Impact of the COVID-19: Hazard Recognition Performance and Safety Risk Perception Among Construction Workers

By

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The construction industry is one of the most hazardous industries in the U.S., and COVID-19 has introduced additional safety risks to the workers' health and safety. Fatalities in the construction industry are higher compared to others. Researchers have identified construction workers' poor hazard recognition performance and safety risk perception as contributing factors to the high rates of accidents and occupational fatalities in construction. However, the long-term impact of COVID-19 as an emerging safety risk on construction workers' hazard recognition performance and safety risk perception has not been investigated. This study aimed to explore the long-term impact of COVID-19 on construction workers' hazard recognition and safety risk perception. The goal is to see if COVID-19 has the same effect on workers' performance as a physical injury and how their performance changes after experiencing COVID-19. Seventy-six workers were interviewed during the study. Each participant was shown four scenarios from a predefined 16 preset construction scenario. T-test was performed to test the research hypotheses between groups (group 1: workers who have not tested positive for COVID-19 and group 2: workers who tested positive for COVID-19). For the first hypothesis, data analysis showed that COVID-19 did not affect the construction workers' hazard recognition as there was no statistical

difference in the test. However, when the safety risk perception score was analyzed, it was observed that there was a statistical difference between the safety risk perception of the two groups. COVID-19 positive workers tend to perceive higher safety risks. The study aimed to aid in the improvement of the construction safety environment across the U.S. and help construction safety managers and trainers to have a better idea about the long-term impact of COVID-19 on the safety performance of the workers.

Impact of the COVID-19: Hazard Recognition Performance and Safety Risk Perception Among Construction Workers

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Risk Perception Among Construction Workers

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Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

The construction industry in the U.S. has valued at around 1.87 trillion U.S. dollars in the first quarter of 2021 (BEA, 2021). 7.41 million are currently employed in the construction sector (U.S. BLS 2021). The construction sector contributes about 4.3% total Gross Domestic Product (GDP) (BEA, 2021). In terms of injury, illness, and fatalities, the construction industry is regarded as one of the most hazardous industries (Namian, Khalid, et al., 2021; U.S. BLS, 2021b). Industry-wise, it represents 20.7% of workplace fatalities and 32% of the nonfatal workplace injuries reported in 2019 while employing just 7% of the total workforce (U.S. BLS, 2021c). The number of reported fatalities in 2019 for the construction workplace was 1061, which means that every eight hours, one construction worker died in a fatal accident (U.S. BLS, 2021b). Construction workers working in the construction industry are already vulnerable to injuries, illness, and fatalities, and the pandemic of COVID-19 has made the situation more critical. Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) virus is responsible for COVID-19, which is very contagious and can be transmitted from person to person via airborne transfer of particles emitted when an infected individual exhales, speaks, vocalizes, coughs, or sneezes (OSHA, 2021). The COVID-19 pandemic has affected every industry in the world. The pandemic crisis deteriorated to the point where the president of the United States declared a national emergency on March 13, 2020 (U.S. BLS, 2021a). The construction industry was no different than any other industry during the pandemic. The construction industry in the U.S. was severely affected by the COVID-19 pandemic (CPWR, 2020).

Due to the pandemic, the nature of businesses changed more or less; industries had to adopt new means to continue their operations. Working from remote locations, preferably home, was widely adopted during the pandemic because social distancing regulations were introduced to prevent the transmission of COVID-19 as per the Center for Disease Control (CDC) guidelines. However, the construction industry could not adapt to working from remote locations due to the nature of construction work. Construction works heavily rely on workers' skills rather than automated machinery. Workers, technicians, and engineers need to work onsite to perform or monitor activities correctly (Gamil & Alhagar, 2020). To keep the construction projects viable, all personnel related to the construction needed to be onsite for various activities to perform. In a recent study, it was observed construction workers had the highest positivity rate compared to other industries; tracking the test result of 730,000 COVID-19 tests found that in the construction trade, 5.7% of the individuals were asymptomatic, and 10.1% of those were with symptoms (Allan-Blitz et al., 2020). Thus, many workers were affected by the COVID-19, and the number is still on the rise. While some preliminary data about the impact of COVID-19 exist, the actual number of construction workers who were affected and recovered from COVID-19 is not publicly available. Though BLS and OHSA have taken steps to record COVID-19 infection as a recordable illness if the worker was infected while performing their duty, they will not produce any estimates about COVID-19 illness particularly (U.S. BLS, 2021a). There are already several studies about the impacts of COVID-19 in the construction industry, but no research has investigated the safety risk perception and hazard recognition of construction workers who contracted COVID-19 during the pandemic. Therefore, this study sought to determine the safety risk perception and hazard recognition of construction workers who contracted COVID-19 and their cautiousness about accidents.

Problem Statement

Workplace injuries are a common phenomenon in the construction workplace. Construction workers are already exposed to various risks and hazards on construction sites.

Construction site safety heavily relies on the safety risk perception of the individual as it enables the ability to assess and respond to the potential risks as they arise. COVID-19 has introduced newer safety risks and threats for construction workers. Many construction workers are affected by COVID-19, and they have started working for the construction industry again. The study assumes that COVID-19 can affect the construction workers' safety risk perception and performance of hazard recognition. It aims to explore the workers' safety risk perception and hazard recognition performance who tested COVID-19 positive and compare them with those who never tested COVID-19 positive.

Goal and Objectives

Many researchers have studied the safety performance of construction workers. The goal of the study is to understand the long-term impact of COVID-19 on workers' safety performance.

This study will address the following objectives:

1. COVID-19 impact on hazard recognition performance of workers.
2. Safety risk perceptions of construction workers are impacted by COVID-19.

The study calls attention to the following research questions:

- Does COVID-19 affect the hazard recognition performance of the construction workers?
- Does COVID-19 affect the safety risk perception behavior of the construction workers?

Hypotheses of Research

The following hypotheses will be tested in this research,

Hypothesis 1:

Null: COVID-19 does not affect the hazard recognition performance of the workers.

Alternative: COVID-19 affects the hazard recognition performance of the workers.

Hypothesis 2:

Null: COVID-19 did not impact construction workers' safety risk perception.

Alternative: COVID-19 impacts construction workers' safety risk perception.

Study Limitation

This study is limited to investigating the impact of COVID-19 safety risk perception and hazard recognition on construction workers. The data used to test the research hypothesis was obtained from a questionnaire survey and literature review. A parametric t-test was performed based on the data normality. COVID-19 variants were not considered as a variable factor in the study.

Organization of the Proposal

This thesis proposal is divided into five sections: (i) Introduction; (ii) Literature Review; (iii) Materials and Methodology; (iv) Initial Results; and (v) Conclusions, and Recommendations. The literature review covers construction safety, hazard recognition, safety risk perception, and COVID-19 in the construction industry.

CHAPTER 2: LITERATURE REVIEW

The construction industry is already hazardous by nature. In 2019, 5,333 workers died, and about 20% of the workers were from construction, accounting for one in five worker deaths for the year (OSHA, 2022). Providing construction site safety is a difficult task even in regular times (Woolley et al., 2020), and during the pandemic, the situation has become more challenging (Pamidimukkala & Kermanshachi, 2021). The nature of the construction work is hazardous (Haslam et al., 2005), requires manual handling (Antwi-Afari et al., 2017), and is labor-intensive. As a result, accidents, workdays, and fatalities continue to plague this industry.

Wuhan, Hubei, China, was the site of the first detection of SARS-CoV-2 in patients in December 2019 (Zhu et al., 2020). The World Health Organization (WHO) named the coronavirus disease COVID-19 and declared it a global pandemic (Guan et al., 2020). The COVID-19 virus is rampant in the entire world. The total number of reported COVID-19 positive cases in the U.S. as of March 2022, is 79,329,689. The total number of deaths is 964,774 (CDC, 2022b). Figure 1 shows a graphical illustration of COVID-19 confirmed cases across the U.S., and Figure 2 shows the reported daily death trends.

As COVID-19 spreads worldwide, it spontaneously evolves into different strains with varying degrees of transmissibility based on the virus's mutated genetic composition (Ramesh et al., 2021). Some newer variants of COVID-19 strains (i.e., Delta, Omicron) appeared to spread more rapidly and efficiently, leading to the rise in COVID-19 cases (Ramesh et al., 2021). The CDC keeps track of the COVID-19 variants. It divides COVID-19 variations into categories based on their ability to cause severe illness, resulting in morbidity and fatality, high infectivity, or diminished response to SARS-CoV-2 antibodies developed from prior infection or immunization (CDC, 2022c).

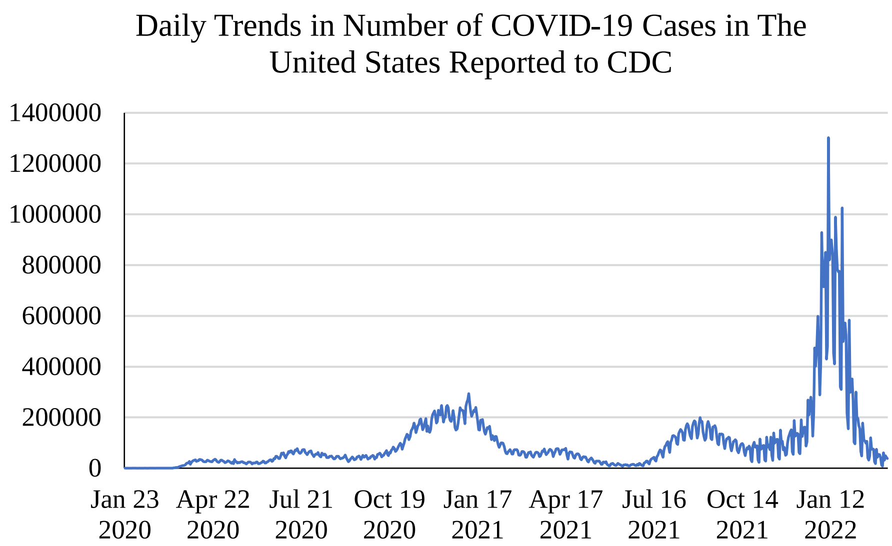

Figure 1: The number of COVID-19 cases reported to the CDC on a daily basis in the United States (CDC, 2022b)

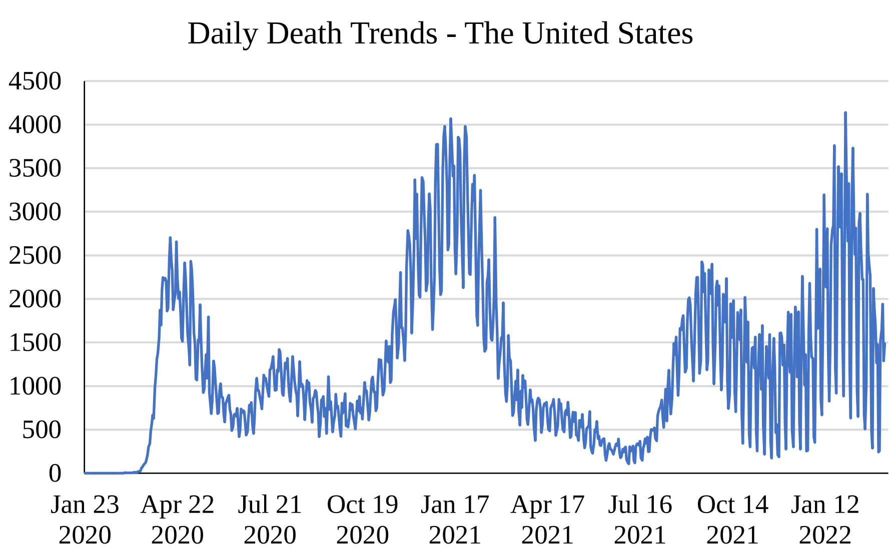

Figure 2: Daily death trends reported to CDC in the United States (CDC, 2022b)

In the United States, the various variations have been classified by CDC as VOI (variants of interest), VOC (variants of concern), or VOHC (variants of high significance). Table 1 represents the variant names and classification of possible attributes of concern.

Table 1: Classification of COVID-19 Variants (CDC, 2022c)

SIG Variant classification scheme	Variant Name	Attributes of a variant of concern
Variant Being Monitored (VBM)	Alpha (B.1.1.7 and Q lineages) Beta (B.1.351 and descendent lineages) Gamma (P.1 and descendent lineages) Epsilon (B.1.427 and B.1.429) Eta (B.1.525) Iota (B.1.526) Kappa (B.1.617.1) 1.617.3 Mu (B.1.621, B.1.621.1) Zeta (P.2)	• Receptor-binding changes in virus structure. • Antibodies produced from a previous illness or immunization have a lower neutralizing rate. • Reduction in treatment effectiveness. • Impact on diagnosis potential while testing. • Increase in disease spread and severity. • There is a limited prevalence or expansion in the United States and other nations.
Variant of Interest (VOI)	There are currently no COVID-19 variants that have been recognized as VOI.	• There is evidence that it has a detrimental impact on diagnosis, treatments, or vaccinations. • Interference with the targets of diagnostic tests is common. • There is evidence that it has a detrimental impact on diagnosis, treatments, or vaccinations. • There is evidence of diminished neutralization by antibodies produced from a previous illness or immunization. • There is evidence that vaccines do not provide as much protection against severe disease compared to the original strain. • Evidence points to an increase in the ability to spread. • Signs that the illness is becoming more severe.

Variant of Concern (VOC)	Delta (B.1.617.2 and AY lineages) Omicron (B.1.1.529 and B.A. lineages)	• There is evidence of a negative influence on diagnoses, treatments, or immunizations. • Interference with diagnostic test targets is widespread. • Evidence of a significant reduction in sensitivity to one or more therapeutic classes. • There is evidence of diminished neutralization by antibodies produced from a previous illness or immunization. • There is evidence that vaccines do not provide as much protection against severe diseases compared to the original strain. • Evidence points to an increase in the ability to spread. • Signs that the illness is becoming more severe.
Variant of High Consequence (VOHC)	No COVID-19 variants are designated as VOHC.	• MCMs are affected. • Diagnostic test objectives that have failed. • Evidence of a considerable decrease in vaccination efficiency, a disproportionately large incidence of illnesses among vaccinated people, or extremely poor vaccine-induced protection against severe disease. • Susceptibility to several EUA or authorized treatments has been significantly lowered. • An increase in hospitalizations and deterioration in clinical conditions.

COVID-19 has introduced a new health hazard in the construction industry. The present epidemic, brought on by COVID-19, has affected people across the world. In an effort to keep the virus from spreading, economic activities involving human connection have been replaced with online activities like shopping, attending school or university, or working from home. The CDC recommended that staying six feet away from others is one of the best ways to protect from contracting COVID-19 (CDC, 2022a). But construction industry workers cannot work remotely as the industry requires human skills over automation. COVID-19's spread is primarily dependent on human interaction; therefore, construction workers' interactions will majorly affect the contraction and spread of the disease on construction job sites (Araya, 2021).

Table 2: Summary of the critical COVID-19 concerns in the construction industry

Issues	Summary	Sources
Spread of COVID-19 on the construction site.	According to the findings of this study, the spread of COVID-19 might result in a 30% to 90% reduction in construction workers. Construction project managers who understand how COVID-19 spreads among construction workers may be better able to provide the right working conditions for their employees, reducing the risk of infection.	(Araya, 2021)
COVID-19's effects on construction workers' health and safety.	Preventing the COVID-19 pandemic's adverse effects, ensuring the health and safety of construction workers, as well as the quality of their work-life balance and overall well-being, are many factors to consider.	(Choi & Staley, 2021)
COVID-19 concerns among construction workers.	To address the concerns of construction workers and share lessons learned in the event of a future pandemic, academics and practitioners may use the findings of this study better to understand current trends in construction site safety and health.	(Bou Hatoum et al., 2021)
COVID-19 pandemic risks.	In order to plan for COVID-19 pandemic hazards during the life cycle of a building project, researchers and industry stakeholders must be aware of the significant COVID-19 risk.	(Al-Mhdawi et al., 2022)
Project-Based Construction Workers' Health and Well-Being during COVID-19 pandemic.	When planning teleworking arrangements, it is important to consider work-life happiness and prospects for better work-family balance. For companies, this article provides evidence that assists them in optimizing health advantages and minimizing dangers connected with home-based working while (and maybe after) the pandemic.	(Pirzadeh & Lingard, 2021)
COVID-19's effect on the global construction industry.	The study's key conclusions emphasize improving workplace health and safety and onsite safety measures to safeguard the construction industry's future.	(Ogunnusi et al., 2021)

COVID-19's global influence on the construction sector.	Psychological work conditions (stress at work, ambiguity in job roles, work-family conflict, autonomy in work and home life, social support, and interpersonal conflict) impacted workers' safety performance. There was a negative correlation between safety performance and factors such as job uncertainty, work-family conflict, interpersonal conflict, and exhaustion.	(Tong et al., 2021)
Transmission of COVID-19 amongst construction workers.	Construction workers are particularly prone to the detrimental effects of COVID-19 because of their physical proximity to each other and the nature of their employment, which increases the risk of infection. COVID-19 spreads rapidly among construction workers and their close connections, reaching its peak within ten days after being introduced to the site.	(Yuan et al., 2022)
COVID-19's recommended crisis management measures, impacts, and evolving construction safety practices.	COVID-19 harms the construction industry in both developed and developing countries. The pandemic necessitates the incorporation of specified safety procedures at building sites and the use of a crisis management framework in order to enhance construction output.	(Iqbal et al., 2021)

COVID-19's Impact on Safety Performance on Construction Worker's

This research aims to identify the potential factors affecting hazard recognition performance. Construction work is labor-intensive. Unlike other industries, construction work cannot be done remotely, or machines cannot do the work by themselves. Human touch is required for every job in construction, regardless of machinery involvement. Workers must come to the site to make construction progress. The COVID-19 pandemic is creating considerable anxiety, tension, and stress worldwide and impacts people's physical, mental, and emotional well-being (Kontoangelos et al., 2020). Amidst the pandemic, the workers resumed their work despite having higher chances of contracting COVID-19.

Table 3: Several factors amplify the impact on worker safety

Challenges	Summary	Source
Mental Stress	Stress about the possible contraction of the COVID-19 virus at work.	(Ryu et al., 2021; Zhang et al., 2021)
Workload	Adapting to a new type of workload.	(Pamidimukkala et al., 2021)
Psychological issues	Uncertainty, disappointment, anxiety, anger, exasperation, burnout, and sadness are common feelings that create psychological issues for workers.	(Ekpanyaskul & Padungtod, 2021)
Newer methods to accomplish the job	Reduced availability of necessary tools and equipment. Getting used to a new work environment and a new work schedule.	(Pamidimukkala et al., 2021)

Many workers have resumed work recovering from COVID-19. Unfortunately, the actual census of COVID-19 recovered workers in construction is not currently available. Table 3 shows health implications related to post COVID-19 conditions. Post COVID-19 conditions can be described as long-term health complications of those diagnosed with the virus known as COVID-19. The majority recover within a few weeks. Despite a recovery, however, others still continue to have symptoms. Even months after recovery, some people still suffer from the Post COVID-19 symptoms, known as "long-haulers" (Fernández-de-Las-Peñas et al., 2021). The number of "long-haulers" is rising as millions of individuals have been infected, and countless more will become sick (Rubin, 2020). A recent study found that 81.4% of patients had post COVID-19 symptoms even after seven months (Fernández-de-Las-Peñas et al., 2021). These post COVID-19 symptoms can cause distraction or stress to the construction workers and cause construction workplace accidents.

Table 4: Health implications developed from COVID-19 (Theoharides et al., 2021)

Symptom	Possible Side Effects
Brain fog	Memory problems, poor concentration, lack of mental clarity, feeling "out of it," confusion, headaches
Confusion	Mental confusion, disorientation
Difficulty multitasking	Difficulty focusing, concentrating at work.
Dizziness	Feeling faint, woozy, weak, or unsteady
Fatigue	Overtired, low energy, and a strong urge to sleep that prevents one from doing their typical daily tasks
Insomnia	Depression, anxiety
Irritability	Frustration
Memory loss	Loss of memory
Shortness of breath	A sense of suffocation or breathlessness, as well as chest tightness, trouble breathing, air hunger, and a feeling of suffocation
Weakness	A decrease in strength

Hazard Recognition

The construction industry is unique in nature and different from other industries (Nudurupati et al., 2007). The construction setting is not similar to the industrial factory work environment. However, there is a difference between the construction and the manufacturing industry. The main difference is manufacturing industry is more technology-based equipment dependent, and the construction industry sticks to traditional methods and technology. The construction work is more labor-intensive rather than being mechanized like the manufacturing industry. Construction projects are more diverse in nature, with several activities to perform. Therefore, any consequence of failure or accident is more severe in the construction industry. Many construction safety manuals and textbooks consider hazard recognition and safety risk perception the first step for safety management in the construction workplace (CoVan, 1995). In the safety management process, hazard recognition is typically referred to as the first phase (Perlman et al., 2014). Yet, most of the hazards in construction sites still remain undetermined by the construction workers (Sacks et al., 2009). Most construction safety management methods rely on the hazard recognition skills of construction workers (Albert, Hallowell, Kleiner, et al., 2014). A research study conducted in the U.K. construction sites identified 6.7% of the method statements in U.K. construction sites identified all the relevant hazards, and 93.3% remain unrecognized (Carter & Smith, 2006).

Many research studies have sought to identify potential hazards in the construction workplace and improve job site safety culture. If hazards remain unrecognized in construction job sites, the probability of an accident at the workplace increases, making the construction job site more hazardous and workers more vulnerable to injuries, illness, and fatalities (Albert, Hallowell, & Kleiner, 2014; Namian et al., 2016). In a research study conducted by Perlman et al. (2014), superintendents working in the construction site were unable to identify all the hazards in their regular job site despite having years of experience.

Safety training in construction job sites can aid in the hazard recognition performance of the construction workers. Namian et al. (2016) found that workers from construction projects who were provided high-engagement training were able to detect a more significant proportion of hazards. The activities of unsafe workers are not the consequence of intentional safety violations but instead of poor hazard recognition and risk assessment ability on their own (Tixier et al., 2014). Both hazard recognition and safety risk perception rely on workers' cognitive abilities, and any element that weakens employees' cognitive capacities, such as fatigue, might influence their safety performance (Namian, Taherpour, et al., 2021).

Safety Risk Perception

Safety risk perception is as equally important as hazard recognition. According to M. Hallowell (2010), safety risk perception is defined as "the subjective judgment that one makes about the frequency and severity of particular risks." Safety risk perception value is calculated by asking individuals about a particular scenario and compiling the data, and it might vary from person to person. For example, two people can come up with two different safety risk perceptions for a fixed scenario. People tend to overestimate their abilities to control or prevent accidents, which results in underestimating risk (Lichtenstein et al., 1976). According to Slovic and Peters (2006), humans perceive and respond to risk in two ways. Individuals' instinctive and intuitive reactions to danger are referred to as risky feelings. Applying logic, reason, and scientific discussion to risk management is known as risk analysis. The "affect heuristic" refers to a person's reliance on risk as a source of feelings. If any individual underestimates or perceives lower risk, they are more likely to be engaged or demonstrate risk-taking behavior (Tixier et al., 2014). In a research study conducted by Perlman et al. (2014), the construction superintendents evaluated the component of accident severity more substantially than the component of chance when evaluating risk levels, expressing concerns about their safety culture, which might be because of their years of expertise. The other group of participants was engineering students who had no experience or little experience.

Many factors can affect the safety risk perception of the construction workers. However, some common factors were identified based on the literature review, impacting construction workers' safety risk perception and hazard recognition performance. They are presented in table 5.

Table 5: Common factors that can impact safety risk perception and hazard recognition

Challenges	Source
When a worker feels unsafe, it may cause work strain and work overload. In addition, it may increase the chance of an accident.	(Rundmo, 1996)
Compared to undistracted workers, distracted workers saw a lower percentage of risks.	(Namian et al., 2018)
Safety training programs help to improve site safety performance. Compared to low-engagement training approaches, high-engagement safety training increases perception of hazard recognition and safety risk.	(Namian et al., 2016)
Fatigue impacts workers' hazard recognition and safety risk perception.	(Taherpour et al., 2020)
Employees' (perceived) safety environment significantly impacts the proportion of safe activities taken.	(Arezes & Miguel, 2008)
Construction workers' safety risk perception statistically and adversely affects their willingness to take risks.	(Bohm & Harris, 2010; Low et al., 2019)
Due to differing safety attitudes, managers and workers do not share the same safety risk perceptions.	(Collinson, 1999; M. Hallowell, 2010; Harvey et al., 1999; Lee, 1998; McDonald et al., 2000)

CHAPTER 3: METHODOLOGY

The impact of COVID-19 on construction workers' safety performance is unknown. No research studies have attempted to identify the impact of COVID-19 on construction workers' two leading safety performance indicators: safety risk perception and hazard recognition. These indicators assess workers' hazard recognition performance and safety risk perception to assess their safety performance. Two groups were created based on COVID-19 diagnoses to identify the impact on the safety performance of the construction workers. They are as below:

1. Control Group: COVID-19 Negative
2. Experimental Group: COVID-19 Positive

In this study, workers who were never tested COVID-19 positive are our control group. In the experimental group, workers who have tested COVID-19 positive are considered.

This chapter discusses a research methodology for determining the effect of COVID-19 on construction workers' hazard recognition performance and safety risk perception.

Literature Review

An extensive literature review was done to review similar studies and the scope of their research. In addition, similar research methodologies were examined as part of the literature review. These sections aimed to provide a background of hazard recognition and safety risk perception from construction industry workers' perspective and how they assess the hazard and safety risk perception in a typical work environment before the COVID-19 pandemic. Database such as Google Scholar, the American Society of Civil Engineers (ASCE), ResearchGate, and Elsevier is used to find similar articles available on the internet. The keywords to search the similar articles were "Construction," "Construction Safety," "Hazard Recognition," "Construction Worker," and "Safety Risk Perception."

Questionnaire Preparation

A questionnaire was prepared to assess the construction workers' safety risk perception and hazard recognition performance. The questionnaire included two sections demographics and hazard recognition/safety risk perception. This questionnaire did not include any personal identifiers. Construction scenario photos were used for the hazard recognition and safety risk perception assessment. These photos were taken at a real construction site in the U.S. Participants were randomly shown four construction scenarios from sixteen preset construction scenarios to recognize hazards and safety risk perception. A safety risk perception instrument was used to capture participant safety risk scenarios for each construction scenario shown. The questionnaire was prepared using Qualtrics. A part of the questionnaire used for this study is attached in APPENDIX A.

IRB Approval

According to federal law, an Institutional Review Board (IRB) approval is needed for a human subject's research proposals. In addition, the IRB must approve or declare that the project is exempt from beginning any study. The questionnaire was submitted to University and Medical Center Institutional Review Board (UMCIRB) for review, and the UMCIRB approved it. Exemptions were granted for the surveys, so they could be sent out to those people who were suitable for the research study. The approval letter is attached as APPENDIX B.

Data Collection

The data collection work was done in person voluntarily and without monetary compensation. Participants used an iPad to share responses through a Qualtrics-based survey. No online survey was done during the data collection process. Participants were approached randomly at the construction site. Active construction sites across North Carolina were visited for data collection. The total number of surveys done for this study was seventy-six. Eight surveys were incomplete. The total number of the study completed was sixty-eight. As all surveys were in person, there is no response rate. Data collection work was done from August 2021 to April 2021.

Hazard Recognition Performance Calculation

This study has considered COVID-19 as an accidental injury illness experience. Workers who have suffered an accident feel less safe than workers who were not in an accident (Rundmo, 1995). This illustrates that workers had changes in hazard recognition and safety risk perception as their experience with the accident made them more aware of their risk assessing performance on the job site. A total of sixteen case images were used in the study, and each worker was shown four case images randomly to evaluate safety risk perception and hazards present in the photo. The case images were taken from actual construction sites. Each image had different construction activities with several hazards present. Figure 4 shows an example of the case image. A panel of experts was formed to identify and standardize the hazards for each photograph. As shown in figure 3, a hazard wheel was shown to the panel of experts to identify all potential hazards. The expert panel consisted of three members. Two of the members are from academia and have research experience on construction safety. One of the members is from the construction industry and has more than five years' experience as a superintendent. One participant identified one hazard for a construction scenario that was not listed on the hazard list determined by the expert panel during data analysis. Later it was added to the list.

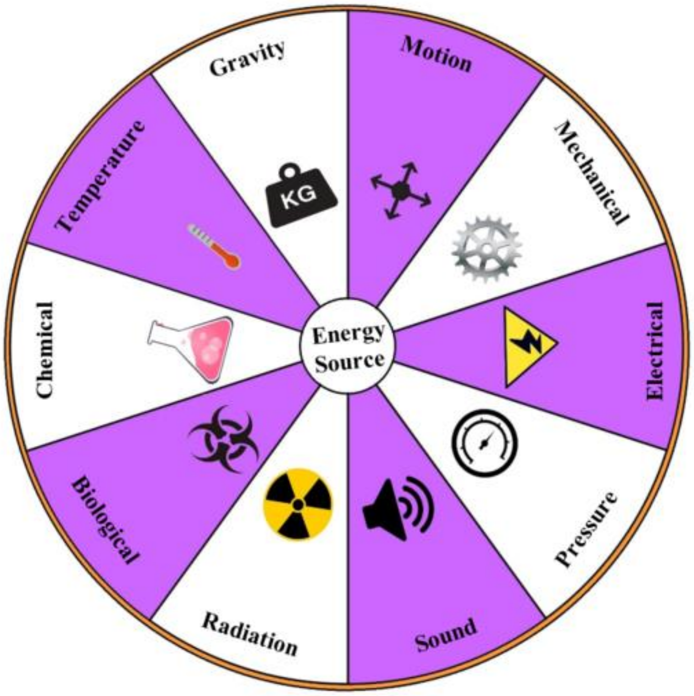

Figure 3: Hazard wheel adopted from Tixier et al. (2018)

To identify hazards, four case photographs were provided randomly to each participant. Participants were asked to identify risks present in the photo based on their experience. The worker's hazard recognition performance was calculated for each case image as the percentage of hazards recognized as indicated in equation 1.

$$\text{Hazard Recognition (H.R.)} = \frac{HR_j}{HR_i} \text{x} 100 \qquad (1)$$

Where H.R. is the overall hazard recognition percentage by the worker.

HR_j is the number of hazards recognized by the participants.

HR_i is the total number of hazards present in the image, which is identified by the expert panel.

Figure 4: A sample case image picture used to measure safety risk perception and hazard recognition performance among construction workers. Photo credit: Robert I. Carr, Ph.D., PE

Safety Risk Perception Calculation

Safety risk perception is not only studied in the construction industry. It is being studied in many industries like mining, oil, aviation, etc. Several studies have focused on the safety risk perception of construction workers working in the construction industry. Authors in those studies have indicated several challenges that impact the safety risk perception of construction workers. Workers are more likely to take protective safety measures to avoid injury if they assess the risk correctly (Arezes & Miguel, 2008). A worker who has experienced COVID-19 may have different safety risk perceptions depending on the severity of their symptoms. COVID-19 has long-term health implications (Del Rio et al., 2020).

The safety risk perception method is used to assess risk and determine the amount of risk present; the word risk perception represents the uncertainty of the risk field, which requires insight but is not certain (Alomari et al., 2018). Furthermore, external contextual variables such as a person's work environment have an effect on their performance to detect hazards; Safety risk perception is a personal assessment of the intensity and characteristics of a risk (M. R. Hallowell, 2008). Previously safety risk perception has been measured by showing workers a case scenario present with hazards and gathering their judgments (Namian et al., 2018; Namian et al., 2016; Zhao et al., 2016). As a result, two risk components (anticipated frequency and severity) for each scenario (i.e., each case photo presented to employees randomly from a set of 16 photos) were evaluated in order to assess participants' perceptions of safety risk. A survey tool shown in table 6 utilized effectively in several research projects was used in this study (Namian et al., 2018; Namian et al., 2016; Taherpour et al., 2020). After calculating the safety risk perception score, the scores were standardized using equation 2.

$$\text{SSRP}=\frac{SRP-R_{SRP}}{\sigma_{SRP}} \qquad (2)$$

Here, SSRP is the standardized safety risk perception score of the participant,

SRP is the participant's raw safety risk perception score,

R_{SRP} is the average of participants' perceived safety risks,

σ_{SRP} is the Standard Deviation of participants' perceived safety risks.

Direction: For the same picture above, please choose injury frequency for each injury type that you think can happen (only one selection for each injury type)

Table 6: Safety Risk perception instrument

Injury Type/ Frequency	Severity Score	Once Every Week (~40 workers-hours)	Once Every Month (~167 workers-hours)	Once Every Year (~2000 workers-hours)	Once Every 10 Years (~20000 workers-hours)
Discomfort / Pain	2.5	0.0625	0.01497	0.00125	0.000125
First Aid	5.5	0.1375	0.032934	0.00275	0.000275
Lost Work Time	7	0.175	0.041916	0.0035	0.00035
Medical Case	8	0.2	0.047904	0.004	0.0004
Permanent Disablement or Fatality	9.5	0.2375	0.056886	0.00475	0.000475

This method of standardization has two significant benefits. For instance, it offered a quick and easy process to compare how employees perceived safety risk levels. A positive score means that the participant rated the safety risk higher than other participants. Conversely, a negative score would implicate that the participant perceived a lower level of a safety risk than other participants for the same case scenario. Zero value would mean that the participant's perception of the safety risk is the same as all participants' average safety risk assessment for that specific picture.

First, for each injury type, a severity score was assigned. The number of anticipated incidents during a particular period is referred to as frequency (i.e., one every week, one every month). Then, based on the participants' answers, the safety risk perception for each case picture was computed. For example, suppose a lost workday has a severity score of seven and is expected to occur every year for a particular case photo (i.e., frequency of 1/2000 worker-hours). In that case, it will have a safety risk perception value of 3.5×10^{-3}. The participant's perception of safety risk was calculated as the average of four case pictures presented to each worker.

COVID-19 Severity

Workers infected with COVID-19 may show no symptoms or might develop a severe condition (McCoy et al., 2020). Most COVID-19 infected individuals fall into one of four severity groups (Sun et al., 2021). During data collection, COVID-19 positive participants were asked about the severity of COVID-19 they have experienced. A score was assigned to each group of the severity based on the World Health Organization progression scale (Marshall et al., 2020). Table 7 represents the score given to each severity group of the COVID-19 illness.

Table 7: COVID-19 Severity Score (Marshall et al., 2020)

Sl.	Patient state	Score
1	Uninfected	0
2	Asymptomatic	1
3	Mild	2.5
4	Moderate	4.5
5	Severe	7.5

CHAPTER 4: DATA ANALYSIS AND RESULT

Descriptive Analysis

Participants were randomly approached on active construction sites and asked to participate in the survey. Sixty-eight construction workers completed the survey. To participate in the survey, workers had to be a minimum of 18 years older. In addition, workers were asked basic demographic questions.

Table 8: Surveyed participant demographic information

	N	Minimum	Maximum	Mean	Std. Deviation
Age (Years)	68	18.00	61.00	36.40	11.43
Experience (Years)	68	0.30	40.00	13.99	9.90

Table 8 shows the participant's age and construction experience. The maximum age of the participants was 61 years, while the minimum age was 18 years. Maximum experience of the

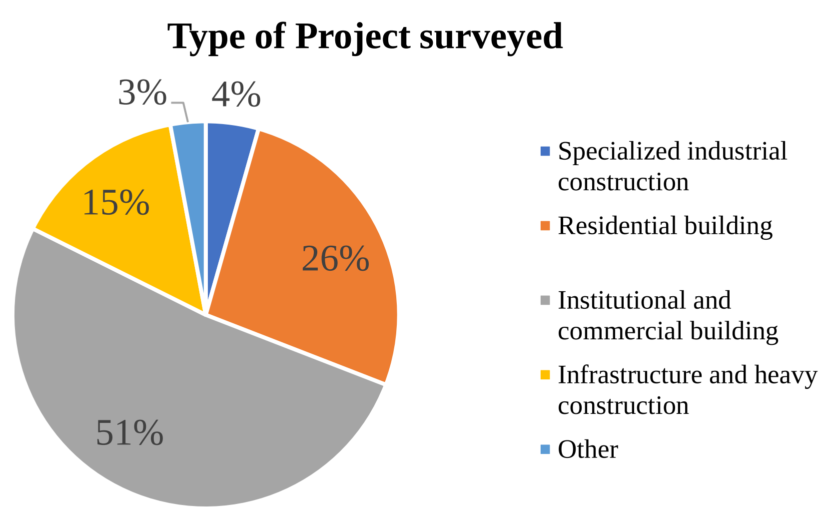

Figure 5: Types of projects surveyed for the research study

surveyed construction worker was 40 years, and the minimum was three months. Only 7.35 % of the 68 participants were female, with 63 males accounting for most of the group. Workers without OSHA 10/30 training certification accounted for 28% of the interviewed participants, 25% of the workers had received OSHA 10 training, and 19% had OSHA 30 training certificates. Workers were also asked whether they have work experience in other states as part of the demographic questionnaire. Workers with experience in other U.S. states represented 60% of the group. Table 9 illustrates the demographic characteristics of the surveyed workers.

Table 9: Demographic information about surveyed participants

Characteristics	Number	%
Gender		
Male	63	92.65
Female	5	7.35
COVID-19 Contraction		
Positive	23	34
Negative	45	66
OSHA Certification		
OSHA 10	17	25
OSHA 30	13	19
Both OSHA 10 /30	19	28
No OSHA certification	19	28
Work Experience in Different states		
Yes	41	60
No	27	40

The results from the survey revealed that 66% of the workers who participated in the study were never affected by COVID-19, and 33% of the workers were COVID-19 positive. COVID-19 positive workers were also asked about the severity of the COVID-19 they had experienced. 16 % of workers responded they had experienced mild COVID-19 symptoms, and 9% said they did not have any symptoms (Asymptomatic). Figure 6 illustrates the COVID-19 Infection ratio among surveyed workers, and Figure 7 shows the vaccination attitude of the construction workers.

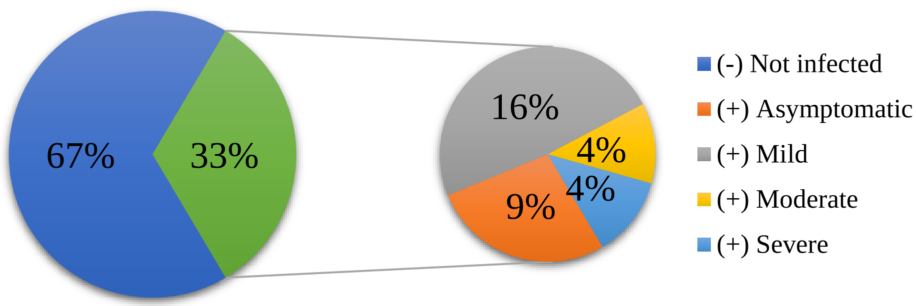

Figure 6: COVID-19 Infection ratio among surveyed workers

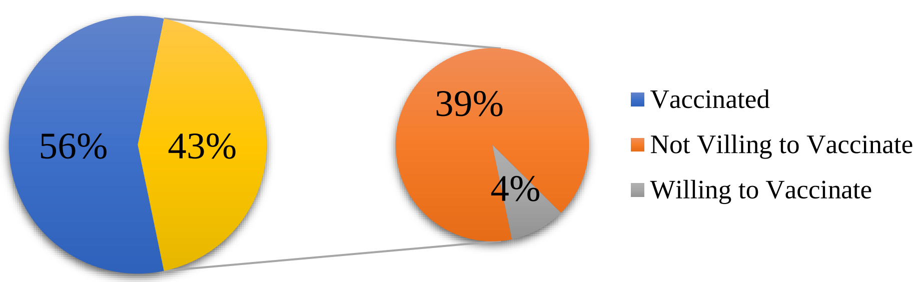

Figure 7: Vaccination attitude among surveyed workers

According to CPWR (2021), vaccination hesitancy for North Carolina is 45%, and 60.3% of the construction workers are already vaccinated. However, our study found the vaccination hesitancy of 39% and 56% of the participants to be vaccinated.

Statistical Analysis

Safety risk perception and hazard recognition performance were analyzed to determine the long-term effect of COVID-19 on construction workers' safety risk perception and hazard recognition. A short macro code was written on visual basic and integrated with Microsoft Excel to calculate the hazard recognition performance and safety risk perception score. A standardized safety risk perception score and a unique hazard recognition score were generated for each of the study's 68 participants. Standardized ratings allow comparing safety risk perception scores across independent scenarios, even though the actual safety risk may differ.

This study aimed to identify the impact of COVID-19 on the safety risk perception and hazard recognition performance of construction workers. To test the research hypotheses, a two-sample test for the independent measure was adopted. SPSS and XLSTAT were used to do the statistical analysis. The first hypothesis predicted that COVID-19 acts as an injury and affects the hazard recognition performance of the construction workers. Two groups were created based on COVID-19 contraction.

Table 10: Normality test results

Groups	N Statistic	Skewness	Kurtosis
Hazard Recognition Performance (COVID-19 Positive)	45	0.41	-0.82
Hazard Recognition Performance (COVID-19 Negative)	23	1.016	0.863
Standardized Safety Risk Perception (COVID-19 Positive)	45	0.63	-0.772
Standardized Safety Risk Perception (COVID-19 Negative)	23	0.065	-1.52

For hazard recognition performance, normality tests for two groups were done. Based on the skewness and kurtosis criteria by Hair Jr et al. (2019) for hazard recognition scores, both groups were normally distributed and within the range of -2 and +2. Accordingly, a two-sample independent t-test was performed to test both research hypotheses. For the first hypothesis, there was no a significant difference in the hazard recognition performance of the construction workers

COVID-19 Positive workers (M= 0.354, SD=0.176) and COVID-19 Negative workers (M= 0.354, SD=0.176) and COVID-19 Negative workers (M=0.397, SD=0.162), t (66) = 0.991, p>0.1

Table 11: Analysis result hazard recognition

Experimental condition	n	Mean	SD	Std.Error Mean	p-value
COVID-19 Negative	45	0.397	0.162	0.024	0.325
COVID-19 Positive	23	0.354	0.176	0.037	

(Significance level alpha=0.1). This data provides support to the null hypothesis. There is no difference in hazard recognition performance of the workers regardless of COVID-19 contraction. Figure 8 represents a box plot created from the hazard recognition score and COVID-19 group. For the COVID-19 negative group, the maximum hazard recognition score is 0.771, the upper quartile score is 0.525, the median score is -0.375, the lower quartile score is 0.250, and the minimum score is 0.150. For the positive group, the maximum hazard recognition score is 0.883, the upper quartile score is 0.50, the median score is -0.325, the lower quartile score is 0.221, and the minimum score is 0.125 (p-value=0.325, alpha=0.1).

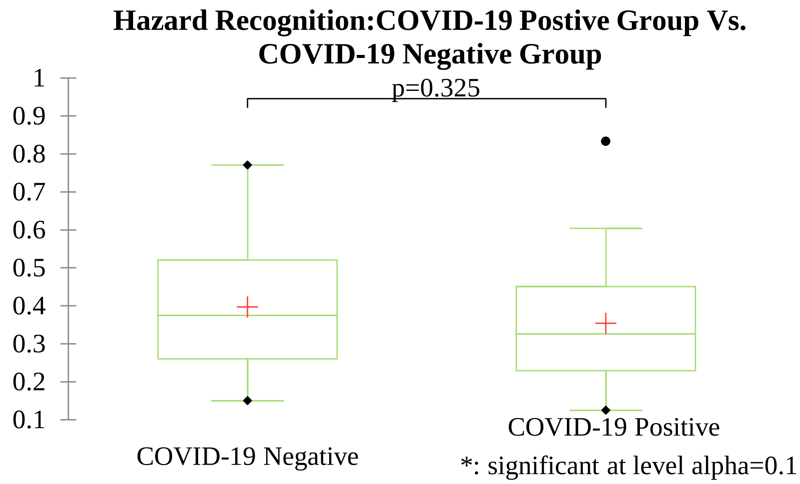

Figure 8: Box plot hazard recognition score vs. COVID-19

A normality test was done to test the standardized safety risk perception score to test the second research hypothesis. Based on the skewness and kurtosis criteria, two groups were tested for normality and found normally distributed and within the range of -2 and +2. The alpha value for this test was considered 10%, meaning there was a 90% interval in the difference between the means. For the second hypothesis, there was a significant difference in the safety risk perception of the workers COVID-19 Positive workers (M=0.264, SD=0.876) and COVID-19 Negative workers (M= -0.135, SD=0.264), t (66) = -1.819, p <0.1 (Significance level alpha=0.1).

Table 12: Analysis result SSRP

Experimental condition	n	Mean	SD	Std.Error Mean	p-value
COVID-19 Negative	45	-0.135	0.842	0.126	0.074
COVID-19 Positive	23	0.264	0.876	0.183	

As the computed p-value is lower than the significance level alpha=0.1, the null hypothesis is rejected, and the alternative hypothesis is accepted. Figure 9 represents a box plot created from

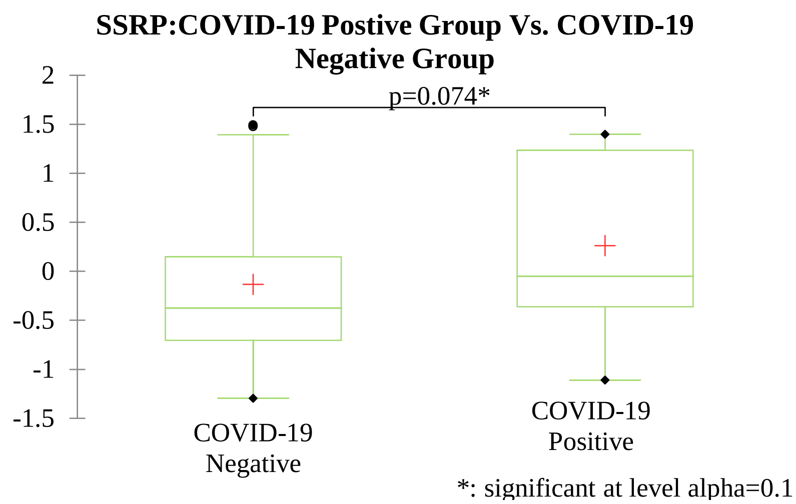

Figure 9: Box plot safety risk perception standardized score vs. COVID-19

the SSRP score and COVID-19 group. For the COVID-19 negative group, the maximum standardized safety risk perception score is 1.492, the upper quartile score is 0.449, the median score is -0.373, the lower quartile score is -0.749, and the minimum score is -1.294. For the positive group, the maximum hazard recognition score is 1.398, the upper quartile score is 1.26, the median score is -0.052, the lower quartile score is -0.40, and the minimum score is -1.110 (p-value=0.74, alpha=0.1). A regression analysis was done for both scenarios to observe the relationship between the severity of COVID-19 and hazard recognition and safety risk perception score. Groups were created based on the severity of COVID-19. The severity score for each group was calculated from the WHO clinical progression scale. For hazard recognition and COVID-19 severity, the R square

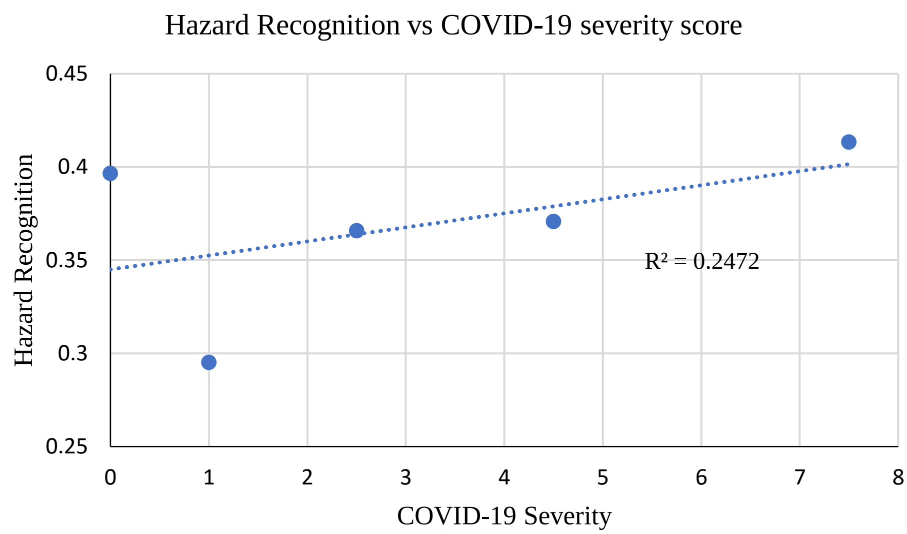

Figure 10: Relationship between COVID-19 severity and hazard recognition

value was 0.2472, which is 25% of the variance hazard recognition performance of the construction workers. For standardized safety risk perception and COVID-19 severity, the R square value was 0.2704, which is 27% of the variance of safety risk perception. From this graph, it was observed that the SSRP value increased when severity increased, but only for moderate symptoms SSRP score did not increase. It can be due to the smaller sample size.

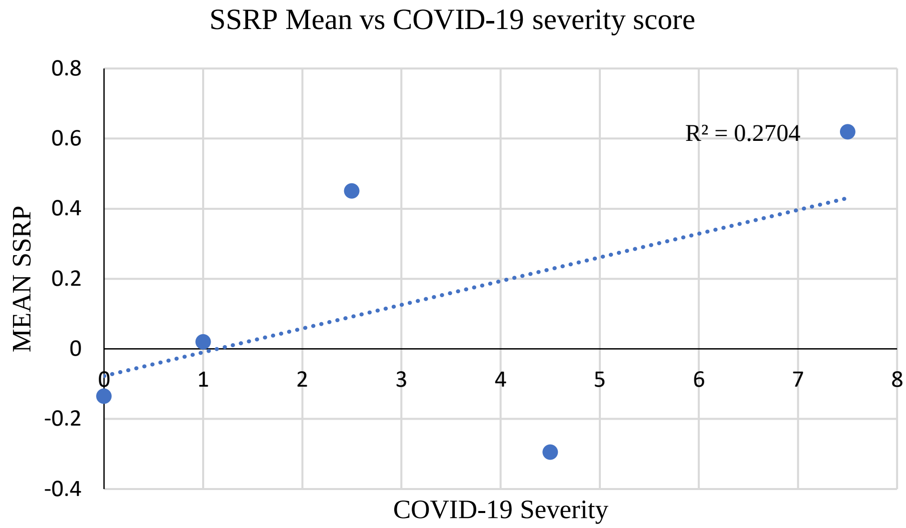

Figure 11: Relationship between COVID-19 severity and standardized safety risk perception

A Pearson correlation analysis was conducted between the COVID-19 Severity score and the hazard recognition score. The results of the analysis are shown in table 13.

Table 13: Pearson correlation results between COVID-19 severity and the hazard recognition

Combination	r	95.00% CI	n	p
COVID-19 severity and Hazard score	-.02	[-.26, .22]	68	.867

Correlation results were evaluated using an alpha value of 0.1. No significant relationship between any two variables was found (p-value>0.1).

Also, a Pearson correlation analysis was conducted between the COVID-19 Severity score and SSRP score. The results of the analysis are shown in table 14.

Table 14: Pearson correlation results between COVID-19 severity scale and SSRP

Combination	r	95.00% CI	n	p
COVID-19 severity and SSRP score	.21	[-.03, .42]	68	.090

Correlation results were evaluated using an alpha value of 0.1. There was a significant relationship between the two variables (p-value<0.1).

CHAPTER 5: CONCLUSION

COVID-19 has impacted the globe, including the construction industry. However, no study has tried to identify the impact of COVID-19 on hazard recognition and safety risk perception. This research aimed to understand the effects of COVID-19 on construction workers on hazard recognition performance and safety risk perception. Safety performance is essential for construction workers as construction job sites are filled with different hazards. The construction work is considered hazardous, due to the number of injuries each year that happens at the construction (U.S. BLS, 2022). Construction ranks at the top regarding workplace fatalities. Many researchers have already concluded that all workplace hazards are not recognized at construction sites (Albert et al., 2014; Namian et al., 2018), which increases the chance of workplace accidents (Carter & Smith, 2006). This study tried to explore the long-term impact of COVID-19 on the safety performance of construction workers. Safety risk perception and hazard recognition performance are two leading indicators for measuring construction workers' safety performance. The study evaluated the construction worker's safety risk perception and hazard recognition performance based on COVID-19 contraction to test the research hypotheses. A qualitative questionnaire was made, and in-person surveys were conducted. Based on the participant's response, each participant's safety risk perception and hazard recognition performance were calculated. Sixty-eight workers were interviewed during the research study. A t-test was done to test the research hypothesis, and the alpha value of 10 was considered. For hypothesis 1, the Null hypothesis was not rejected since the $p\text{-value}>0.1$, and for hypothesis 2, the Null hypothesis was rejected as $p\text{-value}<0.1$. Based on the construction workers' hazard recognition performance and safety risk perception, the study found that COVID-19 does not affect the hazard recognition performance of the workers. When safety risk perception was calculated, a significant statistical difference was found between the two groups. In terms of safety risk perception, workers tend to perceive a higher safety risk with increased COVID-19 severity. Only workers with mild severity perceived lower safety risk. It might be due to the smaller sample size.

The current study is the first study that attempted to investigate the effect of COVID-19 on safety risk perception and hazard recognition performance. This study report can serve as an aid for the construction industry to improve the safety culture. In addition, the results can help safety practitioners, managers, and owners in workplace safety policymaking.

Returning to the jobsite after recovering from COVID-19 illness can be challenging. However, this study found that COVID-19 does not affect the hazard recognition performance of the construction worker. The ability to recognize hazards is based on a combination of knowledge, experience, and safety instruction, and COVID-19 does not intervene with that.

However, when the same group of workers was asked to perceive safety risk from the same case scenario, COVID-19 positive workers perceived a higher level of safety risk. The second finding strongly suggests that COVID-19 illness acted as an injury experience for construction workers. Several studies concluded that injured workers tend to perceive higher safety risks (Fortner et al., 2000; Gucer et al., 2003; Jafari, 2021). The study implications are as below: 1) This study experience can be applied or extended to other infectious diseases. 2) This study aligns with the past studies that experience injury will impact subjective safety risk perception. When a person experiences an injury, their safety risk perception changes. According to research, the likelihood of higher safety risk perception, the better safety performance, and the less likely to do unsafe behavior (Shin et al., 2014). Our study found that COVID-19 positive workers have higher safety risk perception, and we can say that COVID-19 impacted the workers' safety performance. 3) The long-term impact of covid 19 on safety performance can be discussed in the training program or incorporated into the safety training program.

Limitation and Future Research Recommendations

Despite the study's merits, further research may solve some of the study's drawbacks. Since the survey was conducted in person and during the pandemic, not all construction sites were accessible to the researcher. For this study, only sixty-eight data from North Carolina were analyzed, which only illustrates the hazard recognition and safety risk perception state-wise, not for the whole country. A larger sample size from across the regions of the United States within a shorter period may have given a more exact scenario. Case images were used to identify the construction workers' hazard recognition performance and safety risk perceptions. Even though case pictures standardized the assessment of the dependent variables and kept internal validity, the genuine dynamic character of construction activities may not be portrayed in case images. Virtual reality could have served as an aid in performing the actual construction activities. Virtual reality (V.R.) could not be employed in this research study because of the risk of COVID-19 transmission and proliferation. Another constraint of the study was the rapid evolution of COVID-19 variants, which made it challenging to compare the impacts of different strains. The data collection process started in August 2022. During the data collection period, not all variants had the same severity, and there were several variants due to the rapid change in virus RNA. Variants of COVID-19 were not considered in the research study. So, it is hard to assess the actual long-term impact of COVID-19 on construction workers' safety risk perception and hazard recognition performance. Future research should consider variants and the severity of COVID-19 and its impact on safety performance.

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APPENDIX A: SAMPLE QUESTIONNAIRE

ECU

Q2.1. Age (years)

Q2.2. What is your sex?

- Male
- Female
- Non-binary / third gender
- Prefer to self-describe
- Prefer not to say

Q2.3. Construction experience (years)

Q2.4. What is your current job title/speciality?

Q2.5. Type of Current Project you are currently working

- Residential building
- Institutional and commercial building
- Specialized industrial construction
- Infrastructure and heavy construction
- Other

Q2.6.
Location of current project you are working (State)

Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
District of Columbia
Florida

Q2.7. Have you worked in any other states?

- Yes
- No

← →

Hazard Recognition 6.1

Q6.1

Q6.2

For the same picture above, please choose injury frequency for each injury type that you think can happen (only one selection for each injury type.)

	Once Every Week	Once Every Month	Once Every Year	Once Every 10 Years	Not Likely
Discomfort/Pain	○	○	○	○	○
First Aid	○	○	○	○	○
Medical Case	○	○	○	○	○
Lost Work Time (some days away work)	○	○	○	○	○
Permanent Disablement or Fatality	○	○	○	○	○

APPENDIX B: UMCIRB APPROVAL

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
4N-64 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Exempt Certification

From: Social/Behavioral IRB
To: Mostafa Namian
CC:
Date: 7/28/2021
Re: UMCIRB 21-001578
COVID-19 Among Construction Workers

I am pleased to inform you that your research submission has been certified as exempt on 7/28/2021. This study is eligible for Exempt Certification under category # 2a.

It is your responsibility to ensure that this research is conducted in the manner reported in your application and/or protocol, as well as being consistent with the ethical principles of the Belmont Report and your profession.

This research study does not require any additional interaction with the UMCIRB unless there are proposed changes to this study. Any change, prior to implementing that change, must be submitted to the UMCIRB for review and approval. The UMCIRB will determine if the change impacts the eligibility of the research for exempt status. If more substantive review is required, you will be notified within five business days.

Document	Description
Consent.pdf(0.01)	Consent Forms
Email Script.docx(0.01)	Recruitment Documents/Scripts
Questionniare - V5 - IRB.docx(0.01)	Surveys and Questionnaires

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418