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# Traction Splinting for midshaft femoral fractures in the pre-hospital and Emergency Department environment—A systematic review

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ABSTRACT

*Introduction:* Pain and hemorrhage are common in midshaft femoral fractures. Traction splints (TSs) can reduce pain and control hemorrhage, but evidence of their effectiveness in femoral fractures is still lacking. Through a systematic review, we aimed to analyze and discuss the potential role of TSs in the prehospital and emergency department (ED) setting.

*Methods:* The Embase, CINAHL, Cochrane, and PubMed databases were searched up to January 2022. All studies on femoral fractures in the prehospital or ED setting that compared TSs with immobilization or no intervention were included. Articles not written in English, German, or Dutch were excluded. Two authors screened all articles, assessed their quality, and included them if both agreed on their inclusion. The risk of bias was assessed using the modified Methodological Index for Non-Randomized Studies (MINORS). The primary outcome measures were pain and hemorrhage control, while the secondary outcome measures were survivability, morbidity, and complications.

*Results:* A total of 1,248 articles matched the search strategy, 24 articles were assessed for eligibility based on their abstracts, resulting in 20 articles being included in the synthesis. Ten articles reviewed the effects of TSs on pain, while five reported that the use of a TS was appropriate. All five articles that reviewed blood loss found benefits from the use of a TS. One study found significantly fewer pulmonary complications in patients who were splinted earlier at the scene of injury (level III). No difference was found in complications or mortality between prehospital patients receiving a TS or no TS (level III). None of the studies noted that TSs were a necessity in the ED setting; however, some argued that a TS is a necessary and useful prehospital tool in rural or military areas.

*Conclusion:* TS use is associated with a decreased necessity for blood transfusions and fewer pulmonary complications. No favorable effects were found in terms of pain relief. We recommend the use of TSs in situations where one is likely to encounter a femoral fracture as well as when the time to definitive treatment is long. Further well-designed studies are required to validate these recommendations.



## Introduction

### *Rationale*

The femur is the heaviest tubular bone of the body; thus, for it to fracture, a high-energy force is required, such as that from a motor vehicle accident. Femoral fractures are associated with severe complications, such as hemorrhage, fat embolism, and infection. Inappropriate management of femoral fractures can cause prolonged morbidity due to shortening of the bone, misalignment, and deep venous thrombosis. The annual incidence of midshaft femoral fractures is approximately 1 per 10,000 person-years [1]. Prehospital deaths due to femoral shaft fractures were reported to occur at a rate of 3.5 per 100,000 people [2]. Emergency medical service (EMS) personnel should immobilize a suspected femoral fracture to prevent further injury during transport. For midshaft femoral fractures, the use of a traction splint (TS) is recommended to establish patient comfort and improve fracture alignment in the acute setting. TSs are useful in the management of both closed and open fractures of the femoral diaphysis. They are designed to provide temporary stabilization at the scene of injury before the patient is transported to a hospital for definitive surgical treatment and management (i.e., intramedullary nailing or plating) [1]. In

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low- and middle-income countries, TSs are more commonly used as the definitive treatment due to a lack of operative capacity or no osteosynthesis material. However, this is associated with a high incidence of complications as well as a prolonged course of treatment [3].

Moreover, the use of TSs for femoral fractures is controversial [4,5]. Clear evidence-based guidelines for the optimal treatment of femoral fractures prehospitally or in the emergency department (ED) are still absent. During World War I, the application of splints led to a 65% reduced mortality rate [6]. Based on the knowledge available today, other factors might have contributed to this decreased mortality rate, so this figure must be put into perspective [7]. This systematic review appraises the existing literature on the presumed effectiveness of traction splinting with regard to pain and hemorrhage control.

Hemorrhaging from femoral long bone fractures is thought to be significant, with the estimated blood loss ranging from 740 mL up to 2620 mL [8,9]. A TS is thought to significantly decrease bleeding by reducing motion and enhancing the tamponade effect of the muscles and fascia [10]. TSs tire the muscles, resulting in a reduction of muscle spasms and consequently in pain relief [11,12]. The Advanced Trauma and Life Support program published by the American College of Surgeons and Committee on Trauma states that the proper application of a splint helps to control blood loss, reduce pain, and prevent further neurovascular compromise and soft tissue injury [10].

### *Current practice*

Although several rational arguments for TS use have been proposed, the literature still lacks clear evidence of their effectiveness with regard to their effect on pain and hemorrhage control. Studies from the United States (Miami, Florida) [13] and South Africa (Johannesburg) [14] have reported an incidence of only 30–37.5% for TS use before the first radiological exam, regardless of existing guidelines that dictate that a TS must be applied at the scene of femoral fracture. Even after a femoral fracture was confirmed by radiological exam, only 47.5% of patients received a TS. Recent studies have reported that blood loss from a femoral fracture may be less clinically significant than previously thought; therefore, historically formed thoughts and earlier literature on major blood loss from femoral shaft fractures might need to be updated or nuanced. Regarding hemodynamic instability, alternative sources of blood loss or shock must be investigated [15,16]. Thus, the question arises of whether a TS is more valuable than simpler methods of immobilization.

A review of the current EMS guidelines in different countries indicates that TSs have a role in femoral fractures. Yet, the guidelines differ in their recommendations regarding the indications, contraindications, and type of specific splinting devices. EMS protocols in the Netherlands provide instructions for fixating a suspected femoral fracture on a vacuum mattress or using a body splinting technique [17]. Hence, Dutch EMS vehicles are not equipped with traction splints at all. In addition, not all helicopter EMS teams in the Netherlands have access to TS devices. Furthermore, protocols in the United States stipulate that the use of a TS is appropriate for limiting movement as it contributes to patient comfort and a decreased need for pain medication [18]. In Australia, various regional guidelines recommend the use of a CT-6 TS for femoral shaft fractures or fractures of the upper two-thirds of the tibia and fibula unless there are distal fractures or joint involvement [19–22]. Guidelines in Germany recommend the use of TSs for shortened femoral fractures, while a vacuum splint is recommended in all other cases. In addition, the guidelines mention that TSs should not be used on polytrauma patients because contraindications might exist, such as a pelvic fracture [23]. From a military perspective, Tactical Combat Casualty Care guidelines advise all combatants to splint fractures. Thus, military medical personnel should consider TSs for midshaft femoral fractures [24].

### *Objectives*

This systematic review's primary objective was to appraise the international scientific literature on the effectiveness of TS application for femoral fractures in prehospital and ED settings. The secondary aim was to establish clinical recommendations based on the existing literature to improve patient care.

## Methods

### *Search strategy and data collection*

This systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [25]. No predetermined protocol was registered. The Embase, CINAHL, Cochrane, and PubMed scientific databases were searched for relevant articles using various strategies and the following keywords: 'femoral fracture', 'splint', 'traction splint', 'prehospital', 'emergency department', 'pain', and 'hemorrhage control'. No limitations or filters were applied. More specific database-dependent search strategies are outlined in Table 1. Articles and position papers with publication dates up to January 2022 were reviewed. The following PICO (Patient, Intervention, Comparison, and Control) framework was used to determine the search strategy and judge articles by their relevance: patients with long bone fractures: femoral fractures in the prehospital and/or ED setting were included (P); TS devices (defined as longitudinal immobilization, longitudinal forces combined with immobilization of the affected bone) were defined as the intervention (I); patients with applied TS devices were compared with those with nontraction splinting devices (solely immobilization) or those with no intervention at all (C); and the primary outcome measures were pain and hemorrhage control, while the secondary outcome measures were survivability, morbidity, complications, and necessity (O). The titles and abstracts of all studies that matched the search string were independently reviewed by two authors, as were the full texts of all relevant articles. The exclusion criteria were studies without abstracts, publication dates after January 2022, and studies in languages other than English, Dutch, or German. The references of relevant articles were screened to identify other relevant studies. Studies were included if the two authors agreed that the criteria were met as defined by the PICO framework. Disagreements between the authors were solved through discussion. The level of evidence for all included articles was determined according to the Oxford centre of Evidence-based Medicine guidelines [26]. The risk of bias of the included studies was independently assessed by two independent authors. To evaluate the methodological quality of the included studies, the modified Methodological Index for Non-Randomized Studies (MINORS) was used [25]. The global ideal score is 16 and 24 for noncomparative and comparative studies, respectively. The risk of bias was considered high if the MINORS score was less than 12 points and 20 points, respectively (Table 2).

## Results

A total of 1248 studies were retrieved using our search strategy. Twenty studies met the inclusion criteria (Fig. 1). An overview of the included studies is provided in Table 3, while a summary of the results is provided in Table 4. The characteristics of the excluded studies and the reasons for their exclusion are reported in Table 5.

**Table 1**
Literature search strategy (conducted January 2022).

| Database | EMbase | CINAHL | Cochrane | PubMed |
|---|---|---|---|---|
| Search Strategy | ((Exp femur/ AND (exp fracture/ or closed fracture reduction/ or exp fracture healing/)) or exp femur fracture/ or ((femoral.ti,ab,kw. OR femur.ti,ab,kw.) AND fracture*.ti,ab,kw.)) AND (exp traction therapy/ OR traction*.ti,ab,kw. OR exp splint/ OR splint*.ti,ab,kw. OR exp femur fracture/th) AND (exp emergency health service/ OR First Aid/ OR exp patient transport/ OR Ambulance*.ti,ab,kw. OR Paramedic*.ti,ab,kw. OR HEMS.ti,ab,kw. OR Emergency cent*.ti,ab,kw. OR First aid.ti,ab,kw. OR emergency department*.ti,ab,kw. OR pre-hospital.ti,ab,kw. OR prehospital.ti,ab,kw.) | S1 (MH "Femur+")<br>S2 (MH "Fractures+")<br>S3 (MH "Fracture Healing")<br>S4 (MH "Orthopedic Fixation Devices") OR (MH "External Fixators+")<br>S5 (MH "Femoral Fractures+")<br>S6 TI (((femoral OR femur) AND fracture*)) OR AB (((femoral OR femur) AND fracture*)))<br>S7 S2 OR S3 OR S4<br>S8 S1 AND S7<br>S9 S5 OR S6 OR S8<br>S10 (MH "Traction")<br>S11 (MH "Splints")<br>S12 TI (traction* OR splint*) OR AB (traction* OR splint*)<br>S13 S10 OR S11 OR S12<br>S14 S9 AND S13 | #1 MeSH descriptor: [Femoral Fractures] explode all trees<br>#2 MeSH descriptor: [Femur] explode all trees<br>#3 MeSH descriptor: [Fractures, Bone] explode all trees<br>#4 MeSH descriptor: [Closed Fracture Reduction] explode all tree<br>#5 MeSH descriptor: [Fracture Healing] explode all trees<br>#6 #3 or #4 or #5<br>#7 #2 and #6<br>#8 (Femoral or femur) and fracture*:ti,ab,kw (Word variations have been searched)<br>#9 #1 or #7 or #8<br>#10 MeSH descriptor: [Traction] explode all trees<br>#11 MeSH descriptor: [Splints] explode all trees<br>#12 splint* or traction*:ti,ab,kw (Word variations have been searched)<br>#13 #10 or #11 or #12<br>#14 #9 and #13 | (("Femur"[Mesh] AND ("Fractures, Bone"[Mesh] OR "Closed Fracture Reduction"[Mesh] OR "Fracture Healing"[Mesh])) OR "Femoral Fractures"[Mesh] OR ((femoral[tiab] OR femur[tiab]) AND fracture*[tiab])) AND ("Traction"[Mesh] OR traction*[tiab] OR "Splints"[Mesh] OR splint*[tiab] OR Femoral fractures/therapy[Mesh]) AND ("Emergency Medical Services"[Mesh] OR "First Aid"[Mesh] OR "Transportation of Patients"[Mesh] OR Ambulance*[tiab] OR Paramedic*[tiab] OR HEMS[tiab] OR Emergency cent*[tiab] OR First aid[tiab] OR emergency department*[tiab] OR pre-hospital[tiab] OR prehospital[tiab]) |
| Hits (N) | 146 | 403 | 110 | 589 |

*Effect on pain*

Two studies advocated the continued use of TSs as appropriate and effective pain management tools. TSs should be part of an ambulance's equipment [11,27], an opinion indirectly shared by other studies [28,29]. The application of TSs could be a much-needed field therapy for pain management and stabilization [30]. Despite TSs reducing muscle spasms resulting in pain relief, Wood argued that their application results in the manipulation of the injured extremity, which may exacerbate the injury and cause significant pain and discomfort. Wood recommended using a rigid splint and analgesia to provide adequate reductions in pain and blood loss while minimizing the risk of complications [29,31]. In a prospective cohort trial, Bumpass found no significant differences in post-immobilization pain scores between long leg splinting and femoral traction [32]. Moreover, two studies found no benefit from TS application compared with effective analgesia [13,33]. The analgesic requirements in an early traction-splinted group of patients versus a delayed traction-splinted group with isolated femoral shaft fractures did not differ pre- and postoperatively [34]. Five out of 10 studies recommended TSs for pain management; of these, only one small prospective study provided proof, whereas the others only offered expert opinions.

*Effect on blood loss*

Borschneck and Trunkey have stated that the acute management of femoral shaft fractures with TSs is appropriate for controlling hemorrhage, particularly in closed fractures, through reducing the volume of the potential space [11,35]. By restoring the cylindrical shape of the leg, the application of a TS is assumed to inhibit further blood loss and aid in shock prevention. Hoppe found blood transfusion requirements in nonpolytraumatized patients with isolated femoral fractures to be significantly lower in early-splinted patients than in delayed-splinted patients [34]. This finding is in accordance with the outcomes of retrospective studies by Spano and Campagne, in which patients who received a prehospital TS had fewer units of blood transfused in the first 24 h and a shorter hospital stay [36,37]. All five of the aforementioned studies have indicated that TSs are beneficial for reducing blood loss.

*Secondary outcomes*

Hoppe reported a significantly lower rate of pulmonary complications in the early-splinted versus the delayed-splinted group (0% vs. 12.2%, $p = 0.008$) [34]. In the delayed group, a tendency toward prolonged hospitalization was observed simultaneously. The risk of developing fat embolism syndrome substantiates the importance of early long bone fracture traction splinting [38]. However, two of the studies found no difference in complications, morbidity, or mortality in patients who received a prehospital TS compared with those who did not [5,36].

*Complications*

Complications in the use of a TS have mostly been described in case reports and include damage to the foot, ankle, buttocks, and perineum; compartment syndrome; nerve palsies; urethral injury; or ligamentous laxity [38–42]. Furthermore, using excessive force when applying traction with a TS could result in diminished circulation to the distal extremity and stretching of the peripheral nerves, with resultant neurovascular sequelae. Borschneck advocated that, by design, especially the Sager TS overcomes most possible complications and that emphasis should be placed on the correct indications [11]. According to Wood, the use of TSs for polytrauma patients with femoral fractures and concomitant injuries, such as pelvic fractures or injuries, knee injuries, and tibial and/or fibular fractures, is contraindicated due to the increased risk of complications [31]. In such cases, simpler methods of immobilization with fewer complications may be equally efficacious as well as safer.

*Necessity*

Despite the possible complications of TSs, their application may be necessary in certain cases. Three studies have questioned the necessity of a TS device as required equipment for ambulances

**Table 2**
Methodological assessment of the non-randomized studies according to the Methodological Items for Nonrandomized Studies score (MINORS).

| | Bledsoe 2004 | Runcie 2014 | Borschneck 2004 | Nackenson 2017 | Irajpour 2012 | Scheinberg 2004 | Wood 2004 | Martin 2004 | Wood 2003 | Bumpass 2015 | Chu 2003 | Hoppe 2015 | Trunkey 2004 | Spanp 2014 | Campagne 2020 | Gozna 2004 | Abarbanell 2001 | **Rowlands 2003** | **Wieger 2004** | **Haddox 2004** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A clearly stated aim | 1 | 1 | 2 | 2 | 2 | N/A | N/A | N/A | 1 | 2 | 2 | 2 | N/A | 2 | 2 | N/A | 2 | 1 | N/A | N/A |
| Inclusion of consecutive patients | 0 | 1 | 0 | 2 | 2 | N/A | N/A | N/A | 1 | 2 | 2 | 1 | N/A | 1 | 2 | N/A | 1 | 0 | N/A | N/A |
| Prospective collection of data | 0 | 2 | 0 | 1 | 2 | N/A | N/A | N/A | 2 | 2 | 2 | 2 | N/A | 1 | 2 | N/A | 1 | N/A | N/A | N/A |
| Endpoints appropriate to the aim of the study (intention to treat) | 0 | 0 | 0 | 1 | 2 | N/A | N/A | N/A | 0 | 2 | 1 | 2 | N/A | 2 | 2 | N/A | 2 | N/A | N/A | N/A |
| Unbiased assessment of the study endpoint (blinding) | N/A | N/A | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | N/A | N/A | N/A | 0 | 0 | N/A | N/A | N/A | N/A | N/A |
| Follow-up period appropriate to the aim of the study | N/A | N/A | N/A | N/A | 1 | N/A | N/A | N/A | 2 | 2 | 0 | 0 | N/A | 1 | 2 | N/A | 1 | N/A | N/A | N/A |
| Loss to follow-up <5% | N/A | N/A | N/A | N/A | 0 | N/A | N/A | N/A | 0 | 1 | 0 | 0 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Prospective calculation of the study size | N/A | N/A | N/A | N/A | 0 | N/A | N/A | N/A | 0 | 2 | 0 | 0 | N/A | 0 | 0 | N/A | 0 | N/A | N/A | N/A |
| An adequate control group [1] | N/A | N/A | N/A | 1 | 2 | N/A | N/A | N/A | N/A | 2 | N/A | 1 | N/A | 1 | 2 | N/A | N/A | N/A | N/A | N/A |
| Contemporary groups[1] | N/A | N/A | N/A | 2 | 2 | N/A | N/A | N/A | N/A | 2 | N/A | 2 | N/A | 1 | 1 | N/A | N/A | N/A | N/A | N/A |
| Baseline equivalence of groups[1] | N/A | N/A | N/A | N/A | 2 | N/A | N/A | N/A | N/A | 1 | N/A | 2 | N/A | 2 | 1 | N/A | 0 | N/A | N/A | N/A |
| Adequate statistical analyses[1] (CI[2]; RR[3]) | N/A | N/A | N/A | 2 | 1 | N/A | N/A | N/A | 0 | 2 | 0 | 2 | N/A | 2 | 2 | N/A | 0 | N/A | N/A | N/A |
| **Total** | **1** | **4** | **2** | **11** | **16** | **N/A** | **N/A** | **N/A** | **6** | **20** | **7** | **14** | **N/A** | **13** | **16** | **N/A** | **7** | **1** | **N/A** | **N/A** |

Item Score: 0 (not reported); 1 (reported but inadequate); 2 (reported and adequate).
[1] Additional criteria in the case of comparative study.
[2] Confidence intervals.
[3] Relative risk.

**Table 3**
Overview of included articles and studies.

| Reference | Study type | Level of evidence | Number of subjects | Outcome measures | Conclusion |
|---|---|---|---|---|---|
| [3] Bledsoe | Review/position paper | V | N/A | N/A | Relatively low usage of TS demands revisited guidelines for ambulance and rescue vehicles |
| [4] Runcie | Retrospective | III | N/A | Establish incidence rates of femoral fractures in mountain rescue<br>Investigate attitude towards TS<br>Review literature for evidence on TS<br>Test hypothesis that application of TS reduces mortality and morbidity in patients with femoral fractures | Femoral fractures are rare in mountain rescue<br>TS may be no more effective than other methods of splinting in prehospital care<br>No evidence was identified that supports the hypothesis that TS reduces mortality and morbidity |
| [10] Borschneck | Position paper | V | N/A | N/A | Continued use of TS in acute management of femoral shaft fractures seems appropriate |
| [12] Nackenson | Retrospective | III | 170 | Application of TS in blunt versus penetrating injuries<br>Use of analgesia | Only 30% of patients with midshaft femur fracture where immobilized using a TS<br>No association was found between TS utilization and morphine administration |
| [25] Irajpour | Experimental prospective cohort | III | 32 | Pain intensity between simple and traction splint groups | Significant reduction in pain 1, 6 and 12 h after traction splinting |
| [26] Scheinberg | Position paper | V | N/A | N/A | Overriding reason for TS application is pain relief. |
| [27] Wood | Position paper | V | N/A | N/A | In the setting of poly trauma a rigid splint and opioid analgesia provide adequate reduction in pain and blood loss while minimizing complication risks. |
| [28] Martin | Position paper | V | N/A | N/A | TS can be a much-needed field therapy for pain management and stabilization, but lack of relevant and critically unbiased studies |
| [29] Wood | Prospective follow-up | III | 828 | Identify patients with TS in place for femur fracture immobilization<br>Identify injuries patients with injuries that can complicate and/or contraindicate TS use | Of 828 multisystem trauma patients 40 (4.8%) were identified having as having a TS in place for femur fracture<br>Complicating and contraindicating injuries were found in 15 out of 40 (38%) patients<br>No current evidence-based research demonstrating the efficacy of TS or comparing the outcomes of TS versus traditional rigid splints |
| [30] Bumpass | Prospective cohort trial | III | 33 | VAS scores pre immobilization, during application and post immobilization in splint group versus skeletal traction group | Traction pin placement led to less discomfort during application compared with splint placement.<br>No significant difference was seen in post immobilization pain scores |
| [31] Chu | Retrospective | III | 95 | Establish a consensus opinion on best ED practice with regard to TS application in children with femoral fractures<br>Hypovolemic shock and pain scores | Timing of TS did not appear to be associated with hypovolemic shock or neurovascular complications in isolated pediatric femoral shaft fractures<br>Main priority is pain relief preferably via femoral block and titrating analgesia |
| [32] Hoppe | Retrospective | III | 106 | Blood transfusion and analgesic requirements in early versus delayed TS groups | Blood transfusion and pulmonary complications significantly lower in early splinted group<br>No differences in analgesic requirements between early versus delayed TS groups |
| [33] Trunkey | Position paper | V | N/A | N/A | Acute management of femoral shaft fractures with a TS is appropriate.<br>A TS will control hemorrhage, particularly in a closed fracture by reducing the volume of the potential space.<br>It would be appropriate for a multi-institutional RCT to be carried out. |
| [34] Spano | Retrospective | III | 579 | MortalityH<br>Hospital length of stay<br>Units of blood transfused<br>Complications | No difference in complications or mortality in patients receiving prehospital TS versus those who did not<br>Patients who had a prehospital TS placed had fewer units of blood transfused in the first 24 h and shorter hospital LOS<br>However, these patients had a lower ISS and thus were not as sick as the no traction group |
| [35] Campagne | Retrospective | III | 218 | Mortality Hospital length of stay Units of blood transfused Complications | TS can lower hospital length of stay. |

(*continued on next page*)

**Table 3** (*continued*)

| Reference | Study type | Level of evidence | Number of subjects | Outcome measures | Conclusion |
|---|---|---|---|---|---|
| [36] Gozna | Position paper | V | N/A | N/A | *Re*-evaluate the cost-effectiveness and efficacy of the types of splints currently used.<br>Due to substantial risk of developing fat embolism syndrome patients with femoral fractures should be properly and safely splinted. |
| [41] Abarbanell | Retrospective | III | 16 | Use of/need of TS | Position of comfort may constitute an acceptable course of care<br>TS as essential ambulance equipment may be unnecessary |
| [42] Rowlands | Case report | IV | 7 | N/A | TS remains to play an important role in military femoral trauma<br>Application of TS allows early evacuation to a base hospital for internal fixation |
| [43] Wiegert | Position paper | V | N/A | N/A | TS is a tool used by Army medical personnel<br>Unit medical officer will guide protocol on application and/or removal |
| [7] Haddox | Position paper | V | N/A | N/A | Only indication is a suspected closed, isolated, mid-shaft femur fracture.<br>Better and more training required.<br>Future research to be conducted with hospitals and EMS services that have responsibility for ski resorts. |

**Table 4**
Reasons for exclusion of studies.

| Author and year of publication | Reason for exclusion | | | | |
|---|---|---|---|---|---|
| | Not meeting PICO | Not concerning effects on pain | Not concerning effects on blood loss | Using TS as definitive treatment | Summary |
| Canning 2003 | X | X | X | | Letter to editor about infection risk in open femoral fractures |
| Daugherty 2013 | X | X | X | | Retrospective study to assess the rate of misapplication of the Hare traction device among femoral shaft fractures in pediatric patients |
| Mansson 2006 | | | | X | Retrospective analysis of the incidence and prevalence of femoral fractures. Prospective study to determine the force of traction exerted by TSs over time. |
| Short 1984 | X | X | X | | Prospective study comparing simple traction and cast bracing with the Thomas' Splint in terms of time spent in traction, hospital length of stay and return to work |

Canning MC. To splint or not to splint. JEMS. 2003 Aug;28(8):20; discussion 20. PMID: 14,518,505.
Daugherty MC, Mehlman CT, Moody S, LeMaster T, Falcone RA Jr. Significant rate of misuse of the Hare traction splint for children with femoral shaft fractures. J Emerg Nurs. 2013 Jan;39(1):97--103. doi: 10.1016/j.jen.2012.10.008. PMID: 23,295,094.
Mansson, E., A. Ruter, and T. Vikstrom. "Femoral shaft fractures and the prehospital use of traction splints." Scand J Trauma Resusc Emerg Med 14 (2006): 26--9.
Short J, Upadhyay SS. Does simple traction and functional bracing affect the outcome of a fractured femur as compared with the Thomas' splint method? Physiotherapy [Internet]. 1984 Sep [cited 2022 Aug 4];70(9):350--4. Available from: https://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=107579485&site=ehost-live

and rescue vehicles [4,33,43]. Reasons reported for revising existing guidelines were the low incidence rate of femoral fractures and only 0.07% of patients meeting the criteria for TS use [43]. In addition, differences in hypovolemic shock and neurovascular complications were found to be lacking in isolated pediatric femoral shaft fractures between early and late TS applications; thus, the question of whether a TS should be used prehospitally or even in EDs must be addressed [33].

Moreover, military and rural prehospital settings can differ from general prehospital settings when it comes to TS application [44]. Two studies have considered the importance of TSs in the military for facilitating the transport and evacuation of patients, given the potentially long evacuation times [44,45]. Furthermore, one study discussed the applicability of TSs in mountainous terrain prehospitally, concluding that a TS may be no more effective than other methods of splinting in prehospital care [5].

In sum, studies on the necessity of a TS in ambulances and rescue vehicles as well as in military or rural prehospital settings are not unanimous. Two studies have found that the "high-risk, low-frequency" situation does not justify removing TSs from ambulances [11,46]. Despite evidence reporting no benefits from the (early) use of TSs, they might still be useful in military settings.

## Discussion

Twenty-four studies were identified based on our search strategy, of which 4 were excluded mainly due to not answering our primary research question. The current decision to apply traction devices in prehospital and hospital care is mostly based on the opinions of experts; therefore, daily practice differs between various medical services and hospitals. Five out of the 10 articles that have discussed the effects of a TS on pain confirmed that continued TS use is appropriate. The only prospective study (level III) on

**Table 5**
Crosstable. Significance and implication of used articles in relation to level of evidence showing if using a TS is beneficial. Completed by all authors.

| Effect on pain | Author | Conclusion | Level of evidence & study type | No of subjects | P-value | Added value |
|---|---|---|---|---|---|---|
| | Bumpass | no difference in post immobilization scores | III prospective cohort | 71 | 0,12 | |
| | Irajpour | significant reduction 1, 6 and 12 hrs after application of TS | III prospective cohort | 32 | 0,02 | |
| | Chu | pain relief preferably via block or IV | III retrospective | 95 | N/A | |
| | Nackenson | no association TS and analgesia use | III retrospective | 159 | 0,678 | |
| | Hoppe | no difference early and delayed application | III retrospective | 106 | 0,41 | |
| | Wood | regular splinting and IV analgesia provide also adequate relief | V position paper | N/A | N/A | |
| | Borschneck | TS decreases muscle spasm and therefore pain | V position paper | N/A | N/A | |
| | Slishman | same reasoning as Borschneck | V position paper | N/A | N/A | |
| | Scheinberg | reduction when TS applied | V position paper | N/A | N/A | |
| | Martin | TS much needed field therapy for pain relief | V position paper | N/A | N/A | |
| Effect on blood loss | | | | | | |
| | Hoppe | lower requirements for blood transfusion in early splinted group | III retrospective | 106 | 0,04 | |
| | Spano/Campagne | fewer blood units needed first 24 hrs when prehospital TS was placed | III retrospective | 579 | 0,001 | |
| | Campagne | lower hospital length of stay | III retrospective | 218 | 0,05 | |
| | Borschneck | TS will control hemorrhage by reducing volume of potential space | V position paper | N/A | N/A | |
| | Trunkey | same reasoning as Borschneck | V position paper | N/A | N/A | |
| Effect on complications | | | | | | |
| | Wood | in multiple-trauma patients, injuries that can complicate traction splint use are common | III prospective follow-up | 40 | N/A | |
| | Hoppe | lower rate of pulmonary complications in the early-splinted group | III retrospective | 106 | 0,08 | |
| | Spano | no difference in complications or mortality in patients receiving prehospital TS | III retrospective | 579 | 0,09 | |
| | Campagne | no difference in complications or mortality in patients receiving prehospital TS | III retrospective | 218 | 0.771 | |
| | Gozna | due to substantial risk of developing fat embolism patients should be properly TS | V position paper | N/A | N/A | |
| | Runchie | no reduction in mortality and morbidity, TS no more effective than other methods of splinting prehospitally | III retrospective | N/A | N/A | |
| Necessity | | | | | | |
| | Runcie | literature evidence suggests that traction splints may be no more beneficial than simple splints | II review | 5 | N/A | |
| | Abarbanell | TS as essential ambulance equipment may be unnecessary | III retrospective | 16 | N/A | |
| | Chu | timing of TS was not associated with shock or complications. Necessity of TS is questioned | III retrospective | 95 | N/A | |
| | Rowlands | TS remains to play an important role in military trauma. | IV case-report | 7 | N/A | |
| | Bledsoe | considering the relatively low usage of the TS, it is time to revisit guidelines that require TS | V position paper | N/A | N/A | |
| | Borschneck | due to incidence numbers the value of having a TS on board should not be easily underestimated | V position paper | N/A | N/A | |
| | Haddox | no removal before good research has been performed | V position paper | N/A | N/A | |
| | Wiegert | TS is a tool. Application to be decided by medical officer | V position paper | N/A | N/A | |

Despite level of evidence author states there is no clear added value of applying or having a TS.
Despite level of evidence author states there is added value of applying or having a TS.

this topic was conducted by Irajpour, who demonstrated a positive association between TS use and faster pain reduction compared with regular splinting; however, the author also found that regular splinting significantly contributes to pain relief [27]. Other studies have confirmed this finding [13,29,32,34]. Given the low incidence of patients eligible for treatment with a TS (only 30% of patients with midshaft femoral fractures were immobilized using a TS), obtaining large samples is difficult. Based on the reviewed studies, insufficient evidence exists to confirm that TS application reduces pain more effectively than regular rigid splinting, long backboard immobilization, or other alternatives (e.g., femoral block or IV analgesia) [43].

All five articles that have reviewed the effects on blood loss stated that TSs are valuable [11,34–37]. Hoppe's level III retrospective study highlighted that early splinting reduces the requirement for and the amount of transfused blood in patients with isolated femoral fracture. A notable limitation is that the timespan from the accident to the arrival of paramedics was not routinely recorded. Delayed splinting might underestimate the effect of TSs on blood loss. Furthermore, Hoppe did not identify polytrauma patients (except from other fractures) or report the injury severity score (ISS), which might have created substantial bias [34]. Campagne and Spano have reported similar results, with fewer blood products required for prehospital-splinted patients [36,37]. These patients had a lower ISS compared with the non-TS group and were apparently less seriously injured, which was associated with a lower demand for blood transfusions. From a hemorrhage control perspective, TS use is justified by these level III studies. However, reservations regarding selection bias and other confounding factors should be noted.

Comparative literature on TS use in terms of secondary outcomes and associated complications is scarce. After the application

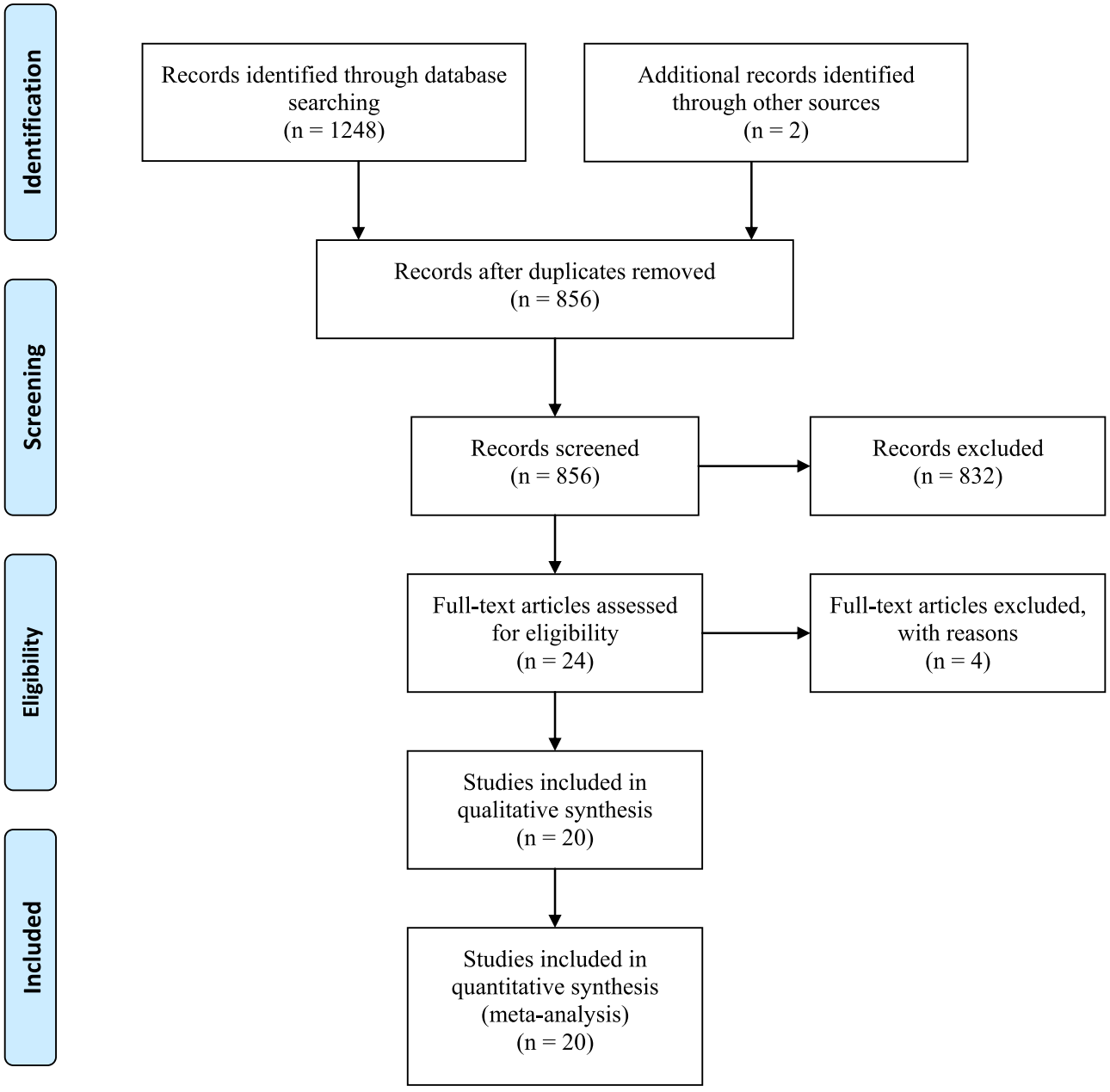


**Fig. 1.** PRISMA Flow Diagram. Maps out the number of records identified, included and excluded during the search process. Format derived from http://prisma-statement.org/prismastatement/flowdiagram.aspx. Completed by all authors.

of a TS, it is imperative to perform regular checks to avoid unintentional side effects. No time limits for the long-term use of TSs have been set by the manufacturers. If prolonged use is unavoidable, splint areas should be frequently monitored, and repositioning of the device should be performed to avoid neurovascular compromise and soft tissue damage.

Furthermore, opinions on pulmonary complications arising from TS application are equally divided. Considering the limitations of the aforementioned studies and the level of evidence provided, no definitive conclusions could be drawn based on the current literature.

Surprisingly, no authors have claimed that TSs are a necessity in the ED setting, while three articles have even questioned their use in a prehospital settings [4,33,43]. One of the major arguments for excluding a TS from the standard equipment in the ED is the low incidence of femoral fractures. However, based on the distribution of incidence of femoral shaft fractures in our region, the use of TSs in the ED of level 1 trauma centers should be considered [47].

Based on the low incidence of femoral fractures [3,48], the chance for an ambulance to encounter a femoral fracture is low. Based on ICD incidence figures and the estimated availability of EMS vehicles in the United States, the chance is 11 per ambulance per year on average. In the Netherlands, the average per ambulance is 4.2 annually [47,49]. Based on calculations from the Dutch National Trauma Registry database, the chance of encountering a femoral fracture during an ambulance shift is approximately 1.43 femoral fractures per registered nurse annually. Using the total number of ambulance trips, femoral fractures have been found to be present in 0.26% of all cases [47,49,50]. With the low a priori chance of encountering a femoral fracture and the potential complications, available alternatives, and required training in the use of a TS, we believe that TSs should not be part of the necessary

equipment for ambulances or rescue vehicles in urban areas. In helicopter EMS operations (including mono- and polytrauma injuries) or operations in austere/military environments with longer transport times, where readily available blood products or alternative methods for pain management are absent, patients might benefit from the application of a TS. This recommendation, however, is based on expert opinions but only poor-quality evidence.

*Strengths and limitations*

This systematic review questioned the advantages and disadvantages of applying TSs for femoral fractures. We acknowledge several limitations, including the low to moderate quality of the included studies and the potential selection and information bias. Furthermore, wide variability existed in study designs, study subjects, and outcome measures, which limited our ability to develop conclusions. We accessed a wide range of scientific databases to include as many articles as possible on this topic published up to January 2022. Nonetheless, our narrow search strategy and our limitation to only articles in the English, Dutch, or German language might have led to missed articles, and therefore, to a potential lack of evidence. Further research concerning TS application must be preceded by investigations into closed femoral fracture blood loss. The described blood loss from femoral fractures in basic training programs has either been estimated or derived from laboratory results. This claimed blood loss should be objectified, and justification for TS application should originate from a clear, significant etiology.

## Conclusion

Literature on the effects of TSs on pain management and blood loss is scarce. This systematic review demonstrated that TS use is associated with a decreased necessity for blood transfusions and fewer pulmonary complications (level III). Moreover, no favorable effects of TSs were found on pain relief. In urban situations, the incidence of femoral fractures for emergency vehicles is low. We recommend the use of TSs in situations where one is likely to encounter a femoral fracture in the ED setting (e.g., a level 1 trauma center) or a prehospital setting (e.g., helicopter EMS teams). We also recommend their use in situations where time to definitive treatment is long, such as in rural areas. Further well-designed research is required to validate these recommendations.

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## Declaration of Competing Interest

The authors have no conflict of interest to declare.

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