New Zealand Journal of Health and Safety Practice; Vol.2, Ed 1. April 2025

Workplace Guidance for Earthquake Preparedness and Injury Prevention in Aotearoa-New Zealand: A Document Analysis

Aiggan Tamene Kitila
Injury Prevention Research Unit, Department of Preventive and Social Medicine, Dunedin School of Medicine, University of Otago, Dunedin, New Zealand
Centre for Sustainability, University of Otago, Dunedin, New Zealand
Email: aiggan.kitila@postgrad.otago.ac.nz
ORCID: http://orcid.org/0000-0001-5504-0905

Rebbecca Lilley
Injury Prevention Research Unit, Department of Preventive and Social Medicine, Dunedin School of Medicine, University of Otago, Dunedin, New Zealand
Email: rebbecca.lilley@otago.ac.nz
ORCID: http://orcid.org/0000-0002-3901-2880

Caroline Orchiston
Centre for Sustainability, University of Otago, Dunedin, New Zealand
Email: caroline.orchiston@otago.ac.nz
ORCID: http://orcid.org/0000-0002-3171-2006

Gabrielle Davie
Injury Prevention Research Unit, Department of Preventive and Social Medicine, Dunedin School of Medicine, University of Otago, Dunedin, New Zealand
Email: gabrielle.davie@otago.ac.nz
ORCID: http://orcid.org/0000-0001-5466-5364

DOI: https://doi.org/10.26686/nzjhsp.v2i1.9758

Abstract

Introduction: Strong earthquakes pose significant risks of fatal and non-fatal injury to populations in affected areas, including workers and workplace bystanders. Under New Zealand's Health and Safety at Work Act 2015 (HSWA 2015), persons conducting a business or undertaking (PCBUs) must manage risks to health and safety so far as is reasonably practicable. To support PCBUs in meeting this obligation, guidance documents have been developed to outline the hazards arising from earthquakes and recommend strategies for controlling the injury risks. The extent to which these resources align with the HSWA 2015, however, remains unclear. This study aimed to analyse currently available workplace earthquake safety guidance documents in New Zealand to evaluate their content and assess their alignment with the HSWA 2015.

Methods: Seventeen guidance documents were identified through targeted searches of 25 organisational websites, Google.nz, and consultations with Occupational Health and Safety Associations. Thematic analysis was conducted to explore key themes within the documents. The findings were then analysed using the Hierarchy of Controls and the Haddon Matrix framework to identify strengths, gaps, and opportunities for improvement in current guidance.

Findings: Six key guidance areas were identified: (1) hazard identification, (2) risk reduction actions, (3) contingency planning, (4) technology integration, (5) training, and (6) communication and coordination. Guidance on administrative controls (e.g., emergency plans) were included in all documents. In contrast, guidance on higher-order controls were less common, with engineering controls (e.g., structural retrofits) in 82% (n=14) and isolation measures (e.g., restricting access to earthquake prone buildings) in only 12% (n=2). Further analysis using the Haddon Matrix showed that pre-earthquake actions were covered in all documents, but post-earthquake actions were less comprehensively addressed (59%, n=10).

Conclusions: Future guidance could be improved by prioritising higher-order controls; providing detailed recommendations for post-earthquake response and recovery; and developing tailored resources for a wider range of work settings. Together, these improvements could help better align workplace earthquake safety practices with the requirements of the HSWA 2015.

Keywords: Earthquake preparedness, workplace safety, Injury prevention, Hierarchy of Controls, Haddon Matrix

Introduction

Each year, approximately 20,000 earthquakes occur in and around Aotearoa-New Zealand (NZ), with around 200 strong enough to be felt (Witze, 2017). Strong earthquakes present significant risks to public safety, including non-fatal and fatal injuries due to structural collapse, falling debris, ground shaking, and secondary hazards such as fires, landslides, or tsunamis (Ramirez and Peek-Asa, 2005, Horspool et al., 2020).

Research indicates that places of work pose an increased risk for injury; for example, people in commercial buildings are more than six times as likely to be injured in earthquakes than those at home, even after accounting for factors such as location, age, and gender (Peek-Asa et al., 2003). This increased injury risk in work settings is due to several factors including higher occupancy density (Manfredi et al., 2023), structural modifications that are sometimes made to accommodate business needs (Grillone, 2020), and outdoor hazards such as scaffolding, which may compromise the safety of both workers and bystanders (Goode et al., 2015). Historically, earthquakes in NZ have caused significant harm in workplaces, resulting in at least 264 fatalities since 1931 (Abeling et al., 2020, Clement et al., 2019, Yeow et al., 2020).

Given these realities, workplace safety legislation in NZ plays an important role in reducing the risks associated with earthquakes. The Health and Safety at Work Act 2015 (HSWA 2015) is the primary legal framework for workplace health and safety in NZ. Under Section 30(1) of the Act, persons conducting a business or undertaking (PCBUs) are required to eliminate risks to health and safety so far as is reasonably practicable. If elimination is not possible, risks must be minimised to the greatest extent practicable *(Health and Safety at Work Act 2015, s.30(1))*. A key component of fulfilling this duty is applying the Hierarchy of Controls (HoC), a systematic approach to identifying and implementing the most effective safety measures *(Health and Safety at Work (General Risk and Workplace Management) Regulations 2016, reg. 6(3)).*

The HSWA 2015, however, is not prescriptive and does not specify how workplaces should manage particular hazards, including those related to earthquakes (Horsfall et al., 2022). Instead, guidance on earthquake-related hazards is provided through supplementary documents that outline strategies for controlling these hazards and minimising associated injury risks. Despite the risks earthquakes continue to pose to workers and workplace bystanders in NZ, research examining the content of these guidance documents and their alignment with the regulatory requirements of the HSWA 2015 remains limited. This paper seeks to address this gap by analysing guidance documents, with the aim of identifying potential opportunities for workplaces to better prepare for and mitigate the ever-present injury risks posed by earthquake events in NZ.

Materials and Methods

Study design

A qualitative review of documents guiding PBCUs on the hazards generated during earthquakes and the range of actions to address the associated injury risks was conducted between October 2023 and May 2024. Document analysis is a systematic method of evaluating electronic and physical documents to interpret their content, context, and purpose (Bowen, 2009). In this study, this methodology was used to systematically review and consolidate fragmented guidance from various resources, with the aim of providing a greater collective understanding of the guidance available to PCBUs for reducing earthquake-related risks and preventing injuries. To guide the study, the READ approach to document analysis was used, as outlined by Dalglish et al. (2021). This approach consists of four stages: (1) readying source materials; (2) extracting data; (3) analysing data; and (4) distilling findings.

Stage 1- Readying source materials

The initial stage involved defining the study parameters, including data sources, search strategies, and inclusion criteria, to establish a framework for identifying relevant documents.

Data sources and search strategy

Grey literature often lacks the centralised indexing systems found in peer-reviewed databases. To address this, a broad search strategy was developed, drawing on four data sources:

Website searches: Twenty-five organisational websites were searched for relevant documents. These sites were selected based on their affiliation with recognised authorities in Occupational Health and Safety, emergency management, or earthquake preparedness. Priority was given to government, educational, and non-profit domains (.gov, .org, .edu). The search was guided by four key terms: "workplace," "earthquake," "injury," and "policy." Boolean operators (e.g., AND, OR) were used to refine the results.

Online search engines: Google.nz was used to broaden the scope of the search. To maintain consistency, the predefined search terms and modifiers from the website searches were applied. This process included two distinct approaches: (1) targeted searches, focusing on specific domains (.gov.nz, .org.nz, and .ac.nz) to prioritise authoritative sources, and (2) broader, unfiltered searches, spanning all domains to capture a wider range of documents.

Consultation with health and safety associations: Several Occupational Health and Safety Associations in NZ were consulted to identify additional resources. These included the New Zealand Health and Safety Association, New Zealand Institute of Safety Management (NZISM), New Zealand Occupational Health Nurses Association (NZOHNA), New Zealand Occupational Hygiene Society (NZEOHS), New Zealand Safety Council (NZESC), and Australian and New Zealand Society of Occupational Medicine (ANZSOM).

Reference lists: The reference lists of documents identified through websites, search engines, and consultations were reviewed to identify additional resources.

Eligibility assessment and document selection

Identified documents were assessed in two stages. In the first stage, documents were screened using titles, abstracts, synopses, webpage entries, or indexes (whichever was accessible) to exclude documents that did not meet the eligibility criteria (Table 1). In the second stage, documents identified as potentially relevant were reviewed in full.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Purpose	Documents guiding PBCUs on the hazards arising from earthquakes and the range of actions to address the associated injury risks	Not related to the identification and management hazards arising from earthquakes
Focus	Sole focus on earthquake hazards	Multi-hazard focus
Type	Full-text documents	Full text is unavailable
Accessibility	Free to access	Behind a paywall
Target audience	Workplaces	Community or household-focused
Language	Available in English	Not available in English
Geographic Context	Relevant to New Zealand	Outside New Zealand
Temporal Context	Most recent version; no start or end year	Drafts or outdated versions

Stage 2 - Extracting data

Documents meeting the inclusion criteria were reviewed several times to fully understand their content. Data on earthquake-related injury risks and recommended controls were extracted and transcribed. Any relevant visual content, such as diagrams were also transcribed.

Stage 3 - Analysing data

The data analysis was conducted in three stages. Further details on each are provided below.

Thematic analysis: Following the Braun and Clarke (2006) framework, the extracted data were first coded based on recurring topics related to the identification and management of earthquake-related injury risks. These codes were then grouped into broader categories to organise the findings. These categories were reviewed and refined to develop themes that represent the key areas where workplaces can take targeted actions to reduce earthquake-related risks and prevent injuries.

Haddon Matrix analysis: The results from the thematic analysis were subsequently organised using the Haddon Matrix (Haddon, 1968). The Haddon Matrix is a conceptual framework used to systematically identify and evaluate multifactorial opportunities for injury prevention by considering two key factors:

- **'When'** actions can be taken: pre-event (before an earthquake), event (during the earthquake), or post-event (after the earthquake), and
- **'Who or what'** the interventions target: the Host (the individual at risk), the Agent (the causes of injury), or the Environment (the social and physical surroundings).

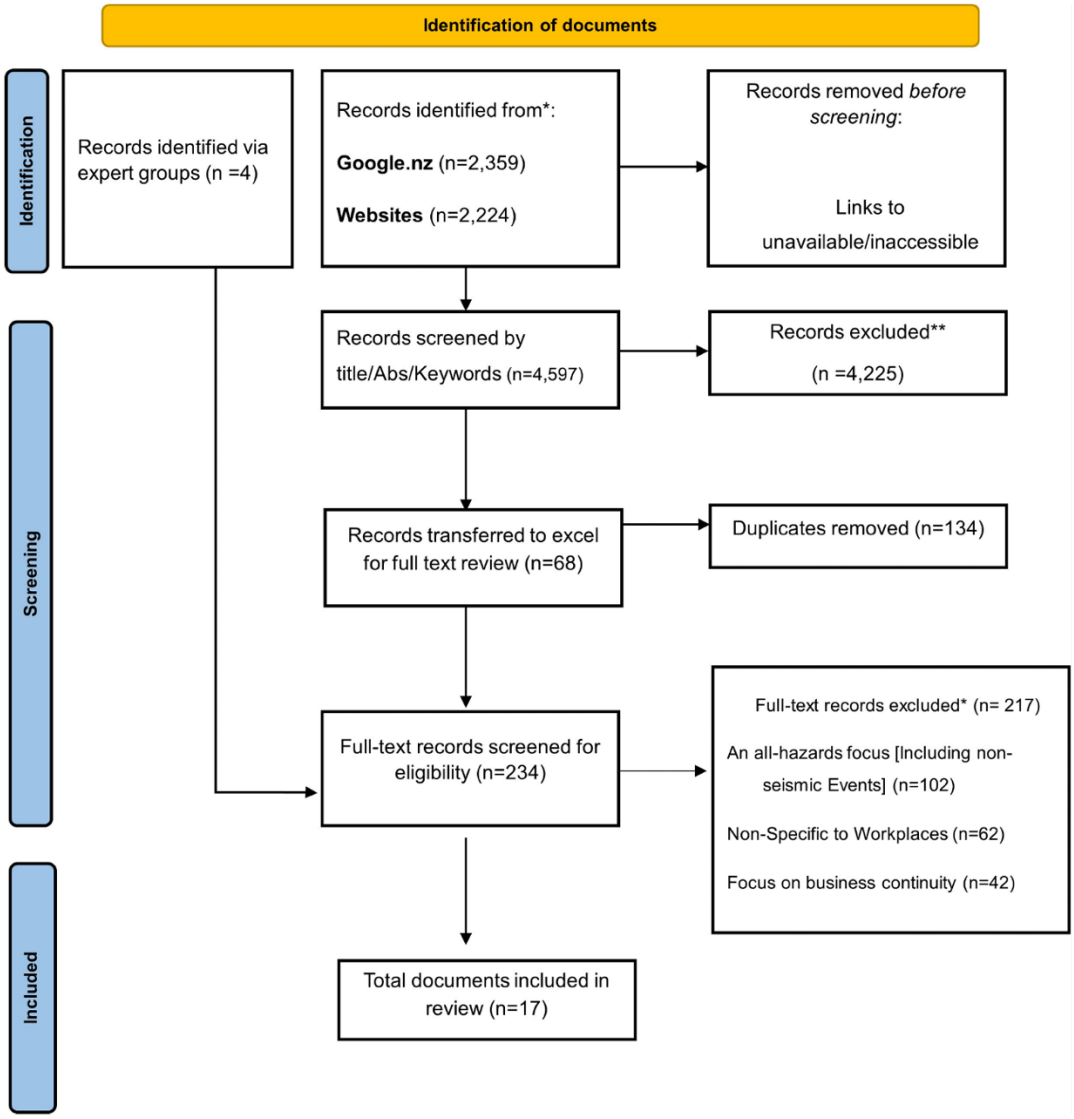
Fit-for-purpose assessment: The fit-for-purpose of the reviewed documents was assessed by evaluating the efficacy of the individual controls they outline. This was done using the Hierarchy of Controls (HoC), a framework introduced by the National Safety Council in 1950 and later formalised by the National Institute for Occupational Safety and Health (NIOSH)**.** Control measures identified during thematic analysis were classified into five levels: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) (NIOSH, 1973*)*.

Results

Document review outcome

A total of 4,601 records were initially identified through searches, including 2,359 from Google.nz, 2,224 from organisational websites, and 18 from reference lists. Additionally, four records were identified through expert recommendations. After removing duplicates and screening based on titles, abstracts, and keywords, 234 records were selected for full-text review. Of these, 17 documents met the inclusion criteria and were included in the final document analysis (Figure 1).

Figure 1 Flowchart of document selection process



Characteristics of included documents

Nearly half (47%, n=8) of the documents were authored by government agencies such as WorkSafe NZ, the National Emergency Management Agency (NEMA), and the Ministry of Business, Innovation and Employment (MBIE), while the rest were produced by non-governmental organisations from the insurance, research, and consultancy sectors (Table 2).

Table 2 Summary of documents included in the review

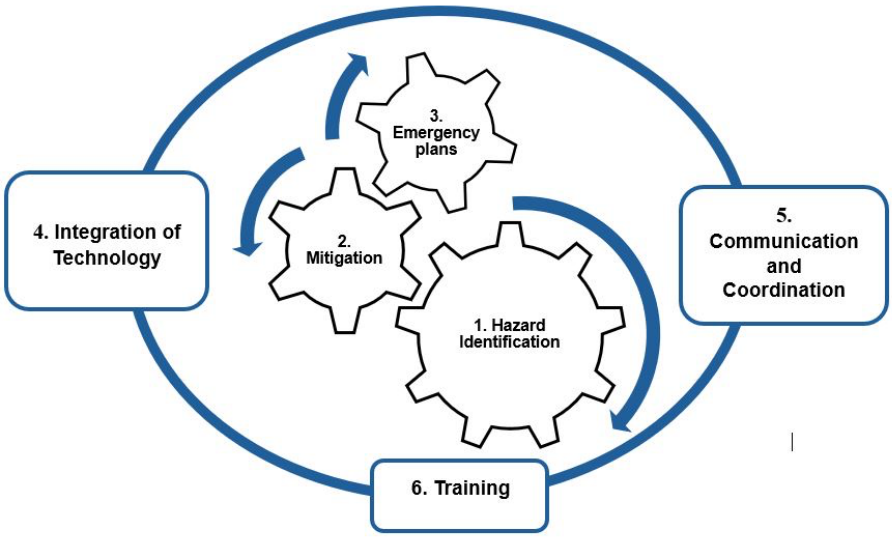
Document ID and Name		Year	Author(s)	Reference
A	Dealing With Earthquake-Related Health and Safety Risks - Information for Employers and Owners of Workplace Buildings	2018	WorkSafe NZ	(WorkSafe, 2018)
B	Stacking And Shelving to Withstand Earthquakes	2016	WorkSafe NZ	(WorkSafe, 2016)
C	NZS4104:1994 Seismic Restraint of Building Contents	1994	Standards New Zealand	(Standards New Zealand, 1994)
D	NZS4219:2009 Seismic Restraint of Engineering Contents	2009	Standards New Zealand	(Standards New Zealand, 2009)
E	NZS170.5:2004 Structural Design Action - Earthquake Actions	2004	Standards New Zealand	(Standards New Zealand, 2004)
F	Seismic Risk Guidance for Buildings - Using Seismic Assessments in Occupancy Decision-Making	2022	MBIE	(MBIE, 2022)
G	Priority Buildings: A Guide to The Earthquake-Prone Building Provisions of The Building Act	2017	MBIE	(MBIE, 2017)
H	Earthquakes Toolbox	2015	Safer Me#	(SaferMe, 2015)
I	Preparing Your Business for Fast Earthquake Reactions - A Guide for Business Owners	n.d.*	Sentinel#	(Sentinel, n.d.-b)
J	Preparing Your Business for Fast Earthquake Reactions - A Guide for Building Owners	n.d.	Sentinel#	(Sentinel, n.d.-a)
K	Seismic Bracing for Building Contents	n.d.	Disaster Prepare#	(Disaster Prepare, 2018)
L	Earthquake Preparedness Checklist	2021	Resilient Organisations#	(Resilient Organisations, 2021)
M	Earthquake Checklist	2019	New Zealand Insurance#	(New Zealand Insurance, 2019)
N	Responding To an Earthquake-Prone Building Notification: A Guide for Building Owners	2020	Quake Centre #	(McDougall and Batchelar, 2020)
O	Shakeout Information for Businesses and Organisations	2023	NEMA+	(NEMA, 2023)
P	How To Set Up an Earthquake Emergency Plan	2019	Dexters' Safety and Protection#	(Dexters' Safety and Protection, 2019)
Q	Earthquake Drill Procedures in The Workplace	2023	Alert Media #	(Alert Media, 2023)

* n.d. Publication date unknown, ⁺Government agency, #non-government organisation

Thematic findings

This section summarises the guidance available on managing earthquake-related hazards at work, as outlined in the reviewed documents. Six key themes were identified: hazard identification, risk reduction actions, contingency planning, training, the integration of technology, and communication and coordination. These themes are interconnected and mutually reinforcing. For example, hazard identification helps determine the specific actions needed to address associated injury risks, and once these actions are implemented, contingency planning provides a framework for responding to any remaining risks. Additionally, training, integration of technology, and communication and coordination were identified as cross-cutting themes that support actions across the other themes, while also reinforcing each other (Figure 2). Each theme is discussed below, with supporting extracts from the documents.

Figure 2. Thematic map



Theme 1: Hazard identification

Hazard identification was a central theme throughout the reviewed documents, with two primary strategies emphasised for proactively identifying hazards that pose a risk of injury before, during, or after an earthquake: pre-occupancy building assessments; and continuous monitoring to identify and address new or evolving hazards overtime.

Sub-Theme 1.1: Pre-occupancy building assessments

The majority of the documents (n=11, 65%) highlighted the importance of evaluating both structural and non-structural hazards at the outset of building occupancy as well as following an earthquake event. Specific recommendations included:

> *"A sound decision about occupancy requires a detailed seismic assessment based on the latest guidelines…… Independent reviews and comprehensive understanding of vulnerabilities are essential." (Document F, p.4)*

> *"After an earthquake: inspect buildings for damage, secure fallen stock, and check for utility hazards and material spills." (Document I, p.5)*

Despite broad consensus on the need for pre-occupancy building assessments, the documents varied in the specificity of their guidance. Some documents (n=4, 24%) provided detailed lists of structural and non-structural elements to evaluate, such as walls, ceilings, and loose equipment. Others offered only general recommendations, leaving the scope of assessments open to interpretation.

Sub-Theme 1.2: Continuous monitoring and adaptation

Similarly, continuous monitoring and adaptation were frequently discussed as integral to the process of hazard identification across the reviewed documents (n=14, 83%). Recommendations included the need to stay up to date on changes in building regulations, emerging geophysical risks, and industry trends to address evolving hazards.

“A yearly safety audit is considered crucially important.” (Document C, p.1)

“Stay informed about current events and learn from the outcomes and impacts of earthquakes in other locations.” (Document P, p.2)

To better understand the focus of the identified documents, a frequency analysis was conducted to determine how often different hazards were addressed. Structural hazards, such as walls, parapets, and verandas were the most frequently mentioned, indicating a strong focus on load-bearing components (Table 3).

Table 3. Frequency analysis of earthquake-related hazards covered in guidance documents

Hazard	Examples	Description	Frequency of documents
Structural elements	Parapets, heavy ceilings, masonry walls, stairs, verandas	Key load-bearing components in a building that provide structural stability.	14
Secondary structural /Non-structural elements	Lighting fixtures, windows, doors, signs, cables, suspended items, partitions	Components that are not part of the main load-bearing structure but can cause injuries if they fall, break, or move uncontrollably.	8
Building contents	Shelving, bookcases, fridges, furniture, heavy equipment, monitors, cabinets, palletised goods	Movable items within a building that can tip, fall, or slide during an earthquake.	12
Hazardous substances	Flammable gases, chemicals, compressed gases, cylinders, fuel	Substances that pose a risk of injury if spilled or released during an earthquake.	3

Theme 2: Risk reduction actions

Risk reduction actions were a recurring theme across the reviewed documents. This theme encapsulates the recommended actions for workplaces to minimise risks of injury related to hazards generated during an earthquake, particularly those involving shifting, falling, or collapsing objects and structures. The guidance here primarily focused on two areas: non-structural components and structural elements.

Sub-Theme 2.1: Non-structural considerations

Securing building components to prevent movement during earthquakes was a recurring recommendation, discussed in 15 of the 17 reviewed documents (88%).

"Building components… such as parapets, heavy ceilings, masonry walls, and other features present risks. WorkSafe expects PCBUs to take steps to identify and eliminate or minimise the risks from these parts, where reasonably practicable…… Minimisation could include steps, such as securing the relevant parts or isolating people from them." (Document A, p.1)

"Items stored above 1.2 metres high and weighing over 5kg must be restrained in order to prevent them from falling onto the ground or personnel working beneath.” (Document B, p.2)

Sub-Theme 2.2: Structural considerations

Improving structural integrity was highlighted in most of the reviewed documents (n=15, 88%) as essential for reducing the risk of earthquake injuries. The most detailed guidance was provided in resources produced by MBIE, which included procedures for conducting seismic assessments, guidance on interpreting building performance standards, and compliance pathways for strengthening earthquake-prone structures.

"Retrofitting older buildings to meet modern earthquake resilience standards is essential." (Document P, p.2)

“Explore options to reduce or avoid the use of vulnerable buildings. Implement temporary and permanent mitigation measures, such as closing risky areas or implementing structural improvements. Involve engineers to assess the effectiveness of proposed measures.” (Document G, p.10)

Theme 3: Contingency planning for earthquakes

Contingency planning was another focus in the reviewed documents, with advice covering two main areas: the pre-earthquake phase and the post-earthquake phase.

Sub-Theme 3.1: Pre-earthquake contingency plans

All of the reviewed documents highlighted the need for contingency planning, particularly for earthquakes, although the level of detail varied. Documents from insurance providers and the National Emergency Management Agency (NEMA) were particularly specific, offering clear recommendations on what should be included.

> *"If you're an employer, you need to prepare for emergencies… This may include practicing earthquake drills, preparing survival kits, keeping up-to-date contact information, and having appropriate plans and procedures in place… Key vulnerabilities should be integrated into emergency response plans." (Document L, p.3)*

Sub-Theme 3.2: Post-earthquake response plans

Post-earthquake responses were addressed in fewer documents (n=6, 35%). These documents discussed the need for having plans in place to ensure quick and coordinated action after an earthquake, such as providing urgent medical care if needed and protecting people from immediate post-earthquake hazards.

> *"If an earthquake has caused stock to fall from shelves, even if there is no apparent rack damage, it is recommended that the store should be immediately closed to the public, the racking system should be inspected, and stored items need to be checked for their stability." (Document B, p.3)*

Theme 4: Integration of Technology

The integration of technology emerged as a cross-cutting theme across the documents, with recommendations for using technological solutions to improve efficiency in two main areas. The first includes hazard identification.

> *"Implement ground-shaking alert systems for real-time building status updates." (Document I, p.3)*

The second focuses on control of hazards.

> *"Install seismically activated automatic shut-off valves for hazardous liquid and gas systems." (Document J, p.4)*

Theme 5: Training

Training was similarly described across the documents as vital for equipping employees with the knowledge and skills required to identify hazards, implement risk reduction measures, and respond effectively during and after an earthquake.

> *"Training staff to identify hazards and conduct immediate action drills is crucial." (Document K, p.1)*

Theme 6: Communication and coordination

Effective communication, both within the workplace and with external stakeholders, was the final cross-cutting theme identified in the reviewed documents.

Sub-Theme 6.1: Internal communication and coordination

Clear and open communication within organisations was consistently highlighted as important for building trust and maintaining a unified approach to managing earthquake-related hazards.

> *"The best approach is to be open and honest with building occupants. Key messages should include: the information you have [about safety risks], what you know, what you don't know, the decision-making process, and the risk management measures being taken." (Document F, p.16)*

Sub-Theme 6.2: External stakeholder engagement

Engaging with external stakeholders was another recurring point across many documents.

"Engage with local business owners, councils, Chambers of Commerce, and industry groups for information and idea sharing." (Document L, p.5)

Table 4 presents the thematic analysis, as identified across the reviewed documents

Table 4. Thematic summary of the document analysis

Main Theme	Category (Sub-theme)	Recommended actions (interventions)
Hazard identification	Pre-Occupancy building assessment	Conduct engineering assessments of buildings (pre/post-earthquake).
	Continuous monitoring and adaptation	Conduct regular safety audits. Monitor Civil Defence websites. Stay up to date with current events. Establish an incident reporting system.
Risk reduction actions	Structural hazards	Upgrade buildings to meet modern seismic standards. Close high-risk areas. Explore alternatives to vulnerable buildings (e.g., work from home options).
	Non-structural hazards	Secure heavy furniture, machinery, and shelving to prevent tipping. Maintain clear spaces under tables and desks. Store heavy items at lower heights. Regularly evaluate office layout and maintain clear exits. Restrain items stored above 1.2 metres high and weighing over 5kg. Engage experts to assess and secure specialised shelving and racking systems. Install protective barriers around hazardous substances to prevent spills.
Contingency plans for earthquakes	Pre-earthquake contingency plans	Develop an emergency plan. Stock and ensure accessibility of emergency supplies and equipment. Install emergency power backup. Discuss emergency procedures with staff. Mark emergency equipment locations, assembly points, and evacuation routes.
	Post-earthquake response plans	Provide first aid if needed. Restrict unauthorised access to building. Check for potential fire hazards caused by earthquakes.
Integration of technology	Use technological solutions	Install early warning systems. Install seismically activated automatic shut-off valves for hazardous liquid and gas distribution systems.
Training	Safety training	Educate workers on seismic risks, first aid, and emergency procedures Train staff on hazard identification and immediate action drills
Communication and Coordination	Internal communication and coordination	Ensure communication systems are in place and tested regularly, Involve employees in safety planning. Maintain up-to-date contact details. Engage with building owners and other tenants to discuss seismic risks.
	External stakeholder engagement	Discuss earthquake risks and response strategies with other businesses, and local authorities.

Haddon Matrix analysis

Building on the thematic findings, the Haddon Matrix was used to categorise the individual controls (interventions) outlined in the documents across three temporal phases (pre-earthquake, earthquake, and post-earthquake) and four domains (host, agent, physical environment, and social environment) of the matrix (Table 5). This helped to identify areas where the reviewed documents provided limited guidance.

Pre-Earthquake Phase: All 17 documents included guidance on primary prevention actions, addressing the agent (e.g., early warning systems), the host (e.g., worker training), the physical environment (e.g., structural reinforcements), and the social environment (e.g., coordination with other businesses). These recommendations, however, focused primarily on conventional indoor places of work such as offices and factories, with little consideration of how they would apply to other settings, including outdoor job sites, mobile workplaces, or remote work (e.g., home offices).

Earthquake Phase: Guidance on actions during an earthquake was almost entirely concentrated on the host domain (employee actions). All documents (100%, n=17) recommended the "Drop, Cover, and Hold" procedure. Some included adaptations for warehouse scenarios, but there was limited consideration of how the procedure might apply in outdoor or mobile places of work. Additionally, no specific guidance was found for individuals unable to follow standard "Drop, Cover, and Hold" procedures, such as those using mobility devices.

Post-Earthquake Phase: Only 59% (n=10) of the documents provided guidance on post-earthquake actions, mainly addressing the host (e.g., administering first aid) and the physical environment (e.g., checking for building damage). However, guidance on the agent (e.g., preparing for aftershocks) and the social environment (e.g., supporting injured employees in recovery and reintegration) was limited. As with the pre-earthquake phase, most recommendations were designed for traditional work settings such as offices, with little consideration of other work environments.

Table 5. Haddon Matrix applied to earthquake-related injury risk controls

Phase	Host (employees)	Agent (earthquake-related characteristics)	Physical environment (building structure, and content)	Social environment (workplace norms, policies, rules)
Pre-earthquake	16 documents Sample: Train workers on "Drop, Cover, and Hold" Conduct regular drills. Provide workers with basic first aid training.	5 Documents Sample: Monitor Civil Defence websites for earthquake and tsunami risk updates. Install and test early warning systems.	17 Documents Sample: Conduct structural assessments. Retrofit buildings. Install seismic bracing for equipment and furniture. Install automated shutdown systems for machinery and utilities.	17 Documents Sample: Ensure compliance with building codes. Develop emergency plans. Stockpile emergency supplies. Coordinate with local authorities, emergency responders, and other businesses.
Post-earthquake	10 Documents Sample: Provide immediate first aid to injured employees	No specific guidance	3 Documents Sample: Inspect buildings for structural and non-structural damage. Restrict unauthorised access.	No specific guidance

Fit-for-Purpose Assessment

Finally, the individual controls outlined in the documents and identified in the thematic analysis were reorganised using the HoC framework (NIOSH, 1973*).* This provided a systematic approach to

ranking the effectiveness of the controls according to the hierarchy set out in the HoC framework, from the most effective (elimination) to the least effective (PPE) (Figure 3).

Elimination: Elimination and substitution involve removing hazards entirely or replacing them with safer alternatives. None of the reviewed documents directly addressed these approaches, and many acknowledged that earthquakes impacts can be unpredictable, and even in work environments where significant safety improvements have been made, some hazards remain unavoidable. For instance, ground displacement caused by surface fault rupture was discussed as a hazard in areas with infrastructure constructed on blind fault lines, or fault lines that were previously unknown.

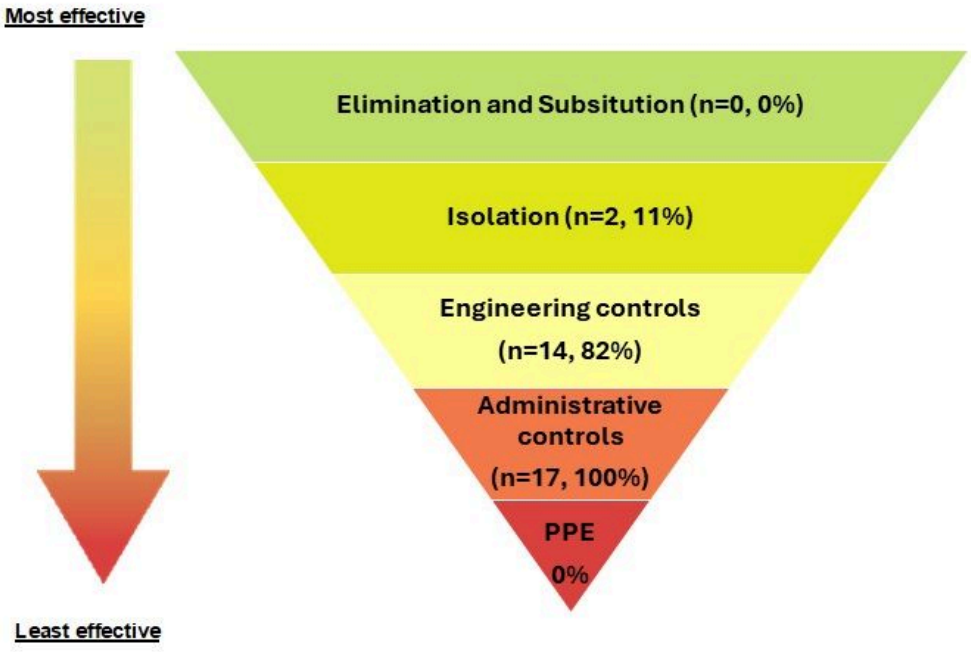
Isolation: Isolation controls, which aim to separate individuals from hazards, were discussed in two documents (12%). Recommendations included restricting access to structurally vulnerable areas of buildings until safety inspections could be conducted.

Engineering controls: Engineering controls involve physical modifications to the environment or infrastructure to minimise the risk of injury. Fourteen documents (82%) included guidance on these measures, such as retrofitting buildings to improve seismic performance, securing heavy equipment, and installing automatic shut-off systems for utilities and machinery.

Administrative Controls: Administrative controls involve changes to workplace procedures, policies, and practices to limit hazard exposure. These controls were the most frequently discussed, covered in all 17 documents (100%). Common recommendations included employee training programs, and stockpiling of emergency supplies.

Personal Protective Equipment (PPE): None of the reviewed documents provided specific guidance on the use PPE for earthquake-related hazards. Where PPE was mentioned, it was only in the context of response-related tasks, such as post-earthquake cleanup.

Figure 3. Distribution of identified interventions across the Hierarchy of Controls framework



Discussion

This study is the first systematic review of workplace guidance documents in NZ that addresses how PCBUs can identify earthquake-related hazards and implement actions to reduce injury risks. A total of 17 documents were reviewed, from which six guidance areas were identified: hazard identification, risk reduction actions, contingency planning, technology integration, training, and communication and coordination. The HoC framework was used to assess the effectiveness of the individual controls outlined in the reviewed documents. The analysis showed that administrative controls were universally included, while higher-order controls were less frequently addressed. Further analysis

using the Haddon Matrix revealed that pre-earthquake actions were covered in all documents, but post-earthquake actions were less comprehensively addressed (59%, n=10).

Under the HSWA 2015, PCBUs are required to identify hazards as part of their duty to manage risks (HSWA 2015, s.30(1)). The reviewed documents outline practical steps, such as pre-occupancy building assessments and equipment and machinery inspections to help them fulfil this obligation. This guidance, however, was largely based on the assumption that most work occurs in traditional environments, such as offices or factories, where workflows are predictable, and layouts are defined and controlled. While this may have reflected past norms, it does not account for the growing diversity of modern work environments. For example, over 40% of NZ employers now offer remote work options, highlighting a shift toward home-based work environments (Stats NZ, 2023). Although all work and workplaces fall under the HSWA 2015 unless specifically excluded *(HSWA 2015, s.20(1)-(2))*, current guidance does not adequately address the unique hazards associated with these evolving workplace contexts and locations. Closing this gap is critical to ensuring that all workplaces, regardless of setting, are equipped to meet their obligations under the HSWA 2015.

Following hazard identification, the reviewed documents outlined similar strategies for hazard control, often emphasising administrative actions such as emergency planning and training. While these measures are practical and relatively easy to implement, they are among the least effective options for controlling injury risk within the HoC, as they primarily rely on behavioural changes rather than addressing the hazard at its source (NIOSH, 1973). In contrast, the HSWA 2015 establishes a preference for higher-order controls, such as elimination, substitution, and engineering measures, which directly address hazards at their source (HSWA 2015, s.30(1)). Although the occurrence of earthquakes themselves cannot be eliminated, the risks of injury to workers and bystanders posed by damaging earthquakes can be significantly reduced through consideration of the whole HoC. This can be achieved through substituting seismically vulnerable buildings with safer structures (Bowden, 2011) or engineering controls such as seismic retrofits within existing buildings (Khan, 2018). Encouraging businesses to implement substitution and engineering controls, where practicable, allows for more effective control of injury risks, aligning guidance more closely with the intent of the HSWA 2015.

Even with effective hazard identification and control strategies, the unpredictability of earthquakes and the impacts they generate remains a challenge. This was acknowledged in the reviewed documents, which consistently highlighted the importance of planning for emergencies, such as earthquakes. Nonetheless, limited guidance was provided preparing for secondary hazards, including aftershocks, landslides, liquefaction, and tsunamis. These secondary hazards are account for nearly 40% of earthquake-related fatalities globally (Daniell et al., 2017). Similarly, the reviewed documents offered limited guidance on how workplaces can support injured employees in their recovery and reintegration into the workforce. Research shows that return-to-work programs following earthquake injuries help reduce long-term health risks, including chronic pain and musculoskeletal disorders, while also lowering the risk of re-injury (Nunnerley et al., 2016, Reinhardt et al., 2022). Beyond physical recovery, the psychological impacts of earthquakes on employees were a missing consideration, as such emergencies can lead to significant stress and anxiety among workers (Brooks et al., 2019). The lack of clear guidance on what PCBUs should do following an earthquake could prolong injury recovery times and increase the risk of further injuries.

Finally, across the reviewed documents, there was broad recognition that the hazards generated during earthquakes vary across different work settings. Nevertheless, several cross-cutting recommendations were outlined for reducing the risk of injuries. These include: (1) training employees on what to do before, during, and after an earthquake; (2) sharing information and collaborating within the workplace and with external stakeholders; and (3) using technology to improve injury risk management. These recommendations reflect a shared objective across the guidance documents: to ensure workplaces take informed, proactive, and coordinated steps to manage earthquake-related hazards effectively.

Implications for Occupational Health and Safety practitioners

The findings of this study carry several important implications for Occupational Health and Safety (OHS) practitioners in NZ. Under the HSWA 2015, PCBUs are required to manage health and safety risks by eliminating them so far as is reasonably practicable or, where elimination is not feasible, minimising them to the greatest extent possible (HSWA 2015, s.30(1)). This study shows that while current guidance provides an initial starting point for managing earthquake-related risks, it predominantly relies on lower-order controls, missing opportunities to implement more effective measures for injury prevention. Strengthening guidance to place greater emphasis on higher-order

controls would not only reduce the risk of injury but also better align workplace safety practices with the requirements of the HSWA 2015.

Beyond the need for more effective controls, OHS practitioners must also account for the changing nature of work environments. As workplaces extend beyond traditional office settings, guidance must evolve to address hazards specific to these locations. Another gap identified in this study is the lack of comprehensive guidance for managing risks across all phases of an earthquake, including recovery. Addressing this gap is necessary to ensure that businesses can effectively support workers and minimise long-term health and safety risks in the aftermath of an earthquake.

These findings also have broader implications beyond earthquake-related risks. The methodological frameworks used in this study, including the HoC and the Haddon Matrix, provide a worked example of how OHS practitioners can evaluate guidance in other areas of OHS concern. This study demonstrates how these frameworks can be applied more broadly to identify the strengths and gaps in organisational guidance documents, as well as identify appropriate actions for injury prevention and safety control.

Conclusions

The reviewed documents outline six key areas where workplaces can take steps to reduce the risk of earthquake-related injuries: hazard identification, risk reduction actions, contingency planning, worker training, technology use, and communication. However, further analysis using the HoC and the Haddon Matrix reveals that current resources often do not prioritise higher-order controls and fail to fully consider the diversity of modern work environments. Additionally, they lack comprehensive strategies for addressing risks across all phases of an earthquake (before, during, and after). To better protect workers and meet their obligations under the HSWA 2015, businesses need improved guidance that emphasises more effective controls, reflects the evolving nature of work settings, and provides comprehensive strategies for managing risks across all the phases of an earthquake.

Funding sources

This project was (partially) supported by Te Hiranga Rū QuakeCoRE, an Aotearoa New Zealand Tertiary Education Commission-funded Centre. This is QuakeCoRE publication number 1034.

Conflicts of interest

None

Author contributions

Conceptualisation AK, RL, CO; Investigation AK; Methodology AK, RL; Supervision AK; RL, CO, GD; Validation RL, CO, GD; Visualisation AK; Writing – original draft AK; Writing – review & editing AK, RL, CO, GD

Acknowledgment

The authors would like to thank Christy Ballard, Subject Librarian at the Health Sciences Library, University of Otago, for her assistance in developing the search strategy for this study.

References

Abeling, S., Horspool, N., Johnston, D., Dizhur, D., Wilson, N., Clement, C. & Ingham, J. 2020. Patterns of earthquake-related mortality at a whole-country level: New Zealand, 1840–2017. *Earthquake Spectra,* 36**,** 138-163.

Alert Media. 2023. *Earthquake Drill Procedures in the Workplace* [Online]. Available: https://www.alertmedia.com/blog/earthquake-drill/ [Accessed 17/11 2023].

Bowden, S. 2011. Aftershock: Business relocation decisions in the wake of the February 2011 Christchurch earthquake. *Journal of Management & Organization,* 17**,** 857-863.

Bowen, G. A. 2009. Document Analysis as a Qualitative Research Method. *Qualitative Research Journal,* 9**,** 27-40.

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology,* 3**,** 77-101.

Brooks, S. K., Dunn, R., Amlôt, R., Rubin, G. J. & Greenberg, N. 2019. Protecting the psychological wellbeing of staff exposed to disaster or emergency at work: a qualitative study. *BMC Psychology,* 7.

Clement, C., Abeling, S., Deely, J., Teng, A., Thomson, G., Johnston, D. & Wilson, N. 2019. Descriptive Epidemiology of New Zealand's Highest Mortality Earthquake: Hawke's Bay in 1931. *Scientific Reports,* 9**,** 4914.

Dalglish, S. L., Khalid, H. & McMahon, S. A. 2021. Document analysis in health policy research: the READ approach. *Health Policy and Planning,* 35**,** 1424-1431.

Daniell, J. E., Schaefer, A. M. & Wenzel, F. 2017. Losses associated with secondary effects in earthquakes. *Frontiers in Built Environment,* 3**,** 30.

Dexters' Safety and Protection. 2019. *How to Set Up an Earthquake Emergency Plan* [Online]. Available: https://dexters.co.nz/blog/edition-10-warehouses-and-factories-how-to-set-up-an-earthquake-emergency-plan-on-paper-online-or-using-a-safety-app/ [Accessed 07/11 2023].

Disaster Prepare 2018. Seismic Bracing for Building Contents. *Disasaster Prepare Ltd.* New Zealand.

Goode, N., Salmon, P. M., Lenné, M. G. & Finch, C. F. 2015. Looking Beyond People, Equipment and Environment: Is a Systems Theory Model of Accident Causation Required to Understand Injuries and Near Misses During Outdoor Activities? *Procedia Manufacturing,* 3**,** 1125-1131.

Grillone, G., Muratore, A., & Nastasi, V. 2020. Seismic risk assessment in workplaces. *Proceedings of the 30th European Safety and Reliability Conference and 15th Probabilistic Safety Assessment and Management Conference.* Venezia, Italy.

Haddon, W., Jr. 1968. The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. *Am J Public Health Nations Health,* 58**,** 1431-8.

Health and Safety at Work Act 2015. Available at: https://www.legislation.govt.nz/act/public/2015/0070/latest/DLM5976660.html [Accessed 16 Jan. 2025].

Health and Safety at Work Act 2015, s.20(1)-(2). Available at: https://www.legislation.govt.nz/act/public/2015/0070/latest/DLM5976660.html [Accessed 16 Jan. 2025].

Health and Safety at Work Act 2015, s.36(1). Available at: https://www.legislation.govt.nz/act/public/2015/0070/latest/DLM5976660.html [Accessed 16 Jan. 2025].

Health and Safety at Work (General Risk and Workplace Management) Regulations 2016. Available at: https://www.legislation.govt.nz/regulation/public/2016/0013/latest/DLM6727382.html [Accessed 16 Jan. 2025].

Horsfall, S., Hatton, T., Collins, T. & Brown, C. 2022. Is health and safety legislation an effective tool for disaster risk reduction? A case study from New Zealand. *International Journal of Disaster Risk Reduction,* 70**,** 102773.

Horspool, N., Elwood, K., Johnston, D., Deely, J. & Ardagh, M. 2020. Factors influencing casualty risk in the 14th November 2016 MW7.8 Kaikōura, New Zealand earthquake. *International Journal of Disaster Risk Reduction,* 51**,** 101917.

Khan, A. A. 2018. The geo-genetic status of earthquake-related hazards and the role of human and policy dimensions in impact mitigation. *Environmental Hazards,* 17**,** 276-291.

Manfredi, V., Nicodemo, G. & Masi, A. 2023. Estimation of human casualties due to earthquakes: overview and application of literature models with emphasis on occupancy rate. *Safety,* 9**,** 82.

MBIE 2017. Priority Buildings: A Guide to the Earthquake-Prone Building Provisions of the Building Act 2004. Ministry of Business, Innovation and Employment: New Zealand.

MBIE 2022. Seismic Risk Guidance for Buildings - Using Seismic Assessments in Occupancy Decision-Making. Ministry of Business, Innovation and Employment: New Zealand.

McDougall, G. & Batchelar, W. 2020. Responding to an Earthquake-Prone Building Notification: A Guide for Building Owners. New Zealand: QuakeCentre.

National Emergency Management Agency. 2023. *Shakeout Information for Businesses and Organizations* [Online]. Available: https://getready.govt.nz/en/involved/shakeout/how-to-shakeout/shakeout-information-for-businesses-and-organisations [Accessed 11/11 2023].

National Institute for Occupational Safety and Health (NIOSH). 1973. *Hierarchy of Controls* [Online]. United State: Centers for Disease Control and Prevention (CDC). Available: https://www.cdc.gov/niosh/hierarchy-of-controls/about/index.html [Accessed 12/02 2025].

New Zealand Insurance 2019. Earthquake Checklist. New Zealand Insurance Risk Solutions: New Zealand.

Nunnerley, J., Dunn, J., McPherson, K., Hooper, G. & Woodfield, T. 2016. Return to work for severely injured survivors of the Christchurch earthquake: influences in the first 2 years. *Disability and Rehabilitation,* 38**,** 987-993.

Peek-Asa, C., Ramirez, M., Seligson, H. & Shoaf, K. 2003. Seismic, structural, and individual factors associated with earthquake related injury. *Injury Prevention,* 9**,** 62-66.

Ramirez, M. & Peek-Asa, C. 2005. Epidemiology of Traumatic Injuries from Earthquakes. *Epidemiologic Reviews,* 27**,** 47-55.

Reinhardt, J., Zhang, X., Chen, S., Li, J., Zhou, M. & Khan, F. 2022. Long-term effectiveness of rehabilitation services delivery for Wenchuan earthquake survivors with impairments over a 4-year period: a prospective cohort study. *BMJ Open,* 12**,** e057158.

Resilient Organisations 2021. Earthquake Preparedness Checklist. *Resilient Organisations.* New Zealand.

SaferMe. 2015. *Earthquakes toolbox talk- A simple, 5 minute outline of what to cover in a toolbox talk on Earthquakes* [Online]. Available: https://www.safer.me/toolbox-talk/earthquakes/ [Accessed 22/12 2023].

Sentinel. n.d.-a. *Preparing Your Business for Fast Earthquake Reactions - A Guide for Building Owners* [Online]. Available: https://insights.sentinel.net.nz/preparing-your-business-for-fast-earthquake-reactions [Accessed 18/12 2023].

Sentinel. n.d.-b. *Preparing Your Business for Fast Earthquake Reactions - A Guide for Business Owners* [Online]. Available: https://insights.sentinel.net.nz/preparing-your-business-for-fast-earthquake-reactions [Accessed 18/12 2023].

Standards New Zealand 1994. Seismic Restraint of Building Contents NZS4104:1994. New Zealand.

Standards New Zealand 2004. Structural Design Action - Earthquake Actions NZS 170.5:2004 New Zealand.

Standards New Zealand 2009. Seismic Restraint of Engineering Contents NZS4219:2009. New Zealand.

Stats NZ. 2023. *Businesses offer employees work style choices* [Online]. Available: https://www.stats.govt.nz/news/businesses-offer-employees-work-style-choices/ [Accessed 21 Nov 2024].

Witze, A. 2017. Ripple effects of New Zealand earthquake continue to this day. *Nature,* 544**,** 402-403.

WorkSafe 2016. Stacking and Shelving to withstand Earthquakes. New Zealand. Available: https://www.worksafe.govt.nz/topic-and-industry/building-and-construction/building-restraint

WorkSafe 2018. Dealing with earthquake-related health and safety risks. New Zealand. Available: https://www.surveyspatialnz.org/Attachment?Action=Download&Attachment_id=2520

Yeow, T., Baird, A., Ferner, H., Ardagh, M., Deely, J. & Johnston, D. 2020. Cause and level of treatment of injuries from earthquake damage to commercial buildings in New Zealand. *Earthquake Spectra,* 36**,** 1254-1270.