

■ **SYSTEMATIC REVIEW**

# The incidence of musculoskeletal injuries: a systematic review and meta-analysis

**V. Ponkilainen,  
I. Kuitunen,  
R. Liukkonen,  
M. Vaajala,  
A. Reito,  
M. Uimonen**

*From Central Finland  
Hospital Nova,  
Jyväskylä, Finland*

**Aims**

The aim of this systematic review and meta-analysis was to gather epidemiological information on selected musculoskeletal injuries and to provide pooled injury-specific incidence rates.

**Methods**

PubMed (National Library of Medicine) and Scopus (Elsevier) databases were searched. Articles were eligible for inclusion if they reported incidence rate (or count with population at risk), contained data on adult population, and were written in English language. The number of cases and population at risk were collected, and the pooled incidence rates (per 100,000 person-years) with 95% confidence intervals (CIs) were calculated by using either a fixed or random effects model.

**Results**

The screening of titles yielded 206 articles eligible for inclusion in the study. Of these, 173 (84%) articles provided sufficient information to be included in the pooled incidence rates. Incidences of fractures were investigated in 154 studies, and the most common fractures in the whole adult population based on the pooled incidence rates were distal radius fractures (212.0, 95% CI 178.1 to 252.4 per 100,000 person-years), finger fractures (117.1, 95% CI 105.3 to 130.2 per 100,000 person-years), and hip fractures (112.9, 95% CI 82.2 to 154.9 per 100,000 person-years). The most common sprains and dislocations were ankle sprains (429.4, 95% CI 243.0 to 759.0 per 100,000 person-years) and first-time patellar dislocations (32.8, 95% CI 21.6 to 49.7 per 100,000 person-years). The most common injuries were anterior cruciate ligament (17.5, 95% CI 6.0 to 50.2 per 100,000 person-years) and Achilles (13.7, 95% CI 9.6 to 19.5 per 100,000 person-years) ruptures.

**Conclusion**

The presented pooled incidence estimates serve as important references in assessing the global economic and social burden of musculoskeletal injuries.

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**Article focus**

- Musculoskeletal injuries cause a major societal burden in the form of increased costs due to treatment, disability, sick leave, and impaired quality of life worldwide.
- We gathered the incidence rates of common musculoskeletal injuries in the adult population.

**Key messages**

- The presented pooled incidence estimates serve as important references in assessing the global economic and social burden of musculoskeletal injuries.
- More epidemiological studies from developing countries are needed.

Correspondence should be sent to Ville Ponkilainen; email: ville.ponkilainen@tuni.fi

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## Strengths and limitations

- The main limitation was the heterogeneity of the included studies, which may predispose the pooled incidence estimates to bias of at least some extent.
- The main strength of this study was its comprehensive search protocol involving the largest medical research databases. The search was conducted separately for each injury type, and the screening was conducted by two blinded authors.

## Introduction

Musculoskeletal injuries cause a major societal burden in the form of increased costs due to treatment, disability, sick leave, and impaired quality of life worldwide.<sup>1-3</sup> Although the burden of non-fatal musculoskeletal injuries is enormous, the amount of funding and efforts for injury prevention and surgical care has been minimal when compared to other major worldwide health issues, such as AIDS and other infectious diseases.<sup>2</sup> Prevention should be the priority when pursuing the reduction of the burden caused by musculoskeletal injuries. In addition to prevention, the optimization of the management, from first aid to rehabilitation, should be well considered to reduce excess costs.<sup>4</sup> However, since the effectiveness of preventive acts treatment optimization is difficult to measure, the benefits of prevention in relation to injury-related societal costs are often underestimated. Therefore, it is essential to understand the commonness of the injuries to better realize the magnitude of the resulting economic burden, and efficiently allocate funds toward effective prevention and optimized treatment of musculoskeletal injuries.<sup>1</sup>

The aim of this systematic review was to gather epidemiological studies of selected musculoskeletal injuries and to provide pooled injury-specific incidence rates.

## Methods

**Information sources and search strategy.** PubMed (National Library of Medicine) and Scopus (Elsevier) databases were searched from inception to the date of the search. All topics were searched individually between 8 June 2021 and 19 June 2022. The selected topics (injuries, sprains, or dislocations in Supplementary Table i) were the ones that were the most common musculoskeletal injuries based on previous studies.<sup>5,6</sup> Search strategies for all topics in both databases are provided in Supplementary Table i. As a supplementary search, we included papers from other topics that included multiple anatomical areas. The PubMed search was limited to title based on the search algorithm, whereas the Scopus search was conducted by using a filter for the title search to narrow the scope of the search more strictly to relevant epidemiological studies. The review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 checklist.

**Eligibility criteria and selection process.** Records from the database search were imported to a free online systematic review platform (Rayyan)<sup>7</sup> and duplicates were removed.

A study was eligible for our analysis if the following inclusion criteria were fulfilled: 1) the incidence was reported as cases per person-years/inhabitants (or count with population at risk); 2) the data contained the adult population (18 years or older); and 3) the article was in English language. A study was excluded if one or more of the following criteria was met: 1) included only paediatric patients; or 2) was limited to certain populations (such as athletes, osteoporotic fractures, low-energy trauma mechanisms, or different age groups). Furthermore, if the study included a cohort that had been used in other studies, we included the publication with the most recent incidence rate. Publication year was not otherwise restricted, but since the incidence of hip fractures has been increasing rapidly and recent studies investigating the incidence of hip fracture were numerous, only studies published after the year 2015 were included to ensure that the most recent incidence would be presented.

All records were screened, and abstracts of resulting articles were assessed by two authors (VP and IK, VP and MU, or IK and MU). In case of a conflict, consensus was achieved by the two authors together. Records meeting the inclusion criteria were selected for eligibility assessment. Humeral and femoral fractures were searched as a whole group, and after the full-text read they were divided into proximal, shaft (diaphyseal), and distal fractures. Foot fractures were grouped as calcaneus, foot (including all foot injuries from calcaneus to metatarsals), metatarsal, and Lisfranc fractures (including fractures affecting the tarsometatarsal joint). Carpal fractures included all carpal bones, including scaphoid fractures, which were also reported separately. Pelvic fractures were grouped as acetabulum and pelvic fractures (including the whole pelvis). All anatomical areas were searched separately, and thus we report separate flowcharts for all injuries (Supplementary Figure a).

**Data extraction.** Data were extracted and recorded by three authors (VP, IK, MU). The extracted data included the study title, author names, publication year, and the journal. We collected the last year of the study period, incidence rate, count, population at risk, and duration for the calculated incidence in years. If the count was not reported, we included the population at risk and calculated the count by multiplying the incidence (per 100,000) with population and dividing the result by 100,000 to achieve the count. If the total incidence of both sexes was not reported, we calculated it by summarizing the count and population at risk of men and women and divided the total count by the total population and multiplied the result by 100,000. If each of these numbers were missing, we calculated them from the incidence for each sex. If two of the following three values were missing: incidence, count, or population at risk, or if the incidence was reported as age- or sex-weighted, we contacted the authors by mail to obtain the missing data. Overall, the authors of three of the studies were contacted, although none of them could share their data. For studies that reported the incidence based on certain age groups, the

values were excluded from the pooled incidence rate but reported separately in the results. As there were multiple studies reporting the incidence of hip fractures in age groups, we also reported pooled incidences of hip fractures by age group.

Injury definitions of every included article were evaluated, and when it was not otherwise mentioned, then the injuries were defined as all fractures or ruptures of the corresponding anatomical area. As the studies investigating the incidence of sacrum, antebrachium, olecranon, and rotator cuff injuries had greatly varying definitions for the injuries, these injuries were excluded from this review to decrease the risk of bias (RoB). The complete data can be requested from the corresponding author.

RoB assessment was conducted by using the Checklist for Prevalence Studies by The Joanna Briggs Institute,<sup>8,9</sup> RoB assessment was conducted by two blinded authors (MV, RL), and conflicts were resolved by a third author (VP). The complete RoB assessment template can be requested from the corresponding author.

**Effect measures.** The primary pooled outcome measure was annual incidence (cases per 100,000 person-years) for each studied injury category. This was either extracted from the data or calculated based on the count and population at risk, as described above.

**Data synthesis and analysis.** We pooled the total incidences of each musculoskeletal injury individually for each anatomical area. The count and population at risk were divided by the duration that they represented. For example, if the data were gathered from multiple years, the count and population at risk for the whole study period was divided by the duration of the study period in years to estimate the annual rate. If the count and population at risk were presented for one year, the figures were divided by one. If only age-weighted incidence or only a certain age group was presented, we did not include the values in the pooled incidence rates but presented them separately. As most of the hip fractures are treated operatively, we included both injury and surgery incidences together in the pooled incidence rates. The pooled incidences with the 95% confidence intervals (CIs) were calculated by either fixed or random effects model. A fixed effects model was used if heterogeneity was low ( $I^2 < 25\%$ ). Otherwise, a random effects model was used. A meta-regression model adjusted by the last year of data included in each study was used to evaluate the change of incidence rates per year. Meta-regression model was interpreted as regression coefficient  $\beta$  (beta) with 95% CIs, which represents the change of incidence per each added year. To mitigate the bias caused by a small sample, we excluded injuries including less than four studies in total and the injuries where the difference between the first and last year of included publications was less than five years. The results of meta-regression analysis are presented in Supplementary Table ii.

All analyses were performed using R version 4.0.3 (R Foundation for Statistical Computing, Austria), and the

**Table I.** The number of included studies per continent.

Continent	N	%
Europe	140	68.0
North America	34	16.5
Asia	23	11.2
Oceania	5	2.4
South America	3	1.5
Africa	1	0.5

pooled incidences were calculated using the function “metarate” and “metareg” from the “meta” package.

## Results

Title screening yielded a total of 206 articles. Of these, 173 (84%) articles provided sufficient information for inclusion in the pooled incidence rates. Most of the studies were conducted in Europe ( $n = 140$ , 68%) (Table I). The median publication year was 2015 (interquartile range (IQR) 2006 to 2017), and the median ending year of the data was 2009 (IQR 2000 to 2013).

**Fractures.** Incidence of fractures was investigated in 160 studies. The most common fractures based on the pooled incidence rates were distal radius fractures (212.0, 95% CI 178.1 to 252.4), finger fractures (117.1, 95% CI 105.3 to 130.2), and hip fractures (112.9, 95% CI 82.2 to 154.9) (Figure 1, Table II).

Acetabulum fractures were investigated in six studies.<sup>10–15</sup> The studies were published between 2005 and 2019 and reported data ending in the years between 2003 and 2016. All these studies were included in the pooled incidence of 5.6 (95% CI 3.3 to 9.7) per 100,000 person-years.

Ankle fractures were investigated in nine studies.<sup>5,16–23</sup> The studies were published between 1987 and 2020 and contained data ending in the years between 1981 and 2016. All these studies were included in the pooled incidence of 94.0 (95% CI 65.3 to 135.3) per 100,000 person-years.

Calcaneus fractures were investigated in five studies.<sup>5,24–27</sup> The studies were published between 1987 and 2020, reporting data ending in the years between 1981 and 2016. All five studies were included in the pooled incidence of 10.0 (95% CI 7.9 to 12.6) per 100,000 person-years.

Carpal fractures were investigated in three studies.<sup>5,28,29</sup> The studies were published between 2006 and 2015 and contained data ending in the years between 2000 and 2009. All these studies were included in the pooled incidence of 34.7 (95% CI 34.5 to 34.9) per 100,000 person-years.

Clavicle fractures were investigated in eight studies.<sup>5,23,28,30–34</sup> The studies were published between 1994 and 2019 and contained data ending in the years between 1987 and 2015. All these studies were included in the pooled incidence of 50.3 (95% CI 25.9 to 97.8) per 100,000 person-years.

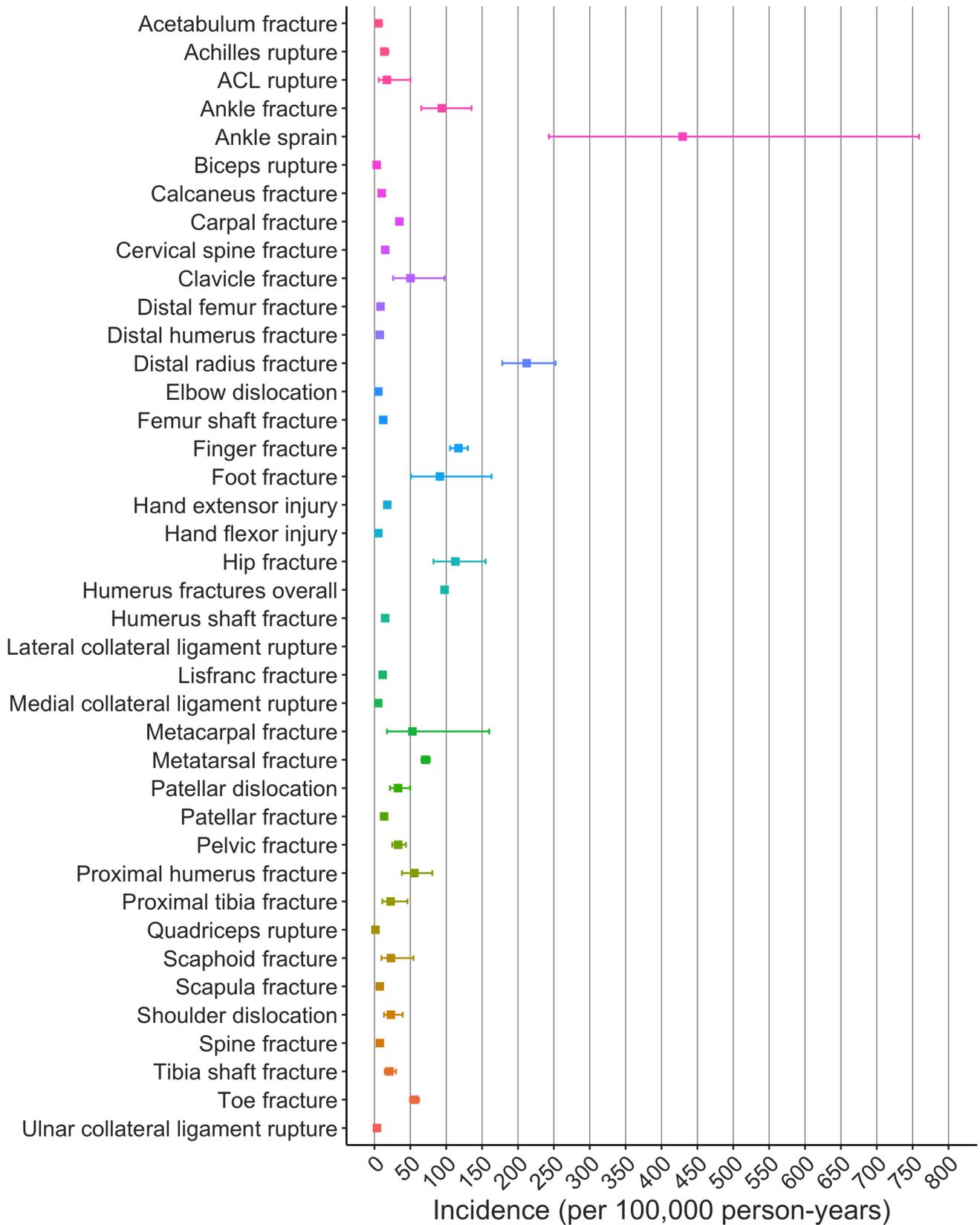


Fig. 1

The pooled incidence rates with 95% confidence intervals of injuries. The incidence rates were calculated by using random or fixed effects model, based on the heterogeneity of the included studies. ACL, anterior cruciate ligament.

**Table II.** The pooled incidences of fractures.

Fracture	Number of articles		Incidence*		
	Total	Pooled	Rate	95% CI	I <sup>2</sup> †
Distal radius fractures	12	12	212.0	178.1 to 252.4	98.7
Finger fractures	2	2	117.1	105.3 to 130.2	92.5
Hip fractures	28	10	112.9	82.2 to 154.9	100.0
Humerus fractures (overall)	1	1	97.7	93.9 to 101.7	N/A
Ankle fractures	9	9	94.0	65.3 to 135.3	99.9
Foot fractures	3	3	91.2	50.9 to 163.2	99.1
Metatarsal fractures	2	2	71.2	65.6 to 77.3	62.0
Proximal humerus fractures	10	7	55.6	38.3 to 80.6	99.9
Toe fractures	1	1	55.5	49.5 to 62.2	N/A
Metacarpal fracture	3	3	52.9	17.5 to 160	100
Clavicle fractures	8	8	50.3	25.9 to 97.8	100.0
Carpal fracture	3	3	34.7	34.5 to 34.9	51.1
Pelvic fractures	12	10	33.0	24.8 to 43.9	99.9
Scaphoid fractures	9	9	23.0	9.7 to 54.4	100.0
Proximal tibia fractures	2	2	22.5	11.0 to 46.0	98.6
Tibial shaft fractures	6	6	20.8	14.4 to 29.8	98.6
Cervical spine fractures	1	1	15.0	14.0 to 16.1	N/A
Humeral shaft fractures	4	4	14.9	13.0 to 17.0	88.7
Patellar fractures	5	5	13.4	10.4 to 17.3	97.5
Femoral shaft fractures	9	9	12.2	10.1 to 14.8	94.0
Lisfranc injuries	2	2	11.4	8.5 to 15.4	84.7
Calcaneus fractures	5	5	10.0	7.9 to 12.6	93.8
Distal femur fractures	6	5	8.4	6.0 to 11.8	85.2
Spine fractures	3	1	7.5	5.5 to 10.2	N/A
Distal humerus fractures	4	3	7.4	6.2 to 8.7	24.5
Scapula fractures	4	4	7.4	4.8 to 11.2	85.3
Acetabulum fractures	6	6	5.7	3.3 to 9.7	98.9

\*Pooled incidence was calculated from count and population at risk of the included studies by using random effects model. If heterogeneity was low ( $I^2 < 25\%$ ), fixed effects model was used. †Heterogeneity ( $I^2$ ) was not calculated if only one study was included.

CI, confidence interval; N/A, not available.

Distal radius fractures were investigated in 12 studies.<sup>5,35–45</sup> The studies were published between 1985 and 2020 and contained data ending in the years between 1981 and 2016. All these studies were included in the pooled incidence of 212.0 (95% CI 178.1 to 252.4) per 100,000 person-years.

Femoral shaft fractures were investigated in nine studies.<sup>5,11,46–52</sup> The studies were published between 1988 and 2014, reporting data ending in the years between 1983 and 2011. All these studies were included in the pooled incidence of 12.2 (95% CI 10.1 to 14.8) per 100,000 person-years.

**Table III.** Pooled incidence rates of hip fractures per age group.

Age group, yrs	Number of included studies	Incidence*		
		Rate	95% CI	I <sup>2</sup> †
Overall	10	112.9	82.2 to 154.9	100.0
Over 40	1	68.5	66.0 to 71.1	N/A
Over 45	1	205.9	201.8 to 210.1	N/A
Over 50	10	194.5	159.8 to 236.9	99.9
Over 55	1	136.7	135.6 to 137.7	N/A
Over 65	3	126.5	35.7 to 448.5	100.0

\*Pooled incidence was calculated from count and population at risk of the included studies by using random effects model. If heterogeneity was low ( $I^2 < 25\%$ ), fixed effects model was used.

†Heterogeneity ( $I^2$ ) was not calculated if only one study was included.

CI, confidence interval; N/A, not available.

Distal femur fractures were investigated in six studies.<sup>5,11,46,53–55</sup> The studies were published between 1988 and 2021 and reported data ending in the years between 1984 and 2017. Altogether, five of these studies were included in the pooled incidence of 8.4 (95% CI 6.0 to 11.8) per 100,000 person-years. One of the studies reported the incidences in age groups, resulting in an incidence of 12.9 (95% CI 12.6 to 13.2) per 100,000 for the population over 65 years of age.<sup>54</sup>

Finger fractures were investigated in two studies published in 2006 and 2015,<sup>5,28</sup> and containing data ending in the years between 2000 and 2009. Both studies were included in the pooled incidence of 124.9 (95% CI 124.2 to 125.6) per 100,000 person-years.

Foot fractures (including whole foot) were investigated in three studies.<sup>23,56,57</sup> The studies were published between 2016 and 2021 and contained data ending in the years between 2010 and 2015. All three studies were included in the pooled incidence of 91.2 (95% CI 50.9 to 163.2) per 100,000 person-years.

Hip (proximal femur) fractures were investigated in 28 studies.<sup>58–85</sup> The studies were published between 2015 and 2021 and reported data ending in the years between 2010 and 2019. Altogether, ten of these studies were included in the pooled incidence of 112.9 (95% CI 82.2 to 154.9) per 100,000 person-years. Overall, 16 of the remaining studies reported the incidences in age groups (Table III). Two of the studies reported only age- or sex-adjusted incidences and thus were not included in the pooled rates.<sup>70,79</sup>

A total of 15 studies investigated the incidence of humerus fractures. Of these, ten investigated proximal fractures, four studied distal fractures, four reported shaft fractures, and one investigated humerus fractures overall. The incidence of overall humeral fractures was 97.7 (95% CI 93.9 to 101.7), based on the data of one study.<sup>23</sup>

Proximal humerus fractures were investigated in ten studies.<sup>28,86–94</sup> The studies were published between 1987 and 2016 and containing data ending in the years between 1983 and 2013. Altogether, seven of these

studies were included in the pooled incidence of 55.6 (95% CI 38.3 to 80.6) per 100,000 person-years. The remaining three studies reported the incidences in age groups, resulting in an incidence of 156.3 (95% CI 74.4 to 328.2) per 100,000 for populations over 50 years of age (two studies)<sup>88,93</sup> and an incidence of 105.0 (95% CI 75.0 to 147.0) per 100,000 for populations over 60 years of age (one study).<sup>87</sup>

Humeral shaft fractures were investigated in four studies published between 2006 and 2016, and containing data ending in the years between 1999 and 2013.<sup>5,28,86,95</sup> All four studies were included in the pooled incidence of 14.9 (95% CI 13.0 to 17.0) per 100,000 person-years.

Distal humerus fractures were investigated in four studies.<sup>5,28,86,96</sup> The studies were published in 2006 and 2016 and reported data ending in the years between 2000 and 2013. Three of the studies excluded patients younger than 12 years and were included in the pooled incidence of 11.3 (95% CI 5.1 to 24.9) per 100,000 person-years. One study did not restrict the age of the patients and thus reported a higher incidence of 43.2 (95% CI 42.8 to 43.6) per 100,000 person-years.<sup>28</sup>

Lisfranc injuries (fractures to the tarsometatarsal joint) were investigated in two studies published in 2020 and 2021,<sup>97,98</sup> and reporting data ending between 2015 and 2016. Both studies were included in the pooled incidence of 11.4 (95% CI 8.5 to 15.4) per 100,000 person-years.

Metacarpal fractures were investigated in three studies.<sup>5,28,99</sup> The studies were published between 2006 and 2015 and contained data ending in the years between 2000 and 2009. All these studies were included in the pooled incidence of 52.9 (95% CI 17.5 to 160.0) per 100,000 person-years.

Metatarsal fractures were investigated in two studies, both published in 2006 and containing data ending in the year 2000.<sup>5,98</sup> Both studies were included in the pooled incidence of 71.2 (95% CI 65.6 to 77.3) per 100,000 person-years.

Patellar fractures were investigated in five studies.<sup>5,23,53,100,101</sup> The studies were published between 2006 and 2020 and contained data ending in the years between 2000 and 2017. All five studies were included in the pooled incidence of 13.4 (95% CI 10.4 to 17.3) per 100,000 person-years.

Pelvic fractures were investigated in 12 studies.<sup>5,12,15,23,102–109</sup> The studies were published between 1981 and 2021 and contained data ending between 1977 and 2016. Ten of the studies were included in the pooled incidence of 33.0 (95% CI 24.8 to 43.9) per 100,000 person-years. Two of the remaining studies reported the incidences in age groups, resulting in an incidence of 264.0 (95% CI 252.9 to 275.5) per 100,000 for populations over 60 years of age,<sup>102</sup> and an incidence of 57.8 (95% CI 54.9 to 60.8) per 100,000 for populations over 65 years of age (one study).<sup>109</sup>

Scaphoid fractures were investigated in nine studies.<sup>28,29,110–116</sup> The studies were published between

1992 and 2021 and contained data ending in the years between 1989 and 2016. All nine studies were included in the pooled incidence of 23.0 (95% CI 9.7 to 54.4) per 100,000 person-years.

Scapula fractures were investigated in four studies published between 1995 and 2016 and containing data ending in the years between 1995 and 2012.<sup>5,23,28,117</sup> All these studies were included in the pooled incidence of 7.4 (95% CI 4.8 to 11.2) per 100,000 person-years.

Spine fractures were investigated in four studies.<sup>5,11,118,119</sup> The studies were published between 2006 and 2015 and contained data ending in the years between 2000 and 2017. One study evaluated the incidence of spine fractures overall, resulting in an incidence of 7.5 (95% CI 5.5 to 10.2).<sup>5</sup> Two of the studies investigated only hospitalized patients, resulting in a pooled incidence of 49.5 (95% CI 21.6 to 113.9) per 100,000 person-years.<sup>11,118</sup> One study investigated the incidence of cervical spine fractures, resulting in an incidence of 15.0 (95% CI 14.0 to 16.1).<sup>119</sup>

Altogether, eight studies investigated the incidence of tibia fractures. Of these, two investigated proximal fractures, whereas six investigated tibial shaft fractures.

Proximal tibia fractures were investigated in two studies,<sup>5,53</sup> both of which were published in 2006 and 2020 and contained data ending in the years between 2000 and 2017. Both studies were included in the pooled incidence of 22.5 (95% CI 11.0 to 46.0) per 100,000 person-years.

Tibial shaft fractures were investigated in six studies.<sup>5,47,120–123</sup> The studies were published between 2006 and 2016 and contained data ending in the years between 1999 and 2013. All six studies were included in the pooled incidence of 20.8 (95% CI 14.4 to 29.8) per 100,000 person-years.

Toe fractures were investigated in one study published in 2006 and containing data ending in the year 2000. Based on this study, the incidence of toe fractures was 55.5 (95% CI 49.5 to 62.2) per 100,000 person-years.<sup>5</sup>

**Sprains and dislocations.** Sprains and dislocations were investigated in 16 studies. The most common sprains and dislocations were ankle sprains (429.4, 95% CI 243.0 to 759.0 per 100,000 person-years) and patellar dislocations (32.8, 95% CI 21.6 to 49.7 per 100,000 person-years) (Figure 1, Table IV).

Ankle sprains were investigated in three studies.<sup>124–126</sup> The studies were published between 1994 and 2010 and contained data ending in the years between 1990 and 2006. All three studies were included in the pooled incidence of 429.4 (95% CI 243.0 to 759.0) per 100,000 person-years.

Elbow dislocations were investigated in three studies.<sup>127–129</sup> The studies were published between 1986 and 2012 and reported data ending in the years between 1982 and 2006. All three studies were included in the pooled incidence of 5.5 (95% CI 4.9 to 6.2) per 100,000 person-years.

**Table IV.** Incidence of sprains, dislocations, and tendon/ligament injuries.

Injury type	Number of articles		Incidence*		
	Total	Pooled*	Rate	95% CI	I <sup>2</sup> †
<b>Sprains and dislocations</b>					
Ankle sprains	3	3	429.4	243.0 to 759.0	100.0
Patellar dislocations	2	2	32.8	21.6 to 49.7	90.0
Shoulder dislocations	8	5	23.9	17.6 to 32.4	97.4
Elbow dislocations	3	3	5.5	4.9 to 6.2	32.1
Knee dislocations	0	0	N/A	N/A	N/A
<b>Ligament and tendon injuries</b>	<b>Total</b>	<b>Pooled*</b>	<b>Rate</b>	<b>95% CI</b>	<b>I<sup>2</sup></b>
Hand extensor injury	1	1	17.9	14.6 to 21.9	N/A
ACL rupture	3	2	17.4	6.0 to 50.2	98.9
Achilles rupture	12	12	13.6	9.6 to 19.4	99.2
Hand flexor injury	2	2	5.5	4.0 to 7.4	23.4
Medial collateral ligament rupture	1	1	5.2	3.6 to 7.6	N/A
Ulnar collateral ligament rupture	1	1	3.4	2.2 to 5.4	N/A
Biceps rupture	4	4	3.1	2.1 to 4.5	91.6
Quadriceps rupture	1	1	1.4	0.7 to 2.8	N/A
Lateral collateral ligament rupture	1	1	0.2	0.0 to 1.3	N/A
PCL rupture	1	N/A	N/A	N/A	N/A
Hand flexor and extensor injury	1	N/A	N/A	N/A	N/A
Hamstring ruptures	N/A	N/A	N/A	N/A	N/A

\*Pooled incidence was calculated from count and population at risk of the included studies by using random effects model. If heterogeneity was low ( $I^2 < 25\%$ ) fixed effects model was used.

†Heterogeneity ( $I^2$ ) was not calculated if only one study was included.

ACL, anterior cruciate ligament; CI, confidence interval; N/A, not available; PCL, posterior cruciate ligament.

Studies investigating the incidence of knee dislocations in the adult population were not found in the articles reviewed.

Patellar dislocations were investigated in two studies.<sup>130,131</sup> Both studies reported only the incidence of first-time patellar dislocations. The studies were published in 2018 and contained data ending in the years between 2013 and 2010. Both studies were included in the pooled incidence of 32.8 (95% CI 21.6 to 49.7) per 100,000 person-years.

Shoulder dislocations were investigated in eight studies.<sup>132–139</sup> Altogether, five studies defined shoulder dislocation as glenohumeral dislocations (anterior or

posterior) and included primary and recurrent cases in the total incidence. The studies were published between 1984 and 2018 and contained data ending in the years between 1979 and 2015. All the studies were included in the pooled incidence of 23.9 (95% CI 17.6 to 32.4) per 100,000 person-years. Two of the studies investigated the incidence of only primary dislocations, resulting in a pooled incidence of 26.4 (95% CI 25.3 to 27.5), and one study investigated the incidence of primary anterior dislocations, resulting in an incidence of 23.1 (95% CI 22.2 to 24.0).

**Ligament and tendon injuries.** Ligament and tendon injuries were investigated in 31 studies. The most common injuries were hand extensor injuries (17.9, 95% CI 14.6 to 21.9), and anterior cruciate ligament (ACL) (17.5, 95% CI 6.0 to 50.2) and Achilles ruptures (13.7, 95% CI 9.6 to 19.5) (Figure 1, Table IV).

Achilles tendon ruptures were investigated in 12 studies.<sup>6,140–150</sup> Studies were published between 1996 and 2017 containing data ending in the years between 1994 and 2013. All the studies were included in the pooled incidence of 13.7 (95% CI 9.6 to 19.5) per 100,000 person-years.

ACL ruptures were investigated in three studies.<sup>6,151,152</sup> The studies were published between 2008 and 2016 and contained data ending in the years between 2000 and 2010. One study reported only the age-weighted incidence and was therefore excluded from the pooled incidence.<sup>151</sup> The other two studies resulted in an incidence of 17.5 (95% CI 6.0 to 50.2) per 100,000 person-years.<sup>6</sup>

Distal biceps ruptures were investigated in three studies.<sup>153–155</sup> As one of the studies reported incidences separately for Finnish and Swedish populations, these incidences were included separately.<sup>154</sup> The studies were published between 2002 and 2020 and contained data ending in the years between 1998 and 2016. All three studies were included in the pooled incidence of 3.1 (95% CI 2.1 to 4.5) per 100,000 person-years.

Studies investigating the incidence of hamstring ruptures in the adult population were not found in the articles reviewed.

Hand tendon ruptures were investigated in three studies.<sup>6,156,157</sup> One of the studies investigated flexor tendon ruptures, and two studies investigated the incidences of both flexor and extensor injuries. One of the studies reporting both injuries together reported only age-weighted incidences, and thus were excluded from the incidences. Therefore, incidence for flexor ruptures was extracted from two studies and extensor ruptures from one study. The studies were published between 2008 and 2017 and contained data ending in the years between 2000 and 2010. The pooled incidence was 5.4 (95% CI 4.0 to 7.3) per 100,000 person-years for flexor ruptures and 17.9 (95% CI 14.6 to 21.9) per 100,000 person-years for extensor ruptures.

Lateral collateral ligament ruptures were investigated in one study.<sup>6</sup> The study was published in 2006 and contained data ending in the year 2000. Based on this

study, the incidence of lateral collateral ligament ruptures was 0.19 (95% CI 0.02 to 1.35) per 100,000 person-years.

Medial collateral ligament ruptures were investigated in one study.<sup>6</sup> The study was published in 2006 and contained data ending in the year 2000. Based on this study, the incidence of medial collateral ligament ruptures was 5.2 (95% CI 3.6 to 7.6) per 100,000 person-years.

Posterior cruciate ligament ruptures were investigated in one study.<sup>158</sup> The included study reported only operatively treated patients and was published in 2017 based on data ending in the year 2010. The study reported only age-weighted incidence of posterior cruciate ligament ruptures and thus was not included in the pooled incidence.

Ulnar collateral ligament ruptures were investigated in one study,<sup>6</sup> which was published in 2006 and contained data ending in the year 2000. Based on this study, the incidence of ulnar collateral ligament ruptures was 3.4 (95% CI 2.2 to 5.4) per 100,000 person-years.

Quadriceps femoris tendon ruptures were investigated in one study.<sup>6</sup> The study was published in 2008 and contained data ending in the year 2000. Based on this study, the incidence of quadriceps ruptures was 1.4 (95% CI 0.6 to 2.8) per 100,000 person-years.

There was a slight increase in the incidence throughout the years in Achilles ruptures ( $\beta$  0.066, 95% CI 0.038 to 0.095) and distal femur fractures ( $\beta$  0.044, 95% CI 0.026 to 0.062) and a slight decrease in tibia shaft fractures (-0.045, 95% CI -0.056 to -0.035), calcaneus fractures (-0.04, 95% CI -0.051 to -0.029), and distal radius fractures (-0.015, 95% CI -0.027 to -0.004). Changes in other injuries throughout the years were not detected (Supplementary Table ii).

RoB assessment was conducted for each included study. The median number of properly evaluated checklist items was 7 (IQR 6 to 8) out of 9 items. The minimum number was 4/9 ( $n = 3$  studies) and maximum was 8/9 ( $n = 51$  studies). Most commonly insufficient items were “8. Was there appropriate statistical analysis?” ( $n = 65$ , 42%), “4. Were the study subjects and the setting described in detail?” ( $n = 43$ , 28%), and “3. Was the sample size adequate?” ( $n = 34$ , 22%). In other items, the number of insufficient studies ranged between 1 and 8. None of the studies were excluded due to high RoB. The complete RoB assessment template can be requested from the corresponding author.

## Discussion

As a result of this systematic review, we have provided pooled incidence rates of common musculoskeletal injuries. The incidence estimates serve as important references in assessing the burden caused by musculoskeletal injuries and when deciding how to guide research efforts. Given the ongoing battle between continuously increasing healthcare costs and limited healthcare resources worldwide, knowledge dissemination regarding injury incidences would assist in determining how the resources should be allocated to have the

highest preventive impact on costs caused by treatment, rehabilitation, and injury-related disability. This knowledge should be used as a guide in decisions regarding health service policies as well as research funding. Often the most common injuries generate the highest costs,<sup>1</sup> thus knowledge on the incidence rates of these injuries is essential for the decision-makers to better allocate resources toward the issues.

It has been previously shown that low-energy osteoporotic fractures have increased rapidly.<sup>159–162</sup> Based on this review, the fractures that occur commonly among older people (distal radius, hip, and humerus) were among those with the highest incidences, even in the pooled samples of the whole population. With the reported increasing trend in incidences of these injuries, it is essential to allocate the resources properly to control the increasing incidences and costs. In particular, prevention strategies for these injuries should be optimized.

With regard to some investigated injuries, unexpectedly few epidemiological studies were found. Although the screening revealed many identified epidemiological studies, many of these unfortunately described only the characteristics of the injuries or did not otherwise report the source population, and thus were not comparable to studies reporting the incidence rate. Not a single study was identified investigating the incidence of knee dislocations or hamstring ruptures in the entire adult population. Only one study each reported toe<sup>5</sup> and cervical spine injuries,<sup>119</sup> and only two studies investigated Lisfranc injuries,<sup>97,163</sup> finger,<sup>5,28</sup> metatarsal,<sup>5,98</sup> and proximal tibia fractures.<sup>5,53</sup> Further, it is surprising that only three studies investigated the incidence of the most common sports injuries – ACL ruptures – in the entire adult population. This unexpected finding may be related to the common practice of reporting injury incidence within population subgroups, such as older people or athletes, which resulted in excluding these studies from this review, based on our predefined exclusion criteria. Further, since minor injuries are commonly treated in primary or private care without involving major trauma centres, such injuries are often left outside the trauma registers. Therefore, valid estimates on the incidences of these injuries may be more difficult to achieve.

The incidence rates in this meta-analysis were consistent between the studies. A clear majority of the studies were conducted in Western countries, while studies conducted in developing countries were few. Thus, the results of this systematic review may be considered to better represent developed countries, indicating the need to conduct more studies in developing countries. Still, some variations between the incidences were detected. The variations may be related to differing injury definitions. Although the anatomical area and the population at risk ought to be verified properly, some of the studies did not report the definitions clearly. For example, pelvic fractures included all fractures of the pelvic ring, and thus the different types of fracture types fall within the same fracture class.

To the best of the authors' knowledge, this is the first meta-analysis to report pooled incidence rates of common musculoskeletal injuries. The main strength of this study was its comprehensive search protocol involving the largest medical research databases. The search was conducted separately for each injury type, and the screening was conducted by two blinded authors (MV, RL). In addition, RoB was low in most of the studies, and no single study was excluded due to high RoB.

The main limitation was the unavoidable heterogeneity of the included studies, which may predispose the pooled incidence estimates to bias of at least some extent. Some of the earliest studies were published in the 1980s and 1990s and thus the incidences of certain injuries may have changed throughout the years. Due to this bias, a meta-regression analysis adjusted for year of the study was performed to mitigate this bias. Meta-regression analysis showed that there were only minor changes in some of the injuries between the years. We also limited hip fractures to publications after the year 2015, which on the other hand may lead to selection bias. Some of the injuries (such as ankle sprains and finger/toe fractures) are usually treated in primary healthcare and may be missing from the studies conducted in larger hospitals. Therefore, the presented figures may be lower than the true incidences. The incidence of some injuries may have changed throughout the years and thus the pooled estimate may be biased. Further, the search included only the titles of the studies; therefore, if a study did not mention what they investigated in the title, such a study might have been missed in the initial search. However, we used papers found in other searches as a complementary source to fulfill some of the potentially missed papers. Nevertheless, due to the massive number of published study articles, it would have been impossible to conduct this review without using filters. Another limitation is that some of the study articles did not explicitly specify how they defined the injuries; thus, this may affect the incidence rates. Further, most of the study articles were from Western countries, thus limiting the generalizability of the study. The presented incidences cover only the selected injuries, and should not be confused with the total incidences of musculoskeletal injuries, especially when evaluating the total burden on society.

In conclusion, the presented pooled incidence estimates serve as important references in assessing the global economic and social burden of musculoskeletal injuries. As the cost of musculoskeletal injuries is known to be massive, it would be important to understand the commonness of these injuries and to aim resources toward prevention and better treatment optimization in the future.

### Supplementary material



Tables showing complete search algorithms for each search conducted in the study and the results of meta-regression analysis adjusted by the

last year of data included in each study; and a figure showing PRISMA flowcharts for the screening process of all injuries.

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**Author information:**

- V. Ponkilainen, MD, PhD, Adjunct Professor, Orthopaedic surgery resident
- M. Uimonen, MD, PhD, Adjunct Professor, Surgery resident  
Department of Surgery, Central Finland Hospital Nova, Jyväskylä, Finland.
- I. Kuitunen, MD, PhD, Adjunct Professor, Researcher, University of Eastern Finland, Institute of Clinical Medicine, Kuopio, Finland.
- R. Liukkonen, BM, Researcher
- M. Vaajala, BM, Researcher
- A. Reito, MD, PhD, Adjunct Professor, Orthopaedic surgeon  
Tampere University, Faculty of Medicine and Health Technology, Tampere, Finland.

**Author contributions:**

- V. Ponkilainen: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Visualization.
- I. Kuitunen: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing.
- R. Liukkonen: Data curation, Investigation, Methodology, Writing – review & editing.
- M. Vaajala: Data curation, Investigation, Methodology, Writing – review & editing.
- A. Reito: Conceptualization, Investigation, Methodology, Writing – review & editing.
- M. Uimonen: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing.

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