Return to sport following low-risk and high-risk bone stress injuries: a systematic review and meta-analysis

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ABSTRACT

Objective Bone stress injuries (BSIs) are classified in clinical practice as being at low- or high-risk for complication based on the injury location. However, this dichotomous approach has not been sufficiently validated. The purpose of this systematic review was to examine the prognostic role of injury location on return-to-sport (RTS) and treatment complications after BSI of the lower extremity and pelvis.

Design Systematic review and meta-analysis.

Data sources PubMed, Web of Science, Cochrane CENTRAL and Google Scholar databases were searched from database inception to December 2021.

Eligibility criteria for selecting studies Peer-reviewed studies that reported site-specific RTS of BSIs in athletes.

Results Seventy-six studies reporting on 2974 BSIs were included. Sixteen studies compared multiple injury sites, and most of these studies (n=11) described the anatomical site of injury as being prognostic for RTS or the rate of treatment complication. Pooled data revealed the longest time to RTS for BSIs of the tarsal navicular (127 days; 95% CI 102 to 151 days) and femoral neck (107 days; 95% CI 79 to 135 days) and shortest duration of time for BSIs of the posteromedial tibial shaft (44 days, 95% CI 27 to 61 days) and fibula (56 days; 95% CI 13 to 100 days). Overall, more than 90% of athletes successfully returned to sport. Treatment complication rate was highest in BSIs of the femoral neck, tarsal navicular, anterior tibial shaft and fifth metatarsal; and lowest in the fibula, pubic bone and posteromedial tibial shaft.

Conclusion This systematic review supports that the anatomical site of BSIs influences RTS timelines and the risk of complication. BSIs of the femoral neck, anterior tibial shaft and tarsal navicular are associated with increased rates of complications and more challenging RTS.

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WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Bone stress injuries can be clinically classified as low-risk or high-risk injuries by anatomic location.
- ⇒ High-risk injuries include anatomical sites prone to delayed union, non-union, refracture, completed fracture, avascular necrosis and failure to (timely) return-to-sport (RTS).
- ⇒ Among others, low-risk injuries may include the posteromedial tibial shaft and the metatarsal shaft while high-risk injuries may include the base of the fifth metatarsal, femoral neck, anterior tibial shaft and tarsal navicular.

WHAT THIS STUDY ADDS

- ⇒ Expected time to RTS, rate of RTS and treatment complications based on 76 studies and 2974 bone stress injuries are presented for multiple skeletal sites of bone stress injuries.
- ⇒ Time to RTS, rate of RTS and treatment complications after bone stress injuries vary by anatomical location.
- ⇒ In particular, anatomical sites of the femoral neck, anterior tibial shaft and tarsal navicular have an increased rate of complication and longer timeline for RTS.

INTRODUCTION

Bone stress injuries (BSIs) encompass the spectrum of overuse injuries caused by microdamage accumulation in bone, often referred to as ‘stress reactions’ and ‘stress fractures’.[1] While uncommon in the general population, this form of injury accounts for up to 20% of all injuries in specific populations, such as runners and military recruits.[2–4]

Many BSIs heal without complication, thus allowing the individual to return to their preinjury level of activity.[5] However, some anatomical sites of BSI, such as the fifth metatarsal, anterior tibial shaft and tarsal navicular, appear at increased risk for complications including delayed union, non-union, fracture progression, refracture, avascular necrosis or prolonged time for return-to-sport (RTS).[1] Consequently, management of BSIs varies by anatomical location. For example, injuries to the first to fourth metatarsal shaft may not require immobilisation and gradual loading is generally permitted as long as pain-free.[6] In contrast, BSIs at other locations (eg, tarsal navicular, fifth metatarsal) may require a minimum of 6 weeks immobilisation caused by concerns for risk due to location relative to bending axes (eg, on the tension-side) or poor blood supply.[7] Accordingly, early surgical fixation has been recommended in selected cases thought to have a low rate of healing non-operatively or in high-level athletes.[1 8]

Despite numerous investigations on optimal treatment and clinical decision-making to guide RTS, complications and failure to (timely) RTS are still common but may vary by anatomical site of injury.[1] For instance, failure of RTS are regularly described for navicular BSIs,[9] and tension-sided

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(anterior) tibial shaft injuries have prolonged time to RTS compared with compression sided (posteromedial) injuries.[10] The variability for RTS and different complication rates reflect major challenges in part attributed to the gap in knowledge on how anatomy affects clinical decision making. To date, no review has systematically investigated treatment complications and RTS after BSIs separated by anatomical location. The purpose of this systematic review was to evaluate the prognostic value of BSI location on time to RTS, rate of RTS and treatment complications. We expected differences in RTS and treatment complications by site of injury.

METHODS

This systematic review with meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.[11] A PRISMA checklist can be found in supplementary file 1. Prior to the beginning of the systematic search, a publicly available protocol was published online.

Search strategy and study selection

A systematic search was performed across PubMed, Web of Science, Cochrane CENTRAL and Google Scholar from inception until December 2021. At first, studies were retrieved from PubMed, Web of Science and Cochrane CENTRAL by using the following search term: *("stress injur*" OR "stress fractur*") AND ("return*" OR "absence" OR "time to" OR "follow-up" OR "non-operative*" OR "non-surgical*" OR "conservative*" OR "operative*" OR "surgical*" OR "days" OR "weeks")*. Afterwards, a "cited-by" (forward) search and a "reference" (backward) search of all included articles were conducted using Google Scholar (forward) and Web of Science (backward). Articles were included or excluded based on previously defined selection criteria (table 1). To be included, studies needed to report on RTS after BSI of the lower extremity or pelvis. In contrast, articles were excluded if the injury was attributed to trauma or occurred outside of movement-related activities. Studies were also excluded if an overuse aetiology of injury was not clearly stated. Furthermore, studies that exclusively reported on non-union injuries were excluded. This study was limited to BSIs of the pelvis and lower extremities as these account for over 80% of all BSIs.[2] The search was independently performed by two reviewers (TH and JE). All articles were screened by title and abstract and, if necessary, full text. Disagreement was resolved through discussion with a third reviewer (TR) being available for all remaining cases.

Data extraction

Data extraction was independently performed by two reviewers (TH and JE). Disagreement was resolved by discussion or a third reviewer (JS). If possible, the following data were extracted: author/s, year of publication, study population, study directionality (prospective/retrospective), number of cases, anatomical location(s), RTS definition, time to RTS, rate of RTS and complication rate. A treatment complication was defined as delayed or non-union, persistence of pain, failure of return to preinjury level of activity, avascular necrosis, need for surgery (if initially treated without surgery), resurgery or reinjury at the same anatomical site of injury.

Quality assessment

Risk of bias was evaluated using the Methodological Index for Non-Randomised Studies (MINORS) tool.[10] The MINORS scale was developed to rate risk of bias of non-randomised studies. It contains eight items for observational non-comparative studies. Each item can score up to 2 points, thus yielding a maximum of 16 points. Studies were judged to be high quality (>75%), moderate quality (50%–74%), low quality (25%–49%) or very low quality (<25%).[12] Two authors (TH and JE) independently assessed the risk of bias. Disagreement was resolved by discussion or a third reviewer (KH).

Data synthesis

Meta-analysis of proportion was performed to determine the rate of RTS and treatment complications for each anatomical location. For treatment complications, the proportion rate was calculated as the number of cases who have developed complications divided by the total number. For RTS, the proportion rate was calculated as the number of cases who returned to sport divided by the total number. A pooled rate of RTS was calculated for the total cohort. Confidence intervals (CIs) were derived. Adjusted proportions were calculated by logit transformations. If an event rate was equal to 0% or 100%, a count of 0.5 was added to event or non-event values for computation of Logit event rate to allow for inclusion in the meta-analysis.[13] Data for time to RTS were pooled as mean with Standard Error (SE) and 95% CI. If studies reported median values with interquartile range, mean values and variances were estimated.[14] All data were analysed using the Comprehensive Meta Analysis software (V.3.3.070, Biostat). Heterogeneity was assessed by using I^2 test.[15] In case of substantial heterogeneity defined as $I^2>50\%$, a random-effects model was used.

RESULTS

Literature search

A total of 4930 records (PubMed: 2724; Web of Science: 2108; Cochrane: 98) were identified through the initial search. After removing 1384 duplicates and 3231 records based on title and abstract, 315 reports were identified for full-text screening. Of these, 70 studies met inclusion criteria with forward and reference search yielding another 6 studies. Finally, 76 studies were included (figure 1).[9 16–90]

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Bone stress injuries of the lower extremity and pelvis	Bone stress injuries of the trunk or upper extremity; traumatic fracture or unclear aetiology; injury occurred outside of movement-related activities
Recreational and competitive athletes; military recruits	Athletes with chronic underlying health conditions; inadequate description of patient cohort
Studies providing bone-specific data on return-to-sport and/or treatment complications	No or inadequate definition of return-to-sports
Peer-reviewed original research articles; English or German language	Non-peer-reviewed articles, newspapers, opinion pieces, reviews and meta-analyses, case reports with <5 cases, editorials, commentaries and letters to the editor, conference proceedings/abstracts, book chapters, patient-oriented educational article, anecdotal studies

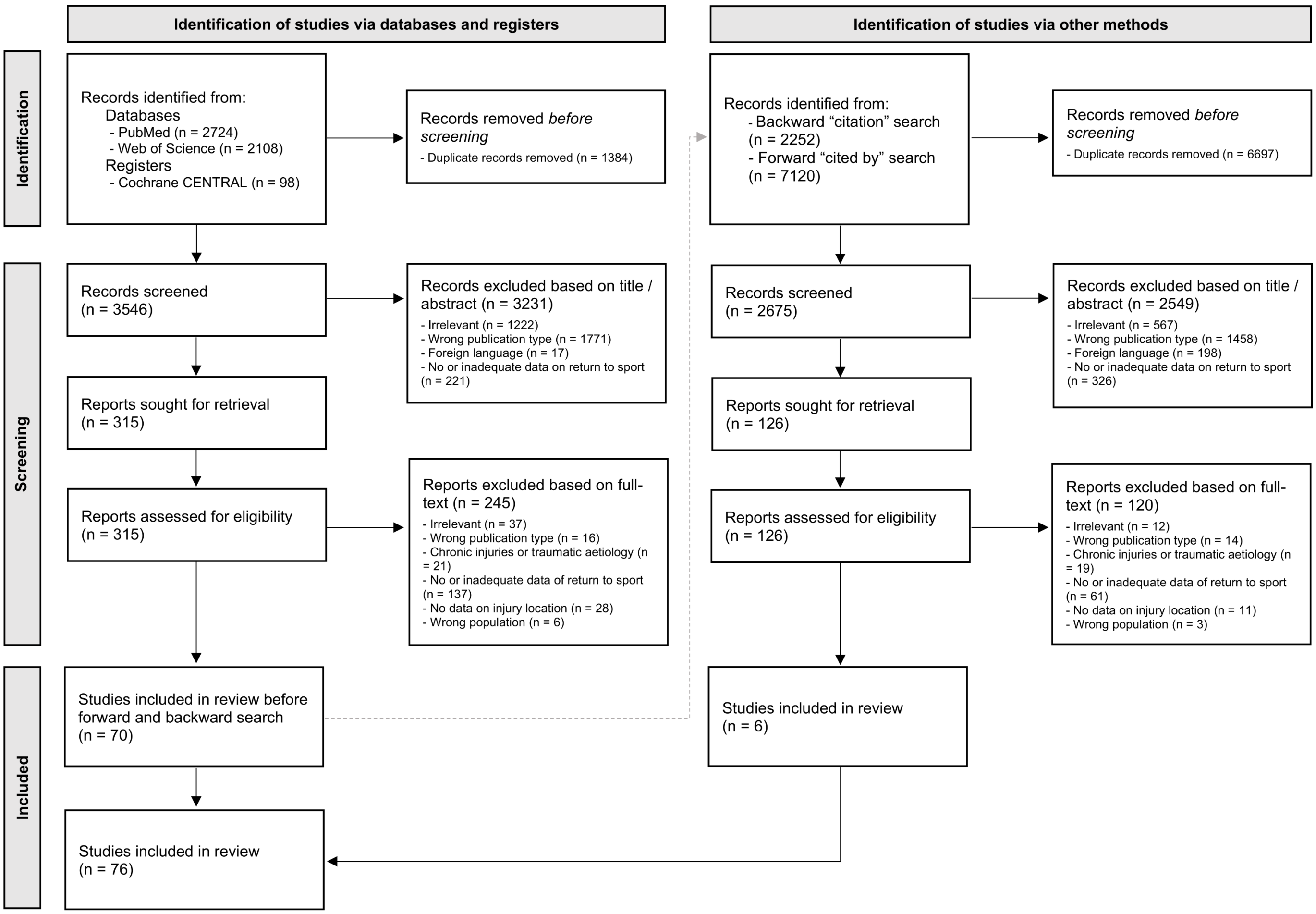

Figure 1 PRISMA chart. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Study characteristics

The 76 included studies reported for a total of 2974 BSIs. Most studies reported on BSIs in male athletes (2077 cases). Study design was retrospective in 58 studies and prospective in 18 studies. Most studies evaluated BSIs for a single anatomical location, with 16 studies reporting on multiple sites of injury.[22 24 26 28 30 32 34 38 42 50 51 53 65 77 78 88]

The most reported bone sites were the tibia (1091 cases), followed by metatarsals (901 cases), femur (370 cases) and tarsal navicular (343 cases). A comprehensive overview on characteristics and outcome parameter can be found in online supplemental files 1 and 2. The MINORS tool classified 14, 37 and 24 studies to be of high, moderate and low quality, respectively, and 1 study to be of very low quality (figure 2).

Time to RTS

Most studies (58 of 76) reported the time for RTS in at least one anatomical site of injury. Pooled data by anatomical site are presented in figure 3. The longest times to RTS were reported for BSIs of the tarsal navicular (127 days; 95% CI 103 to 151 days) and femoral neck (107 days; 95% CI 79 to 135 days). In contrast, the shortest times to RTS were reported for BSIs of the posteromedial tibial shaft (44 days, 95% CI 27 to 61 days) and fibula (56 days; 95% CI 13 to 100 days). Other outcomes included the medial malleolus (106 days; 95% CI 79 to 132 days), pubic bone (77 days; 95% CI 41 to 112 days), femoral shaft (86 days; 95% CI 54 to 117 days), fifth metatarsal (82 days; 95% CI 68 to 96 days) and first to fourth metatarsal (78 days; 95% CI 56 to 101 days). Of all included studies, 11 studies reported the time to RTS of more than one injury site,[22 24 26 28 32 50 51 53 65 77 78] thus directly comparing the time to RTS across anatomical sites. Seven of these studies[22 28 32 50 51 65 77] supported the hypothesis that site of BSI is a prognostic factor for time to RTS while two studies[24 53] did not; two studies[26 78] were unclear.

Figure 2 Assessment of risk of bias. Minors tool revealed 14 studies of high quality, 37 studies of moderate quality, 24 studies of low quality and 1 study of very low quality. Studies are numbered in alphabetical order (as listed in online supplemental file 1).

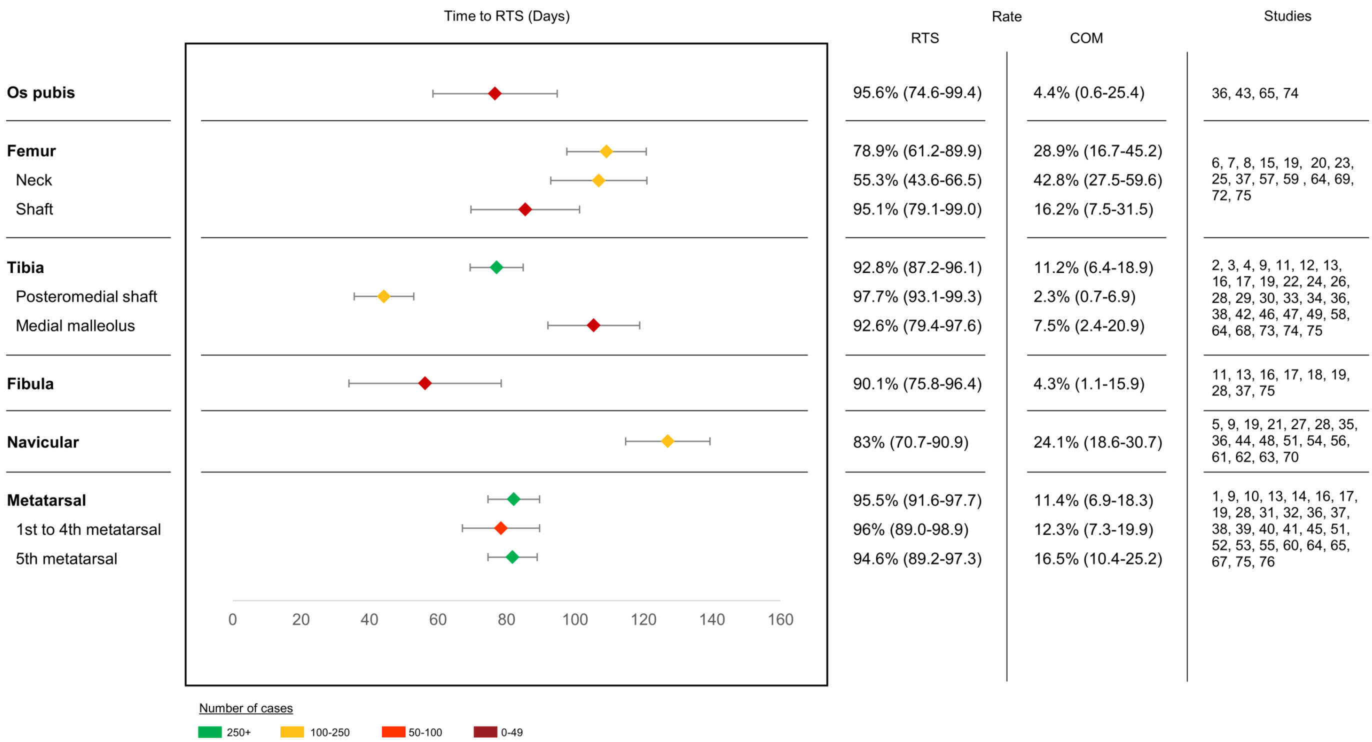

Figure 3 Pooled data on time to return to sports (mean±SE), rate of return-to-sports (RTS) (%, 95% CI) and treatment complication rate (%, 95% CI) according to site of injury. Studies are numbered in alphabetical order (as listed in online supplemental table 1). COM, complication.

Rate of RTS

Sixty-one of 76 studies reported the rate of RTS of at least one injury site. Overall, 90% of athletes returned to sport. The highest rate of RTS was reported for BSIs of the posteromedial tibial shaft (97.7%, 95% CI 93.1% to 99.3%), first to fourth metatarsal (96%; 95% CI 89% to 98.6%) and pubic bone (95.6%; 95% CI 74.6% to 99.5%). The lowest rate of RTS was reported for the femoral neck (55.3%; 95% CI 43.6% to 66.5%), talus (68.9%; 95% CI 44.6% to 85.9%), anterior tibial shaft (75.5%; 95% CI 54.1% to 88.9%) and tarsal navicular (83.0%; 95% CI 70.7% to 90.9%). Other injury locations with available pooled data included the femoral shaft (95.1%; 95% CI 79.1% to 99%), fifth metatarsal (94.6%; 95% CI 89.2% to 97.3%), medial malleolus (92.6%; 95% CI 79.4% to 97.6%), fibula (90.1%; 95% CI 75.8% to 96.4%), hallux sesamoid (86.5%; 95% CI 75.1% to 93.2%) and patella (88.3%; 95% CI 48.2% to 98.4%).

Of all included studies, eight studies reported the rate to RTS of more than one injury site,[24 26 34 38 42 50 78 88] thus directly comparing the rate of RTS across anatomical sites. Of these, two studies[38 42] supported the hypothesis that site of injury is a prognostic factor for rate of RTS while four studies[24 26 78 88] did not; two studies[34 50] were unclear.

Rate of treatment complications

Overall, 58 of 76 studies reported on treatment complications. The highest rate of complications was reported for BSIs of the femoral neck (42.8%; 95% CI 27.5% to 59.6%), anterior tibial shaft (40.9%; 95% CI 24.2% to 59.9%), hallux sesamoid (33.5%, 95% CI 8.3% to 73.7%) and tarsal navicular (24.1%; 95% CI 18.6% to 30.7%). The lowest complication rate was reported for BSIs of the posteromedial tibial shaft (2.3%, 95% CI 0.7% to 6.9%), fibula (4.3%, 95% CI 1.1% to 15.9%) and pubic bone (4.4%; 95% CI 0.6% to 25.4%). Other injury locations with available pooled data included the fifth metatarsal (16.5%; 95% CI 10.4% to 25.2%), femoral shaft (16.2%; 95% CI 7.5% to 31.5%), first to fourth metatarsal (12.3%; 95% CI 7.3% to 19.9%) and medial malleolus (7.5%, 95% CI 2.4% to 20.9%). Of all included studies, seven studies reported the treatment complication rate of more than one injury site,[26 30 34 38 50 78 88] thus directly comparing the treatment complication rate across anatomical sites. Of these, four studies[30 34 38 50] supported the hypothesis that site of injury is a prognostic factor for treatment complications while three studies[26 78 88] did not.

DISCUSSION

Findings from the present study support that the anatomical location of a BSI influences treatment outcomes and RTS. The most clinically concerning BSIs were localised to the anterior tibial shaft, tarsal navicular, and femoral neck, and were associated with an increased rate of complications and a prolonged time for RTS. In contrast, BSIs to the posteromedial tibial shaft, fibula and femoral shaft resulted in lower complication rates with full RTS typically seen within 3 months.

Low-risk and high-risk BSIs: current recommendations on treatment and RTS

The treatment of BSIs may be guided by injury site.[1] Thereto, BSIs are clinically classified as either low-risk or high-risk.[91 92] Low-risk injuries typically heal without major complications; and gradual RTS can be initiated earlier.[1 92] In contrast, high-risk injuries need a more cautious treatment strategy due to factors such as high tensile loading and limited blood supply to the injury site.[1 91] Despite its perceived clinical importance, the classification of low-risk and high-risk BSIs has lacked detailed scientific evidence.[1] Although new recommendations have been recently published,[1 5] clinical decision making on RTS may be challenging in certain patient populations, such as elite athletes,

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where wrong decisions can be season-ending or career-ending. In the military, failure to manage a bone injury may result in medical discharge if optimal military readiness cannot be achieved in a timely manner. The demand for earlier return to physical activity[93] should be balanced by knowledge that BSI healing takes time.[94] Recent findings on skeletal strength deficits indicate that recovery may require a full 6 months, extrapolated from healing from a tibial BSI.[95 5]

Role of risk stratification in management of BSIs

Several retrieved studies compared anatomical site of injury and concluded that injury site may affect bony healing, RTS and treatment complication rate.[22 28 30 32 34 38 42 50 51 65 77] Bone sites associated with a long time to RTS were the femoral neck, tarsal navicular and medial malleolus. Failure to RTS were predominantly reported at the femoral neck, anterior tibial shaft, talus and tarsal navicular. Moreover, the results from the current systematic review suggest that the location of BSI on a given bone (i.e., anterior tibial shaft vs. posteromedial tibial shaft) is an important consideration in BSI management. In addition to risk stratifying between low-risk and high-risk injuries, BSIs may be distinguished between bone sites believed to have greater trabecular (eg, femoral neck, sacrum, calcaneus) versus cortical bone (eg, femoral shaft, metatarsals, tibia).[96–98] A study from Nattiv *et al*[97] indicated longer time to RTS after BSIs at trabecular-rich bone sites compared with cortical-rich sites, but this classification by bone composition ratio remains to be established histologically. As such, it was presumed that bone composition may influence RTS, but evidence is inconclusive.[5 99]

Although the majority of studies included in the current systematic review supported the hypothesis of site-specific healing and complication rates, some studies reported opposite findings. Miller *et al*[53] retrospectively studied 38 injured athletes and reported a time to RTS of 12.9±5.2 weeks without a significant difference between bone anatomical locations. Within a population of 208 military recruits, it took on average 5 weeks to recover from BSIs and only time to return to training at preinjury level of activity was different between anatomical sites (ranging from 12.2 weeks±1.3 in metatarsal BSIs to 21.1 weeks±4.1 in femoral BSIs).[88]

‘High-risk’ BSIs: anterior tibial shaft, tarsal navicular, femoral neck

Pooled data identified the femoral neck, anterior tibial shaft and tarsal navicular as injury sites with long RTS time, low RTS rates, prone to complication, and therefore “high risk”. An early report in 1987 compared the recovery time between BSI sites and found that the tarsal bones needed more than twice as long as other bone sites (eg, metatarsals (17.3 weeks vs 7.9 weeks)).[51] Subsequent reports identified the tarsal navicular to be associated with the longest time to full sports participation (22.3 weeks) in elite athletes,[50] and the anterior tibial shaft, sesamoid, fifth metatarsal, olecranon and tarsal navicular were prone to delayed or non-union.[34] In a prospective cohort of youth football players, Wik *et al*[87] reported the highest time-loss of BSIs to be located at the foot compared with the lower leg and os pubis, but did not specify which bones or bone sites of the foot or lower leg were included in the analysis. Our findings highlight the discrepancies in RTS time and rate by anatomical location and may help to inform BSI prognosis and manage clinical and RTS expectations, particularly when a BSI is sustained at a site that is prone to long RTS time or complication.

‘Low-risk’ BSIs: posteromedial tibial shaft, femoral shaft, fibula

Pooled data identified the fibula, posteromedial tibial shaft and femoral shaft as injury sites with short RTS time, high RTS rates, not prone to complication and therefore ‘low risk’. Other sites that have been identified as being low-risk may include the first to fourth metatarsal shaft and the pelvic girdle.[1] For instance, Hulkko and Orava[34] reported a short bony healing time between 2 weeks and 2 months for most metatarsal BSIs. Therefore, BSIs need individual management strategies. Though typically recommended, low-risk bone sites without a fracture line do not necessarily need assisted off-loading (e.g., crutches, pneumatic walking boot).[1] However, unloading should be considered if pain is provoked with ambulation. Surgical fixation is rarely necessary in low-risk BSIs and may only be offered if there is an implicit argument in its favour (eg, immediate need for early weight-bearing). Nevertheless, RTS at preinjury level can be expected in most cases.[5] Overall, treatment complications in low-risk BSIs are rarely seen.

The framework for an evidence-based consensus on risk stratification of BSIs: time to RTS, rate of RTS and treatment complications

Classifying BSIs as being low-risk or high-risk needs to account for all treatment complications including fracture progression, refracture, delayed union, non-union and avascular necrosis. In addition, the site-specific consequences must be considered. For instance, displacement of a femoral neck stress fracture can be assumed to have a more fatal outcome than other bones (eg, displaced metatarsal stress fracture). The many factors to be included when making decisions on treatment and rehabilitation highlight the need for individual athlete-specific approaches. Injury sites prone to non-union should be considered high risk. Also, refracture rate is important to consider. For instance, Lareau *et al*[100] reported a refracture rate in fifth metatarsal bone of 12% (average time to RTS of 8.7 weeks). Of note, this study was excluded during the systematic search as the traumatic or overuse aetiology of included cases was unclear, but its findings may be included in the discussion of the results according to the 2020 PRISMA statement.[11] The need for differentiating a traumatic from an overuse (repetitive traumatic) aetiology in the occurrence of fifth metatarsal base fracture is a matter of scientific debate.[8 101 102] In accordance with previous reports,[8 102] this review exclusively included studies that refer to overuse injuries.

In addition to low-risk and high-risk BSIs, findings from this systematic review may identify bone sites at intermediate risk. However, expert consensus should critically re-evaluate this preliminary work. From a clinical perspective, intermediate-risk BSIs may only require a short time of non-weight-bearing treatment approaches with surgical fixation only recommended in very select cases (eg, high professional athletes). Overall, this review demonstrates that differences in expected RTS between bone sites exist. Therefore, guiding management of BSIs by injury site should become a clinical standard. Findings from this study can be used for communicating between medical professionals, coaches and athletes when estimating time to RTS in athletes.

Other factors to consider when guiding RTS

Our findings suggest that site of injury is important when guiding safe RTS. The most important practical finding from this report may be that individualisation in the treatment of BSIs is crucial, and the most cautious treatment strategies should be applied to the femoral neck, tarsal navicular and anterior tibial shaft. However, site of injury is only one part of many factors that can guide expectations on when an athlete can RTS. Other factors include grade of injury,[5 103] freedom from pain[7] and findings from repeated imaging.[104 105] Also, independent predictors for a prolonged time to RTS return have been identified, including relative energy deficiency in sport and low bone mineral density.[95 97]

Strength and limitations

The strengths of this review include its systematic approach with meta-analysis across multiple studies. The high number of included studies allowed for a systematic review with a particular focus on high-quality research. Nevertheless, the number of studies reporting on a specific bone site was limited. Therefore, a best-evidence meta-analysis was not possible but the numbers of included cases are indicated in figure 3. Overall, this review comprises best evidence for BSIs of the tibia, metatarsals, femur and tarsal navicular. There is no clear evidence if generalisation to other bone sites is possible due to a limited number of included cases at rare injury sites (eg, cuboid, calcaneus, sacrum or patella). Further limitations of this review should be noted, including heterogeneity across included studies and that studies were not blinded. In terms of the latter, it is not possible to determine whether the observations are due to use of a more cautious RTS protocol for high-risk injury sites or actual differences in healing rates (eg, between 'tensile/compressive' or 'trabecular/cortical' injury sites). Also, RTS may be affected by age, gender, injury severity, and other biases that were not taken into account while calculating pooled data.[102] The risk of publication bias is another limitation. For instance, successful RTS may be more likely reported than failure to RTS in treatment of BSIs. As reporting of RTS was not standardised across studies, this review only provides the approximate range of expected time to RTS. Of note, most studies reported mean rather than median values, which may result in an under- or overestimation of expected time to RTS due to the inclusion of outliers (ie, selected athletes with abnormally long time to RTS).

CONCLUSION

Medical professionals should recognise and draw attention to the site of injury when managing BSIs and guiding RTS. In other words, BSI of different bones and locations within a bone should not be considered identical, and decision making needs to be individualised and location specific. According to this review, the most serious BSIs are injuries to the femoral neck, tarsal navicular and anterior tibial shaft. In contrast, injuries to the fibula and posteromedial tibial shaft are associated with a low complication rate and a timely RTS. Findings from this meta-analysis can be used for communicating between medical professionals, coaches and athletes when estimating time to RTS in athletes.

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	Authors	Study population (sports, age)	Directionality	Bone(s)	Return to sports (RTS) definition	Risk of bias (RoB) rating	RoB judgement (study quality)
1	Albisetti 2010	Trainee ballet dancers, 10-21 years	Retrospective	Metatarsal	Full activity after onset of symptoms	68.75	moderate
2	Allen 2004	Active duty military, 18-32 years	Prospective	Tibia	Pain-free one mile run	56.25	moderate
3	Beals & Cook 1991	High-performance athletes (mostly Basketball), 16-24 years	Retrospective	Tibia	Return to full activity	43.75	low
4	Beck 2008	Mostly distance runners, 18-50 years	Prospective	Tibia	Hopping for 30 seconds without pain	93.75	high
5	Burne 2005	College athletes, different sports, 13 - 48 years	Retrospective	Navicular	Return to sport at the same competitive level as before injury	68.75	moderate
6	Butler 1982	College track athletes, 18 - 22 years	Retrospective	Femur	Full return to sport	43.75	low
7	Clement 1993	Competitive and recreational runners, different sports (mostly runners), mean age 29 years	Prospective	Femur	Resumed to full activity without limitations	37.5	low
8	Cochran 2020	Active duty military, 18-26 years	Retrospective	Femur	According to Hip function, Hip Outcome Score Sport, military discharge	56.25	moderate
9	Curell 2019	Active duty military, 21 ± 3 years	Retrospective	Talus, Navicular, Metatarsal, Tibia	Return to training	68.75	moderate
10	DeLee 1983	High-performance athletes, different sports (mostly Basketball), 18-28 years	Prospective	Metatarsal	Return to competitive athletics	75	high
11	Dickson & Kichline 1987	Recreational and competitive athletes, different sports, 14-40 years	Prospective	Fibula, Tibia	Return to competition	50	moderate
12	Ditmars 2020	Pediatric athletes, different sports (mostly runners), 7-18 years	Retrospective	Tibia	Full Sports participation	56.25	moderate
13	Ekstrand & Torstveit 2012	Elite football (soccer) players, 25±5 years	Prospective	Metatarsal, Tibia, Pelvic, Fibula	Return to sports participation	87.5	high
14	Fernández Fairen 1999	Competitive basketball players, 15-32 years	Prospective	Metatarsal	Resumption of sports	87.5	high
15	Fullerton & Snowdy 1988	Active military (mostly basic training), 16-33 years	Retrospective	Femur	Full activity without pain	43.75	low
16	Harrington 1993	Professional and recreational ballet dancers, 15-24 years	Retrospective	Metatarsal, Fibula, Tibia	Return to full dancing	50	moderate
17	Heaslet & Kanda-Mehtani 2007	High school, college and recreational athletes, different sports, 16-66 years	Retrospective	Metatarsal, Fibula, Tibia	Return to activity at pre-injury level	37.5	low
18	Hong & Chu 2009	Active military (basic training), 20-22 years	Retrospective	Fibula	Able to perform all activities	37.5	low
19	Hulkko & Orava 1987	Recreational and competitive athletes, different sports (mostly runners), 22±7 years	Retrospective	Tibia, Metatarsal, Fibula, Hallux Sesamoid, Femur, Navicular, Talus, Digitus 1	Resume training	56.25	moderate
20	Ivkovic 2006	Top level runners, 17-21 years	Retrospective	Femur	Return to full sport	31.25	low
21	Jacob & Paterson 2013	Level not specified, different sports, 18-50 years	Retrospective	Navicular	Full return to sports	31.25	low
22	Jamieson 2017	College track and field athletes, 20±1 years	Retrospective	Tibia	Return to running	50	moderate

23	Johansson 1990	Elite and recreational, different sports (mostly runners), 17-49 years	Retrospective	Femur	Return to previous activity level	50	moderate
24	Johansson 1992	Mixed sports cohort (dancing, running, soccer, tennis, volleyball, handball, triathlon, athletics), 11-44 years	Retrospective	Tibia	No symptoms whatsoever	50	moderate
25	Johnson 1994	NCAA Division I athletes (Lacrosse, athletics, football), 18-20 years	Retrospective	Femur	Full activity	37.5	low
26	Jowett 2008	Elite athletes, mixed sports (Athletics, Australian Rules Football, Cricket), 18-28 years	Retrospective	Tibia	Resume sporting activity at previous level	31.25	low
27	Khan 1992	International, national, and recreational athletes, sports not specified, 14-39 years	Retrospective	Navicular	Return to sports	56.25	moderate
28	Khan 2018	Male elite basketball players (NBA), 25.4±4.1 years	Retrospective	Metatarsal, Tibia, Fibula, Navicular, Patella, Calcaneus, Hallux Sesamoid	Return to play	56.25	moderate
29	Kijowski 2012	Different level, mixed sports(long-distance running, sprinting, pole vaulting, high jumping, basketball, soccer and dancing), 14-54 years	Retrospective	Tibia	Return to sports activity	50	moderate
30	Kilcoyne 2013	Military recruits (USNA), no information on age	Retrospective	Tibia	Return to activity	31.25	low
31	Larsson 2016	Male elite football players (UEFA), no information on age	Prospective	Metatarsal	Full participation in training sessions and availability for match selection	75	high
32	Lee 2011	Elite level athletes (mainly male soccer), 13-33 years	Retrospective	Metatarsal	Return to previous level of sports activity	37.5	low
33	Lempainen 2012	Athletics (jumping events and hurdling), long-distance running, soccer, biathlon, 17-39 years	Retrospective	Tibia	Fully return to the pre-injury level of sporting activities	56.25	moderate
34	Liimatainen 2009	Elite level, different sports (predominantly endurance runners), 16-37 years	Retrospective	Tibia	Fully return to sporting activities	37.5	low
35	Malliaropoulos 2017	Elite athletics athletes, age not specified	Prospective	Navicular	Return to previous high competition level	56.25	moderate
36	Maquirriain & Ghisi 2006	Elite tennis players, 20±5 years	Retrospective	Navicular, Metatarsal, Tibia, Os pubis	Practise and compete without restrictions and without relapse	68.75	moderate
37	Matheson 1987	Different level, different sports (predominantly running), 13-61 years	Retrospective	Femur, Fibula, Metatarsal	Recovery	31.25	low
38	Miller 2018	Collegiate (NCAA Division I) level athletics and cross-country, 18-23 years	Retrospective	Tibia, Metatarsal	Return to unrestricted sports participation	56.25	moderate
39	Miller 2019	Male professional soccer players, 17-31 years.	Retrospective	Metatarsal	Player being available for first team selection	81.25	high
40	Morimoto 2021	High level athletes (soccer, basketball, athletics, rugby), 16-46 years	Retrospective	Metatarsal	Return to their original sport at their preinjury level of performance	75	high
41	Nagao 2012	Soccer, basketball, rugby, handball, 19±3.2 years	Retrospective	Metatarsal	Return to full activity	68.75	moderate

42	Nguyen 2019	Male professional soccer player, 18-31 years	Retrospective	Tibia	Return to the same level of professional sport as prior to the injury	68.75	moderate
43	Noakes 1985	Runners from different levels, 21-54 years.	Retrospective	Os Pubis	Recovery	12.5	very low
44	Nunley 2021	No information on lever or sports, 15-66 years	Retrospective	Navicular	Return to preinjury level of sport without pain	62.5	moderate
45	O'Malley 1996	Professional ballet dancers, 15-40 years	Retrospective	Metatarsal	Return to performance	31.25	low
46	Orava & Hulkko 1984	Different level, different sports (athletics, running, soccer, volleyball) 24-39 years	Retrospective	Tibia	Return to athletic activities	25	low
47	Orava 1991a	International and national level, different sports (athletics, running, cross-country skiing, soccer, volleyball, dancing), 14-39 years	Retrospective	Tibia	Return to athletic activities	25	low
48	Orava 1991b	No information on level, different sports (athletics, baseball, soccer), 19±2 years	Retrospective	Navicular	Full return to preinjury level sports activities	25	low
49	Orava 1995	Elite and recreational level, athletics, 18-60 years	Retrospective	Tibia	Healing	25	low
50	Orava 1996	No information on level, different sport (endurance runner, high jumper, orienteerer, volleyball and soccer player), 19-25 years	Retrospective	Patella	Continue sports normally and being symptom free	25	low
51	Pearce 2011	Male professional rugby union players, no information on age	Prospective	Cuboid, Metatarsal, Navicular, Metatarsal, Sesamoid	Absence	50	moderate
52	Pecina 2011	Competitive athletes, no information on sports, 16-26 years	Retrospective	Metatarsal	Return to full activity	50	moderate
53	Porter 2005	Competitive and recreational level, different sports (basketball, running, track, soccer, lacrosse, baseball), 15-28 years	Retrospective	Metatarsal	Return to sport	56.25	moderate
54	Porter & Torma 2008	Competitive athletes, different sports (predominantly basketball and soccer), mean of 17.6 years	Retrospective	Navicular	Return to sport	25	low
55	Porter 2009	Recreational to professional, different sports (basketball, running, soccer, volleyball, athletics, lacrosse, softball, football, rugby), 15-48 years	Retrospective	Metatarsal	Return to sport	56.25	moderate
56	Potter 2006	No information on level or sports, 33.5±9.6 years	Retrospective	Navicular	Return to sport	37.5	low
57	Ramey 2016	No information on level, predominantly female runners, 32.9±9.2 years	Retrospective	Femur	Return to running	50	moderate
58	Rettig 1988	Competitive basketball players, 14-23 years	Retrospective	Tibia	Complete return of symptom-free sports activities	68.75	moderate
59	Rohena-Quinquilla 2018	Active military, 18-37 years	Retrospective	Femur	Return to military duty without activity limitations	50	moderate
60	Rongstad 2013	No information on level, different sports (runners, Basketball, other), 16-38 years	Retrospective	Metatarsal	Return to sport without pain or decreased function	62.5	moderate
61	Saxena 2000	Elite and recreational athletes, different sports (mostly runners), 17-48 years	Retrospective	Navicular	Return to activity	68.75	moderate
62	Saxena & Fullem 2006	Competitive and recreational athletes, different sports (mostly runners, others not stated), 16-43 years	Prospective	Navicular	Return to activity	93.75	high

63	Saxena 2017	Competitive and recreational athletes, different sports (mostly runners, basketball, other), 13-63 years	Prospective	Navicular	Return to activity	93.75	high
64	Sharma 2015	Military (initial military training program), age not stated for BSI sub-cohort	Prospective	Tibia, Metatarsal, Femur, Calcaneus	Rehabilitation	75	high
65	Simon 2014	High performance athletes, different sports (mostly football (soccer)), 25±4 years	Retrospective	Metatarsal, Calcaneus, Os Pubis	Return to full training/competition	62.5	moderate
66	Stein 2019	Competitive and recreational athletes, different sports (mostly dancers, runners, other), 9-21 years	Retrospective	Hallux Sesamoid	Clearance to return to sports	43.75	low
67	Stone 2021	Professional football (soccer) players, 17-32 years	Retrospective	Metatarsal	Return to play	87.5	high
68	Swenson 1997	Competitive and recreational athletes, different sports (sports discipline not specified), 15-45 years	Prospective	Tibia	Return to full activity	81.25	high
69	Talbot 2008	Active military (training), 17-26 years	Retrospective	Femur	Return to training	37.5	low
70	Torg 1982	Competitive and recreational athletes, different sports (runners, basketball, other), 15-44 years	Retrospective	Navicular	Full activity	62.5	moderate
71	Vajapey 2019	Competitive and recreational runners, 16-53 years	Retrospective	Sacrum	Return to regular activity	25	moderate
72	Volpin 1990	Active military (elite basic training), age not specified	Prospective	Femur	Symptoms subsided completely	56.25	moderate
73	Whitelaw 1991	Competitive athletes, different sports (runners, basketball, other), 17-25 years	Prospective	Tibia	Return to competition	68.75	moderate
74	Wik 2021	Elite youth football (soccer) players, age not specified for BSI subcohort	Prospective	Tibia, Os Pubis	Time loss	93.75	high
75	Wood 2014	Active military (basic training), age not specified	Prospective	Femur, Fibula, Tibia, Metatarsal	Training at preinjury stage	75	high
76	Young 2020	Elite athletes, different sports (mostly soccer), 14-30 years	Retrospective	Metatarsal	Return to previous level of activity	68.75	moderate

1. Time to return to sports

Table 1A. Mean time to RTS (days) meta-analysis for anatomic sites

Study	Mean [95%-CI]	SE	Z-value	p-value	Weight (Pooled tau)
Femur					
Ivkovic 2006	96.000 [80.814-111.186]	7.748	12.390	<0.001	14.85
Johnson 1994	74.800 [58.862-90.738]	8.132	9.199	<0.001	14.75
Ramey 2016	99.880 [81.869-117.891]	9.189	10.869	<0.001	14.46
Rohena-Quinquilla	91.454 [81.396-101.512]	5.132	17.821	<0.001	15.42
Sharma 2015	116.0 [107.919 124.081]	4.123	28.134	<0.001	15.59
Talbot 2008	152.50 [107.162-197.838]	23.132	6.593	<0.001	9.74
Wood 2014	147.70 [135.425-159.975]	6.263	23.583	<0.001	15.20
Total Femur	**109.210 [86.481-131.940]**	**11.597**	**9.417**	**<0.001**	
Heterogeneity: Tau²=548.7, I²=92.3%					
Fibula					
Dickson 1987	30.000 [29.999-30.001]	0.001	51961.524	<0.001	58.47
Wood 2014	93.100 [56.693-129.507]	18.575	5.012	<0.001	41.53
Total Fibula	**56.205 [12.620-99.789]**	**22.238**	**2.527**	**0.011**	
Heterogeneity: Tau²=1818.3, I²=91.3%					
Metatarsal					
Albisetti 2010	45.680 [40.716-50.644]	2.533	18.036	<0.001	6.66
Ekstrand 2012	95.000 [81.365-108.635]	6.957	13.655	<0.001	6.35
Harrington 1993	138.00 [105.834-170.166]	16.412	8.409	<0.001	5.09
Larsson 2016	92.000 [33.477-150.523]	29.859	3.081	0.002	3.27
Maquirriain & Ghisi 2006	58.310 [49.169-67.451]	4.664	12.503	<0.001	6.54
Miller 2019	73.500 [65.831-81.169]	3.913	18.785	<0.001	6.59
Morimoto 2021	76.300 [71.112-81.488]	2.647	28.827	<0.001	6.65
Nagao 2012	78.400 [70.961-85.839]	3.796	20.656	<0.001	6.60
Pecina 2011	63.000 [56.097-69.903]	3.522	17.889	<0.001	6.61
Porter 2005	52.500 [45.499-59.501]	3.572	14.697	<0.001	6.61
Porter 2009	65.100 [47.460-82.740]	9.000	7.233	<0.001	6.12
Rongstad 2013	94.182 [81.184-107.180]	6.632	14.202	<0.001	6.38
Sharma 2015	82.000 [78.537-85.463]	1.767	46.409	<0.001	6.68
Stone 2021	77.700 [72.131-83.269]	2.841	27.348	<0.001	6.65
Wood 2014	85.400 [83.909-86.891]	0.761	112.224	<0.001	6.70
Young 2020	155.40 [145.385-165.415]	5.110	30.411	<0.001	6.51
Total Metatarsal	**82.112 [67.348-96.875]**	**7.532**	**10.901**	**<0.001**	
Heterogeneity: Tau²=313.8, I²=97.4					
Navicular					
Curell 2019	41.000 [28.553-53.447]	6.351	6.456	<0.001	17.12
Jacob 2013	239.600 [99.216-379.984]	71.626	3.345	0.001	2.54
Maquirriain & Ghisi 2006	156.331 [87.180-225.482]	35.282	4.431	<0.001	7.25
Nunley 2021	203.30 [152.805-253.795]	25.763	7.891	<0.001	10.05
Saxena 2000	109.523 [85.887-133.159]	12.059	9.082	<0.001	15.30

Saxena 2006	121.197 [103.0-139.387]	9.280	13.059	<0.001	16.27
Saxena 2017	134.726 [122.60-146.849]	6.185	21.782	<0.001	17.16
Torg 1982	158.219 [129.55-186.885]	14.626	10.818	<0.001	14.31
Total Navicular	**127.107 [102.97-151.244]**	**12.315**	**10.321**	**<0.001**	
Heterogeneity: Tau²=2705.3, I²=95.7%					
Os pubis					
Noakes 1985	96.830 [77.514-116.146]	9.855	9.825	<0.001	34.93
Simon 2014	129.300 [91.211-167.389]	19.433	6.654	<0.001	26.92
Wik 2021	21.000 [12.718-29.282]	4.226	4.969	<0.001	38.14
Total Os pubis	**76.650 [41.078-112.221]**	**18.149**	**4.223**	**<0.001**	
Heterogeneity: Tau²=3287.7, I²=97.3%					
Tibia					
Allen 2004	40.900 [33.406-48.394]	3.824	10.697	<0.001	6.98
Beck 2008	27.500 [22.987-32.013]	2.303	11.942	<0.001	7.06
Curell 2019	40.000 [18.500-61.500]	10.970	3.646	<0.001	6.22
Dickson 1987	27.000 [24.211-29.789]	1.423	18.974	<0.001	7.09
Ekstrand 2012	88.000 [15.186-160.814]	37.151	2.369	0.018	2.70
Jamieson 2017	95.900 [80.499-111.301]	7.858	12.205	<0.001	6.62
Johansson 1992	88.200 [79.254-97.146]	4.564	19.324	<0.001	6.93
Kijowski 2012	43.500 [40.424-46.576]	1.569	27.720	<0.001	7.08
Nguyen 2019	125.050 [98.897-151.203]	13.344	9.371	<0.001	5.87
Orava 1991a	200.94 [148.609-253.271}	26.700	7.526	<0.001	3.85
Orava 1995	144.875 [135.628-154.12]	4.718	30.708	<0.001	6.92
Sharma 2015	85.000 [82.752-87.248]	1.147	74.117	<0.001	7.09
Swenson 1997	45.889 [42.437-49.340]	1.761	26.059	<0.001	7.08
Whitelaw 1991	36.750 [24.605-48.895]	6.197	5.930	<0.001	6.79
Wik 2021	58.700 [18.031-99.369]	20.750	2.829	0.005	4.71
Wood 2014	147.70 [141.231-154.169]	3.300	44.751	<0.001	7.01
Total Tibia	**77.115 [61.924-92.305]**	**7.750**	**9.950**	**<0.001**	
Heterogeneity: Tau²=1261.1, I²=99.6%					

Table 1B. Mean time to RTS (days) meta-analysis for anatomic sites (sub-analysis)

Study	Mean [95%-CI]	SE	Z-value	p-value	Weight (Pooled tau)
Femur neck					
Ramey 2016	99.880 [81.869-117.891]	9.189	10.869	<0.001	37.56
Rohena-Quinquilla 2018	91.454 [81.396-101.512]	5.132	17.821	<0.001	42.24
Talbot 2008	152.50 [107.162-197.838]	23.132	6.593	<0.001	20.21
Total femur neck	**106.953 [79.439-134.468]**	**14.038**	**7.619**	**<0.001**	
Heterogeneity: Tau²=234.3, I²=71.1%					
Femur shaft					
Ivkovic 2006	96.000 [80.814-111.186]	7.748	12.390	<0.001	50.30
Johnson 1994	74.800 [58.862-90.738]	8.132	9.199	<0.001	49.70
Total femur shaft	**85.464 [54.372-116.557]**	**15.864**	**5.387**	**<0.001**	
Heterogeneity: Tau²=161.6, I²=71.9%					
Metatarsal 1-4					
Albisetti 2010	45.680 [40.716-50.644]	2.533	18.036	<0.001	28.42
Harrington 1993	138.000 105.834 170.166	16.412	8.409	<0.001	17.89
Maquirriain & Ghisi 2006	58.310 49.169 67.451	4.664	12.503	<0.001	27.48
Rongstad 2013a	94.182 81.184 107.180	6.632	14.202	<0.001	26.21
Total Metatarsal 1-4	**78.380 [56.298-100.463]**	**11.267**	**6.957**	**<0.001**	
Heterogeneity: Tau²=648.1, I²=95.9%					
Metatarsal 5					
Ekstrand 2012	95.000 81.365 108.635	6.957	13.655	<0.001	10.56
Miller 2019	73.500 65.831 81.169	3.913	18.785	<0.001	11.32
Morimoto 2021	76.300 [71.112-81.488]	2.647	28.827	<0.001	11.53
Nagao 2012	78.400 [70.961-85.839]	3.796	20.656	<0.001	11.35
Pecina 2011	63.000 [56.097-69.903]	3.522	17.889	<0.001	11.40
Porter 2005	52.500 [45.499-59.501]	3.572	14.697	<0.001	11.39
Porter 2009	65.100 [47.460-82.740]	9.000	7.233	<0.001	9.90
Stone 2021	77.700 [72.131-83.269]	2.841	27.348	<0.001	11.51
Young 2020	155.40 [145.385-165.415]	5.110	30.411	<0.001	11.06
Total Metatarsal 5	**81.771 [67.695-95.848]**	**7.182**	**11.385**	**<0.001**	
Heterogeneity: Tau²=557.7, I²=97.4%					
Tibia medial malleolus					
Curell 2019	40.000 [18.500-61.500]	10.970	3.646	<0.001	32.06
Nguyen 2019	125.050 [98.897-151.203]	13.344	9.371	<0.001	29.07
Orava 1995	144.88 [135.628-154.122]	4.718	30.708	<0.001	38.86
Total Tibia medial malleolus	**105.484 [79.206-131.761]**	**13.407**	**7.868**	**<0.001**	
Heterogeneity: Tau²=3291.1, I²=97.4%					
Tibia posteromedial					
Allen 2004	40.900 [33.406-48.394]	3.824	10.697	<0.001	16.63
Beck 2008	27.500 [22.987-32.013]	2.303	11.942	<0.001	16.98

Dickson 1987	27.000 [24.211-29.789]	1.423	18.974	<0.001	17.11
Johansson 1992	88.200 [79.254-97.146]	4.564	19.324	<0.001	16.41
Swenson 1997	45.889 [42.437-49.340]	1.761	26.059	<0.001	17.06
Whitelaw 1991	36.750 [24.605-48.895]	6.197	5.930	<0.001	15.81
Total Tibia posteromedial *Heterogeneity: Tau²=263.6, I²=97.7%*	**44.203 [27.155-61.252]**	**8.698**	**5.082**	**<0.001**	

2. Return to sport (RTS) rate

Table 2A. Rate of RTS (event rate) meta-analysis for anatomic sites

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur				
Butler 1982	0.833 [0.369-0.977]	1.469	0.142	8.92
Clement 1993	0.821 [0.636-0.924]	3.093	0.002	15.86
Fullerton 1988	0.464 [0.292-0.646]	-0.378	0.706	17.26
Hulkko 1987	0.979 [0.741-0.999]	2.694	0.007	6.44
Ivkovic 2006	0.938 [0.461-0.996]	1.854	0.064	6.25
Johansson 1990	0.522 [0.325-0.712]	0.208	0.835	16.80
Johnson 1994	0.944 [0.495-0.997]	1.947	0.052	6.28
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	15.77
Wood 2014	0.977 [0.723-0.999]	2.629	0.009	6.43
Total Femur	**78.9 [0.612-0.899]**	**2.993**	**0.003**	
Heterogeneity: Tau²=0.86, I²=66.8%				
Fibula				
Dickson 1987	0.875 [0.266-0.993]	1.287	0.198	16.19
Hong 2009	0.962 [0.597-0.998]	2.232	0.026	17.28
Hulkko 1987	0.989 [0.846-0.999]	3.156	0.002	17.61
Khan 2018	0.750 [0.377-0.937]	1.346	0.178	32.06
Wood 2014	0.929 [0.423-0.996]	1.748	0.081	16.87
Total Fibula	**0.901 [0.758-0.964]**	**4.058**	**<0.001**	
Heterogeneity: Tau²=0.41, I²=20.0%				
Hallux				
Hulkko 1987	0.969 [0.650-0.998]	2.390	0.017	27.30
Stein 2019	0.850 [0.721-0.925]	4.336	<0.001	72.70
Total Hallux	**0.865 [0.751-0.932]**	**4.818**	**<0.001**	
Heterogeneity: Tau²=0.33, I²=22.9%				
Metatarsal				
Albisetti 2010	0.975 [0.702-0.998]	2.558	0.011	3.91
Curell 2019	0.500 [0.059-0.941]	0.000	1.000	3.98
Delee 1983	0.955 [0.552-0.997]	2.103	0.035	3.86
Ekstrand 2012	0.988 [0.833-0.999]	3.088	0.002	3.95
Fernandez Fairen 1999	0.778 [0.421-0.944]	1.562	0.118	7.30
Harrington 1993	0.833 [0.369-0.977]	1.469	0.142	5.44
Hulkko 1987	0.993 [0.901-1.000]	3.517	<0.001	3.96
Khan 2018	0.571 [0.316-0.794]	0.533	0.594	9.31
Lee 2011	0.993 [0.903-1.000]	3.536	<0.001	3.96
Maquirriain & Ghisi 2006	0.875 [0.266-0.993]	1.287	0.198	3.63
Miller 2019	0.987 [0.822-0.999]	3.033	0.002	3.95
Morimoto 2021	0.987 [0.822-0.999]	3.033	0.002	3.95
Nagao 2012	0.992 [0.882-0.999]	3.377	0.001	3.96
O'Malley 1996	0.992 [0.889-1.000]	3.423	0.001	3.96
Pecina 2011	0.976 [0.713-0.999]	2.594	0.009	3.92
Porter 2005	0.980 [0.749 0.999]	2.724	0.006	3.93
Porter 2009	0.976 [0.713-0.999]	2.594	0.009	3.92
Rongstad 2013	0.958 [0.575-0.997]	2.170	0.030	3.87
Simon 2014	0.833 [0.194-0.990]	1.039	0.299	3.51
Stone 2021	0.952 [0.729-0.993]	2.924	0.003	5.84
Wood 2014	0.997 [0.947-1.000]	3.995	<0.001	3.97
Young 2020	0.974 [0.835-0.996]	3.563	<0.001	5.91
Total Metatarsal	**0.955 [0.916-0.977]**	**8.892**	**<0.001**	

Heterogeneity: Tau²=1.96, I²=57.8%				
Navicular				
Burne 2005	0.650 [0.426-0.823]	1.320	0.187	10.84
Curell 2019	0.667 [0.376-0.869]	1.132	0.258	9.60
Hulkko 1987	0.889 [0.500-0.985]	1.961	0.050	6.19
Jacob 2013	0.800 [0.459-0.950]	1.754	0.080	8.11
Khan 1992	0.535 [0.429-0.637]	0.646	0.518	12.65
Khan 2018	0.333 [0.043-0.846]	-0.566	0.571	5.25
Malliaropoulos 2017	0.962 [0.597-0.998]	2.232	0.026	4.26
Maquirriain & Ghisi 2006	0.667 [0.154-0.957]	0.566	0.571	5.2
Nunley 2021	0.933 [0.648-0.991]	2.550	0.011	6.37
Orava 1991b	0.950 [0.525-0.997]	2.029	0.042	4.23
Porter 2008	0.950 [0.525-0.997]	2.029	0.042	4.23
Potter 2006	0.983 [0.783-0.999]	2.859	0.004	4.33
Saxena 2000	0.978 [0.732-0.999]	2.662	0.008	4.31
Saxena 2006	0.974 [0.690-0.998]	2.519	0.012	4.30
Torg 1982	0.810 [0.588-0.927]	2.604	0.009	10.09
Total Navicular	**0.830 [0.707-0.909]**	**4.393**	**<0.001**	
Heterogeneity: Tau²=0.89, I²=63.2%				
Os pubis				
Noakes 1985	0.962 [0.597-0.998]	2.232	0.026	50.21
Simon 2014	0.950 [0.525-0.997]	2.029	0.042	49.79
Total Os pubis	**0.956 [0.746-0.994]**	**3.014**	**0.003**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Patella				
Khan 2018	0.833 [0.194-0.990]	1.039	0.299	48.34
Orava 1996	0.917 [0.378-0.995]	1.623	0.105	51.66
Total Patella	**0.883 [0.482-0.984]**	**1.892**	**0.059**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Talus				
Curell 2019	0.667 [0.406-0.854]	1.266	0.206	72.4
Hulkko 1987	0.833 [0.194-0.990]	1.039	0.299	27.52
Total Talus	**0.689 [0.446-0.859]**	**1.539**	**0.124**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia				
Allen 2004	0.976 [0.713-0.999]	2.594	0.009	3.54
Beals & Cook 1991	0.733 [0.467-0.896]	1.733	0.083	8.10
Beck 2008	0.989 [0.843-0.999]	3.140	0.002	3.57
Curell 2019	0.875 [0.266-0.993]	1.287	0.198	3.28
Dickson 1987	0.955 [0.552-0.997]	2.103	0.035	3.49
Ditmars 2020	0.988 [0.840-0.999]	3.123	0.002	3.57
Ekstrand 2012	0.929 [0.423-0.996]	1.748	0.081	3.42
Hulkko 1987	0.997 [0.958-1.000]	4.166	<0.001	3.59
Johansson 1992	0.756 [0.603-0.863]	3.111	0.002	9.61
Jowett 2008	0.917 [0.378-0.995]	1.623	0.105	3.39
Khan 2018	0.692 [0.409-0.880]	1.349	0.177	7.98
Kilcoyne 2013	0.974 [0.690-0.998]	2.519	0.012	3.54
Lempainen 2012	0.900 [0.533-0.986]	2.084	0.037	5.13
Liimatainen 2009	0.755 [0.610-0.859]	3.247	0.001	9.72
Nguyen 2019	0.971 [0.664-0.998]	2.436	0.015	3.53
Orava & Hulkko 1984	0.938 [0.461-0.996]	1.854	0.064	3.45
Orava 1991a	0.972 [0.678-0.998]	2.479	0.013	3.53
Orava 1995	0.944 [0.495-0.997]	1.947	0.052	3.46
Rettig 1988	0.938 [0.461-0.996]	1.854	0.064	3.45
Swenson 1997	0.974 [0.690-0.998]	2.519	0.012	3.54
Whitelaw 1991	0.972 [0.678-0.998]	2.479	0.013	3.53

Wood 2014	0.991 [0.866-0.999]	3.275	0.001	3.58
Total Tibia	**0.928 [0.872-0.961]**	**7.808**	**<0.001**	
Heterogeneity: Tau²=0.85, I²=51.2%				

Table 2B. Rate of RTS (event rate) meta-analysis for anatomic sites (sub-analysis)

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur neck				
Fullerton 1988	0.464 [0.292-0.646]	-0.378	0.706	31.70
Hulkko 1987	0.950 [0.525-0.997]	2.029	0.042	9.55
Johansson 1990	0.522 [0.325-0.712]	0.208	0.835	30.59
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	28.16
Total Femur Neck	**0.553 [0.436-0.665]**	**0.886**	**0.375**	
Heterogeneity: Tau²=0.21, I²=44.9%				
Femur shaft				
Hulkko 1987	0.967 [0.634-0.998]	2.341	0.019	33.78
Ivkovic 2006	0.938 [0.461-0.996]	1.854	0.064	33.02
Johnson 1994	0.944 [0.495-0.997]	1.947	0.052	33.20
Total Femur Shaft	**0.951 [0.791-0.990]**	**3.548**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Metatarsal 1-4				
Albisetti 2010	0.975 [0.702-0.998]	2.558	0.011	15.67
Harrington 1993	0.833 [0.369-0.977]	1.469	0.142	22.68
Hulkko 1987	0.992 [0.885-1.000]	3.401	0.001	15.87
Maquirriain & Ghisi 2006	0.875 [0.266-0.993]	1.287	0.198	14.44
O'Malley 1996	0.992 [0.889-1.000]	3.423	0.001	15.87
Rongstad 2013	0.958 [0.575-0.997]	2.170	0.030	15.47
Metatarsal 1-4	**0.960 [0.890-0.986]**	**5.724**	**<0.001**	
Heterogeneity: Tau²=0.22, I²=10.5%				
Metatarsal 5				
Curell 2019	0.500 [0.059-0.941]	0.000	1.000	5.35
Delee 1983	0.955 [0.552-0.997]	2.103	0.035	5.17
Ekstrand 2012	0.988 [0.833-0.999]	3.088	0.002	5.31
Fernandez Fairen 1999	0.778 [0.421-0.944]	1.562	0.118	10.76
Hulkko 1987	0.958 [0.575-0.997]	2.170	0.030	5.19
Khan 2018	0.571 [0.316-0.794]	0.533	0.594	14.56
Lee 2011	0.993 [0.903-1.000]	3.536	<0.001	5.33
Miller 2019	0.987 [0.822-0.999]	3.033	0.002	5.30
Morimoto 2021	0.987 [0.822-0.999]	3.033	0.002	5.30
Nagao 2012	0.992 [0.882-0.999]	3.377	0.001	5.32
Pecina 2011	0.976 [0.713-0.999]	2.594	0.009	5.26
Porter 2005	0.980 [0.749-0.999]	2.724	0.006	5.27
Porter 2009	0.976 [0.713-0.999]	2.594	0.009	5.26
Stone 2021	0.952 [0.729-0.993]	2.924	0.003	8.26
Young 2020	0.974 [0.835-0.996]	3.563	<0.001	8.37
Metatarsal 5	**0.946 [0.892-0.973]**	**7.508**	**<0.001**	
Heterogeneity: Tau²=2.14, I²=62.2%				
Tibia anterior				
Beals & Cook 1991	0.733 [0.374-0.924]	1.423	0.247	32.35
Johansson 1992	0.091 [0.013-0.439]	-2.195	0.028	13.22
Liimatainen 2009	0.755 [0.610-0.859]	3.247	0.001	28.98
Orava & Hulkko 1984	0.938 [0.461-0.996]	1.854	0.064	8.40
Orava 1991a	0.972 [0.678-0.998]	2.479	0.013	8.64

Rettig 1988	0.938 [0.461-0.996]	1.854	0.064	8.40
Total Tibia Anterior	**0.755 [0.541-0.889]**	**2.300**	**0.021**	
Heterogeneity: Tau²=1.32, I²=63.4%				
Tibia medial malleolus				
Curell 2019	0.875 [0.266-0.993]	1.287	0.198	17.17
Jowett 2008	0.917 [0.378-0.995]	1.623	0.105	17.79
Lempainen 2012	0.900 [0.533-0.986]	2.084	0.037	28.29
Nguyen 2019	0.971 [0.664-0.998]	2.436	0.015	18.57
Orava 1995	0.944 [0.495-0.997]	1.947	0.052	18.19
Total Tibia Medial	**0.926 [0.794-0.976]**	**4.196**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia posteromedial				
Allen 2004	0.976 [0.713-0.999]	2.594	0.009	16.68
Beck 2008	0.989 [0.843-0.999]	3.140	0.002	16.84
Dickson 1987	0.955 [0.552-0.997]	2.103	0.035	16.41
Johansson 1992	0.984 [0.789-0.999]	2.883	0.004	16.78
Swenson 1997	0.974 [0.690-0.998]	2.519	0.012	16.65
Whitelaw 1991	0.972 [0.678-0.998]	2.479	0.013	16.63
Total Tibia Posteromedial	**0.977 [0.931-0.993]**	**6.422**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				

3. Complication rate

Table 3A. Complication rate (event rate) meta-analysis for anatomic sites

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur				
Wood 2014	0.023 [0.001-0.277]	-2.629	0.009	4.56
Hulkko 1987	0.043 [0.006-0.252]	-3.023	0.003	7.00
Johnson 1994	0.056 [0.003-0.505]	-1.947	0.052	4.45
Ivkovic 2006	0.063 [0.004-0.539]	-1.854	0.064	4.42
Volpin 1990	0.222 [0.056-0.579]	-1.562	0.118	8.93
Clement 1993	0.258 [0.135-0.437]	-2.573	0.010	13.21
Cochran 2020	0.267 [0.104-0.533]	-1.733	0.083	11.25
Butler 1982	0.333 [0.084-0.732]	-0.800	0.423	8.32
Johansson 1990	0.565 [0.326-0.777]	0.520	0.603	12.15
Fullerton 1988	0.571 [0.387-0.738]	0.753	0.451	13.52
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	12.20
Total Femur	**0.289 [0.167-0.452]**	**-2.493**	**0.013**	
Heterogeneity: Tau²=0.91, I²=68.9%				
Fibula				
Hulkko 1987	0.011 [0.001-0.154]	-3.156	0.002	25.97
Hong 2009	0.038 [0.002-0.403]	-2.232	0.026	25.45
Wood 2014	0.071 [0.004-0.577]	-1.748	0.081	24.82
Dickson 1987	0.125 [0.007-0.734]	-1.287	0.198	23.77
Total Fibula	**0.043 [0.011-0.159]**	**-4.240**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Hallux				
Stein 2019	0.102 [0.043-0.222]	-4.609	<0.001	73.43
Hulkko 1987	0.969 [0.650-0.998]	2.390	0.017	26.57
Total Hallux	**0.335 [0.083-0.737]**	**-0.785**	**0.432**	
Heterogeneity: Tau²=14.6, I²=92.7%				
Metatarsal				
Wood 2014	0.003 [0.000-0.053]	-3.995	0.000	2.84
Morimoto 2021	0.013 [0.001-0.178]	-3.033	0.002	2.82
Porter 2005	0.020 [0.001-0.251]	-2.724	0.006	2.81
Albisetti 2010	0.025 [0.002-0.298]	-2.558	0.011	2.80
Nagao 2012	0.033 [0.008-0.124]	-4.682	<0.001	6.01
Delee 1983	0.045 [0.003-0.448]	-2.103	0.035	2.76
Pecina 2011	0.050 [0.007-0.282]	-2.870	0.004	4.29
Hulkko 1987	0.055 [0.021-0.137]	-5.537	<0.001	7.40
Maquirriain & Ghisi 2006	0.125 [0.007-0.734]	-1.287	0.198	2.59
O'Malley 1996	0.140 [0.074-0.248]	-5.039	<0.001	8.45
Porter 2009	0.150 [0.049-0.376]	-2.770	0.006	6.62
Simon 2014	0.167 [0.010-0.806]	-1.039	0.299	2.49
Harrington 1993	0.167 [0.023-0.631]	-1.469	0.142	3.98
Rongstad 2013	0.182 [0.046-0.507]	-1.924	0.054	5.61
Lee 2011	0.200 [0.124-0.306]	-4.802	<0.001	8.89
Young 2020	0.211 [0.109-0.368]	-3.322	0.001	8.21
Fernandez Fairen 1999	0.222 [0.056-0.579]	-1.562	0.118	5.49

Stone 2021	0.222 [0.093-0.444]	-2.387	0.017	7.33
Miller 2019	0.405 [0.261-0.568]	-1.144	0.253	8.61
Total Metatarsal	**0.114 [0.069-0.183]**	**-7.234**	**<0.001**	
Heterogeneity: Tau²=0.59, I²=61.3%				
Navicular				
Malliaropoulos 2017	0.038 [0.002-0.403]	-2.232	0.026	3.86
Orava 1991b	0.050 [0.003-0.475]	-2.029	0.042	3.83
Saxena 2006	0.053 [0.007-0.294]	-2.813	0.005	5.97
Saxena 2017	0.129 [0.066-0.237]	-5.041	<0.001	11.63
Nunley 2021	0.200 [0.066-0.470]	-2.148	0.032	9.06
Saxena 2000	0.227 [0.098-0.444]	-2.405	0.016	10.38
Potter 2006	0.241 [0.120-0.427]	-2.639	0.008	11.11
Hulkko 1987	0.330 [0.109-0.664]	-0.999	0.318	8.47
Maquirriain & Ghisi 2006	0.333 [0.043-0.846]	-0.566	0.571	4.83
Torg 1982	0.333 [0.168-0.553]	-1.497	0.134	10.83
Jacob 2013	0.400 [0.158-0.703]	-0.628	0.530	9.06
Burne 2005	0.450 [0.253-0.664]	-0.446	0.655	10.96
Total Navicular	**0.241 [0.186-0.307]**	**-6.783**	**<0.001**	
Heterogeneity: Tau²=0.23, I²=38.6%				
Os pubis				
Noakes 1985	0.038 [0.002-0.403]	-2.232	0.026	50.22
Simon 2014	0.050 [0.003-0.475]	-2.029	0.042	49.78
Total Os pubis	**0.044 [0.006-0.254]**	**-3.014**	**0.003**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia				
Wood 2014	0.009 [0.001-0.134]	-3.275	0.001	3.43
Beck 2008	0.011 [0.001-0.157]	-3.140	0.002	3.43
Allen 2004	0.024 [0.001-0.287]	-2.594	0.009	3.39
Swenson 1997	0.026 [0.002-0.310]	-2.519	0.012	3.39
Whitelaw 1991	0.028 [0.002-0.322]	-2.479	0.013	3.39
Hulkko 1987	0.044 [0.022-0.085]	-8.517	<0.001	10.24
Dickson 1987	0.045 [0.003-0.448]	-2.103	0.035	3.34
Orava 1995	0.056 [0.003-0.505]	-1.947	0.052	3.32
Nguyen 2019	0.063 [0.009-0.335]	-2.622	0.009	5.16
Orava & Hulkko 1984	0.063 [0.004-0.539]	-1.854	0.064	3.30
Jamieson 2017	0.067 [0.012-0.293]	-2.944	0.003	6.00
Jowett 2008	0.083 [0.005-0.622]	-1.623	0.105	3.24
Lempainen 2012	0.100 [0.014-0.467]	-2.084	0.037	5.04
Rettig 1988	0.125 [0.015-0.573]	-1.703	0.089	4.58
Johansson 1992	0.244 [0.137-0.397]	-3.111	0.002	10.22
Liimatainen 2009	0.245 [0.141-0.390]	-3.247	0.001	10.36
Orava 1991a	0.529 [0.303-0.745]	0.242	0.808	9.22
Beals & Cook 1991	0.533 [0.293-0.759]	0.258	0.796	8.95
Total Tibia	**0.112 [0.064-0.189]**	**-6.623**	**<0.001**	
Heterogeneity: Tau²=1.38, I²=73.5%				

Table 3B. Complication rate (event rate) meta-analysis for anatomic sites (sub-analysis)

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur neck				
Hulkko 1987	0.050 [0.003-0.475]	-2.029	0.042	4.78
Volpin 1990	0.222 [0.056-0.579]	-1.562	0.118	11.37
Clement 1993	0.258 [0.026-0.822]	-0.800	0.423	5.59
Cochran 2020	0.267 [0.124-0.483]	-2.098	0.036	18.54
Johansson 1990	0.565 [0.363-0.748]	0.624	0.533	20.27
Fullerton 1988	0.571 [0.387-0.738]	0.753	0.451	21.39
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	18.06
Total Femur neck	**0.428 [0.275-0.596]**	**-0.835**	**0.404**	
Heterogeneity: Tau²=0.45, I²=58.0%				
Femur shaft				
Johnson 1994	0.056 [0.003-0.505]	-1.947	0.052	13.96
Ivkovic 2006	0.063 [0.004-0.539]	-1.854	0.064	13.87
Hulkko 1987	0.070 [0.010-0.370]	-2.469	0.014	23.36
Clement 1993	0.258 [0.105-0.508]	-1.905	0.057	48.80
Total Femur shaft	**0.162 [0.075-0.315]**	**-3.718**	**<0.001**	
Heterogeneity: Tau²=0.05, I²=4.3%				
Metatarsal 1-4				
Hulkko 1987	0.008 [0.000-0.115]	-3.401	0.001	8.93
Albisetti 2010	0.025 [0.002-0.298]	-2.558	0.011	8.80
Maquirriain & Ghisi 2006	0.125 [0.007-0.734]	-1.287	0.198	8.04
O'Malley 1996	0.140 [0.074-0.248]	-5.039	<0.001	39.67
Harrington 1993	0.167 [0.023-0.631]	-1.469	0.142	13.43
Rongstad	0.182 [0.046-0.507]	-1.924	0.054	21.12
Total Metatarsal 1-4	**0.123 [0.073-0.199]**	**-6.702**	**<0.001**	
Heterogeneity: Tau²=0.18, I²=18.0%				
Metatarsal 5				
Morimoto 2021	0.013 [0.001-0.178]	-3.033	0.002	3.05
Porter 2005	0.020 [0.001-0.251]	-2.724	0.006	3.03
Nagao 2012	0.033 [0.008-0.124]	-4.682	<0.001	7.96
Delee 1983	0.045 [0.003-0.448]	-2.103	0.035	2.96
Pecina 2011	0.050 [0.007-0.282]	-2.870	0.004	5.06
Porter 2009	0.150 [0.049-0.376]	-2.770	0.006	9.19
Lee 2011	0.200 [0.124-0.306]	-4.802	<0.001	14.85
Young 2020	0.211 [0.109-0.368]	-3.322	0.001	12.92
Fernandez Fairen 1999	0.222 [0.056-0.579]	-1.562	0.118	7.02
Stone 2021	0.222 [0.093-0.444]	-2.387	0.017	10.74
Hulkko 1987	0.364 [0.143-0.661]	-0.893	0.372	9.18
Miller 2019	0.405 [0.261-0.568]	-1.144	0.253	14.04
Total Metatarsal 5	**0.165 [0.104-0.252]**	**-5.938**	**<0.001**	
Heterogeneity: Tau²=0.53, I²=62.7%				
Tibia anterior				
Orava & Hulkko 1984	0.063 [0.004-0.539]	-1.854	0.064	6.05
Rettig 1988	0.125 [0.015-0.573]	-1.703	0.089	8.96
Liimatainen 2009	0.245 [0.141-0.390]	-3.247	0.001	28.69
Orava 1991a	0.529 [0.303-0.745]	0.242	0.808	23.61
Beals & Cook 1991	0.533 [0.293-0.759]	0.258	0.796	22.51
Johansson 1992	0.909 [0.561-0.987]	2.195	0.028	10.17
Total Tibia anterior	**0.409 [0.242-0.599]**	**-0.939**	**0.348**	

Heterogeneity: Tau²=0.96, I²=71.3%				
Tibia medial malleolus				
Orava 1995	0.056 [0.003-0.505]	-1.947	0.052	18.72
Nguyen 2019	0.063 [0.009-0.335]	-2.622	0.009	31.97
Jowett 2008	0.083 [0.005-0.622]	-1.623	0.105	18.26
Lempainen 2012	0.100 [0.014-0.467]	-2.084	0.037	31.04
Total Tibia medial malleolus	**0.075 [0.024-0.209]**	**-4.179**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia posteromedial				
Beck 2008	0.011 [0.001-0.157]	-3.140	0.002	16.86
Johansson 1992	0.016 [0.001-0.211]	-2.883	0.004	16.79
Allen 2004	0.024 [0.001-0.287]	-2.594	0.009	16.69
Swenson 1997	0.026 [0.002-0.310]	-2.519	0.012	16.65
Whitelaw 1991	0.028 [0.002-0.322]	-2.479	0.013	16.63
Dickson 1987	0.045 [0.003-0.448]	-2.103	0.035	16.38
Total Tibia posteromedial	**0.023 [0.007-0.069]**	**-6.422**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				

	Authors	Study population (sports, age)	Directionality	Bone(s)	Return to sports (RTS) definition	Risk of bias (RoB) rating	RoB judgement (study quality)
1	Albisetti 2010	Trainee ballet dancers, 10-21 years	Retrospective	Metatarsal	Full activity after onset of symptoms	68.75	moderate
2	Allen 2004	Active duty military, 18-32 years	Prospective	Tibia	Pain-free one mile run	56.25	moderate
3	Beals & Cook 1991	High-performance athletes (mostly Basketball), 16-24 years	Retrospective	Tibia	Return to full activity	43.75	low
4	Beck 2008	Mostly distance runners, 18-50 years	Prospective	Tibia	Hopping for 30 seconds without pain	93.75	high
5	Burne 2005	College athletes, different sports, 13 - 48 years	Retrospective	Navicular	Return to sport at the same competitive level as before injury	68.75	moderate
6	Butler 1982	College track athletes, 18 - 22 years	Retrospective	Femur	Full return to sport	43.75	low
7	Clement 1993	Competitive and recreational runners, different sports (mostly runners), mean age 29 years	Prospective	Femur	Resumed to full activity without limitations	37.5	low
8	Cochran 2020	Active duty military, 18-26 years	Retrospective	Femur	According to Hip function, Hip Outcome Score Sport, military discharge	56.25	moderate
9	Curell 2019	Active duty military, 21 ± 3 years	Retrospective	Talus, Navicular, Metatarsal, Tibia	Return to training	68.75	moderate
10	DeLee 1983	High-performance athletes, different sports (mostly Basketball), 18-28 years	Prospective	Metatarsal	Return to competitive athletics	75	high
11	Dickson & Kichline 1987	Recreational and competitive athletes, different sports, 14-40 years	Prospective	Fibula, Tibia	Return to competition	50	moderate
12	Ditmars 2020	Pediatric athletes, different sports (mostly runners), 7-18 years	Retrospective	Tibia	Full Sports participation	56.25	moderate
13	Ekstrand & Torstveit 2012	Elite football (soccer) players, 25±5 years	Prospective	Metatarsal, Tibia, Pelvic, Fibula	Return to sports participation	87.5	high
14	Fernández Fairen 1999	Competitive basketball players, 15-32 years	Prospective	Metatarsal	Resumption of sports	87.5	high
15	Fullerton & Snowdy 1988	Active military (mostly basic training), 16-33 years	Retrospective	Femur	Full activity without pain	43.75	low
16	Harrington 1993	Professional and recreational ballet dancers, 15-24 years	Retrospective	Metatarsal, Fibula, Tibia	Return to full dancing	50	moderate
17	Heaslet & Kanda-Mehtani 2007	High school, college and recreational athletes, different sports, 16-66 years	Retrospective	Metatarsal, Fibula, Tibia	Return to activity at pre-injury level	37.5	low
18	Hong & Chu 2009	Active military (basic training), 20-22 years	Retrospective	Fibula	Able to perform all activities	37.5	low
19	Hulkko & Orava 1987	Recreational and competitive athletes, different sports (mostly runners), 22±7 years	Retrospective	Tibia, Metatarsal, Fibula, Hallux Sesamoid, Femur, Navicular, Talus, Digitus 1	Resume training	56.25	moderate
20	Ivkovic 2006	Top level runners, 17-21 years	Retrospective	Femur	Return to full sport	31.25	low
21	Jacob & Paterson 2013	Level not specified, different sports, 18-50 years	Retrospective	Navicular	Full return to sports	31.25	low
22	Jamieson 2017	College track and field athletes, 20±1 years	Retrospective	Tibia	Return to running	50	moderate

23	Johansson 1990	Elite and recreational, different sports (mostly runners), 17-49 years	Retrospective	Femur	Return to previous activity level	50	moderate
24	Johansson 1992	Mixed sports cohort (dancing, running, soccer, tennis, volleyball, handball, triathlon, athletics), 11-44 years	Retrospective	Tibia	No symptoms whatsoever	50	moderate
25	Johnson 1994	NCAA Division I athletes (Lacrosse, athletics, football), 18-20 years	Retrospective	Femur	Full activity	37.5	low
26	Jowett 2008	Elite athletes, mixed sports (Athletics, Australian Rules Football, Cricket), 18-28 years	Retrospective	Tibia	Resume sporting activity at previous level	31.25	low
27	Khan 1992	International, national, and recreational athletes, sports not specified, 14-39 years	Retrospective	Navicular	Return to sports	56.25	moderate
28	Khan 2018	Male elite basketball players (NBA), 25.4±4.1 years	Retrospective	Metatarsal, Tibia, Fibula, Navicular, Patella, Calcaneus, Hallux Sesamoid	Return to play	56.25	moderate
29	Kijowski 2012	Different level, mixed sports(long-distance running, sprinting, pole vaulting, high jumping, basketball, soccer and dancing), 14-54 years	Retrospective	Tibia	Return to sports activity	50	moderate
30	Kilcoyne 2013	Military recruits (USNA), no information on age	Retrospective	Tibia	Return to activity	31.25	low
31	Larsson 2016	Male elite football players (UEFA), no information on age	Prospective	Metatarsal	Full participation in training sessions and availability for match selection	75	high
32	Lee 2011	Elite level athletes (mainly male soccer), 13-33 years	Retrospective	Metatarsal	Return to previous level of sports activity	37.5	low
33	Lempainen 2012	Athletics (jumping events and hurdling), long-distance running, soccer, biathlon, 17-39 years	Retrospective	Tibia	Fully return to the pre-injury level of sporting activities	56.25	moderate
34	Liimatainen 2009	Elite level, different sports (predominantly endurance runners), 16-37 years	Retrospective	Tibia	Fully return to sporting activities	37.5	low
35	Malliaropoulos 2017	Elite athletics athletes, age not specified	Prospective	Navicular	Return to previous high competition level	56.25	moderate
36	Maquirriain & Ghisi 2006	Elite tennis players, 20±5 years	Retrospective	Navicular, Metatarsal, Tibia, Os pubis	Practise and compete without restrictions and without relapse	68.75	moderate
37	Matheson 1987	Different level, different sports (predominantly running), 13-61 years	Retrospective	Femur, Fibula, Metatarsal	Recovery	31.25	low
38	Miller 2018	Collegiate (NCAA Division I) level athletics and cross-country, 18-23 years	Retrospective	Tibia, Metatarsal	Return to unrestricted sports participation	56.25	moderate
39	Miller 2019	Male professional soccer players, 17-31 years.	Retrospective	Metatarsal	Player being available for first team selection	81.25	high
40	Morimoto 2021	High level athletes (soccer, basketball, athletics, rugby), 16-46 years	Retrospective	Metatarsal	Return to their original sport at their preinjury level of performance	75	high
41	Nagao 2012	Soccer, basketball, rugby, handball, 19±3.2 years	Retrospective	Metatarsal	Return to full activity	68.75	moderate

42	Nguyen 2019	Male professional soccer player, 18-31 years	Retrospective	Tibia	Return to the same level of professional sport as prior to the injury	68.75	moderate
43	Noakes 1985	Runners from different levels, 21-54 years.	Retrospective	Os Pubis	Recovery	12.5	very low
44	Nunley 2021	No information on lever or sports, 15-66 years	Retrospective	Navicular	Return to preinjury level of sport without pain	62.5	moderate
45	O'Malley 1996	Professional ballet dancers, 15-40 years	Retrospective	Metatarsal	Return to performance	31.25	low
46	Orava & Hulkko 1984	Different level, different sports (athletics, running, soccer, volleyball) 24-39 years	Retrospective	Tibia	Return to athletic activities	25	low
47	Orava 1991a	International and national level, different sports (athletics, running, cross-country skiing, soccer, volleyball, dancing), 14-39 years	Retrospective	Tibia	Return to athletic activities	25	low
48	Orava 1991b	No information on level, different sports (athletics, baseball, soccer), 19±2 years	Retrospective	Navicular	Full return to preinjury level sports activities	25	low
49	Orava 1995	Elite and recreational level, athletics, 18-60 years	Retrospective	Tibia	Healing	25	low
50	Orava 1996	No information on level, different sport (endurance runner, high jumper, orienteerer, volleyball and soccer player), 19-25 years	Retrospective	Patella	Continue sports normally and being symptom free	25	low
51	Pearce 2011	Male professional rugby union players, no information on age	Prospective	Cuboid, Metatarsal, Navicular, Metatarsal, Sesamoid	Absence	50	moderate
52	Pecina 2011	Competitive athletes, no information on sports, 16-26 years	Retrospective	Metatarsal	Return to full activity	50	moderate
53	Porter 2005	Competitive and recreational level, different sports (basketball, running, track, soccer, lacrosse, baseball), 15-28 years	Retrospective	Metatarsal	Return to sport	56.25	moderate
54	Porter & Torma 2008	Competitive athletes, different sports (predominantly basketball and soccer), mean of 17.6 years	Retrospective	Navicular	Return to sport	25	low
55	Porter 2009	Recreational to professional, different sports (basketball, running, soccer, volleyball, athletics, lacrosse, softball, football, rugby), 15-48 years	Retrospective	Metatarsal	Return to sport	56.25	moderate
56	Potter 2006	No information on level or sports, 33.5±9.6 years	Retrospective	Navicular	Return to sport	37.5	low
57	Ramey 2016	No information on level, predominantly female runners, 32.9±9.2 years	Retrospective	Femur	Return to running	50	moderate
58	Rettig 1988	Competitive basketball players, 14-23 years	Retrospective	Tibia	Complete return of symptom-free sports activities	68.75	moderate
59	Rohena-Quinquilla 2018	Active military, 18-37 years	Retrospective	Femur	Return to military duty without activity limitations	50	moderate
60	Rongstad 2013	No information on level, different sports (runners, Basketball, other), 16-38 years	Retrospective	Metatarsal	Return to sport without pain or decreased function	62.5	moderate
61	Saxena 2000	Elite and recreational athletes, different sports (mostly runners), 17-48 years	Retrospective	Navicular	Return to activity	68.75	moderate
62	Saxena & Fullem 2006	Competitive and recreational athletes, different sports (mostly runners, others not stated), 16-43 years	Prospective	Navicular	Return to activity	93.75	high

63	Saxena 2017	Competitive and recreational athletes, different sports (mostly runners, basketball, other), 13-63 years	Prospective	Navicular	Return to activity	93.75	high
64	Sharma 2015	Military (initial military training program), age not stated for BSI sub-cohort	Prospective	Tibia, Metatarsal, Femur, Calcaneus	Rehabilitation	75	high
65	Simon 2014	High performance athletes, different sports (mostly football (soccer)), 25±4 years	Retrospective	Metatarsal, Calcaneus, Os Pubis	Return to full training/competition	62.5	moderate
66	Stein 2019	Competitive and recreational athletes, different sports (mostly dancers, runners, other), 9-21 years	Retrospective	Hallux Sesamoid	Clearance to return to sports	43.75	low
67	Stone 2021	Professional football (soccer) players, 17-32 years	Retrospective	Metatarsal	Return to play	87.5	high
68	Swenson 1997	Competitive and recreational athletes, different sports (sports discipline not specified), 15-45 years	Prospective	Tibia	Return to full activity	81.25	high
69	Talbot 2008	Active military (training), 17-26 years	Retrospective	Femur	Return to training	37.5	low
70	Torg 1982	Competitive and recreational athletes, different sports (runners, basketball, other), 15-44 years	Retrospective	Navicular	Full activity	62.5	moderate
71	Vajapey 2019	Competitive and recreational runners, 16-53 years	Retrospective	Sacrum	Return to regular activity	25	moderate
72	Volpin 1990	Active military (elite basic training), age not specified	Prospective	Femur	Symptoms subsided completely	56.25	moderate
73	Whitelaw 1991	Competitive athletes, different sports (runners, basketball, other), 17-25 years	Prospective	Tibia	Return to competition	68.75	moderate
74	Wik 2021	Elite youth football (soccer) players, age not specified for BSI subcohort	Prospective	Tibia, Os Pubis	Time loss	93.75	high
75	Wood 2014	Active military (basic training), age not specified	Prospective	Femur, Fibula, Tibia, Metatarsal	Training at preinjury stage	75	high
76	Young 2020	Elite athletes, different sports (mostly soccer), 14-30 years	Retrospective	Metatarsal	Return to previous level of activity	68.75	moderate

1. Time to return to sports

Table 1A. Mean time to RTS (days) meta-analysis for anatomic sites

Study	Mean [95%-CI]	SE	Z-value	p-value	Weight (Pooled tau)
Femur					
Ivkovic 2006	96.000 [80.814-111.186]	7.748	12.390	<0.001	14.85
Johnson 1994	74.800 [58.862-90.738]	8.132	9.199	<0.001	14.75
Ramey 2016	99.880 [81.869-117.891]	9.189	10.869	<0.001	14.46
Rohena-Quinquilla	91.454 [81.396-101.512]	5.132	17.821	<0.001	15.42
Sharma 2015	116.0 [107.919 124.081]	4.123	28.134	<0.001	15.59
Talbot 2008	152.50 [107.162-197.838]	23.132	6.593	<0.001	9.74
Wood 2014	147.70 [135.425-159.975]	6.263	23.583	<0.001	15.20
Total Femur	**109.210 [86.481-131.940]**	**11.597**	**9.417**	**<0.001**	
Heterogeneity: Tau²=548.7, I²=92.3%					
Fibula					
Dickson 1987	30.000 [29.999-30.001]	0.001	51961.524	<0.001	58.47
Wood 2014	93.100 [56.693-129.507]	18.575	5.012	<0.001	41.53
Total Fibula	**56.205 [12.620-99.789]**	**22.238**	**2.527**	**0.011**	
Heterogeneity: Tau²=1818.3, I²=91.3%					
Metatarsal					
Albisetti 2010	45.680 [40.716-50.644]	2.533	18.036	<0.001	6.66
Ekstrand 2012	95.000 [81.365-108.635]	6.957	13.655	<0.001	6.35
Harrington 1993	138.00 [105.834-170.166]	16.412	8.409	<0.001	5.09
Larsson 2016	92.000 [33.477-150.523]	29.859	3.081	0.002	3.27
Maquirriain & Ghisi 2006	58.310 [49.169-67.451]	4.664	12.503	<0.001	6.54
Miller 2019	73.500 [65.831-81.169]	3.913	18.785	<0.001	6.59
Morimoto 2021	76.300 [71.112-81.488]	2.647	28.827	<0.001	6.65
Nagao 2012	78.400 [70.961-85.839]	3.796	20.656	<0.001	6.60
Pecina 2011	63.000 [56.097-69.903]	3.522	17.889	<0.001	6.61
Porter 2005	52.500 [45.499-59.501]	3.572	14.697	<0.001	6.61
Porter 2009	65.100 [47.460-82.740]	9.000	7.233	<0.001	6.12
Rongstad 2013	94.182 [81.184-107.180]	6.632	14.202	<0.001	6.38
Sharma 2015	82.000 [78.537-85.463]	1.767	46.409	<0.001	6.68
Stone 2021	77.700 [72.131-83.269]	2.841	27.348	<0.001	6.65
Wood 2014	85.400 [83.909-86.891]	0.761	112.224	<0.001	6.70
Young 2020	155.40 [145.385-165.415]	5.110	30.411	<0.001	6.51
Total Metatarsal	**82.112 [67.348-96.875]**	**7.532**	**10.901**	**<0.001**	
Heterogeneity: Tau²=313.8, I²=97.4					
Navicular					
Curell 2019	41.000 [28.553-53.447]	6.351	6.456	<0.001	17.12
Jacob 2013	239.600 [99.216-379.984]	71.626	3.345	0.001	2.54
Maquirriain & Ghisi 2006	156.331 [87.180-225.482]	35.282	4.431	<0.001	7.25
Nunley 2021	203.30 [152.805-253.795]	25.763	7.891	<0.001	10.05
Saxena 2000	109.523 [85.887-133.159]	12.059	9.082	<0.001	15.30

Saxena 2006	121.197 [103.0-139.387]	9.280	13.059	<0.001	16.27
Saxena 2017	134.726 [122.60-146.849]	6.185	21.782	<0.001	17.16
Torg 1982	158.219 [129.55-186.885]	14.626	10.818	<0.001	14.31
Total Navicular	**127.107 [102.97-151.244]**	**12.315**	**10.321**	**<0.001**	
Heterogeneity: Tau²=2705.3, I²=95.7%					
Os pubis					
Noakes 1985	96.830 [77.514-116.146]	9.855	9.825	<0.001	34.93
Simon 2014	129.300 [91.211-167.389]	19.433	6.654	<0.001	26.92
Wik 2021	21.000 [12.718-29.282]	4.226	4.969	<0.001	38.14
Total Os pubis	**76.650 [41.078-112.221]**	**18.149**	**4.223**	**<0.001**	
Heterogeneity: Tau²=3287.7, I²=97.3%					
Tibia					
Allen 2004	40.900 [33.406-48.394]	3.824	10.697	<0.001	6.98
Beck 2008	27.500 [22.987-32.013]	2.303	11.942	<0.001	7.06
Curell 2019	40.000 [18.500-61.500]	10.970	3.646	<0.001	6.22
Dickson 1987	27.000 [24.211-29.789]	1.423	18.974	<0.001	7.09
Ekstrand 2012	88.000 [15.186-160.814]	37.151	2.369	0.018	2.70
Jamieson 2017	95.900 [80.499-111.301]	7.858	12.205	<0.001	6.62
Johansson 1992	88.200 [79.254-97.146]	4.564	19.324	<0.001	6.93
Kijowski 2012	43.500 [40.424-46.576]	1.569	27.720	<0.001	7.08
Nguyen 2019	125.050 [98.897-151.203]	13.344	9.371	<0.001	5.87
Orava 1991a	200.94 [148.609-253.271}	26.700	7.526	<0.001	3.85
Orava 1995	144.875 [135.628-154.12]	4.718	30.708	<0.001	6.92
Sharma 2015	85.000 [82.752-87.248]	1.147	74.117	<0.001	7.09
Swenson 1997	45.889 [42.437-49.340]	1.761	26.059	<0.001	7.08
Whitelaw 1991	36.750 [24.605-48.895]	6.197	5.930	<0.001	6.79
Wik 2021	58.700 [18.031-99.369]	20.750	2.829	0.005	4.71
Wood 2014	147.70 [141.231-154.169]	3.300	44.751	<0.001	7.01
Total Tibia	**77.115 [61.924-92.305]**	**7.750**	**9.950**	**<0.001**	
Heterogeneity: Tau²=1261.1, I²=99.6%					

Table 1B. Mean time to RTS (days) meta-analysis for anatomic sites (sub-analysis)

Study	Mean [95%-CI]	SE	Z-value	p-value	Weight (Pooled tau)
Femur neck					
Ramey 2016	99.880 [81.869-117.891]	9.189	10.869	<0.001	37.56
Rohena-Quinquilla 2018	91.454 [81.396-101.512]	5.132	17.821	<0.001	42.24
Talbot 2008	152.50 [107.162-197.838]	23.132	6.593	<0.001	20.21
Total femur neck	**106.953 [79.439-134.468]**	**14.038**	**7.619**	**<0.001**	
Heterogeneity: Tau²=234.3, I²=71.1%					
Femur shaft					
Ivkovic 2006	96.000 [80.814-111.186]	7.748	12.390	<0.001	50.30
Johnson 1994	74.800 [58.862-90.738]	8.132	9.199	<0.001	49.70
Total femur shaft	**85.464 [54.372-116.557]**	**15.864**	**5.387**	**<0.001**	
Heterogeneity: Tau²=161.6, I²=71.9%					
Metatarsal 1-4					
Albisetti 2010	45.680 [40.716-50.644]	2.533	18.036	<0.001	28.42
Harrington 1993	138.000 105.834 170.166	16.412	8.409	<0.001	17.89
Maquirriain & Ghisi 2006	58.310 49.169 67.451	4.664	12.503	<0.001	27.48
Rongstad 2013a	94.182 81.184 107.180	6.632	14.202	<0.001	26.21
Total Metatarsal 1-4	**78.380 [56.298-100.463]**	**11.267**	**6.957**	**<0.001**	
Heterogeneity: Tau²=648.1, I²=95.9%					
Metatarsal 5					
Ekstrand 2012	95.000 81.365 108.635	6.957	13.655	<0.001	10.56
Miller 2019	73.500 65.831 81.169	3.913	18.785	<0.001	11.32
Morimoto 2021	76.300 [71.112-81.488]	2.647	28.827	<0.001	11.53
Nagao 2012	78.400 [70.961-85.839]	3.796	20.656	<0.001	11.35
Pecina 2011	63.000 [56.097-69.903]	3.522	17.889	<0.001	11.40
Porter 2005	52.500 [45.499-59.501]	3.572	14.697	<0.001	11.39
Porter 2009	65.100 [47.460-82.740]	9.000	7.233	<0.001	9.90
Stone 2021	77.700 [72.131-83.269]	2.841	27.348	<0.001	11.51
Young 2020	155.40 [145.385-165.415]	5.110	30.411	<0.001	11.06
Total Metatarsal 5	**81.771 [67.695-95.848]**	**7.182**	**11.385**	**<0.001**	
Heterogeneity: Tau²=557.7, I²=97.4%					
Tibia medial malleolus					
Curell 2019	40.000 [18.500-61.500]	10.970	3.646	<0.001	32.06
Nguyen 2019	125.050 [98.897-151.203]	13.344	9.371	<0.001	29.07
Orava 1995	144.88 [135.628-154.122]	4.718	30.708	<0.001	38.86
Total Tibia medial malleolus	**105.484 [79.206-131.761]**	**13.407**	**7.868**	**<0.001**	
Heterogeneity: Tau²=3291.1, I²=97.4%					
Tibia posteromedial					
Allen 2004	40.900 [33.406-48.394]	3.824	10.697	<0.001	16.63
Beck 2008	27.500 [22.987-32.013]	2.303	11.942	<0.001	16.98

Dickson 1987	27.000 [24.211-29.789]	1.423	18.974	<0.001	17.11
Johansson 1992	88.200 [79.254-97.146]	4.564	19.324	<0.001	16.41
Swenson 1997	45.889 [42.437-49.340]	1.761	26.059	<0.001	17.06
Whitelaw 1991	36.750 [24.605-48.895]	6.197	5.930	<0.001	15.81
Total Tibia posteromedial *Heterogeneity: Tau²=263.6, I²=97.7%*	**44.203 [27.155-61.252]**	**8.698**	**5.082**	**<0.001**	

2. Return to sport (RTS) rate

Table 2A. Rate of RTS (event rate) meta-analysis for anatomic sites

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur				
Butler 1982	0.833 [0.369-0.977]	1.469	0.142	8.92
Clement 1993	0.821 [0.636-0.924]	3.093	0.002	15.86
Fullerton 1988	0.464 [0.292-0.646]	-0.378	0.706	17.26
Hulkko 1987	0.979 [0.741-0.999]	2.694	0.007	6.44
Ivkovic 2006	0.938 [0.461-0.996]	1.854	0.064	6.25
Johansson 1990	0.522 [0.325-0.712]	0.208	0.835	16.80
Johnson 1994	0.944 [0.495-0.997]	1.947	0.052	6.28
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	15.77
Wood 2014	0.977 [0.723-0.999]	2.629	0.009	6.43
Total Femur	**78.9 [0.612-0.899]**	**2.993**	**0.003**	
Heterogeneity: Tau²=0.86, I²=66.8%				
Fibula				
Dickson 1987	0.875 [0.266-0.993]	1.287	0.198	16.19
Hong 2009	0.962 [0.597-0.998]	2.232	0.026	17.28
Hulkko 1987	0.989 [0.846-0.999]	3.156	0.002	17.61
Khan 2018	0.750 [0.377-0.937]	1.346	0.178	32.06
Wood 2014	0.929 [0.423-0.996]	1.748	0.081	16.87
Total Fibula	**0.901 [0.758-0.964]**	**4.058**	**<0.001**	
Heterogeneity: Tau²=0.41, I²=20.0%				
Hallux				
Hulkko 1987	0.969 [0.650-0.998]	2.390	0.017	27.30
Stein 2019	0.850 [0.721-0.925]	4.336	<0.001	72.70
Total Hallux	**0.865 [0.751-0.932]**	**4.818**	**<0.001**	
Heterogeneity: Tau²=0.33, I²=22.9%				
Metatarsal				
Albisetti 2010	0.975 [0.702-0.998]	2.558	0.011	3.91
Curell 2019	0.500 [0.059-0.941]	0.000	1.000	3.98
Delee 1983	0.955 [0.552-0.997]	2.103	0.035	3.86
Ekstrand 2012	0.988 [0.833-0.999]	3.088	0.002	3.95
Fernandez Fairen 1999	0.778 [0.421-0.944]	1.562	0.118	7.30
Harrington 1993	0.833 [0.369-0.977]	1.469	0.142	5.44
Hulkko 1987	0.993 [0.901-1.000]	3.517	<0.001	3.96
Khan 2018	0.571 [0.316-0.794]	0.533	0.594	9.31
Lee 2011	0.993 [0.903-1.000]	3.536	<0.001	3.96
Maquirriain & Ghisi 2006	0.875 [0.266-0.993]	1.287	0.198	3.63
Miller 2019	0.987 [0.822-0.999]	3.033	0.002	3.95
Morimoto 2021	0.987 [0.822-0.999]	3.033	0.002	3.95
Nagao 2012	0.992 [0.882-0.999]	3.377	0.001	3.96
O'Malley 1996	0.992 [0.889-1.000]	3.423	0.001	3.96
Pecina 2011	0.976 [0.713-0.999]	2.594	0.009	3.92
Porter 2005	0.980 [0.749 0.999]	2.724	0.006	3.93
Porter 2009	0.976 [0.713-0.999]	2.594	0.009	3.92
Rongstad 2013	0.958 [0.575-0.997]	2.170	0.030	3.87
Simon 2014	0.833 [0.194-0.990]	1.039	0.299	3.51
Stone 2021	0.952 [0.729-0.993]	2.924	0.003	5.84
Wood 2014	0.997 [0.947-1.000]	3.995	<0.001	3.97
Young 2020	0.974 [0.835-0.996]	3.563	<0.001	5.91
Total Metatarsal	**0.955 [0.916-0.977]**	**8.892**	**<0.001**	

Heterogeneity: Tau²=1.96, I²=57.8%				
Navicular				
Burne 2005	0.650 [0.426-0.823]	1.320	0.187	10.84
Curell 2019	0.667 [0.376-0.869]	1.132	0.258	9.60
Hulkko 1987	0.889 [0.500-0.985]	1.961	0.050	6.19
Jacob 2013	0.800 [0.459-0.950]	1.754	0.080	8.11
Khan 1992	0.535 [0.429-0.637]	0.646	0.518	12.65
Khan 2018	0.333 [0.043-0.846]	-0.566	0.571	5.25
Malliaropoulos 2017	0.962 [0.597-0.998]	2.232	0.026	4.26
Maquirriain & Ghisi 2006	0.667 [0.154-0.957]	0.566	0.571	5.2
Nunley 2021	0.933 [0.648-0.991]	2.550	0.011	6.37
Orava 1991b	0.950 [0.525-0.997]	2.029	0.042	4.23
Porter 2008	0.950 [0.525-0.997]	2.029	0.042	4.23
Potter 2006	0.983 [0.783-0.999]	2.859	0.004	4.33
Saxena 2000	0.978 [0.732-0.999]	2.662	0.008	4.31
Saxena 2006	0.974 [0.690-0.998]	2.519	0.012	4.30
Torg 1982	0.810 [0.588-0.927]	2.604	0.009	10.09
Total Navicular	**0.830 [0.707-0.909]**	**4.393**	**<0.001**	
Heterogeneity: Tau²=0.89, I²=63.2%				
Os pubis				
Noakes 1985	0.962 [0.597-0.998]	2.232	0.026	50.21
Simon 2014	0.950 [0.525-0.997]	2.029	0.042	49.79
Total Os pubis	**0.956 [0.746-0.994]**	**3.014**	**0.003**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Patella				
Khan 2018	0.833 [0.194-0.990]	1.039	0.299	48.34
Orava 1996	0.917 [0.378-0.995]	1.623	0.105	51.66
Total Patella	**0.883 [0.482-0.984]**	**1.892**	**0.059**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Talus				
Curell 2019	0.667 [0.406-0.854]	1.266	0.206	72.4
Hulkko 1987	0.833 [0.194-0.990]	1.039	0.299	27.52
Total Talus	**0.689 [0.446-0.859]**	**1.539**	**0.124**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia				
Allen 2004	0.976 [0.713-0.999]	2.594	0.009	3.54
Beals & Cook 1991	0.733 [0.467-0.896]	1.733	0.083	8.10
Beck 2008	0.989 [0.843-0.999]	3.140	0.002	3.57
Curell 2019	0.875 [0.266-0.993]	1.287	0.198	3.28
Dickson 1987	0.955 [0.552-0.997]	2.103	0.035	3.49
Ditmars 2020	0.988 [0.840-0.999]	3.123	0.002	3.57
Ekstrand 2012	0.929 [0.423-0.996]	1.748	0.081	3.42
Hulkko 1987	0.997 [0.958-1.000]	4.166	<0.001	3.59
Johansson 1992	0.756 [0.603-0.863]	3.111	0.002	9.61
Jowett 2008	0.917 [0.378-0.995]	1.623	0.105	3.39
Khan 2018	0.692 [0.409-0.880]	1.349	0.177	7.98
Kilcoyne 2013	0.974 [0.690-0.998]	2.519	0.012	3.54
Lempainen 2012	0.900 [0.533-0.986]	2.084	0.037	5.13
Liimatainen 2009	0.755 [0.610-0.859]	3.247	0.001	9.72
Nguyen 2019	0.971 [0.664-0.998]	2.436	0.015	3.53
Orava & Hulkko 1984	0.938 [0.461-0.996]	1.854	0.064	3.45
Orava 1991a	0.972 [0.678-0.998]	2.479	0.013	3.53
Orava 1995	0.944 [0.495-0.997]	1.947	0.052	3.46
Rettig 1988	0.938 [0.461-0.996]	1.854	0.064	3.45
Swenson 1997	0.974 [0.690-0.998]	2.519	0.012	3.54
Whitelaw 1991	0.972 [0.678-0.998]	2.479	0.013	3.53

Wood 2014	0.991 [0.866-0.999]	3.275	0.001	3.58
Total Tibia	**0.928 [0.872-0.961]**	**7.808**	**<0.001**	
Heterogeneity: Tau²=0.85, I²=51.2%				

Table 2B. Rate of RTS (event rate) meta-analysis for anatomic sites (sub-analysis)

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur neck				
Fullerton 1988	0.464 [0.292-0.646]	-0.378	0.706	31.70
Hulkko 1987	0.950 [0.525-0.997]	2.029	0.042	9.55
Johansson 1990	0.522 [0.325-0.712]	0.208	0.835	30.59
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	28.16
Total Femur Neck	**0.553 [0.436-0.665]**	**0.886**	**0.375**	
Heterogeneity: Tau²=0.21, I²=44.9%				
Femur shaft				
Hulkko 1987	0.967 [0.634-0.998]	2.341	0.019	33.78
Ivkovic 2006	0.938 [0.461-0.996]	1.854	0.064	33.02
Johnson 1994	0.944 [0.495-0.997]	1.947	0.052	33.20
Total Femur Shaft	**0.951 [0.791-0.990]**	**3.548**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Metatarsal 1-4				
Albisetti 2010	0.975 [0.702-0.998]	2.558	0.011	15.67
Harrington 1993	0.833 [0.369-0.977]	1.469	0.142	22.68
Hulkko 1987	0.992 [0.885-1.000]	3.401	0.001	15.87
Maquirriain & Ghisi 2006	0.875 [0.266-0.993]	1.287	0.198	14.44
O'Malley 1996	0.992 [0.889-1.000]	3.423	0.001	15.87
Rongstad 2013	0.958 [0.575-0.997]	2.170	0.030	15.47
Metatarsal 1-4	**0.960 [0.890-0.986]**	**5.724**	**<0.001**	
Heterogeneity: Tau²=0.22, I²=10.5%				
Metatarsal 5				
Curell 2019	0.500 [0.059-0.941]	0.000	1.000	5.35
Delee 1983	0.955 [0.552-0.997]	2.103	0.035	5.17
Ekstrand 2012	0.988 [0.833-0.999]	3.088	0.002	5.31
Fernandez Fairen 1999	0.778 [0.421-0.944]	1.562	0.118	10.76
Hulkko 1987	0.958 [0.575-0.997]	2.170	0.030	5.19
Khan 2018	0.571 [0.316-0.794]	0.533	0.594	14.56
Lee 2011	0.993 [0.903-1.000]	3.536	<0.001	5.33
Miller 2019	0.987 [0.822-0.999]	3.033	0.002	5.30
Morimoto 2021	0.987 [0.822-0.999]	3.033	0.002	5.30
Nagao 2012	0.992 [0.882-0.999]	3.377	0.001	5.32
Pecina 2011	0.976 [0.713-0.999]	2.594	0.009	5.26
Porter 2005	0.980 [0.749-0.999]	2.724	0.006	5.27
Porter 2009	0.976 [0.713-0.999]	2.594	0.009	5.26
Stone 2021	0.952 [0.729-0.993]	2.924	0.003	8.26
Young 2020	0.974 [0.835-0.996]	3.563	<0.001	8.37
Metatarsal 5	**0.946 [0.892-0.973]**	**7.508**	**<0.001**	
Heterogeneity: Tau²=2.14, I²=62.2%				
Tibia anterior				
Beals & Cook 1991	0.733 [0.374-0.924]	1.423	0.247	32.35
Johansson 1992	0.091 [0.013-0.439]	-2.195	0.028	13.22
Liimatainen 2009	0.755 [0.610-0.859]	3.247	0.001	28.98
Orava & Hulkko 1984	0.938 [0.461-0.996]	1.854	0.064	8.40
Orava 1991a	0.972 [0.678-0.998]	2.479	0.013	8.64

Rettig 1988	0.938 [0.461-0.996]	1.854	0.064	8.40
Total Tibia Anterior	**0.755 [0.541-0.889]**	**2.300**	**0.021**	
Heterogeneity: Tau²=1.32, I²=63.4%				
Tibia medial malleolus				
Curell 2019	0.875 [0.266-0.993]	1.287	0.198	17.17
Jowett 2008	0.917 [0.378-0.995]	1.623	0.105	17.79
Lempainen 2012	0.900 [0.533-0.986]	2.084	0.037	28.29
Nguyen 2019	0.971 [0.664-0.998]	2.436	0.015	18.57
Orava 1995	0.944 [0.495-0.997]	1.947	0.052	18.19
Total Tibia Medial	**0.926 [0.794-0.976]**	**4.196**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia posteromedial				
Allen 2004	0.976 [0.713-0.999]	2.594	0.009	16.68
Beck 2008	0.989 [0.843-0.999]	3.140	0.002	16.84
Dickson 1987	0.955 [0.552-0.997]	2.103	0.035	16.41
Johansson 1992	0.984 [0.789-0.999]	2.883	0.004	16.78
Swenson 1997	0.974 [0.690-0.998]	2.519	0.012	16.65
Whitelaw 1991	0.972 [0.678-0.998]	2.479	0.013	16.63
Total Tibia Posteromedial	**0.977 [0.931-0.993]**	**6.422**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				

3. Complication rate

Table 3A. Complication rate (event rate) meta-analysis for anatomic sites

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur				
Wood 2014	0.023 [0.001-0.277]	-2.629	0.009	4.56
Hulkko 1987	0.043 [0.006-0.252]	-3.023	0.003	7.00
Johnson 1994	0.056 [0.003-0.505]	-1.947	0.052	4.45
Ivkovic 2006	0.063 [0.004-0.539]	-1.854	0.064	4.42
Volpin 1990	0.222 [0.056-0.579]	-1.562	0.118	8.93
Clement 1993	0.258 [0.135-0.437]	-2.573	0.010	13.21
Cochran 2020	0.267 [0.104-0.533]	-1.733	0.083	11.25
Butler 1982	0.333 [0.084-0.732]	-0.800	0.423	8.32
Johansson 1990	0.565 [0.326-0.777]	0.520	0.603	12.15
Fullerton 1988	0.571 [0.387-0.738]	0.753	0.451	13.52
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	12.20
Total Femur	**0.289 [0.167-0.452]**	**-2.493**	**0.013**	
Heterogeneity: Tau²=0.91, I²=68.9%				
Fibula				
Hulkko 1987	0.011 [0.001-0.154]	-3.156	0.002	25.97
Hong 2009	0.038 [0.002-0.403]	-2.232	0.026	25.45
Wood 2014	0.071 [0.004-0.577]	-1.748	0.081	24.82
Dickson 1987	0.125 [0.007-0.734]	-1.287	0.198	23.77
Total Fibula	**0.043 [0.011-0.159]**	**-4.240**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Hallux				
Stein 2019	0.102 [0.043-0.222]	-4.609	<0.001	73.43
Hulkko 1987	0.969 [0.650-0.998]	2.390	0.017	26.57
Total Hallux	**0.335 [0.083-0.737]**	**-0.785**	**0.432**	
Heterogeneity: Tau²=14.6, I²=92.7%				
Metatarsal				
Wood 2014	0.003 [0.000-0.053]	-3.995	0.000	2.84
Morimoto 2021	0.013 [0.001-0.178]	-3.033	0.002	2.82
Porter 2005	0.020 [0.001-0.251]	-2.724	0.006	2.81
Albisetti 2010	0.025 [0.002-0.298]	-2.558	0.011	2.80
Nagao 2012	0.033 [0.008-0.124]	-4.682	<0.001	6.01
Delee 1983	0.045 [0.003-0.448]	-2.103	0.035	2.76
Pecina 2011	0.050 [0.007-0.282]	-2.870	0.004	4.29
Hulkko 1987	0.055 [0.021-0.137]	-5.537	<0.001	7.40
Maquirriain & Ghisi 2006	0.125 [0.007-0.734]	-1.287	0.198	2.59
O'Malley 1996	0.140 [0.074-0.248]	-5.039	<0.001	8.45
Porter 2009	0.150 [0.049-0.376]	-2.770	0.006	6.62
Simon 2014	0.167 [0.010-0.806]	-1.039	0.299	2.49
Harrington 1993	0.167 [0.023-0.631]	-1.469	0.142	3.98
Rongstad 2013	0.182 [0.046-0.507]	-1.924	0.054	5.61
Lee 2011	0.200 [0.124-0.306]	-4.802	<0.001	8.89
Young 2020	0.211 [0.109-0.368]	-3.322	0.001	8.21
Fernandez Fairen 1999	0.222 [0.056-0.579]	-1.562	0.118	5.49

Stone 2021	0.222 [0.093-0.444]	-2.387	0.017	7.33
Miller 2019	0.405 [0.261-0.568]	-1.144	0.253	8.61
Total Metatarsal	**0.114 [0.069-0.183]**	**-7.234**	**<0.001**	
Heterogeneity: Tau²=0.59, I²=61.3%				
Navicular				
Malliaropoulos 2017	0.038 [0.002-0.403]	-2.232	0.026	3.86
Orava 1991b	0.050 [0.003-0.475]	-2.029	0.042	3.83
Saxena 2006	0.053 [0.007-0.294]	-2.813	0.005	5.97
Saxena 2017	0.129 [0.066-0.237]	-5.041	<0.001	11.63
Nunley 2021	0.200 [0.066-0.470]	-2.148	0.032	9.06
Saxena 2000	0.227 [0.098-0.444]	-2.405	0.016	10.38
Potter 2006	0.241 [0.120-0.427]	-2.639	0.008	11.11
Hulkko 1987	0.330 [0.109-0.664]	-0.999	0.318	8.47
Maquirriain & Ghisi 2006	0.333 [0.043-0.846]	-0.566	0.571	4.83
Torg 1982	0.333 [0.168-0.553]	-1.497	0.134	10.83
Jacob 2013	0.400 [0.158-0.703]	-0.628	0.530	9.06
Burne 2005	0.450 [0.253-0.664]	-0.446	0.655	10.96
Total Navicular	**0.241 [0.186-0.307]**	**-6.783**	**<0.001**	
Heterogeneity: Tau²=0.23, I²=38.6%				
Os pubis				
Noakes 1985	0.038 [0.002-0.403]	-2.232	0.026	50.22
Simon 2014	0.050 [0.003-0.475]	-2.029	0.042	49.78
Total Os pubis	**0.044 [0.006-0.254]**	**-3.014**	**0.003**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia				
Wood 2014	0.009 [0.001-0.134]	-3.275	0.001	3.43
Beck 2008	0.011 [0.001-0.157]	-3.140	0.002	3.43
Allen 2004	0.024 [0.001-0.287]	-2.594	0.009	3.39
Swenson 1997	0.026 [0.002-0.310]	-2.519	0.012	3.39
Whitelaw 1991	0.028 [0.002-0.322]	-2.479	0.013	3.39
Hulkko 1987	0.044 [0.022-0.085]	-8.517	<0.001	10.24
Dickson 1987	0.045 [0.003-0.448]	-2.103	0.035	3.34
Orava 1995	0.056 [0.003-0.505]	-1.947	0.052	3.32
Nguyen 2019	0.063 [0.009-0.335]	-2.622	0.009	5.16
Orava & Hulkko 1984	0.063 [0.004-0.539]	-1.854	0.064	3.30
Jamieson 2017	0.067 [0.012-0.293]	-2.944	0.003	6.00
Jowett 2008	0.083 [0.005-0.622]	-1.623	0.105	3.24
Lempainen 2012	0.100 [0.014-0.467]	-2.084	0.037	5.04
Rettig 1988	0.125 [0.015-0.573]	-1.703	0.089	4.58
Johansson 1992	0.244 [0.137-0.397]	-3.111	0.002	10.22
Liimatainen 2009	0.245 [0.141-0.390]	-3.247	0.001	10.36
Orava 1991a	0.529 [0.303-0.745]	0.242	0.808	9.22
Beals & Cook 1991	0.533 [0.293-0.759]	0.258	0.796	8.95
Total Tibia	**0.112 [0.064-0.189]**	**-6.623**	**<0.001**	
Heterogeneity: Tau²=1.38, I²=73.5%				

Table 3B. Complication rate (event rate) meta-analysis for anatomic sites (sub-analysis)

Study	Event rate [95%-CI]	Z-value	p-value	Weight (Pooled tau)
Femur neck				
Hulkko 1987	0.050 [0.003-0.475]	-2.029	0.042	4.78
Volpin 1990	0.222 [0.056-0.579]	-1.562	0.118	11.37
Clement 1993	0.258 [0.026-0.822]	-0.800	0.423	5.59
Cochran 2020	0.267 [0.124-0.483]	-2.098	0.036	18.54
Johansson 1990	0.565 [0.363-0.748]	0.624	0.533	20.27
Fullerton 1988	0.571 [0.387-0.738]	0.753	0.451	21.39
Talbot 2008	0.667 [0.429-0.842]	1.386	0.166	18.06
Total Femur neck	**0.428 [0.275-0.596]**	**-0.835**	**0.404**	
Heterogeneity: Tau²=0.45, I²=58.0%				
Femur shaft				
Johnson 1994	0.056 [0.003-0.505]	-1.947	0.052	13.96
Ivkovic 2006	0.063 [0.004-0.539]	-1.854	0.064	13.87
Hulkko 1987	0.070 [0.010-0.370]	-2.469	0.014	23.36
Clement 1993	0.258 [0.105-0.508]	-1.905	0.057	48.80
Total Femur shaft	**0.162 [0.075-0.315]**	**-3.718**	**<0.001**	
Heterogeneity: Tau²=0.05, I²=4.3%				
Metatarsal 1-4				
Hulkko 1987	0.008 [0.000-0.115]	-3.401	0.001	8.93
Albisetti 2010	0.025 [0.002-0.298]	-2.558	0.011	8.80
Maquirriain & Ghisi 2006	0.125 [0.007-0.734]	-1.287	0.198	8.04
O'Malley 1996	0.140 [0.074-0.248]	-5.039	<0.001	39.67
Harrington 1993	0.167 [0.023-0.631]	-1.469	0.142	13.43
Rongstad	0.182 [0.046-0.507]	-1.924	0.054	21.12
Total Metatarsal 1-4	**0.123 [0.073-0.199]**	**-6.702**	**<0.001**	
Heterogeneity: Tau²=0.18, I²=18.0%				
Metatarsal 5				
Morimoto 2021	0.013 [0.001-0.178]	-3.033	0.002	3.05
Porter 2005	0.020 [0.001-0.251]	-2.724	0.006	3.03
Nagao 2012	0.033 [0.008-0.124]	-4.682	<0.001	7.96
Delee 1983	0.045 [0.003-0.448]	-2.103	0.035	2.96
Pecina 2011	0.050 [0.007-0.282]	-2.870	0.004	5.06
Porter 2009	0.150 [0.049-0.376]	-2.770	0.006	9.19
Lee 2011	0.200 [0.124-0.306]	-4.802	<0.001	14.85
Young 2020	0.211 [0.109-0.368]	-3.322	0.001	12.92
Fernandez Fairen 1999	0.222 [0.056-0.579]	-1.562	0.118	7.02
Stone 2021	0.222 [0.093-0.444]	-2.387	0.017	10.74
Hulkko 1987	0.364 [0.143-0.661]	-0.893	0.372	9.18
Miller 2019	0.405 [0.261-0.568]	-1.144	0.253	14.04
Total Metatarsal 5	**0.165 [0.104-0.252]**	**-5.938**	**<0.001**	
Heterogeneity: Tau²=0.53, I²=62.7%				
Tibia anterior				
Orava & Hulkko 1984	0.063 [0.004-0.539]	-1.854	0.064	6.05
Rettig 1988	0.125 [0.015-0.573]	-1.703	0.089	8.96
Liimatainen 2009	0.245 [0.141-0.390]	-3.247	0.001	28.69
Orava 1991a	0.529 [0.303-0.745]	0.242	0.808	23.61
Beals & Cook 1991	0.533 [0.293-0.759]	0.258	0.796	22.51
Johansson 1992	0.909 [0.561-0.987]	2.195	0.028	10.17
Total Tibia anterior	**0.409 [0.242-0.599]**	**-0.939**	**0.348**	

Heterogeneity: Tau²=0.96, I²=71.3%				
Tibia medial malleolus				
Orava 1995	0.056 [0.003-0.505]	-1.947	0.052	18.72
Nguyen 2019	0.063 [0.009-0.335]	-2.622	0.009	31.97
Jowett 2008	0.083 [0.005-0.622]	-1.623	0.105	18.26
Lempainen 2012	0.100 [0.014-0.467]	-2.084	0.037	31.04
Total Tibia medial malleolus	**0.075 [0.024-0.209]**	**-4.179**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				
Tibia posteromedial				
Beck 2008	0.011 [0.001-0.157]	-3.140	0.002	16.86
Johansson 1992	0.016 [0.001-0.211]	-2.883	0.004	16.79
Allen 2004	0.024 [0.001-0.287]	-2.594	0.009	16.69
Swenson 1997	0.026 [0.002-0.310]	-2.519	0.012	16.65
Whitelaw 1991	0.028 [0.002-0.322]	-2.479	0.013	16.63
Dickson 1987	0.045 [0.003-0.448]	-2.103	0.035	16.38
Total Tibia posteromedial	**0.023 [0.007-0.069]**	**-6.422**	**<0.001**	
Heterogeneity: Tau²=0.0, I²=0.0%				