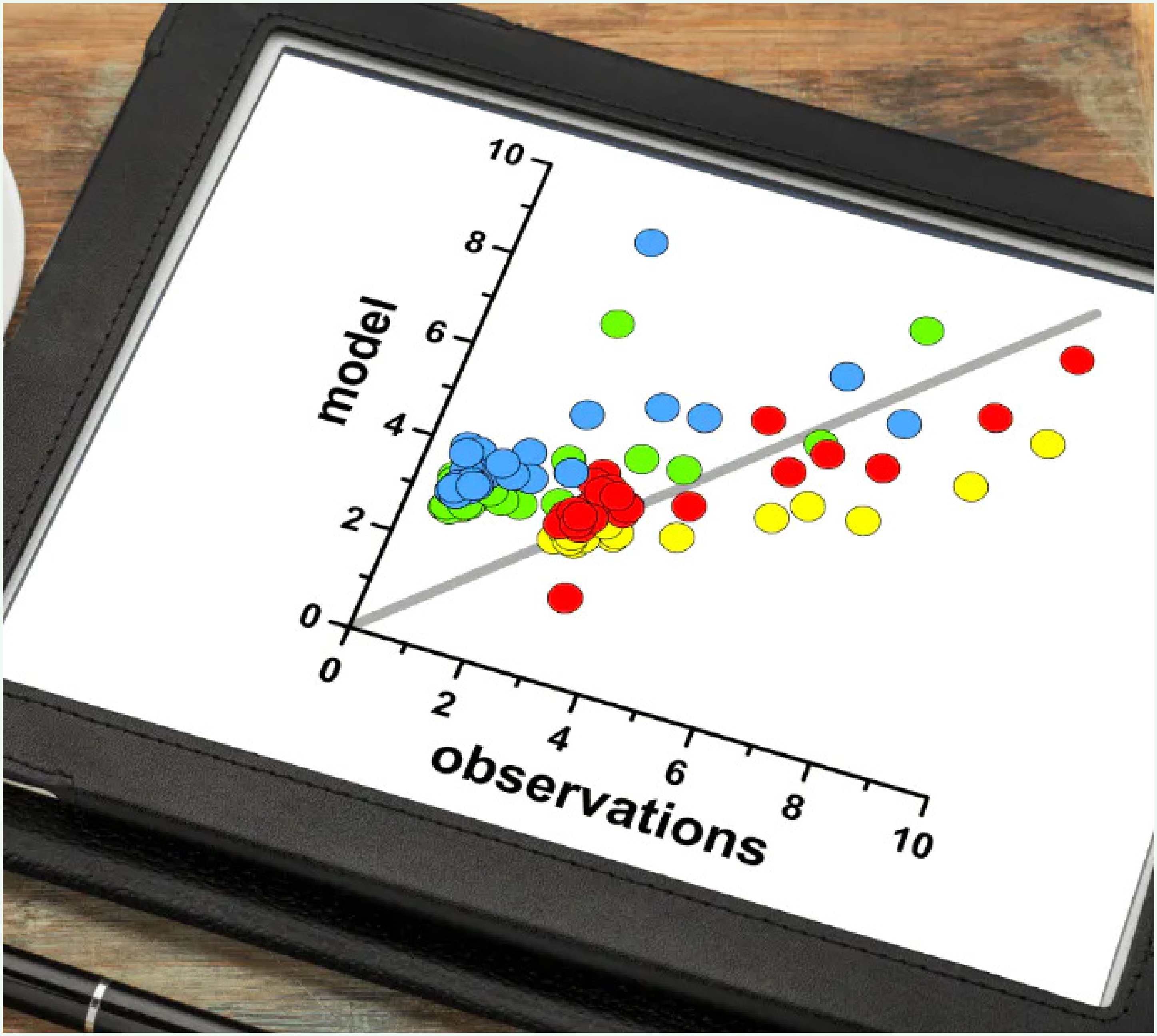
FORMAT: ONLINE
ISSN 2832-2681

VOLUME II, ISSUE I

March 2023

SHIFT

GLOBAL EHS RESEARCH TO PRACTICE



Benchmarking of Three Integrated Management System Models in Respect to Occupational Health and Safety Management Systems Implementation

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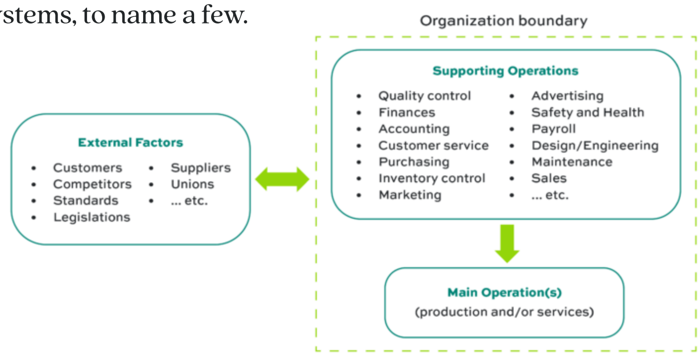
Abstract

Organizations use different standardized management systems to run their operations. Management System Standards (MSS), such as Occupational Health and Safety Management Systems (OHSMS), allow organizations to optimize their operation. In order to avoid duplicities, share commonly needed resources, and achieve their strategic goals, companies tend to implement Integrated Management Systems (IMS). Development and implementation of such an IMS have their own challenges and benefits. This study aims to compare three different models to develop and implement IMS by using benchmarking methods. The study is conducted in three steps. First, three holistic IMS models (i.e., ISO 45001, ILO-OSH-2001, and OSHA Recommended Practices) are identified from publications during the past 10 years. Next, three commonly used safety and health standards are identified and analyzed to develop benchmarking criteria. Finally, the three identified IMS are benchmarked. The findings show that each IMS model has its own advantages and shortcomings. The major differences may be due to the way each model is developed. Overall, there are gaps between the models' concepts and elements and how they are implemented. By understanding the characteristics of each IMS model, management can custom design their own IMS models by modifying the existing IMS models to better fit their organization.

KEY WORDS: *Management Systems Standards, Integrated Management System, benchmarking, occupational safety and health*

1. Introduction

There are different aspects of management that make a company function in a sustainable manner in terms of profitability and finances, quality of products or services, safety and health of employees, etc. Every activity that is performed in a company can be grouped into one of the following two operations: main operation(s) and supporting operation(s). The main operation(s) is a set of activities essential for the company to successfully achieve its objectives and complete its mission. The supporting operation(s) are sets of activities that are necessary to make the main operation(s) efficient (Fig. 1). For example, the main operation(s) can be manufacturing a particular good or providing services to potential customers, and supporting operation(s) can be purchasing, accounting, quality control, inventory control, customer services, payroll, and safety and health systems, to name a few.



Any company, regardless of size and type of product/service, needs to establish specific strategies, procedures, documentation, etc., to align its primary and supporting operations with the company's objective and mission. Research has shown that such organized efforts can be standardized according to specific models developed by experts to help organizations improve performance and create an organizational culture that engages everyone in a continuous improvement cycle of planning, self-assessment, and correction (Dominques et al., 2016a, Hardjono et al., 1996). Management System Standards (MSS) are the models developed by prominent organizations in standardization, such as International Organization for Standardization (ISO), American National Standard Institute (ANSI), and British Standards (BSI), among others. Some are industry-specific, while others are generic, and their models can apply to any organization (Boiral and Heras-Saizarbitoria, 2015). A management system can be defined as the way by which an organization manages the interrelated parts of its business to achieve its objectives (ISO, n.d.).

It is possible that a company uses more than one MSS to conduct its business. It is management's responsibility to coordinate all the activities performed simultaneously through each MSS since there are overlaps among them. In other words, there are activities that are required by more than one MSS, or there are resources needed by multiple MSS at the same time. This is when management should try to integrate all MSS that have been developed and implemented independently into one overall and comprehensive system, optimizing its operations and using its resources more effectively. There is no universally accepted definition for Integrated Management System (IMS). The commonly used definitions are, "A single integrated system used by an organization to manage the totality of its processes, in order to meet the organization's objectives and equitably satisfy the stakeholders," (CQI-IMSIG, n.d.) or "An integrated management system (IMS) is a management system which combines all components of a business into one coherent system so as to enable the achievement of its purpose and mission," (Olaru et al., 2014).

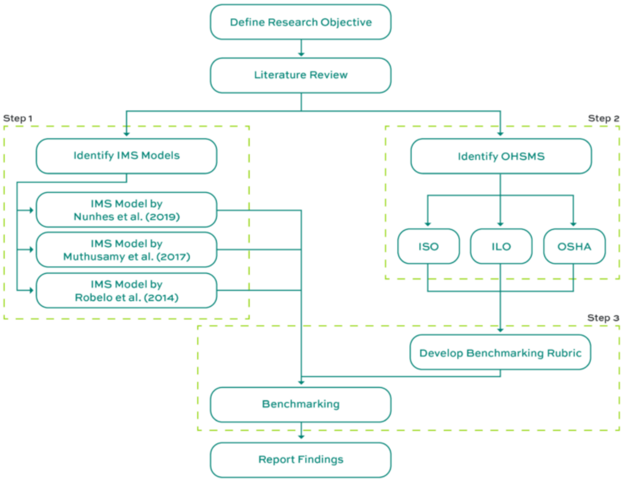
Since there is no international standard for IMS, companies must decide how to design and implement an IMS that fits their needs (Bernardo et al., 2009). Despite existing studies, there is no blueprint for developing a factual IMS in a step-by-step manner (Muthusamy et al., 2015). A factual IMS consists of essential MSS, which can be found or used in any industry and environment and provides for the adoption of future MSS and obligatory compliances. It is an IMS that allows organizations to smoothly integrate all MSS that are applicable to the business function, maximize the strengths of these MSS, and be able to update the IMS as new applicable standards evolve. The lack of institutionalization and standardization of IMS has resulted in varied outcomes when IMS is implemented (Domingues et al., 2016). Recently, there has been research to develop holistic IMS models to achieve an ideal and tailored IMS suitable for any organization's business goals.

Among all the different management systems, this study is focused on Occupational Health and Safety Management Systems (OHSMS), whose purpose is to enable companies to keep employees safe, sustain or even improve the health of the environment, comply with regulations and standards, fulfill companies' social responsibilities, uphold stakeholders' confidence, allow profitability, etc. It is evident that some of these areas overlap with other aspects of management, and an IMS can be a helpful approach to successfully implement OHSMS. Depending on which IMS model is used, the effectiveness of OHSMS can vary. The objective of this study is to determine the strengths and weaknesses of selected IMS models in effective implementation of OHSMS by using the benchmarking method with minor modifications. This allows the researchers to make comparisons across IMS instead of companies/organizations.

Benchmarking is an ongoing activity of comparing one's own processes, production, or service (such as occupational health and safety programs) against the best know similar activities. This allows organizations to take a realistic course of action to become and remain the best organization with best practices in a reasonable time. Through this process, companies can discover new ideas for methods and processes and even adopt good features of similar programs in their own organization (Balm, 1992). There are different types of benchmarking. Functional benchmarking is the one that fits this study, and it focuses on a single function or operation for improvement. This is suitable for complex operations such as occupational health and safety, human resources, finance, and accounting, which are difficult to be compared directly in terms of cost and efficiency (Karlöf & Östblom, 1993; Balm, 1992). Instead of making comparisons across companies, it is done across three selected IMS models. Determining the advantages and disadvantages of selected IMS models in regard to OHSMS implementation can help companies select the right model to maximize their productivity and performance.

2. Methodology

Figure 2 represents the overall approach used for this study, which marks the three steps described in the methodology section. In order to do functional benchmarking across IMS models in regards to OHSMS, a 3-step approach is utilized. First, it is necessary to identify the IMS models recommended and used during the past 10 years. It is essential to select IMS models that are holistic (generic) and have been used by or recommended for various industries and avoid industry-specific models. As explained in more detail in the Results section, the three models selected in this study are the ones published by Nunhes et al. (2019), Muthusamy et al. (2017), and Robelo et al. (2014).



Second, the most commonly used OHSMS across industries are identified. This step is a prerequisite for the next step. The selected OHSMS should be the type of management systems widely accepted by experts, developed by credible organizations, and commonly used in industry; they should not be industry-specific systems.

Third, it is essential to develop benchmarking criteria by which the selected IMS models are assessed. To complete this step, the authors studied the OHSMS selected in step two and identified major elements of each system, and categorized them in different criteria.

All three steps rely heavily on a literature review of published peer-reviewed journal articles, conference proceedings, and books written during the past 10 years. A scoring scheme is developed based on how each IMS model addresses each element of benchmarking criteria. If the IMS fully addresses the element, a score of 2 is assigned; if it is not addressed, a score of 0 is assigned. In case the element is partially addressed by the IMS model, a score of 1 is assigned. In the end, the overall scores for all criteria of all IMS models are compared to identify the strengths and weaknesses of each model.

3. Results

As is mentioned in the Methodology section, for step 1, the IMS models that are selected in this study are the ones recommended by Nunhes et al. (2019), Muthusamy et al. (2017), and Robelo et al. (2014). Each of these three models intended to create synergy across various MSS by integrating them, while each used a different approach. Nunhes et al. (2019) created guiding principles for IMS through a systematic content analysis of the 30 most cited articles between 2006 and 2016. They identified essential elements for its development and maintenance in order to move towards unifying a starting point in the literature. Muthusamy et al. (2017) developed a comprehensive IMS model for the holistic integration of MSS, which called for a Factual IMS model. Rebelo et al. (2014) developed a flexible, integrator, and lean model for the integration of MSS that can be adapted and progressively assimilated by other management systems, such as SA 8000/ ISO 26000, ISO 31000, and ISO/IEC 27001.

The OHSMS that are identified and included in this study (step 2) are ISO 45001 Occupational Health and Safety Management Systems (Dentch, 2018), ILO-OSH 2001- International Labour Organization Guidelines on Occupational Safety and Health Systems (ILO, 2009), and OSHA Recommended Practices for Safety and Health Programs (OSHA, 2016). The ISO and ILO are internationally recognized agencies whose recommendations and guidelines are widely used in management and labor practices. OSHA is another agency that is the official agency in the U.S. to establish safety and health standards for industries. Even though OSHA is a national agency, its standards, guidelines, and recommendations have been adopted by companies in other countries for many years.

The three selected OHSMS are studied carefully by the authors, and major elements of each system are identified, are categorized in eight criteria (step 3). Table 1 provides a list of all the criteria and the elements that are used as rubrics for evaluation and benchmarking of the selected IMS models. As described in the methodology, if an IMS model fully or partially addresses any of the elements in each criterion, a score of 2 or 1 is assigned respectably, and if it is not addressed, a score of 0 is assigned. One of the authors (A.Y.) used the information provided by the published literature to decide if each element under every criterion was fully addressed before assigning a score to them. The number of elements in each criterion is different from one another, and that means the overall scores for each criterion can be different. For example, the highest score for Leadership criterion with 4 elements can be 8, and for Regulation and Compliance criterion with only 2 elements can be 4. Therefore, it is better to normalize the scores by calculating a simple average for each criterion to make the comparison meaningful.

Model 1 (Nunhes et al., 2019) provides 6 systemized principles for implementing IMS, and these principles are based on and made up of 28 elements for the development and implementation of IMS. The elements are cross-referenced with published articles (2006-2016) to determine their frequency of citation, which is used to prioritize the elements. The elements are grouped into principles based on their functionality.

Table 1: The list of criteria and their elements used as rubric for benchmarking

Benchmark Criteria	Criteria elements
Leadership	• Leadership commitment to OH&S can be clearly defined and communicated using policy and objective statements • Assigns overall responsibility and accountability for OH&S to top management • OH&S scope, context, and interested parties' expectation can be clearly defined • Responsibilities/authorities and resources for OH&S planning, implementation, and performance monitoring can be clearly defined
Worker Participation	• Employees are to be consulted and involved in defining the OH&S scope and program • Ensures that employees have access to OH&S documented information • Incorporates training, competence and skill development of employees to support the OH&S management system
Regulations & Compliance	• Clear definition of OH&S legal requirements and non-regulatory requirement related to processes and operations • Documentation of established process for evaluating compliance with legal requirements and non-regulatory requirement
Operational Control	• Documentation of plan to achieve OH&S objectives and program, including timeline and methodology • Control of documented information (OH&S plan, procedure, safe work practices, forms, and checklist) • Incorporates clear communication of relevant OH&S information • Incorporates operational control that accounts for 3rd party impact on OH&S performance • Documentation of plan to manage change that affects OH&S performance
Hazard & Risk Management	• Optimized hazard and risk management via risk assessment of all business processes • Incorporates evaluation of control measures for effectiveness in mitigating risks • Documentation of plan to address risks and opportunities identified, including an emergency preparedness plan for non-routine scenarios
Performance Measurement	• Incorporates performance measurement and setting of performance indicators • Audits are incorporated to monitor that OH&S program performs as designed and complies with regulations
Continuous Improvement	• Incorporates continuous improvement, including management review of OH&S performance indicators, audit findings, correction of nonconformity, and incident investigation findings
IMS Model Characteristics	• Can be tailored to meet any organization's scope, size, and environment • Straightforward instruction that gives consistent and effective linking of information across MSSs • Follows a process mapping approach to identify critical operation activities so that policies, objectives, legal requirements, procedures, and performance can be linked • Common risk assessment methodology for all business aspects, with a template of set standards for measuring severity and occurrence of hazard/threats • MSS integration is based on the PDCA cycle that supports re-feed of corrections for continuous improvement • Identifies IMS content – states what should be integrated in an IMS • Integration of MSS elements on strategic, tactical, and operational levels • Identifies that not all MSS requirements are compatible, and propose when to use identical, integrable, parallel, and different MSS integration type

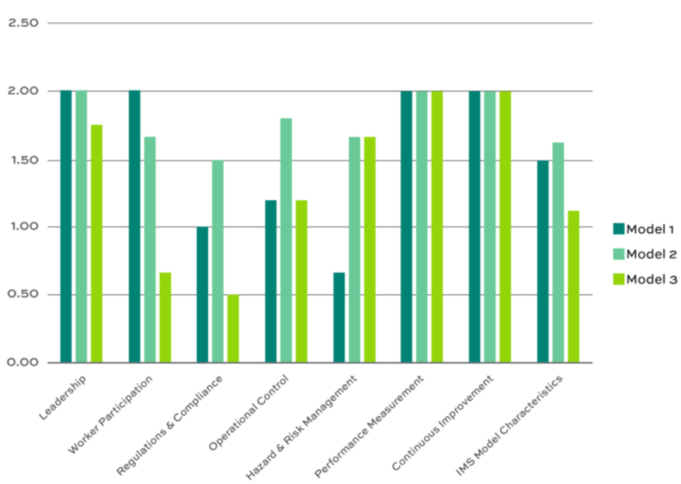
Model 2 (Muthusamy et al., 2017) presents an 8-stage holistic approach for IMS implementation, which is to serve as a process-based strategy for IMS design, implementation, and institutionalization by considering its micro-level perspectives. Also, a comprehensive model of IMS is presented by the authors, which shows how the elements of existing and proposed management systems can be integrated at different levels based on the 4 principal elements of process change put forth by Hardjono et al. (1996).

Model 3 (Robelo et al., 2014) develops a flexible, integrator, and lean model for IMS based on ISO 9001, ISO 14001, and OHSAS 18001. The model is designed such that it can be adapted and progressively assimilate other MSS. It was developed based on a preliminary investigation conducted through a questionnaire. This model consists of 7 fundamental components and provides guiding principles and actions for implementation.

Each of these 3 models has unique characteristics, and depending on which is selected and implemented by any organization, the outcomes of their OHSMS can be different. In order to identify each model's strengths and weaknesses, the rubric scale, which was developed by the authors (Table 1), is used to benchmark the 3 models described above. Table 2 demonstrates the scores each model receives for each element. Figure 3 demonstrates how each model is scored for each criterion by using the average scores. It seems that the "Worker Participation, Regulation and Compliance, Operational Management, and Hazard and Risk Management" criteria are the four areas where the greatest differences exist.

Table 2: Benchmarking Scores

Benchmark Criteria	Criterion Elements	Model 1	Model 2	Model 3
Leadership	• Leadership commitment to OH&S can be clearly defined and communicated using policy and objective statements	2	2	2
	• Assigns overall responsibility and accountability for OH&S to top management	2	2	1
	• OH&S scope, context, and interested parties' expectation can be clearly defined	2	2	2
	• Responsibilities/authorities and resources for OH&S planning, implementation, and performance monitoring can be clearly defined	2	2	2
Worker Participation	• Employees are to be consulted and involved in defining the OH&S scope and program	2	2	0
	• Ensures that employees have access to OH&S documented information	2	1	1
	• Incorporates training, competence, and skill development of employees to support the OH&S management system	2	2	1
Regulations & Compliance	• Clear definition of OH&S legal requirements and non-regulatory requirement related to processes and operations	1	2	1
	• Documentation of established process for evaluating compliance with legal requirements and non-regulatory requirement	1	1	0
Operational Control	• Documentation of plan to achieve OH&S objectives and program, including timeline and methodology	1	2	2
	• Control of documented information (OH&S plan, procedure, safe work practices, forms, and checklist)	2	2	0
	• Incorporates clear communication of relevant OH&S information	2	2	2
	• Incorporates operational control that accounts for 3rd party impact on OH&S performance	0	2	2
	• Documentation of plan to manage change that affects OH&S performance	1	1	0
Hazard & Risk Management	• Optimized hazard and risk management via risk assessment of all business processes	1	2	2
	• Incorporates evaluation of control measures for effectiveness in mitigating risks	0	2	2
	• Documentation of plan to address risks and opportunities identified, including an emergency preparedness plan for non-routine scenarios	1	1	1
Performance Measurement	• Incorporates performance measurement and setting of performance indicators	2	2	2
	• Audits are incorporated to monitor that OH&S program performs as designed and complies with regulations	2	2	2
Continuous Improvement	• Incorporates continuous improvement, including management review of OH&S performance indicators, audit findings, correction of nonconformity, and incident investigation findings	2	2	2
IMS Model Characteristics	• Can be tailored to meet any organization's scope, size, and environment	1	2	2
	• Straightforward instruction that gives consistent and effective linking of information across MSSs	1	1	1
	• Follows a process mapping approach to identify critical operation activities, so that policies, objectives, legal requirement, procedures, and performance can be linked	2	2	2
	• Common risk assessment methodology for all business aspects, with a template of set standards for measuring severity and occurrence of hazard/threats	1	1	1
	• MSS integration is based on the PDCA cycle that supports re-feed of corrections for continuous improvement	2	2	2
	• Identifies IMS content – states what should be integrated in an IMS	2	2	0
	• Integration of MSS elements on strategic, tactical, and operational levels	2	2	1
	• Identifies that not all MSS requirements are compatible, and propose when to use identical, integrable, parallel, and different MSS integration type	1	1	0
0 = Not Fulfilled 1 = Partially Fulfilled 2 = Totally Fulfilled	**TOTAL SCORE**	**42**	**49**	**36**



By counting the number of elements that are entirely, partially, or never addressed by each model, it appears that Model 2 covers more items than the other two (Table 3).

Table 3: Comparison of models in terms of number of elements addressed

	Model 1	Model 2	Model 3
Fully Addressed	16 (57.1%)	21 (75.0%)	14 (50.0%)
Partially Addressed	10 (35.7%)	7 (25.0%)	8 (28.6%)
Never Addressed	2 (7.1%)	0	6 (21.4%)

4. Discussion

As discussed earlier, companies are implementing different management systems standardized for specific operations, either main or supporting, to help management and companies achieve their strategic goals. Independent implementation of multiple management system standards (MSS) can lead to a duplication of procedures, primarily with respect to training, audits, and inspections. It can also affect management and operational efficiency by causing complexity and extra cost to the organization (Holdsworth, 2003; Zeng et al., 2007).

With increases in implementing such MSS in a company, the need for integrating such systems increases too. It is very likely that some companies or organizations have already implemented some kind of integrated management system (IMS), or they need to start implementing an IMS for the first time to include occupational safety and health management systems (OHSMS). This process has its own benefits and challenges.

A true IMS should incorporate an essential MSS, along with a sector-specific management system. So far, current integration strategies are unable to adequately provide a complete roadmap for implementation processes of IMS. The lack of clarity and complexity in the integration process puts more emphasis on research to develop better IMS models for companies (Muthusamy et al., 2015). If IMS models allow effective implementation of multiple MSS, it can help organizations cut down on repetition of processes and maximize utilization of resources. A good IMS model should allow companies to tailor the integration process to fit their organizational needs (Bernardo et al., 2009; Lopez-Fresno, 2010).

In this research, the authors use the benchmarking method to assess three different holistic IMS models recommended by others in order to identify their strengths and weaknesses with respect to implementation of OHSMS. The results of this study show that when OHSMS and other MSS are already in place in an organization, management can identify the best IMS model that can optimize the outcomes of the integration process.

The benchmarking criteria are developed based on three commonly used OHSMS, which are accepted by experts in this field (i.e., ISO 45001, ILO-OSH-2001, and OSHA Recommendations). Three IMS models are selected (Nunhes et al., 2019; Rebelo et al., 2014; Muthusamy et al., 2017) and compared against 28 important elements required for an OHSMS to see which one addresses them better.

According to the results of this study, all three models included in benchmarking have certain deficiencies in Worker Participation, Regulation and Compliance, Operational Control, and Hazard & Risk Management areas. In order to explain the differences and deficiencies, it is better to look at each model separately. Nunhes et al. (2019) studied previously published articles about IMS development and implementation and identified major elements cited more frequently. They developed their own guiding principles for implementing an IMS. This model (Model 1) is not concerned about OHSMS or any specific MSS; instead, it tries to address major challenges in the implementation of IMS (i.e., i. lack of resources, ii.

dissimilarities among MSS, iii. cultural differences among work groups, and iv. lack of motivation and resistance to change by employees). These could be the reason Model 1 did not score high in Regulation and Compliance, Operational Control, and Hazard/Risk Management criteria in the benchmarking process.

Muthusamy et al. (2018) tried to provide a comprehensive model and holistic approach to allow smooth and efficient integration of different elements of MSS. The researchers developed their model (Model 2) mostly based on the requirements of ISO Standards (i.e., ISO 9000, ISO 14000, ISO 18000, and ISO 26000). Throughout their approach, the authors followed the continuous improvement mentality, and they were focused on the PDCA (Plan-Do-Check-Act) approach. Their holistic approach to the integration process helped their model cover more elements and score higher in the areas in which the first model did not score well. The process used in Model 2 is mostly a top-down process by which the management initiates the integration and manages the process. This could be the reason that this model scored lower in the Worker Participation area in the benchmarking process.

A major difference between Model 3 and the previous two models is that the Robelo et al. (2014) study is empirical. By conducting a survey, they tried to answer four major questions (i.e., i. importance of factors identified as motivators for the implementation of the IMS model, ii. influence of stakeholders on the performance and evaluation of IMS, iii. main internal difficulties in the development of the IMS model and its implementation, iv. potential benefits of implementation of the IMS model). Similar to Model 2, they were strictly focused on ISO standards (ISO 9001, ISO 14001, and ISO 18001), and their goal was to conceive a model which is lean, flexible, and integrator and can be adapted and progressively assimilate other ISO standards such as ISO 26000 (Social Accountability), ISO 31000 (Risk Management), and ISO 27001 (Information Security Management). This model scored low in Worker Participation, Regulation and Compliance, and Operational Control areas in the benchmarking process. The reason for such low scores could be that Robelo et al. (2014) were primarily focused on the practical aspect of the IMS development and implementation instead of the conceptual aspect of it.

5. Conclusion

The three models discussed in this article scored equally or close to one another in other areas (Leadership, Performance Measurement, Continuous Improvement, and IMS Model Characteristics) in the benchmarking process. The major differences remain in the areas which are crucial in the implementation of the IMS model. Considering that Model 3, developed by Robelo et al. (2014), is empirical and data-driven, while the other two models are mostly conceptual and based on literature review. This highlights that there are still gaps between what a comprehensive IMS model should look like and what experts and employees experience when they try to practice their knowledge and implement such models. Knowing the strengths and weaknesses of each IMS model and being aware of the challenges during implementation can help organizations prepare themselves in order to increase the likelihood of success when choosing and implementing an integrated management system. Obviously, there is still room for improvement, and more empirical studies are needed to close the gap between developing IMS models and their implementation.

Funding Details:
This study did not receive any funding from any agency or organization.

Statement of Conflict of Interest:
The authors had no financial interest or benefit from conducting or publishing this study.

References

Balm, G.J. (1992). Benchmarking: A Practitioner's Guide for Becoming and Staying Best of the Best (2nd ed). QPMA Press.

Bernardo, M., Casadesús, M., Karapetrovic, S. & Heras, I. (2009). How integrated are environmental, quality and other standardized management systems? An empirical study. Journal of Cleaner Production, 17(8), 742-750.

Boiral, O. & Heras-Saizarbitoria, I. (2015). Management System Standards. In Su Mi Dahlgaard-Park (Ed.), The SAGE Encyclopedia of Quality and the Service Economy (390-395). Thousand Oaks: SAGE Publications, Inc.

CQI-IMSIG (n.d.). Chartered Quality Institute-Integrated Management Special Interest Group. https://www.integratedmanagement.info/what-is-ims

Dentch, M. P. (2018). The ISO 45001:2018 implementation handbook: guidance on building an occupational health and safety management system. ASQ Quality Press.

Domingues, J.P.T., Fonseca, L., Sampaio, P. & Arezes, P.M. (2016a). Integrated versus nonintegrated perspectives of auditors concerning the new ISO 9001 revision. IEEE International Conference on Industrial Engineering and Engineering Management, Bali, Indonesia.

Domingues, P., Sampaio, P. & Arezes, P.M. (2016b). Integrated management systems assessment: A maturity model proposal. Journal of Cleaner Production, 124, 164-174.

Hardjono, T. W., Ten Have S., & Ten Have, W. D. (1996). The European Way to Excellence, London: European Quality Publications Ltd.

Holdsworth, R. (2003). Practical applications approach to design, development and implementation of an integrated management system. Journal of Hazardous Materials, 104(1), 193-205.

International Labour Organization (ILO). (2009). Guidelines on occupational safety and health management systems (ILO-OSH 2001) (2nd ed.). Geneva: International Labour Office.

ISO (n.d.). Management system standards, International Organization for Standardization. https://www.iso.org/management-system-standards.html

Karlöf, V. and Östblom, S. (1993). Benchmarking, A signpost to Excellence in Quality and Productivity. John Wiley & Sons.

Lopez-Fresno, P. (2010). Implementation of an integrated management system in an airline: A case study. The TQM Journal, 22(6), 629-647.

Muthusamy, G., Palanisamy, C. & Ammasaiappan, M. (2015). Integrated management systems for better environmental performance and sustainable development – A review. Environmental Engineering and Management Journal, 14(5), 985-1000.

Muthusamy, G., Palanisamy, C., & Mohanraj, M. (2017). A Comprehensive Model and Holistic Approach for Implementing an Integrated Management Systems. Journal of Computational and Theoretical Nanoscience, 15, 392-401.

Nunhes, T.V, Bernardo, M., & Oliveira, O.J. (2019). Guiding principles of integrated management systems: Towards unifying a starting point for researchers and practitioners. Journal of Cleaner Production, 210, 977-993.

Occupational Safety and Health Administration (OSHA). (2016). Recommended Practices for Safety and Health Programs. www.osha.gov/shpguidelines

Olaru, M., Maier, D., Nicoară, D., & Maier, A. (2014). Establishing the basis for Development of an Organization by Adopting the Integrated Management Systems: Comparative study of various models and concepts of integration. Procedia-Social and Behavioral Sciences, 109, 693-697.

Rebelo, M.F., Santos, G., & Silva, R. (2014). Conception of a flexible integrator and lean model for integrated management systems. Total Quality Management & Business Excellence, 25(5-6), 683-701.

Zeng, S.X., Shi, J.J., & Lou, G.X. (2007). A synergetic model for implementing an integrated management system: an empirical study in China. Journal of Cleaner Production, 15(18), 1760-1767.

Analyses of Postures and Musculoskeletal Disorders of Emergency Medical Technicians in the United States

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Abstract

The job of emergency medical technicians (EMTs) involves manually handling patients. The force required to safely lift or lower a patient during an emergency response depends on the weight of the patient. These tasks elevate the risk of musculoskeletal disorder (MSD). The objective of this study is to assess the level of MSD risk associated with the most frequently performed tasks of EMTs during emergency response and measure their level of MSD prevalence using a recorded simulation of five frequently performed tasks: (1) stretcher removal, (2) stretcher return with the patient, (3) patient lift: ground to a stretcher, (4) two-person stretcher removal with a patient, and (5) moving a patient down the stairs. Biomechanical and postural assessments are performed using rapid upper limb assessment (RULA) and rapid entire body assessment (REBA). The Nordic Musculoskeletal Questionnaire (NMQ) is used to measure MSD occurrence. Also, a fishbone diagram is developed to determine hidden causes of MSD. Both RULA and REBA scores indicate that Task 3 has the highest MSD risk. The MSD frequency is high in the back (43%) and one or both ankles or feet (21%). Posture, load, and force are three risk factors related to the tasks. Overall, the assessments agree that the most risk is on the lower back. This indicates where ergonomic intervention is needed to reduce the risk of musculoskeletal injury.

KEY WORDS: *Biomechanics, EMT, ergonomics, musculoskeletal disorders (MSD), safety*

1. Introduction

There are approximately 1,030,760 licensed emergency medical services professionals in the United States, including emergency medical responders and paramedics (National EMS Assessment, 2020). Emergency medical technicians (EMTs) are exposed to various physical and mental risk factors unique to their profession (Rahimi et al., 2015; Jones & Lee, 2005; Lavender et al., 2000). They are exposed to tragic and gruesome events while working in highly-charged emergencies—facing hazards such as assault, violence, and transportation accidents, potentially leading to fatal injuries (Maguire and Smith, 2013; Broniecki et al., 2010; Reichard and Jackson, 2009). Perhaps the most common physical hazards EMTs are exposed to are biomechanical and postural. Working as a first emergency responder has high demands on the musculoskeletal system requiring repetitive motions such as lifting, bending, and twisting (Hong et al., 2010; Aasa et al., 2005; Broniecki et al., 2010; Weaver et al., 2015). Tasks such as moving and transporting patients and performing cardiopulmonary resuscitation (CPR) are some physical stressors to EMTs' musculoskeletal systems (Studnek and Crawford, 2007).

According to a recent and comprehensive review of work-related MSDs and injuries among EMTs and paramedics (EMTs-Ps), back pain is the most common complaint (Friendenberg et al., 2020). That report found that the annual prevalence of back pain among EMTs-Ps ranges from 30% to 88%. In a study among 180 nurses working as EMTs, about two-thirds had at least one type of back pain (Rahimi et al., 2014). This finding was in congruence with those of the ambulance officers in Hong Kong who reported back discomfort (60%) during CPR (Jones and Lee, 2005). In the United States, data from the Department of Labor's Bureau of Labor Statistics reported 21,690 cases of non-fatal injuries or illnesses that resulted in lost workdays among EMTs-Ps from 2003 through 2007, and of those, 9,290 (43%) were back injuries (Maguire, 2013). This means that EMTs-Ps have a rate of injury about 3 times the national average for all occupations.

A good number of studies have been conducted to document the prevalence and risk factors of MSDs in EMTs-Ps (Aasa et al., 2005; Jones and Lee, 2005; Lavender et al., 2000; Maguire, 2013; Studnek and Crawford, 2007; Lavander et al., 2007). However, the analyses of biomechanical and postural risk factors that are inherent to this profession have been minimal. To continuously improve the performance and design of ergonomic equipment and processes involved in patient handling during emergency response, there is a need for continuous investigation to understand the tasks performed, including the degree to which these tasks stress the workers and their frequency of performance (Lavender et al., 2000). Also, there must be an analysis of work that describes the postures assumed and the forces applied when EMTs-Ps perform emergency rescue tasks. In ergonomics, task analysis is a common practice used to identify which specific task components expose a worker to ergonomic risk factors and the magnitude of those exposures. In most cases, postural and biomechanical analyses are conducted with the use of a 2D or 3D motion capture system (Schurr et al., 2107).

In this study, the researchers test the effectiveness of typical postural and biomechanical assessment tools that generate levels of MSD risk to provide data that would be used to determine what task component needs the most ergonomic intervention. The researchers hypothesize that the availability of equipment and technology (or the lack thereof) is insufficient to minimize the risk of MSDs and that there are still task components and micro-tasks that may pose cumulative pain and discomfort to the musculoskeletal system of EMTs-Ps. These task components may cause cumulative trauma or acute injuries if not examined thoroughly. The objective of this study is to assess the level of MSD risk associated with frequently-performed work tasks of EMTs during emergency response and measure the level and prevalence of their MSDs.

2. Materials and Methods

2.1 Study Design and Sample

This cross-sectional study is conducted to measure the level of MSD risk faced by emergency medical technicians (EMTs) when performing their tasks during an emergency response. Convenient sampling is used to determine the number of participants with the use of inclusion criteria that includes at least one year of work experience as an EMT at a minimum of 18 years of age. Before data collection and task observation, we excluded those who had previous MSD injuries; we also excluded those who were currently pregnant from the survey. A total of 14 EMTs answered the survey. Three EMTs performed the simulation of patient transfer tasks, and one played the patient. Our research is approved by Keene State College's Institutional Review Board (IRB) with an assigned protocol number #472.

2.2 Data Gathering Tools

This study uses rapid upper limb assessment (RULA) (McAtamney and Corlett, 1993) and rapid entire body assessment (REBA) (Hignett and McAtamney, 2000) to measure the level of MSD risk associated with each of the frequently performed tasks. RULA evaluates the exposure of individual workers to ergonomic risk factors associated with upper extremity MSD. It considers biomechanical and postural load requirements of job demands on the neck, trunk, and upper extremities. The worksheet generates a single score that represents the level of MSD risk per task and per worker (McAtamney and Corlett, 1993). The score ranges from 1 to 6+, the former having negligible risk and the task requiring no action, the latter having a very high risk with a necessity to implement abrupt change on the task. Also, REBA measures the probability of developing pain or discomfort with the addition of the lower parts of the musculoskeletal system. It accounts for body posture, forceful exertions, type of movement, repetition, and coupling. In the last portion of the evaluation, a score between 1 and 11+ is generated, with 1 having negligible risk and 11+ having very high risk with a need to implement change (Hignett and McAtamney, 2000). Using both MSD assessment tools provides a robust result because it allows cross-validation of findings.

The pain or discomfort of each body region was surveyed through the use of the Nordic Musculoskeletal Questionnaire (NMQ) (Kourinka et al., 1987). The first part of the questionnaire asks for the participant's job, gender, age, height, weight, length of employment (doing the same job), and hours worked each week. The second section contains a diagram showing the different body regions on a back view, which is used to guide survey participants in answering the NMQ. The questionnaire itself is divided into two columns. Answerable by a "yes" or "no," Column 1 asks, "Have you at any time during the last 12 months had trouble (ache, pain, discomfort, numbness) in the neck, shoulders (left, right, both), elbows (left, right, both), wrists/hands (left, right, both), upper back, lower back, one or both hips/thighs, one or both knees, and one or both ankles or feet?" Those who answered "yes" in this column have to respond to two more questions, "Have you at any time during the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble?" and "Have you had trouble at any time during the last 7 days?" An important element of the NMQ is the information regarding how much influence the pain or discomfort had on the worker's daily routine. The data used in this study is the prevalence in the last seven days.

A root-cause analysis (RCA) is a fundamental, underlying, system-related reason why an incident occurred that identifies one or more correctable system failures (Department of Energy, 1992). It analyzes underlying factors in any given adverse reaction to identify a problem's source and take corrective measures to fix it. This process is unique as it delves deeper to find answers based on hidden causes and their effects rather than merely looking at the most apparent. Typically, it is considered a reactive process, but when applied thoroughly, it can take the shape of a highly valuable source by becoming a proactive mechanism as it predicts problems before they occur (White, 2022; Bright Hub PM, 2011). In the field of occupational and environmental safety, the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) urge employers (owners and operators) to conduct an RCA following an incident or near miss at a facility (Department of Energy, 1992).

To narrow the cause of hazards for the task that generates the highest RULA and REBA scores, an RCA using a fishbone diagram is performed (Fig. 3). The fishbone diagram is the preferred RCA technique because of its content and visual clarity. It specifies multiple components that have the potential to influence outcomes, which helps prioritize relevant causes. The researchers used the simulated tasks to conduct an RCA. To link the level of MSD risk with RCA, REBA is used because RCA works better with whole-body assessments. The diagram is focused on the body part that has the highest score (trunk). Then, three important factors that influenced the scores are examined: posture, load, and force. For posture, the angle of the upper body while performing the task is assessed. The load is the average body weight in the U.S. based on the findings of Fryar et al. (2018). It is divided between the average weight of men (197.9 lbs.) and women (170.6 lbs.). The force requirement is computed based on a previously described formula for rotational force or moment: M=Weight (W) x Distance (D) (Stack et al., 2016). A moment is defined as the product of the applied force and the perpendicular distance through which the force is applied. The national average of weights and a distance of 10 in, which is the most conservative distance of the load from the lumbosacral joint of the spine during a lifting task, are used in the computations.

2.3 Data Collection Procedures

Following IRB approval, the researchers visited a local EMT company to ask permission to conduct the study. After speaking to the owner and supervisor and receiving approval to survey their workers, the objective of the research, the role of their employees in the study, and the amount of time expected for participation were explained. To protect the privacy of both the company and the employees, the researchers avoided asking for or recording any identifying information. During the first visit to the worksite, the EMTs were gathered to explain the content of the consent form. In considerable detail, they were informed about the purpose of the study, the expectations, potential benefits and incentives, conflicts of interest, confidentiality, their rights as study participants, and their freedom not to participate. The NMQ was handed to those who expressed willingness to support the research and collected the questionnaires within the following week.

In the final visit, the simulation of tasks by three EMTs using a video camera was recorded. One worker acted as a patient, while the other two acted as emergency responders. The tasks were: (1) stretcher removal, (2) stretcher return with patient, (3) patient lift from the ground to the stretcher, (4) two-person stretcher removal with a patient, and (5) moving a patient down the stairs. Figure 1 shows a sample of the five tasks in side and back views. In the first task observed, the workers simulated the removal of a stretcher from the ambulance without a patient on it. This is what they do when they arrive at a scene to recover a patient. For the second task, the first responders showed how they put the stretcher back into the ambulance once the patient is on it. Next, they lifted them from the ground up onto the stretcher (task 3). This represents a situation where the responders show up at the scene with an ambulance that lacks the lifting equipment required for this maneuver. A "two-person stretcher removal with a patient" describes when the EMTs arrive at the hospital with the patient and must remove them from the ambulance (task 4). If the patient is upstairs and the EMTs are incapable of traversing them, they will need to use a piece of equipment (e.g., backboard, stretcher, stairchair, etc.) to transport a patient down the stairs (task 5). These five tasks are a few of the most common work tasks that first responders do when responding to an emergency medical situation (Conrad et al., n.d.). The individual task lasts for 3 to 5 minutes. As it was a simulation, the EMTs explained that the length of time required might vary depending on the anthropometric characteristics, illness, cause of injury of the patient, and sometimes weather conditions. The video clips are used to evaluate the MSD risk using RULA and REBA.

2.4 Data Analyses

The socio-demographic characteristics of the study participants are expressed, in percentage, in terms of sex (male and female). Age, height, weight, body mass index (BMI), year, industry, and hours worked per week are presented in mean and standard deviation. The levels of MSD risk are shown as the original numerical value generated by RULA (1 to 6+) and REBA (1 to 11+). The prevalence of MSD is expressed in percentages. All analyses are performed using Microsoft Excel version 16.59.

3. Results

The personal and occupational profiles of the study participants are summarized in Table 1. Among them, 64% are female, and 36% are male. The average age of the EMTs is 40 years, 1.7 m in height, and 219.8 lbs. in weight. The participants' average BMI is 32.8 kg/m2. In terms of work history, the EMTs work for an average of 9 years with a standard deviation (SD) of 12 years and 48 hours per week with an SD of 20 hours. Table 2 presents the RULA scores of the study participants. It shows that the task with the highest score of 7 is task 3 (patient lift: ground to the stretcher), followed by task 1 (stretcher removal) with a score of 5, and task 4 (two-person stretcher removal) with a score of 4. Task 5 (moving patient down the stairs) has the lowest RULA score of 2. It can be gleaned from Table 3 that the highest REBA score is 8 for task 3 (patient lift: ground to the stretcher), followed by task 4 (two-person stretcher removal with a patient) with a score of 6. The task with the lowest score of 2 was task 5 (moving the patient down the stairs).

In terms of the prevalence of MSD, Fig. 2 shows that pain in the lower back is the most common (43%). Also, the EMTs reported discomfort in one or both feet (21%), one or both knees (14%), one or both hips (14%), and the wrists (14%). The participants reported no pain in the elbows. The fishbone in Fig. 3 shows the scores received by each body region and the risk factors that influenced them. The risk factors include posture, load, and force requirements that influenced the scores. Among the six body parts (e.g., neck, trunk, leg, upper arm, lower arm, and wrist) evaluated by REBA, the trunk has the highest score of 4, followed by the leg with a score of 3. The neck, upper arm, and wrist have the lowest scores of 1. With posture, the upper body of the EMT is flexed forward to more than 90° while lifting from the ground. The average weight for men in the US is 198 lbs. and 171 lbs. for women. After applying the biomechanical formula (Stack et al., 2016), we found that the muscles generate 2699 lbs. of force for men and 2426 lbs. for women to statically hold patients with the average weights mentioned above.

Table 1: Socio-demographic and work-related profile of study participants, n=14

Variable	%	Mean	SD
Sex			
Male	36		
Female	64		
Age (year)		39.4	14.6
Height (m)		1.7	0.1
Weight (lbs.)		219.8	85.1
BMI (kg/m²)		32.8	11.3
Year in industry		8.5	12.1
Work hour per week		48.1	20.3

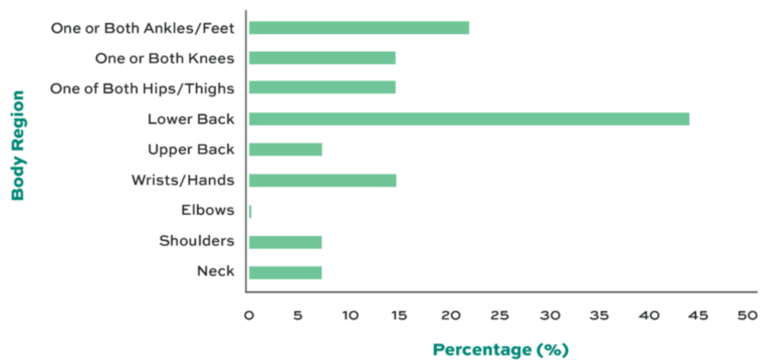

Table 2: RULA scores of study participants, n=2

RULA Score	Task	Description
5	1	Stretcher removal
3	2	Stretcher return with patient
7	3	Patient lift: ground to stretcher
4	4	2-person stretcher removal with patient
2	5	Moving patient down the stairs

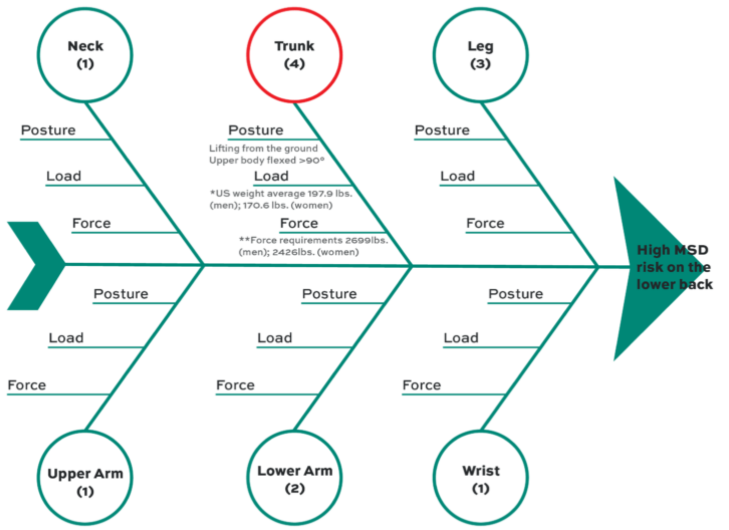

Table 3: REBA scores of study participants, n=2

REBA Score	Task	Description
4	1	Stretcher removal
4	2	Stretcher return with patient
8	3	Patient lift: ground to stretcher
6	4	2-person stretcher removal with patient
2	5	Moving patient down the stairs

4. Discussion

This study assesses the postural and biomechanical risks associated with frequently performed tasks of EMTs. It is shown that lifting the patient from the ground onto the stretcher (Fig. 1) results in a high MSD risk, as shown in the RULA and REBA scores (Tables 2 and 3). The result of the NMQ reveals that low back pain is the most common complaint of the study participants in the last 7 days (Fig. 2). This is confirmed by the highest score in the trunk region of the body in the REBA analysis, as shown in Fig. 3. Our findings show that posture, load, and force requirements have negative impacts on the different body regions, but more so on the lower back. This finding should be cause for concern given the relative weights of the patients during an actual response to an emergency and the frequency of exposure of EMTs.

In the present study, there is a 43% prevalence of low back pain among the participants. Low back disorder is the most common form of MSD among health professionals who respond to emergencies (Rahimi et al., 2015; Jones and Lee, 2005;

Aasa et al., 2005). Studies show that physical, socio-psychological, and individual risk factors influence this prevalence. Working in awkward postures, lifting a load that is hard to hold, lifting a heavy load (Hansen et al., 2012), CPR procedure, reaching for overhead equipment, and seated tasks that require horizontal bending and twisting (Jones and Lee, 2005) narrow passageways, stairs, and obstacles at the scene, and prolonged flexed and twisted postures (Prairie and Corbeil, 2014) are some of the physical risk factors. Although most of these factors are not investigated in the present study, we believe they contribute to the occurrence of MSD symptoms in the study participants. Other established individual risk factors can include age, physical fitness, being overweight, and a history of back problems. In the present study, the average BMI of the EMTs is 32.8, which is in the obese category, and their average age is 40 years. This means that, on average, the surveyed participants are more likely to develop MSD symptoms. In a study among machine drivers, construction carpenters, and office workers between the ages of 40-45, an increased risk of low back pain (including all types) was found. The symptoms were associated with disc degeneration due to aging (Luoma et al., 2000). Also, prolonged exposure to the above-mentioned physical risk factors has a detrimental effect on the musculoskeletal system, which can be brought about by high call volume, especially when working in an urban setting and depending on the length of career. We found that the study participants worked for 48 hours a week on average. This means that they can be exposed to MSD hazards for at least 8 hours a day.

The RULA and REBA scores show that lifting a patient from the ground to a stretcher (task 3) has the highest MSD risk (Fig. 2). Further analysis reveals that the trunk has the highest score (Fig. 3) among all of the body parts evaluated. Lifting the patient from the ground to the stretcher requires force and proper body mechanics to avoid injuring the back. In the simulation of task 3, the EMT bent his back forward, flexing more than 90°. Apart from that, his source of force came from the back during the peak of the lifting task. The source of force required during lifting directly correlates with the posture followed by the EMT. For instance, if the patient is a 198 lb. man, which is the average weight of males in the US, the erector spinae muscle has to release 2699 lbs. of force to stabilize the lifting task when holding the patient 10 inches away from the trunk (Fig. 3). For patients with an average weight of 171 lbs., the force required to be generated is 2426 lbs. among female EMTs to stabilize the spine during the lifting task. Therefore, the force required is always higher than the weight of the load to stabilize movement during lifting and lowering tasks (Stack et al., 2016). With prolonged exposure, this can be a serious biomechanical risk in the lumbosacral (L5/S1) region of the spine. The farther the load from the lumbosacral region and the more forward flexed the back, the higher the risk of injury.

Removing the need to lift altogether during the patient transfer from the ground to a stretcher is the ideal solution. It's been proven that transferring and transporting a patient from point A to B with the use of mechanical equipment minimizes the risk of musculoskeletal injuries. Lavender et al. (2007) proved that changing the backboard carrying task to a rolling and sliding task with a mechanical-aided decent control system reduced the demand on the erector spinae muscles, minimized muscle activity in the rectus abdominis, and decreased the rating of perceived exertion. However, ergonomically-designed equipment may not always be available for use and therefore requires EMTs to manually lift and lower patients, as in the case of the study participants in this study.

The findings in this study highlight the need for an ergonomic intervention. We found that knowledge of good body mechanics through ergonomic intervention is necessary to minimize the risk of injury. During manual lifting, awkward posture and overexertion must be avoided. But without proper ergonomic training, the workers may have to sort to what they perceive as normal techniques. Amit and Song (2021) found that significant improvement in workers' posture can be observed when given ergonomic intervention. The intervention can include awareness of proper lifting techniques, modification of equipment used at work, a healthy lifestyle, and physical activities. The posture of the EMT, the weight of the patient, and the force required in lifting are three of the main factors that influence the REBA scores in the present study. Given that the trunk is exposed to improper posture and high biomechanical loading, it should not be surprising that the NMQ survey indicates the highest prevalence of MSD in the low back region. Given this knowledge, and in the absence of lifting equipment, the EMT should avoid bending forward when lifting. Squatting as a starting posture and maintaining a straight trunk must be observed to utilize the force generated by the legs. This way, lifting or lowering tasks become safer because the capacity of the legs to release force is higher compared to that of the rectus abdominis and extensor muscles. Based on these findings, the need for an ergonomic intervention is warranted among EMTs. Personalizing the intervention by breaking them into specific tasks and movements and considering the personal profiles of the workers (e.g., age, BMI, etc.) can yield better results. The human body can sometimes take time to fully adjust to newly introduced movements. It must be noted, therefore, that getting accustomed to proper lifting techniques and other posture-related interventions must be closely investigated before full implementation.

4.1 Limitations of this Study

There are three major limitations to this study. First, the sample size of the respondents who answered the MSD prevalence survey is small and may not be representative of the emergency medical services profession in the United States. We believe, however, that our findings on MSD prevalence are consistent with those of previously published studies among EMTs and paramedics. To update the existing knowledge on MSDs, we recommend that a survey with a larger sample size be conducted. This can provide important insights into the condition, especially with the fact that most EMT companies are now using state-of-the-art technology and equipment.

The second limitation pertains to the quality of the simulation. Ideally, observations would be obtained from real emergencies. It is anticipated that this can't be done without interfering with the quality of EMS service. Legal and ethical considerations were also important challenges. We conducted the simulations with the guidance of the EMS manager of the company. The combined expertise of the manager and the workers was used to ensure that the simulated tasks were as close as possible to the generic situations encountered by the personnel. We also anticipate that the improper postures shown by the EMTs may not be representative of the majority of personnel in the industry. The majority may be knowledgeable in proper lifting techniques and may have access to ergonomically-designed equipment. However, we argue that manual lifting can still exist during an emergency response, especially in the absence of such equipment. Therefore, shedding a light on the issue is necessary. Lastly, the design of the study being cross-sectional does not substantially support cause and effect. For future research, we suggest exploring other methodologies that establish a clinical association between the tasks and the condition.

Conflict of Interest
No conflicts of interest to declare.

Acknowledgment
We thank the EMTs and their management for participating in this study, the Center of Creative Inquiry, and the SSH Dean's Office at Keene State College for the funding.

References

Aasa, U., Barnekow-Bergkvist, M., Ängquist, K. A., & Brulin, C. (2005). Relationships between work-related factors and disorders in the neck-shoulder and low-back region among female and male ambulance personnel. Journal of Occupational Health, 47(6), 481–489. https://doi.org/10.1539/joh.47.481

Amit, L. M., & Song, Y.-W. (2021). Effectiveness of ergonomic intervention in work-related postures and musculoskeletal disorders of call center workers: A case-control study. Industrial Engineering & Management Systems, 20(2), 109–118. https://doi.org/10.7232/iems.2021.20.2.109

BrightHub Project Management. (2011). A brief history of root cause analysis. https://www.brighthubpm.com/risk-management/123244-how-has-the-root-cause-analysis-evolved-since-inception/

Broniecki, M., Esterman, A., May, E., & Grantham, H. (2010). Musculoskeletal disorder prevalence and risk factors in ambulance officers. Journal of Back and Musculoskeletal Rehabilitation, 23(4), 165–174. https://doi.org/10.3233/bmr-2010-0265

Conrad, K. M. L. (n.d.). Ergonomic study of fire service musculoskeletal injuries. Final performance report. NTIS. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB98130776.xhtml

Friedenberg, R., Kalichman, L., Ezra, D., Wacht, O., & Alperovitch-Najenson, D. (2020). Work-related musculoskeletal disorders and injuries among emergency medical technicians and paramedics: A comprehensive narrative review. Archives of Environmental & Occupational Health, 77(1), 9–17. https://doi.org/10.1080/19338244.2020.1832038

Fryar, C. D., Kruszon-Moran, D., Gu, Q., Carroll, M., & Ogden, C. L. (2021). Mean body weight, height, waist circumference, and body mass index among children and adolescents: United States, 1999–2018. https://doi.org/10.15620/cdc:107559

Hansen, C. D., Rasmussen, K., Kyed, M., Nielsen, K. J., & Andersen, J. H. (2012). Physical and psychosocial work environment factors and their association with health outcomes in Danish Ambulance Personnel – a cross-sectional study. BMC Public Health, 12(1). https://doi.org/10.1186/1471-2458-12-534

Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment (reba). Applied Ergonomics, 31(2), 201–205. https://doi.org/10.1016/s0003-6870(99)00039-3

Hong, S. W., Uhm, D. C., & Jun, M. H. (2010). Job stress and work-related musculoskeletal symptoms of 119 emergency medical technicians. Korean Journal of Occupational Health Nursing, 19(2), 223-235. (In Korean)

Jones, A. Y. M., & Lee, R. Y. W. (2005). Cardiopulmonary resuscitation and back injury in ambulance officers. International Archives of Occupational and Environmental Health, 78(4), 332–336. https://doi.org/10.1007/s00420-004-0577-3

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., & Jørgensen, K. (1987). Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics, 18(3), 233–237. https://doi.org/10.1016/0003-6870(87)90010-x

Lavender, S. A., Conrad, K. M., Reichelt, P. A., Gacki-Smith, J., & Kohok, A. K. (2007). Designing ergonomic interventions for EMS workers, part I: Transporting patients down the stairs. Applied Ergonomics, 38(1), 71–81. https://doi.org/10.1016/j.apergo.2005.12.005

Lavender, S. A., Conrad, K. M., Reichelt, P. A., Johnson, P. W., & T. Meyer, F. (2000). Biomechanical analyses of paramedics simulating frequently performed strenuous work tasks. Applied Ergonomics, 31(2), 167–177. https://doi.org/10.1016/s0003-6870(99)00040-x

Luoma, K., Riihimäki, H., Luukkonen, R., Raininko, R., Viikari-Juntura, E., & Lamminen, A. (2000). Low back pain in relation to lumbar disc degeneration. Spine, 25(4), 487–492. https://doi.org/10.1097/00007632-200002150-00016

Maguire, B. J., & Smith, S. (2013). Injuries and fatalities among emergency medical technicians and paramedics in the United States. Prehospital and Disaster Medicine, 28(4), 376–382. https://doi.org/10.1017/s1049023x13003555

McAtamney, L., & Nigel Corlett, E. (1993). Rula: A survey method for the investigation of work-related upper limb disorders. Applied Ergonomics, 24(2), 91–99. https://doi.org/10.1016/0003-6870(93)90080-s

NASEMSOorg. (2020). NASEMSO releases 2020 National EMS Assessment.). https://nasemso.org/news-events/news/news-item/nasemso-releases-2020-national-ems-assessment-2/

OSTI.GOV. (1992). Root cause analysis guidance document. DOE guideline. Root cause analysis guidance document. https://www.osti.gov/biblio/10125866-root-cause-analysis-guidance-document-doe-guideline

Prairie, J., & Corbeil, P. (2014). Paramedics on the job: Dynamic Trunk Motion Assessment at the workplace. Applied Ergonomics, 45(4), 895–903. https://doi.org/10.1016/j.apergo.2013.11.006

Rahimi, A., Alhani, F., & Anoosheh, M. (2015). Relationship between low back pain with quality of life, depression, anxiety and stress among emergency medical technicians. Trauma Monthly, 20(2). https://doi.org/10.5812/traumamon.18686

Reichard, A. A., & Jackson, L. L. (2009). Occupational injuries among emergency responders. American Journal of Industrial Medicine. https://doi.org/10.1002/ajim.20772

Schurr, S. A., Marshall, A. N., Resch, J. E., & Saliba, S. A. (2017). Two-dimensional video analysis is comparable to 3D motion capture in lower extremity movement assessment. International Journal of Sports Physical Therapy, 12(2), 163–172.

Stack, T., Ostrom, L. T., & Wilhelmsen, C. A. (2016). Occupational ergonomics: A practical approach. J. Wiley.

Studnek, J. R., & Crawford, J. M. (2007). Factors associated with back problems among emergency medical technicians. American Journal of Industrial Medicine, 50(6), 464–469. https://doi.org/10.1002/ajim.20463

Weaver, M. D., Patterson, P. D., Fabio, A., Moore, C. G., Freiberg, M. S., & Songer, T. J. (2015). An observational study of shift length, crew familiarity, and occupational injury and illness in emergency Medical Services Workers. Occupational and Environmental Medicine, 72(11), 798–804. https://doi.org/10.1136/oemed-2015-102966

White, S. K. (2022). What is root cause analysis? A proactive approach to change management. CIO. https://www.cio.com/article/350219/what-is-root-cause-analysis-a-proactive-approach-to-change-management.html#:~:text=root%20cause%20analysis%3F-,A%20proactive%20approach%20to%20change%20management,to%20reoccur%20in%20the%20future.

Construction Safety Personnel Qualifications: The Impact of Education, Experience, and Certificate Programs

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Abstract

Construction is among the most hazardous industries, with an annual fatality rate of over 1000 workers in the United States. Researchers and practitioners have proclaimed that implementing effective safety management plans can prevent most construction accidents. Safety personnel, who oversee the design, implementation, and enhancement of safety management plans, play an essential role in preventing accidents and enhancing construction safety. Despite their important role, there is little research, if any, to examine if the actual qualifications of construction safety personnel match recommended qualifications by safety associations and professional organizations. Moreover, the impact of the qualifications of safety personnel on achieved safety outcomes has not yet been thoroughly examined. The present study aims to (1) examine if the qualifications of construction safety personnel match recommended qualifications by safety associations and professional organizations, and (2) empirically analyze the impact of three key safety personnel qualifications, namely education, experience, and certifications, on overall construction site safety performance. Sixty-five construction safety personnel participated in the study by responding to a questionnaire survey. Regression analysis between construction safety performance measured by the Total Recordable Incident Rate (TRIR) and three qualification criteria revealed that 1) higher levels of experience of safety personnel, as well as certificate programs, significantly contribute to lowering TRIR rates, and 2) the level of education of safety personnel is not statistically associated with lower or higher TRIR rates. The findings of this study contribute to the body of knowledge by highlighting the negative associations (1) between the level of experience and TRIR and (2) between certifications and TRIR—both of which are findings of practical value to safety personnel who aim to maximize their positive influence on safety performance. In particular, this finding justifies why construction management should prioritize experience level and safety certifications over education when selecting safety personnel.

KEY WORDS: *construction safety, occupational accidents, qualifications, safety personnel*

1. Introduction

Construction is an important element in achieving a strong economy. The construction industry contributes approximately one billion dollars annually to the gross domestic product (GDP) in the United States (BEA, 2020). Globally, this number is about one thousand times greater, meaning that the construction industry contributes over $10 trillion to the gross world product (GWP) (Mckinsey Global Institute, 2017). The contribution of the construction industry is only possible due to the production of the industry workers (Kamas et al., 2019; Nnaji et al., 2022; Rasheed, 2016). Over 2% of the US population works in construction, which accounts for over 7 million individuals, with an anticipated annual increase of approximately half a million new employees (BLS1, 2020; BLS2, 2020). With all of their importance and critical role in maintaining a prosperous economy, the construction workforce faces significant challenges, especially in terms of maintaining their health and safety. Every year, the construction industry loses about 1,000 employees due to workplace fatalities, and many others become injured or disabled. In 2019, 1,061 employees were killed in workplace operations, according to the Bureau of Labor Statistics (BLS1, 2020). Construction employees face a risk of encountering a fatal accident that is 3-4 times higher than employees working in, say, the manufacturing industry (GÜRCANLI and MÜNGEN, 2013; Jin et al., 2019).

To curb the increasing number of workplace injuries and fatalities, it should be ensured that safety personnel leading the safety efforts on construction sites are well-qualified and have the necessary training, education, and experience. The probability of improving overall safety performance increases 2.29 times when having full-time safety personnel (Al-Bayati et al., 2020). The process of determining if safety personnel are well-qualified for a job is oftentimes subjective and does not follow recommendations or requirements provided by safety associations and professional organizations (Al-Bayati et al., 2019; Tam et al., 2004). However, there is no literature on determining if construction safety personnel are adequately qualified for the responsibility of their positions. Relatedly, few studies have examined the qualifications of safety personnel in the construction industry. Only a single study conducted by Awolusi et al. (2017) focused on the qualifications of construction safety personnel. The study of Awolusi et al. (2017) found that construction firms are equipped with higher numbers of safety personnel to manage construction activities than the staffing size recommended by existing literature on the topic. The ISO 45001-2018 standards titled "Occupational health and safety management systems — Requirements with guidance for use," stresses that organizations should ensure their safety personnel is competent for the job responsibilities that they are upholding. It is recommended that competence be evaluated by three major elements: education, training, and experience. Accordingly, the goals of the present study are to (1) examine if the qualifications of construction safety personnel match recommended qualifications by safety associations and professional organizations, and (2) empirically analyze the impact of three key safety personnel qualifications (namely education, experience, and certifications) on overall construction site safety performance. Based on a review of existing literature, safety qualification is assessed by three key aspects: (1) education, (2) experience, and (3) certification (ASSP (American Society of Safety Professionals), 2016).

2. Research Hypothesis Development

The first goal of this study is achieved using descriptive statistics. With respect to the second goal of the research study, a research hypothesis is developed and will be tested using inferential statistics. The hypothesis examines the association between safety performance measured by the TRIR, as shown in the subsequent section, and the qualifications of safety personnel with respect to three aspects: education, experience, and certifications. Accordingly, three research hypotheses were developed, as follows:

1. Education versus safety performance.

    1. Null hypothesis (1Ho): Higher levels of education of safety personnel are not associated with improved construction site safety performance.

    2. Alternative hypothesis (1H1): Higher levels of education of safety personnel are associated with improved construction site safety performance.

2. Experience versus safety performance.

    1. Null hypothesis (2Ho): More years of experience are not associated with improved construction site safety performance.

    2. Alternative hypothesis (2H1): More years of experience are associated with improved construction site safety performance.

3. Certifications versus safety performance.

1. Null hypothesis (3Ho): Acquiring a safety certification is not associated with improved construction site safety performance.
2. Alternative hypothesis (3H1): Acquiring a safety certification is associated with improved construction site safety performance.

3. Research Objectives

To test the research hypotheses stated in the previous section, the specific objectives are set for the present study, as follows:

- Assess the qualifications of safety personnel holding safety positions in the construction industry and whether they possess the minimum qualifications recommended by safety associations and professional organizations.
- Examine the association between three recommended qualifications (education, experience, and certification) and safety performance outcomes on construction projects.

For the second objective, the TRIR was considered the primary indicator to measure safety outcomes. Construction researchers and practitioners widely adopt TRIR to evaluate the safety performance of a construction company. According to the Occupational Safety and Health Administration (OSHA), TRIR is calculated by multiplying the total number of recordable cases by 200,000 and dividing by the total hours worked by all employees within a company during the year covered (Karakhan et al., 2018).

4. Research Methodology

A questionnaire survey was developed and distributed to safety practitioner personnel who were responsible for construction safety management in the US. The authors developed a questionnaire survey for safety personnel and approved by the Lawrence Technological University's Institutional Review Board (IRB). The questionnaire was pilot tested with three knowledgeable professionals active in construction health and safety management. This pilot testing ensured that the survey questions were practical and consistent with the terminology used in the industry and minimized any potential bias with the survey (Abowitz and Toole, 2010). The questionnaire was revised based on the feedback received from three professionals who participated in the pilot testing and distributed to the targeted audience via email. The researchers distributed the survey to safety professionals in their contacts and asked the participants to forward the survey to other safety personnel who uphold an active safety position within their firms. Thus, the researchers utilized a convenience sample (i.e., snowball), which is often used by construction scholars (Abowitz and Toole, 2010).

Corresponding to the research goals, the questionnaire consisted of three main parts. The first part focused on collecting demographic information about the survey participants, such as sector, organization type, job title, etc. The second part collected information about the participants' qualifications (i.e., education, experience, and certification) and their safety roles. Finally, the third part solicited information pertaining to safety performance metrics of the participants' firms, such as TRIRs and the number of dedicated full-time and part-time safety personnel within each company.

Sixty-five (65) construction safety practitioners participated in the study. The construction industry is known for lacking participation in surveys and questionnaires (Nabi and El-adaway, 2021). There is no clear threshold for sample size that should be considered for construction research. Accordingly, a wide range of sample sizes has been suggested, including a minimum sample size of 35 data points, 50 data points, and 75 data points by Fowler (1995), Sudman (1983), and Converse and Presser (1986), respectively. Thus, the obtained sample size seems to be within the standard ranges used in construction research.

5. Research Findings

The majority of the participants (over 70%) were either safety practitioners/specialists or safety managers/senior specialists. The remainder of the participants (approximately 30%) were distributed between safety interns, safety directors, safety executives, safety presidents, and so forth, as presented in Table 1. The responding participants equivalently represented general contractors (33 participants, 50.77%) and subcontractors (32 participants, 49.23%). Overall, all regions throughout the U.S. (northeast, west, southwest, midwest, south, and mid-Atlantic) were represented in the survey. The participants were located in 13 different geographical locations throughout the U.S. (12 states and the District of Columbia). Due to the extended contacts of the researchers in North Carolina and the surrounding area, the majority of the responses came from the state of North Carolina (22 responses, which represents approximately 34% of the total responses received). South Carolina came second regarding the number of individuals participating in the questionnaire survey, with 12 responses (18.5%). Nearly 10% of the respondents (six respondents) were located in the state of New Jersey, and 6% of the respondents (four respondents) were located in the District of Columbia. Arizona, California, and Georgia each had two individuals participate in the study. Finally, only one individual participated in the study from the following states: Maryland, Massachusetts, New York, Ohio, Vermont, and Virginia. Table 1 summarizes the demographic information of the survey respondents.

Professional experience is one of the most important factors that guarantee the validity and reliability of the study findings (Karakhan et al., 2021). As shown in Table 1, more than 90% of participants have more than 5 years of professional experience, which increases the level of confidence in the study findings.

Table 1: Demographic information of participants (n = 65)

Category	Demography	Count	Percent
Gender	Female	05	7.69%
	Male	60	92.31%
Construction Sector	Commercial building	34	52.31%
	Civil and heavy construction	14	21.54%
	Residential construction	07	10.77%
	Special trades	05	7.69%
	Other	05	7.69%
Organization Type	General contractor	33	50.77%
	Sub-contractor	32	49.23%
Job Title	Safety intern	01	1.54%
	Safety practitioner/specialist	25	38.46%
	Safety manager/senior specialist	21	32.31%
	Safety director/senior safety position	04	6.15%
	Safety Executive/president/VP	05	7.69%
	Other	09	13.85%
Professional Experience	Less than 5 years	04	6.15%
	5-10 years	22	33.85%
	11-20 years	20	30.77%
	21-30 years	10	15.38%
	More than 30 years	09	13.85%
Education	High school diploma or equivalent	01	1.54%
	Associate degree or equivalent	09	13.85%
	Trade school or equivalent	11	16.92%
	Bachelor's degree or equivalent	33	50.77%
	Graduate degree or equivalent	11	16.92%

5.1 Qualifications of Construction Safety Personnel

To achieve the first research objective and assess whether safety personnel in the construction industry possess the minimum required qualifications, the participants were asked about their education, experience, and any certification(s) they possess. After integrating the data, it was found that all of the surveyed safety personnel obtained the minimum required level of experience needed for safety positions, as reported in the existing literature on the topic. Similarly, most of the participants (86%) possessed the minimum education level recommended by professional organizations and safety associations for their safety positions. Finally, with respect to certification, possessing the required certification varies depending on the position of safety personnel. In contrast, the majority of the surveyed safety practitioners/specialists (72%) possessed the minimum certification recommended for their safety position. However, all the surveyed safety executives/presidents/vice presidents (100%) did not possess the minimum certification level recommended for their position. However, this could be a result of the fact that the safety professional certification programs were not mature several years ago. On average, 42% of the surveyed safety personnel did not possess the recommended certification level determined by professional organizations and safety associations for their safety positions. Table 2 shows the distribution of the possessed qualifications for the surveyed construction safety personnel.

Table 2: Qualification of safety personnel covered in the survey (n = 56)

Position	Recommended education		Recommended experience		Recommended certification	
	Yes	No	Yes	No	Yes	No
Safety Entry Position (or Equivalent)	100%	-	100%	-	Certification not required	
Safety Practitioner/ Specialist (or equivalent)	100%	-	100%	-	72%	28%
Safety Manager/Senior Specialist (or equivalent)	71%	39%	100%	-	57%	43%
Safety Director/Senior Safety Position (or equivalent)	75%	25%	100%	-	50%	50%
Safety Executive/ President/VP (or equivalent)	80%	20%	100%	-	-	100%
Average across all positions	86%	14%	100%	-	42%	58%

5.2 Impact of Qualifications of Construction Safety Personnel on Safety Performance

To achieve the second research objective, the association between the qualifications of construction safety personnel and safety performance (i.e., TRIRs) was examined. Therefore, the TRIRs of the surveyed construction companies were collected from the participants. Given the sensitivity of the information requested (i.e., injury statistics), only 43% of the surveyed construction safety personnel initially responded to these questions and provided the requested information, yielding 28 responses. To increase the level of participation, another email was sent to the participants who did not provide safety metrics for their organizations, and it was clarified that company names and other personal information would be kept confidential and excluded from the study (i.e., not shared with anyone outside the research team). As a result, an additional five participants provided information about the safety metrics of their organizations, increasing the number of participants to 33. This piece of information can assist in answering the three sub-hypotheses for the second goal of the study.

When examining the association between a response variable (i.e., TRIR) and multiple exploratory variables (i.e., qualifications) needed to test the research hypothesis, multiple linear regression is considered an appropriate analysis method (Cobb et al., 2000). Multiple linear regression analysis is a statistical method that uses several explanatory variables to examine the association and predict the outcome of a response variable. The purpose of multiple linear regression analysis is to model the linear relationship between explanatory (independent) variables and a response (dependent) variable (Cobb et al., 2000). In this case, TRIR is the response variable, and safety qualifications of construction personnel (i.e., education, experience, and certification) are the exploratory variables. Equation (1) shows the multiple linear regression utilized in the present study. The scale of exploratory variables is as follows:

- Certification: 0 for no certification at all and 1 for acquiring certification.
- Education: 0 for no education, 1 for a 2-year program, 2 for a 4-year program, and 3 for a program of 4 years or longer.
- Experience: Years of experience.

TRIR = **β0** + **β1*Education** + **β2*Experience** + **β3*Certification (1)**

Where:

β0 is the intercept (a constant value), and

β1-3 are the estimates for the explanatory variables.

Accordingly, multiple regression was run to predict TRIR from education, experience, and certification status. There was linearity between the continuous exploratory variable and TRIR. There was also independence of residuals, as assessed by a Durbin-Watson statistic of 1.87. There were no studentized deleted residuals greater than ±3 standard deviations. The assumption of normality was met. Accordingly, the assumptions of the test were all met. Afterward, a regression model was developed, and the results indicated that there is statistically significant evidence that the developed multiple regression model predicted TRIR; $F(3, 29) = 6.08$, p-value = 0.002, adj. R2 = 0.38. The output of the produced multiple linear regression model is presented in Table 3. The output includes information about coefficient estimate (β), standard error (SE), t-statistic, p-value, and confidence interval (CI). Equation 2 numerically expresses the model output.

Based on the regression output, years of experience and certification status added statistically significant results to the prediction, p-value < 0.001. Higher levels of experience of safety personnel and possession of certification are negatively associated with TRIR based on the sample studied. This negative association means that each additional year of experience that construction safety personnel possess is expected to be associated with a 0.068 decrease in TRIR, holding other variables constant (t-statistic = −3.578, p-value = 0.001). Similarly, each additional certification possessed by construction safety personnel is expected to be associated, on average, with a 1.910 decrease in TRIR, holding other variables constant (t-statistic = −2.926, p-value = 0.001). On the other hand, no statistically significant evidence of an association between the level of education of safety personnel (2- and 4-year degree or even higher education) and TRIR was found based on the sample studied (t- statistic = 0.517, p-value = 0.610).

TRIR = **4.008** + **0.197*Education – 0.068*Experience – 1.910*Certification (2)**

Table 3: Characteristics of multiple linear regression model (n = 33)

Variable	Estimate	SE	t-statistic	p-value	Lower 95%	Upper 95%
Intercept (β0)	4.008	1.045	3.837	0.001*	1.871	6.146
Education (β1)	0.197	0.653	0.517	0.610	−0.584	0.980
Experience (β2)	−0.068	0.382	−3.578	0.001*	−0.107	−0.029
Certification (β3)	−1.910	0.653	−2.926	0.001*	−3.245	−0.575

Note: The symbol "*" indicates that the variable is statistically significant.

6. Testing Research Hypothesis: Statistical Analysis Findings

Three research hypotheses were tested using the statistical analysis of the multiple linear regression model. This section of the manuscript describes the findings of the statistical analysis with respect to each hypothesis.

6.1 First Hypothesis: Education vs. Safety Performance

The statistical analysis found no statistical evidence against the null hypothesis (1Ho) that higher levels of education are not associated with improved safety performance on construction projects (t-statistic = 0.517, p-value = 0.610). This means that the null hypothesis (1Ho) cannot be rejected and that, based on the study sample, higher levels of education do not lead to lower TRIR and improved safety performance on construction projects.

6.2 Second Hypothesis: Experience vs. Safety Performance

The statistical analysis found substantial statistical evidence against the null hypothesis (2Ho) that more years of industry experience are not associated with improved safety performance on construction projects (t-statistic = –3.578, p-value = 0.001). This means that the alternative research hypothesis (2H1) should be accepted instead. The alternative research hypothesis states that more years of experience are associated with lower TRIR and improved safety performance on construction projects.

6.3 Third Hypothesis: Certifications vs. Safety Performance

The statistical analysis found substantial statistical evidence against the null hypothesis (3Ho) that acquiring a safety certificate is not associated with improved safety performance on construction projects (t-statistic = –2.926, p-value = 0.001). This means that the alternative research hypothesis (3H1) should be accepted instead. The alternative research hypothesis states that acquiring a safety certificate is associated with lower TRIR and improved safety performance on construction projects.

7. Discussion and Recommendations

The analysis of the collected responses shows that less than 50% of the surveyed construction safety personnel possess the combined minimum qualifications in terms of education, experience, and certification recommended for their safety positions as determined by ASSP. Concerning education, most of the surveyed safety personnel (86%) possess the minimum education level required. Several of them have higher education levels than the minimum education recommended. Regarding the relevant experience of construction safety personnel, all of the surveyed individuals (100%) possess the minimum experience level for their safety position. As the data suggest, the vast majority of the surveyed safety personnel possess the recommended education and experience levels in alignment with the fact that education and prior experience are key requirements for most safety positions in the construction industry. The percentage of safety personnel who did not obtain the recommended certification level is undesirable, especially for higher safety positions. Overall, 58% of the surveyed construction safety personnel possess the minimum certification level recommended for their safety positions. To provide a perspective, less than one-third of the safety personnel in managerial safety positions (directors, executives, presidents, etc.) possess one of the recommended safety certifications. Safety certification and licensure are often obtained during professional development offered by the hiring organization. Professional development opportunities related to safety are sometimes underutilized in the construction industry, especially for small- and medium-sized organizations, due to the limited financial and non-financial resources (Al-Bayati, 2021b). Obtaining a professional certification or licensure related to safety is a sign of maturity that can positively influence safety behaviors and outcomes of construction projects (Gambatese, 2019). These results may suggest that the industry emphasizes experience over other qualifications.

On the other hand, the statistical analysis using multiple linear regression indicates mixed findings. While statistically significant evidence of association is detected between experience level and certification possession of safety personnel and their corresponding companies' TRIRs, no statistical evidence of an association between the education level of safety personnel and TRIR is observed, according to the regression outputs. The statistical association between the experience level of safety personnel and TRIR is found to be negative, leading to an average of 0.068 potential decreases in TRIR for each additional year of experience safety personnel possess, assuming that education and certification levels remain constant ($\beta 2 = -0.068$, SE = 0.382, 95% CI = −0.107 to −0.029, t-statistic = −3.578, p-value = 0.001). This finding is in line with previous studies that found a statistical relationship between years of experience and safety performance on construction projects (Awolusi et al., 2017; Jaselskis et al., 1996). Similarly, the regression model reveals a statistically significant negative association between the certification level of safety personnel and TRIR. To be specific, each additional certification acquired by construction safety personnel is expected to be associated, on average, with a 1.910 reduction in TRIR, assuming that experience and education levels remain constant ($\beta 3 = -1.910$, SE = 0.653, 95% CI = −3.245 to −0.575, t-statistic = −2.926, p-value = 0.001). Ideally, all safety personnel should have a certification (Hinze et al., 2013). The finding highlights the importance of safety certifications. However, the industry doesn't seem to acknowledge the necessity of having the recommended safety certifications, according to the majority of participants who did not possess the recommended level of certifications. Safety certification has multiple benefits, including encouraging safety personnel to continue professional development and learning safety best practices for mitigating and managing workplace hazards. However, it should be acknowledged that sponsoring and providing opportunities to obtain and maintain professional licensing and certification require financial and non-financial resources, which may not be available for smaller construction firms (Al-Bayati, 2021a).

Startlingly, the regression analysis indicates no statistically significant evidence of association between the level of education acquired by safety personnel and TRIR ($\beta 1 = 0.197$, SE = 0.653, 95% CI = −0.584 to 0.980, t-statistic = 0.517, p-value = 0.610). This finding could be explained by the fact that students receive a wide range of topics through their educational programs, which may not be related to their specific duties. However, experience and certifications are often related to the daily duties of safety personnel. It should be noted that this surprising finding could be attributed to the fact that all 33 surveyed safety personnel who provided information about their companies' TRIR possessed the minimum education level recommended for their safety position. This means that the regression analysis did not examine whether not having the required education level is associated with different TRIR—basically, only the impact of having different levels of education that exceed the minimum level on TRIR was tested in the regression analysis. Ideally, the impact of not having the minimum education level recommended on TRIR should be understood within its statistical meaning, not practical implications. The statistical results reveal that having higher levels of education than the minimum recommended level is not statistically always associated with reduced TRIR. However, it is not practical to totally ignore the positive influence of educated safety personnel on overall site safety. On the other hand, it should be clarified that the correlation between education and TRIR does not necessarily express a cause-and-effect relationship. Instead, this correlation may be attributed to multiple contributing factors that cause increased TRIRs on construction projects.

8. Limitations

The current study contributes to the body of knowledge by providing exclusive insights into the role of different elements of the desired qualifications for construction safety personnel. Despite its merit, this study has several limitations. First, the sample size of 65 safety personnel was sufficient enough for statistical data analysis. However, larger sample sizes can provide a broader perspective on the distribution of safety personnel qualifications in the U.S. Second, only 33 (i.e., 51%) of surveyed participants provided their companies' TRIRs. Increasing the number of participants who voluntarily provide TRIR information can shed more light on the subject matter. Third, the analysis presented in this study has mixed levels. Namely, the independent variables (i.e., qualifications of safety personnel) are for the individual survey participants, whereas the dependent variable (i.e., TRIR) is for the survey participants' firms. To avoid having mixed levels of analysis, future researchers are advised to measure the extent to which all safety personnel in the firm meet the recommended

ASSP safety qualifications. Fourth, the TRIR scores were analyzed in aggregate, whereas the survey sample included individuals with different levels of responsibility and professional qualifications. There may be a relationship between one type of qualification and TRIR, but it was masked by aggregating the different levels of responsibility. Fifth, the findings of the present study are limited to the U.S. construction industry and cannot be generalized across other countries. Each country has unique work environments, rules, regulations, incident reporting, recording criteria, culture, weather conditions, etc., and it is unrealistic to generalize the findings of a study conducted in a country across other nations. Sixth, the adjusted R2 for the overall model was 38%, a moderate size effect, according to Cohen (1988). Construction safety scholars are encouraged to address these critical limitations to improve the industry's understanding of the necessary safety practitioner qualifications.

In addition, TRIR was considered the only measurement of a company's safety outcome, which may not fully represent the safety performance of a company (Al-Bayati et al., 2020). Future studies must consider other leading indicators to investigate the role of safety personnel qualifications in improving safety performance in their companies. It is also recommended that future research examines the impact of designating safety personnel for each construction site, given its size and characteristics, on the overall TRIR. The impact of a different safety-officer-to-employee-ratio on the safety performance of a project should be studied as well.

9. Conclusions

Construction as a profession suffers from high rates of incidents in the workplace. However, most of these incidents, specifically severe incidents, can be prevented by implementing an effective safety plan. Safety personnel play a key role in the successful development and implementation of safety plans. There is scarce research on the role of effective safety personnel qualifications in enhancing construction safety performance. The present research study aimed to assess the qualifications of safety personnel in the construction industry and examine the association between the qualifications of safety personnel and overall construction site safety. Among others, the study revealed a lack of significant association between TRIR and education, which is a concerning finding that requires further investigation and special attention from related safety educational programs. On the other hand, the study suggests a negative correlation between TRIR and construction safety experience, as well as related safety certifications possessed by safety personnel. Despite its importance and its role in preventing accidents, there is a lack of certification attainment among safety personnel in the construction industry in general and upper safety positions. Attaining the required certification for all safety positions is critical. The finding of this study revealed a statistically significant association between certification attainment and TRIRs on construction projects. Construction organizations are recommended to consider certification attainment as one of the critical requirements when hiring safety personnel. In addition, construction firms should sponsor and provide opportunities for safety personnel to obtain and maintain professional safety certification. Although such sponsorship might be costly upfront, the benefits of acquiring a safety certification are expected to outweigh any cost spent. Finally, project owners should incorporate a requirement of certifications for safety personnel handling construction projects due to the importance of these certifications in improving the safety performance of construction projects.

References

Abowitz, D.A., & Toole, T.M., Mixed Method Research: Fundamental Issues of Design, Validity, and Reliability in Construction Research, J. of Construction Engineering and Management, vol. 136(1), pp. 108–116, (2010). DOI: https://doi.org/10.1061/(asce)co.1943-7862.0000026

Al-Bayati, A.J., Albert, A., & Ford, G., Construction Safety Culture and Climate: Satisfying Necessity for an Industry Framework, Practice Per. on Structural Design and Construction, (2019). DOI https://doi.org/10.1061/(ASCE)SC.1943-5576.0000452

Al-Bayati, A.J., Impact of Construction Safety Culture and Construction Safety Climate on Safety Behavior and Safety Motivation, Safety, vol. 7(2), pp. 41, (2021a). DOI: https://doi.org/10.3390/safety7020041

Al-Bayati, A.J., Firm Size Influence on Construction Safety Culture and Construction Safety Climate, Practice Per. on Structural Design and Construction, vol. 26(4), (2021b). DOI: https://doi.org/10.1061/(asce)sc.1943-5576.0000610

Al-Bayati, A.J., O'Barr, K., Suk, S., Albert, A., & Chappell, J., Experience Modification Rate as a Prequalification Criterion for Safety Performance, Prof. Safety, vol. 65(07), pp. 31–38, (2020).

ASSP (American Society of Safety Professionals), The Employer's Guide to Hiring a Safety Professional, (2016).

Awolusi, I., Marks, E., & Vereen, S., Qualifications and Staffing Requirements of Safety Personnel in Construction, Practice Per. on Structural Design and Construction, vol. 22(4), (2017). DOI: https://doi.org/10.1061/(asce)sc.1943-5576.0000328

BEA, I. E. A. D., GDP by Industry: Components of Value Added by Industry, (2020).

BLS1, Workforce statistic, US Bureau of Labor Statistics, (2020).

BLS2, Industries at a Glance, US Bureau of Labor Statistics, (2020).

Cobb, G.W., Ramsey, F.L., & Schafer, D.W., The Statistical Sleuth, The American Statistician, vol. 54(1), pp. 78, (2000). DOI: https://doi.org/10.2307/2685617

Cohen, J., Statistical Power Analysis for the Behavioral Sciences, 2nd Ed., New York: Routledge, (1998).

Fowler, F., & Cosenza, C., Design and Evaluation of Survey Questions, in The SAGE Handbook of Applied Social Research Methods,, SAGE Publications, Inc., pp. 375–412, (2009). DOI: https://doi.org/10.4135/9781483348858.n12

Gambatese, J. , K.A.A., and S.D.R., Sustainability Model for Construction, The Center for Construction Research and Training, (2019).

GÜRCANLI, G.E., & MÜNGEN, U., Analysis of Construction Accidents in Turkey and Responsible Parties, Industrial Health, vol. 51(6), pp. 581–595, (2013). DOI: https://doi.org/10.2486/indhealth.2012-0139

Hinze, J., Thurman, S., & Wehle, A., Leading Indicators of Construction Safety Performance, Safety Science, vol. 51(1), pp. 23–28, (2013). DOI: https://doi.org/10.1016/j.ssci.2012.05.016

Jaselskis, E.J., Anderson, S.D., & Russell, J.S. Strategies for Achieving Excellence in Construction Safety Performance, J. of Construction Engineering and Management, vol. 122(1), pp. 61–70, (1996). DOI: https://doi.org/10.1061/(asce)0733-9364(1996)122:1(61)

Jin, Z., Gambatese, J., Liu, D., & Dharmapalan, V., Using 4D BIM to Assess Construction Risks During the Design Phase, Engineering, Construction and Architectural Management, vol. 26(11), pp. 2637–2654, (2019). DOI: https://doi.org/10.1108/ecam-09-2018-0379

Kamas, W.M., Hasan, A.A., & Fadel, A.H., Economic Benefits for the Application of Standards of Sustainability in Construction Projects, J. of Engineering, vol. 25(3), pp. 117–126, (2019). DOI: https://doi.org/10.31026/j.eng.2019.03.10

Karakhan, A.A., Gambatese, J.A., Simmons, D.R., & Al-Bayati, A.J. Identifying Pertinent Indicators for Assessing and Fostering Diversity, Equity, and Inclusion of the Construction Workforce, J. of Management in Engineering, vol. 37(2), (2021). DOI: https://doi.org/10.1061/(asce)me.1943-5479.0000885

Karakhan, A., Rajendran, S., & Gambatese, J., Validation of Time-Safety Influence Curve Using Empirical Safety and Injury Data Poisson Regression, Construction Research Congress 2018, (2018). DOI: https://doi.org/10.1061/9780784481288.038

Mckinsey Global Institute. Reinventing Construction Through a Productivity Revolution, (2017).

Nabi, M.A., & El-adaway, I.H., Understanding the Key Risks Affecting Cost and Schedule Performance of Modular Construction Projects, J. of Management in Engineering, vol. 37(4), (2021). DOI: https://doi.org/10.1061/(asce)me.1943-5479.0000917

Nnaji, C., Jin, Z., & Karakhan, A., Safety and Health Management Response to COVID-19 in the Construction Industry: A Perspective of Fieldworkers, Process Safety and Environmental Protection, vol. 159, pp. 477–488, (2022). DOI: https://doi.org/10.1016/j.psep.2022.01.002

Quarm, D., Converse, J.M., & Presser, S., Survey Questions: Handcrafting the Standardized Questionnaire, Teaching Sociology, vol. 16(3), pp. 314, (1998). DOI: https://doi.org/10.2307/1317544

Rasheed, E.K., A Program Applying Professional Safety Basics in Construction Projects, J. of Engineering, vol. 22(4), pp. 1–21, (2016). DOI: https://joe.uobaghdad.edu.iq/index.php/main/article/view/240

Sudman, S., Applied Sampling, in Handbook of Survey Research, , Elsevier, pp. 145–194, (1983). DOI: https://doi.org/10.1016/b978-0-12-598226-9.50011-2

Tam, C.M., Zeng, S.X., & Deng, Z.M., Identifying Elements of Poor Construction Safety Management in China, Safety Science, vol. 42(7), pp. 569–586, (2004). DOI: https://doi.org/10.1016/j.ssci.2003.09.001

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