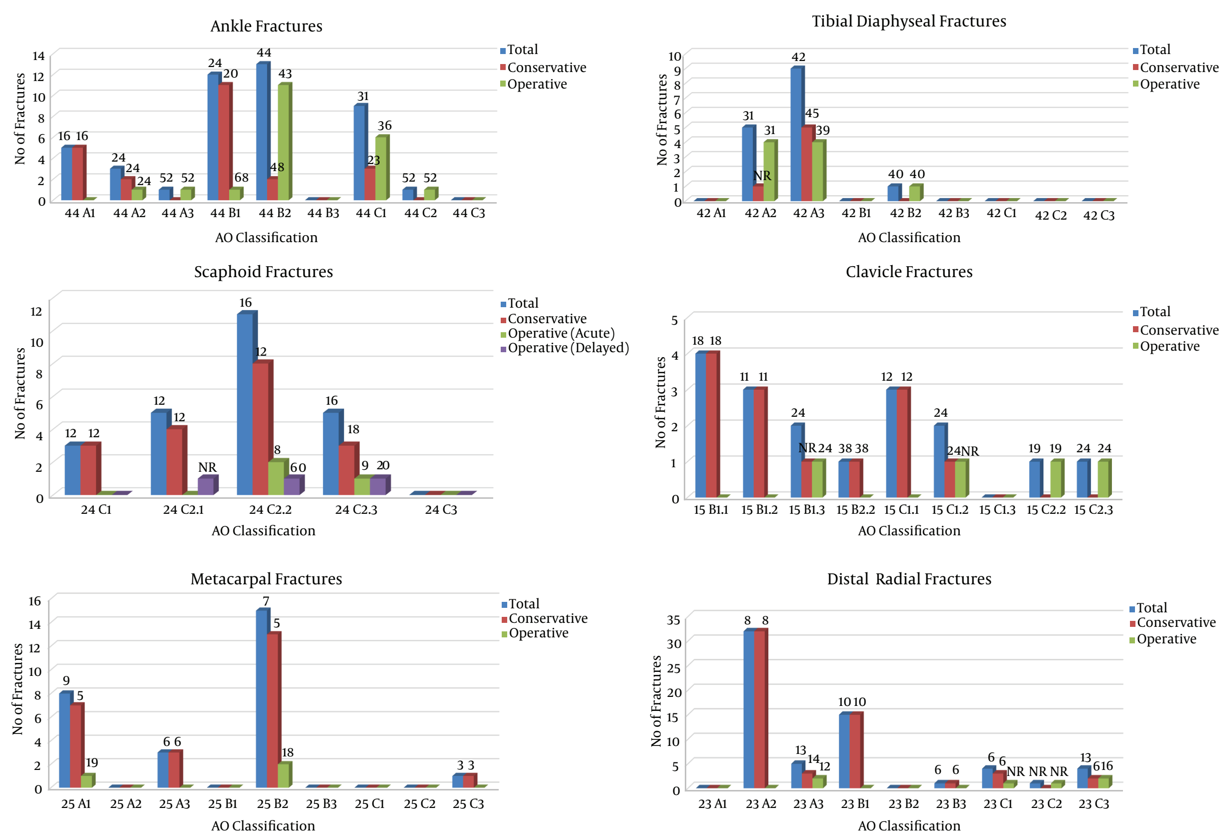

Figure 1. A, The Ankle Fracture Cohort divided by AO Classification and Management. (The duration to return to full level soccer (weeks) is noted at the top of each bar.); B, The Tibial Diaphyseal Fracture Cohort divided by AO Classification and Management. (The duration to return to full level soccer (weeks) is noted at the top of each bar.); C, The Scaphoid Fracture Cohort divided by AO Classification and Management. (The duration to return to full level soccer (weeks) is noted at the top of each bar.); D, The Clavicle Fracture Cohort divided by AO Classification and Management. (The duration to return to full level soccer (weeks) is noted at the top of each bar.); E, The Metacarpal Fracture Cohort divided by AO Classification and Management. (The duration to return to full level soccer (weeks) is noted at the top of each bar.); F, The Distal Radial Fracture Cohort divided by AO Classification and Management. (The duration to return to full level soccer (weeks) is noted at the top of each bar.).

fractures cohorts is required to fully determine the effects of varying management strategies on sporting outcome.

Assessing the site-specific cohorts from this study, for ankle fractures, those managed operatively took twice as

Table 4. Persisting Symptoms by Managed and Severity of Fracture[a]

Type	Persisting Symptoms	Persisting Symptoms Surgical: Non Surgical	Persisting Symptoms Displaced: Non-Displaced	Persisting Symptoms Comminuted: Non Comminuted	Persisting Symptoms Over 30: Under 30
Upper Limb					
Clavicle	6 (35)	2 (50): 4 (31)	3 (43): 3 (30)	0 (0): 6 (38)	1 (20): 5 (42)
Distal Radius	13 (21)	3 (50):10 (18)	5 (50): 8 (15)[b]	4 (40): 9 (17)	6 (29): 7 (17)
Metacarpal	10 (43)	2 (67): 8 (40)	2 (67): 8 (40)	1 (33): 9 (45)	2 (50): 8 (42)
Scaphoid	13 (65)	4 (80): 9 (60)	13 (65): 0 (0)	13 (65): 0 (0)	8 (57): 5 (83)
Lower Limb					
Ankle	17 (39)	12 (57): 5 (22)[b]	12 (57): 5 (22)[b]	15 (58): 2 (11)[b]	9 (82): 8 (24)
Tibial Diaphysis	11 (73)	8 (89): 3 (50)	8 (89): 3 (50)	1 (100): 10 (71)	2 (100): 9 (69)

[a]Values are expressed as No. (%).
[b]$P < 0.05$.

Table 5. Delayed, Non- and Mal- Union Rates[a]

Type	Delayed Union		Non Union		Mal-Union	
Upper Limb						
Clavicle	1/20 (5)	1 MS N/O	0/20 (0)		4/20 (20)	2 MS N/O, 2 Lat N/O
Metacarpal	0/27 (0)		1/27 (4)	1 O - MUA and KW	4/27 (15)	2 N/O, 2 O - MUA and KW
Distal Radius	0/73 (0)		0/73 (0)		1/73 (1)	1 N/O Cast
Scaphoid	4/24 (17)	4 N/O: All had ORIF	2/24 (13)	2 N/O: No further Sx	0/24 (0)	
Lower Limb						
Ankle	0/49 (0)		0/49 (0)		0/49 (0)	
Tibial Diaphysis	0/18 (0)		0/18 (0)		0/18 (0)	

Abbreviations: Cast, Cast Management; Lat, Lateral; MS, Mid Shaft; MUA and KW, Manipulation under Anaesthetic and K-Wire; N/O, Non-Operative; O, Operative; ORIF, Open Reduction Internal Fixation; Sx, Surgery.
[a]Values are expressed as No. (%).

long to return to soccer as those managed non-operatively. Similarly those managed operatively had nearly three times the rate of persisting symptoms. Reviewing the treatment strategies within the sub-groups of AO Classifications, we found variations in management for 44A.2, 44B.1, 44B.2 and 44C.1 fractures, with fracture displacement directing the need for surgical intervention. Operative management significantly increased the duration of return to soccer for 44B.1 and 44C.1 fractures but not for 44A.2 and 44B.2 fractures. It would appear that similar ankle fracture patterns are currently managed both operatively and non-operatively, with operative management resulting in significantly prolonged duration to return to soccer. This is keeping with the study by Robertson et al. (5), who also found that for similar ankle fracture types, surgical management resulted in higher return times to sport over conservative management. The decision for surgical management in that study was directed by the presence of fracture displacement (5). Thus, it was recommended that all undisplaced fractures could be attempted for conservative management, given the benefits noted (5). Similarly, we would recommend non-operative management for all undisplaced ankle fractures, with operative management reserved for displaced fractures.

For tibial diaphyseal fractures, those managed operatively returned earlier to soccer; however they were noted to have a higher rate of persisting symptoms. This is in keeping with the results from a recent systemtic review by Robertson and Wood (10), who similarly found that operatively managed tibial diaphyseal fractures returned to sport sooner. This was felt due to the fact that the operative cohort could mobilise earlier, allowing for preservation of muscle mass, avoidance of joint stiffness and early return to rehabilitation (10). Assessing the time to return to soccer by AO Classification, simple oblique fractures took less time to return than simple transverse or bending wedge fractures. Variation in management of simple oblique and simple transverse fractures was present, with fracture displacement indicating the need for operative management. It would appear that operative management of tibial diaphyseal fractures reduces time to return to soccer, though increases the rate of persisting post-operative symptoms. While fracture displacement guides the choice for surgical management, it would appear that undisplaced fractures may benefit from operative management, as noted by Robertson and Wood (10). This, however, is at the risk of surgical complications and so, any such treatment decisions need to be discussed extensively with the patient (10). We would advocate consideration of operative management in young fit individuals who aim to return to sport as soon as possible though appreciate that such decisions should be directed by clinical context, fracture configuration, clinician experience and patient preference.

For scaphoid fractures, those of the waist or proximal region managed operatively with acute percutaneous screw fixation demonstrated the quickest return to sport at a mean return time of 8.5 weeks compared to 12.7 weeks with cast management Those with delayed union and subsequent surgical fixation demonstrated significantly prolonged return times with a mean of 40 weeks. Comparing the AO sub-classifications, there existed variation in the management of waist (24 C2.2) and proximal (24 C2.2) fractures, owing to the possibility of acute percuateous screw fixation for such fractures. Our results are in keeping with those from McQueen et al. (13) who found that acute percutaneous screw fixation of undisplaced scaphoid waist and proximal fractures resulted in improved return times to sport over cast management (6.4 weeks vs. 15.5 weeks). As such, we would recommend consideration of such a technique in the athlete to aid a quicker return to sport. However, in such cases, given that conservative management is an equally acceptable alternative, the patient must be fully counselled on the risk and benefits of both forms of management before treatment decisions are finalised.

For clavicle fractures, the return to soccer times showed variation based on the configuration and location of the fracture and the mode of treatment. Undisplaced fractures showed good results with conservative management, with a mean return time of 13.8 weeks. Similar findings were noted in a recent systematic review by Robertson and Wood (11), who performed a meta-analysis of all the available studies reporting return to sport following clavicle fracture; as such we recommend conservative management for all undisplaced clavicle fractures. Displaced lateral fractures showed a prolonged return to sport with surgical management, but given the risk of non-union with conservative management, this is the required treatment for such injuries (11). Further research into the optimal surgical modality for such injuries should be promoted to optimise return times (11). For displaced mid shaft fractures, surgical management was found to result in a reduced time to sport compared to conservative management. This is keeping with the results from Robertson and Wood (11) who found that, on meta-analysis of the available studies, conservative management of mid-shaft fractures resulted in a mean time to return of 21.5 weeks, while operative management resulted in a mean time to return of 9.4 weeks. As such there is a growing trend for the consideration of surgical management of such injuries, particularly in the high level athlete, as this can offer improvement both in return times to sport as well as resultant function (11). However all such patients much be counselled of the surgical risks before embarking on such treatment, given that conservative treatment remains a suitable option (11).

For metacarpal fractures, those managed operatively took four times longer to return to soccer with nearly twice the rate of persisting symptoms. Comparing the AO Classification sub-groups, variation in management existed for 25 A1 and 25 B2 fractures, with fracture displacement directing the requirement for surgical intervention. Management of such fractures is dictated by fracture severity and displacement, and in certain cases surgical management is required to provide fracture reduction and stability. To note we found that those treated with ORIF return quicker than those treated with MUA and K-Wire (12 weeks vs. 21.5 weeks). Similar results were reported by Rettig et al. (25) who found conservative management resulted in a mean return time of 12 days, internal fixation 14 days and MUA and K-Wiring 36 days. As such, we recommend to employ conservative management where possible, but if surgical management is required, this should preferably be performed with internal fixation.

For distal radial fractures, those managed operatively took twice as long to return to soccer with nearly three times the rate of persisting symptoms. Comparing by AO Classification, variation in management existed for fracture types 22A.3, 23C.1, and 23C.3, with fracture displacement directing the requirement for surgical management. Comminuted fractures were noted to be associated with a prolonged return to soccer. It is difficult to draw firm conclusions from this data given the limited cohorts within each AO classification. Fracture displacement and severity serve as the key indicators for surgical management; thus in certain fracture types surgery is required, and patients should be advised that return to sport will be prolonged following. What was interesting to note, was that patients treated with delayed surgery, for undisplaced, radiologically unstable fractures, which later displaced during follow-up, had prolonged return times compared to those managed with immediate surgery. This is in keeping with a growing trend to consider immediate surgical fixation of all undisplaced, radiologically unstable fractures in high level athletes, in order to prevent prolonged rehabilitation and return to sport (26). However in such cases, initial conservative management remains a possible option, and as such, the management plan should be thoroughly discussed with the patient, before treatment decisions are made. Regarding surgical techniques, we noted a reduced return rate (33% vs. 100%) and prolonged return time (24 weeks vs. 10.7 weeks) for non-bridging external fixation compared to locked volar plating (ORIF); as such, when surgical intervention is required, we would recommend internal fixation of such fractures in the athletic patient (26).

There were a number of limitations from this study.

The first limitation relates to the cohort selection of the patients. This study was designed from a one year observational register of all adult fractures sustained during soccer in our region. This provided a uniform cohort, from which the return rates and return times to soccer could be recorded and analyzed. Fractures sustained during other sports were specifically excluded, as this would have provided a heterogeneous sporting outcome, reducing the accuracy of the data. No other exclusion criteria were enforced. While inclusion of all sport-related fractures could have provided a more comprehensive assessment of sporting outcome, the inclusion criteria provided a homogeneous end-point, allowing more accurate comparisons to be made.

The second limitation relates to the study design: the observational process of the study only enabled retrospective descriptive data on the treatment outcomes to be obtained. While prospective, randomised outcome data would have preferable, this unfortunately is a consequence of the study methods. We encourage future studies to perform prospective stratification of treatment, along with prospective recording of outcome. Nevertheless, with significant limitations of such data in the present literature, the current data serves to provide a useful description of the outcomes of the current treatment available.

The third limitation relates to the wide variety of fracture locations and patterns contained within the study. This again reflects the observational design of the study, recording all adult soccer-related fractures in a set population over a year period. However, to improve the accuracy of the treatment comparisons, the fractures have been group by fracture location and AO classification. This provides comparative data for fractures at similar locations and of similar configuration.

The final limitation relates to the allocation of treatment for the fractures. Again, secondary to the observational design of the study, set within standard orthopaedic practice, the allocation of treatment for each fracture was based on the recommended orthopaedic methods as specified by Court-Brown et al. (8). Given such circumstances, the choice of treatment will be influenced by fracture severity, with the more severe fracture types more often requiring surgical intervention. This will likely adversely influence the outcome of the surgically-managed fractures. However, as specified above, the outcome comparisons for surgical versus non-surgical treatment were stratified by AO Classification, allowing direct comparison between similar fracture patterns with differing management strategies.

5.1. Conclusion

The management of fractures within athletic populations remains varied despite significant implications on return times to sport and persisting symptoms post-treatment. The role of operative management in the treatment of soccer-related fractures is specific to the location and nature of the fracture. The effect of operative management on return times to sport is fracture specific, though invariably this is associated with higher rates of persisting symptoms. The decision regarding the choice of non-operative versus operative management requires clinical judgment on an individual basis, based on the fracture location and configuration. Experienced clinical judgement with consideration of individual patient characteristics remain important factors in planning management and combined discussion of cases at regular trauma meetings will likely provide the best mode of decision.

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Footnotes

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Appendix VIII: Football Cohort Follow-up Questionnaire

Football Cohort – Follow-up Telephone Questionnaire

Patients were asked about:

1. the level of football that the patient was playing at, prior to injury
2. the level of football that the patient returned to after injury
3. the length of time (in weeks) that it took the patient to return to a training level of football (i.e. being able to run and kick the ball about but not being able to play full contact football).
4. the length of time (in weeks) that it took the patient to return to full contact football
5. if playing competitively, then the length of time (in weeks) it took for the patient to return to full team football.
6. the presence of any persisting symptoms from the fracture.
7. the presence of any persisting symptoms from the fracture which impaired their ability to play football.

Appendix IX: Rugby Cohort Follow-up Questionnaire

Rugby Cohort – Follow-up Telephone Questionnaire

Patients were asked about:

1. the level of rugby that the patient was playing at prior to injury
    - including the club or school that they played for and the team within the club or the school they played for.
2. the position they played at the time of injury.
3. the mechanism of injury with specific regards to the type of rugby incident that it occurred during.
4. the level of rugby that the patient returned to after injury.
5. if they did not return, the reason for not returning.
6. the length of time (in weeks) that it took the patient to return to non-contact sports
7. the length of time (in weeks) that it took the patient to return to a training level of rugby (i.e. being able to run and catch ball)
8. the length of time (in weeks) that it took the patient to return to full contact rugby
9. if playing competitively, then the length of time (in weeks) it took for the patient to return to full team rugby
10. the presence of any persisting symptoms at follow-up from the fracture.
11. the presence of any persisting symptoms at follow-up from the fracture which impaired their ability to play rugby
    - including how these symptoms affected their rugby ability.

Appendix X: Hockey Cohort Follow-up Questionnaire

Hockey Cohort – Follow-up Telephone Questionnaire

Patients were asked about:

1. the level of hockey that the patient was playing at, prior to injury
2. the level of hockey that the patient returned to after injury
3. the length of time (in weeks) that it took the patient to return to a training level of hockey (i.e. being able to run and dribble the ball about but not being able to play full contact hockey).
4. the length of time (in weeks) that it took the patient to return to full contact hockey
5. if playing competitively, then the length of time (in weeks) it took for the patient to return to full team hockey.
6. the presence of any persisting symptoms from the fracture.
7. the presence of any persisting symptoms from the fracture which impaired their ability to play hockey.

Appendix XI: Ankle Cohort Follow-up Questionnaire

Ankle Cohort – Follow-up Telephone Questionnaire

Patients were asked about:

1. the level of sport that the patient was playing at prior to injury
    - including the club or school that they played for and the team within the club or the school they played for.
2. the mechanism of injury with specific regards to the type of sport incident that it occurred during.
3. the level of sport that the patient returned to after injury.
4. if they did not return, the reason for not returning.
5. the length of time (in weeks) that it took to return to non-contact sports
6. the length of time (in weeks) that it took to return to a training level of sport (i.e. being able to run and play sport leisurely)
7. the length of time (in weeks) that it took to return to full level sport
8. if playing competitively, then the length of time (in weeks) it took for return to full team sport
9. the presence of any persisting symptoms at follow-up from the fracture.
10. the presence of any persisting symptoms at follow-up from the fracture which impaired their ability to play sport
    - including how these symptoms affected their sporting ability.

Appendix XII: Ethical approval

South East Scotland Research Ethics Service
DIFFERENTIATING AUDIT, SERVICE EVALUATION AND RESEARCH

November 2006
The "Ad Hoc Advisory Group on the Operation of NHS Research Ethics Committees" recommended NRES should develop guidelines to aid researchers and committees in deciding what is appropriate or inappropriate for submission to RECs, and NRES (with the Health Departments and with advice from REC members) has prepared the guidelines in the form of the attached table.

RESEARCH	CLINICAL AUDIT	SERVICE EVALUATION
The attempt to derive generalisable new knowledge including studies that aim to generate hypotheses as well as studies that aim to test them.	Designed and conducted to produce information to inform delivery of best care.	Designed and conducted solely to define or judge current care.
Quantitative research – designed to test a hypothesis. Qualitative research – identifies/explores themes following established methodology.	Designed to answer the question: "Does this service reach a predetermined standard?"	Designed to answer the question: "What standard does this service achieve?"
Addresses clearly defined questions, aims and objectives.	Measures against a standard.	Measures current service without reference to a standard.
Quantitative research -may involve evaluating or comparing interventions, particularly new ones. Qualitative research – usually involves studying how interventions and relationships are experienced.	Involves an intervention in use ONLY. (The choice of treatment is that of the clinician and patient according to guidance, professional standards and/or patient preference.)	Involves an intervention in use ONLY. (The choice of treatment is that of the clinician and patient according to guidance, professional standards and/or patient preference.)
Usually involves collecting data that are additional to those for routine care but may include data collected routinely. May involve treatments, samples or investigations additional to routine care.	Usually involves analysis of existing data but may include administration of simple interview or questionnaire.	Usually involves analysis of existing data but may include administration of simple interview or questionnaire.
Quantitative research - study design may involve allocating patients to intervention groups. Qualitative research uses a clearly defined sampling framework underpinned by conceptual or theoretical justifications.	No allocation to intervention groups: the health care professional and patient have chosen intervention before clinical audit.	No allocation to intervention groups: the health care professional and patient have chosen intervention before service evaluation.
May involve randomisation	No randomisation	No randomisation
ALTHOUGH ANY OF THESE THREE MAY RAISE ETHICAL ISSUES, UNDER CURRENT GUIDANCE:-		
RESEARCH REQUIRES R.E.C. REVIEW	AUDIT DOES NOT REQUIRE R.E.C. REVIEW	SERVICE EVALUATION DOES NOT REQUIRE R.E.C. REVIEW

Appendix XIII: My Role and the Co-Authors' Roles in the Studies submitted within this Thesis

My Role in the Co-Authored Studies submitted within this Thesis

Paper 1: The Epidemiology, Morbidity and Outcome of Soccer-Related Fractures in a Standard Population.

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; designed the format of the study; performed the retrospective review of all the patients' case-notes; performed all the telephone questionnaire follow-up interviews; performed all the statistical and data analyses; and authored the manuscript. In summary, the thesis author contributed around 90% of the workload of the publication.

Paper 2: The Epidemiology, Morbidity and Outcome of Fractures in Rugby Union from a Standard Population

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; designed the format of the study; performed the retrospective review of all the patients' case-notes; performed all the telephone questionnaire follow-up interviews; performed all the statistical and data analyses; and authored the manuscript. In summary, the thesis author contributed around 90% of the workload of the publication.

Paper 3: The Epidemiology, Management and Outcome of Field Hockey Related Fractures in a Standard Population.

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; designed the format of the study; performed the retrospective review of all the patients' case-notes; performed all the telephone questionnaire follow-up interviews; performed all the statistical and data analyses; and authored the manuscript. In summary, the thesis author contributed around 90% of the workload of the publication.

Paper 4: The Epidemiology, Management and Outcome of Sport-Related Ankle Fractures in a Standard UK Population.

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; designed the format of the study; performed the retrospective review of all the patients' case-notes; performed all the telephone questionnaire follow-up interviews; performed all the statistical and data analyses; and authored the manuscript. In summary, the thesis author contributed around 90% of the workload of the publication.

Paper 5: The Epidemiology of Sports-Related Fractures in Adolescents

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; performed the data analyses; and co-authored the manuscript. In summary, the thesis author contributed around 33% of the workload of the publication.

Paper 6: The Epidemiology of Open Fractures in Sport: One Centre's 15-year Retrospective Study

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; performed the retrospective review of all the patients' case-notes; performed the data analyses; and co-authored the manuscript. In summary, the thesis author contributed around 45% of the workload of the publication.

Paper 7: The Management of Sport-Related Fractures: Operative versus Non-Operative Management

For this paper, the thesis author: performed the retrospective review of the pre-formed prospectively-collated epidemiology database; designed the format of the study; performed the retrospective review of all the patients' case-notes; performed all the telephone questionnaire follow-up interviews; performed all the statistical and data analyses; and authored the manuscript. In summary, the thesis author contributed around 90% of the workload of the publication.

<u>The Co-Authors' Roles in the Studies submitted within this Thesis</u>

Paper 1: The Epidemiology, Morbidity and Outcome of Soccer-Related Fractures in a Standard Population.

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Joshua Bakker-Dyos: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; and co-authored the manuscript.

For this paper, Stuart Aitken: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Andre Keenan: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; and co-authored the manuscript.

For this paper, Charles Court-Brown: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

Paper 2: The Epidemiology, Morbidity and Outcome of Fractures in Rugby Union from a Standard Population

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Kieran Heil: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; and co-authored the manuscript.

For this paper, Stuart Aitken: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Charles Court-Brown: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

Paper 3: The Epidemiology, Management and Outcome of Field Hockey Related Fractures in a Standard Population.

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Stuart Aitken: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Charles Court-Brown: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

Paper 4: The Epidemiology, Management and Outcome of Sport-Related Ankle Fractures in a Standard UK Population.

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Stuart Aitken: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Charles Court-Brown: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

Paper 5: The Epidemiology of Sports-Related Fractures in Adolescents

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Louise Rennie: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Benjamin Caesar: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Charles Court-Brown: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

Paper 6: The Epidemiology of Open Fractures in Sport: One Centre's 15-year Retrospective Study

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Kirsty MacLeod: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; and co-authored the manuscript.

For this paper, Anna Porter: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; and co-authored the manuscript.

For this paper, Charles Court-Brown: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

Paper 7: The Management of Sport-Related Fractures: Operative versus Non-Operative Management

For this paper, Alexander Wood: co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

For this paper, Stuart Aitken: co-applied for ethical approval for the study; co-performed participant recruitment for the study; co-performed data collection and collation for the study; co-performed the retrospective review of the pre-formed prospectively-collated epidemiology database; co-designed the format of the study; and co-authored the manuscript.

	Paper 1: The Epidemiology, Morbidity and Outcome of Soccer-Related Fractures in a Standard Population.	Paper 2: The Epidemiology, Morbidity and Outcome of Fractures in Rugby Union from a Standard Population	Paper 3: The Epidemiology, Management and Outcome of Field Hockey Related Fractures in a Standard Population	Paper 4: The Epidemiology, Management and Outcome of Sport-Related Ankle Fractures in a Standard UK Population.	Paper 5: The Epidemiology of Sports-Related Fractures in Adolescents	Paper 6: The Epidemiology of Open Fractures in Sport: One Centre's 15-year Retrospective Study	Paper 7: The Management of Sport-Related Fractures: Operative versus Non-Operative Management
Idea and study design	Done by author with coinvestigators	Done by author with coinvestigators	Done by author with coinvestigators	Done by author with coinvestigators	Done by coinvestigators with author.	Done by author with coinvestigators	Done by author with coinvestigators
Ethical approval	Done by coinvestigators with author	Done by coinvestigators with author	Done by coinvestigators with author	Done by coinvestigators with author	Done by coinvestigators	Done by coinvestigators	Done by coinvestigators with author
Participant recruitment	Done by coinvestigators and author with assistance from research nurses	Done by coinvestigators and author with assistance from research nurses	Done by coinvestigators and author with assistance from research nurses	Done by coinvestigators and author with assistance from research nurses	Done by coinvestigators with assistance from research nurses	Done by coinvestigators with assistance from research nurses	Done by coinvestigators and author with assistance from research nurses
Data collection/collation	Done by coinvestigators with author	Done by coinvestigators with author	Done by coinvestigators with author	Done by coinvestigators with author	Done by coinvestigators	Done by coinvestigators	Done by coinvestigators with author
Data Analysis	Done by author	Done by author	Done by author	Done by author	Done by coinvestigators with author	Done by author with coinvestigators	Done by author
Statistical analysis	Done by author	Done by author	Done by author	Done by author	Done by author with coinvestigators	Done by author	Done by author
Writing first draft of manuscript	Done by author	Done by author	Done by author	Done by author	Done by coinvestigators with author	Done by author with coinvestigators	Done by author
Agreed final draft of manuscript for publication	Done by author with coinvestigators	Done by author with coinvestigators	Done by author with coinvestigators	Done by author with coinvestigators	Done by coinvestigators with author	Done by author with coinvestigators	Done by author with coinvestigators