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REVIEW

Leading Indicators for Farmers' Work Health and Safety in Western Agricultural Systems: A Systematic Review

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ABSTRACT

Introduction: Identifying and utilizing valid and reliable farm safety leading indicators will help to ensure farmers' well-being, safety and personal health, as well as the sustainability and the productivity of agricultural operations. This paper aimed to summarise the literature on valid and reliable safety indicators, focused on leading (preventive) metrics, for farmers' health and safety.

Methods: All studies on the agricultural population with objective and measurable leading indicators for farmers' health and safety were included. Systematic reviews and original quantitative research studies were included. Five databases were searched: Medline, Scopus, Web of Science, Informit and Google Scholar. Two independent reviewers then conducted the full-text screening in Covidence. An analysis was performed to identify and summarise agricultural safety indicators.

Results: Four studies were included in the review with a total of 71 leading indicators focused on dairy ($n = 2$), poultry ($n = 1$) and aquaculture ($n = 1$). Two studies reported the same set of indicators. Two studies reported content and face validity but no further assessments of validity. None of the studies reported reliability assessments. Two studies found evidence of association between injury and illness and the lead indicators reported.

Discussion: Further studies focusing on leading indicators for agriculture are required and need to have robust reporting on their validity and reliability to guarantee research quality and efficacy. It is recommended to have a set of leading indicators for agriculture, noting that there should be a manageable number. This study provides valuable insights and serves as a foundation for future research and guidance.

KEYWORDS

Rural; farm; agriculture; occupational health; safety management; workplace

Introduction

Agriculture is one of the most hazardous industries globally, with farmers facing numerous health and safety risks daily.[1] Ensuring the well-being of farmers is crucial not only for their personal health, but also for the sustainability (social, economic and environmental) and productivity of agricultural operations.[2] To effectively manage and mitigate these risks, it is essential to identify and utilize high quality farm safety indicators.[3] These indicators can be categorized into leading (preventive action to reduce the likelihood of an incident) and lagging metrics (measuring past events), each serving a unique purpose in the overall safety management system.[4] Furthermore, the relationship between leading and lagging indicators is complex and not as straightforward as previously assumed.[5] This is further complicated by efforts to discern safety climate and culture.[5]

Leading indicators can help identify potential hazards in farming activities, such as machinery maintenance schedules and safety training for handling chemicals. Due to their focus on preventive action, leading indicators provide critical information to potentially reduce the burden of injury. However, to date, there has been limited attention on developing and assessing leading indicators within agriculture. Published systematic reviews of safety indicators in industries outside of agriculture have focused on construction,[6] utility industries,[7] plus occupational health and safety in general.[8] Overall, there is a lack of standardisation and consensus on the definition and categorisation of leading indicators.

Research quality is a factor that is widely recognised as essential in developing robust indicators.[9]

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Central to research quality are the principles of attaining valid and reliable data to inform subsequent interventions.[10] In general terms, validity refers to measuring what is intended to be measured. There are several types of validity, including content validity (which includes face validity), construct validity (which includes convergent, divergent, factorial and discriminant validity), and criterion validity (which includes concurrent and predictive validity).[11] In contrast, reliability focuses on how reproducible results are under the same conditions (e.g., consistency or error measurement).[11] There are also several types of reliability assessments including inter-rater reliability, test–retest reliability and inter-item reliability for internal consistency.[11] The importance of having valid and reliable measures is well-documented across a range of areas. For example, significant investment in injury prevention, predominantly involving lag indicators, has been undertaken on road trauma,[12] home safety,[13,14] and concerning work health and safety (WHS) across all industries.[3,8]

The research quality and use of valid and reliable leading indicators for health and safety within the agricultural industry are poorly defined.[5] Earlier work, which included assessing leading indicators, has undertaken validity (face/content) and reliability (internal consistency, inter-rater, and test-retest) measures.[15,16] However, these publications are now dated (~15 years), and no known contemporaneous information focuses on leading indicators in agriculture. Consequently, the quality of research in this area requires further development. This paper aimed to examine the literature on leading safety indicators within agriculture and the extent to which they have been assessed for validity and reliability to provide a robust platform for future preventive intervention work.

Methods

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guided the development of this paper.[17] The eligibility criteria included studies focused on the agricultural population (farm owners, workers and farm residents) and concepts of leading safety indicators for farmers' health and safety. We included systematic reviews and original research studies that were quantitative in nature. To be eligible for inclusion, a study had to report the method for developing leading indicators (e.g., panel of experts or Delphi method, literature review, surveys and questionnaires, or workshops). Additionally, the indicators had to be reported in the form of quantifiable and objective measures, actions or context-specific metrics.[4] Studies reporting on subjective measures such as attitudes and perceptions that employees have about safety in their organisation were excluded (e.g., safety climate). We excluded non-English papers and papers from Asia, Africa and South America due to the differences in agricultural production processes.[18] We excluded abstracts, reports, presentations and papers where full text was not available.

Leading indicators were defined as proactive, preventive and predictive measures that examine and provide real-time information about the performance, activities and processes related to farm health and safety (e.g., percentage of machines guarded, number of corrective actions completed, number of inspections or percentage of sites inspected, etc). These indicators help identify and control workplace risks, thereby preventing incidents and injuries.[4,19]

The search strategy was developed in consultation with a librarian from the Western NSW Local Health District and undertaken in accordance with PRISMA.[17] Five databases were searched including Medline, Scopus, Web of Science, Informit and Google Scholar. The search terms were –("farm" OR "agriculture" OR "occupational health" OR "safety management" AND "workplace" (Appendix 1).

The results were limited to studies published in 2015 or later. The search was undertaken on 15 and October 16, 2024 and covers studies published from January 1, 2015 to October 16, 2024.

Covidence (literature review support software), was used to screen the studies. The automatic function in Covidence to assess and remove duplicates was utilised, followed by a manual screening to verify removal. One independent reviewer (CMC) completed the screening of titles and abstracts. Two independent reviewers then conducted the full-text screening (CMC and TL). Disagreements on text inclusion were resolved by

consensus. One reviewer (CMC), performed independent data extraction from the selected studies including the following information: title, journal, lead author contact details, the country in which the study was conducted, the aim of the study, study design, publication date, organisation, study funding sources, conflicts of interest for study authors, agricultural industry, total sample size, name and measuring of the leading indicators, context of evidence of the leading indicators and reporting on their validity and reliability. Before data charting, a pilot test was conducted on a random sample of two publications by both reviewers independently. This assessed any variations in coding between the reviewers and necessary amendments were made.

Regarding data analysis and synthesis, an analysis was conducted to identify and extract the leading agricultural indicators from the included papers and their validity and reliability. The definitions of validity (measures what it purports to measure) and reliability (is consistent over time) within each of the included studies, were contrasted against those reported by Bannigan and Watson 2009[11] and Karnia 2024.[10] This includes issues pertaining to reliability (internal consistency, test-retest) and validity (face, content, criterion, concurrent, predictive and construct). Results were then synthesised and presented in narrative form with tables.

The extracted data were analysed and tabulated to search for recurring categories or topics. Broad categories were developed using inductive and deductive analysis. The output was analysed and discussed in consultation with the research team.

Results

The initial search resulted in 5472 studies; of these, 274 were screened in full text and 270 excluded. The most common reason for exclusion was that studies assessed the wrong outcomes (64%) e.g. retrospectively examined what had led to injury or subjective measures. Four studies were included in the review (Figure 1).

The characteristics of the included studies are reported in Table 1. Of the four studies included, two were conducted in the United States, one in Ireland and one in Norway. Three studies were cross-sectional, with one being a mixed methods design. Two focused on dairy, one on poultry and one on fish farming.

Table 2 shows the summary of leading indicators for farmers' work health and safety, with Appendices 2 and 3 including more information for each measure including indicator's name, number of indicators per study, process development, validity, reliability and results. Regarding the leading indicators for farmers' Work Health and Safety (WHS), three studies reported that their indicators were developed and endorsed by experts in the field.[20–22] The remaining study focused on aquaculture and was developed through interviews and workshops.[23] Two studies reported the same tool measure, which was applied to different agricultural industries (dairy and poultry), in the United States of America.[20,21] Two studies reported content and face validity.[22,23] Hogan et al. (2024) reported their survey indicators were validated with six farmers to determine their feasibility and comprehensiveness, with appropriate alterations made where required before distribution.[22] Holen et al. (2018) reported that as part of the validation process, the proposed indicators were discussed with health, safety, environment and quality managers.[23] None of the included studies reported on the reliability of the leading indicators.

Table 3 presents the extracted leading indicators by study and described in six broad categories: hazard identification and analysis ($n = 15$ indicators), safety and health programs and policies ($n = 15$ indicators), training and competence ($n = 11$ indicators), management and leadership ($n = 10$ indicators), employee involvement ($n = 9$ indicators), and operational metrics ($n = 11$ indicators).

Discussion

This systematic review of the literature aimed to examine the extent to which leading indicators for farmers' health and safety have been assessed for validity and reliability. Importantly, such indicators have potential to be utilised to provide a robust platform for future preventive intervention work. The main finding is that while some efforts have been made to validate indicators, no work has been done to assess reliability. Without

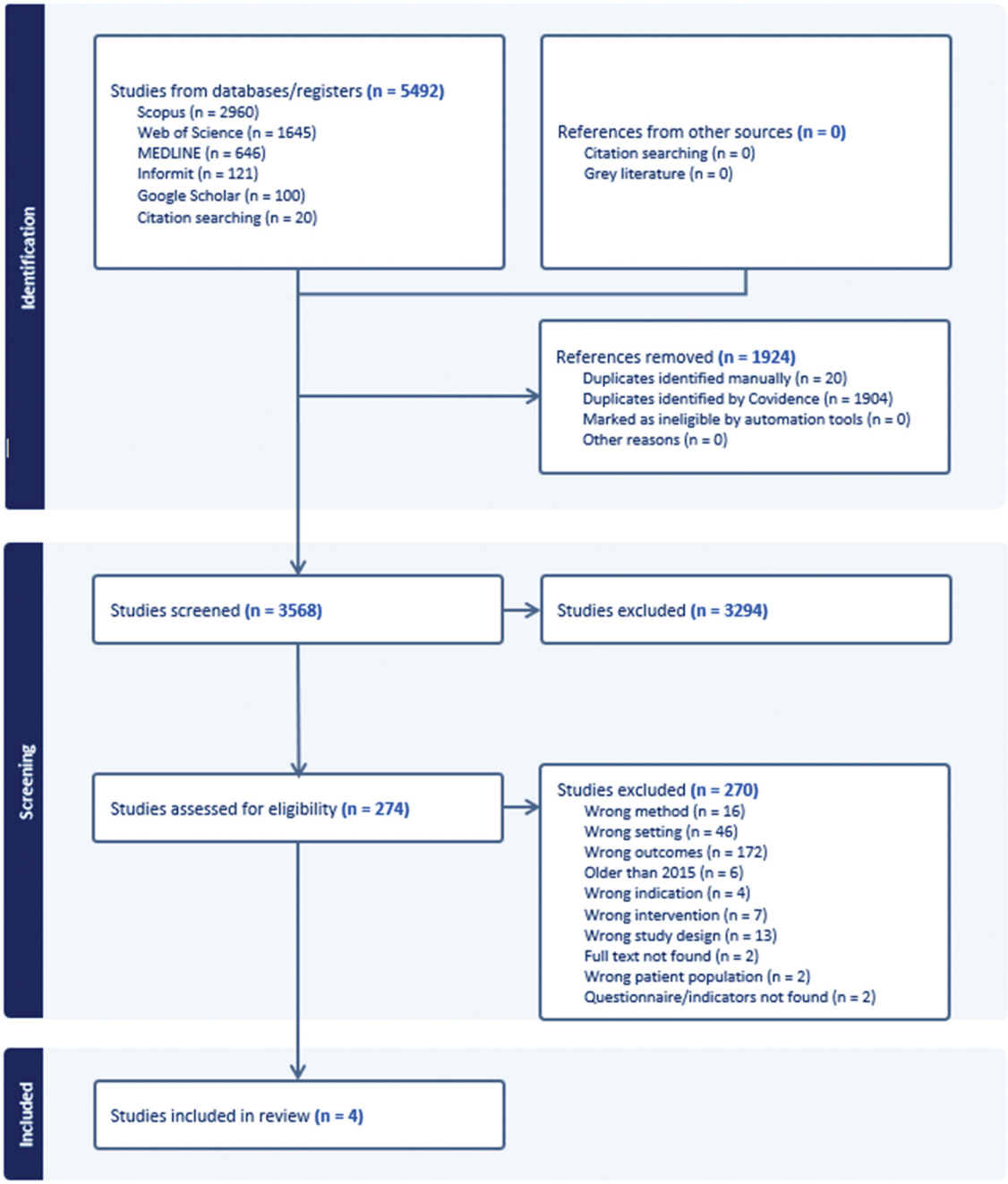

Figure 1. Prisma of identification and screening process.

further assessment of their reliability, this calls into question the use of these instruments as a tool to monitor leading indicators.

The four studies reported 71 leading indicators for agriculture. Of these, 61 indicators focused on the dairy industry, 10 on poultry and 10 on the aquaculture industry (note that some indicators overlap across industries). Only two of the studies reported on validity (face),[22,23] which is at the lower end of the hierarchy in terms of assessing validity rigour.[10] Meanwhile, none assessed reliability. Consequently, there is a need to improve the quality and development of leading indicators for WHS in agriculture.

Autenrieth 2016a[21] and 2016b[20] studies incorporated the revised Occupational Safety and Health Administration OSHA form 33. The OSHA form 33 is reported to be consistent with many national and international consensus standards.[25] It includes 58 questions and was

Table 1. Characteristics of the studies included.

#	Study ID	Title	Aim	Country in which the study conducted	Study design	Agricultural industry	Total sample size	Farm health and safety outcome type
1	Autenrieth 2016[20]	The associations between occupational health and safety management system programming level and prior injury and illness rates in the U.S. dairy industry	To determine if occupational health and safety management System (OHSMS) programming is associated with lower injury rates for dairy workers, and if so, what components and attributes of an OHSMS are more likely to help prevent injuries and illness in the U.S. dairy industry.	United States	Cross-sectional study	Dairy	45 dairy cattle and milk production industry records	Components associated with reduced injury and illness
2	Autenrieth 2016[21]	Comparing Occupational Health and Safety Management System Programming with Injury Rates in Poultry Production	To determine if OHSMS programming is associated with lower injury rates for poultry production.	United States	Cross-sectional study	Poultry	32 poultry industry records	Components associated with reduced injury and illness
3	Hogan 2024[22]	The factors contributing to better workplaces for farmers on pasture-based dairy farms	To examine the factors influencing specified metrics of farmer workplaces using a survey of representative pasture-based dairy farms in Ireland.	Ireland	Cross sectional study	Dairy	313 farmers	Lead indicators of farmer workplace effectiveness
4	Holen 2018[23]	A Framework Based on a Systems Approach to Developing Safety Indicators in Fish Farming	(i) To establish a framework based on a systems thinking approach that can be used for developing safety indicators for sea-based Atlantic salmon fish farming, and (ii) to demonstrate the framework and identify relevant safety indicators.	Norway	Mixed methods	Aquaculture	Six participants (Three fish farm managers, one former fish farm manager, and two subcontractor managers)	Lead indicators of farmer safety

endorsed by the Department of Labor of the United States of America in 1988,[24] and it was updated in May 2022.[25] Both studies show evidence of association between components of the indicators and injury and illness in agriculture, specifically in the dairy and poultry industries.[20,21]

Hogan et al (2024) focused on farmer workplace effectiveness in the pasture-based dairy industry and reported three indicators that were characteristic of effective work organisation for dairy farms.[22] The indicators include 1. Hours worked per week; 2. Days of holidays per year; and Finish time in the spring. Health and safety was not the main focus of their indicators. However, the authors opined that their indicators lead to significant improvements in farm social sustainability metrics, such as lowering workload stress, enhancing health and safety, boosting the quality of life for farm operators, making farm workplaces more appealing, and increasing farm financial performance.[22] Further work to assess the generalisability of these results in an agricultural context is required and to verify that they do indeed have WHS benefits.

Holen et al (2018) reported 13 safety indicators in fish farming, which were the result of a case series analysis of interviews with six fish farmers.[23] Overall, the proposed indicator set serves as a tool for identifying safety issues and has potential to be used as the basis for decisions and actions that must be undertaken to ensure safe operations on fish farms. Ten of the 13 indicators were recommended for future implementation studies. However, it must be noted that the small sample size used within this study, has implications in relation to the

Table 2. Summary of methods and results of leading indicators for farmers' work health and safety.

Study	Name of indicators set	Number of indicators	Indicator's development	Indicators' validity	Indicators' reliability	Results
Autenrieth 2016[20]	Occupational Safety and Health Administration – OSHA form 33	58	Endorsed by individuals, corporations, professional associations, and labor representatives who responded to the Occupational Safety and Health Administration (OSHA). Department of Labor request for comments and information. 53 FR 26,790, published on July 15, 1988.[24] The OSHA Form 33 was updated in May 2022.[25]	Not reported	Not reported	The overall score has a moderate association with injury and illness rates in the dairy industry
Autenrieth 2016[21]	Occupational Safety and Health Administration – OSHA form 33	10	Endorsed by individuals, corporations, professional associations, and labor representatives who responded to the Occupational Safety and Health Administration (OSHA). Department of Labor request for comments and information. 53 FR 26,790, published on July 15, 1988.[24] The OSHA Form 33 was updated in May 2022.[25]	Not reported	Not reported	Ten attributes (indicators) were found with the strongest relationship between higher programming levels and lower injury rates in the poultry industry
Hogan 2024[22]	Work organisation effectiveness	3	Identified by previous studies[26,27] and based on the knowledge of researchers based at Teagasc Moorepark Animal and Grassland Research and Innovation Centre, County Cork, Ireland.[28]	Content and Face	Not reported	Results highlighted that farmer workload, farm facilities, adopted labor-efficient and human resource management practices, as well as farmer attitudes toward their farm work-life balance, influenced making the farm a better workplace in the dairy industry
Holen 2018[23]	Safety indicators in fish farming	10	Interviews with three fish farm managers, one former fish farm manager, and two subcontractor managers. In addition, one author participated in a two-day workshop where a large part was group work discussing hazardous operations. After the workshop a joint interview with two fish farm managers was conducted.	Content and Face	Not reported	The indicators set was found to be promising as a tool to communicate safety issues both to higher-level management and to operators working on the fish farms.

external validity of the findings and hence, should be treated with caution.

Overall, the indicators were grouped into six categories including hazard identification and analysis, safety and health programs and policies, training and competence, management and leadership, employee involvement, and operational metrics (Table 3). These categories align with the overall guidance and direction within the Australian WHS Regulations and also other noted health and safety frameworks including the International Standard for Occupational Health and Safety Management Systems (ISO 45001).[29,30]

Strengths and limitations

This is the first review specifically focusing on the use of leading indicators and their validity and reliability for agriculture. The intent is to provide an opportunity to be more proactive to prevent future events. However, this research has limitations that may affect the generalisability of its findings. The study is constrained by the limited number of databases reviewed, which may have excluded relevant findings from other sources, potentially introducing bias. The tightly focused inclusion criteria, will have also excluded papers

Table 3. Leading indicators for farmer's health and safety.

Broad category	Leading indicators	Study name
Hazard identification and analysis	1. Comprehensive baseline hazard survey	Autenrieth 2016[20,21]
	2. Effective safety and health self-inspections	
	3. Effective surveillance of established hazard controls	
	4. Effective hazard reporting system	
	5. Change analysis is performed whenever a change in facilities, equipment, materials, or processes occurs	
	6. Accidents are investigated for root cause	
	7. Material Safety Data Sheets are used to reveal potential hazards associated with chemical products in the workplace	
	8. Effective job hazard analysis is performed	
	9. Expert hazard analysis is performed	
	10. Incidents are investigated for root causes	
	11. Feasible engineering controls are in place	
	12. Effective preventive maintenance is performed	
	13. An effective procedure for tracking hazard correction is in place	
	14. Workplace injury/illness data are effectively analysed	
	15. Hazard incidence data are effectively analysed	
Safety and health programs and policies	16. Effective safety and health rules and work practices are in place.	Autenrieth 2016[20,21]
	17. Applicable OSHA-mandated programs are effectively in place.	
	18. Personal protective equipment is effectively used.	
	19. Housekeeping is properly maintained.	
	20. The organisation is properly prepared for emergency situations.	
	21. The organisation has an effective plan for providing competent emergency medical care to employees and others present at the site.	
	22. A safety and health goal and supporting objectives exist.	
	23. An action plan designed to accomplish the organisation's safety and health objectives is in place.	
	24. A review of in-place OSHA-mandated programs is conducted at least annually.	
	25. A review of the overall safety and health management system is conducted at least annually.	
	26. Safety and health program tasks are each specifically assigned to a person or position for performance or coordination.	
	27. Each assignment of safety and health responsibility is clearly communicated.	
	28. An accountability mechanism is included with each assignment of safety and health responsibility.	
	29. Organisational policies promote the performance of safety and health responsibilities.	
	30. Organisational policies result in correction of non-performance of safety and health responsibilities.	
Training and competence	31. Individuals with assigned safety and health responsibilities have the necessary knowledge, skills, and timely information to perform their duties.	Autenrieth 2016[20,21]
	32. Individuals with assigned safety and health responsibilities have the authority to perform their duties.	
	33. Individuals with assigned safety and health responsibilities have the resources to perform their duties.	
	34. Employees receive appropriate safety and health training.	
	35. New employee orientation includes applicable safety and health information.	
	36. Supervisors receive appropriate safety and health training.	
	37. Supervisors receive training that covers the supervisory aspects of their safety and health responsibilities.	
	38. Safety and health training is provided to managers.	
	39. Relevant safety and health aspects are integrated into management training.	
	40. Ratio of personnel with individual training program	Holen 2018[23]
	41. Ratio of operations where untrained operators participate.	
Management and leadership	42. Top-management policy establishes clear priority for safety and health.	Autenrieth 2016[20,21]
	43. Top management considers safety and health to be a line rather than a staff function.	
	44. Top management provides competent safety and health staff support to line managers and supervisors.	
	45. Managers personally follow safety and health rules.	
	46. Managers delegate the authority necessary for personnel to carry out their assigned safety and health responsibilities effectively.	
	47. Managers allocate the resources needed to properly support the organisation's safety and health system.	
	48. Managers assure that appropriate safety and health training is provided.	

(*Continued*)

Table 3. (Continued).

Broad category	Leading indicators	Study name
	49. Managers support fair and effective policies that promote safety and health performance.	
	50. Top management is involved in the planning and evaluation of safety and health performance.	
	51. Top management values employee involvement and participation in safety and health issues.	
Employee involvement	52. There is an effective process to involve employees in safety and health issues.	Autenrieth 2016[20,21]
	53. Employees are involved in organisational decision making in regard to safety and health policy.	
	54. Employees are involved in organisational decision making in regard to the allocation of safety and health resources.	
	55. Employees are involved in organisational decision making in regard to safety and health training.	
	56. Employees participate in hazard detection activities.	
	57. Employees participate in hazard prevention and control activities.	
	58. Employees participate in the safety and health training of co-workers.	
	59. Employees participate in safety and health planning	
	60. Employees participate in the evaluation of safety and health performance.	
Operational metrics	61. Hours worked per week	Hogan 2024[22]
	62. Days of holidays per year	
	63. Finish time in the spring	
	64. Ratio of planned maintenance task on critical equipment not performed (backlog).	Holen 2018[23]
	65. Number of incidents in operations caused by harsh weather	
	66. The share of operations with subcontractors exceeding the planned time.	
	67. The number of overtime hours in operations.	
	68. The ratio of operations where subcontractors participate in Safe Job Analysis.	
	69. The ratio of Fish Farm Managers responsible for Safe Job Analysis with training.	
	70. Ratio of subcontractors who participate in emergency preparedness exercises of critical operations.	
	71. The ratio of safety critical operations where debriefing meetings are held.	

from other areas e.g. safety climate and behavioural surveys etc. This was an intentional direction of this review, with a focus on high quality leading indicators. Additionally, most of the screened studies were mainly at the concept and theoretical stage, with little to no evidence of practical assessment. Furthermore, the sample sizes in each of the studies with the exception of that by Hogan (2024), were small and may have influenced the findings and their real-world application. Also, it only includes published studies from 2015 onwards. Despite these limitations, the study provides valuable insights and serves as a foundation for future research and guidance.

Recommendation

The ISO 45001 is a key international framework built on data across all industries and may offer evidence-based guidance to develop valid and reliable lead indicators.[29] Importantly, ISO 45001 also articulates almost seamlessly with requirements under the national WHS Regulations in Australia.[30] Core components of ISO 45001 that may also guide the development of lead indicators are: 1. leadership commitment; 2. worker participation; 3. hazard identification and risk assessment 4; legal and regulatory compliance; 5. emergency planning, 6. incident investigation and, 7. continual improvement. These are all factors that are well recognised internationally across the work safety field.

Others have noted the need for increased rigor and simplicity in using leading indicators for small family-owned businesses.[23] Given the extensive owner-operator status in Australian agriculture (~95%),[31,32] it is recommended to have a manageable number of leading indicators.[23] Indicators assessing safety culture or climate are complex and generally may not suit small businesses.[33,34] Further, to be effective in reducing injury, leading indicators need to be objectively measurable and comply with WHS requirements.

Conclusion

In conclusion, this systematic review reported 71 leading indicators for farmers' health and safety. Of these, only 12 indicators included the

assessment of validity (content and face validity), meanwhile, none assessed reliability. Further studies focusing on leading indicators for agriculture require robust reporting on the validity and reliability of indicators to guarantee research quality. This must be balanced with the operational context and capacity to utilise indicators for the predominantly small family farms across Australia.

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Author contribution statement

Carlos Mesa-Castrillon: conceptualisation, methodology, qualitative analysis, writing – original draft, writing – review & editing, project administration.

Kerri-Lynn Peachey: conceptualisation, methodology, writing – review & editing

Lisa Harrison: writing – review & editing

Richard Franklin: conceptualisation, methodology, writing – review & editing

David Lyle: conceptualisation, methodology, writing – original draft, writing – review & editing

Tony Lower: conceptualisation, methodology, qualitative analysis, writing – original draft, writing – review & editing

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