

Review

Occupational Hazards, Risks and Preventive Measures in Forestry Logging: A Scoping Review of Published Evidence (2015–2025)

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Abstract

Forestry logging is among the most hazardous economic activities, so identifying where hazards and risks concentrate supports targeted prevention. This scoping review mapped evidence on logging hazards and risks, their co-occurrence with operations, and preventive measures. PRISMA-ScR was followed. Only peer-reviewed journal articles (2015–2025) in English on occupational hazards/risks, risk-assessment methods or preventive measures in logging were included, found in Scopus, Web of Science, Inspec and Dimensions (last search 15 September 2025). Independent data screening and extraction were performed by two reviewers, with a third reviewer resolving any disagreements. No formal risk-of-bias appraisal was conducted. Forty-two studies were included. Hazards and risks concentrated in three phases—chainsaw/manual cutting, skidding/cable yarding, and loading/short-haul transport—where acute injury mechanisms (struck-by events, slips/trips/falls, rollovers, lacerations) coexisted with chronic exposures (musculoskeletal strain, noise, vibration, diesel exhaust). Preventive measures emphasised engineering and organisational controls, complemented by training and PPE, but were inconsistently specified and evaluated. Evidence was heterogeneous and geographically concentrated in few countries, limiting generalisability. A small set of tasks consistently concentrates acute and chronic risks; prevention should integrate accident control and health protection, prioritising engineering/organisational measures supported by training and PPE. Future studies should standardise descriptors and outcome metrics to enable comparisons.

Keywords: forestry logging; work-related hazard; hazard mitigation; occupational risk; occupational safety



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1. Introduction

1.1. Background

Forestry logging is recognised as one of the most dangerous economic activities due to the combination of remote and dynamic work sites, steep terrain, unpredictable weather, and the interaction of workers, heavy logs, and mobile machinery [1].

Over the last decades, many operations have shifted from manual or motor-manual systems toward partially or fully mechanised systems. While mechanisation may reduce specific traumatic hazards, such as chainsaw-related injuries or manual handling of heavy loads, it also reshapes exposure profiles, with recurrent concerns about noise, hand-arm and

whole-body vibration, awkward postures, musculoskeletal strain and diesel exhaust [2]. According to FAOSTAT, global roundwood production has increased steadily since 2014 and is projected to continue rising, with the USA, the Russian Federation, China, Brazil and Canada among the leading producers [3].

The scholarly literature on logging safety and health is substantial but fragmented across disciplines (occupational safety, ergonomics, industrial engineering, public health) and logging systems (manual, motor-manual, cable yarding, cut-to-length, whole-tree). Studies vary widely in their definitions, descriptors, and outcome measures—from incident rates and injury typologies to exposure metrics for physical agents—hampering comparisons across settings and limiting the translation of findings into targeted prevention. Existing reviews tend to focus on specific risk domains (e.g., accident causation or a single exposure, such as noise or vibration), particular logging systems, or narrow geographies. Few syntheses map where hazards and risks co-occur along the logging workflow, such as felling, delimbing, processing, skidding/cable yarding, loading and short-haul transport, while also collating the preventive measures reported and how these are specified or evaluated.

1.2. Definitions and Scope

For this review, standard distinctions are adopted: hazard denotes a source or situation with potential to cause harm, whereas risk refers to the likelihood and severity of that harm given exposure. Tasks/operations are the discrete phases of logging (e.g., chain-saw/manual cutting, skidding/cable yarding, loading/short-haul transport), and logging systems include manual/motor-manual and partially or fully mechanised configurations. Given the heterogeneity of designs and metrics, a scoping review approach is appropriate for mapping concepts, characterising the body of evidence, and identifying gaps, rather than estimating pooled effects. Reporting follows PRISMA-ScR guidance [4] and aligns with PRISMA 2020 recommendations for transparent reporting [5].

1.3. Objectives and Review Questions

This scoping review aims to provide a task-centred map of hazards, risks and preventive measures in forestry logging. Specifically, it seeks to:

1. Identify which hazards and risks are reported in peer-reviewed studies on forestry logging (2015–2025);
2. Examine the co-occurrence of hazards/risks with specific tasks/operations and logging systems;
3. Synthesise the preventive measures reported (engineering, organisational, administrative, training and PPE) and how these are specified or evaluated;
4. Describe how the evidence is distributed by geography, study design and data sources, and identify gaps that limit comparability and implementation.

2. Materials and Methods

2.1. Reporting Guidelines and Protocol

This review was conducted in accordance with the PRISMA-ScR guidelines [4] and adhered to the updated PRISMA 2020 standards for transparent reporting. Before initiating the screening process, we developed a comprehensive protocol that outlined the objectives, eligibility criteria, sources of information, data-charting templates, and our planned approach for synthesis.

2.2. Eligibility Criteria

Studies were eligible if they were peer-reviewed journal articles published in English between 2015 and 2025 that addressed at least one of the following: (i) occupational hazards and risks in forestry logging; (ii) risk or exposure-assessment methods in logging operations; or (iii) preventive or mitigation measures (engineering, organisational/administrative, training or personal protective equipment). Studies focusing exclusively on environmental/ecological risks, non-peer-reviewed sources (e.g., reports, theses), non-English publications and studies unrelated to logging operations were excluded.

2.3. Information Sources, Search and Full Search Strategies

Evidence was sought in Scopus, Web of Science Core Collection, Inspec and Dimensions. Searches covered the period from inception to 15 September 2025. Citation chasing on included records and relevant reviews, as well as consultation with professional/authority websites, was used to identify additional peer-reviewed articles. Records were exported and deduplicated prior to screening.

To enhance reproducibility, draft database strings are provided below and should be verified prior to reuse. Field tags and filters reflect platform-specific syntax.

Scopus (TITLE-ABS-KEY): ("forestry" OR "forest*") AND ("logging" OR "harvest*") AND ("occupational" OR "work*") AND ("risk" OR "hazard" OR "injure*" OR "safety") AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")).

Web of Science (TS=): TS=((forestry OR forest*) AND (logging OR harvest*) AND (occupational OR work*) AND (risk OR hazard OR injure* OR safety)); Timespan: 2015–2025; Indexes: SCI-EXPANDED, SSCI, ESCI; Languages: English; Document Types: Article.

Inspec: ((forestry OR logging) AND (occupational OR worker OR safety) AND (risk OR hazard)) | Years: 2015–2025 | Language: English | Document Type: Article.

Dimensions: ("forestry" AND "logging" AND ("occupational" OR "worker") AND ("risk" OR "hazard" OR "safety")) | Years: 2015–2025 | Document Type: Article | Language: English.

2.4. Selection Process

Titles/abstracts and full texts were screened independently by two reviewers against the eligibility criteria. Disagreements were resolved by consensus or through a third-party review. No automation tools were used in the screening or selection process. Reasons for full-text exclusion were recorded and are summarised in the flow diagram.

2.5. Data Charting (Extraction) Process

A piloted data-charting form was used. Two reviewers independently charted data, with discrepancies reconciled through discussion and arbitration by a third reviewer when needed. Items captured included study identifiers, design/data sources, geography/setting, logging system (manual/motor-manual/partially or fully mechanised), tasks/operations, hazards, risks/outcomes, preventive measures and funding/conflicts of interest. Operations and tasks were defined as logging phase activities; when a study analysed the same worker cohorts performing on-site pre- or post-harvest tasks at the logging worksite, we coded these as "Nursery and afforestation", used here as shorthand for site preparation and planting on site. This does not include nursery plant production.

2.6. Data Items

Primary outcomes comprised acute injury outcomes (e.g., incident types/rates) and longer-term exposures or health outcomes (e.g., noise, hand-arm/whole-body vibra-

tion, postural load/musculoskeletal symptoms, diesel exhaust). Contextual variables included country/region, terrain/setting when available, workforce descriptors (e.g., role/experience), and details of logging systems and tasks. All items and operational definitions were specified a priori.

2.7. Critical Appraisal and Certainty of Evidence

Consistent with the scoping review methodology, a formal study-level risk-of-bias appraisal was not undertaken; the certainty of the evidence was not assessed. Findings are descriptive and should be interpreted with caution. No formal study-level risk-of-bias appraisal was undertaken, consistent with the scoping review's aim of mapping the evidence base rather than estimating the effects of interventions.

2.8. Synthesis Methods

Given heterogeneity in designs, measures and reporting, no meta-analysis was planned. A narrative synthesis was conducted, complemented by descriptive quantitative summaries. Co-occurrence matrices were constructed to map intersections between tasks/operations and hazards/risks, and results were structured by outcome domain.

2.9. Deviations from Protocol

No deviations from the pre-specified protocol were introduced during the review process.

All retrieved records were imported into Microsoft Excel for effective management and analysis. The selection workflow, which includes the stages of identification, screening, and inclusion, is summarised in Figure 1 (PRISMA-ScR flow diagram).

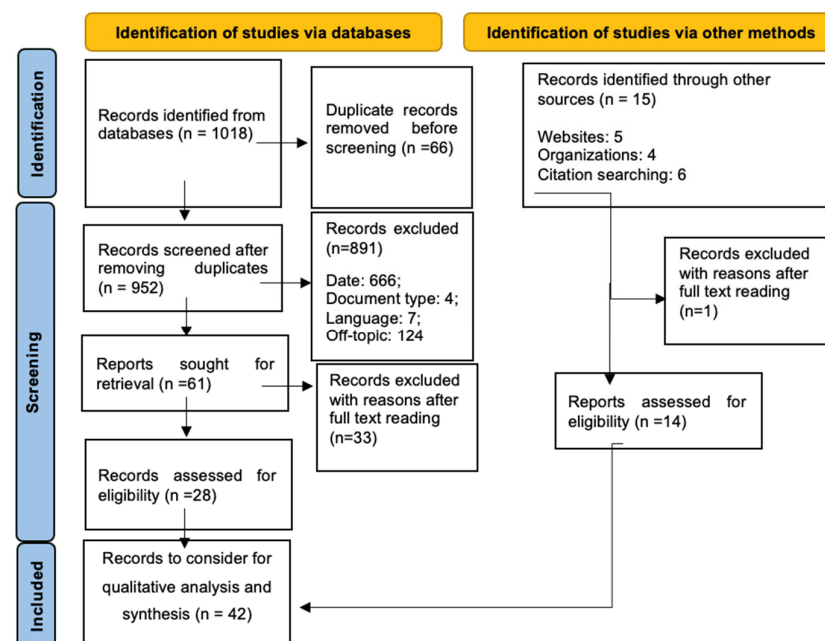


Figure 1. Systematic Scoping review flow diagram adapted from PRISMA [5].

For transparency, a coded version of the extraction sheet (including authors, country/setting, and four thematic domains: hazards, risks, operations/tasks, and preventive/protective measures) is provided in Table 1. Category labels are abbreviated (Hxx, Rxx, Oxx, Pxx) according to the coding framework developed for this review. The full descriptive dataset and codebook can be made available by the authors upon reasonable request.

Table 1. Summary of included forestry logging studies by country and coded safety-related variables.

Authors	Country	Hazards	Risks	Operations	Preventive Measures
[6]	C01	N/S	N/S	N/S	N/S
[7]	C02	H01; H08	R02; R09	O01	N/S
[8]	C03	H01; H09; H10	R10; R12; R13; R11	O01	N/S
[9]	C04	H07; H06; H08	R02; R09	O08; O07	P04; P07; P06; P19
[10]	C05	H02	R10	O06	N/S
[11]	C06	H01; H09; H10; H07	R10	O01; O02; O07	P15; P10
[12]	C06	H01	R10	O01; O03; O13; O12	N/S
[13]	C04	H01; H05; H07	R12	O01; O02; O07	P21; P25; P26; P27
[14]	C04	H09; H03; H04; H07; H08	R01; R02; R05; R08; R09	O05; O04; O03; O08; O14	P20; P19; P06; P12; P15
[15]	C07	N/S	R03; R04; R02; R08; R10	N/S	P06; P07; P09; P26; P27
[16]	C08	N/S	R08; R09	N/S	N/S
[17]	C03	H05; H07; H09; H10	R12; R13; R11; R14; R10	O02; O08; O09	P12; P13; P15; P16; P07; P09; P08; P21
[18]	C03	H01	R12; R13; R11; R15; R10	O01	P07; P09; P21; P25; P26; P27
[19]	C02	H01; H05; H07; H09; H10; H13; H12	R01; R02; R03; R04; R05; R08; R09; R10; R12; R13; R11; R14	O01; O02; O07; O08; O09; O14; O10; O11; O12	N/S
[20]		H01; H07; H09; H10	R10; R12; R13; R11; R14; R15	O01; O13	P07; P09; P15; P01
[21]	C04	H03; H05; H07; H06; H08; H10; H01	R01; R02; R03; R05; R08; R10; R14; R16	O08; O09; O01; O02; O07	P14; P10; P19; P07; P08; P09; P12
[22]	C04	N/S	N/S	N/S	N/S
[23]	C04	H01; H03; H04; H06; H09; H10	R03; R02; R01; R10; R16	O01; O05; O04; O07	P20; P19
[24]	C04	H01; H03; H04; H09; H10	R01; R02; R10; R16	O01; O08; O07	N/S
[25]	C09	H01; H03; H04; H10	R10; R13	O01; O05; O04	P20; P17; P15
[26]	C05	H01; H05; H07; H08; H09; H10; H13; H12	R01; R02; R03; R12; R13; R14; R15	O01; O02; O03; O07; O10; O14	N/S
[27]	C10	N/S	R16	N/S	P01; P13
[28]	C11	H01; H05; H06; H08; H10; H11	R01; R02; R08	O10; O01; O02; O07; O11; O14	P19; P12; P06; P03; P18; P05; P20; P07
[29]	C05	H01; H12	R12; R13; R15	O01	N/S
[30]	C06	N/S	R09; R08	N/S	P06; P07
[31]	C04	H06; H09; H10	R08; R09; R16	O07	P01; P13; P07
[32]	C04	H01; H07; H09; H08	R02; R01; R05; R03; R16	O01; O03; O08; O07	P14; P20; P10; P19; P03; P06
[33]	C12	H01; H09; H10	R01; R02	O01; O13; O11	P04; P07; P06; P03; P25; P26; P27
[34]	C13	H05; H09	R12	O02	N/S
[35]	C14; C05	H03; H04; H09; H10; H11	R12; R13	O05; O04; O08	P10; P15; P01
[36]	C04	N/S	R10; R11; R16	O08; O02; O07	P07; P13
[37]	C04	H01; H06; H08; H09	R02; R01; R11; R16	O01; O03; O07	P04; P07; P06
[38]	C11	H01; H07	R11; R12; R13	O01; O11	N/S
[39]	C05	H07; H08	R10	O08; O11; O09	P10; P15; P20
[40]	C15	H01; H05; H07; H08; H09; H10	R01; R02; R03; R04; R05; R08; R09	O01; O02; O03	P04; P07; P06; P21; P25; P26; P27
[41]	C04	N/S	N/S	N/S	N/S
[42]	C16	H01; H08	R10	O01; O13	N/S
[43]	C16	H01; H08; H10; H11; H09; H13; H12	R01; R02; R03; R09; R10; R12; R13; R11; R15; R14; R16	O01; O13; O09; O14	P04; P07; P19; P06; P12; P03; P18; P01; P13; P25; P26; P27
[44]	C16	H01; H05; H06; H07	R10; R16	O01; O02; O07; O12; O13	P07; P11; P21
[45]	C16	N/S	N/S	N/S	P04; P07; P06; P19; P21
[46]	C04	H07; H06; H09; H10	R01; R10; R16	O08; O07	N/S
[47]	C04	H07; H08	R02; R09	O01; O03; O08	P14; P03; P10

3. Results

3.1. Selection of Sources of Evidence

Following a more detailed reading, 33 articles were excluded due to their lack of relevance. In parallel, 15 additional articles were included through snowballing. These

articles are shown in the “additional records identified through other sources” box in Figure 1. A total of 42 studies met the inclusion criteria and were considered in the review. Reasons for full-text exclusion comprised wrong population or context, non-logging focus, non-peer-reviewed source and language other than English.

3.2. Study Characteristics

Characteristics of included studies are summarised in Table 1. Studies primarily reported hazards and risks within core logging operations, but varied in design, measures, and reporting detail. Geographic coverage was concentrated in a small number of countries with specific logging systems in place.

To keep the matrix compact, we use stable codes that map one-to-one to controlled vocabularies. Countries are coded as Cxx, following the order listed; for example, C01 for the USA, C02 for Italy, . . . , C30 for the UK. Hazards are Hxx in the stated order: H01 Hand-held cutting tools, H02 Steep slopes, H03 Uneven or slippery surfaces, H04 Unspecified machinery, H05 Logs, H06 Tractor or skidder, H07 Trucks short haul, H08 Harvester, H09 Forwarder, H10 Chemical agents, H11 Biological agents, H12 Vegetation or obstacles, H13 Wood chipper. Operations or tasks are Oxx in the stated order O01 Chainsaw or manual cutting felling and crosscutting, O02 Loading and transport including short haul driving, O03 Machine operation unspecified, O04 Skidding including planning, O05 Cable yarding, O06 Manual hauling, O07 Machine maintenance or repair including cleaning, O08 Walking in woods, O09 Yard operations receiving or processing or storage, O10 Forwarder operation, O11 Harvester operation, O12 Infrastructure construction, O13 Nursery and afforestation, O14 Wood chipper operation. Risk codes Rxx cover accident risks first then occupational disease risks and finally psychosocial risk in the order shown, for example, R01 Struck by or against objects or vehicles, R02 Slips or trips or falls, R03 Fatal injury, R04 Unspecified injury, R05 Lacerations and amputations, R06 Vehicle or machine rollover, R07 Fractures, R08 Musculoskeletal strain posture or repetition or overexertion, R09 Noise exposure, R10 Vibration exposure, R11 Thermal stress heat or cold, R12 Diesel exhaust, R13 Wood dust exposure, R14 Work stress or production pace. Preventive or protective measures are Pxx in the order shown across organisational or engineering controls and personal protective equipment, for example, P01 OHS training, P02 Safety rule enforcement, P03 Machine-specific operator training, P04 Safer or ergonomic machine procurement, . . . , and PPE-related items such as PPE provision, PPE use training and PPE maintenance. Codes can be read directly to retrieve descriptive labels, for example, “H01; H09; H10” means “Handheld cutting tools; Forwarder; Chemical agents”, “O01; O13” means “Chainsaw or manual cutting; Nursery and afforestation”, and “R02; R09” means “Slips or trips or falls; Noise exposure”.

3.3. Results of Syntheses

Across the included studies, hazards and risks consistently concentrated in chain-saw/manual cutting, skidding/cable yarding, and loading/short-haul transport. These operations combined high acute injury potential (e.g., struck-by incidents involving logs or vehicles, slips/trips/falls, rollovers, lacerations) with longer-term exposures (postural overload/musculoskeletal symptoms, noise, hand-arm and whole-body vibration, diesel exhaust). Reported preventive measures clustered around engineering and organisational controls, complemented by targeted training and PPE, although specification and evaluation of measures were often incomplete. Co-occurrence heatmaps corroborated the convergence of hazards/risks at the task–operation intersections.

3.4. Certainty of Evidence

A primary analysis was conducted regarding the article's geographical distribution, resulting in the graphic shown in Figure 2. Almost 22% of the collected articles originated from the United States of America (USA), followed by Italy with approximately 9%, and then several other countries, including Indonesia, Romania, and Turkey, each contributing roughly 6%.

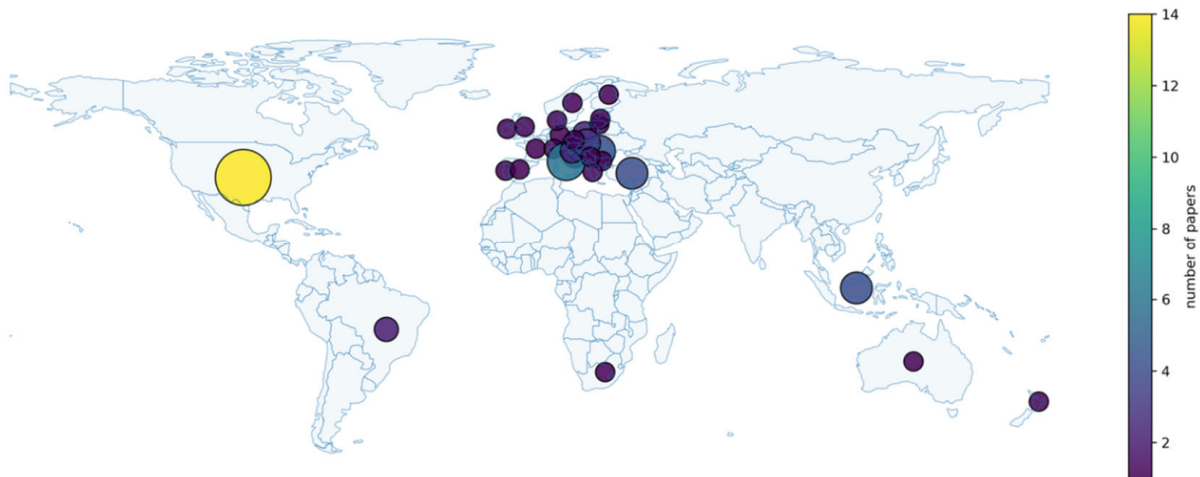


Figure 2. Geographical distribution of included studies by reported country of data collection and study setting.

The map in Figure 2 shows that published studies are concentrated in a small number of countries with substantial research and industrial capacity, with only sporadic contributions elsewhere. Most studies originated from a small set of regions, with noticeable gaps in Central Europe. This pattern likely reflects the effects of database indexing and terminology, as well as the possible exclusion of non-English or non-indexed national outlets, rather than an absence of research activity. This asymmetry limits comparability and generalizability because many patterns reflect country-specific contexts, such as prevailing logging systems, terrain, and regulatory frameworks, rather than global conditions; therefore, cross-country comparisons should be interpreted with caution.

The operations and procedures highlighted in the literature review offer insight into the current research focus within the forestry industry and identify the aspects deemed most significant by the scientific community. Figure 3 summarises the most frequently mentioned tasks in wood logging, which include tree felling and cutting, chainsaw operations, wood loading and transport, skidding, driving short-haul vehicles, and crosscutting logs. This is noteworthy because it corresponds with hazardous equipment previously identified, underscoring essential aspects of the logging process, such as felling, skidding, processing, and transportation.

According to Figure 4, the most critical hazards are, in this order, handheld cutting tools (primarily chainsaws), logs, unspecified logging machinery, and trucks. Unspecified logging machinery refers to a variety of mechanised machines used for felling and processing trees.

This review identifies three categories of occupational risks (Figure 5): (i) risks of occupational diseases linked to illnesses acquired through work-related exposure; (ii) risks of occupational accidents related to incidents that result in either fatal or non-fatal injuries; and (iii) psychosocial occupational risks associated with hazards of a psychosocial nature as outlined in ISO 45003:2021 [14].

Accidents in forestry are often severe and sometimes fatal. They frequently involve chainsaws, with common injuries including cuts and amputations, or machinery accidents, such as being struck by moving vehicles or equipment [26]. Falling trees or branches are among the leading causes of injuries and fatalities, with incidents often occurring during felling operations [7,15]. Skidding operations, where logs are dragged to a collection point, also present significant risks of accidents due to equipment failure, rugged terrain, and poor visibility [19,40]. Workers also suffer from slips, trips, and falls, often exacerbated by uneven terrain and adverse weather conditions [2]. Regarding occupational accident risks, the most frequently examined incidents include being struck by or against inanimate objects and falls and slips (Figure 6).

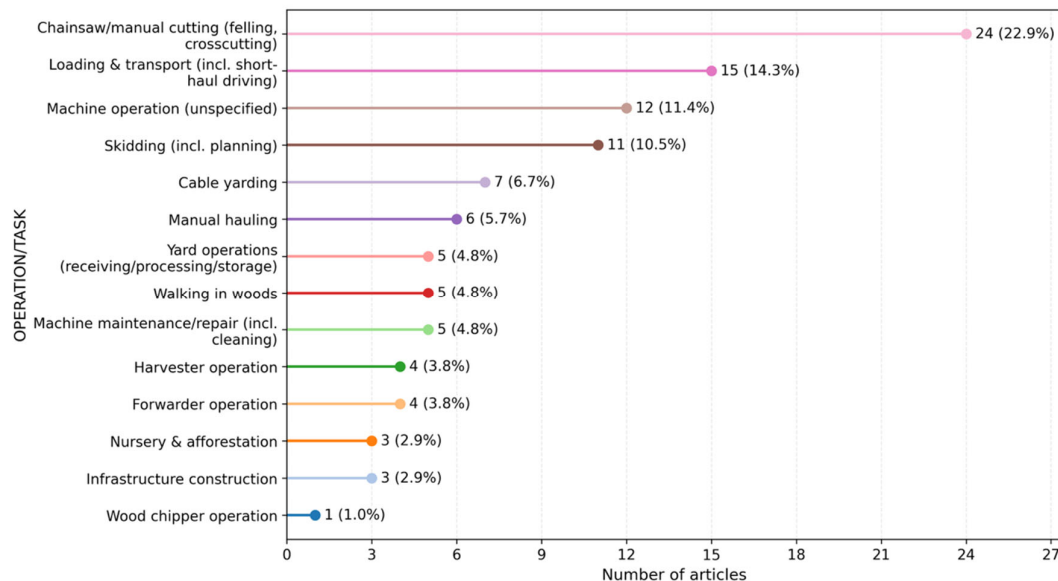


Figure 3. Tasks and operations per number of papers identified in the literature review.

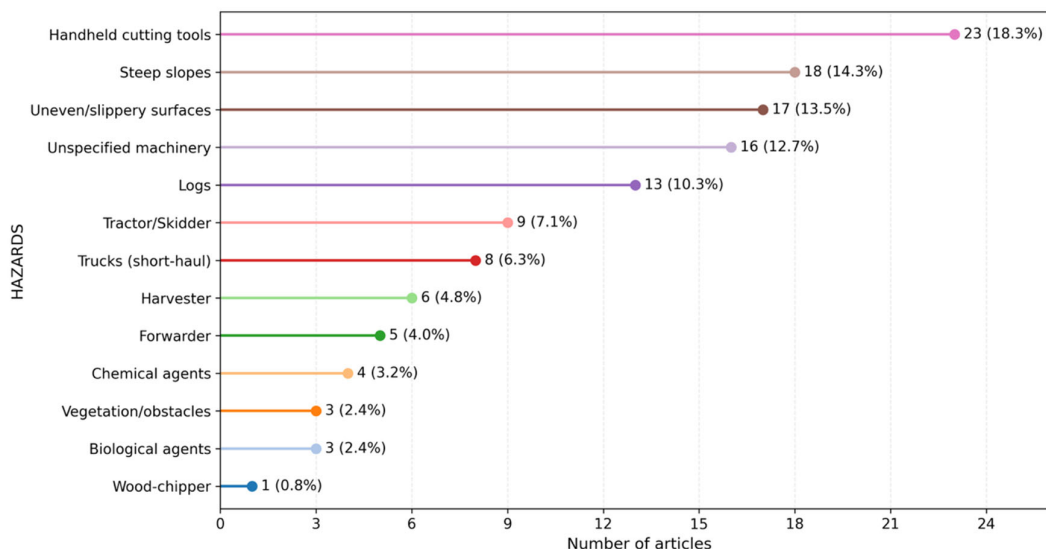


Figure 4. Hazards per number of papers identified in the literature review.

As for occupational disease risks (Figure 7), physical overexertion and incorrect postures, followed by noise exposure, are among the most prevalent topics for investigation. Forestry workers commonly have musculoskeletal disorders due to the physically demanding nature of their work. Back pain, joint pain, and repetitive strain injuries are prevalent, particularly among individuals involved in manual logging operations [8,36].

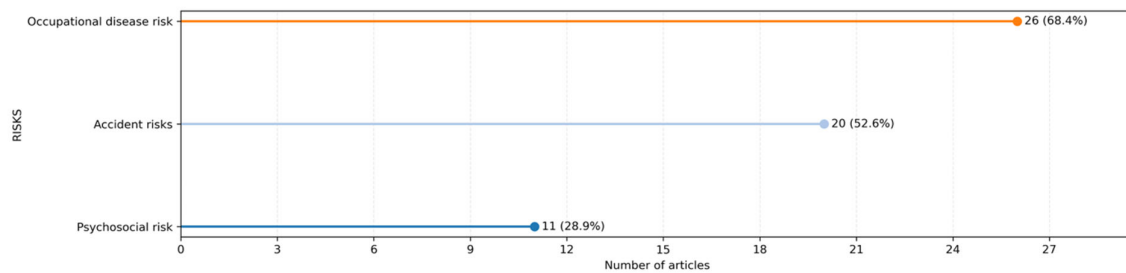


Figure 5. Types of occupational risks, categorised by the number of papers identified in the literature review.

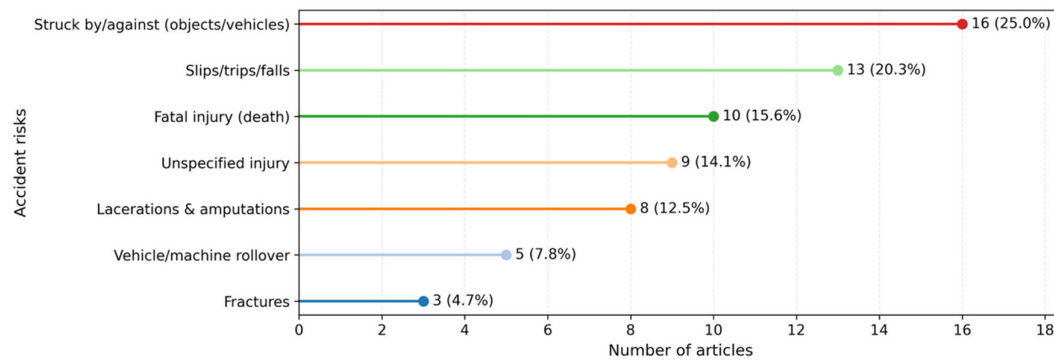


Figure 6. Occupational accident risks per number of papers identified in the literature review.

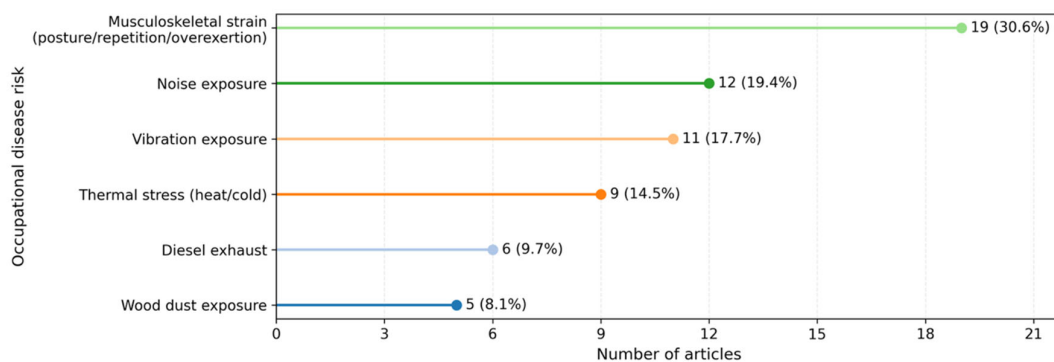


Figure 7. Occupational disease risks per number of papers identified in the literature review.

Noise-induced hearing loss is another widespread issue, primarily affecting machine operators who are continuously exposed to high-decibel sound levels [13,34]. Respiratory diseases, such as chronic bronchitis and asthma, are reported among workers exposed to wood dust and chemical agents, such as pesticides and diesel exhaust [29]. Prolonged exposure to vibration can lead to hand-arm vibration syndrome (HAVS), which affects motor and sensory functions, as also referred to [11,12].

According to Figure 8, injury preventive and protective measures in the forest wood logging industry have been investigated. Organisational or engineering measures account for more than 50% of the publications, followed by individual protection with 16% and collective protection with 4%.

Figure 9 illustrates the relationship between specific hazards and corresponding forestry operations and tasks. The results indicate that a small set of tasks accounts for the majority of reported hazards.

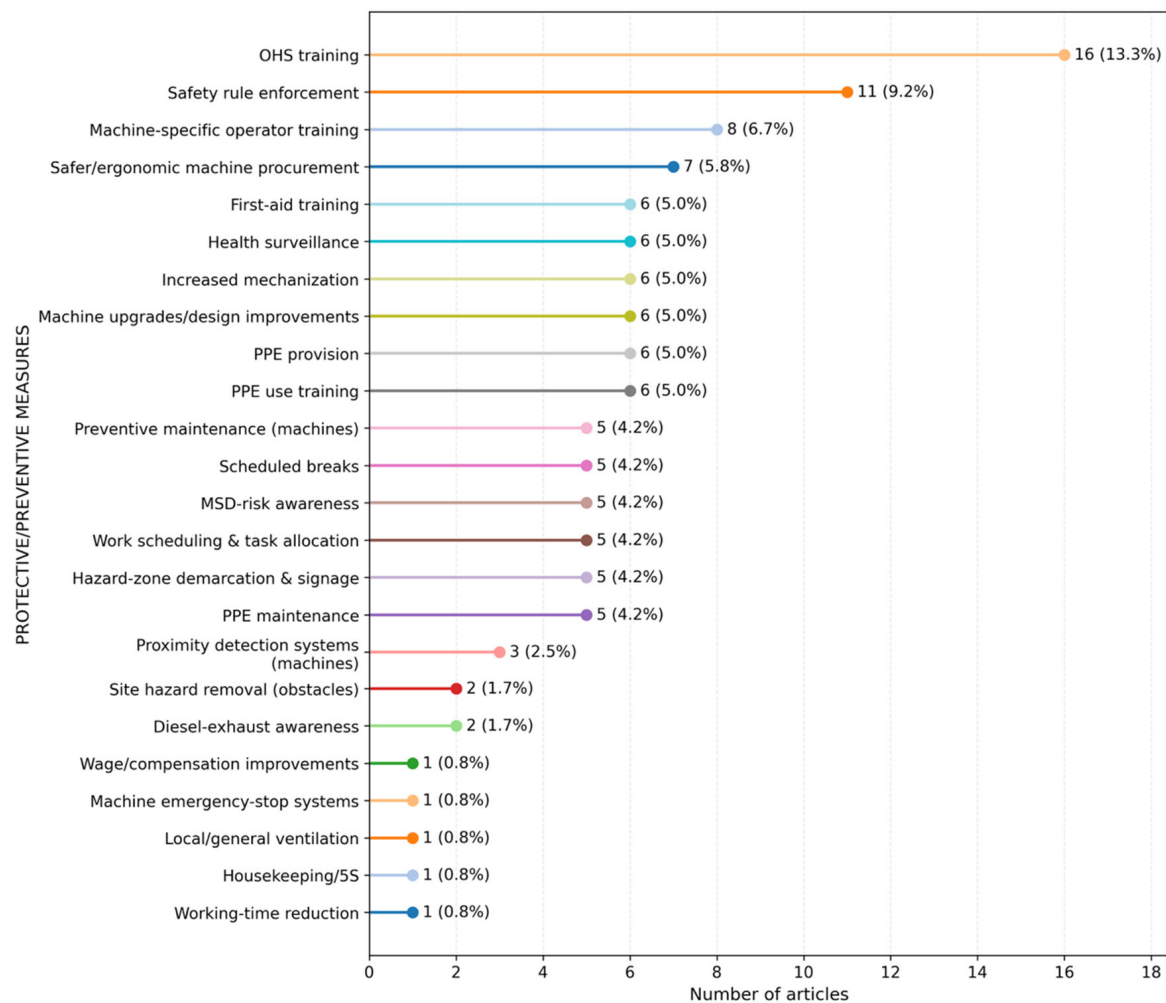


Figure 8. Preventive measures, as per the number of papers identified in the literature review.

Figure 10 links operations/tasks to reported occupational risks, including both acute accident risks (e.g., “Struck by/against (objects/vehicles)”, “Slips/trips/falls”, “Lacerations & amputations”, “Fatal injury (death)”) and longer-term health and exposure risks (e.g., “Musculoskeletal strain (posture/repetition/overexertion)”, “Noise exposure”, “Vibration exposure”, “Diesel exhaust”, “Thermal stress (heat/cold)”). “Chainsaw/manual cutting (felling, crosscutting)” is repeatedly associated with both types. This indicates that manual cutting is described not only as an activity with high immediate injury potential (including impact, falls, cuts, and, in some cases, fatal events), but also as physically demanding and exposure-intensive (characterised by awkward posture, repetitive exertion, vibration, high noise, and thermal stress).

Figure 11 links hazards directly to risks. Hazards such as “Handheld cutting tools”, “Steep slopes”, and “Uneven/slippery surfaces” frequently appear together with accident risks like “Struck by/against (objects/vehicles)”, “Slips/trips/falls”, and “Lacerations & amputations”. This combination corresponds to typical chainsaw felling scenarios in rugged terrain, where loss of balance, uncontrolled tree or log movement, and direct contact with cutting tools are described as primary causes of serious injury.

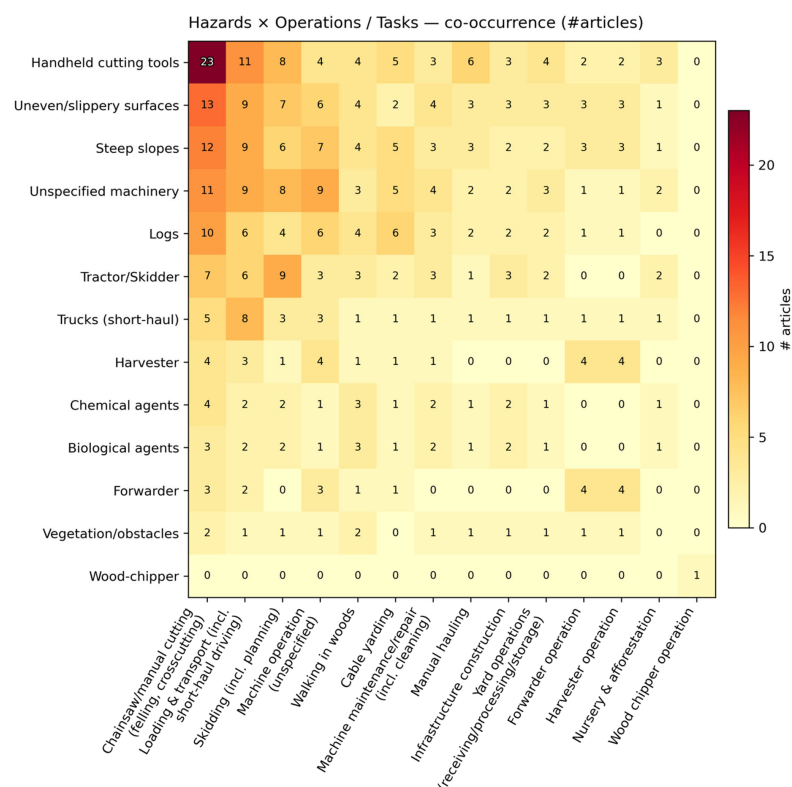


Figure 9. Heatmap of co-occurrence between hazards and operations/tasks. Each cell shows the number of articles that report both the specific hazard and the specific task.

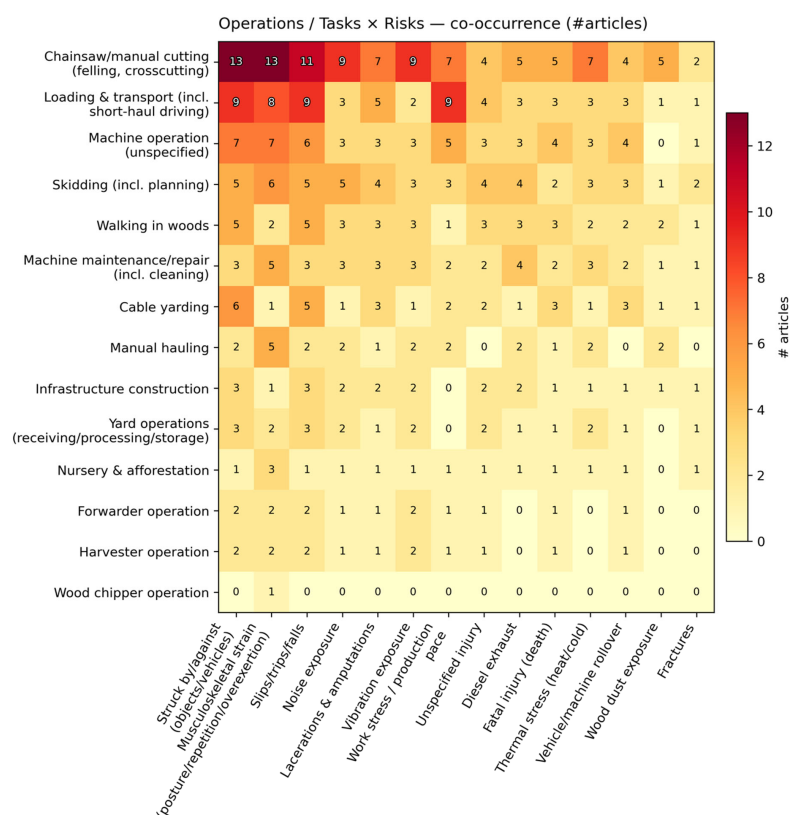


Figure 10. Heatmap of co-occurrence between operations/tasks and reported occupational risks. Each cell shows the number of articles that report both the specific task and the specific risk.

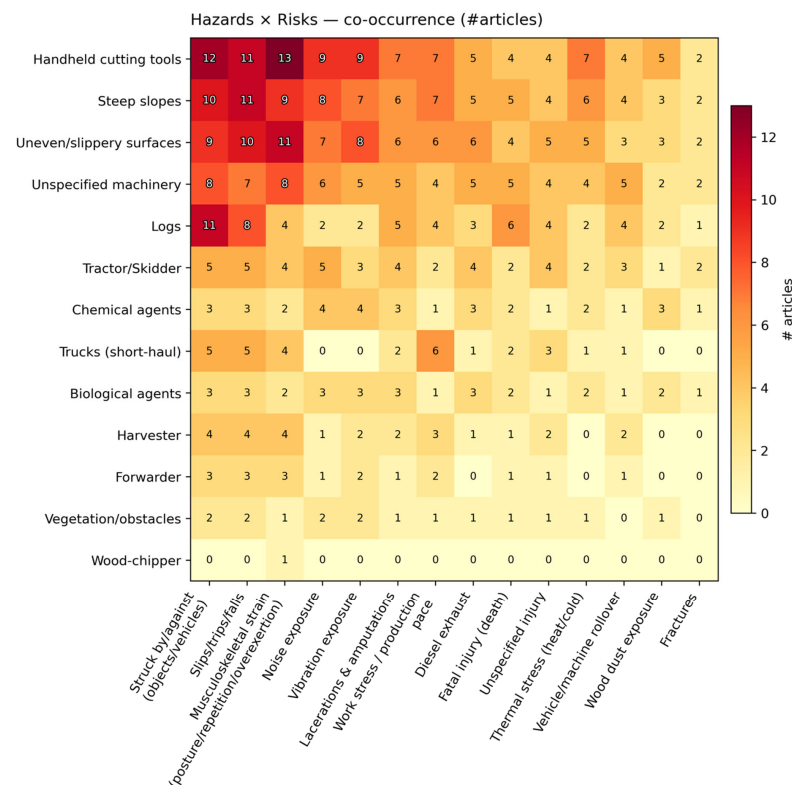


Figure 11. Heatmap of co-occurrence between hazards and reported occupational risks. Each cell shows the number of articles that report both the specific hazard and the specific risk.

4. Discussion

4.1. Principal Findings

Across the included sources, hazards and risks consistently concentrated in three operational phases, chainsaw/manual cutting, skidding/cable yarding, and loading/short-haul transport, where workers, heavy logs, and mobile machinery interact at close range. These operations combined high acute injury potential (e.g., struck-by incidents, slips/trips/falls, rollovers, lacerations) with longer-term exposures such as postural overload/musculoskeletal symptoms, noise, hand–arm and whole-body vibration, and diesel exhaust. Co-occurrence patterns reinforce the need for prevention to target task–hazard intersections rather than isolated risk factors, and that acute injuries and chronic health outcomes should be addressed jointly, rather than as separate agendas.

This pattern aligns with prior observations that mechanisation may reduce specific direct cutting hazards while reshaping exposure profiles. In machinery-intensive contexts, such as skidding, short-haul transport, or general machine operation, chronic exposures were frequently reported, notably noise, vibration, diesel exhaust and, in some contexts, dust. Consequently, part of the risk profile shifts towards hearing damage, vibration-related disorders, respiratory exposure and cumulative musculoskeletal strain. These shifts argue for integrated control strategies that combine engineering solutions (e.g., cab isolation, maintenance regimes that limit vibration and exhaust leakage), organisational controls (e.g., task rotation, traffic management, exclusion zones), targeted training, and consistent PPE programmes (e.g., hearing conservation).

Beyond physical agents, several studies indicated contributory organisational and human-factors determinants, including time pressure, communication failures at the worker–machine interface, and suboptimal situational awareness in complex terrain. Although these determinants were not consistently measured, their recurrent description

suggests that technical controls will be most effective when embedded in systems approaches (work design, supervision, competency frameworks, and safety culture).

Mechanisation has reshaped parts of the risk profile. While chainsaw work remains the most injury-prone task, harvester and forwarder operations introduce exposure to noise and whole-body vibration, as well as raise cognitive demands, including attention, vigilance, and monotony. Across systems, the human factor persists as a key driver, with non-adherence to procedures, inconsistent PPE use, and pressure from production pace. Practical implications include task-specific training, compliance monitoring, scheduled breaks and rotation for machine operators, and preventive maintenance and ergonomic upgrades.

4.2. Limitations of the Evidence

The evidence base was heterogeneous in terms of design (surveillance analyses, cross-sectional surveys, exposure measurements, and case series) and reporting quality. Outcome definitions and denominators varied; confidence intervals were infrequently presented; descriptors of logging systems and tasks were inconsistently specified; and measurement protocols for noise and vibration were often under-reported. Geographical concentration in a limited number of countries and logging systems constrains generalisability to other contexts (e.g., small-scale motor-manual operations vs. fully mechanised cut-to-length). Reliance on self-report and administrative datasets introduced potential information bias (misclassification of tasks and incomplete injury capture), and the use of small or convenience samples increased imprecision. Residual and unmeasured confounding (e.g., terrain, weather, operator experience, maintenance state of machinery) likely affected several estimates.

4.3. Limitations of the Review Process

This scoping review prioritised breadth over depth. Only peer-reviewed English-language sources were considered, which may introduce language and publication biases. Study-level risk-of-bias appraisal and certainty of evidence were not undertaken, as per the scoping methodology; therefore, the findings are descriptive and hypothesis-generating. Despite multi-database searches and citation chasing, relevant studies may have been missed due to indexing limitations and variable terminology across disciplines.

4.4. Implications for Practice, Policy and Research

Practice: Prevention should prioritise the task–hazard intersections identified: chainsaw/manual cutting, skidding/cable yarding, and loading/short-haul transport. Engineering and organisational controls should be implemented as a package, including machine guarding and cab isolation, separation of worker–machine envelopes with clear exclusion zones, traffic management, and stable work platforms. Additionally, routine maintenance should be conducted to control vibration and exhaust, task rotation should be implemented to reduce cumulative load, and hearing conservation programmes should be in place. Training should emphasise communication protocols at the worker–machine interface and decision-making under variable terrain and weather.

Policy: Inspection, guidance and funding programmes should focus on high-risk phases where acute injury risks co-occur with chronic exposures. Adopting minimum reporting elements for logging systems, tasks, and exposure/outcome metrics would enhance surveillance and comparability. Incentives for the uptake of proximity-alert technologies and for documented machinery maintenance may accelerate risk reduction.

Research: Priorities include: (i) harmonised descriptors of logging systems and tasks with validated taxonomies; (ii) standardised measurement protocols for noise, vibration and diesel exhaust with transparent uncertainty; (iii) routine reporting of study-level

estimates with 95% CIs; (iv) evaluation of bundled interventions (engineering + organisational + training) and proximity-alert or geofencing solutions; (v) longitudinal and quasi-experimental designs to quantify cumulative burdens and intervention effects; and (vi) transparent reporting of funding and conflicts of interest.

4.5. External Validity and Transferability

Findings appear most directly transferable to contexts sharing similar terrain, machinery fleets and regulatory environments. In small-scale or mixed systems where motor-manual tasks persist, the acute injury profile may dominate; in fully mechanised systems, the chronic exposure profile becomes more salient. Local adaptation should therefore consider terrain class, machine type and age, maintenance regimes, and workforce experience.

4.6. Overall Interpretation

Taken together, the evidence indicates that a small set of core logging operations consistently concentrates both acute and chronic risks. Mechanisation changes rather than eliminates risk, shifting part of the burden toward chronic exposures. Consequently, the most promising strategies are integrated, task-centred packages that combine engineering and organisational controls with training and PPE, supported by standardised descriptions and measurements that enable monitoring and comparative evaluation.

4.7. Limitations

Reporting bias cannot be excluded due to the restriction to English-language publications and variable reporting of outcomes, definitions, and denominators across studies. In addition, heterogeneity in logging systems and regulatory contexts, together with the geographic concentration of evidence, limits cross-study comparability and generalizability. Standardised operational descriptors and outcome metrics would strengthen future mapping and enable more robust comparisons across settings.

5. Conclusions

Across the included studies (2015–2025), hazards and risks in forestry logging consistently clustered in three operational phases: chainsaw/manual cutting, skidding/cable yarding, and loading/short-haul transport, where close interaction between workers, heavy logs, and mobile machinery occurs. These phases combined high acute injury potential (e.g., struck-by events, slips/trips/falls, rollovers, lacerations) with longer-term exposures, notably postural overload/musculoskeletal symptoms, noise, hand–arm and whole-body vibration, and diesel exhaust. Mechanisation appears to reduce specific direct cutting hazards while reshaping the exposure profile toward chronic burdens; as a result, part of the risk shifts to hearing damage, vibration-related disorders, respiratory exposure and cumulative musculoskeletal strain.

Effective risk reduction is most likely with integrated, task-centred packages that prioritise engineering and organisational controls, such as segregation of worker-machine envelopes, traffic management, and stable work platforms, as well as cab isolation and maintenance to control vibration and exhaust, complemented by targeted training and appropriate PPE, including hearing conservation. Given the heterogeneity in designs, measures, and reporting, as well as the geographical concentration of studies, the synthesis should be interpreted as descriptive and hypothesis-generating rather than definitive.

Future work should adopt harmonised descriptors of logging systems and tasks, standardise measurement protocols for noise, vibration, and diesel exhaust, and routinely report study-level estimates with 95% confidence intervals. Evaluation of bundled interventions (engineering, organisational, and training) and proximity-alert solutions, alongside longitudinal designs to characterise cumulative burdens, would strengthen the evidence

base and support implementation. Overall, prevention strategies that explicitly target the identified task–hazard intersections are the most promising avenue to deliver meaningful and durable gains in safety and health.

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References

1. FAO; ILO; UN. *Occupational Safety and Health in the Future of Forestry Work*; Forestry Working Paper No. 37; FAO: Rome, Italy, 2023. [CrossRef]
2. Garland, J.; Belart, F.; Crawford, R.; Chung, W.; Cushing, T.; Fitzgerald, S.; Wimer, J. Safety in steep slope logging operations. *J. Agromed.* **2019**, *24*, 138–145. [CrossRef] [PubMed]
3. FAOStat. Forestry Production and Trade. Available online: <http://www.fao.org/faostat/en/#data/FO/visualize> (accessed on 12 November 2024).
4. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef] [PubMed]
5. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *PLoS Med.* **2021**, *18*, e1003583. [CrossRef] [PubMed]
6. Akay, A.; Akgul, M.; Esin, A.; Demir, M.; Senturk, N.; Ozturk, T. Evaluation of occupational accidents in forestry in Europe and Turkey by k-means clustering analysis. *Turk. J. Agric. For.* **2021**, *45*, 495–509. [CrossRef]
7. Allman, M.; Dudáková, Z.; Jankovský, M. Long-term temporal analysis of fatal and severe occupational accidents in Central European forests of the Slovak Republic. *J. Safety Res.* **2023**, *87*, 488–495. [CrossRef]
8. Cheta, M.; Marcu, M.; Borz, S. Workload, exposure to noise, and risk of musculoskeletal disorders: A case study of motor-manual tree felling and processing in poplar clear cuts. *Forests* **2018**, *9*, 300. [CrossRef]
9. Conway, S.; Pompeii, L.; Casanova, V.; Douphrate, D. A qualitative assessment of safe work practices in logging in the southern United States. *Am. J. Ind. Med.* **2017**, *60*, 58–68. [CrossRef]
10. Cremasco, M.; Giustetto, A.; Caffaro, F.; Colantoni, A.; Cavallo, E.; Grigolato, S. Risk assessment for musculoskeletal disorders in forestry: A comparison between RULA and REBA in the manual feeding of a wood-chipper. *Int. J. Environ. Res. Public Health* **2019**, *16*, 793. [CrossRef]
11. Enez, K.; Nalbantoğlu, S. Comparison of ergonomic risk assessment outputs from OWAS and REBA in forestry timber harvesting. *Int. J. Ind. Ergon.* **2019**, *70*, 51–57. [CrossRef]

12. Eroglu, H.; Yilmaz, R.; Kayacan, Y. A study on determining the physical workload of the forest harvesting and nursery-afforestation workers. *Anthropologist* **2015**, *21*, 168–181. [\[CrossRef\]](#)
13. Fonseca, A.; Aghazadeh, F.; de Hoop, C.; Ikuma, L.; Al-Qaisi, S. Effect of noise emitted by forestry equipment on workers' hearing capacity. *Int. J. Ind. Ergon.* **2015**, *46*, 105–112. [\[CrossRef\]](#)
14. ISO 45003:2021; Occupational Health and Safety Management: Psychological Health and Safety at Work: Guidelines for Managing Psychosocial Risks. ISO: Geneva, Switzerland, 2021.
15. Ghaffariyan, M. Analysis of forestry work accidents in five Australian forest companies for the period 2004 to 2014. *J. For. Sci.* **2016**, *62*, 545–552. [\[CrossRef\]](#)
16. Grzywiński, W.; Skonieczna, J.; Jelonek, T.; Tomczak, A. The influence of the privatization process on accident rates in the forestry sector in Poland. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3055. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Iftime, M.; Dumitrascu, A.; Dumitrascu, D.; Ciobanu, V. An investigation on major physical hazard exposures and health effects of forestry vehicle operators performing wood logging processes. *Int. J. Ind. Ergon.* **2020**, *80*, 103041. [\[CrossRef\]](#)
18. Iftime, M.; Dumitrascu, A.; Ciobanu, V. Chainsaw operators' exposure to occupational risk factors and incidence of professional diseases specific to the forestry field. *Int. J. Occup. Saf. Ergon.* **2022**, *28*, 8–19. [\[CrossRef\]](#) [\[PubMed\]](#)
19. Jankovský, M.; Allman, M.; Allmanová, Z. What are the occupational risks in forestry? Results of a long-term study in Slovakia. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4931. [\[CrossRef\]](#)
20. Justavino, F.; Ramirez, R.; Perez, N.; Borz, S. The use of OWAS in forest operations postural assessment: Advantages and limitations. *Bull. Transilv. Univ. Bras. Ser. II* **2015**, *8*, 7–16.
21. Kim, S.; Nussbaum, M.; Schoenfisch, A.; Barrett, S.; Bolding, M.; Dickerson, D. Occupational safety and health concerns in logging: A cross-sectional assessment in Virginia. *Forests* **2017**, *8*, 440. [\[CrossRef\]](#)
22. Kyung, M.; Lee, S.; Dancu, C.; Hong, O. Underreporting of workers' injuries or illnesses and contributing factors: A systematic review. *BMC Public Health* **2023**, *23*, 558. [\[CrossRef\]](#)
23. Lagerstrom, E.; Magzamen, S.; Brazile, W.; Rosecrance, J. Active surveillance of musculoskeletal disorder symptoms in the development of safety interventions for professional loggers. *Safety* **2019**, *5*, 23. [\[CrossRef\]](#)
24. Lagerstrom, E.; Magzamen, S.; Kines, P.; Brazile, W.; Rosecrance, J. Determinants of safety climate in the professional logging industry. *Safety* **2019**, *5*, 35. [\[CrossRef\]](#)
25. Landekić, M.; Katuša, S.; Mijoč, D.; Šporčić, M. Assessment and comparison of machine operators' working posture in forest thinning. *South-East Eur. For.* **2019**, *10*, 29–37. [\[CrossRef\]](#)
26. Laschi, A.; Marchi, E.; Foderi, C.; Neri, F. Identifying causes, dynamics and consequences of work accidents in forest operations in an alpine context. *Saf. Sci.* **2016**, *89*, 28–35. [\[CrossRef\]](#)
27. Lilley, R.; Feyer, A.; Kirk, P.; Gander, P. A survey of forest workers in New Zealand—Do hours of work, rest, and recovery play a role in accidents and injury? *J. Safety Res.* **2002**, *33*, 53–71. [\[CrossRef\]](#) [\[PubMed\]](#)
28. Lima, K.; Meira Castro, A.C.; Santos Baptista, J.; Silva, U. Wood-logging process management in Eastern Amazonia (Brazil). *Sustainability* **2020**, *12*, 7571. [\[CrossRef\]](#)
29. Marchi, E.; Neri, F.; Cambi, M.; Laschi, A.; Foderi, C.; Sciarra, G.; Fabiano, F. Analysis of dust exposure during chainsaw forest operations. *iForest* **2017**, *10*, 341–347. [\[CrossRef\]](#)
30. Melemez, K. Risk factor analysis of fatal forest harvesting accidents: A case study in Turkey. *Saf. Sci.* **2015**, *79*, 369–378. [\[CrossRef\]](#)
31. Monsey, L.M.; Harrington, M.; Clonch, A.; Spector, J.; Vignola, E.F.; Baker, M.G. Exploring barriers and facilitators to well-being among logging industry workers: A mixed methods study. *Int. J. For. Eng.* **2025**, *36*, 248–263. [\[CrossRef\]](#)
32. Newman, S.; Keefe, R.; Brooks, R.; Ahonen, E.; Wempe, A. Human factors affecting logging injury incidents in Idaho and the potential for real-time location-sharing technology to improve safety. *Safety* **2018**, *4*, 43. [\[CrossRef\]](#)
33. Nkomo, H.; Niranjani, I.; Reddy, P. Effectiveness of health and safety training in reducing occupational injuries among harvesting forestry contractors in KwaZulu-Natal. *Workplace Health Saf.* **2018**, *66*, 499–507. [\[CrossRef\]](#)
34. Poje, A.; Potočnik, I.; Danilović, M.; Antonić, S. A case study of the impact of skidding distance on tractor operator exposure to noise. *Balt. For.* **2016**, *22*, 357–364.
35. Poje, A.; Grigolato, S.; Potočnik, I. Operator exposure to noise and whole-body vibration in a fully mechanised CTL forest harvesting system in Karst terrain. *Croat. J. For. Eng.* **2019**, *40*, 139–150.
36. Rodriguez, A.; Casanova, V.; Levin, J.; de Porras, D.; Douphrate, D. Work-related musculoskeletal symptoms among loggers in the Ark-La-Tex region. *J. Agromedicine* **2019**, *24*, 167–176. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Rosecrance, J.; Lagerstrom, E.; Murgia, L. Job factors associated with occupational injuries and deaths in the United States forestry industry. *Chem. Eng. Trans.* **2017**, *58*, 115–120. [\[CrossRef\]](#) [\[PubMed\]](#)
38. Soranso, D.; Minette, L.; Bermudes, W.; Oliveira, M.; Schettino, S.; Fiedler, N.; Vieira, F. Risk analysis in a tropical forest wood exploration and processing system in Mato Grosso State, Brazil. *J. Exp. Agric. Int.* **2019**, *41*, 1–10. [\[CrossRef\]](#)
39. Spinelli, R.; Aminti, G.; de Francesco, F. Postural risk assessment of mechanised firewood processing. *Ergonomics* **2016**, *60*, 375–383. [\[CrossRef\]](#)

40. Tsioras, P.; Rottensteiner, C.; Stampfer, K. Wood harvesting accidents in the Austrian State Forest Enterprise 2000–2009. *Saf. Sci.* **2014**, *62*, 400–408. [[CrossRef](#)]
41. Wachter, J.; Yorio, P. A system of safety management practices and worker engagement for reducing and preventing accidents: An empirical and theoretical investigation. *Accid. Anal. Prev.* **2014**, *68*, 117–130. [[CrossRef](#)]
42. Yovi, E.; Prajawati, W. High risk posture on motor-manual short wood logging system in *Acacia mangium* plantation. *J. Manaj. Hutan Trop.* **2015**, *21*, 11–18. [[CrossRef](#)]
43. Yovi, E.; Yamada, Y. Strategy to disseminate occupational safety and health information to forestry workers: The felling safety game. *J. Trop. For. Sci.* **2015**, *27*, 213–221.
44. Yovi, E.; Yamada, Y. Addressing occupational ergonomics issues in Indonesian forestry: Laborers, operators, or equivalent workers. *Croat. J. For. Eng.* **2017**, *40*, 351–363. [[CrossRef](#)]
45. Yovi, D.; Nurrochmat, D. An occupational ergonomics in the Indonesian state mandatory sustainable forest management instrument: A review. *For. Policy Econ.* **2018**, *91*, 27–35. [[CrossRef](#)]
46. Zenir, M.; Milkovich, P.; Donnelly, P.; Lundstrom, W.; Fullen, M.; Scott, E. Qualitative perspectives on safety, health, and productivity from Northeast United States loggers: Implications for industry sustainability. *For. Policy Econ.* **2025**, *178*, 103604. [[CrossRef](#)]
47. Zimbelman, E.; Keefe, R.; Strand, E.; Kolden, C.; Wempe, A. Hazards in motion: Development of mobile geofences for use in logging safety. *Sensors* **2017**, *17*, 822. [[CrossRef](#)]

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