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A Work Systems Hierarchy of Controls: Analysis of Risk Controls Developed by Paramedics

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ABSTRACT

Background: The hierarchy of control (HOC) is a fundamental construct in work health and safety practice and central for employers to manage risk to the health and safety of workers in Australia, to fulfil their legal obligations. The current HOC has been identified as more effective for developing risk controls for physical hazards than for psychosocial hazards.

Methods: To address this limitation, this study involved development and testing of a more comprehensive hierarchy of risk control. The work systems hierarchy of control (WS-HOC) includes three hierarchical levels; elimination, re-design of systems and individual actions. Non-hierarchical categories within levels were developed to distinguish different risk control options, suitable for both physical and psychosocial hazards. Using the WS-HOC, risk controls developed by paramedics to address physical and psychosocial hazards associated with work-related musculoskeletal disorders were analyzed. These risk controls were developed using the APHIRM (A Participative Hazard Identification and Risk Management) toolkit in an ambulance service.

Results: The WS-HOC provided a single, contemporary, nuanced approach to evaluating the risk controls for paramedics and their likely effectiveness, regardless of the type of hazard.

Conclusions: This novel approach provides an alternative to previous attempts at supplementing the HOC to improve its application to psychosocial hazards. Further evaluation is required by both practitioners and researchers to examine its utility for other, different occupations.

1 | Introduction

More than 1.71 billion people worldwide experience a musculoskeletal condition leading to outcomes that include early retirement, disability, and reduced ability to participate in society [1]. Work-related musculoskeletal disorders (WMSDs) are a major workplace problem requiring the management of their significant impacts on health and productivity [2–4]. However, common workplace practices used for WMSD prevention often omit key evidence-based requirements including the need to address psychosocial hazards and to involve workers in risk management, continuing instead to use ineffective risk controls such as training [5, 6].

Paramedics, and more generally employees in the healthcare sector, are recognized as having high rates of WMSDs [7–11]. The evaluation of the impact of risk controls to prevent WMSDs in paramedics is not a new research focus. Previous work has examined stretcher design [10], manual handling of bariatric patients [12], mountain rescue stretchers [13], portable emergency care

pods, packs and units [14], stretcher loading [15, 16], ambulance design [17–19], and paramedic kit bags [20]. Despite this breadth of research, a practical source of industry-specific guidance addressing all aspects of pre-hospital work (tasks, systems, equipment, people, environment) to assist ambulance services to efficiently identify the most suitable and effective risk controls to optimize the musculoskeletal health of the workforce is currently unavailable.

1.1 | The Hierarchy of Control—Reach and Application

The hierarchy of control (HOC) was developed in the 1950s, for use by employers across all industries, to guide the selection of risk controls to address physical hazards [21, 22]. Model regulatory material published by Safe Work Australia, the national body responsible for the development of policy relating to work health and safety and workers' compensation in Australia, promotes the HOC as a key construct to inform the development of appropriate risk controls to reduce the risk of injury to workers [23]. This Australian-model regulatory material and similar ones used in other countries [24–26] state that "higher order" risk controls (i.e., elimination, substitution and engineering risk controls) are more effective, providing increased protection and reliability, when compared to "lower order," less effective risk controls (i.e., administrative risk controls; those reliant on people). The conventional HOC proposes that an employee's performance is variable; thus, risk controls dependent on people are unreliable, less desirable and less effective [27]. This approach contradicts the objective of human factors and ergonomics, to optimize human and system performance [28].

The HOC has been identified as suitable for "individual" hazards (e.g., hazardous chemicals, radiation, working at heights) when safety operates in a model of centralized control [29]. However, individual hazard management is not appropriate for problems with complex etiologies such as WMSDs. The original concept of the HOC has been modified over time for specific purposes and contexts. The National Institute of Occupational Safety and Health (NIOSH) proposed a HOC applied to "Total Worker Health" (TWH), to act as a companion to the conventional HOC and to highlight organizational interventions that broadly advance worker wellbeing, alongside the traditional occupational safety focus of the conventional HOC [30]. The HOC applied to TWH was revised to produce a psychosocial HOC (P-HOC), which was used to evaluate risk controls developed by Danish employers [22]. The P-HOC was developed following a scoping review and synthesis of evidence about the effectiveness of interventions to address psychosocial hazards and is therefore hazard-specific. In healthcare, a modified action hierarchy, based on the HOC, has been proposed for patient safety incidents [31]. Similarly to the P-HOC, the Government Health and Safety Lead in New Zealand developed a modified HOC [32] to guide employers on the selection of risk controls to address psychosocial hazards and risks to psychological health and safety.

While both complementary and hazard specific HOCs have been developed to address organizational and psychosocial hazards, this approach requires practitioners to refer to two or more HOCs, increasing workload and potentially creating confusion as different hazards, within the same complex environment, need to be considered under different HOCs. To minimize these potential issues, a "hazard agnostic" approach may be beneficial. The concept of a hazard agnostic approach has recently been promoted in emergency management [33] and urban systems [34], to address these complex systems.

1.2 | The Importance of Psychosocial Hazards

Psychosocial hazards have been described as those "arising from or in relation to the design or management of work; the working environment; plant at a workplace, or, workplace interactions or behaviors" [35] (p. 5). The HOC is not referred to in recent model Australian regulatory material about psychosocial hazard and risk management [35]. This is also the case in Australian guidance about "good work design" [36], which aims to address both physical and psychosocial hazards through the design of work systems. Arguably, the absence of the HOC from these key Australian materials, and also the modification of the HOC to suit psychosocial hazards in other countries [22, 32], raises a concern about the utility of the HOC to assist employers to select appropriate risk controls to address all hazards identified in work systems.

Addressing psychosocial hazards and risks in the workplace to reduce work-related stress and improve mental health is of critical importance [37, 38] and a major focus of policy and regulatory bodies [35, 39, 40]. Extensive evidence demonstrates the importance of psychosocial hazards (i.e., workload, relationships or behaviors) in WMSD development [41–46]. A multi-jurisdictional review of the HOC, in the context of suitability to prevent WMSDs, found considerable variation in both the content and the degree of focus on organizational or systems interventions [21]. Although Australian codes of practice designed to address WMSD prevention [47, 48] identify multiple contributory factors, they promote a focus on tasks and identification of discrete hazards, rather than the interaction of hazards which affect workers in work systems [49]. Confusion about the application of the HOC to develop effective risk controls for psychosocial hazards, along with the difficulty applying the HOC to the complex etiology of WMSDs, may explain the limited use of "higher order" risk controls and preference for "lower order" risk controls, found when examining risk management practices that aimed to prevent WMSDs in Australia [5].

1.3 | The Case for Modifying the Hierarchy of Control

The current situation creates potential conflict for those with work health and safety duties because the HOC is potentially not fit for purpose for use with psychosocial hazards [22], nor suitable when considering work systems [36] and yet, the HOC must be used (according to Australian work health and safety (WHS) regulatory requirements), when developing and implementing controls for all occupational hazards [23]. This includes addressing WMSDs, where both physical and psychosocial hazards are important.

The conventional HOC is based on the premise that "lower order" risk controls reliant on people are inferior [27]. In contrast, current health and safety practice highlights the importance of the interactions of people with work systems when managing health and safety risk [29, 36, 50–53], including physical and psychosocial hazards [36, 54], and WMSDs [4]. Currently, a clear link between these contemporary concepts and the HOC is not presented, which could lead to confusion in the selection of effective risk controls for WMSDs and other work-related conditions such as mental health disorders.

Additional HOCs to complement the use of the conventional HOC have been developed (e.g., HOC applied to TWH [30], P-HOC [22]) and these were considered for use in this study. The HOC applied to TWH has been proposed as a companion to the conventional HOC and suitable for WMSDs [30]. However, we propose that a single HOC, that is flexible for use for all physical or psychosocial hazards (or group of concurrent or interacting hazards, as is common in work systems) is needed. Similarly, the P-HOC [22] was discounted for application in this study as it was developed for use exclusively with psychosocial hazards and does not address physical hazards.

Rather than using a companion HOC, this study modifies the conventional HOC so that it can be applied to any type of hazard and then tests the modified version by classifying an existing set of risk controls. We aim to progress the design of the conventional HOC to address the needs of duty holders, health and safety professionals and regulators; to develop and evaluate the potential effectiveness of risk controls that address both physical and psychosocial hazards. We propose that grounding this progression of the HOC in human factors and ergonomics principles will result in alignment to contemporary practice which aims to improve work design, human and system performance.

1.4 | Aims

The aim of this study is to classify the risk controls generated by paramedics using the APHIRM toolkit [55] for their likely effectiveness, using a modified HOC. The APHIRM toolkit [5] was developed to support the comprehensive identification of physical and psychosocial hazards relevant to addressing WMSDs, and the development of risk controls to address the hazards. The toolkit uses a participatory ergonomics approach, involving workers in all aspects of risk management.

This study involves three steps:

1. Identify the challenges in using the HOC to classify risk controls for problems with complex etiologies such as WMSDs, using the jurisdiction in which the study was conducted to illustrate the practical considerations.
2. Develop a modified HOC to address the identified gaps in the practical application of the current HOC, enabling use for physical and psychosocial hazards, and in complex work systems.
3. Test the modified HOC, using risk controls previously developed by paramedics.

2 | Step 1: Review Current Hierarchy of Control

2.1 | Materials and Methods

One author (K.D.) reviewed the information about using the HOC to classify risk controls, contained in three Codes of Practice (hereafter known as a "code"); the general risk management code [56], the psychosocial hazards and risks code [57] and the hazardous manual tasks code [58]. All codes are published and enforced by the WHS Regulator in Queensland, Australia, where the study was undertaken. In Queensland, duty holders are required to comply with a code or use another approach that is equivalent to or higher than the standard in the code, and for this reason, codes can be used in court proceedings [59].

The review involved reading all sections in each code related to developing risk controls and classifying them using the HOC, including examples. The review then identified any differences between the codes, for example, statements relating to the HOC, the examples used, and the link between the HOC levels and the examples. Consideration was given to a second author conducting the review and comparing the findings. However, it was determined that the approach using one author was most appropriate and pragmatic, as it aligned to the usual practice of a WHS professional when advising an employer how to manage hazards and risks according to regulatory requirements.

2.2 | Results

The results of the review of the three codes are presented in Table 1, including statements made in the codes about the HOC and a brief commentary about the examples of risk controls provided in the code.

The statements about the HOC in all three codes consistently emphasize that duty holders in Queensland must apply the HOC to all hazards. All codes state that risk controls higher on the HOC are more effective and reliable than those at a lower level (i.e., administrative controls and PPE), because lower order controls do not control the hazard at the source and rely on human behavior and supervision.

Risk controls to address physical hazards are a strong focus of the general code [56] and the hazardous manual tasks code [58]. In these codes, examples demonstrate higher order risk controls to address these hazards, that are clearly identified by their position on the HOC. For example, the general code mentions that paint type can be substituted, guards and barriers can isolate people from hazards and that engineering controls including sound dampening measures, trolleys and hoists can minimize risk. The hazardous manual tasks code [58] provides examples of substituting heavier items with lighter ones, isolating machinery and using engineering controls such as mechanical aids.

In contrast to physical hazards, the general code [56] and hazardous manual tasks code [58] provide few examples of risk controls to address psychosocial hazards. Comprehensive examples of risk controls are provided in the psychosocial

TABLE 1 | Comparison of three codes of practice in queensland related to the prevention of WMSDs.

Code of Practice	Statements related to the HOC in the code	Examples in the code - commentary
How to manage work health and safety risks [56]	"The ways of controlling risks are ranked from the highest level of protection and reliability to the lowest...This ranking is known as the HOC measures. The HOC can be applied in relation to any risk." (p. 18) Definition of control measure – "An action taken to eliminate or minimise health and safety risks so far as reasonably practicable. A HOC measures is set out in the WHS Regulation to assist duty holders to select the highest control measures reasonably practicable." (p. 26) "The lower levels of the hierarchy are less effective because controls that change the hazard or minimise exposure to the hazard can only minimise the risk. Administrative controls and Personal Protective Equipment (PPE) are the least effective at minimizing risk because they do not control the hazard at the source and rely on human behavior and supervision." (p. 19)	Examples of substitution, isolation and engineering almost exclusively focus on physical hazards. (p. 19) Examples of administrative controls include work methods or procedures designed to minimize exposure to a hazard; implement anti-bullying policies; limit exposure time to a hazardous task. (p. 20) Appendix C—Example involves several control measures that are ambiguous as to their level on the HOC. The HOC is referred to in the introduction to the example. However, the level of each control measure in the example, according to the HOC, is not listed. For example, providing specific training, information to customers and procedures for managing difficult customers. (pp.37)
Managing the risk of psychosocial hazards at work [57]	"The HOC must be followed if it is not reasonably practicable to eliminate psychosocial risk." (p. 28) "The HOC ranks control measures from the highest level of protection and reliability to the lowest...," including isolating or substituting the hazard or reducing the risks by engineering controls. (p. 28) "Administrative control measures and PPE do not control the hazard at the source. They rely on human behavior and supervision and used on their own tend to be the least effective in minimizing risks." (p. 28)	Examples under substitution, isolation and engineering controls include "minimising psychosocial hazards through the design of work and work systems." (p. 29) Examples of administrative controls refer to "organisational policies and standard operating procedures that are designed to minimize exposure to a hazard," which contradicts the above. (p. 30) In the case studies in Appendix 2, the HOC is not used to distinguish the risk controls listed (they are not in any order). However, in Appendix 4 the control measure examples are stated to be listed in order of the HOC and yet when reviewing the actual examples, it is unclear which controls are assigned to the levels, as they are not labeled.
Hazardous manual tasks [58]	"The WHS Regulation requires duty holders to work through the HOC measures when managing certain risks, including risks from hazardous manual tasks." (p. 27) "The HOC ranks control measures from the highest level of protection and reliability to the lowest." (p. 27) "Administrative control measures and PPE do not control the hazard at the source. They rely on human behavior and supervision and used on their own tend to be the least effective in minimising risks." (p. 27)	The role of psychosocial hazards in the development of MSDs was not referred to in the code. Table 2 in code (p. 29)—Examples are included for all levels of the HOC but mainly focus on physical processes and items. In subsequent sections information on changing the system of work is provided, but it is not clear if this is an administrative control or a higher order control, as the examples are varied.

code [57] but these examples are not all clearly identified by their position on the HOC. In addition, when the HOC is mentioned, similar controls are allocated inconsistently, to higher and lower order levels. The code provides examples to demonstrate good work design and system design and classifies these as higher order risk controls. These include increasing the level of support in peak times, using trauma informed approaches, consulting workers about organizational change and allowing more time for task completion for novice workers. Although similar to the above examples (relying on human

intervention and supervision), changes to the work organization, such as task rotation and developing procedures to use devices and human resources, are positioned as administrative controls in the code, indicating that they are inferior in effectiveness and reliability. The reason for assigning these similar risk controls to different levels of the HOC is not clear.

The review revealed that the position of risk controls on the HOC is inconsistent and at times missing in the codes. This mainly occurs where controls involve the modification or redesign of work systems, processes and procedures to change exposure to a psychosocial hazard (including in ways that involve human behavior and supervision). Therefore, the authors concluded that the conventional HOC represented within the three codes was not suitable to evaluate risk controls to address psychosocial and physical hazards, as required for this study.

3 | Step 2: Development of a Modified Hierarchy of Control

3.1 | Materials and Methods

Drawing on previous work [30, 32] and considering the examples within relevant Queensland codes [56–58], a modified "work systems" HOC (WS-HOC), including alternate terms and descriptions, was developed. The WS-HOC was developed and tested using an iterative approach. Initially, all authors (who each had extensive experience in WHS and the application of the conventional HOC) independently evaluated the same sample of 10 risk controls and allocated each to one of the resultant three levels and then, if elimination was not possible, to one of several categories. Subsequently, all three authors met as a group to discuss chosen levels and categories (if appropriate), with each author explaining their reasoning for each allocation, enabling the team to identify potential areas for confusion and to resolve disagreements. Refinements were made to the levels and categories where necessary and the process repeated iteratively until consensus was reached on the number of levels and categories, the definitions, and the method of allocation of risk controls to levels and categories.

3.2 | Results

The final WS-HOC (Table 2) addresses the problem that existing HOCs may need to be used in combination, to cover all hazards [22, 32, 37]. The WS-HOC addresses this problem through progressing the design of a single, hazard agnostic HOC, rather than utilizing a complementary HOC such as the HOC applied to TWH [30] or the hazard specific P-HOC [22]. The WS-HOC includes two key changes; first to modify the levels of the hierarchy and secondly, to define nonhierarchical categories within levels.

The first change, drawing on previous work [22, 32, 37] resulted in the renaming of the terms "higher" and "lower" order controls to more descriptive levels of risk controls, "re-design work systems" and "individual actions." This change supports the implementation of established human factors and ergonomics principles [28]; reinforcing that the re-design of human centered systems is a preferred, effective risk control [36]. Similarly to the conventional HOC, the HOC applied to TWH and the P-HOC, the concept of a preferred order of risk controls has been retained in the WS-HOC. Through iterative testing, the authors developed and defined three distinct, hierarchical levels.

The preferred level, to eliminate the hazard remains unchanged at the top of the hierarchy. The second and third levels "re-design work systems" and "individual actions" focus on the target of the control (systems or individual), confirming that re-design, through any means, reduces exposure to a hazard with greater effect than individual action. This approach aligns to the focus of the HOC applied to TWH and the P-HOC, which emphasize the preference for organizational/systems risk controls over those targeted at individuals. The authors considered that the conventional HOC referred to several options for "higher order" controls (substitution, isolation and engineering); however, subsequent discussions concluded that none of these options was superior to another and all were intended to re-design the source of the problem. In fact, the HOC found in Australian regulatory materials [23], including those reviewed in this study [56–58], was noted to position these options as equal on the HOC. Therefore, we decided to develop an inclusive description of "re-design work systems," removing unnecessary levels. The third level of the WS-HOC was developed to place emphasis on the role of individual actions to "further minimize" exposure to the hazard and subsequent risk, supporting the implementation of the "re-design work systems" risk control. Positioning administrative controls as supportive of organizational and work systems controls, aligns to the HOC applied to TWH and the P-HOC, as well as guidance found in the Australian regulatory materials referred to previously [23, 57, 58].

Secondly, additional categories are provided within the second and third levels of the WS-HOC, to expand the range of risk controls to be considered. The level "re-design work systems" contains two categories ("optimize, replace or isolate the source of the hazard" and "additional or modified engineering solutions") and the level "individual actions" contains five categories ("training," "procedures," "supervision," "information," and "personal protective equipment - PPE"). Categories are not hierarchical and the use of more than one category is encouraged in the description of the second and third levels of the WS-HOC. The intended purpose of the categories is to assist those using the WS-HOC to discern all available options.

Descriptions within the WS-HOC were developed to reduce ambiguity, through being inclusive of a wide range of ways to address physical or psychosocial hazards. The term "hazard source" was included to clearly define the target of the risk control, including nonphysical hazards. The term "work characteristics" was chosen as it describes "Any cognitive, physical, psychological or biomechanical characteristic of work which contributes as a source of a hazard. A work characteristic may arise from a work task, work system, workplace, work environment, people and/or work plant/equipment," according to Australian guidance material about good work design [36].

TABLE 2 | Work Systems Hierarchy of Control (WS-HOC).

Level	Category	Description
Elimination	**The hazard is eliminated**	The work characteristic which is the source of the hazard is **eliminated.** Partial elimination should be used in combination with other categories. **Note:** Total elimination is not appropriate for all hazards. Optimization of the hazard state through re-design may be the most appropriate control.
Re-design work systems	**The hazard/risk is minimized by the design of work systems:**	**One or both options** below can be used. **Note:** The two categories within this level are **not** hierarchical.
	Optimize, replace or isolate the source of the hazard	The work characteristic which is the source of the hazard is **optimized**, **replaced and/or isolated**, through re-design of policies, programs, systems, practices and/or tasks.
	Additional or modified engineering solutions	The work characteristic which is the source of the hazard is addressed by using **additional or modified physical** infrastructure, plant or equipment.
Individual actions	**The hazard/risk is further minimized by implementing individual actions:**	**One or more options** below can be used. **Note:** The five categories within this level are **not** hierarchical.
	Training	**Training/instruction** is designed to provide workers with the skills to manage their exposure to hazards, by identifying work hazards and risks and implementing risk controls.
	Procedures	**Procedures/work instructions** are designed to provide workers with information to manage their exposure to hazards by identifying work hazards and risks and implementing risk controls.
	Supervision	**Supervision** requirements are designed to ensure that workers engage in the identification of hazards and implementation of risk controls, in accordance with procedures, work instructions and/or training
	Information	General **information** is provided to workers to encourage them to engage in actions and behaviors conducive to optimal health.
	Personal Protective Equipment	**PPE** is provided that eliminates or reduces the exposure of workers to a hazard or risk, when properly fitted, used and maintained.

Drawing on the examples found in the three codes reviewed in step 1, examples of risk controls for each level and category in the WS-HOC are provided in Table 3 below.

During the iterative testing process referred to in Section 3.1, some differences between authors emerged when deciding how to choose the most appropriate level on the WS-HOC. This was particularly evident when a proposed risk control involved a re-design and a training or procedural change. This informed the development of a working approach for step 3 of the study, to choose the highest level applicable to the risk control under consideration. Commonly, risk controls involve several related steps to achieve risk reduction; for example, the re-design of a work system or process, followed by circulation of written procedures, and/or implementation of training and supervision to support the change. In this case, the highest level of risk control would be "re-design work systems" not "individual actions." The examples provided in Table 3 demonstrate that a re-design risk control typically incorporates an individual action (such as training, a procedure or supervision).

4 | Step 3: Use the Work Systems Hierarchy of Control

4.1 | Materials and Methods

The APHIRM (A Participative Hazard Identification and Risk Management) toolkit [5] is a participatory ergonomics method which includes a four-step risk management process (required when managing hazards and risks in the workplace in Australia [48]) to address the physical and psychosocial hazards

TABLE 3 | WS-HOC with general examples of risk controls.

Level	Category	Example (not specific to this study)
Elimination	**The hazard is eliminated.**	1. The need to lift a piece of heavy equipment is eliminated from the role. 2. Self-service is introduced to eliminate workers delivering customer service.
Re-design work systems	**The hazard/risk is minimized by the design of work systems:**	
	Optimize, replace, or isolate the source of the hazard	1. The role workload is optimized through additional resourcing, roster design, and enabling workers to control their workflow. Manager training in systems is provided to enable supervision of the control. 2. A hazardous chemical is replaced by a nonhazardous chemical. 3. Less experienced workers are isolated from complex tasks, in their first 3 months of employment.
	Additional or modified engineering solutions	1. A manually propelled trolley is replaced with a motorized trolley and workers are trained in use. 2. Improving the work environment to reduce stressors (e.g., sound dampening; improved lighting; physical changes to improve safe customer interactions)
Individual actions	**The hazard/risk is further minimized by implementing individual actions:**	
	Training	1. Training is provided covering when, how and why to use the patient hoisting equipment including fault detection, inspection, cleaning, and storage requirements. 2. Training is provided for line managers about how to have difficult conversations using trauma-informed practices.
	Procedures	1. A standard operating procedure sets out how to undertake a dynamic risk assessment in the field and what to do when hazards are identified. 2. Organizational procedure sets out how reports of bullying will be managed.
	Supervision	1. A supervisory protocol sets out how to respond when workers identify hazards but do not implement risk controls. Supervisors actively promote processes at team huddles. 2. A supervisory protocol sets out how to identify and support workers exposed to occupational violence in the workplace.
	Information	1. A fact sheet is provided to workers encouraging them to utilize the optional annual health assessment service. 2. Information is provided in an easy-to-read format about how to access reporting options for harassment or bullying.
	Personal Protective Equipment	1. Workers are provided with hearing protection devices for use when they are concerned noise levels may be high or when signage requires. 2. Workers are provided with ready access to gloves, gowns and eye shields, to reduce stress associated with potential exposure to high risk biological hazards.

associated with WMSDs. The use of the toolkit aimed to improve the musculoskeletal health of paramedics, through workers identifying hazards and re-designing aspects of the work (tasks, systems, equipment, people, environment), by developing and implementing risk controls. A total of 79 risk controls were developed during the APHIRM implementation in an Australian ambulance service [55] and form the data for the current study. Ethics approval for the data collection [55] was granted by the La Trobe University Human Research Ethics Committee in June 2021 (HEC 21166).

Using the WS-HOC, one author (K.D.) independently assigned the 79 risk controls to one level of the WS-HOC, and when the level "re-design work systems" or "individual actions" was assigned, to one category in the WS-HOC. The highest level applicable to the risk control was selected (the working method identified in step 2); however, as noted in the WS-HOC, when the second level is selected, the third should also be selected if this further minimizes the risk. As described in the development of the WS-HOC, one or more categories within a level may be appropriate for a risk control. For example, a risk control measure may involve optimizing a work system and a modified engineering solution; however, for the purposes of the study, only one category was selected. The approach (select one level and one category for each risk control) was considered suitable for the purpose of the study which was to conduct an initial test of the WS-HOC using the risk controls available, rather than to evaluate in depth the suitability and implementation requirements of the specific risk controls developed by the paramedics.

Consideration was given to having each author assign the risk controls independently and comparing the results. As this study was preliminary, grounded in real-world practice, and conducted using definitions and method of classifying risk controls that were developed iteratively (including discussion between authors), the authors decided that it was appropriate that the classification was completed only by the author with detailed organizational and context knowledge.

4.2 | Results

None of the 79 risk controls were assigned to the level "elimination." The majority (42/79, 53%) of the risk controls were assigned to the level "re-design work systems" and slightly fewer (37/79, 47%) were assigned to "individual actions."

After assigning the risk controls to one WS-HOC level, they were assigned to an appropriate WS-HOC category. "Optimize, replace, isolate" was the most frequent category assigned (26/79, 33%) followed by "training" (17/79, 22%) and "engineering solutions" (16/79, 20%). Table 4 includes the number of risk controls assigned to each level and category and examples of the risk controls used to test the WS-HOC in this study.

5 | Discussion

This study aimed to identify and address the practical challenges of using the HOC to classify risk controls to reduce WMSD risk. A hazard agnostic, work systems HOC was developed and applied to a set of risk controls developed by paramedics who had used the APHIRM toolkit. The selection of the most suitable and effective risk controls to address physical and psychosocial hazards is an important part of reducing WMSD risk and a legislative requirement for Australian employers [60].

A review of three codes used by duty holders and health and safety professionals in Queensland, Australia, where the study was undertaken, found that information in the codes is particularly inconsistent and unclear when suggesting risk controls involving the modification or re-design of work systems, processes and procedures to change exposure to a psychosocial hazard, (including in ways that involve human behavior and supervision). There was clarity about how to classify risk controls to address physical hazards, using the HOC. This finding confirmed that the HOC, as applicable in Queensland, was not suitable to evaluate the risk controls included in this study, as both physical and psychosocial hazards need to be managed through suitable and effective risk controls, to address the risk of WMSD.

To address this problem, a single HOC was developed that was suitable for both physical and psychosocial hazards. Previous work was considered, including that undertaken to develop a complementary HOC [30] and a HOC suitable for psychosocial hazards [22, 32], publications including guidance material about good work design [36], and regulatory material about risk controls for psychosocial hazards [35, 57]. An iterative design process was used, with authors assigning samples of risk controls independently, comparing the results, discussing differences, refining the levels, categories, and descriptions, and reaching consensus on the final WS-HOC.

Two key changes resulted. First, three hierarchical levels ("elimination"; "re-design work systems"; "individual actions") replaced the conventional levels of "higher order" (elimination, substitution, isolation, and engineering controls) and "lower order" (administrative controls and PPE) risk controls. The levels, associated definitions and the examples developed in the WS-HOC were chosen to provide both clarity and to shift the focus away from whether a risk control relied on human action and toward a more contemporary approach, redesigning work and systems. The key term "work characteristic that is the source of the hazard" applies regardless of whether the target work characteristic (for risk control) is psychosocial, physical, related to the actions of people, or a combination of these. This provides one concept to cover all situations faced by duty holders, simplifying the process. Retaining the hierarchical framework in the WS-HOC maintains the current stated purpose of the HOC, to guide the selection of the most suitable and effective risk controls. This facilitates the continuation of the HOC concept and therefore, the familiar role the HOC has held in the Australian legislative framework for health and safety.

Secondly, nonhierarchical categories within two of the three hierarchical levels were developed to assist duty holders to discern various options in each level, in no preferred order. This serves an educative function, encouraging the use of several options to address one hazard source, to minimize the risk so far as reasonably practicable, which is the requirement when

TABLE 4 | Classification of risk controls using the WS-HOC.

Level	Category	*N*	Examples (specific to this study)[a]
Elimination	**The hazard is eliminated.**	0	
Re-design work systems	**The hazard/risk is minimized by the design of work systems:**		
	Optimize, replace or isolate the source of the hazard	26	1. Review and improve the access to facilities by paramedics at hospitals and ensure information about these arrangements is readily available to employees. 2. Enhance systems, scripts, and advice provided during telephone interactions with patients awaiting arrival of an ambulance, to optimize on-scene interactions. 3. Review the optimal approaches to access/select bags (containing clinical equipment) and stretchers in the field, to balance clinical care and physical loads, including when working as a single operator.
	Additional or modified engineering solutions	16	1. Explore alternate design of bags containing clinical equipment that are lifted and carried to scene to optimize postures, weights, etc., for employees who work as a single operator. 2. Explore options for additional stretcher features to improve handling and designs for extrication on outdoor trails. 3. Investigate options to reduce the weight of the defibrillator.
Individual actions	**The hazard/risk is further minimized by implementing individual actions:**		
	Training	17	1. Develop task-specific scenario-based training for high-risk manual handling tasks, e.g., extrication; working in tight spaces. 2. Develop a training video to demonstrate appropriate stocking of bags containing clinical equipment. 3. Develop a training package to demonstrate ways to de-escalate on-scene interactions following a period of time awaiting ambulance arrival.
	Procedures	0	
	Supervision	8	1. Develop and implement a supervisory checklist for ergonomic principles of working in the field. 2. Equip supervisors to provide ongoing support to their team, in the context of increased demand, complex social needs and ensuring high standards of professional practice.
	Information	10	1. Provide information to employees about health promotion measures for musculoskeletal health e.g., stretches, movement. 2. Provide information to supervisors about the scope of the available specialist services/alternate care pathways and the resultant systems of work, to improve understanding and teamwork.
	Personal Protective Equipment	2	1. Provide information and encouragement for employees to use knee padding options when kneeling is required.

[a]The risk controls have been re-worded for brevity for the purposes of this paper.

the hazard cannot be eliminated. The level "elimination" did not require categories, as this level of risk control achieves the elimination of the work characteristic identified as the source of the hazard.

Assigning the 79 risk controls included in the study to one level and one category of the WS-HOC provided the opportunity to test the utility of the tool in a real-world context, where both physical and psychosocial hazards required risk controls to reduce WMSD risk. All risk controls were assigned to the one level on the WS-HOC and in addition, for the levels "re-design work systems" and "individual actions," the most suitable category.

None of the risk controls were assigned to the "elimination" level, which is the preferred option on the WS-HOC. This finding was not unexpected; hazards are an inherent part of work in the pre-hospital environment, where care is provided to the community in a dynamic work context, with highly variable and challenging conditions beyond the control of the employees of the ambulance service [9, 61, 62].

More than half of the risk controls were assigned to the level "re-design work systems" and there was a strong focus on both of the categories in this level; "optimize, replace or isolate the source of the hazard" and "additional or modified engineering solutions." This finding is consistent with this study context because paramedics deliver frontline pre-hospital care in a variety of settings in the community, interacting with people, equipment, technology and organizational aspects of complex socio-technical systems [8].

Slightly less than half the risk controls were assigned to the level "individual actions." Among these, the category "training" was assigned most frequently, confirming that training is highly important to paramedics; however, suggestions about supervisory practices and information were also common. Paramedics are highly trained, autonomous healthcare workers, required to make evidence informed decisions in a vast array of circumstances [61, 63, 64] and therefore, ongoing training and supervision in the clinical and nonclinical aspects of the role is routine.

5.1 | Limitations

This novel study identified the need for and developed a modified HOC, which was tested on a set of risk controls developed by paramedics. However, as with all studies some limitations exist. The study was preliminary, modifying the conventional HOC in response to practical need in one organization, and, as a result, three key limitations should be considered when interpreting the results. First, one experienced practitioner with specific knowledge of the organization reviewed the three Codes and assigned the risk controls to one level of the WS-HOC, rather than several practitioners. Second, as this study was undertaken using a specific occupational group operating under state-based regulation, this may influence generalizability. Third, no comparison of the classification of risk controls using the conventional HOC and the WS-HOC was undertaken.

5.2 | Future Research

The HOC is a key construct in WHS requirements in Australia and other countries. However, the HOC has been supplemented by other HOCs, is not used in all countries, and at times it is referred to in a limited or alternate way [32, 35, 39, 40]. Future research could explore the reasons for the variation in application and the risk control outcomes achieved in jurisdictions that do and do not use the HOC. This study would inform whether the HOC is a construct to be continued and progressed (as was done in this study) or whether the HOC should be retired and replaced with other ways to support duty holders to select the most effective risk controls.

The importance of clear definitions and guidance for WHS methods has been highlighted, to enable stakeholders to work together to achieve health and safety outcomes [65]. If the HOC is to continue as a key construct, then an urgent need exists for research to develop consensus with various stakeholder groups about the design of the HOC, to ensure that it is suitable and effective for the purpose of assisting duty holders, WHS professionals, and regulators in the selection of risk controls suitable for all hazards, occupational groups and contemporary work systems. This study provides a starting point for future work.

In addition, further work is needed to fully understand the concept of the "effectiveness" of risk controls. Although the commonly espoused view is that risk controls higher on the conventional HOC are more effective, the HOC does not in itself address the issue of the effectiveness of the implementation of risk controls, particularly when they are positioned within complex socio-technical systems, such as healthcare. Further research could explore how to evaluate the effectiveness and the "reasonable practicability" of risk controls to address WMSDs.

6 | Conclusion

In conclusion, the authors propose that the conventional HOC is modifiable, through further research involving a range of end users and organizations, to ensure that it is fit for purpose as a means for assisting duty holders to select the most effective and reliable risk controls. The WS-HOC was developed to address problems identified when using the HOC to control psychosocial hazards and risks, and for problems with complex etiologies such as WMSDs. The WS-HOC is a potential solution, to provide clarification and address ambiguity, to complement what is currently contained within the examples in three codes [56–58] in Queensland, Australia where the study was conducted. The WS-HOC was applied to risk controls developed by paramedics to address physical and psychosocial hazards associated with WMSDs. The WS-HOC was designed as a single, hazard agnostic tool to highlight the importance of the redesign of systems of work in which people are key, reducing the chance that these useful risk controls would be misclassified as lower order, administrative controls and then discounted as ineffective.

Author Contributions

Karen Davies conceived and designed the study, with supervision provided by Jodi Oakman and Victoria Weale. All authors contributed to the acquisition, analysis, or interpretation of data for the work. Karen Davies led the writing of the paper, all authors contributed to revising it critically for accuracy and important intellectual content. All authors approved the final version to be published and all authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Disclosure

Karen Davies declares that at the time of this study she was an employee of the Queensland Ambulance Service. The other authors declare no conflicts of interest.

Disclosure by AJIM Editor of Record

John Meyer declares that he has no conflicts of interest in the review and publication decision regarding this article.

Ethics Statement

Ethics approval for the data collection was granted by the La Trobe University Human Research Ethics Committee in June 2021 (HEC 21166).

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