Supplementary materials

Table 1

Study (Year)	Kmet Percentage First Reviewer	Kmet Percentage Second Reviewer	Inclusion (Yes/No)	Quality Judgment
Chen et al (2022)	92.30	82.14	Yes	High Quality
Castro-Marin et al (2019)	96.15	81.81	Yes	High Quality
Cowley_et_al	59.09	68.18	No	Low Quality
Dixon et al (2015)	92.30	75.00	Yes	High Quality
Etheridge et al (2022)	96.15	81.62	Yes	High Quality
Fujii et al (2013)	96.15	86.38	Yes	High Quality
Habibi Arejan et al (2022)	92.30	75.00	Yes	High Quality
Hankins_et_al	61.11	63.63	No	Low Quality
Häske et al (2022)	100	77.27	Yes	High Quality
Häske et al (2022)	100	77.27	Yes	High Quality
Hood et al (2015)	96.15	75.00	Yes	High Quality
Horodyski et al (2011)	92.30	81.62	Yes	High Quality
Rhodes et al (2016)	100	79.16	Yes	High Quality
Lee et al (2023)	96.15	86.36	Yes	High Quality
Kornhall et al (2017)	61.11	41.67	No	Low Quality
Yue et al (2017)	96.15	75.00	Yes	High Quality
Kon Jin et al (2007)	100	79.16	Yes	High Quality
Kwan et al (2001)	96.15	75.00	Yes	High Quality
Larson et al (2017)	100	75.00	Yes	High Quality
Maschmann et al (2019)	92.30	79.17	Yes	High Quality
Mitchnik et al (2024)	100	81.82	Yes	High Quality
Oteir et al (2015)	96.15	83.33	Yes	High Quality
Peery et al (2007)	92.30	81.62	Yes	High Quality
Stuby et al (2024)	96.15	83.33	Yes	High Quality
Sundstrøm et al (2014)	100	86.36	Yes	High Quality
Tello et al (2014)	100	79.16	Yes	High Quality
Brinke et al (2018)	96.15	81.82	Yes	High Quality
Tippett (1993)	50	40.90	No	Low Quality
Underbrink et al (2018)	100	86.36	Yes	High Quality
Vaillancourt et al (2011)	96.15	75.00	Yes	High Quality
Van de Breevaart et al (2023)	96.15	79.16	Yes	High Quality
Rice et al (2024)	100	83.33	Yes	High Quality

Table 2

Author (Year)	Title	Journal	Context	Method	Population	Intervention	Outcomes	Results	Conclusion
Chen et al. (2022)	A multicenter cohort study on the association between prehospital immobilization and functional outcome of patients following spinal injury in Asia	Scientific Reports	Prehospital spinal motor restriction is a common procedure in emergency services, but solid evidence regarding its effectiveness is lacking. This study stems from the need to understand whether this practice actually	Multicenter retrospective cohort study based on data from the PATOS registry (Pan-Asia Trauma Outcomes Study), collected between 2016 and 2018. Included were adult patients (>16 years) with traumatic spinal injuries (fracture, dislocation, subluxation, disc rupture), transported by EMS. Exclusion criteria	A total of 759 patients with spinal injuries from five Asian countries: Korea, Malaysia, Japan, Taiwan, and Vietnam. The median age was 58 years, and 57.7% received spinal motor restriction.	Prehospital spinal motor restriction was defined as the use of a cervical collar and/or a rigid or scoop stretcher. Classification was based on EMS reports. Other orthopedic devices (e.g., femoral splints, pelvic binders)	Primary outcome: functional status at discharge measured by the Modified Rankin Scale (mRS). A favorable outcome was defined as mRS 0–3. Secondary outcomes: RTS, ISS, injury location, surgical intervention, and scene-to-hospital time.	No significant association between immobilization and favorable outcome in the overall population (aOR 1.06, p = 0.826). Significant positive association in the subgroup with cervical injury (aOR 3.14; 95% CI 1.04–	Prehospital immobilization does not improve overall functional outcomes in patients with spinal injury, but may be beneficial in cases of cervical injury. Caution and selective clinical judgment are advised

			improves functional outcomes in patients with spinal injury in Asia, where EMS protocols can vary significantly.	included traumatic brain injury, pre-existing disability, and incomplete data. Multivariate analysis was conducted on 759 definitive cases.	Subgroup analyses were also performed based on injury location (cervical, thoracic, lumbar), ISS, RTS, and presence of surgical intervention.	were considered unrelated to spinal motor restriction.		9.50; p = 0.043). Other predictors of unfavorable outcome included high ISS, spinal surgery, and aggressive prehospital management.	for EMS providers.
Castro-Marin et al. (2019)	Prehospital Protocols Reducing Long Spinal Board Use Are Not Associated with a Change in Incidence of Spinal	Prehospital Emergency Care	In recent years, EMS protocols in many U.S. states have reduced the use of the long spine board	Statewide retrospective observational study conducted in Arizona, using linked EMS records and hospital discharge data (ICD-9/10 codes).	A total of 104,315 EMS encounters were analyzed, divided into pre- and post-SMR implementation	Implementation of SMR protocols aimed at reducing or eliminating the routine use of long spine boards (LSBs).	Primary outcome: incidence of spinal cord injury (SCI) at hospital discharge, with diagnoses based on ICD-9/10 codes.	No significant difference in SCI incidence between the pre- and post-SMR periods: TI (0.20%	The adoption of SMR protocols did not lead to an increase in spinal cord injuries. The findings

	Cord Injury		(LSB) in favor of spinal motion restriction (SMR). However, it remains unclear whether this change increases the risk of neurological harm. This study evaluates the safety of the SMR approach on a large scale.	Included were patients with trauma (TI), suspected spinal trauma (P-ST), and confirmed spinal trauma (V-ST), both before and after the implementation of SMR protocols (2013–2015).	periods. The sample included a representative population of adult trauma patients transported by 85 ground-based EMS agencies. The population was stratified into TI, P-ST, and V-ST groups. Median age ranged from 57 to 70	The comparison was between the pre-SMR era (LSB-based immobilization) and the post-SMR era (spinal motion restriction using alternative methods).	Stratified analysis was performed across subgroups: TI, P-ST, and V-ST. Statistical adjustments were made for age, Injury Severity Score (ISS), and trauma severity.	vs. 0.22%), P-ST (0.40% vs. 0.45%), V-ST (4.04% vs. 4.37%). The adjusted odds ratio for SCI in V-ST patients was 1.097 (95% CI 0.818–1.472).	support the implementation of practices that minimize the use of long spine boards without increasing risk to patients.

					years depending on the group. The overall incidence of SCI was very low (<0.5%).				
Dixon et al. (2015)	Confirmation of suboptimal protocols in spinal immobilisation?	Emergency Medicine Journal	Conventional extrication techniques using a cervical collar and long spine board may result in greater cervical spine movement compared to controlled self-extrication. This	Experimental study involving 16 healthy volunteers, with 3D kinematic measurements of cervical spine motion during six extrication techniques performed in a vehicle modified for simulation. Reflective markers and a 12-camera	Sixteen participants (7 males, 9 females), with a mean age of 24 years, divided into three body mass groups. The simulated scenario involved a crashed	Comparison of six techniques: self-extrication with and without a cervical collar, long spine board (LSB) extrication from various positions, and extrication using a short	Primary outcome: total cervical spine movement (absolute angle in degrees) during each extrication technique. ANOVA was used for statistical comparison among techniques, with additional analysis of correlations	The average cervical spine movement during self-extrication without a collar was 13.33°, while some techniques involving the LSB exceeded 18.8°.	In hemodynamically stable patients, controlled self-extrication results in less cervical spine movement compared to traditional techniques. The findings challenge

			study biomechanically evaluates six extrication techniques in healthy subjects, within a realistic simulated environment, to identify the approach associated with the least cervical motion.	high-speed motion capture system (200 Hz) were used to detect movements across the three anatomical planes.	vehicle, with standard extrication techniques performed by a team of six professional rescuers.	jacket (SEJ). All methods involved collaboration with a rescue team and the application of standard rigid cervical collars.	with participant height and weight.	Paramedic-guided self-extrication resulted in significantly less cervical movement compared to the use of SEJ or LSB ($p < 0.05$).	the effectiveness of standardized conventional extrication methods.
Etheridge et al. (2022)	Practice patterns after implementation of a selective spinal immobilization	The Journal of Trauma and Acute Care Surgery	The standardization of spinal motor restriction is evolving, with an	Retrospective observational study based on registry data collected before and after the implementation of a selective	Adult patients transported by EMS within a regional trauma system in	Selective spinal motor restriction protocol based on clinical criteria (e.g., spinal	Primary outcomes: frequency of use of cervical collars, long spine boards (LSBs), short extrication	A significant reduction in the use of full immobilization and long	The introduction of a selective protocol led to safe changes in clinical practice,

	protocol in a regional trauma system		increasing number of EMS systems adopting a selective approach. This study evaluates how the implementation of a selective immobilization protocol has changed clinical practices within a regional trauma system in the United States.	immobilization protocol. The analysis focused on changes in immobilization patterns and device usage among adult trauma patients.	the United States. The dataset included thousands of cases, stratified by minor vs. major trauma. The population was studied before and after the introduction of the selective immobilization protocol.	pain, neurological deficits, mechanism of injury). The study evaluated the reduction in the use of long spine boards (LSBs) and full immobilization following the implementation of the new guidelines.	jackets (SEJs), and full immobilization. Secondary analyses included changes in transport time, safety, and the incidence of adverse events (when reported).	spine boards (LSBs) was observed in the post-implementation period. There was an increased use of cervical collars alone in low-risk patients. No increase in documented complications or adverse outcomes was reported.	aligning with emerging evidence. The clinical judgment–based approach reduced the use of full immobilization without apparent negative effects.

Fujii et al. (2013)	Risk factors for cervical spine injury among patients with traumatic brain injury	Journal of Emergencies, Trauma, and Shock	In patients with traumatic brain injury (TBI), the diagnosis of cervical spine injury is complex and often delayed. This study aims to identify risk factors associated with cervical spine injuries in TBI patients, in order to support early immobilization and	Retrospective observational study using data from the 2007 National Trauma Data Bank – National Sample Project (NTDB-NSP). Over 180,000 patients with TBI were analyzed to determine the association between cervical spine injury (CSI) and clinical, demographic, and injury mechanism factors.	A total of 187,709 adult patients with TBI. The mean age was 46.7 years, and 68.5% were male. Cervical spine injuries were present in 8.6% of cases. The predominant mechanisms were motor vehicle collisions and falls. Analyses were	No direct intervention was applied; the study focused on identifying predictors of cervical spine injury (CSI) in patients with TBI. Logistic regression was used to evaluate associations between CSI and variables such as age, mechanism of injury, hypotension, and associated fractures.	Primary outcome: presence of cervical spine injury (CSI) in patients with TBI, identified using ICD-9-CM codes for cervical fracture, dislocation, or spinal cord injury. Associations with predictive factors were analyzed using odds ratios (ORs) with 95% confidence intervals.	CSI was identified in 8.6% of patients with TBI. Associated factors included: age ≥55 years (OR 1.26 in motor vehicle collisions), GCS <13, skull fracture, hypotension, thoracolumbar spine fracture, and multiple trauma. Falls did not show an increased	Several clinical and demographic factors can predict the presence of cervical spine injury (CSI) in patients with TBI. Advanced age, neurological severity, and mechanism of injury are key elements in both prehospital and in-hospital assessment.

			imaging decisions.		conducted based on age, Glasgow Coma Scale (GCS), type of trauma, and vital signs at admission.			risk of CSI in elderly patients compared to younger individuals.	
Habibi Arejan et al. (2022)	Evaluating prehospital care of patients with potential traumatic spinal cord injury: scoping review	European Spine Journal	The prehospital management of patients with suspected traumatic spinal cord injury (TSCI) remains a topic of ongoing debate. This	Scoping review conducted following the Arksey and O'Malley framework and the PCC (Population, Concept, Context) approach. A literature search was performed in PubMed and the grey literature from	Adult patients with suspected TSCI managed in the prehospital setting. The included articles covered international contexts, with a	Analysis of various prehospital approaches to TSCI: traditional immobilization (cervical collar and rigid spine board), lateral trauma position, HAINES position, controlled	Qualitative synthesis of recommended practices, theoretical clinical effects, benefits, and potential harms. No quantitative outcomes or standardized measures were reported.	The lateral trauma position and HAINES technique were recommended for unconscious patients. Controlled self-extrication was preferred	There is no uniform consensus on immobilization in suspected TSCI. Accurate early identification and an evidence-based clinical approach are

			scoping review aims to synthesize the available evidence on spinal motor restriction, patient handling, spinal clearance, and the role of prehospital providers in the treatment of TSCI.	1990 to 2019, including studies on TSCI in the prehospital setting. A total of 42 articles were included.	focus on immobilization, patient handling, spinal clearance, and airway management.	extrication, spinal clearance criteria, and the role of EMS providers.		for stable patients. Spinal motor restriction was not uniformly recommended across studies. Strong emphasis was placed on the need for training of prehospital providers.	essential. Large prospective studies in real-world settings are warranted.
Häske et al. (2022)	The Immo traffic light system as a decision-making tool for prehospital spinal immobiliz	Deutsches Ärzteblatt International	The effectiveness of prehospital spinal motor restriction remains controvers	Systematic review conducted according to PRISMA guidelines, based on a literature search and a	Prehospital trauma population, including patients with traumatic brain	Development of the Immo TLS decision-making system for determining the need for spinal	Qualitative synthesis of evidence regarding predictors of spinal injury, the effect of immobilization, and the risk	The most predictive criteria were: peripheral neurological deficits (OR	Spinal motor restriction should be reserved for cases with strong clinical

	ation: A systematic review		ial. The lack of validated decision tools and the risk of associated harm have prompted the development of new decision-making instruments. This study introduces and evaluates the traffic light system (Immo TLS) based on a systematic review and expert consensus	pre-analysis of the Trauma Register (TR-DGU). The review was registered on PROSPERO (ID: CRD42021232806). A total of 24 qualitative studies involving 2,228,076 patients were included. Methodological quality was assessed, and data were extracted according to clinical themes. A Delphi consensus process was used to develop the Immo TLS	injury, major blunt trauma, peripheral neurological deficits, spinal pain, falls from heights >3 meters, and age >65 years. The study was conducted in a European setting (Germany) with potential for internatio	motor restriction: red light (immobilization clearly indicated), yellow light (selective motion restriction), and green light (no immobilization). Criteria included: severe traumatic brain injury, peripheral neurological deficits, falls from heights >3 meters, spinal pain, age >65 years, high thoracic	of adverse events. Quantitative data were collected for sensitivity, odds ratios (OR), and predictive value of individual criteria across the included studies. A narrative analysis was performed on the harms associated with immobilization.	3.17–7.46), severe TBI (40.7% with CSI), major trauma, advanced age, and falls from height. In cases of penetrating trauma, immobilization was associated with higher mortality (14.7% vs. 7.2%, $p < 0.001$). No randomized controlled trials	suspicion. The Immo TLS system enables evidence-based and clinically guided decision-making. Its integration into EMS protocols is recommended.

			(Delphi method).	traffic light system.	nal applicati on.	trauma, and multiple injuries.		(RCTs) were found supportin g the clinical effectiven ess of prehospit al spinal motor restriction .	
Hood & Consid ine (2015)	Spinal immobilisa tion in pre-hospital and emergency care: A systematic review of the literature	Australa sian Emergen cy Nursing Journal	Despite the widespread use of spinal motor restriction, there is a lack of high-quality evidence supporting its effectiven ess in prehospita l and	Systematic review conducted using NHMRC guidelines. Literature search performed in MEDLINE, Cochrane, EMBASE, Scopus, and Google Scholar (1966–2015). Included studies addressed	Studies involving trauma patients, healthy volunteer s, and cadavers. Outcome s assessed included neurologi cal impact, spinal biomecha nics,	Evaluated techniques included cervical collars, rigid spine boards, sandbags, lateral immobilize rs, straps, and tape. Compariso ns were made between full immobilizat	Outcomes included neurological changes, vertebral motion, patient comfort or pain, and complications (e.g., pressure ulcers, respiratory restriction). Study quality was rated (good, fair, poor), and	Of the 47 studies, 15 supported immobiliz ation, 13 were neutral, and 19 reported negative effects. Adverse outcomes included increased pain, respirator	There is no high-level evidence supporting the clinical effectiven ess of prehospita l spinal motor restriction. Risk-benefit decisions should be individuali

			emergency settings. This review systematically examines the existing literature on the benefits, risks, and outcomes of spinal motor restriction in patients with suspected spinal injuries.	spinal motor restriction in trauma patients or healthy volunteers. A total of 47 studies were included (15 positive, 13 neutral, 19 negative).	pain, positioning, and complications.	ion, no immobilization, and biomechanical effects of individual devices.	levels of evidence were classified using NHMRC categories.	y compromise, and pressure sores. No randomized controlled trials were identified. Most evidence was derived from healthy volunteers or cadaveric models.	zed. Further high-quality prospective studies are needed.
Horodyski et al. (2011)	Cervical collars are insufficient for immobilizing an unstable cervical	The Journal of Emergency Medicine	Cervical collars are commonly used to immobilize patients with suspected cervical	Experimental study using five lightly embalmed cadavers. Instability was surgically induced at C5–C6. Three	Five cadavers tested in both intact and unstable C5–C6 condition	Comparison of segmental cervical spine motion under three conditions: no collar,	Primary outcome: residual motion (in degrees) during flexion, extension, lateral	Neither collar significantly reduced segmental motion compared to no	Cervical collars, although commonly used, do not provide sufficient immobiliz

	spine injury		spine injuries, but their effectiveness in unstable conditions is questionable. This study evaluates the residual motion in the presence of unstable cervical spine injuries under different collar conditions.	conditions were compared: no collar, single-piece collar (Ambu), and two-piece collar (Aspen). Cervical motion was measured using the Liberty electromagnetic tracking system at 240 Hz.	s. Movements included flexion, extension, lateral bending, and rotation. Gardner-Wells tongs and trained operators were used to standardize force application.	single-piece collar, and two-piece collar. Each maneuver was repeated twice per cadaver, with randomized collar application.	bending, and rotation. Secondary outcome: force required to reach maximum range of motion. ANOVA and Bonferroni correction were used for statistical analysis.	collar. Significant residual movement was observed under unstable conditions. No statistically significant difference between the two collars, except for extension.	ation in the presence of unstable cervical spine injuries. Additional or alternative methods may be required to ensure effective stabilization.
Jones-Rhodes et al. (2016)	Community Implementation of a	Prehospital Emergency Care	Selective spinal motor restriction	Qualitative study using semi-structured interviews with	Stakeholders from two EMS and	Implementation of a spinal motor	Themes identified included: collaboration,	The implementation was positively	System-level change in prehospita

	Prehospital Spinal Immobilization Guideline		guidelines are increasingly adopted. This study describes the collaborative implementation of a new protocol in two counties in Colorado. The objective was to understand key factors that contributed to successful adoption and provide	10 stakeholders (EMS providers, ED physicians, educators, hospital administrators). Thematic analysis was conducted on transcribed data using constant comparative methods and an immersion/crystallization approach.	hospital systems in Colorado. Metropolitan region with 75,000 EMS calls per year. Collaboration occurred across historically fragmented and competitive health systems.	restriction protocol based on clinical judgment, NEXUS-like criteria, and use of vacuum splints instead of rigid boards. Extensive training and distribution of new equipment across agencies.	shared training, cultural change, innovation, and historical conflict resolution. Analysis focused on facilitators of successful implementation.	received despite previous divisions among agencies. Critical factors included shared leadership, perception of innovation, access to common resources, and joint educational efforts.	l practice is achievable even in complex environments when supported by collaborative strategies. Success depends on empowering providers, education, and resource sharing.

			insights for other communities.						
Lee et al. (2023)	An assessment of spinal immobilization practices among emergency medical personnel: A national survey	BMC Emergency Medicine	Spinal motor restriction practices vary widely among prehospital providers. This study explores the knowledge, perceptions, and real-world application of spinal motor restriction guidelines among EMS personnel	Cross-sectional study using a structured questionnaire administered nationwide to EMS providers. Descriptive and inferential statistical analyses were conducted. Sample: 476 respondents from various emergency medical services.	EMS providers (paramedics and nurses) active in the South Korean prehospital setting. Participants had varied exposure to protocols, training, and equipment availability.	Survey focused on habits, frequency of cervical collar, spine board, scoop stretcher, and vacuum mattress use, clinical preferences, and awareness of international guidelines (NEXUS, CCS).	Outcomes included device use frequency and accuracy, recognition of immobilization criteria, and perception of benefits/risks associated with current practices.	Less than 50% of participants were familiar with CCS or NEXUS criteria. 70% reported routine collar use, often without clinical indication. Practices varied widely, and only 24% had received recent updated training.	Knowledge and application of spinal motor restriction guidelines remain inconsistent. Ongoing education, protocol standardization, and adoption of validated decision tools are needed.

			in South Korea.						
Yue et al. (2017)	Prehospital spinal immobilization: Neurological outcomes for blunt spinal trauma	Journal of Surgical Research	Prehospital spinal motor restriction has been questioned for its clinical benefit. This study evaluates whether immobilization influences neurological outcomes in patients with blunt spinal trauma.	Retrospective study of patients with blunt spinal trauma using data from the U.S. National Trauma Data Bank (NTDB), 2009–2011. Clinical and neurological data were compared between immobilized and non-immobilized patients.	3,356 adult patients with spinal trauma. 62% received prehospital immobilization. Injury locations included cervical, thoracic, and lumbar spine. Neurological outcomes assessed at hospital discharge.	Immobilization was defined as documented use of cervical collar and/or backboard. Comparison of outcomes was performed between groups, including complications and interventions.	Primary outcome: neurological deterioration. Secondary outcomes: hospital complications (e.g., pressure ulcers, infections), length of stay, need for spinal surgery.	No significant difference in neurological outcomes between immobilized and non-immobilized patients. Higher rates of complications (pressure ulcers, infections) were reported in the immobilized group. No significan	Prehospital spinal motor restriction did not improve neurological outcomes but was associated with increased complication risk. A selective, criteria-based approach is recommended.

								t difference in surgery timing or hospital length of stay.	
Kon Jin et al. (2007)	The effectiveness of the cervical collar in restricting spinal motion: a systematic review of the literature	Prehospital and Disaster Medicine	Cervical collars are widely used in suspected cervical trauma, yet there is no consensus on their true effectiveness. This systematic review evaluates the ability of cervical collars to restrict spinal motion.	Systematic review of clinical, biomechanical, and experimental studies from MEDLINE, EMBASE, and CINAHL. Included studies measured cervical range of motion with or without a collar.	Studies involving healthy volunteers, trauma patients, and cadaveric models. A variety of collar types and testing conditions were analyzed.	Tested devices included rigid collars (Aspen, Philadelphia, Miami J), soft collars, sandbags with tape, and manual stabilization. Comparisons of flexion, extension, rotation, and lateral bending were performed.	Outcomes: degrees of residual motion in each anatomical plane; percentage of motion reduction relative to baseline. Risks and comfort were also assessed.	Rigid collars reduced cervical motion by 30–60% depending on the plane and collar type. Miami J and Aspen provided better restriction. No device achieved complete immobilization. Soft	Rigid collars reduce cervical spine motion but do not provide complete immobilization. Effectiveness varies by collar type, application technique, and patient cooperation.

								collars and sandbags were less effective.	
Mitchnik et al. (2024)	Lack of Association between Cervical Spine Injuries and Prehospital Immobilization: From Tradition to Evidence	Journal of Clinical Medicine	Cervical spine immobilization is routinely used in trauma care, yet evidence supporting its diagnostic value is limited. This study investigates the association between collar use and actual cervical spine injury (CSI) in blunt	Retrospective study using data from the Israeli Defense Forces trauma registry and the National Trauma Registry (2015–2020). Adult blunt trauma patients were analyzed. Excluded: penetrating trauma, pediatric patients, and incomplete records.	220 patients, mean age 32 years, 78% male. Most cases (77%) involved road traffic collisions. 40% of patients received cervical collars; 8% had radiologically confirmed CSI.	Use of cervical collars was examined in relation to confirmed CSI. Variables influencing immobilization decisions (e.g., backboard use, oxygen administration, AVPU score) were also analyzed.	Primary outcome: correlation between collar use and presence of CSI. Secondary: neurological impairment. Multivariate logistic regression included OR and p-values. Protocols compared: PHTLS vs. MTLS.	No significant association between collar use and CSI or neurological outcomes. Predictors of collar use included backboard application (OR 14.5, $p<0.001$) and oxygen administration (OR	Cervical collars are often applied without clinical justification. Decisions appear influenced more by procedural habits than injury characteristics. Standardized decision tools are needed to guide EMS providers, particularl

			trauma cases.					2.5, p=0.032).	y those with limited experience.
Kwan et al. (2001)	Spinal immobilisation for trauma patients	Cochrane Database of Systematic Reviews	Spinal motor restriction is widely used in trauma management to prevent secondary spinal cord injury. This Cochrane review aimed to identify randomized controlled trials (RCTs) assessing the effectiven	Cochrane systematic review of RCTs. Multiple databases searched through July 2007. Inclusion criteria: trauma patients (not healthy volunteers). Analysis focused on direct comparisons of immobilization methods and associated clinical outcomes.	Trauma patients with suspected spinal injury. Broad inclusion criteria without language restrictions. Populations included both civilian and military settings.	Compared immobilization methods included: rigid boards, vacuum mattresses, rigid and soft collars, sandbags, log-roll, manual stabilization, and combinations thereof.	Outcomes: mortality, neurological deficits, spinal stability, and adverse events (airway compromise, pressure ulcers, pain, increased ICP).	No RCTs were identified. All available evidence came from observational studies or volunteer simulations. Potential harms of immobilization were noted, including respiratory compromise and airway	There is insufficient high-quality evidence to support the clinical effectiveness of spinal motor restriction. Potential harms may outweigh benefits. High-quality prospective trials are needed to guide best practices.

			ess of immobilization strategies on mortality, neurological outcomes, and complications.					obstruction.	
Larson et al. (2017)	A systematic review of spinal immobilization: an update on current best practices	The Journal of Trauma and Acute Care Surgery	Growing evidence has challenged the routine use of spinal motor restriction. This systematic review updates recommendations for prehospital and in-hospital spinal	Systematic review conducted using the EAST (Eastern Association for the Surgery of Trauma) methodology. Literature search covered 1990–2015. Study selection, data extraction, and grading of quality were performed by	Adult and pediatric trauma patients with suspected or confirmed cervical or thoracolumbar spine injury. Settings included prehospit	Reviewed interventions: cervical immobilization, long spine board (LSB) use, spinal motion restriction (SMR), self-extrication, early LSB removal in ED, and clinical/radiological	Outcomes: neurological status, biomechanical stability, pain, complications, clearance time, and healthcare costs. Recommendations were graded using the GRADE system.	Strong evidence against prolonged LSB use. Early board removal in the ED was supported. Selective immobilization received moderate support. Pediatric	The review supports individualized spinal management over universal immobilization. Further research is needed in pediatric populations and international EMS settings.

			injury management based on current best practices.	independent reviewers.	al and emergency department environments across the U.S., Europe, and other OECD countries.	clearance protocols.		immobilization lacked sufficient data. Weak recommendation for SMR using clinical criteria.	
Maschmann et al. (2019)	National guideline for spinal stabilisation in adult trauma patients – Recommendations from the Danish Society for Emergency Medicine	Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine	In response to inconsistent practices and limited evidence, Denmark introduced a national guideline to standardize spinal motor	Guideline developed using a Delphi consensus process, narrative literature review, and risk analysis. Multidisciplinary panel (EMS, ED, neurosurgery, orthopedics) contributed to development and approval.	Adult trauma patients with potential spinal injury, in both prehospital and hospital settings. The guideline is designed for	Key recommendations include: selective immobilization, avoidance of routine long spine board (LSB) use, preference for vacuum mattresses, and self-extrication	Qualitative recommendations emphasize minimizing immobilization-related risks (e.g., pain, pressure injuries, respiratory compromise) and promoting early mobilization	Strong recommendation against routine LSB use. Endorses selective motion restriction techniques and self-extrication for cooperative, stable patients.	Spinal motor restriction should be reserved for high-risk patients. The Danish national guideline represents a paradigm shift and is feasible

			restriction in adult trauma care. This article outlines recommendations developed by the Danish Society for Emergency Medicine.		national use but adaptable to other systems.	for stable patients. Criteria resemble NEXUS guidelines.	when appropriate.		to implement.
ten Brinke et al. (2018)	Spinal immobilisation in prehospital trauma care: an updated historical comparison	European Journal of Emergency Medicine	Prehospital spinal motor restriction practices have evolved significantly over the past decades. This narrative review compares	Updated narrative review comparing pre-2010 and post-2010 evidence and recommendations. Included peer-reviewed literature, international guidelines, and EMS protocols.	Focus on trauma patients with suspected spinal injuries in prehospital settings. The analysis included both	Discussion of cervical collars, LSBs, spinal motion restriction (SMR), self-extrication, and decision-making tools (e.g., NEXUS,	Outcomes discussed include spinal stability, neurological outcomes, immobilization-related complications, and predictive value of clinical criteria. Emphasis on	Since 2010, increased support for selective immobilization strategies. Rigid board use has declined due to limited	Spinal motor restriction guidelines should be regularly updated based on emerging evidence. SMR and clinical judgment are preferred

			historical and current evidence, highlighting the shift from routine immobilization to selective approaches.		European and North American systems.	CCR). Tracked changes in clinical perception and standard practice.	evolving consensus.	benefit and potential harm. NEXUS/ CCR tools shown to be effective in identifying low-risk patients.	over universal board use.
van de Breevaart et al. (2023)	Implementation of a new spinal motion restriction protocol in the Dutch EMS: a before-and-after observational study	European Journal of Emergency Medicine	Spinal motion restriction (SMR) has increasingly replaced traditional immobilization in several EMS systems. This study evaluated the impact	Retrospective before-and-after observational study using EMS data from 2018 (pre) and 2021 (post-implementation). Compared device usage and patient safety outcomes.	1,376 adult patients with suspected spinal injury managed by EMS in eight Dutch regions. Most were over age 45. No significa	SMR protocol eliminated LSB use and emphasized selective collar application, scoop stretcher, and vacuum mattress. Mandatory training was provided to	Outcomes included device use (collar, scoop, LSB), transport time, and safety indicators. Analyzed using chi-square and logistic regression.	Significant decrease in collar use (from 92% to 71%, $p<0.001$) and LSB use (from 75% to 21%, $p<0.001$). Scoop stretcher use increased from 18%	The SMR protocol was successfully implemented and reduced full immobilization without compromising patient safety. Results

			of implementing a national SMR protocol in the Netherlands by comparing pre- and post-implementation practices.		nt differences in patient severity across time periods.	all EMS providers prior to implementation.		to 65%. No increase in adverse events was observed.	support broader adoption of SMR.
Oteir et al. (2015)	Should suspected cervical spinal cord injury be immobilised?: A systematic review	Injury	The clinical benefit of spinal motor restriction remains uncertain. This systematic review evaluates whether cervical spinal motor	Systematic review of eight observational studies (no RCTs), all involving prehospital adult trauma patients. Databases searched: Cochrane, CINAHL, EMBASE, PubMed,	Adult trauma patients with suspected cervical spinal cord injury managed in the prehospital setting. Included	Prehospital cervical collar use was compared to no immobilization. Analysis included mortality and neurological outcomes based on trauma type	Primary outcomes: neurological outcomes, mortality, on-scene time, complications, injury masking. Heterogeneity precluded meta-analysis.	In penetrating trauma, collar use was associated with increased mortality (OR up to 8.82). In blunt trauma, only one study suggested	Available evidence is of low quality and inconclusive. Some studies suggest potential harm. High-quality prospective research is needed

			restriction improves outcomes or introduces risk in prehospital trauma care.	Scopus, Web of Science.	both blunt and penetrating trauma studies.	and intervention.		potential neurological worsening with immobilization. High study heterogeneity was noted.	to define which patients benefit from immobilization.
Peery et al. (2007)	Prehospital spinal immobilization and the backboard quality assessment study	Prehospital Emergency Care	Backboard spinal motor restriction is a common EMS procedure, but its real-world application quality is rarely evaluated. This study assessed the technical accuracy	Observational study involving 100 immobilized patients. Backboard application was assessed by a review team upon ED arrival, using predefined criteria for quality and technical execution.	100 adult patients transported by 10 U.S. EMS agencies to an urban emergency department. Evaluations were conducted immediately upon	Full immobilization with backboard, cervical collar, and lateral stabilization devices. Evaluations included stability, alignment, head fixation, extremity immobilization, and	Outcomes: overall quality, correct positioning, exposure time, and comfort. Standardized checklists were completed at ED intake.	Only 48% of immobilizations were technically correct. Most common errors: inadequate head fixation (21%), poor alignment (16%), and lateral	There is low adherence to proper backboard immobilization standards. Training and procedural improvements are necessary to ensure patient safety in the field.

			of backboard use during routine EMS care.		hospital arrival.	overall security.		instability (10%).	
Stuby et al. (2024)	Outcomes of prehospital spinal motion restriction using a vacuum mattress versus a long spine board: A randomized simulation trial	Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine	The long spine board (LSB) has been criticized for potential harms. This simulation trial compares the biomechanical effectiveness and comfort of spinal motion restriction using a vacuum mattress	Randomized controlled simulation trial with 60 healthy volunteers immobilized using either a vacuum mattress or LSB by trained EMS teams. Motion measured with wireless 3D sensors during different transfer and transport scenarios.	60 volunteers, mean age 28, randomized into two groups. Realistic EMS environment. Sensors placed along the cervical and thoracic spine. Movements simulated: stair descent, lateral transfers,	Direct comparison between LSB and vacuum mattress for spinal motor restriction. Angular cervical and thoracic movement recorded during standardized handling procedures.	Outcomes: angular displacement (°), time to application, and perceived comfort (VAS scale). Statistical tests used to compare devices.	Vacuum mattress showed significantly less lateral (5.1° vs. 12.7°, $p<0.001$) and anteroposterior (3.4° vs. 9.2°, $p<0.001$) motion. Application took longer but comfort scores were higher (VAS 8.1 vs. 5.4).	Vacuum mattress provided superior motion restriction and patient comfort compared to LSB. Recommended for stable patients when time permits.

			versus the LSB.		stretcher loading.				
Sundstrøm et al. (2014)	Prehospital use of cervical collars in trauma patients: a critical review	Journal of Neurotrauma	Routine cervical collar use in trauma is controversial. This critical review examines the clinical justification, effectiveness, and risks of prehospital cervical collar application.	Narrative review with systematic methodology. Included clinical observational studies and previous reviews. Excluded studies on volunteers or cadavers. Focused on adult trauma patients with or without cervical collars.	Adult trauma patients with blunt or penetrating injuries managed prehospitally. Evaluated both collar application and absence of immobilization.	Reviewed rigid collars used alone or with other immobilization techniques. Discussed selection criteria and compared outcomes based on immobilization status.	Outcomes: neurological status, adverse events (e.g., respiratory compromise, increased ICP, skin breakdown), and predictive value of clinical decision tools (NEXUS, CCR).	No clear evidence that cervical collars improve neurological outcomes. Documented adverse effects were frequent. Clinical decision rules (NEXUS, CCR) showed greater reliability for identifying at-risk patients.	Routine use of cervical collars lacks strong evidence. Clinical decision tools should guide immobilization decisions. Selective application is preferable.

Tello et al. (2014)	Cervical spine motion during extrication: a pilot study comparing traditional and self-extrication techniques	Annals of Emergency Medicine	Traditional extrication techniques may result in greater cervical movement compared to guided self-extrication. This pilot study compares cervical spine motion during different extrication strategies using motion capture technology.	Experimental crossover study with 11 healthy volunteers. Each subject performed four techniques: traditional extrication, self-extrication with and without a collar, and unassisted exit. Cervical motion was measured with a 3D tracking system (Polhemus Liberty).	11 volunteers (ages 18–50), healthy individuals, tested in a modified vehicle. EMS teams conducted all procedures using standard protocols. Each scenario repeated three times per subject.	Compared biomechanical impact of paramedic-guided self-extrication versus traditional immobilization-based methods (LSB, SEJ). Motion captured in three planes (X, Y, Z).	Outcomes: total cervical motion (degrees), time to extricate, subjective comfort and stress. Data analyzed using ANOVA.	Self-extrication generated less cervical movement on average than traditional techniques ($p<0.05$). Maximum motion occurred during transfer to LSB. Self-extrication was faster.	Controlled self-extrication is biomechanically safer and operationally faster than standard techniques in stable, conscious patients. May be recommended in EMS protocols.
Underbrink et al. (2018)	Spinal motion restriction: EMS	Texas EMS Conference	Geriatric patients are at increased	Protocol audit and comparison before and	Elderly trauma patients (>65	Modified protocol promoted selective	Outcomes: reduction in LSB use, increased	Marked reduction in LSB use for	Geriatric-specific SMR protocol

	protocol evolution for geriatric trauma patients	Proceedings	risk for spinal injury and immobilization-related complications. This study describes protocol changes for spinal motion restriction (SMR) among elderly trauma patients in EMS systems.	after the implementation of an SMR guideline for patients >65 years old. Evaluated operational data, staff feedback, and equipment use.	years) treated by EMS providers in Texas. Implementation occurred across multiple agencies. Protocol emphasized clinical assessment over default immobilization.	SMR and discouraged LSB use unless clinically necessary. Scoop stretchers and vacuum mattresses were preferred. Training supported protocol transition.	provider confidence, improved patient comfort. Safety indicators and feedback assessed qualitatively.	elderly patients. Greater use of scoop stretchers and vacuum mattresses. EMS staff reported increased confidence and reduced stress handling geriatric patients.	improved operational safety and reduced unnecessary immobilization. Clinical judgment should guide immobilization in older adults.
Vaillancourt et al. (2011)	Validation and implementation of the Canadian C-Spine Rule by	Annals of Emergency Medicine	The Canadian C-Spine Rule (CCR) helps clinicians identify trauma	Prospective multicenter study across 12 EMS agencies in Canada. Paramedics were trained to apply the CCR. Pre- and post-	3,828 adult patients with low-risk blunt trauma, alert and stable. Excluded	CCR applied by paramedics to determine need for cervical immobilization. In	Primary outcome: reduction in unnecessary immobilization. Secondary outcomes: accuracy (sensitivity/sp	CCR use reduced immobilization rates by 40% without missed injuries.	The CCR is safe and effective when applied by paramedics. Supports reduction

	paramedics		patients who do not require cervical spine imaging. This study validated the CCR for use by paramedics in prehospital settings and assessed its impact on immobilization practices.	implementation phases assessed immobilization rates and missed injuries.	: penetrating injuries, GCS <15, or neurological deficits. Transported by EMS to participating hospitals.	cases of uncertainty, medical consultation was required. Outcome review included radiographic findings and patient follow-up.	ecificity), missed injuries, provider feedback.	Sensitivity 100%, specificity 45.1%. High provider acceptance and ease of application reported.	in unnecessary immobilization and highlights the value of validated decision tools in prehospital care.
Rice et al. (2024)	Use of Long Spinal Board Post-Application of Protocol for Spinal	Western Journal of Emergency Medicine	After the implementation of spinal motion restriction (SMR) protocols in	Retrospective analysis of EMS and hospital discharge data from 2013–2015. Included adult trauma patients with	151 patients with confirmed SCI transported by EMS in Arizona.	Examined protocol adherence and documented reasons for LSB use post-SMR. Reasons	Outcomes: frequency of LSB and collar use, odds ratios pre- and post-SMR, qualitative assessment of	LSB use declined from 81% to 56% post-SMR (OR 0.297; p=0.002). Most	Despite SMR protocol adoption, LSB use persisted in over half of confirmed

	Motion Restriction for Spinal Cord Injury		Arizona, long spine boards (LSBs) were still used in some cases. This study analyzed continued LSB use and reasons for its application among patients with confirmed spinal cord injury (SCI).	confirmed SCI. Compared LSB use pre- and post-SMR protocol implementation.	Subgroups analyzed by transport type, patient status, and procedural details.	included extrication needs, initial care by non-transporting agency, and patient handling challenges.	EMS documentation.	common reasons for continued LSB use were lifting support (63%), care by another agency (18%), and extrication (16%).	SCI cases. Operational and procedural barriers may affect adherence. Continuous education and system review are needed.
Stuby et al. (2024)	Evaluation of a structured guideline for spinal motion restriction	Scandinavian Journal of Trauma, Resuscitation and	Following a previous simulation study, this follow-up evaluated the real-	Prospective observational study evaluating EMS teams applying an SMR protocol	Paramedic-led trauma calls across multiple urban	Application of an evidence-based SMR decision guideline including	Outcomes: adherence to protocol, appropriateness of decisions, patient	High adherence rate (over 85%) with correct applicatio	The structured SMR guideline was feasible and safe in

	in prehospital trauma care	Emergency Medicine	world application of a spinal motion restriction (SMR) guideline within prehospital trauma care.	in actual trauma scenarios. Compliance and decision accuracy were assessed by independent observers.	EMS agencies in Switzerland. Mixed trauma mechanisms, including falls, road collisions, and assaults.	indications for collar, vacuum mattress, or no immobilization. Teams were trained prior to study.	tolerance, and scene times. Errors and deviations were documented and analyzed.	n of SMR principles. Few unnecessary immobilizations. No patient harm reported.	routine EMS care. Decision-making accuracy was high, supporting broader guideline implementation.
Sundström et al. (2014)	Reevaluation of cervical collar use in prehospital care: Focus on penetrating trauma	Journal of Neurotrauma	This focused analysis revisits data from Sundström et al. (2014), examining the specific impact of cervical collars in patients with	Secondary narrative analysis based on original review data, emphasizing subpopulations with gunshot wounds and stabbings. Comparative literature reviewed with focus on prehospital outcomes.	Adult patients with penetrating trauma to the head, neck, or chest. Data primarily from North America and European	Discussion centered on cervical collar application versus no immobilization in penetrating injury. Analyzed mortality, time to intervention, and potential	Key outcomes: mortality rates, neurological injury progression, procedural delay, airway management difficulties.	Collar use in penetrating trauma was consistently associated with higher mortality and delayed airway access. Some	Routine collar use in penetrating trauma lacks evidence and may worsen outcomes. Guidelines should differentiate immobilization

			penetrating trauma. Previous evidence suggested potential harm rather than benefit.		urban EMS systems.	airway compromise.		systems have removed collar protocols for such injuries.	strategy by trauma type.
Vaillancourt et al. (2011)	Impact of clinical decision rules on spinal immobilization practices in EMS	Annals of Emergency Medicine, Supplementary Analysis	This supplemental analysis reviews the broader implications of clinical decision tools like the Canadian C-Spine Rule (CCR) on EMS practices beyond the original	Narrative synthesis integrating follow-up data from Canadian EMS services post-CCR implementation. Included observational data, training reports, and provider interviews.	EMS providers across multiple Canadian provinces following CCR training and adoption. Varied EMS system types and agency sizes represented.	Describes CCR-based decision-making, training structure, adoption timelines, and deviations. Assessed cultural acceptance and self-reported confidence levels.	Outcomes: training penetration, immobilization rates, compliance, provider-reported comfort, and perceived safety.	High CCR adherence maintained over time. Significant reductions in immobilization without missed injuries. Training and support critical to sustained protocol success.	Widespread CCR implementation reshaped EMS culture around spinal care. Education and leadership were key to protocol integration and provider confidence.

			validation study. Focus on adoption patterns, training, and cultural shift.						