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Does the implementation of a trauma system affect injury-related morbidity and economic outcomes? A systematic review

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ABSTRACT

Background Trauma accounts for a huge burden of disease worldwide. Trauma systems have been implemented in multiple countries across the globe, aiming to link and optimise multiple aspects of the trauma care pathway, and while they have been shown to reduce overall mortality, much less is known about their cost-effectiveness and impact on morbidity.

Methods We performed a systematic review to explore the impact the implementation of a trauma system has on morbidity, quality of life and economic outcomes, in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. All comparator study types published since 2000 were included, both retrospective and prospective in nature, and no limits were placed on language. Data were reported as a narrative review.

Results Seven articles were identified that met the inclusion criteria, all of which reported a pre-trauma and post-trauma system implementation comparison in high-income settings. The overall study quality was poor, with all studies demonstrating a severe risk of bias. Five studies reported across multiple types of trauma patients, the majority describing a positive impact across a variety of morbidity and health economic outcomes following trauma system implementation. Two studies focused specifically on traumatic brain injury and did not demonstrate any impact on morbidity outcomes.

Discussion There is currently limited and poor quality evidence that assesses the impact that trauma systems have on morbidity, quality of life and economic outcomes. While trauma systems have a fundamental role to play in high-quality trauma care, morbidity and disability data can have large economic and cultural consequences, even if mortality rates have improved. The sociocultural and political context of the surrounding healthcare infrastructure must be better understood before implementing any trauma system, particularly in resource-poor and fragile settings.

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INTRODUCTION

Trauma accounts for approximately 9% of all global deaths.¹ It contributes to the greatest loss of disability-adjusted life years (DALY) for adolescents and young adults worldwide² as well as more deaths

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ The implementation of a trauma system is known to improve overall mortality rates within a region.
- ⇒ Morbidity and disability data can have large economic and cultural consequences, even if mortality rates have improved.

WHAT THIS STUDY ADDS

- ⇒ Only limited poor-quality evidence is available that reports the impact trauma systems have on morbidity, quality of life and economic outcomes, all of which have been studied only in high-income settings.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Further research is needed to better understand and unpick how context-specific trauma systems can be best implemented, particularly in resource-poor and fragile settings.

than from HIV, tuberculosis and malaria combined.³ There remains a disproportionately high number of trauma-related casualties in low and middle-income countries (LMICs)⁴ and approximately two million lives each year could be saved if similar outcomes were achieved among seriously injured persons in LMICs as in high-income countries (HICs).⁵

Trauma systems have been variably defined,⁶ but can be considered as a framework to link and optimise multiple aspects of the trauma care pathway, from prehospital triage protocols and predefined transport links through definitive care and rehabilitation services, either as an inclusive or exclusive system, with the overall aim of improving trauma patient outcomes. Trauma systems have been implemented across multiple countries around the world for over 15 years,^{7–12} and multiple high-level estimates suggest that they significantly improve overall mortality rates in patients with trauma.^{13–15} However, trauma system development has mainly been driven from mortality data and much less is known about their cost-effectiveness and impact on morbidity and economic outcomes.



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Given the benefits seen in survival outcomes, it may be reasonable to assume that morbidity and economic outcomes might also be improved with the implementation of a trauma system. However, improvements may conversely result in a greater burden of morbidity with increasing numbers of survivors requiring ongoing medical care. This is an important consideration for maturing healthcare settings when choosing whether or how to implement trauma systems. Indeed, much of the consensus on trauma system benefit has derived from HIC settings, which already have pre-existing and established systems of rehabilitation and social care. It is difficult to interpret this experience in the context of fragile health systems in LMICs, which, despite the greatest burden of traumatic disease, have a relative paucity of available literature on which to base trauma system implementation.

To understand the current evidence for trauma system impact beyond mortality rates, we performed a systematic review to explore the impact of the implementation of a trauma system on morbidity, quality of life and economic outcomes in the population served by that service.

METHODS

Literature search

A literature search was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.¹⁶ The study was registered with PROSPERO (www.crd.york.ac.uk/prospero) prior to the initial literature search being undertaken and the full protocol has previously been published in an open-access peer-reviewed journal.¹⁷ The literature search was designed by a health librarian (IK) in collaboration with the lead author (MFB), using a combination of free text terms and subject headings where appropriate. No patients or public were involved in the design of the study.

We conducted searches using the following databases: MEDLINE via Ovid, Embase via Ovid, Web of Science Core Collection, PsycINFO via Ebsco, Global Health via Ebsco, SciELO via Web of Science, WHO Global Index Medicus, including African Index Medicus, Index Medicus for Eastern Mediterranean Region, Index Medicus for South-East Asian Region, Latin America and the Caribbean Literature on Health Sciences (Lilacs), and Western Pacific Region Index Medicus (the full search strategy is included in the online supplemental material). A grey literature search was also performed.

The study question was derived around the following PICO format: Population=all types of trauma patients; Intervention=implementation of an organised trauma system within a region; Comparison=no organised trauma system within a region; Outcome=any morbidity, quality of life, or economic outcomes.

Eligibility criteria

Any study that assessed the impact of the implementation of an organised trauma system on morbidity, quality of life, or economic outcomes was included. An organised trauma system was defined as any “pre-planned approach to the provision of the spectrum of trauma services”,¹⁸ and only studies that assessed the implementation of a full trauma system, not just a sub-component, were included. We took a pragmatic approach to study inclusion, such that those studies reporting on either formal or informal trauma systems in place (often termed a “hard” system vs a “soft” system) were included.

All comparator study types were included, both retrospective and prospective. Case studies or case series (<10 patients),

reviews, and editorials were excluded, as were studies on the implementation of a specific technique or equipment involved in a trauma system (ie, not a whole-system intervention) or studies that reported outcomes for pre-existing trauma systems (ie, not newly implemented). Further details on the inclusion criteria are described in the previously published protocol.¹⁷

Due to significant developments in trauma care in recent years,¹⁹ only studies published from January 2000 to August 2022 were included. No limits by publication type or language were applied, with any non-English language published manuscripts translated locally using University translation services where required.

Data analysis

Articles were screened initially by title and then abstract by two authors independently, with discrepancies resolved by consensus. The final data extraction of all included studies was performed by the lead author (MFB). Due to the mixed study populations involved and heterogeneous outcomes reported, no quantitative statistical assessment was possible, with data reported as a narrative review and conducted in accordance with the SWiM guidelines²⁰ (online supplemental material). A risk of bias assessment for included studies was performed using the Risk of Bias in Non-randomised Studies of Interventions (ROBINS-I).²¹ Due to the high heterogeneity in the included study outcomes, publication bias was not feasible for assessment.

RESULTS

Following removal of duplicates, we identified 8087 articles for screening and an additional 94 articles through grey literature and reference searching, resulting in a total of 8181 articles screened (figure 1). Seven articles met the study inclusion criteria and were included in the final review.^{22–28}

All studies reported a pre and post-trauma system implementation comparison. Three articles reported all trauma patient types,^{22 23 27} two articles reported on patients with traumatic brain injury (TBI),^{24 25} one article reported on lower limb open fracture patients,²⁶ and one article reported on penetrating thoracic trauma patients.²⁸ In total, 17 137 patients were included across all studies (table 1).

We analysed studies including all trauma patient types, with a subset analysis for patients with TBI; we had originally planned to perform a subanalysis on paediatric cases, but no suitable studies were identified in the literature search; therefore, this could not be performed. All included studies demonstrated a severe risk of bias from the ROBINS-I assessment (table 2).

All trauma patients

Three studies were identified that reported specific morbidity outcomes.^{26–28} A study from the West Midlands, United Kingdom (UK), evaluated the implementation of a regional trauma system in 2012, assessing its impact on patients achieving a ‘good recovery’, which was defined as patients being discharged home to live independently, with no new arrangements for domiciliary care.²⁷ The implementation of the trauma system showed a significant increase in the proportion of patients having a good recovery, from 55.5% to 62.3% ($p<0.001$).

A study from Suwon, South Korea, also reported morbidity outcomes, describing the impact of their regional trauma system implementation on trauma patients who suffered an open fracture below the knee and with Gustilo-Anderson classification type II or type III and rates of limb salvage.²⁶ Limited details were provided on the specific trauma system implemented,

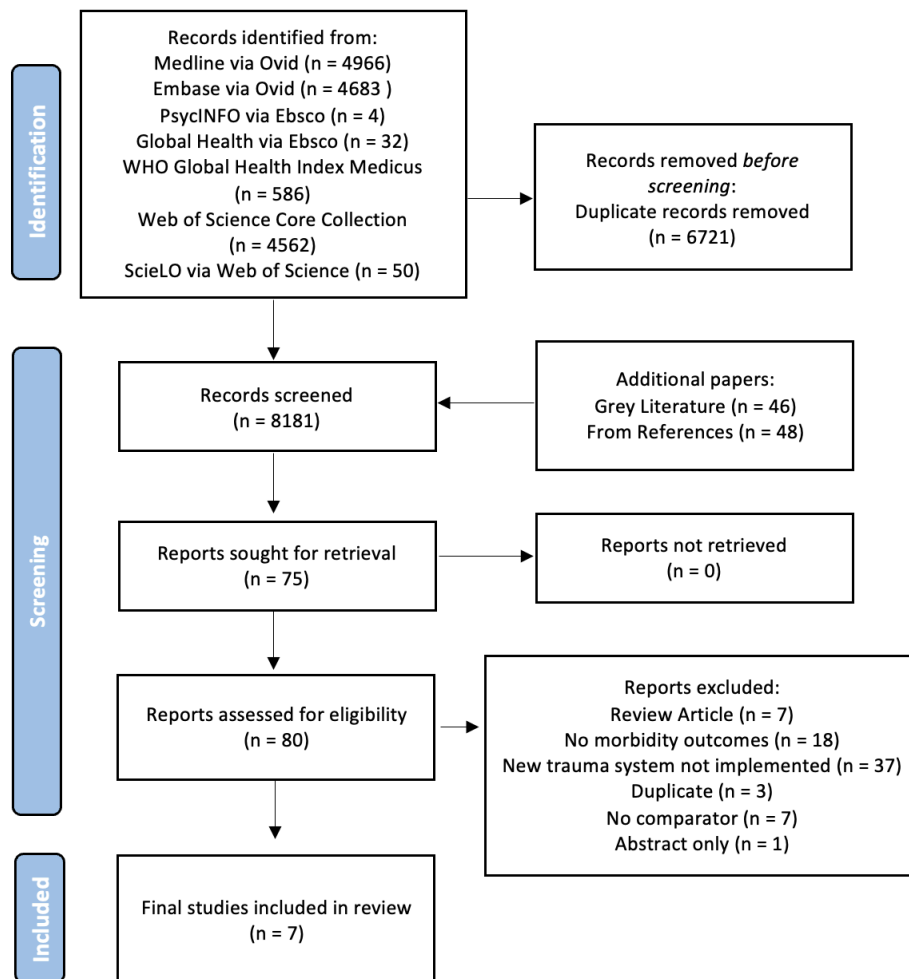


Figure 1 PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

although trauma system care in South Korea has previously been well described. Limb salvage was defined as the resolution of soft tissue wounds without a requirement for major amputation. The study concluded that the establishment of the trauma centre significantly increased the lower limb salvage rate.

The final study that reported on morbidity outcomes focused on penetrating thoracic trauma patients, following the implementation of a regional trauma system in the Provence-Alpes-Cote-d'Azur region, France, in 2014.²⁸ Again, minimal details were provided of the trauma system itself, but it was described as being centred around 'structural change in the management of severe trauma patients to modified and standardised the structural organisation for the management of severe trauma'. Minimal details were given on the exact composition of this outcome measure, yet the authors concluded that 30-day morbidity-mortality rates were unchanged with the trauma system implementation and only a minimal reduction in morbidity-mortality rates when adjusted for severity score and patient compliance.

Two studies were identified that reported specific health economic and cost-effectiveness outcomes.^{22 23} A study from Alabama, USA, evaluated the impact of their regional trauma system implemented in 1996 on the average cost for trauma care provision.²² Financial analysis was determined through total charges, total cost and direct costs, with linear regression models then used to estimate and compare average costs for pre and postsystem implementation, adjusting for changes in case

mix. The authors concluded that there was a significant decrease in the average total costs after system implementation among patients with moderate to severe injuries.

The other study described the implementation of a regional trauma system in the state of Victoria, Australia, between 2000 and 2003 and evaluated its impact on DALY and cost savings made in road transport-related major trauma cases.²³ The study calculated DALYs through years of life lost (YLLs) and years lived with disability (YLDs), adjusted using disability weights calculated via an EQ-5D questionnaire, and cost per DALY was also calculated based on Gross Domestic Product (GDP) per capita or value of a statistical life year. The group reported a 28% reduction in DALYs with implementation of the trauma system, but this was comprised of a 43% reduction in YLLs and a 32% increase in YLDs. There was an overall cost saving in trauma care with implementation of the trauma system, estimating a saving of between A\$209 750 and A\$633 446 per case.

Patients with TBI

Two studies were identified that focused on the outcomes of patients with TBI with the implementation of a trauma system.^{24 25}

One study from Ohio, USA, evaluated the implementation of a regional trauma system on all patients with TBI aged >14 years with a head Abbreviated Injury Scale ≥ 3 .²⁴ Their trauma

Table 1 Included studies from the systematic review

Authors	Year	Region	Study population	Comparison type	Patients included	Outcome measure reported
Abernathy III <i>et al</i> ²²	2002	Alabama, USA	All trauma patients	Before–after	3024	Total overall cost per case (\$)
Gabbe <i>et al</i> ²³	2015	Victoria, Australia	Road transport-related major trauma cases	Before–after	7828	Disability-adjusted life years (DALY) and total cost per case (A\$)
Kelly <i>et al</i> ²⁴	2015	Ohio, USA	Patients with TBI > 14 years with a head AIS score ≥ 3	Before–after	3496	Functional Independence Measure scores at discharge
Kim J <i>et al</i> ²⁵	2019	Ulsan, South Korea	Severe trauma (ISS > 15) with TBI	Before–after	322	Glasgow Outcome Scale at 3 months
Kim M <i>et al</i> ²⁶	2022	Suwon, South Korea	Open fracture below the knee level and Gustilo type II/III	Before–after	273	Rates of limb salvage during admission
Metcalf <i>et al</i> ²⁷	2014	West Midlands, UK	All major trauma patients	Before–after	1768	Rates of good recovery* at discharge
Vasse <i>et al</i> ²⁸	2022	Provence-Alpes-Cote-d'Azur, France	Penetrating thoracic trauma patients	Before–after	426	Combined 30-day morbidity–mortality rates

† Defined as the resolution of soft tissue wounds without a requirement for major amputation; * defined as patients being discharged home to live independently, with no new arrangements for domiciliary care. ISS, Injury Severity Scores; TBI, traumatic brain injury.

system comprised two large hospital systems, including one level 1 trauma centre and four level 2 centres. Functional Independence Measure (FIM) scores were obtained only from patients admitted to the regional TBI rehabilitation unit, both at admission and discharge. The authors reported similar FIM scores to the rehabilitation unit before and after the implementation of their trauma system.

The other identified study evaluated the impact of the implementation of a trauma centre establishment in Ulsan, South Korea in 2015 on all severe trauma patients (Injury Severity Scores (ISS) > 15) with a TBI.²⁵ Minimal details were given regarding the surrounding trauma system and only single centre data were reported. Glasgow Outcome Scale (GOS) classification was recorded at 3 months after the traumatic event and the authors reported no significant difference from before to after centre establishment based on GOS classifications.

DISCUSSION

Extensive evidence has shown that the implementation of a trauma system in a country or region can confer significant improvements to mortality outcomes.^{13–15} However, while often assumed to be the case, concurrent improvements to morbidity outcomes or cost-effectiveness do not necessarily go hand-in-hand with this. Our systematic review demonstrates a sparsity of high-quality evidence assessing the impact that trauma systems can have on these measures, despite a growing number of countries adopting trauma systems into their healthcare policy. Importantly, at present, the level of evidence suggesting any improvement to morbidity or cost-effectiveness outcomes with trauma system implementation is of poor quality. Indeed, the studies that were identified through our systematic review provide a mixed picture on trauma system implementation, with certain studies suggesting potential benefit, while others demonstrating no such advantage.

Assessing the impact of morbidity following trauma is a complex area, whether through assessing return to work rates or via disability prevalence. Previous work from the USA has shown trauma centre treatment improves the 3-month postinjury return to work rate,²⁹ but such data are derived from a HIC setting, where pre-existing healthcare services are often sufficient in rehabilitation and care capacity to cope with increased survival numbers. Through our systematic review, we only identified two papers that analysed the impact of quality of life after trauma system implementation;^{23,27} Metcalfe *et al* demonstrated that the implementation of a regional trauma system in the UK led to a higher proportion of patients being discharged home to live independently without any new arrangements for domiciliary care,²⁷ while Gabbe *et al* reported that the implementation of a trauma system resulted in a 28% reduction in DALY following traumatic injury.²³ As an example, however, within this latter study, the authors also reported that while there was a 43% reduction in YLLs, there was also a 32% increase in YLD. Similar conclusions of reducing YLLs with increasing YLDs have been identified from recent Global Burden of Disease studies within trauma.³⁰ We reason that while an increase in YLDs may be acceptable to a healthcare system that has the capacity to support the increased rehabilitation costs and care requirements, for those with little or no such infrastructure, such a disability might prove economically challenging, bringing with it far-reaching societal challenges. Moreover, there are often cultural elements to the acceptability of long-term disability and increased care requirements that is highly context specific. Unfortunately, however, at present there is no primary data to support this.

Table 2 Risk of bias assessment, using ROBINS-I tool

Study	Confounding	Selection of participants into the study	Classification of interventions	Deviations from intended interventions	Missing data	Measurement of outcome	Selection of the reported result	Overall
Abernathy III <i>et al</i> ²²	M	L	L	L	NI	L	S	S
Gabbe <i>et al</i> ²³	S	L	L	L	M	L	S	S
Kim J <i>et al</i> 2019	S	L	S	L	NI	S	S	S
Kelly <i>et al</i> ²⁴	S	L	L	L	M	L	S	S
Kim M <i>et al</i> ²⁶	S	L	L	L	NI	L	S	S
Metcalfe <i>et al</i> ²⁷	S	L	S	L	L	L	S	S
Vasse <i>et al</i> ²⁸	S	L	L	L	L	L	M	S

C, critical risk; L, low risk; M, moderate risk; NI, no information; S, severe risk.

While we do not question the direct effect trauma systems can have on mortality, we speculate that improved survival may confer increased rates of disability and a secondary trauma burden. In resource-poor countries, this might be an important cultural or financial consideration when deciding whether, or how, to implement trauma systems. Indeed, having an intervention that improves mortality with worsening morbidity is not unfamiliar territory in many aspects of trauma care. The RESCUEicp study, published in the *New England Journal of Medicine*, compared the use of decompressive craniectomy versus ongoing medical care for patients with a TBI and elevated intracranial pressure;³¹ the study demonstrated that while there were indeed lower mortality rates with decompressive craniectomy, concomitant higher rates of vegetative state and severe disability were also observed, both at 6 months and 2 years.^{31 32} Indeed, from our systematic review, the two TBI-related papers we identified showed no significant benefit in morbidity outcomes with the implementation of a trauma system.^{24 25} If lives saved also lead to an increased public and economic burden, such detail and data must be considered by any government or health ministry prior to a trauma system being implemented.

The cost-effectiveness of trauma system development does not solely relate to costs of in-hospital care, but those of ongoing rehabilitation and a delayed return to work. We identified only two studies that assessed the impact of trauma systems from a health economics aspect, with one study addressing in-hospital costs²² and one addressing the cost-per-DALY achieved.²³ Both studies reported benefits in their respective cost-effectiveness outcomes, yet these studies were also based on HICs, which arguably does not accurately reflect the impact traumatic injuries may have in terms of DALY in an LMIC setting. Indeed, previous studies on the cost-effectiveness of trauma centres have predominantly been in HICs.^{33 34} We would further argue that the cost-per-DALY is also a context-specific outcome metric.

Our findings come with limitations. The small number of studies identified were of poor quality, with a severe risk of bias in all studies with many likely to be underpowered (as the primary outcome was often not morbidity-related). This supports our position that higher quality studies on trauma system implementation are required, exploring a range of outcomes beyond mortality. There was a high level of heterogeneity in the included studies' designs and inconsistent outcome measures, including one study with a poorly described combined morbidity–mortality outcome measure;²⁸ this had been provisionally expected and was accounted for in our protocol,¹⁷ and as such a prospective plan for a narrative review, rather than any meta-analyses, was opted for. The way by which a trauma system was defined did vary significantly between papers, some in keeping with a 'hard'

system design while others describing a more 'soft' system; as a pragmatic approach, we kept our inclusion criteria broad and both were included. Finally, despite being planned for in our study protocol, a lack of available studies meant we were unable to report any specific paediatric data or study data from LMIC regions, emphasising the need for focused trauma research within these areas and highlighting the current caution that must be taken prior to implementing any trauma system.

As early as 2004, a formal review by the US Agency for Healthcare Research and Quality regarding the regionalisation of trauma care in the US concluded that 'formalised protocols for prehospital and hospital care contribute to improved patient outcomes'.³⁵ However, these conclusions were driven by survival figures and in-hospital costs from the USA, not by specific global morbidity or economic outcome measures. Subsequent recommendations from multiple trauma groups worldwide on trauma system implementation have made similar recommendations based on mortality metrics only. As more and more countries aim to develop formalised trauma systems, a better understanding of the morbidity, economic impacts and associated strains to rehabilitation and healthcare services is required.

Conclusion

There is a lack of high-quality data that have accurately assessed the impact the implementation of trauma systems has on morbidity, quality of life and economic outcomes, and current studies on the topic paint a mixed picture on their benefit. While we believe that trauma systems do have a fundamental role to play in high-quality trauma care, care also needs to be taken to understand the sociocultural and political context of their surrounding healthcare infrastructure. We propose that a range of further research is required, both in terms of assessing benefit from existing trauma systems and in the methodological basis for rationally designing and implementing context-specific trauma systems, particularly in resource-poor and fragile settings.

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Supplementary Material

Literature Search Terms for Medline

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions <1946 to August 30, 2022>

- 1 - ("quality of life" or qualy or "quality adjusted life" or "burden of disease" or "disability adjusted life year" or "disability-adjusted life year" or DALY).ti,ab.
- 2 - ("economic burden" or "burden on the state" or "economic productivity" or "earning potential" or "cost of injur*" or employment or employed or income or welfare or poverty or socioeconomic or unemployed or unemployment or job loss or redundan* or "return to work" or value of life or life valuation*).ti,ab.
- 3 - (Morbidity or co-morbid* or comorbid*).ti,ab.
- 4 - (sf36 or "sf 36" or sf6 or "sf 6" or sf12 or "sf 12" or "sf 16" or sf16 or sf20 or "sf 20").ti,ab.
- 5 - ("burden of disease" or wellbeing or well being or health status or health state* or health level* or "functional outcome*" or "recovery period").ti,ab.
- 6 - (long term outcome* or longterm outcome* or (duration adj3 recovery)).ti,ab.
- 7 - exp "Cost of Illness"/ or exp "Quality of Life"/ or exp "Value of Life"/ or quality-adjusted life years/ or exp health status/ or employment/ or unemployment/ or social welfare/ or poverty/ or social class/ or morbidity/
- 8 - or/1-7
- 9 - (trauma adj (service* or centre* or center* or system* or pathway*)).ti,ab.
- 10 - exp Trauma Centers/
- 11 - or/9-10
- 12 - 8 and 11
- 13 - limit 12 to yr="2000 -Current"

Table A1 - Synthesis Without Meta-analysis (SWiM) reporting items

SWiM is intended to complement and be used as an extension to PRISMA			
SWiM reporting item	Item description	Page in manuscript where item is reported	Other*
<i>Methods</i>			
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g., groupings of populations, interventions, outcomes, study design)	4	
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	N/A	
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	4-6	
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	3	
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g., based on study design, risk of bias assessments, directness in relation to the review question)	2	

SWiM reporting item	Item description	Page in manuscript where item is reported	Other*
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	3	
6 Certainty of evidence	Describe the methods used to assess certainty of the synthesis findings	4-6	
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g., tables, forest plots, harvest plots). Specify key study characteristics (e.g., study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included	4	
<i>Results</i>			
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings, and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	4-6	
<i>Discussion</i>			
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis, and how these affect the conclusions that can be drawn in relation to the original review question	7-8	