The Foot 39 (2019) 106–114

Contents lists available at ScienceDirect

The Foot

journal homepage: www.elsevier.com/locate/foot

Review

The health economics of ankle and foot sprains and fractures: A systematic review of English-language published papers. Part 1: Overview and critical appraisal

Iwona A. Bielska*, Xiang Wang, Raymond Lee, Ana P. Johnson

Department of Public Health Sciences, Queen's University, Canada

ARTICLE INFO

Keywords:
Ankle fracture
Ankle injuries
Foot injuries
Health economics
Cost of illness

ABSTRACT

Background: Ankle and foot sprains and fractures are common injuries affecting many individuals, often requiring considerable and costly medical interventions. The objectives of this systematic review are to collect, assess, and critically appraise the published literature on the health economics of ankle and foot injury (sprain and fracture) treatment.

Methods: A systematic literature review of Ovid MEDLINE, EMBASE, Cochrane DSR, ACP Journal Club, AMED, Ovid Healthstar, and CINAHL was conducted for English-language studies on the costs of treating ankle and foot sprains and fractures published from January 1980 to December 2014. Two reviewers assessed the articles for study quality and abstracted data.

Results: The literature search identified 2047 studies of which 32 were analyzed. A majority of the studies were published in the last decade. A number of the studies did not report full economic information, including the sources of the direct and indirect costs, as suggested in the guidelines. The perspective used in the analysis was missing in numerous studies, as was the follow-up time period of participants. Only five of the studies undertook a sensitivity analysis which is required whenever there are uncertainties regarding cost data.

Conclusion: This systematic review found that publications do not consistently report on the components of health economics methodology, which in turn limits the quality of information. Future studies undertaking economic evaluations should ensure that their methods are transparent and understandable so as to yield accurate interpretation for assistance in forthcoming economic evaluations and policy decision-making.

1. Introduction

Ankle sprains are common injuries with an incidence of 206–215 per 100,000 people per year based on administrative data in the United States [1,2]. These injuries account for 1.1 million emergency room encounters annually and make up 4% of all injury-related visits in the country [3]. The ankle joint is also the most fractured part of the lower extremity, representing close to a quarter of fractures to the lower limb [4]. The incidence of ankle fractures is lower than that of ankle sprains at 49–148 per 100,000 people per year based on literature from the United States and the United Kingdom [2,5,6]. Foot fractures have a similar incidence of 121–137 fractures per 100,000 people in the United Kingdom [5,6].

The physical consequences of ankle and foot injuries may remain for months and even years after the initial injury, leading to chronic symptoms for patients [7–10]. Further to this, the economic burden of these injuries is substantial, with medical and physiotherapy treatments for ankle sprains accounting for up to $3.65 billion (2003 USD) in annual costs in the United States [11,12]. Affected patients may also experience productivity loss with previous studies demonstrating that ankle and foot injuries contribute to a significant number of days lost from work among employed individuals, especially for those with fractures [13–16].

Although ankle sprains and fractures affect a substantial proportion of the population per year [1–3,5,6], little information is known about the economic impact of these injuries. This is needed in order to guide physicians and decision makers in the adoption of various treatments and the allocation of health care resources. Thus, the objectives of this systematic review are to collect, assess, and critically appraise the published literature on the health economics of ankle and foot injury (sprain and fracture) treatment.

* Corresponding author at: Department of Public Health Sciences, Queen's University Abramsky Hall Kingston, ON K7L 3N6, Canada.
E-mail address: iwona.bielska@queensu.ca (I.A. Bielska).

http://dx.doi.org/10.1016/j.foot.2017.04.003
Received 17 September 2016; Received in revised form 12 April 2017; Accepted 13 April 2017

Table 1
Glossary of terminology.

Term	Definition
Direct health system costs	Costs covered by the payer, for example the health care system, including physician remuneration, costs of investigations and hospital fees [49]
Out-of-pocket and indirect costs	Costs of services not covered by the payer, including out-of-pocket expenses and productivity loss [49]
Perspective	Describes the viewpoint assumed in the calculations and provides information on the payer and the recipients of the services [49]
Cost-minimization analysis	Type of economic analysis in which the treatments being compared are reported to have the same effectiveness, thereby comparing the costs of the alternatives [49]
Cost-effectiveness analysis	Type of economic analysis in which the incremental cost of a treatment program is compared to the incremental health improvement due to an alternative treatment program, measured as natural effects or physical units [49]
Cost-utilization analysis	Type of economic analysis in which the incremental cost of a treatment program is compared to the incremental health improvement due to the alternative program. It can be measured as quality-adjusted life-years (QALYs) gained [49]
Discounting	A mathematical method of accounting for time preference by adjusting the future benefits and costs of interventions to present-day values [49]
Sensitivity analysis	A mathematical method of accounting for uncertainty and observing the impact on the study results [49]

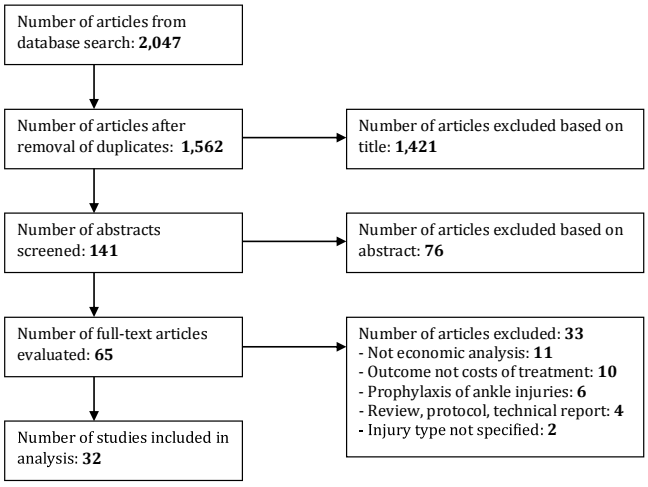

Fig. 1. Flowchart of search results.

2. Materials and methods

2.1. Search strategy

A systematic literature review was undertaken to identify publications on the costs of treating ankle and foot injuries. The Cochrane Handbook for Systematic Reviews of Interventions was used to guide the review process [17]. Publications were searched from January 1, 1980 (or later if the database was not available) up to December 31, 2014 through the following databases: Ovid MEDLINE (1980–2014), Ovid Healthstar (1980–2014), Embase (1980–2014), CINAHL (Cumulative Index to Nursing and Allied Health Literature, 1981–2014), AMED (Allied and Complementary Medicine, 1985–2014), Cochrane DSR (Cochrane Database of Systematic Reviews, 2005–2014), and ACP Journal Club (American College of Physicians Journal Club, 1991–2014). The search strategy for OVID Medline was: [[[“exp Ankle Joint/or exp Ankle/” or “exp Foot/or exp Foot Bones/or exp Foot Joints/”] and [“exp Sprains and Strains/” or “exp Fractures, Bone/” or “(injur$ or fractur$ or strain$ or sprain$).mp”]] or [“exp Ankle Injuries/or exp Ankle Fractures/” or “exp Foot Injuries/”]] and [“cost of illness/” or “economics/” or “cost.mp”]. A similar database-specific search strategy was used for the other databases. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Checklist was used to report the systematic review results [18]. The protocol for this systematic review has not been previously printed.

2.2. Inclusion and exclusion criteria

Published observational studies and trials conducted in the English language, which reported on the costs of treating injuries to the ankle or foot joint, such as sprains and fractures, were included. Studies dealing solely with preventing or diagnosing ankle or foot injuries or regarding injuries to other parts of the lower limb were excluded. All reviews, protocols, technical reports, commentaries, and letters were also excluded. The inclusion and exclusion criteria were applied to the titles and abstracts of the studies. Two independent reviewers screened the abstracts. A consensus was reached if any discrepancies existed. After screening the abstracts, the full-text articles were retrieved and reviewed independently. The reference lists were hand searched for any relevant studies.

2.3. Critical appraisal and data abstraction

Both reviewers abstracted data using a predetermined form. To assess the quality of the studies, criteria from the British Medical Journal Checklist for Authors and Peer Reviewers of Economic Submissions [19] and the CHEC List for Assessment of Methodological Quality of Economic Evaluations [20] were used as recommended in the Cochrane Handbook [17]. Data quality items encompassed the inclusion of the study perspective for the cost data (i.e. who the payer was – health care system, society, etc.), stating the form of economic analysis used, appropriately valuing the costs and outcomes, recording the currency and price data, using discounting if applicable, indicating the presence of a sensitivity analysis, and providing a conclusion appropriate to the data presented. If the perspective was not stated directly in the publication, it was deduced from the presented costs for the purpose of this review. Table 1 provides definitions for commonly used economic terms.

3. Results

A flow chart of the review process is presented in Fig. 1. The literature search identified 2047 studies of which 1562 remained after the removal of duplicates. Of these studies, 141 were kept after the application of the inclusion and exclusion criteria to the abstracts. After screening the abstracts, 65 full-text articles were selected and reviewed. Out of these, 33 articles were excluded due to not being economic analyses, having outcomes that were not costs, investigating the prevention of ankle injuries, being a review, protocol, or technical report, or not specifying the injury type. No additional papers were identified through hand searching of reference lists. Overall, 32 studies were selected for analysis.

The characteristics of the included studies are presented in Table 2. Some of the key highlights of the 32 chosen papers are:

- Several assessed more than one type of foot or ankle injury:
  - 22 (69%) reviewed ankle fractures [21–42]
  - 8 (25%) reviewed foot fractures (including metatarsal, tarsal, talus, calcaneal fractures) [15,16,21,25,28,29,38,43]
  - 3 (9%) reviewed limb threatening ankle and/or foot fractures [43–45]

Table 2
Characteristics of studies.

Authors	Location (study years)	Sample size	Sex	Age range (years)	Study design	Economic analysis	Type of injury	Treatment	Treatment alternatives	Follow-up period
Audenaert et al. [14]	Belgium (2005–2007)	200	M: 71%, F: 29%	Mean: 35 ± 11	Retrospective database review	Cost description	Ankle sprain – grades 1, 2, 3	Any treatment for injury	None	Not stated
Avilucea et al. [44]	Nashville, TN, USA (2000–2010)	56	M: 46%, F: 54%	Mean: 44 ± 15 (cases), 45 ± 14 (controls)	Case control study	Cost description	Isolated ankle fractures: open and closed	Any treatment for injury among cases (individuals with fracture complications) and controls	None	Not stated
Bhandari et al. [42]	Hamilton, ON, Canada (1999)	30	M: 57%, F: 43%	18-81 (mean: 52)	Prospective cohort study	Cost description	Unstable ankle fracture (Weber Type B)	Lateral one-third semi-tubular plate and interfragmentary screw fixation; medial malleolar screw fixation (n = 25)	None	12 months
Bostman [22]	Helsinki, Finland (1985–1991)	888	Not stated	Not stated	Retrospective database review	Cost description	Unimalleolar, bimalleolar, and trimalleolar (severe) ankle fractures	a. Open reduction and internal fixation using absorbable polymer pins or screws	b. Open reduction and internal fixation using metallic implants	Not stated
Bostman [23]	Helsinki, Finland (1985–1993)	1886	Not stated	a. 18–70 (mean: 39) b. 17–78 (mean: 41)	Retrospective database review	Cost minimization analysis	Displaced unimalleolar and trimalleolar ankle fractures	a. Open reduction and internal fixation using absorbable implants (polyglycolide, lactide-glycolide copolymer, polylactide)	b. Open reduction and internal fixation using conventional metallic screws and plates or Kirschner wires	Not stated
Boutis et al. [24]	Toronto, ON, Canada (2003–2005)	104	Not stated	5–18	Randomized controlled trial	Cost-effectiveness analysis	Undisplaced distal fibular types I and II Salter-Harris fractures, avulsion fractures of distal fibula or fibular epiphysis	Aircast air-stirrup ankle brace	Below-knee fiberglass walking cast	3 months
Brauer et al. [15]	Calgary, AB, Canada (date not provided)	102 (with cost data)	M: 94%, F: 6%	Mean: 40	Modelling	Cost-utility analysis	Displaced intra-articular calcaneal fracture	a. Nonoperative treatment (n = 73)	b. Operative treatment (n = 69)	4 years
Cooke et al. [46]	United Kingdom (2003–2005)	551 (318 in cost-utility analysis)	M: 58%, F: 42%	Mean: 30 ± 10.8	Randomized controlled trial	Cost-utility analysis	Severe ankle sprain (grade II or III)	a. Tubular bandage	b. Below knee cast c. Aircast ankle brace d. Bledsoe boot	9 months
Coughlin [16]	Idaho, USA (1992–1994)	48	M: 88%, F: 12%	17–62 (mean: 39)	Retrospective database review	Cost description	Non-displaced extra-articular calcaneal fracture (n = 18), displaced intra-articular calcaneal fracture (n = 30)	Nonoperative treatment, open reduction and internal fixation	None	Not stated
Cumps et al. [47]	Flanders, Belgium (2003)	Not stated by injury	Not stated	22–60 (mean: 44) Not stated	Retrospective database review	Cost description	Acute sport-related ankle sprains among other injuries	Any treatment for injury	None	Not stated

(*continued on next page*)

Table 2 (*continued*)

Authors	Location (study years)	Sample size	Sex	Age range (years)	Study design	Economic analysis	Type of injury	Treatment	Treatment alternatives	Follow-up period
De Boer et al. [21]	Netherlands (2010)	108,167	M: 51%, F: 49%	All ages	Retrospective database review	Cost description	Osseous foot injury (ICD-10 S920-3, S925, S929, S931, S933); ligamentous foot injury (S935-6); osseous ankle injuries (S824-6, S828, S930); ligamentous ankle injuries (S934)	Any treatment for injury	None	Not stated
Dischinger et al. [25]	Maryland, USA (2000–2001)	Ankle: 204, Foot: 98	Not stated	Mean: 33 (single lower-extremity injury)	Retrospective database review	Cost description	Ankle fracture (including uni-, bi-trimalleolar), foot fracture (calcaneus, talus, metatarsal or tarsal)	Any treatment for injury	None	Not stated
Eekman et al. [26]	Netherlands (2007–2008)	10	M: 44%, F: 56%	≥50 (mean: 65 ± 9)	Prospective cohort study	Cost description	Low trauma ankle fracture	Any treatment for injury	None	12 months
Ganesh et al. [27]	USA (1988–2000)	160,598	M: 40%, F: 60%	Not stated	Retrospective database review	Cost description	Ankle fracture (ICD-9 CM 824.0–824.9, 837.0–837.1) requiring surgery	Operative treatment	None	Not stated
Grimm and Fallat [28]	Dearborn, MI, USA (1996)	245	M: 64%, F: 36%	≥20 (mean: 37 ± 9)	Retrospective chart review	Cost description	Ankle injuries (47%), foot injuries (53%); Sprains (41%), fractures (19%)	Any treatment for injury including surgery (open reduction and internal fixation)	None	Not stated
Hartholt et al. [29]	Netherlands (2003–2007)	Ankle: 2000, foot/toe: 1500	Whole cohort: M: 24% F: 76%	≥65 (whole cohort mean: 79)	Retrospective database review	Cost description	Ankle fracture and foot/toe fracture among other fall-related injuries	Any treatment for injury	None	Not stated
Hartholt et al. [30]	Netherlands (2007–2009)	2257	M: 21%, F: 79%	≥65	Retrospective database review	Cost description	Ankle fracture among other fall-related injuries	Any treatment for injury	None	Not stated
Hewitt et al. [31]	Durham, NC, USA (2006–2008)	35	a. M: 40%, F: 60%	a. 18–61 (mean: 37)	Retrospective chart review	Cost description	Displaced lateral malleolus fracture (Weber Type B)	a. Open reduction and internal fixation with TriMed Sidewinder plate	b. Open reduction and internal fixation with interfragmentary screw and one-third tubular neutralization plate	Not stated
			b. M: 20%, F: 80%	b. 21–88 (mean: 52)						
Hoiness et al. [32]	Oslo, Norway (1995, 1998)	191	M: 38%, F: 62%	Mean: 51.3 (SD 17.5)	Retrospective chart review, prospective cohort study	Cost description	Closed ankle fracture	Open reduction and internal fixation	None	3–63 months (mean 30.1 months)
Jain et al. [33]	United Kingdom (2004, 2005)	111	a. M: 49%, F: 51%	a. Mean: 46	Retrospective chart review, prospective cohort study	Cost description	Stable ankle fracture (AO Type A1.2, A1.3, B1.1)	Airloc brace or below-knee walking cast	None	Not stated
			b. M: 44%, F: 56%	b. Mean: 51						

(*continued on next page*)

Table 2 (*continued*)

Authors	Location (study years)	Sample size	Sex	Age range (years)	Study design	Economic analysis	Type of injury	Treatment	Treatment alternatives	Follow-up period
Juutilainen et al. [34]	Helsinki, Finland (1989–1992)	140	a. M: 63%, F: 37% b. M: 50%, F: 50% c. M: 50%, F: 50%	a. 15–73 (mean: 39) b. 18–63 (mean: 38) c. 18–72 (mean: 47)	Prospective cohort study	Cost minimization analysis	Ankle fracture (unimalleolar, bimalleolar, and trimalleolar fractures) requiring operative treatment	a. Self-reinforced polyglycolide acid (SR-PGA) screws	b. Self-reinforced poly-L-lactide acid (SR-PLLA) screws c. Metallic implants	Not stated
Kheir et al. [35]	Leeds, England, United Kingdom (2007–2009)	85	M: 39%, F: 61%	16–84 (mean: 46)	Retrospective database review	Cost description	Isolated, unilateral, closed, and displaced ankle fracture, with or without dislocation	a. Early open reduction and internal fixation (ORIF)	b. Plaster cast (back slab) and application of ice c. Application of temporary external fixation, elevation and ice packs	a. 2–8 days (mean: 6) b. 5–15 days (mean: 10) c. 6–25 days (mean: 14 days)
Kilgore et al. [36]	50 States and Washington D.C., USA (1999–2005)	13,454	Not stated	Age ≥ 65	Retrospective database review	Cost description	Ankle fracture (medial or lateral malleolus, talus) among other fractures	Any treatment for injury	None	6 months
Kleweno et al. [37]	Maryland, USA (2008–2012)	208	Not stated	Age ≥ 18	Retrospective database review	Cost description, profitability analysis	Ankle fracture (ICD-9 CM 824.0, 824.2, 824.4, 824.6) among other injuries	Hospitalization, treated with internal fixation	None	Not stated
MacKenzie et al. [43]	USA (1994–1997)	44	Whole cohort: M: 77% F: 23%	Whole cohort: 72% patients between 20–45	Prospective cohort study	Cost description	Unilateral limb-threatening foot fracture (severe hindfoot or midfoot injury) among other injuries	Any treatment for injury	None	24 months
Meerding et al. [38]	Netherlands (1997)	Not stated	Not stated	Not stated	Modelling	Cost description	Ankle fracture (ICD-9 824), foot/toe fracture (825, 826) among other injuries	Any treatment for injury	None	Lifetime costs
Murray et al. [39]	Belfast, Northern Ireland, UK (2007–2008)	264	M: 49%, F: 51%	14–90 (mean: 46)	Retrospective review of clinical records	Cost description	Ankle fracture (lateral malleolar, bimalleolar, trimalleolar) requiring operative stabilization	Open reduction and internal fixation or external fixation	None	Minimum of 6 months
Roudsari et al. [40]	USA (1998)	Not stated	Not stated	Age ≥ 65 years	Retrospective database review	Cost description	Ankle fracture (ICD-9 824.0)	Any treatment for fracture	None	Not stated
Sanders et al. [45]	Tampa, FL, USA (1983–1989)	11	M: 73%, F: 27%	18–60 (mean: 40)	Case series	Cost description	Open grade IIIB fractures of ankle or talus	Operative treatment	None	Up to 85 months

(*continued on next page*)

Table 2 (*continued*)

Authors	Location (study years)	Sample size	Sex	Age range (years)	Study design	Economic analysis	Type of injury	Treatment	Treatment alternatives	Follow-up period
Slobogean et al. [41]	Canada (date not provided)	81	Not stated	18–65 (mean: 41)	Modelling	Cost-utility analysis	Unstable, isolated, lateral malleolus fracture (Weber Type B)	a. Open reduction and internal fixation (ORIF)	b. Nonoperative management (cast or brace)	12 months, lifetime
Soboroff et al. [11]	USA (date not provided)	Not stated	Not stated	Not stated	Modelling	Cost-effectiveness analysis	Severe ankle sprain	a. Wrapping ankle immediately	b. Casting ankle c. Stress films followed by appropriate treatment d. Arthrograms followed by appropriate treatment e. Stress films followed by arthrograms and then appropriate treatment	Not stated
Yang et al. [48]	Taiwan (2000–2005)	Ankle dislocation: 121	Whole cohort: M: 62% F: 38%	All ages	Retrospective database review	Cost description	Dislocation of ankle (ICD-9 CM 837.X) including fracture-dislocations (52% of cases) among other dislocations studied	Any treatment for dislocation including surgery	None	5 years

  - 5 (16%) reviewed ankle sprains [11,14,21,46,47]
  - 1 (3%) reviewed ankle dislocations [48]
- Close to 60% of the studies (18/32) were published since 2006
- Geographic region of origin was Europe or North America in 31 of 32 (97%) papers as shown in Fig. 2
- The sample sizes varied between the papers:
  - 9 studies (28%) had sample sizes of < 100 subjects [16,26,31,35,41–43,45,44]
  - 9 studies (28%) had sample sizes of between 100 and 250 subjects [14,15,24,28,32–34,37,48]
  - 8 studies (25%) had sample sizes of > 250 subjects [22,23,25,29,30,36,39,46]
  - 2 studies (6%) included data on > 100,000 cases from administrative databases [21,27]
  - 4 studies (13%) did not provide a sample size [11,38,40,47]
- Injuries among children [24] or individuals who were 50 years of age or older [26,29,30,36,40] were only focused on in 20% of the studies (6/32)
- Review of administrative databases or hospital charts was the most common data source in 60% of the studies (19/32)
- The follow-up period was stated in only 44% of the studies (14/32) and ranged from 3 months to 7 years

Table 3 summarizes the health economics information included in the papers. It shows that:

- All of the studies (32/32) were conducted from the payer's perspective of which 31% (10/32) also included the societal perspective
- Discounting was included in 6% of the papers (2/32) and a further two studies provided a rationale for not using discounting
- Sensitivity analysis was undertaken in 16% of the studies (5/32)
- All of the papers (32/32) reported one or more types of direct costs for the treatment of foot and ankle injuries as presented in Fig. 3. The most common costs considered were:
  - Inpatient physician fees: 94% of studies (30/32)
  - Hospital fees: 94% of studies (30/32)
  - Medical devices, treatment costs, inpatient medication: 94% of studies (30/32)
  - Operative costs and hospital stay: 91% of studies (29/32)
  - Diagnostic tests such as radiography and other imaging: 88% of studies (28/32)
  - In 84% of the studies (27/32), the costs came from governmental health insurance, administrative data, or hospital data sources. One study did not report the data source.
- Only 34% of the studies (11/32) assessed indirect costs. The most common costs assessed were:
  - Lost productivity: 100% of studies (11/11)
  - Disability benefits: 36% of studies (4/11)
  - The majority of the information came from governmental statistics and surveys. The sources of indirect costs were reported in 81% of the papers (9/11).

4. Discussion

The present systematic review is the most comprehensive review to include economic analyses of both foot and ankle injury treatments, as well as to assess the inclusion of critical health economics information in the papers. It identified 32 English-language studies dealing with the health economics of the treatment of ankle and foot injuries, including papers that assessed more than one type of injury: 22 (69%) on ankle fractures, 8 (25%) on foot fractures (including metatarsal, tarsal, talus, calcaneal fractures), 3 (9%) on limb threatening ankle and/or foot fractures, 5 (16%) on ankle sprains, and a single study (3%) on ankle dislocations. Approximately 60% of the studies were published in the last decade with the majority reporting findings based on reviews of

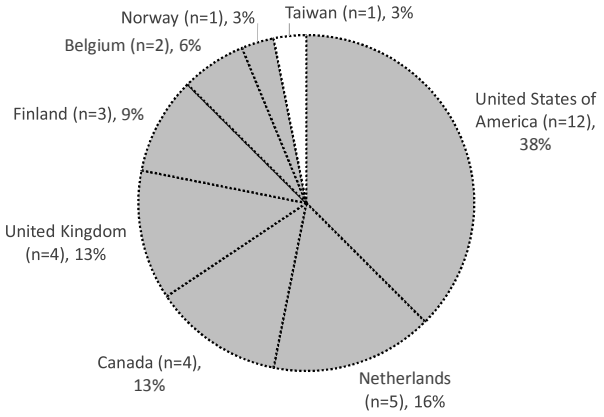

Fig. 2. Pie chart of the distribution of the included articles by country of study.

databases or charts. The papers were mostly focused on adult patients. All but one of the studies were conducted in Europe or North America. The included papers varied substantially in sample size with two database studies assessing costs from over 100,000 individuals. Although obtaining data from many patients is usually related to better precision in estimating the true system costs of treating ankle and foot injuries, it is important to note that the sources of these values are often administrative in nature. Therefore, the reported costs may not capture all expenses, such as patient-level indirect and out-of-pocket costs. In contrast, studies with smaller sample sizes often address these limitations by obtaining the cost information directly from the patients or other data sources and thereby avoid estimations in cost calculations.

In terms of the economic information presented in the selected papers, a number of the studies omitted important data, including the sources of the direct and indirect costs, as suggested in the guidelines [19,20]. For example, the perspective used in assessing the costs in the analyses was not stated implicitly in all of the studies and needed to be determined from the data presented. Moreover, under half of the papers reported the follow-up time period for cost collection and assessment, which ranged from three months to seven years. Data on the length of follow-up are important so that it can be determined whether enough time has lapsed to capture the full extent of recovery and to get a clear estimate of costs related to disability and lost productivity. Another area of weakness was that only five studies undertook a sensitivity analysis in their methodology. This is required whenever there are uncertainties regarding cost data, for example, when they are estimated based on outside sources.

Some of the limitations of this systematic review are the heterogeneity of the included research papers on ankle and foot injuries, as well as the different methods of data collection and presentation used in the studies. Nonetheless, the review provides insight into the expenses related to ankle and foot injury management and highlights the use of health economics methodology in this field. Another limitation is that

Table 3
Cost information and data sources.

Authors	Perspective	Discounting	Sensitivity analysis undertaken	Direct costs considered	Source of direct cost data	Indirect costs considered	Source of indirect cost data
Audenaert et al. [14]	Payer, societal	Not stated	No	1,3,7,8,11	C	14,15	C
Avilucea et al. [44]	Payer	Not stated	No	1,3,4,7,8	B	Not assessed	Not applicable
Bhandari et al. [42]	Payer	Not stated	No	1–8,10	A,B	Not assessed	Not applicable
Bostman [22]	Payer, societal	Not stated	No	1–4,6–8	A,B	14	F
Bostman [23]	Payer, societal	Not stated	No	1–4,6–8	A,B	14	F
Boutis et al. [24]	Payer, societal	Not stated	No	2,6–8,12	A,D,E	14,16,17	F,G
Brauer et al.[15]	Payer, societal	Yes (3, 5, 7%)	Yes	1–8	A,B	14	F,G
Cooke et al. [46]	Payer, societal	No	Yes	1–9,11–13	A,B,E	14	F
Coughlin [16]	Payer	Not stated	No	1–4,6–8	H	14,15	H
Cumps et al. [47]	Payer, societal	Not stated	No	1–9,11,13	C	Not assessed	Not applicable
De Boer et al. [21]	Payer	Not stated	No	1–13	B,G	Not assessed	Not applicable
Dischinger et al. [25]	Payer	Not stated	No	1,3,4	B	Not assessed	Not applicable
Eekman et al. [26]	Payer, societal	No	Yes	1–8,11,13	B,G	14	F
Ganesh et al. [27]	Payer	Not stated	No	1,3,4,7,8	B	Not assessed	Not applicable
Grimm and Fallat [28]	Payer	Not stated	No	1–4	B	Not assessed	Not applicable
Hartholt et al. [29]	Payer	Not stated	No	1–8,10,11	B	Not assessed	Not applicable
Hartholt et al. [30]	Payer	Not stated	No	1–8,10,11	B	Not assessed	Not applicable
Hewitt et al. [31]	Payer	Not stated	No	1,3,4,7,8	B	Not assessed	Not applicable
Hoiness et al. [32]	Payer, societal	Not stated	No	1–4,6–8,11	B	14,15	F
Jain et al. [33]	Payer	Not stated	No	2,5-8	B	Not assessed	Not applicable
Juutilainen et al. [34]	Payer, societal	Not stated	No	1–4, 6-8	B	14,15	Not stated
Kheir et al. [35]	Payer	Not stated	No	1,3,4,7,8,11	B	Not assessed	Not applicable
Kilgore et al. [36]	Payer	Not stated	No	1–4,6,8,10	B	Not assessed	Not applicable
Kleweno et al. [37]	Payer	Not stated	No	1,3,4,8	B	Not assessed	Not applicable
MacKenzie et al. [43]	Payer	Not stated	No	1–4,6–8,11	A,B,C	Not assessed	Not applicable
Meerding et al. [38]	Payer	Not stated	No	1–8,10,11	A,B	Not assessed	Not applicable
Murray et al. [39]	Payer	Not stated	No	1,3,4,7,8	A,B	Not assessed	Not applicable
Roudsari et al. [40]	Payer	Not stated	No	1–8,13	B,C	Not assessed	Not applicable
Sanders et al. [45]	Payer	Not stated	No	1,3,4,7,8	Not stated	Not assessed	Not applicable
Slobogean et al. [41]	Payer	Yes (3%)	Yes	1,3,4,7,8	A,B	Not assessed	Not applicable
Soboroff et al. [11]	Payer	Not stated	Yes	1–9,11	B	14	Not stated
Yang et al. [48]	Payer	Not stated	No	1–8	B	Not assessed	Not applicable

Description of costs and sources of cost data for Table 3.
Costs considered: 1. inpatient physician fees; 2. outpatient physician fees; 3. hospital fees; 4. operative costs and hospital stay; 5. emergency department fees; 6. outpatient clinic/visit fees; 7. diagnostic tests (radiography and other imaging); 8. medical devices, treatment costs and inpatient medication; 9. supportive medical devices (crutches, tapes, etc.); 10. home care or long-term care fees; 11. physical therapy and rehabilitation, occupational therapy; 12. over-the-counter medications; 13. prescription medications; 14. lost productivity; 15. disability benefits; 16. travel costs; 17. child care costs.
Source of cost data: A. Schedule of benefits for health care professional fees and procedures; B. governmental health insurance, administrative or hospital data; C. private insurance data; D. schedule of pharmaceutical benefits, survey of pharmacies; E. manufacturer's information; F. hourly wage information (governmental statistics and surveys); G. self-reported costs; H. workers' compensation.

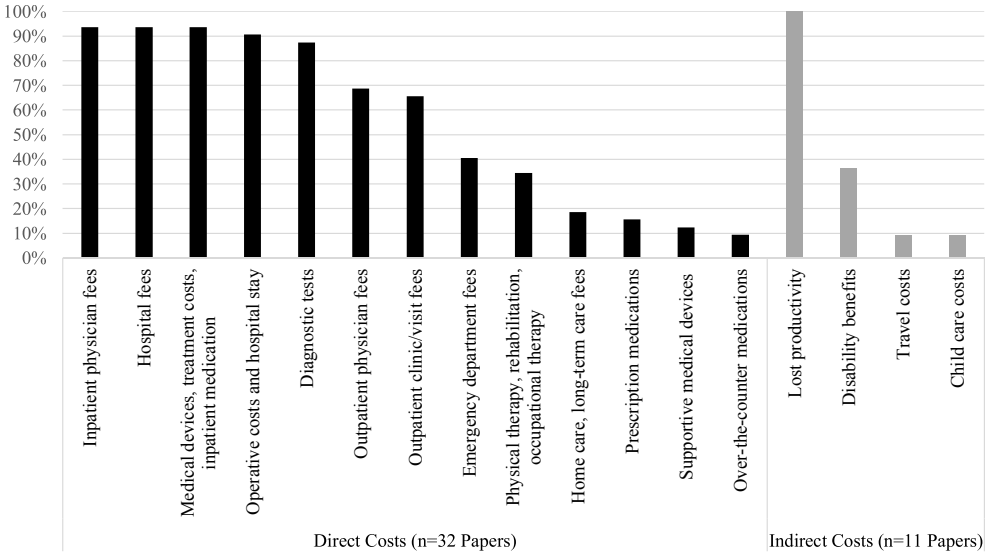

Fig. 3. Percentage of papers by direct and indirect costs considered.

only English-language studies were included in the systematic review thereby eliminating papers that were published in other languages. The generalizability of the systematic review results is impacted by the overwhelming majority of the included studies being conducted in Europe or North America. As such, the direct and indirect costs can only be applied to countries that have similar health care systems as the reviewed papers. Moreover, the majority of the research was conducted on adults with only a few papers reporting the costs among children or the elderly, further affecting the generalizability of the findings.

This systematic review identified numerous research gaps that exist in the health economics of ankle and foot injury treatment. As indicated previously, one area that may need future exploration is how direct and indirect costs of treating ankle and foot injuries differ among children and the elderly. Injuries among children, in particular, may affect their guardians in terms of lost productivity and out-of-pocket expenses. Future studies may also consider the analysis of population databases, such as governmental or private health insurance registries. Such research would provide insight into the direct costs of ankle and foot sprains and fractures and clarify uncertainties about the burden of these injuries on the health care system using large sample sizes.

In summary, studies undertaking economic evaluations should follow the available guidelines and ensure that their cost collection methods are transparent and understandable for readers. Future economic evaluations should include certain critical components in their methodology, such as ensuring that:

- the study perspective for the cost data is included,
- the form of economic analysis used is stated,
- appropriate valuing of the costs and outcomes is undertaken,
- the currency and price data are recorded,
- discounting is used if applicable,
- sensitivity analyses are presented if applicable,
- and a conclusion appropriate to the data is presented.

5. Conclusions

This systematic review summarized and critiqued English-language studies on the economics of ankle and foot injury treatment. It found that the published literature is very heterogeneous and does not consistently report on the various components of health economics methodology as outlined in the guidelines. This in turn limits the quality of information to guide health care providers and policy makers on the costs of treatment associated with these injuries. Future studies should incorporate health economics into their methodology to ensure that these data are collected for the planning of the provision of health services and allocation of health funds.

References

[1] Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont PJ. The epidemiology of ankle sprains in the United States. J Bone Jt Surg Am 2010;92:2279–84.
[2] Lambers K, Ootes D, Ring D. Incidence of patients with lower extremity injuries presenting to US emergency departments by anatomic region, disease category, and age. Clin Orthop Relat Res 2012;470:284–90.
[3] Schappert SM, Rechtsteiner EA. Ambulatory medical care utilization estimates for 2007. Vital Heal Stat 2011;13:1–38.
[4] Kaye JA, Jick H. Epidemiology of lower limb fractures in general practice in the United Kingdom. Inj Prev 2004;10:368.
[5] Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury 2006;37:691–7.
[6] Van Staa TP, Dennison EM, Leufkens HGM, Cooper C. Epidemiology of fractures in England and Wales. Bone 2001;29:517–22.
[7] Coughlin MJ, Smith BW, Traughber P. The evaluation of the healing rate of subtalar arthrodeses, part 2: the effect of low-intensity ultrasound stimulation. Foot Ankle Int 2008;29:970–7.
[8] van Rijn RM, van Os AG, Bernsen RMD, Luijsterburg PA, Koes BW, Bierma-Zeinstra SMA. What is the clinical course of acute ankle sprains? A systematic literature review. Am J Med 2008;121:324–31. http://dx.doi.org/10.1016/j.amjmed.2007.11.018. e7.
[9] Hubbard TJ, Hicks-Little CA. Ankle ligament healing after an acute ankle sprain: an evidence-based approach. J Athl Train 2008;43:523–9.
[10] Arangio GA. Fractures of the ankle and foot in the diabetic population. Curr Opin Orthop 2007;18:128–32.
[11] Soboroff SH, Pappius EM, Komaroff AL. Benefits, risks, and costs of alternative approaches to the evaluation and treatment of severe ankle sprain. Clin Orthop Relat Res 1984;183:160–8.
[12] Osborne MD, Rizzo TD. Prevention and treatment of ankle sprain in athletes. Sport Med 2003;33:1145–50.
[13] Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. Br J Sports Med 2005;39:e14.
[14] Audenaert A, Prims J, Reniers GLL, Weyns D, Mahieu P, Audenaert E. Evaluation and economic impact analysis of different treatment options for ankle distortions in occupational accidents. J Eval Clin Pract 2010;16:933–9.
[15] Brauer CA, Manns BJ, Ko M, Donaldson C, Buckley R. An economic evaluation of operative compared with nonoperative management of displaced intra-articular calcaneal fractures. J Bone Jt Surg Am 2005;87:2741–9.
[16] Coughlin MJ. Calcaneal fractures in the industrial patient. Foot Ankle Int 2000;21:896–905.
[17] Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions vol. 5.1.0. The Cochrane Collaboration; 2011.
[18] Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;339:b2535.
[19] Drummond MF, Jefferson TO. Guidelines for authors and peer reviewers of economic submissions to the BMJ: the BMJ economic evaluation working party. BMJ 1996;313:275–83.
[20] Evers S, Goossens M, De Vet H, Van Tulder M, Ament A. Criteria list for assessment of methodological quality of economic evaluations: consensus on health economic criteria. Int J Technol Assess Health Care 2005;21:240–5.
[21] DeBoer AS, Schepers T, Panneman MJ, Van Beeck EF, Van Lieshout EM. Health care

consumption and costs due to foot and ankle injuries in The Netherlands, 1986–2010. BMC Musculoskelet Disord 2014;15:128.
[22] Böstman O. Economic considerations on avoiding implant removals after fracture fixation by using absorbable devices. Scand J Soc Med 1994;22:41–5.
[23] Böstman OM. Metallic or absorbable fracture fixation devices: a cost minimization analysis. Clin Orthop Relat Res 1996;329:233–9.
[24] Boutis K, Willan AR, Babyn P, Narayanan UG, Alman B, Schuh S. A randomized controlled trial of a removable brace versus casting in children with low-risk ankle fractures. Pediatrics 2007;119:e1256–63.
[25] Dischinger PC, Read KM, Kufera JA, Kerns TJ, Burch CA, Jawed N, et al. Consequences and costs of lower extremity injuries. Annu Proc Assoc Adv Automot Med 2004;48:339–53.
[26] Eekman DA, Ter Wee MM, Coupe VMH, Erisek-Demirtas S, Kramer MH, Lems WF. Indirect costs account for half of the total costs of an osteoporotic fracture: a prospective evaluation. Osteoporos Int 2014;25:195–204.
[27] Ganesh SP, Pietrobon R, Cecilio WAC, Pan D, Lightdale N, Nunley JA. The impact of diabetes on patient outcomes after ankle fracture. J Bone Jt Surg Am 2005;87:1712–8.
[28] Grimm DJ, Fallat L. Injuries of the foot and ankle in occupational medicine: a 1-year study. J Foot Ankle Surg 1999;38:102–8.
[29] Hartholt KA, Van Beeck EF, Polinder S, Van Der Velde N, Van Lieshout EMM, Panneman MJM, et al. Societal consequences of falls in the older population: injuries, healthcare costs, and long-term reduced quality of life. J Trauma 2011;71:748–53.
[30] Hartholt KA, Polinder S, Van Der Cammen TJM, Panneman MJM, Van Der Velde N, Van Lieshout EMM, et al. Costs of falls in an ageing population: a nationwide study from The Netherlands (2007–2009). Injury 2012;43:1199–203.
[31] Hewitt J, Haytmanek CT, Tennant J, May R, Parekh S. Cost effectiveness of the TriMed Sidewinder plate for the treatment of Weber B ankle fractures. Curr Orthop Pract 2011;22:534–7.
[32] Høiness P, Engebretsen L, Strømsøe K. Cost of surgical treatment of closed ankle fractures. Eur J Trauma 2002;28:258–62.
[33] Jain N, Symes T, Doorgakant A, Dawson M. Clinical audit of the management of stable ankle fractures. Ann R Coll Surg Engl 2008;90:483–7.
[34] Juutilainen T, Pätiälä H, Ruuskanen M, Rokkanen P. Comparison of costs in ankle fractures treated with absorbable or metallic fixation devices. Arch Orthop Trauma Surg 1997;116:204–8.
[35] Kheir E, Charopoulos I, Dimitriou R, Ghoz A, Dahabreh Z, Giannoudis P. The health economics of ankle fracture fixation. Bull R Coll Surg Engl 2012;94:1–5.
[36] Kilgore ML, Morrisey MA, Becker DJ, Gary LC, Curtis JR, Saag KG, et al. Health care expenditures associated with skeletal fractures among Medicare beneficiaries, 1999–2005. J Bone Miner Res 2009;24:2050–5.
[37] Kleweno CP, O'Toole RV, Ballreich J, Pollak AN. Does fracture care make money for the hospital? An analysis of hospital revenues and costs for treatment of common fractures. J Orthop Trauma 2015;29:e219–24.
[38] Meerding WJ, Mulder S, van Beeck EF. Incidence and costs of injuries in The Netherlands. Eur J Public Health 2006;16:272–8.
[39] Murray AM, McDonald SE, Archbold P, Crealey GE. Cost description of inpatient treatment for ankle fracture. Injury 2011;42:1226–9.
[40] Roudsari BS, Ebel BE, Corso PS, Molinari NAM, Koepsell TD. The acute medical care costs of fall-related injuries among the US older adults. Injury 2005;36:1316–22.
[41] Slobogean GP, Marra CA, Sadatsafavi M, Sanders DW. Is surgical fixation for stress-positive unstable ankle fractures cost effective? Results of a multicenter randomized control trial. J Orthop Trauma 2012;26:652–8.
[42] Bhandari M, Sprague S, Ayeni OR, Hanson BP, Moro JK. A prospective cost analysis following operative treatment of unstable ankle fractures: 30 patients followed for 1 year. Acta Orthop Scand 2004;75:100–5.
[43] MacKenzie EJ, Jones AS, Bosse MJ, Castillo RC, Pollak AN, Webb LX, et al. Health-care costs associated with amputation or reconstruction of a limb-threatening injury. J Bone Jt Surg Am 2007;89:1685–92.
[44] Avilucea FR, Greenberg SE, Grantham WJ, Sathiyakumar V, Thakore RV, Nwosu SK, et al. The costs of operative complications for ankle fractures: a case control study. Adv Orthop 2014:1–7.
[45] Sanders R, Pappas J, Mast J, Helfet D. The salvage of open grade IIIB ankle and talus fractures. J Orthop Trauma 1992;6:201–8.
[46] Cooke MW, Marsh JL, Clark M, Nakash R, Jarvis RM, Hutton JL, et al. Treatment of severe ankle sprain: a pragmatic randomised controlled trial comparing the clinical effectiveness and cost-effectiveness of three types of mechanical ankle support with tubular bandage. The CAST trial. Health Technol Assess (Rockv) 2009:13.
[47] Cumps E, Verhagen E, Annemans L, Meeusen R. Injury rate and socioeconomic costs resulting from sports injuries in Flanders: data derived from sports insurance statistics 2003. Br J Sports Med 2008;42:767–72.
[48] Yang N-P, Chen H-C, Phan D-V, Yu I-L, Lee Y-H, Chan C-L, et al. Epidemiological survey of orthopedic joint dislocations based on nationwide insurance data in Taiwan, 2000–2005. BMC Musculoskelet Disord 2011;12:253.
[49] Drummond MF, Sculpher MJ, Torrance GW, O'Brien BJ, Stoddart GL. Methods for the economic evaluation of health care programmes vol. 3. Oxford: Oxford University Press; 2005.