**Appendix 7: Narrative Summary of Evidence Identified**

A total of 66 original studies were identified for inclusion in this scoping review.

Appendix 6 provides an overview of equity-relevant data provided by these studies, according to the PROGRESS-Plus framework.
The majority of the studies were conducted in the USA (n=26), followed by the UK (n=7), the Netherlands (n=6) and Australia (n=4). Other countries in which the studies were performed were Canada (n=3), Turkey (n=3), Taiwan (n=3), Poland (n=3), Germany (n=2), Iran (n=2), Italy (n=1), Spain (n=1), Iceland (n=1), Korea (n=1), and Thailand (n=1). Two studies made use of the Pan-Asia Trauma Outcomes Study multicenter trauma registry from 14 Asian countries.
Overall, the studies only provided data on the gender/sex and the age of the participants. Healthy volunteer studies mostly used younger populations, often recruited from university, medical training or residency programs. The studies in trauma patients provided a more balanced image across age categories. Gender/sex was relatively balanced across all studies.

In the following paragraphs, narrative summaries are provided for the following categories and subcategories:

1. Spinal motion restriction vs no spinal motion restriction
	1. Cervical collar vs no cervical collar
	2. Long backboard/vacuum mattress with or without cervical collar vs no spinal motion restriction
	3. Cervical collar + device vs no spinal motion restriction
	4. Multiple (combinations of) devices
	5. Spinal motion restriction (unspecified) vs no spinal motion restriction
2. Mutual comparisons of types of spinal motion restriction
	1. Cervical collar 1 vs cervical collar 2
		1. Soft foam collar vs rigid collar
		2. Improvised vs commercially available collar
		3. One-piece rigid collar vs two-piece rigid collar
		4. Other mutual comparisons of cervical collars
	2. Cervical collar vs other type of (improvised) device
	3. Cervical collar + device vs cervical collar only
	4. Cervical collar + device 1 vs cervical collar + device 2
	5. Device 1 vs device 2
3. Extrication studies
4. Post- vs pre- implementation of selective spinal motion restriction protocols

Please note that a single study may have provided evidence for more than one (sub)category.

**Category 1: Spinal motion restriction versus no spinal motion restriction**

* 1. *Cervical collar vs no cervical collar*

A total of 35 studies provided evidence on the effectiveness of applying a cervical collar compared to no cervical collar, including:

* Thirteen randomized controlled trials (RCTs) in healthy volunteers {[Ala 2021 59](#_ENREF_1), [Gavin 2003 527](#_ENREF_16), [Karason 2014 37](#_ENREF_25), [Kim 2020 24](#_ENREF_26), [Ladny 2018 1](#_ENREF_31), [Maissan 2018 e24](#_ENREF_38), [Rahmatalla 2019 32](#_ENREF_49), [Russell 2024 106178](#_ENREF_52), [Szarpak 2018 68](#_ENREF_57), [Tescher 2007 1120](#_ENREF_58), [Tescher 2016 E304](#_ENREF_59), [Yard 2019 141](#_ENREF_67), [Zhang 2005 264](#_ENREF_69)};
* Twelve non-RCTs: seven in healthy volunteers {Chi 2005 386, [Eisner 2022 726](#_ENREF_12), [Evans 2013 S10](#_ENREF_14), [Holla 2012 104](#_ENREF_19), [Hudson 2023 101788](#_ENREF_20), [Pryce 2016 36](#_ENREF_48), [Schneider 2007 E1](#_ENREF_53)}, four in human cadavers {[Bednar 2004 251](#_ENREF_4), [Ben-Galim 2010 447](#_ENREF_5), [Liao 2018 e0195215](#_ENREF_35), [Richter 2001 848](#_ENREF_50)}, and one in trauma patients {[Hunt 2001 511](#_ENREF_21)};
* Three interrupted time series: one in trauma patients {[Colak 2020 89](#_ENREF_11)} and two in healthy volunteers {[Kroeker 2019 196](#_ENREF_29), [Woster 2018 430](#_ENREF_66)}:
* Five case series: three in trauma patients {[Asha 2021 19](#_ENREF_2), [Bruton 2024](#_ENREF_6) , [Mobbs 2002 389](#_ENREF_43)}, one in healthy volunteers {[Stone 2010 100](#_ENREF_55)}, and one in patients without cervical spine injury presenting to the Emergency Department (ED) and requiring a lumbar puncture {[Kolb 1999 135](#_ENREF_27)};
* Three retrospective chart reviews in trauma patients {[Lee 2023](#_ENREF_32), [Lin 2011 1028](#_ENREF_36), [Yazici 2024 126](#_ENREF_68)}.

In the paragraphs below, the brand names, types (rigid, semi-rigid, soft, improvised) and designs (one-piece, two-piece) of the different cervical collars are explicitly mentioned, for the sake of clarity and to illustrate the marked between-study heterogeneity. If a study did not report this information, or it could not be deduced by the Scoping Review Team to a reliable extent, features were not reported.

The **risk of (secondary) spinal injury** was studied in one case series {[Asha 2021 19](#_ENREF_2)} and in one retrospective chart review {[Lin 2011 1028](#_ENREF_36)}.

In a case series of 2,036 patients assessed for a traumatic cervical spine injury in 7 EDs in Australia {[Asha 2021 19](#_ENREF_2)}, 1,133 patients had a soft collar applied in the ED, whereas 268 patients arrived and remained in a rigid collar (Stifneck® one-piece, Philadelphia® two-piece, or Miami J® two-piece collars), and 582 presented and remained without a collar. Nine patients in total developed a new neurologic deficit after arriving at the ED: 6 in the soft collar group (3 due to progression of intracranial injuries, 1 due to spinal cord injury and 2 with no organic cause found), 3 in the rigid collar group (2 due to spinal cord injury and 1 with no organic cause found) and 0 in the no collar group. The authors concluded that the secondary spinal cord injury can occur regardless of spinal immobilization due to progression of spinal cord oedema or hemorrhage.

Using a retrospective chart review of 5,139 motorcycle crash victims at low to moderate speeds who were directly transported by EMS to a hospital, Lin *et al.* {[Lin 2011 1028](#_ENREF_36)} studied the possible correlation between cervical spinal injury and prehospital application of an unspecified type of cervical collar. There was no significant correlation between cervical spine injury and collar application (p=0.896). The authors concluded that prehospital collar application to people who have sustained a lightweight motorcycle accident in the urban area should be revised to avoid unnecessary restraint and possible complications.

Two retrospective chart reviews, including the one by Lin *et al.* {[Lin 2011 1028](#_ENREF_36)} mentioned in the previous paragraph, provided data on **survival**. In the review of 2,733 trauma patients with suspected head and neck injuries hospitalized in one hospital in Taipei between Jan 2009 and May 2019, Lee and colleagues {[Lee 2023](#_ENREF_32) } investigated the relationship between prehospital cervical collar application and in-hospital mortality. Multivariable logistic regression analysis revealed that neck collar immobilization was significantly associated with an increased odds of in-hospital mortality (adjusted OR: 1.850, 95% CI [1.24;2.76], p=0.003). Subgroup analysis revealed that immobilization was associated with higher in-hospital mortality in older adults (age ≥65), patients with unclear consciousness (GCS ≤8), those with major traumatic injuries (ISS ≥16 and RTS ≤7), and individuals in shock (shock index > 1).

One case series looked at **functional outcomes**. Bruton *et al.* {[Bruton 2024](#_ENREF_6) } studied 2,098 patients in which a soft cervical collar was applied by paramedics for potential traumatic cervical spine injury during pre-hospital care, in selected metropolitan and regional geographical areas of New South Wales ambulance service between May 2022 and March 2023. Of those 2,098, 74 (3.5%) were subsequently found to have a cervical spine injury. Eight patients had a spinal cord injury, of which two experienced a worsening neurological deficit after soft collar application. In both instances, comprehensive case reviews determined that this was unlikely to have been attributable to the soft collar.

**Cervical range of motion (CROM)** was investigated by seven of the thirteen RCTs {[Gavin 2003 527](#_ENREF_16), Karason 2014 37, [Kim 2020 24](#_ENREF_26), [Rahmatalla 2019 32](#_ENREF_49), [Tescher 2007 1120](#_ENREF_58), [Tescher 2016 E304](#_ENREF_59), [Zhang 2005 264](#_ENREF_69)} and by ten of the eleven non-RCTs {[Bednar 2004 251](#_ENREF_4), [Ben-Galim 2010 447](#_ENREF_5), [Chi 2005 386](#_ENREF_9), [Eisner 2022 726](#_ENREF_12), [Evans 2013 S10](#_ENREF_14), [Holla 2012 104](#_ENREF_19), [Liao 2018 e0195215](#_ENREF_35), Pryce 2016 36, [Richter 2001 848](#_ENREF_50), [Schneider 2007 E1](#_ENREF_53)}.
Taken together, the studies in healthy volunteers (seven RCTs and ten non-RCTs) indicated that cervical collars decrease CROM. The four non-RCTs in cadavers with destabilized spines showed increased displacement/misalignment after collar application. In the paragraphs below, the individual studies and their findings are discussed further:

RCTs:

1. In a first RCT with 20 healthy volunteers {[Gavin 2003 527](#_ENREF_16)}, each of the 4 different cervical orthoses (Aspen® two-piece semi-rigid collar, Miami J® two-piece semi-rigid collar, Aspen 2-post cervical thoracic orthosis (CTO) and Aspen 4-post CTO) significantly reduced gross and intervertebral motion in flexion and extension (p<0.05).
2. A second RCT in 30 healthy volunteers {[Kim 2020 24](#_ENREF_26)} that measured CROM in three planes involving flexion/extension, bilateral bending, and bilateral axial rotation in three cervical collars (Philadelphia® two-piece semi-rigid, Stifneck® Select™ one-piece rigid, and Xcollar® one-piece rigid) showed that CROM was reduced with all collars.
3. In a third RCT with 20 healthy volunteers {[Zhang 2005 264](#_ENREF_69)}, the effectiveness of two newer cervical collars (Philadelphia® C-Breeze® two-piece rigid, and XTW two-piece semi-rigid) was compared to that of two established cervical collars (Aspen® two-piece semi-rigid and Miami J® two-piece rigid) in restricting range of motion in the cervical spine. Again, all 4 collars significantly reduced range of motion in the cervical spine in flexion, extension, lateral flexion and rotation, compared to unbraced conditions (all p<0.05).
4. The fourth RCT by Rahmatalla *et al.* {[Rahmatalla 2019 32](#_ENREF_49)} investigated cervical movement using a dynamic simulation model on 16 healthy adult male volunteers through augmented rides in a helicopter and road ambulance. Use of an (unspecified) cervical collar together with a cot limited cervical flexion/extension and rotation relative to the cot only.
5. The fifth RCT by Karason 2014 {[Karason 2014 37](#_ENREF_25)} included 10 healthy volunteers and demonstrated that all cervical collar types (Stifneck® one-piece rigid, Miami J® Advanced two-piece rigid, Philadelphia® Tracheotomy two-piece rigid, and Aspen Vista® two-piece rigid) reduced CROM when compared to no collar.
6. A sixth RCT with 48 healthy volunteers {[Tescher 2007 1120](#_ENREF_58)} studied the effects of 4 commercially available cervical collars (Aspen® two-piece semi-rigid, Philadelphia® two-piece, Miami J® two-piece rigid, and Miami J® with Occian® Back two-piece rigid) on cervical range of motion in the seated position, and on mandibular and occipital tissue-interface pressure in upright and supine positions. All collars produced a statistically significant restriction of movement (p<0.001).
7. In a seventh RCT, the same authors {[Tescher 2016 E304](#_ENREF_59)} investigated cervical range of motion in 48 healthy volunteers fitted with 4 commercially available collar types (Aspen® two-piece semi-rigid, Miami J® two-piece rigid, Aspen Vista® two-piece rigid, Miami J® Advanced two-piece rigid). Again, all 4 collars significantly reduced cervical range of motion compared to no collar (p<0.001).

Non-RCTs:

1. A first non-RCT in 18 healthy female volunteers {[Chi 2005 386](#_ENREF_9)} showed that placement of a Stifneck® Select™ one-piece rigid cervical collar significantly reduced cervical range of motion in all directions.
2. A non-inferiority trial by Eisner *et al.* {[Eisner 2022 726](#_ENREF_12)} conducted in 30 young healthy volunteers showed that the Stifneck® Select™ one-piece rigid cervical collar reduced median cervical range of motion in six cardinal directions in seated and supine positions by an average of −36.83° seated (−17.75° supine) compared to no immobilization.
3. A third non-RCT in 19 healthy volunteers {[Evans 2013 S10](#_ENREF_14)} showed that application of the Aspen® two-piece semi-rigid, Aspen Vista® two-piece rigid, Philadelphia®, Miami J® two-piece rigid and Miami J® Advanced two-piece rigid collars all restricted cervical spine movement in the sagittal, coronal and axial planes (all p<0.001).
4. In a non-RCT {[Holla 2012 104](#_ENREF_19)}, active range of motion (lateral bending, flexion-extension and rotation) of the cervical spine was measured in 10 healthy volunteers without and with immobilization using the Stifneck® Select™ one-piece rigid cervical collar. The collar statistically significantly reduced active range of motion in all directions (all p<0.005).
5. Schneider *et al*. {[Schneider 2007 E1](#_ENREF_53)} evaluated the biomechanical effectiveness of 4 different cervical collars (Philadelphia® two-piece semi-rigid, Aspen® two-piece semi-rigid, PMT® two-piece rigid, and Miami J® two-piece rigid collars) for restricting head motion in 45 healthy adult volunteers as well as intervertebral motion in the cervical spine. Overall range of motion of the head in 3 planes as well as intervertebral motion in the sagittal plane were measured while wearing the cervical orthoses. This study showed all cervical braces signiﬁcantly reduced overall sagittal plane ﬂexion/extension motion of the head, as well as axial rotation and coronal plane side-to-side bending (p<0.0001) and all braces signiﬁcantly (p <0.001) reduced intervertebral rotation at all levels.
6. Pryce and colleagues {[Pryce 2016 36](#_ENREF_48)} studied CROM, by attaching accelerometers to the bodies of 13 healthy adult volunteers to measure range of movements of the cervical spine with no immobilization, with an Ambu® Perfit ACE™ one-piece rigid cervical collar alone, and with the cervical collar + a long spinal board. The authors showed that the range of movements possible decreased with use of the cervical collar alone, and further decreased with cervical collar with a long spine board. Multiplanar movements produced a greater range of movements and acceleration than uniplanar movements.
7. In a seventh non-RCT with 6 fresh cadavers with destabilized necks {[Bednar 2004 251](#_ENREF_4)}, angulation and translation were measured in the prone, decubitus and side-bending positions, either with the neck unsupported (no collar), or with soft (Soft Straight one-piece collar), semi-rigid (Philadelphia® two-piece collar) and rigid collar (Stifneck® one-piece collar) applied. In all cases, there was no effective limitation of pathological displacement, and in many cases, displacement was increased after collar application.
8. Similarly, in a non-RCT with 9 fresh cadavers with destabilized upper cervical spines {[Ben-Galim 2010 447](#_ENREF_5)}, application of the Ambu® Perfit ACE™ one-piece rigid cervical collar significantly worsened axial misalignment by causing distractive separation of the head and C1 vertebra away from C2.
9. In an nineth non-RCT with 4 fresh frozen cadavers {[Richter 2001 848](#_ENREF_50)}, the effect of 2 different orthoses (an unspecified soft collar, and a Miami J® two-piece rigid collar) on reducing range of motion in the cervical spine was assessed, both on the intact spine and after osteotomy. Both orthoses reduced the range of motion at both C1-2 and C2-3 of the intact spine significantly. The soft collar did not give any clinically relevant stability to the unstable spine. Miami J® provided moderate control in the sagittal plane but a much better control of “torque” in the upper cervical spine compared to the soft collar.
10. Finally, in a tenth non-RCT, Liao and colleagues {[Liao 2018 e0195215](#_ENREF_35)} simulated ligamentous atlanto-occipital dislocation (AOD) as well as AOD combined with ligamentous atlanto-axial instability (AAI) in two newly developed cadaveric trauma models, using six cadavers. During the application of the Stifneck® Select™ one-piece rigid cervical collar, there was a significant increased angulation at the C0/C1 level in the AOD model. Immense three-dimensional movement up to 22.9° of cervical spine flexion was documented during the procedure.

**Adverse effects** of spinal motion restriction using a cervical collar were studied in seven RCTs {[Ala 2021 59](#_ENREF_1), [Karason 2014 37](#_ENREF_25), [Ladny 2020 e19740](#_ENREF_30), [Maissan 2018 e24](#_ENREF_38), [Russell 2024 106178](#_ENREF_52), [Szarpak 2018 68](#_ENREF_57), [Yard 2019 141](#_ENREF_67)}, three non-RCTs {[Hudson 2023 101788](#_ENREF_20), [Hunt 2001 511](#_ENREF_21), [Liao 2018 e0195215](#_ENREF_35)}, three interrupted time series {[Colak 2020 89](#_ENREF_11), [Kroeker 2019 196](#_ENREF_29), [Woster 2018 430](#_ENREF_66)}, four case series {[Bruton 2024](#_ENREF_6) , [Kolb 1999 135](#_ENREF_27), [Mobbs 2002 389](#_ENREF_43), [Stone 2010 100](#_ENREF_55)}, and one retrospective chart review {[Yazici 2024 126](#_ENREF_68)}.
Overall, these studies showed:

* decreases in respiratory function and swallowing function;
* increases in jugular venous pressure, intrajugular vein dimensions, cerebrospinal fluid pressure, optic nerve sheath diameter, intracranial pressure, and dural sac compression;
* no differences in skin hydration or transepidermal water loss.

In the paragraphs below, the individual studies and their findings are discussed further:
RCTs:

1. In a first RCT with 80 healthy volunteers {[Ala 2021 59](#_ENREF_1)} , the effect of two types of cervical collars (Philadelphia®, and Miami J® two-piece rigid) on pulmonary function and ventilation were investigated. Following application of either type of collar, there was a significant obstruction of expiratory flow, leading the study authors to state that efforts to remove cervical collars early, particularly in respiratory compromised patients, could be justified.
2. In a second RCT {[Karason 2014 37](#_ENREF_25)}, all studied collar types (Stifneck® one-piece rigid, Aspen Vista® two-piece rigid, Miami J® Advanced two-piece rigid, and Philadelphia® Tracheotomy two-piece rigid) increased the jugular venous pressure when applied, and this was maintained regardless of body positioning (supine vs 20-degree head-up position).
3. A third RCT {[Ladny 2020 e19740](#_ENREF_30)} measured changes in optic nerve sheath diameter (ONSD) as a surrogate for intracranial pressure, after the application of 5 different types of cervical collar (Ambu® Perfit ACE one-piece rigid, Philadelphia® One-Piece™ one-piece rigid, NecLoc® two-piece rigid, NeXsplint Plus one-piece rigid, and NECKLITE™ one-piece rigid) in 60 healthy volunteers. For all collars except the NECKLITE™, there was a statistically significant increase in the ONSD from baseline after cervical collar placement at 5 minutes and 20 minutes, with no significant differences between both time points. The authors concluded that the increase in diameter may be much more detrimental to traumatic brain injury patients.
4. Similarly, a fourth RCT with 20 healthy volunteers {[Szarpak 2018 68](#_ENREF_57)} studied the effects of two cervical collars (NECKLITE™ one-piece rigid, and Patriot® one-piece rigid) on the increase in ONSD. Both collars caused a statistically significant increase in median ONSD (baseline: 3.6 mm; Patriot®: 4.6 mm, p=0.01 vs baseline; NECKLITE™: 3.75, p<0.001 vs baseline).
5. In the same way, in an RCT with 45 healthy volunteers, Maissan *et al.* {[Maissan 2018 e24](#_ENREF_38)} found that application of the Stifneck® one-piece rigid cervical collar resulted in a statistically significant increase in the ONSD. This suggests that ICP will increase when a rigid cervical collar is applied. The authors concluded that, although this seems to be of minor importance to healthy volunteers, the effect of a collar on ONSD and ICP in patients with mild and moderate TBI needs to be determined.
6. In a fifth crossover RCT {[Yard 2019 141](#_ENREF_67)}, 30 healthy volunteers were randomized to either have the ONSD measured first without a cervical collar or initially with a Patriot® one-piece rigid cervical collar. Cervical collar placement caused a significant increase in overall mean ONSD (MD: 0.026 ± 0.064 cm (95%CI [0.015;0.038]; p<0.001).
7. Finally, an RCT of 25 healthy volunteers {[Russell 2024 106178](#_ENREF_52)}, skin hydration and transepidermal water loss were not statistically significantly affected (p>0.5) by application of a cervical collar (either a Miami J® two-piece rigid, Stifneck® Select™ one-piece rigid, Philadelphia® Adjustable Tracheotomy Collar two-piece semi-rigid, or Aspen Vista® two-piece rigid collar).

Non-RCTs:

1. In a non-RCT in 23 healthy volunteers {[Hudson 2023 101788](#_ENREF_20)}, application of a Miami J® two-piece rigid collar led to statistically significant changes in swallowing physiology in both younger and older volunteers. The authors speculated that collar use might increase risk of aspiration associated with these changes and mentioned that this risk should be carefully balanced with the benefit gained from collar use in the management of cervical spine injury, particularly in the older population who have physiological changes to the swallow that occur with age (presbyphagia) and where baseline risk of aspiration is higher.
2. In a non-RCT in 30 patients with severe traumatic brain injury without a confirmed spinal cervical injury {[Hunt 2001 511](#_ENREF_21)}, there were no significant differences in cardiovascular parameters during the 5 minutes before, during and after placement of the Stifneck® one-piece rigid cervical collar. Cerebral perfusion pressure was maintained >60 mmHg in all patients. There were also no changes in arterial oxygen partial pressure and arterial carbon dioxide partial pressure during the study period. Mean baseline intracranial pressure (ICP) was 14.1±6.6 mmHg and this rose to 18.8±8.4 mmHg following the application of the rigid collar (p<0.0001). In all patients the rise in ICP was sustained at the higher level whilst the collar was in position. ICP decreased to baseline values immediately following removal of the collar. The mean increase in ICP in patients with a baseline ICP<15 mmHg was 3.6±2.7 mmHg compared to 5.9±3.1 mmHg in those in whom the baseline ICP was >15 mmHg (p < 0.05). These findings suggest that in head-injured patients, rigid collars should be removed as soon as cervical spine injury has been excluded or, if this is delayed, an alternative method of spinal stabilization considered.
3. In their cadaver models of simulated ligamentous atlanto-occipital dislocation (AOD) as well as AOD combined with ligamentous atlanto-axial instability (AAI), Liao and colleagues {[Liao 2018 e0195215](#_ENREF_35)} showed that mean dural sac compression was significantly increased during application of a Stifneck® Select™ one-piece rigid cervical collar to -1.1 mm (-1.3 to -0.7 mm) in case of AOD and -1.2 mm (-1.6 to -0.6 mm) in the combined model of AOD and AAI.

Interrupted time series:

1. In an interrupted time series of 20 healthy volunteers, Woster and colleagues {[Woster 2018 430](#_ENREF_66)} assessed the ONSD before and after the placement of a(n unspecified) rigid cervical collar. At baseline, mean ONSD was 3.77 mm, which increased to 4.47 mm 5 min after placement of the collar. At 20 min, mean ONSD was 4.53 mm. ONSD at 5 min and at 20 min were significantly increased compared to the ONSD at baseline (p < 0.001), but there was no significant difference between the ONSD at 5 min and at 20 min.
2. Colak *et al.* {[Colak 2020 89](#_ENREF_11)} measured ONSD values in 94 trauma patients while wearing a(n unspecified) cervical collar (at admission to the ED, and 20 min later) and 20 minutes after the collar was removed (40 min after admission to the ED). Compared to the levels measured at admission, ONSD values were statistically significantly increased after 20 minutes in the cervical collar (p<0.05). ONSD decreased significantly after removal of the collar. However, the levels obtained after removal of the collar were significantly higher than the values recorded at the time of admission (p<0.05).
3. In a study with 17 healthy volunteers {[Kroeker 2019 196](#_ENREF_29)}, a significant increase in the circumference and the cross-sectional area of the intrajugular vein was seen with prolonged wear of the Stifneck® Select™ one-piece rigid cervical collar over a 4-hour interval (p<0.05). In contrast to the study by Colak, dimensions decreased back to baseline five minutes after collar removal.

Case series:

1. In a first case series, Bruton *et al.* {[Bruton 2024](#_ENREF_6) } studied 2,098 patients in which a soft cervical collar was applied by paramedics for potential traumatic cervical spine injury during pre-hospital care, in selected metropolitan and regional geographical areas of New South Wales ambulance service between May 2022 and March 2023. The majority of patients found the soft collar comfortable, and they were well-tolerated by patients who generally complied with immobilization directions.
2. In a second case series {[Kolb 1999 135](#_ENREF_27)}, the change in cerebrospinal fluid pressure after the application of a Philadelphia® two-piece rigid cervical collar was measured in 20 adult patients without cervical spine injury presenting to the ED and requiring a lumbar puncture. Pressure increased by 24.8 mmH2O on average (p<0.001). The authors concluded that although it is uncertain if this would be a clinically important difference, the small increment in pressure could be significant in patients who already have an elevated intracranial pressure.
3. In a third case series by Mobbs *et al.* {[Mobbs 2002 389](#_ENREF_43)}, a prospective series of 10 head-injured patients with a GCS of 9 or less presenting at the hospital with a Stifneck® one-piece rigid collar in place had ICP measurements before and after reapplication of the same collar 24-48 hours after presentation. Nine out of 10 patients had a rise in ICP following application of the collar. The post-application ICP was significantly higher than the value recorded prior to application (mean difference 4.4 mmHg, P<0.05). Intracranial pressure differences ranged from –3 to +12 mmHg (–7 to +171%).
4. In a fourth case series {[Stone 2010 100](#_ENREF_55)}, 42 healthy volunteers underwent ultrasound examination of the internal jugular vein before and after application of the Ambu® Perfit ACE™ one-piece rigid cervical collar. The cross-sectional area of the internal jugular vein increased significantly (p < 0.0001) after application of the cervical collar. The mean percentage increase in the cross-sectional area was 37% (95% CI [20;53]). According to the authors, these results show that venous obstruction in the neck may contribute to the increase in intracranial pressure seen after rigid collar application.

Retrospective chart review:

In a retrospective chart review of 169 trauma patients who presented to a Turkish ED in 2021 {[Yazici 2024 126](#_ENREF_68)}, the ONSD on brain CT of the trauma patients was measured and analyzed to determine whether there was a difference between patients with or without a cervical collar in place. Patients with a cervical collar in place had statistically significantly higher mean ONSD (p<0.001) for both the right and left eyes. The authors concluded that the effect of this increase on clinical outcomes needs to be investigated, and the actual need for cervical collar in the ED should be evaluated on a case-by-case basis.

* 1. *Long backboard/vacuum mattress with or without cervical collar vs no spinal motion restriction*

A total of five studies provided evidence on the effectiveness of using a long backboard or a vacuum mattress with or without applying a cervical collar, compared with not applying any spinal motion restriction.

One retrospective chart review investigated the **risk of spinal injury** with or without some form of spinal motion restriction. The review of 277 trauma patients brought to hospital with a subsequently documented spinal injury {[Nilhas 2022 119](#_ENREF_44)}, did not identify a difference in the proportion of patients with spinal injury between patients that were and were not on long spine boards upon arrival at the ED. No patient in either group “suffered spinal paralysis”.

**Adverse effects** of spinal motion restriction were studied in one RCTs, one non-RCT, two case series, and one retrospective chart review.

In an RCT, Totten *et al.* {[Totten 1999 347](#_ENREF_60)} evaluated comfort levels and respiratory function of 39 volunteers aged 7-85 years before and after immobilization with either a Stifneck® one-piece rigid cervical collar + a long backboard, or with a vacuum mattress + a vacuum collar. Six out of eight respiratory function measures were significantly decreased by an average of 17% from baseline across all age groups with both methods of immobilization, and to a greater degree for young and elderly subjects. Comfort was rated higher with the vacuum mattress than the wooden backboard. The restriction of respiratory function with immobilization on a hard spine board or vacuum mattress may be significant in an already compromised trauma patient.

In a non-RCT, Ay and colleagues {[Ay 2011 103](#_ENREF_3)} applied a Philadelphia® collar and long spinal backboard with straps in 60 healthy volunteers and performed spirometry to measure pulmonary function 5 and 30 minutes after application. Compared to baseline, forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) were significantly decreased after 5 minutes of spinal motion restriction (both p<0.001). Compared to the measurements at 5 minutes, there was a further significant decrease in FVC at 30 minutes of spinal motion restriction (p=0.002). There were no significant differences in FEV1/FVC levels at 5 or 30 minutes. This study shows that application of a cervical collar and long spinal board with straps causes a decrease in pulmonary function, and that this decrease becomes more pronounced when the immobilization period is extended.

March *et al.* {[March 2002 421](#_ENREF_39)} enrolled twenty healthy volunteers (13 male and 7 females) without previous back pain or injuries, to determine whether spinal immobilization causes changes in physical exam findings over time. This study was undertaken to determine whether immobilization with a cervical collar and longboard causes midline vertebral pain that is reproducible on palpation. Participants were fully immobilized for one hour with a cervical collar and strapped to a long wooden backboard. Midline palpation of vertebrae to elicit pain was performed at 10-minute intervals. In addition, the participants were asked to rate neck and back pain on a scale from 1 to 10 (1 for no pain, and 10 for unbearable pain), to see whether subjective pain from immobilization correlated with tenderness to palpation. Three participants had point tenderness of cervical vertebrae within 40 minutes. Five developed point tenderness of vertebrae by 60 minutes. Eighteen of 20 participants complained of increasing discomfort over time. The median initial pain scale was 1 (range 1–1), in contrast to 4 (range 1–9) at 60 minutes (p<0.05).

* 1. *Cervical collar + device vs no spinal motion restriction*

In a series of 342 patients admitted to the ED with cervical collar and head blocks, Ham *et al.* {[Ham 2016 1924](#_ENREF_17)} investigated the incidence and severity of **pressure ulcers, indentation marks and pain**. 78.4% of the patients had pressure ulcers after removal or replacement of the cervical collar and head blocks. 258 (75.4%) trauma patients had at least one category 1 lesion (non-blanchable redness of intact skin) as most severe pressure ulcer, and 10 (2.9%) had at least one category 2 lesion (partial thickness skin loss or blister) as most severe, with a mean of 2.5 lesions per patients (682/268). In 221 patients (64.6%) indentation marks were identified. All indentation marks followed the pattern of the extrication collar. In 96 (28.1%) trauma patients, they observed at least one severe indentation mark, with a mean of 1.9 marks per patient (428/221). 182 patients (63.2%) experienced pain. 48 (16.7%) experienced mild pain, 71 (24.6%) moderate pain and 111 (38.5%) severe pain. Pain occurred most frequently at the occiput (160 times).

* 1. *Multiple (combinations of) devices*

**Functional outcomes following spinal injury** were studied in one retrospective cohort study.

This study {[Chen 2022 3492](#_ENREF_8)} included prospectively collected data from 759 patients over 16 years of age with spinal injury identified in the Pan-Asian Trauma Outcomes Study (PATOS) registry between 1 January 2016 to 30 November 2018. The study aimed to determine the association between prehospital spine immobilization and favorable functional outcomes at hospital discharge in trauma patients with spinal injury. Spinal injury was defined as any spinal fracture, dislocation, subluxation or traumatic disc rupture with or without spinal cord injury. Prehospital spine immobilization included the use of a cervical collar and/or backboard or scoop stretcher. Functional outcome was measured with the modified Rankin Scale (mRS) at discharge. Patients with traumatic brain injury were excluded.

Of the 759 patients with spinal injury, 438 (57.7%) had prehospital spine immobilization. In multivariable logistic regression, prehospital spinal immobilization was not associated with favorable functional outcomes (aOR 1.06; 95% CI [0.62;1.81]; p=0.826). However, subgroup analysis showed prehospital spinal immobilization to be associated with favorable functional outcomes for the subgroup of cervical spinal injury (aOR 3.14; 95% CI [1.04;9.50]; p=0.043). For patients with an injury severity score of ≥9 and a cervical spinal injury, a positive association was also found between immobilization and favorable functional outcome (aOR 5.50; 95% CI [1.02;29.69]; p=0.048). The authors concluded that prehospital spinal immobilization may be beneficial for patients with cervical spinal injury without traumatic brain injury.

One prospective cohort study investigated the **risk of spinal injury** with or without some form of spinal motion restriction.In the cohort of 285 children transported to hospital by EMS {[Leonard 2012 513](#_ENREF_34)}, 173 had some form of spinal immobilization (SI) (“having a cervical collar and/or secured to a rigid spine board”) and 112 had no SI despite meeting the American College of Surgeons guidelines. Only one child from the SI group had a spinal fracture.

**Adverse effects** of spinal motion restriction were studied in one retrospective chart review. In Oosterwold 2017 {[Oosterwold 2017 513](#_ENREF_46)}, of the 1,082 adult patients transported to a trauma center between 2008 and 2012, 84% of patients received extensive spinal immobilization (“rigid collar, head blocks, spine board, and straps”). Adverse effects of spinal immobilization included pain (n=10, 0.9%), shortness of breath (n=3, 0.3%) and anxiety/combativeness (n = 6, 0.6%).

* 1. *Spinal motion restriction (unspecified) vs no spinal motion restriction*

In a prospective multi-national cohort study {[Jung 2023 e32849](#_ENREF_24)}, the association between ‘cervical spine immobilization’ (techniques and devices not specified) prior to arriving at the hospital and **mortality and poor functional outcomes** at hospital discharge was studied in adult trauma patients using the PATOS registry. In multivariable logistic regression analysis, cervical spine immobilization was not associated with in-hospital mortality (aOR: 1.32, 95%CI [0.77;2.27]) or poor functional outcome (aOR: 1.19, 95%CI [0.91-1.45]). In a subgroup of patients with traumatic brain injury, although cervical spinal immobilization was not associated with in-hospital mortality (aOR: 1.16, 95%CI [0.91;1.34]), it was significantly associated with an increased rate of poor functional outcomes (aOR: 1.23, 95%CI [1.03;1.44]). The odds ratios for poor functional outcomes of traumatic brain injury patients differed according to mean arterial pressure (MAP) (P < 0.01). The association of cervical spine injury with poor functional outcomes was maintained only in patients with decreased prehospital MAP (aOR: 1.38, 95%CI [1.14;1.56]), but not in patients with normal MAP (aOR: 1.12, 95%CI [0.93;1.24]).

In a retrospective chart review of 658 adult blunt trauma patients transported by EMS and hospitalized with radiographic cervical spine injuries from 2011 to 2019 at a level 1 trauma center {[Jao 2023 e001092](#_ENREF_23)}, the relationship between prehospital cervical spine immobilization and patient outcomes was investigated. Compared to those who did not receive prehospital cervical spinal motion restriction, those without prehospital cervical spinal motion restriction had a significantly lower **ICU admission rate** (29.1% vs 55.2%) and median **length of hospital stay** (6 days vs 8 days), but not **ICU length of stay**. **In-hospital mortality** was not significantly different between those without prehospital spinal motion restriction and those with (4.3% vs 7.4%). Hospital discharge disposition was also not significantly different between groups.

A second retrospective chart review {[Stroh 2001 609](#_ENREF_56)} evaluated the sensitivity of a protocol for selective cervical spinal immobilization used by EMS in a large US (California) county. Of 504 patients transported by EMS with a subsequent diagnosis of cervical spinal injury, 495 arrived immobilized. Of the 9 patients who arrived without cervical spinal immobilization, 4 refused or could not be immobilized, 3 were missed by protocol criteria, and 2 were missed because of protocol violations. Extremes of age (>67 years, <12 months) were noted in the 5 patients with cervical spinal injuries that were missed by protocol criteria or because of protocol violations. Of the 2 patients missed because of protocol violations, one was discharged with residual quadriparesis. However, the extent of neurologic dysfunction did not change between the initial paramedic evaluation and the ED evaluation. Consequently, it seems unlikely that spinal immobilization would have changed the outcome in this situation.

**Category 2: Mutual comparisons of types of spinal motion restriction**

* 1. *Cervical collar 1 vs cervical collar 2*

Twenty-three studies provided evidence on the comparative effectiveness of different types of cervical collars. In the paragraphs below, results are provided for the following comparisons within this subcategory:

* Soft foam collar vs rigid collar;
* Improvised vs commercially available collar;
* One-piece rigid collar vs two-piece rigid collar.

*2.1.1 Soft foam collar vs rigid collar*

Five studies compared a soft foam collar with a rigid collar {[Asha 2021 19](#_ENREF_2), [Bednar 2004 251](#_ENREF_4), [Eisner 2022 726](#_ENREF_12), [Mitra 2024 e13239](#_ENREF_42), [Richter 2001 848](#_ENREF_50)}.

The **risk of (secondary) spinal injury** was studied in one cohort study and in one case series {[Asha 2021 19](#_ENREF_2)}.

Mitra *et al.* {[Mitra 2024 e13239](#_ENREF_42)} performed a retrospective cohort of 1,762 trauma patients presenting to a major trauma center in Melbourne, Australia, with a cervical collar placed by EMS, either before or after shifting from semi-rigid collars to soft collars in 2021. After adjustment for age categories and mechanisms of injury, use of a soft cervical collar was not statistically significantly associated with the risk of cervical spinal cord injury (aOR 1.51; 95% CI [0.43;5.27]). However, since the study was underpowered to detect significant differences, the authors concluded that the practice of soft collars for prehospital care of patients with suspected neck injury requires ongoing surveillance.

In the case series of Asha and colleagues {[Asha 2021 19](#_ENREF_2)} 1,133 patients had a soft collar applied at the ED, whereas 268 patients arrived and remained in a rigid collar. Nine patients in total developed a new neurologic deficit after arriving at the ED: 6 in the soft collar group (3 due to progression of intracranial injuries, 1 due to spinal cord injury and 2 with no organic cause found) and 3 in the rigid collar group (2 due to spinal cord injury and 1 with no organic cause found). The authors concluded that the use of soft foam cervical collars in patients at risk for a cervical spine injury does not appear to increase the risk of secondary spinal cord injury.

**CROM** was measured in 3 non-RCTs conducted in healthy volunteers {[Eisner 2022 726](#_ENREF_12)} or in cadavers {[Bednar 2004 251](#_ENREF_4), [Richter 2001 848](#_ENREF_50)}.

A first non-RCT in 30 young healthy volunteers {[Eisner 2022 726](#_ENREF_12)} compared the use of folded towels, Stifneck® Select™ one-piece rigid cervical collars and foam neck braces with no immobilization (control) on outcomes of CROM in six cardinal directions in both seated and supine positions. Foam neck braces were inferior compared to cervical collars (seated composite score = 2.35, supine composite score = 2.10).

In a second non-RCT in 6 fresh cadavers with destabilized necks {[Bednar 2004 251](#_ENREF_4)}, angulation and translation were measured in the prone, decubitus and side-bending positions, either with the neck unsupported (no collar), or with soft (Soft Straight one-piece collar), semi-rigid (Philadelphia® two-piece collar) and rigid collars (Stifneck® one-piece collar) applied. During posterior destabilization, there were no statistically significant differences between types of collars in angulation, translation and distraction. During complete destabilization, there was a trend toward increased flexural translation in prone loading with the soft collar applied, but increased distraction of the index motion segments with more rigid collar support was such that the net malalignment was similar in all cases. With side-bending stress the data showed a trend toward increased angulation with the soft collar, but even the more rigid collars often allowed angulation of over 10°, bringing their effectiveness into question. Extension stressing of this model showed little variance of displacements between orthoses.

In the third non-RCT in 4 fresh frozen cadavers {[Richter 2001 848](#_ENREF_50)}, use of a(n unspecified) soft collar provided the least control of motion in all planes of the intact spine, compared to the Miami J® two-piece rigid collar. The soft collar did not give any clinically relevant stability to the unstable spine. Miami J® provided moderate control in the sagittal plane but a much better control of “torque” in the upper cervical spine compared to the soft collar.

With regards to **adverse effects**, the cohort study by Mitra *et al.* {[Mitra 2024 e13239](#_ENREF_42)} revealed no differences in the number of pressure sores (0.11% vs. 0.23%, p = 0.97) or hospital acquired pneumonia (2.0% vs. 2.7%; p=0.44) when comparing semi-rigid to soft cervical collar use.

*2.1.2 Improvised vs commercially available collar*

One study compared an improvised with a commercially available collar {[Porter 2019 412](#_ENREF_47)}. In this small RCT in 24 healthy volunteers, Porter and colleagues showed that the degree of CROM was not significantly different in flexion/extension, rotation or sideways motion between an improvised collar created by a folded fleece jacket and the commercially available one-piece semi-rigid EMT Select Extrication collar. The fleece jacket collar was more comfortable than the commercially collar (p<0.001).

*2.1.3 One-piece rigid collar vs two-piece rigid collar*

Six studies compared one-piece to two-piece rigid cervical collars {[James 2004 138](#_ENREF_22), [Karason 2014 37](#_ENREF_25), Ladny 2020 e19740, [Leenen 2020 100878](#_ENREF_33), [Russell 2024 106178](#_ENREF_52), [Worsley 2018 87](#_ENREF_65)}. This comparison was of interest to the Scoping Review Team, as in an emergency or out-of-hospital setting, a one-piece collar is considered by many to be easier, more efficient and rapid for application.

**CROM** was measured in 4 RCTs in healthy volunteers {[James 2004 138](#_ENREF_22), [Karason 2014 37](#_ENREF_25), Russell 2024 106178, [Worsley 2018 87](#_ENREF_65)} .
In the first RCT, James *et al.* {[James 2004 138](#_ENREF_22)} had 17 certified athletic trainers apply four cervical collars to 2 healthy volunteers to assess cervical spinal movement in seated and supine positions. The Stifneck® one-piece rigid collar and the Stifneck® Select™ one-piece rigid collar allowed statistically significantly less range of motion in all directions when compared with the NecLoc® two-piece rigid collar and Rapid Form™ Vacuum Immobilizer.

In a second RCT by Karason in 10 healthy volunteers {[Karason 2014 37](#_ENREF_25)}, the Philadelphia® Tracheotomy two-piece rigid collar decreased motion significantly less than the Stifneck® one-piece rigid collar (p=0.01), and the Aspen Vista® two-piece rigid collar decreased motion significantly less than the other 3 collars (all p<0.05).

In the third RCT {[Worsley 2018 87](#_ENREF_65)} two different rigid cervical collars (Aspen Vista® two-piece and Stifneck® one-piece collar) were applied under three different tension fitting conditions (optimal, high and low tension) in a random order to each of 15 healthy volunteers. When compared to the Aspen Vista® collar, the Stifneck® collar provided slightly more CROM restriction (p>0.05).

Finally, a very recent RCT {[Russell 2024 106178](#_ENREF_52)} measured the effect of 4 cervical collars (Miami J®, Stifneck® Select™, Philadelphia® Adjustable Tracheotomy Collar, Aspen Vista®) on CROM in 25 healthy volunteers and did not observe significant differences between collars.

**Adverse effects** of spinal motion restriction were reported by five RCTs {[Karason 2014 37](#_ENREF_25), Ladny 2020 e19740, [Leenen 2020 100878](#_ENREF_33), [Russell 2024 106178](#_ENREF_52), [Worsley 2018 87](#_ENREF_65)}.

In the RCT by Karason 2014 in 10 healthy volunteers {[Karason 2014 37](#_ENREF_25)}, the Aspen Vista® two-piece rigid collar and the Philadelphia® Tracheotomy two-piece rigid collar increased internal intrajugular venous pressure significantly more than the Stifneck® one-piece rigid collar and the Miami J® Advanced two-piece rigid collar (all p<0.05). The Philadelphia® Tracheotomy collar showed the highest increase in pressure (p<0.001 vs Aspen Vista®). The Aspen Vista® collar received the highest comfort scores. The Stifneck® and the Philadelphia® Tracheotomy collar were significantly less comfortable than the other two collars (both p<0.05).

The second RCT by Ladny 2020 {Ladny 2020 e19740} reported that among all 5 investigated types of cervical collar, the Philadelphia® One-Piece™ one-piece rigid caused the maximum increase in optic nerve sheath diameter.

A third RCT by Leenen and colleagues {[Leenen 2020 100878](#_ENREF_33)} studied three important factors for collar-related pressure ulcers during immobilization with two cervical collars (Stifneck® one-piece rigid and Philadelphia® Tracheotomy two-piece rigid collar) in 60 healthy volunteers: indentation marks, temperature and comfort of the immobilized healthy adults. In comparison to the Stifneck® collar, fewer and less severe indentation marks were observed from the Philadelphia® collar. There was a higher, but not significant, increase in skin temperature in the Philadelphia group overall, compared to the Stifneck group (1.3 °C versus 1.0 °C). The comfort level was rated as neither uncomfortable nor comfortable and was not statistically significantly different between both collars.

In a fourth RCT, Worsley *et al.* {[Worsley 2018 87](#_ENREF_65)} applied two different cervical collars (Aspen Vista® two-piece rigid and Stifneck® one-piece rigid collar) under three different tension fitting conditions (optimal, high and low tension) in a random order to each of 15 healthy volunteers. The results showed that, when compared to the Aspen Vista® cervical collar, the Stifneck® collar resulted in statistically significantly higher interface pressures (p<0.05). The Stifneck® collar also resulted in a higher increased skin humidity (21% vs 5.2%), and tended to be more uncomfortable (p>0.05).

Finally, a very recent RCT {[Russell 2024 106178](#_ENREF_52)} measured the effect of 4 cervical collars (Miami J®, Stifneck® Select™, Philadelphia® Adjustable Tracheotomy Collar, Aspen Vista®) on interface pressure, skin microclimate, transepidermal water loss and skin hydration in 25 healthy volunteers. The occiput experienced significantly higher interface pressures than the chin and mandibles for most collar designs. Interface pressure at the occiput was significantly higher for the Stifneck® Select™ single-piece collar compared to the other collars. Relative humidity at the device skin interface was significantly higher for the Stifneck® Select™ and Philadelphia® collars corresponding to closed cell foam padding, in contrast to the open cell foams lined with permeable fabric used in the other collars. Collar discomfort correlated with both occipital pressure and skin humidity. The authors concluded that the occiput is at increased risk of cervical collar-related pressure ulcers during supine immobilization, especially for Stifneck® Select™ collars, and suggest that lined open-cell foams could be used to minimize skin humidity and increase comfort.

*2.1.4 Other mutual comparisons of cervical collars*

**CROM** was measured in 8 RCTs in healthy volunteers {[Gavin 2003 527](#_ENREF_16), James 2004 138, Karason 2014 37, [Kim 2020 24](#_ENREF_26), [Russell 2024 106178](#_ENREF_52), [Tescher 2007 1120](#_ENREF_58), [Tescher 2016 E304](#_ENREF_59), [Zhang 2005 264](#_ENREF_69)}, and in 3 non-RCTs conducted in healthy volunteers {[Evans 2013 S10](#_ENREF_14), [McGrath 2009 166](#_ENREF_41), [Schneider 2007 E1](#_ENREF_53)}.
RCTs:

1. In a first RCT with 20 healthy volunteers {[Gavin 2003 527](#_ENREF_16)}, no statistically significant differences were found between the Miami J® and Aspen® collars in reducing gross or intervertebral sagittal motion, except at C5-6. The Aspen® 2-post cervical thoracic orthosis (CTO) and the 4-post CTO provided significantly more restriction of gross and intervertebral flexion and extension motion as compared to the two collars (p<0.05). The two CTOs performed similarly in flexion, but the Aspen® 4-post CTO provided significantly more restriction of extension motion (p<0.05).
2. A second RCT by Kim *et al.* {[Kim 2020 24](#_ENREF_26)}measured CROM in three planes involving flexion/extension, bilateral bending, and bilateral axial rotation in three cervical collars: the Philadelphia®, the Stifneck® Select™, and XCollar® collar. In a total of 30 healthy university students, the reduction in CROM was the most superior for the XCollar®.
3. A third RCT with 48 healthy volunteers {[Tescher 2007 1120](#_ENREF_58)} studied the effects of 4 commercially available cervical collars (Aspen® two-piece semi-rigid, Philadelphia® two-piece, Miami J® two-piece rigid, and Miami J® with Occian® Back two-piece rigid) on cervical range of motion in the seated position. Of the four collars, the Philadelphia® was the most restrictive of cervical range of motion in all movement planes (p < 0.001), followed by the Miami J®. The difference in restrictiveness between the Philadelphia® and Miami J® collars in all movement planes was not statistically significant. The Aspen® collar was the least restrictive of flexion and rotation, and the Miami J® with Occian® Back was the least restrictive of extension and lateral flexion movements.
4. Nine years later, in the fourth RCT, the same research team {[Tescher 2016 E304](#_ENREF_59)} investigated cervical range of motion and tissue-interface pressures in 48 healthy volunteers fitted with 4 commercially available collar types (Aspen® two-piece semi-rigid, Miami J® two-piece rigid, Aspen Vista® two-piece rigid, and Miami J® Advanced two-piece rigid). The Aspen® collar was more restrictive than the Aspen Vista® and the Miami J® in 4 movement planes, but not significantly different from the Miami J® Advanced. The authors noted however that, although the collar-to-collar comparisons were statistically significant, the differences may have little clinical significance in the acutely injured trauma patient.
5. In the fifth RCT {[Zhang 2005 264](#_ENREF_69)}, two newer cervical orthoses (Philadelphia® C-Breeze® and XTW collar) performed either comparably or better than the two established cervical orthoses (Aspen® and Miami J®).
6. In the sixth RCT, James *et al.* {[James 2004 138](#_ENREF_22)}, CROM was not significantly different when comparing the one-piece rigid collars (Stifneck® and the Stifneck® Select™). The NecLoc® two-piece rigid collar allowed statistically significantly less range of motion in all directions when compared with the Rapid Form™ Vacuum Immobilizer.
7. In the seventh RCT by Karason in 10 healthy volunteers {[Karason 2014 37](#_ENREF_25)}, the Aspen Vista® two-piece rigid collar decreased motion significantly less than the other two-piece rigid collars (Philadelphia® Tracheotomy and Miami J® Advanced) (p<0.05).
8. In the eighth and most recent RCT of 25 healthy volunteers {[Russell 2024 106178](#_ENREF_52)}, no significant differences in CROM were observed between 4 cervical collars (Miami J®, Stifneck® Select™, Philadelphia® Adjustable Tracheotomy Collar, Aspen Vista®). However, differences in mean value indicate that the Stifneck® collar was the most restrictive, and the Aspen® and Miami J® collars were the least restrictive.

Non-RCTs:

1. A first non-RCT {[Schneider 2007 E1](#_ENREF_53)} evaluated the biomechanical effectiveness of 4 different cervical collars (Philadelphia®, Aspen®, PMT®, and Miami J®) for restricting head motion in 45 healthy adult volunteers as well as intervertebral motion in the cervical spine. Overall range of motion of the head in 3 planes as well as intervertebral motion in the sagittal plane were measured while wearing the cervical orthoses. The only statistically significant differences were identified between the Philadelphia and Miami J collars, in both the sagittal plane rotation from maximum flexion to maximum extension (p=0.001) and the coronal plane rotation of the head between maximum left and right bending (p=0.004).
2. McGrath *et al.* {[McGrath 2009 166](#_ENREF_41)} performed a non-RCT using 13 healthy volunteers evaluating the effectiveness in limitation of cervical spine motion in 5 different movements with use of a one-piece rigid SAM® splint-molded cervical collar compared with use of a Philadelphia® 2-piece semi-rigid cervical collar. The results of this small study showed no statistically signiﬁcant difference between the Philadelphia® collar and the SAM® splint at limiting movement of the cervical spine in any of the measured movements or in total allowed degrees of movement and suggest that the SAM® splint, when molded into a cervical collar, is as effective as the Philadelphia® collar at limiting movement of the cervical spine.
3. In a third non-RCT by Evans *et al.* {[Evans 2013 S10](#_ENREF_14)}, the Aspen® collar was the most effective at restricting flexion/extension in the sagittal plane. Both the Aspen® and Philadelphia® collars were significantly more effective than the Aspen Vista® (p<0.001), Miami J® (p<0.001 and p<0.01, respectively) and Miami J® Advanced (p<0.01 and p<0.05, respectively) collars. In the transverse plane, the Aspen® collar was the most effective at restricting rotation and was significantly more effective than the Aspen Vista® (p<0.001) and Miami J® (p<0.05) collars. In the coronal plane, the Aspen® collar was the most effective, and the Aspen Vista® collar was the least effective at restricting lateral bend. The authors concluded that the Aspen® collar was superior to the other collars when measuring restriction of movement of the cervical spine in all planes, particularly the sagittal and transverse planes, while the Aspen Vista® was the least effective collar.

**Adverse effects** of spinal motion restriction were reported by eight RCTs {[Ala 2021 59](#_ENREF_1), Karason 2014 37, [Ladny 2018 1](#_ENREF_31), Ladny 2020 e19740, Russell 2024 106178, [Szarpak 2018 68](#_ENREF_57), [Tescher 2007 1120](#_ENREF_58), [Tescher 2016 E304](#_ENREF_59)} and one non-RCT {[Schneider 2007 E1](#_ENREF_53)}.
RCTs:

1. In an RCT with 80 healthy volunteers {[Ala 2021 59](#_ENREF_1)}, the effect of a Philadelphia® collar on expiratory flow restriction outpaced that of the Miami J® two-piece rigid collar.
2. In Karason *et al.* {Karason 2014 37}, the Philadelphia® Tracheotomy two-piece rigid collar increased internal intrajugular venous pressure significantly more than the Aspen Vista® two-piece rigid collar, that in its turn increased the pressure significantly more than the Miami J® Advanced two-piece rigid collar (all p<0.05). The Aspen Vista® collar was significantly more comfortable than the other two two-piece rigid collars.
3. Using an RCT in 32 healthy volunteers {[Ladny 2018 1](#_ENREF_31)}, level of comfort after applying a cervical collar was compared for two different types of collar: a rigid standard collar (Ambu® Perfit ACE™ one-piece rigid) and the NECKLITE™ one-piece rigid collar. The use of the NECKLITE™ collar was associated with greater comfort (less pressure on the mastoid processes and less pain; both p<0.001) compared to the standard cervical collar.
4. In an RCT by the same authors {[Ladny 2020 e19740](#_ENREF_30)}, for all types of one-piece rigid collars, except the NECKLITE™, there was a statistically significant increase in the ONSD from baseline after cervical collar placement at 5 minutes and 20 minutes, with no significant differences between both time points.
5. An RCT with 48 healthy volunteers {[Tescher 2007 1120](#_ENREF_58)} studied the effects of 4 commercially available cervical collars (Aspen®, Philadelphia®, Miami J®, and Miami J® with Occian® back) on mandibular and occipital tissue-interface pressure in upright and supine positions. The Aspen® collar had the highest mean pressures on both mandibles and occiput in the upright and supine positions (p < 0.001). The Philadelphia® collar had the highest maximal pressure on the occiput in the supine position (p < 0.001). The Miami J® with Occian® back had the lowest mean pressure on the occiput in the upright and supine positions, and on both mandibles in the supine position.
6. In Tescher 2016 {[Tescher 2016 E304](#_ENREF_59)}, the same author team later investigated tissue-interface pressures in 48 healthy volunteers fitted with 4 commercially available collar types (Aspen®, Miami J®, Aspen Vista®, and Miami J® Advanced). Peak tissue pressure on the mandible and occiput varied between collar types and positioning of patient in upright and supine positions. Overall, the Miami J® collar had the lowest tissue interface pressure. The authors stated that the provider must determine whether the benefit of a small increase in restrictiveness provided by the Aspen® and Miami J® Advanced collars outweighs the risks of higher tissue-interface pressures compared with the standard Miami J® collar, and that this decision will certainly be influenced by the patient’s mobility and ability to communicate discomfort.
7. A randomized cross-over study with 20 healthy volunteers {[Szarpak 2018 68](#_ENREF_57)} studied the effects of two cervical collars (NECKLITE™ and Patriot® cervical extraction collar) on the increase in ICP, measured indirectly by means of the ONSD.

Median ONSD during baseline was 3.6 mm. When using the NECKLITE™ cervical collar, an increase in ONSD to 3.75 mm was seen, while with the Patriot® collar an ONSD of 4.6 mm was observed. Differences were statistically significant between NECKLITE™ and Patriot® collars (p<0.01). The authors concluded that the use of a standard Patriot® cervical collar caused a significant increase in optic nerve thickness, which is a manifestation of an increase in intracranial pressure. The use of the innovative NECKLITE™ cervical collar was associated with a much smaller increase in the thickness of the optic nerve sheath.

1. Finally, in an RCT of 25 healthy volunteers {[Russell 2024 106178](#_ENREF_52)}, although not statistically significant, perceived discomfort was higher for the Philadelphia® Adjustable Tracheotomy Collar two-piece semi-rigid than for the two two-piece rigid collars (Philadelphia Miami J® and Aspen Vista®).

Non-RCT:
Schneider *et al.* {[Schneider 2007 E1](#_ENREF_53)} evaluated the reported comfort of 4 different cervical collars (Philadelphia®, Aspen®, PMT®, Miami J®) in 45 healthy adult volunteers. Comfort varied between braces, albeit not in a statistically significant manner.

* 1. *Cervical collar vs other type of (improvised) device*

**CROM** was measured in three non-RCTs.
In a non-inferiority trial {[Eisner 2022 726](#_ENREF_12)} conducted in 30 young healthy volunteers, a folded towel immobilization protocol was found to be non-inferior for immobilizing the cervical spine in extension and rotation, but not flexion, compared to the Stifneck® Select™ cervical collar. The study authors propose that folded towels could be trialed in combination with backboards to deliver affordable and effective prehospital traumatic spinal cord injury management in resource-limited settings.
In a second non-RCT by Holla and colleagues {[Holla 2012 104](#_ENREF_19)}, use of a spine board + Sof-Loc® head blocks led to a statistically significantly higher reduction in active range of motion (lateral bending, flexion-extension and rotation) of the cervical spine in 10 healthy volunteers, compared to use of a cervical collar (all p<0.005).

In the third non-RCT by Roebke *et al.* {[Roebke 2023 e2987](#_ENREF_51)}in three cadavers with destabilized spines, a spray-on foam splint (FastCast™) was rated superior by ortho consultants to SAM® splint collar immobilization for the cervical spine. In 100% of cases, raters indicated that FastCast™ passed the initial radiographic alignment following immobilization, whereas 66% of the SAM® splints passed (p=0.04). In 100% of cases, raters indicated that FastCast™ passed radiographic alignment after the gravity stress examination, whereas 47% of the SAM® splints passed (p<0.01).

* 1. *Cervical collar + device vs cervical collar only*

**CROM** was measured in one RCT, one non-RCT and one cohort study.Rahmatalla *et al.* {[Rahmatalla 2019 32](#_ENREF_49)}compared the cervical movement using a dynamic simulation model on 16 healthy adult male volunteers through augmented rides in a helicopter and road ambulance through a randomized controlled crossover trial. Use of a long spine board + a cervical collar + head blocks and use of a vacuum mattress + cervical collar + head blocks decreased cervical rotation and cervical lateral bend to a significantly greater extent than the cot + cervical collar.

In a non-RCT with a cross-over design {[Pryce 2016 36](#_ENREF_48)}, acceleration of the head during voluntary motion was statistically significantly lower (p<0.05) during immobilization with a long spine board + Ambu® Perfit ACE™ collar, compared to collar only, during atlanto-occipital flexion, neck flexion, extension, side flexion and rotation. Application of a collar was associated with a 36.1% (SD = 8.0%) decrease in displacement (relative to no SI), and full SI a further 40.0% (SD = 4.0%) decrease (relative to collar).

In one prospective observational study of 9 patients with suspected spinal injury treated by EMS, comparing long back board + head blocks + cervical collar vs cervical collar alone, and compliant vs non-compliant patients {[McDonald 2021 117](#_ENREF_40)}, the authors found no difference in the range of movements and rate of change in position between both interventions. They found significant greater range of movements in non-compliant patients (struggling or attempting to remove restraints) than in compliant patients. They also noted a greater range of movements of the cervical spine in actual patients than reported in simulation studies.

* 1. *Cervical collar + device 1 vs cervical collar + device 2*

Two RCTs {[Mahshidfar 2013 462](#_ENREF_37), [Rahmatalla 2019 32](#_ENREF_49)} and two non-RCTs {[Krell 2006 46](#_ENREF_28), [Uzun 2020 382](#_ENREF_61)} assessed **CROM**.

In a first RCT comparing long back board with vacuum mattress splint for spinal immobilization in 60 adult fully conscious patients with possible traumatic spinal injuries {[Mahshidfar 2013 462](#_ENREF_37)}, the authors found that the long back board provided better immobilization of the spine than the vacuum mattress splint.

The RCT by Rahmatalla 2019 and colleagues {[Rahmatalla 2019 32](#_ENREF_49)} compared the cervical movement using a dynamic simulation model on 16 healthy adult male volunteers through augmented rides in a helicopter and road ambulance. Under all but one condition (ambulance real-world field ride), cervical rotation was statistically significantly lower under immobilization with a long spine board + collar + head blocks compared to immobilization with a vacuum mattress + collar.

A first non-RCT {[Krell 2006 46](#_ENREF_28)} compared movement of the cervical spine in 31 healthy adults during immobilization with a WizLoc® one-piece rigid cervical collar + a traditional long backboard versus with the collar + a Ferno® Scoop Stretcher. Significantly greater motions were demonstrated in sagittal, lateral and axial planes during application of the long backboard compared with the scoop stretcher.

The second non-RCT {[Uzun 2020 382](#_ENREF_61)} used biomechanical analysis to determine CROM following different types of cervical spine immobilization (a vacuum mattress or a long spine board with varying configurations of a rigid cervical collar/no collar, a headlock system, head blocks, spider straps or speedclips) performed on 3 healthy subjects. Test subjects had their heads moved passively following immobilization to measure the remaining range of motion for flexion, extension, bending and rotation. Use of a rigid cervical collar + long spine board + spider straps/speed clips led to less remaining movement of the cervical spine (mean 1-9°) compared with a rigid collar + vacuum mattress with or without head blocks (mean 1-15°).

The **adverse effects** of spinal motion restriction were studied in two RCTs {[Mahshidfar 2013 462](#_ENREF_37), [Totten 1999 347](#_ENREF_60)} and one non-RCT {[Krell 2006 46](#_ENREF_28)}.In a first randomized experimental crossover study immobilized 39 volunteers aged 7-85 years with either a Stifneck® one-piece rigid cervical collar + a long backboard, or with a vacuum mattress + a vacuum collar {[Totten 1999 347](#_ENREF_60)}. Participants showed lower forced expiratory volume in the vacuum mattress restraint condition than when restrained on the backboard (p<0.05). Other respiratory measures were not statistically different between both devices. In addition, the study found that comfort was rated higher with the vacuum mattress than the wooden backboard.

In a second RCT in 60 adult fully conscious patients with possible traumatic spinal injuries {[Mahshidfar 2013 462](#_ENREF_37)}, the authors found that an unspecified rigid cervical collar + long spine board was more comfortable for the patient than the rigid collar + vacuum mattress splint (median score 4 vs 1 out of 5).

A non-randomized controlled trial {[Krell 2006 46](#_ENREF_28)} found that greater comfort and perceived security were reported by 31 healthy adults during immobilization with a WizLoc® one-piece rigid cervical collar and a Ferno® Scoop Stretcher, compared with immobilization with the collar + a traditional long backboard.

* 1. *Device 1 vs device 2*

An explorative experimental study {[Uzun 2020 382](#_ENREF_61)} used biomechanical analysis to determine **CROM** following different types of cervical spine immobilization performed on 3 healthy subjects. Immobilization was better on a spine board + spider straps (mean remaining movement 1°) compared with a vacuum mattress (without head blocks: mean 14-37°, with headblocks: mean 2-5°).

**Category 3: Extrication studies**
Two RCTs {[Engsberg 2013 122](#_ENREF_13), [Gabrieli 2020 712](#_ENREF_15)} and two non-RCTs {[Hernández 2019 36](#_ENREF_18), [Nutbeam 2021 108](#_ENREF_45)}, all four in healthy volunteers, assessed **CROM** during simulated extrication from vehicles.

In a first RCT of 10 healthy volunteers of simulated extrication from a vehicle {[Engsberg 2013 122](#_ENREF_13)}, it was found that unassisted self-extrication after application of a two-piece cervical collar significantly reduced the range of motion compared with unassisted self-extrication without restriction devices. Extrication techniques performed by EMS using a cervical collar alone (‘assisted extrication’) did not provide further restriction of movement for flexion/extension and rotation of cervical spine.

The second RCT {[Gabrieli 2020 712](#_ENREF_15)} evaluated cervical movement and muscle activity in 23 adult males who were extricated from a vehicle using different techniques: 1) self-extrication without instructions, 2) self-extrication with instructions, 3) application of a WizLoc 449-I™ one-piece rigid cervical collar followed by unassisted self-extrication. A fourth technique was used that involved extrication by 2 professional rescuers following application of the cervical collar and with use of a Ferno XT™ extrication device. However, given that this is a highly specialized extrication device, it was deemed irrelevant to first aid. During the maneuver and exiting period, the least range of motion was observed during cervical collar + unassisted self-extrication (~17°). The greatest range of motion was observed during autonomous exit and instructed exit (~45°). The use of the cervical collar allows for a reduction in peak speed and acceleration compared to autonomous exit and instructed exit during exit (p< 0.001).

In a first non-RCT in 16 healthy volunteers {[Hernández 2019 36](#_ENREF_18)}, biomechanical data were collected from inertial sensors to detect misalignment of the cervical spine during self-extrication with and without a cervical collar. Misalignment was greater during self-extrication with a collar in place (on average 3.12° for the Stifneck collar® one-piece rigid collar and 5.95° for the Xcollar® one-piece rigid collar), but this did not reach statistical significance (p>0.05). In conclusion, this study shows that misalignment of the cervical spine is similar during self-extrication with or without a cervical collar in place.

A second non-RCT of 391 extrication trials in 10 healthy volunteers {[Nutbeam 2021 108](#_ENREF_45)}, self-extrication with no instructions but with a Stifneck® one-piece rigid collar resulted in the smallest spinal movement of the four self-extrication approaches used (mean 6.9 mm anterior/posterior and 4.4 mm lateral). The largest overall movements were seen in the cervical spine anterior/posterior when no instructions and no collar were used (28.3 mm). For cervical spine lateral movements, no collar but with instructions produced the greatest movement (18.5 mm). The authors concluded that when a casualty is suitable for self-extrication, they should receive the simple instruction to leave the vehicle, and that in organizations which use collars, these may be applied to minimize spinal movement during extrication.

**Category 4: Post- vs pre- implementation of selective spinal motion restriction protocols**
Incidence rates of **spinal (cord) injury and** **functional outcomes** of trauma patients before and after implementation of spinal motion restriction protocols were determined in three retrospective cohort studies.

Using a retrospective cohort of 104,315 cases of traumatic injury, 51,199 cases of possible spinal trauma and 5,178 cases of verified spinal trauma, Castro-Marin 2020 {[Castro-Marin 2020 401](#_ENREF_7)} compared the incidence rate of spinal cord injury before and after the implementation of spinal motion restriction protocols. Implementation of these protocols designed to reduce the use of the long spine board was not associated with a statistically significantly increase in the incidence of spinal cord injury, neither in the subcohort of traumatic injury (0.22% after vs 0.20% before; p=0.390), that of possible spinal trauma (0.45% after vs 0.40% before; p=0.0436), or that of verified spinal trauma cases (4.04% after vs 4.37%; p=0.561). In the highest risk subcohort of patients with verified spinal trauma, the odds ratio adjusted for age and injury severity after the implementation was 1.097 (95%CI [0,818;1,472]).

In a second retrospective cohort of 1,172 patients transported by EMS to a hospital with spine or spinal cord injury due to blunt trauma {[Clemency 2021 708](#_ENREF_10)}, the incidence of disabling spinal injuries was studied. Of those 1,172 patients, 623 were transported after implementation of the spinal motion restriction protocol, whereas the other 549 were transported prior to implementation and therefore underwent spinal immobilization. Incidence rates of disabling spinal injuries were not statistically significantly different: 4.5% for the spinal motion restricted patients vs 5.1% for the spinal immobilized patients (p=0.628).

In the third retrospective cohort of 1,147 trauma patients with a presumed spinal injury transported by EMS, van de Breevaert and colleagues {[van de Breevaart 2023 101345](#_ENREF_62)} compared the prevalence of non-immobilized spinal fractures and adverse patient outcomes before and after the implementation of a selective spinal immobilization protocol. Implementation of this protocol was not associated with a statistically significant increase in the prevalence of non-immobilized spinal fractures. In addition, in both periods, no neurological injuries or mortality due to non-immobilized spinal fractures were found.