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Data driven insights of Roof Work-Related Injuries: Analyzing the Impact of Time & Seasonal Effect

Rownoak Bin Rouf, Oklahoma State University

Rownoak Bin Rouf is a Master's student in Civil Engineering at Oklahoma State University, expected to graduate in December 2025. He completed his Bachelor's degree in Civil Engineering from Rajshahi University of Engineering and Technology (RUET), Bangladesh. Rownoak's research interests include Construction Engineering, Concrete, BIM, Occupational Safety, and Construction Laws.

He has contributed to several publications, including studies on construction accidents and roof work-related injuries, presented at major conferences like the ASC Annual International Conference.

Professionally, Rownoak has worked as a Quality Control Engineer and Inspector of Works on key infrastructure projects, including the Hazrat Shahjalal 3rd Terminal Extension and Purbachal Elevated Expressway. His responsibilities included construction supervision, quality control, and project monitoring.

MD ABU NAEEM KHAN
Dr. Rachel Mosier, Oklahoma State University

Dr. Rachel Mosier is an Associate Professor at Oklahoma State University, with a background in structural engineering and construction project management. Dr. Mosier has received regional and international teaching awards through the Associated Schools of Construction and continues research in engineering education and construction workforce topics.

Dr. Heather N Yates, Oklahoma State University

Dr. Yates joined the Oklahoma State University Construction Faculty in 2006 working her way up to the rank of Professor in 2020. She has served in multiple regional and executive roles in the Associated Schools of Construction, and is currently serving as President through 2026. Her research interests are women in STEM and construction education.

Dr. Nicholas Tymvios, Bucknell University

Nicholas Tymvios received a B.S. and M.S. degree in Civil Engineering from Purdue University in 1999, and 2002 respectively. After working in the construction industry, he was accepted into the Ph.D. program at Oregon State University and graduated with a PhD in Civil Engineering (Construction Engineering) in 2013. From 2013 till 2017 he was an Assistant Professor at UNC-Charlotte within the Engineering Technology and Construction Management Department. From 2017 till present he is an Assistant professor at Bucknell University with the Civil & Environmental Engineering Department. his primary area of research is construction safety and in particular the topic of Prevention through Design.

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Abstract: Safety in construction environments, particularly in roofing, remains a critical concern. Although many studies have investigated the root cause of falling from heights and other work injuries of roofers, very few have focused on the specified timeline when accidents occur or examined seasonal effects and its significance. This study utilizes data from Occupation Health and Safety Administration (OSHA) to determine the relationship between accident timing, seasonal variations, and workers injuries in the roofing industry between 2014 to 2023. The OSHA report data includes records of roof related accidents, injuries, hospitalizations and fatalities which were analyzed to identify trends based on time of day and seasonality.

The paper aims to identify key risk periods and the impact of seasonal changes on roofers. The objective of this study is threefold: (1) to examine whether roofing accidents occur at different rates during different seasons; (2) to identify temporal characteristics of roof-related construction accidents for the past few years; and (3) to check if these fluctuations are statistically significant. Statistical methods including chi square tests were applied to determine the significance of these factors.

The results indicated that accidents occurred more frequently in specific time periods, particularly during the morning hours, with a significant peak in the summer months. The findings underscore the importance of tailored safety interventions during high-risk periods, particularly in the summer and early work hours. The study provides valuable insight into how seasonal effects and specific work periods contribute to roofing related accidents, supporting the development of more targeted safety measures to the roofing industry.

Key Words: Construction Accidents, Severity, Specific Time Period, Seasonal Effect

Introduction

Roofing is ranked fourth most dangerous job in the United States as of 2016 and major causes of accidents like tripping, falling, and slipping are related to it [1]. Shishtar found that roofing is especially vulnerable to falls, as it involves hazardous elements including steep slopes, hazardous material, and difficult working conditions [2]. The Bureau of Labor Statistics (BLS) concludes that a large number of construction industry workers die from fall from heights [3]. OSHA states that the most often reported construction industry violation is not having fall protection [4]. This has remained a major cause of high injury incidences in roofers, especially where the projects being implemented are relatively small [5].

A common cause of accidents is falls, and even today, roofers remain the most dangerous workers in the building industry regarding mortality rates. To some extent, there have been extensive studies on fall-related accidents; however, this research indicates that there are significant gaps for current research studies. Huang and Hinze analyzed 7543 records of the accidents collected by OSHA from 1990 to 2001. The authors found out that falls were the leading cause of the injuries, accounting for 34.6 % of the occurrence [6]. Kang and others

analyze 20997 case records from OSHA that were collected in the period between 1997 and 2012 years [7]. A scient metric analysis by Vigneshkumar and Salve points to Falling From Hazards (FFH) protection, which is increasingly being served by Computer and Information Technology (CIT) tools and, while pointing to the absence of dedicated survey that considers environmental stimuli, worker behavior, and light and weather conditions in assessments [8].

It has seen that, though-workers are now aware of many hazards that are inherent in construction work and especially hazards related to working at heights FFH still remains the leading cause of fatalities [9]. In addition, working conditions like unfavorable weather, and low light conditions act as other risks to the workers. Since temperature has been observed to have effects especially during summer due to tiredness and thirst, the effects of temperature to the rate of accidents were caused were examined. The increase in accident rate during the summer can be attributed to factors such as fatigue, dehydration, and a decreased ability to concentrate that is often present in hot weather. These difficulties indicate that there is need for explicit protective measures, especially during summer, involving specific working and environmental realities of roofing [10].

Despite the increasing awareness of seasonal variations with work related incidents, little actual focused research work has been done on roofing accidents at crucial periods of the year, more so during the summer months. It is a research dilemma and major deficiency of theories and empirical evidence for the specific causes and effects of roofing accidents as a function of seasonal variations with focus on heat as a particularly hazardous environmental factor.
This research focusses on recent roof construction accidents in the United States. The incentive for doing this research is rooted in the discovery during the literature assessment that there are few studies based on recent data in this area of study. Though there are many research papers that investigated the root cause of roof related injuries, however, roofers are still at high risk. Few studies have focused solely on the consequences of year-over-year study of seasonal effects on roofers. The study aims to determine the following research questions. (1) What are the temporal trends in roof- related construction accidents in the United States over recent years? (2) Do the number of roofing accidents significantly vary across different seasons? (3) Are they Statistically Significant? To answer these questions, this study also aims to address and analyze roofing incidents more effectively in terms of the various types of injuries that took place, the workers' profile, and the highest falls that were experienced during recent periods. The need for the research is also in identification of any trends in the incidence of accident rates of roofers and roof assistants by age. When exploring the relationship between medium, high and low fall heights and accident rates, this research also seeks to look at the occurrence of fall and distribution of the injuries common to the body part such as the head and foot.

Methodology

Dealing with accident data is very crucial specially when we do not have full and accurate information regarding the system's state, we are dealing with an uncertain situation, and risk analysis deals with such situations. The data for this study was sourced from the Occupational Safety and Health Administration (OSHA), with a particular emphasis on roof-related accident records from 2014 to 2023 [11]. Fundamental methodologies were utilized to extract our data from the comprehensive dataset (Figure 1). To categorize accidents across various time blocks

and seasons, a series of data filtration steps were implemented. Additionally, demographic data, including age, was examined to determine the most recent situation of the employees. To generate credible and valid results, each of the inputs that were absent was meticulously examined. The appropriate statistical techniques were employed to systematically address these values to reduce the likelihood of distorted results.

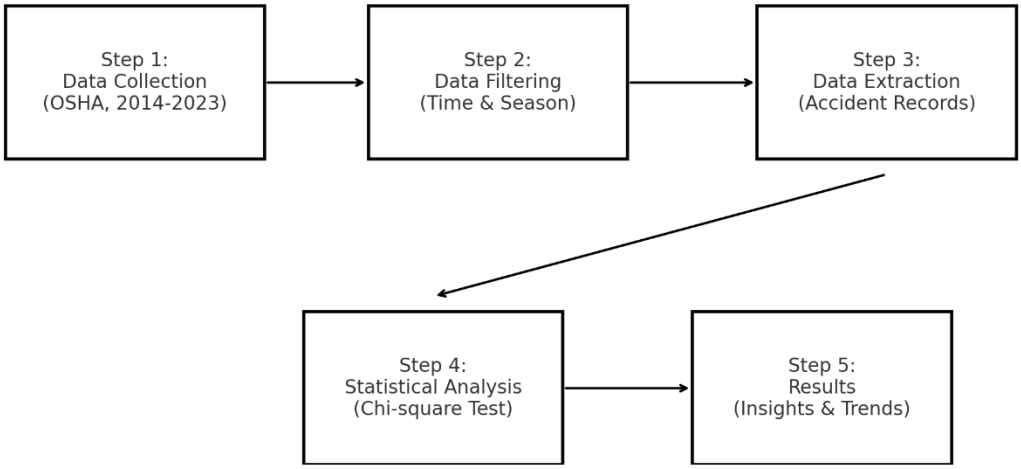

Figure 1. Framework of Study

Chi-square goodness-of-fit test was applied to examine whether accidents were uniformly distributed per season and time period. The temporal distribution of the accident data is done in accordance with six-time sections of the day. The seasonal analysis, on the other hand, puts the data into four groups: Fall, Winter, Spring and Summer. The number of accidents as recorded during the study was checked against the norm where the accidents would have occurred at different times of the year. The chi square statistics (X^2) were calculated using the formula:

$$\chi 2 = \sum \frac{(O - E)2}{E}$$

Where O represents the observed frequency and E represents the expected frequency.

According to both analyses, finding the patterns in accident occurrences it was established that focused prevention methods should be used in high-risk hours and months, namely morning and summer months. Statistics on construction accidents are usually imprecise because of inadequate reporting, and thus, it is difficult to analyze trends. The chi-square test proved important in a systematic identification of accident trends in relation to time or season, including if inaccuracies were present. The test showed that the observed frequency (O) was significantly higher than the expected frequency (E) during the high-risk periods such as during morning and summer accident time. Since it proved to be reliable and easy to use, the tool enabled us to analyze information from over 8 years to identify high-risk areas requiring immediate safety measures. A low p-value (<0.05) therefore suggesting that the occurrence of accidents was not uniform across time and According to both analyses, finding the patterns in accident occurrences it was established that focused prevention methods should be used in high-risk hours and months, namely morning and summer months.

Results

The breakdown revealed that there were 802 roof accidents that occurred in the construction industry from 2014 to 2023. Among them 287 people died which is highly concerning.

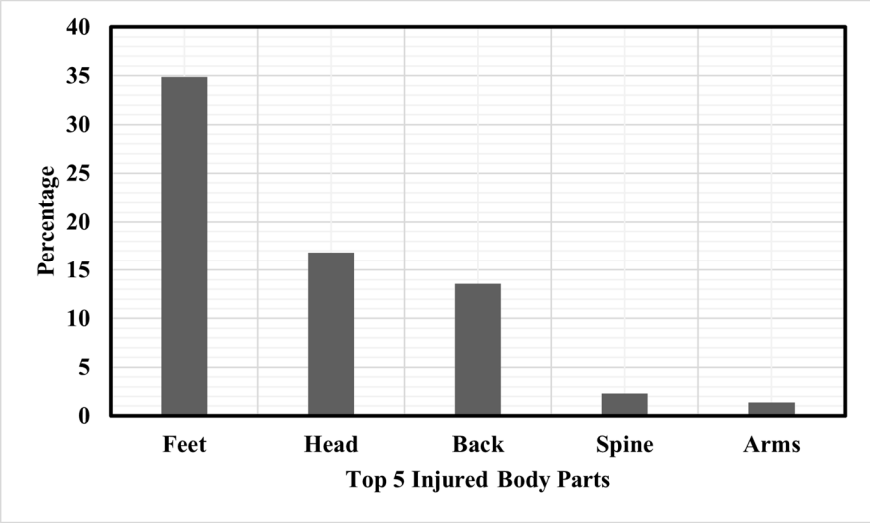

Figure 2. Body Parts Injury Percentage from falling

In the following bar graph (Figure 2), the selected data make the top 5 body parts where the injured workers are most affected in fall incidents. It is also observed that the feet are the most common sites of injury which is 34.9% of the total cases. This has an implication on the feet during falls from height as has been observed in the case of the impact on lower extremities. The head comes second; workers sustained 16.8 % injuries. These injuries are commonly serious, which explains the high risk associated with numerous incidents. The back is the third most affected body part where 13.6% were reported. The spine constitutes 2.3% though not as frequent as the other anatomical areas. Falls are extremely dangerous because spine injuries may result in permanent disabilities. At last, arms makes up 1.4%. In this study, it is depicted that although lower extremities (feet) are more often involved in falls, they also endanger important body regions like head and spine and lead to conditions that are either lifelong or lead to death.

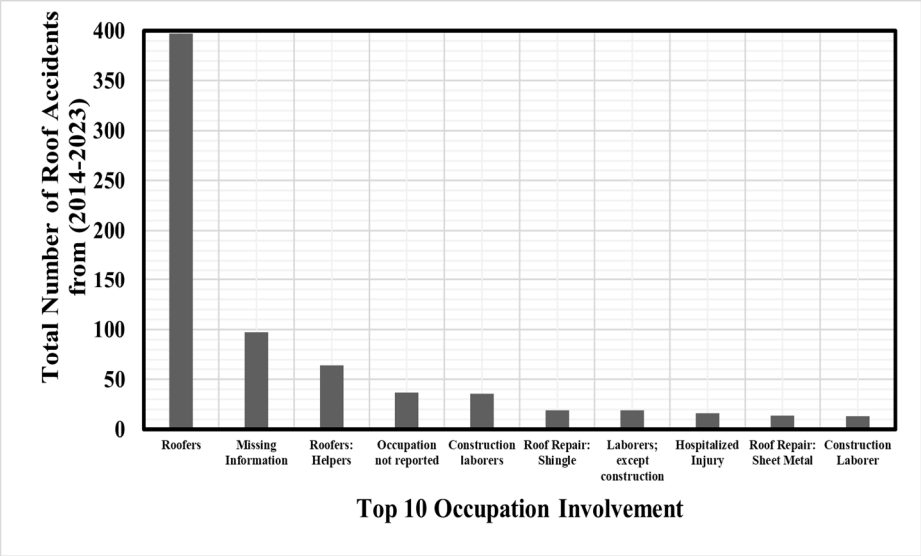

Figure 3. Top 10 Workers Occupational Involvement

The above bar shows (Figure 3) the breakdown of the 10 most implicated occupations and roofers even off the chart are implicated in an astonishing 397 incidents. Roofers' helpers faced 64 injuries. Construction laborers and cases where the occupation was not specified have the lower but significant participation, at 36 and 37. While we have cases with roof repair jobs, the general jobs involving in the event being a laborer, the involvements were between 19 and 14. The least employee category reported in the list is construction laborer with 13 experiences. This data also brings out the fact that helpers in roofing-related jobs bear the highest risks as indicated in the experiences hence the call to apply stiffer measures to reduce the risks related to the roofing jobs. There were 97 involvements where no information was recorded.

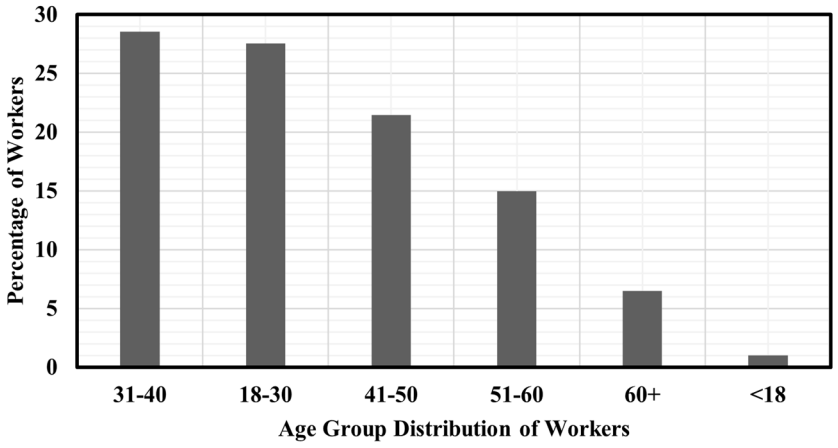

Figure 4. Age Group Distribution of the Worker

The following bar graph (Figure 4) provides the age group with workers proportions for different categories. The age group between 31-40 led in the generation of worker proportions, focusing 28.55% of the total workforce. In second place the workers who fall in the age bracket of between 18 and 30 years old comprise 27.54% of the total number of the workers. Employees

belonging to the 41-50 age group account for 21,45% of the employees, thus being significantly less in comparison with the previous age groups. The workers in the 51-60 age group account for 14.97%, a much smaller percentage but still reasonable, and the people working at this age may well be more experienced. The age band 60+ comprises 6.47% this refers to a smaller number of elderly employees. Finally, the under 18 group is the smallest; it only comprises 1.02 percent of the total workforce opposed to the large compositional presence of youths in the region; hence, this once again portrays less employment of young people in this stream.

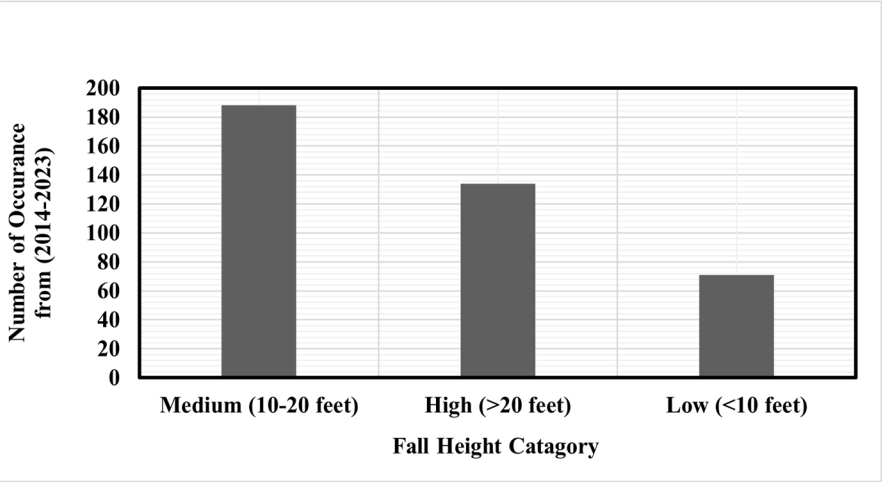

Figure 5. Different Height Category

The represented chart (Figure 5) describes the number of roofing accidents depending on the distance that a person fell during the years from 2014 to 2023. Medium height roof is the most dangerous with about 197 reported accidents on the heights of between 10- 20 feet. There are relatively few falls on heights of fifty feet or more; however, they occur and there were more than one hundred of these reported. Low roof heights where the roof is less than, 10 ft falls are the least frequent and the least occurrence of accidents. From this data it is noticeable that the greatest risk is associated with buildings with medium height roofs, and the number of accidents decreases as the roof height reduces.

The bar chart shows “Total Number of roof incidents from 2014-2023 (Figure 6). The y axis reveals the total number of injuries with time values along the x axis, ranging from 0 through 24 hours. The magnitude of each bar along the vertical (y) axis is the sum of number of accidents. Altogether, the chart denotes that a comparatively small number of incidents are recorded overnight and that moderately starts to rise to 25 recorded incidents between 6 and 7 in the morning, 8 a.m. has a sharp increase in incidents to 81 and so is hour 9 with 81. The number of incidents peaked at 97 at 10 and 90 at 11 a.m. After 11 a.m. or lunchtime, the value gradually

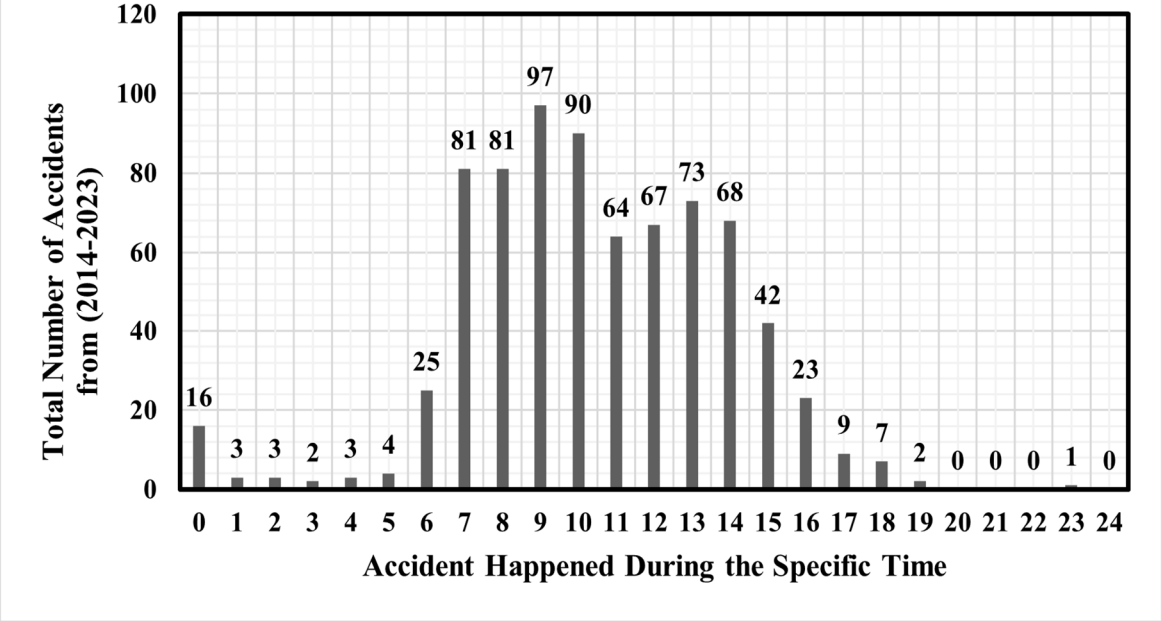

Figure 6. Total Number of Accidents from 2014-2023

declined. During the afternoon, the numbers increased and then decreased starting with 64, increasing to 67 and then to 73 before a decrease to 68 and then a further decrease to the end of the day. The numbers significantly decreased in the late evening, which is clear by observing the totals for this indicator that equal to a very low number 2 at 10 p.m.and 1 at 11 p.m. It also means that it is evident to observe that the rate of accidents increases at mid-morning even up to lunchtime then gradually decrease as the day warps in even up to night.

Table 1 Chi Square Test to Check Significance

Time Interval	Observed (O)	Expected (E)	$(O - E)^2 / E$	Contribution to χ^2
00:00–03:59	21	126.17	87.72	87.72
04:00–07:59	30	126.17	73.29	73.29
08:00–11:59	352	126.17	403.91	403.91
12:00–15:59	271	126.17	165.9	165.9
16:00–19:59	83	126.17	14.77	14.77
20:00–23:59	0	126.17	126.21	126.21
Total			871.8	871.8

Chi-square statistical test showed a value of 871.80 (Table 1) which is much greater than 11.07 which is considered critical for the data. This indicates the existing differences are significant in as much as the obtained p-value of less than 0.00001 reflects the minute distribution likelihood of such results as a version of chance variation. The data reveals that the highest number of accidents occurs between 08:00 a.m. to 11:59 a.m., 352 incidents, these areas alone account for approximately over half the total regarding deviation from the expected number of accidents. Since 271 accidents occurred between 12:00 p.m. to 15:59 p.m., this time frame is also not small. In contrast, the 20:00p.m. to 23:59 p.m. state no accidents while the other periods report higher

than expected frequency of accidents. Taking all these factors into consideration analyzing the data, it is possible to conclude that the probability of accident occurrence dramatically rises in the morning and early afternoon and reaches the absolute maximum during the working hours. This, in turn, explain why more attention, and probably preventive measures, should be paid during such time zone.

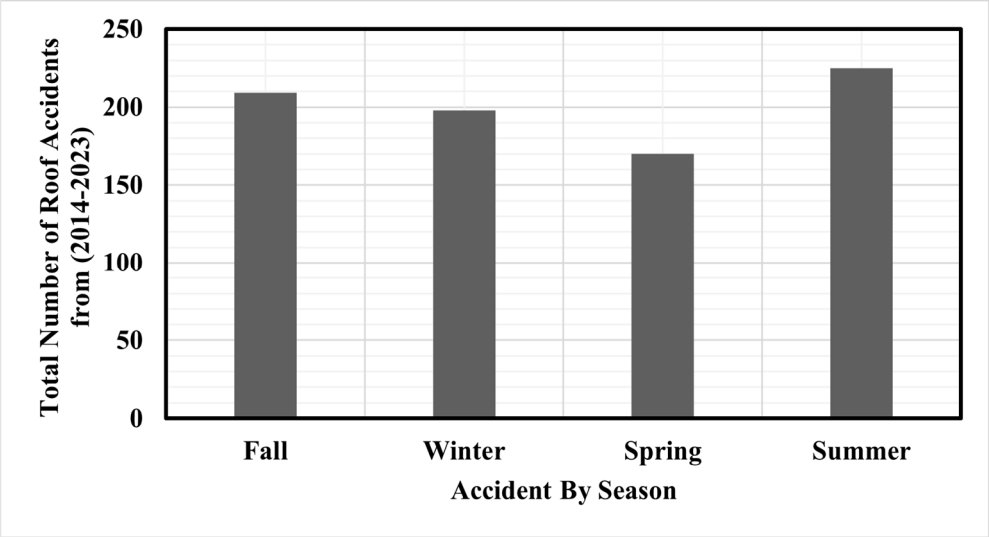

Figure 7. Accident Comparison by Seasons from 2014-2023

The bar chart (Figure 7) on the page reveals the number of accidents that occurred each season: Fall (September, October, November), Winter (December, January, February), Spring (March, April, May), Summer (June, July, August), in order to compare the seasons' characteristics in terms of the accident rate. Leading by numbers of summer where total number of accidents recorded was 225, this indicates that the heat periods of the year have the most incidences of the accident. Fall is just behind it with 209 accidents, denoting persistent high rates may be due to variations of weather or holiday traffic. Winter captures slightly fewer accidents at 198, which may be attributed to unfriendly weather such as icy state but with low mobility in some areas. Accident rate in spring is comparatively low: 170, it may be explained using the weather conditions and the lack of large-scale work. The chart shows an increased propensity for accidents to happen during the warm months of the year with summer having the highest rate while spring months report the fewest numbers of accidents.

Table 2 Chi Square Test to Check Significance

Season	**Observed (O)**	**Expected (E)**	**$(O - E)^2$**	**$(O - E)^2 / E$**	**Contribution to χ^2**
Fall	209	200.5	72.25	0.36	0.36
Winter	198	200.5	6.25	0.03	0.03
Spring	170	200.5	930.25	4.64	4.64
Summer	225	200.5	600.25	2.99	2.99
Total				8.02	8.02

Analysis using the chi-square (Table 2) yields results of seasonality where accidents occur, which is evidence that accidents are not uniform throughout a calendar year. The value of Chi-square we get in above consideration is equal to 8.02 which is more than the Chi-square critical value 7.815, at 5% level of significance, hence null hypothesis H0 stated that the distribution is equally likely to be rejected. Summer reports the highest number of accidents, 225, and it is the main reason for a relative high chi-square value, ≈ 2.99 because the number of accidents is greater than 200.5 that was expected. However, Spring saw lesser accidents (170), which yielded a relatively higher standard deviation in the negative of the contribution approximately 4.64. Once again, the observations can be close to expectations such as Fall (209) or Winter (198) contributing little to the chi square value. Based on this study, it can be concluded that the accident frequency is highest during Summer and relatively low during Spring season, support for seasonal initiatives in safety, especially during summer holidays since they are most vulnerable.

Discussion

This analysis of roofer's accident provides new interpretation of specifics of high-risk factors concerning age, occupation, time periods and roof height. The results of the present study suggest the necessity of more targeted initiatives meant to reduce accident threats and implement preventive solutions by identifying a non-random nature of accidents as well as significant differences between observed and expected numbers of incidents across multiple significant domains.

Occupational Risks: Based on information on occupational accidents, roofers are said to be the most affected, happening to experience 397 of the accidents. This goes to show that roofing is a very dangerous area to work in. The above unknown vocations recorded 59 incidents, while roofers' assistants recorded 46 incidents. Hence, improving the safety compliance to a higher level, compulsory wearing of suitable PPE and effective delivery of safety training is deemed to be essential in the roofing business due to what seems to have a significantly high chance of accidents in those vocations.

Injury Patterns: In terms of injury, no details about 320 events were reported. There were, however, 94 cases labeled severe, illustrating the fact that, although incidences are a regular occurrence, the consequences are serious. Head and back are the most frequent reasons with 93 and 47, respectively; this suggests employee vulnerability to falls and other working mishaps. This underlines the importance of better ways to practice preventing falls and the gadgets that can be used in the prevention.

Age Groups: Regarding the age distribution, the most represented accident age group is within 30–40 years with 213 victims, while the second most represented age group is between 18–30 with 199 victims. What might look like a conclusion here is that younger and more energetic workers engage in the demanding physical jobs that increase the risk of accidents. As for the injury incidence rate, a very low figure was recorded for those who were more than fifty years old in contrast with those individuals who are between ages zero to eighteen years old in which safety measures should be for the young employees who are most likely the ones performing risky tasks.

Risks Associated with Roof Height: A report that also followed various accidents for several years established that roof height with the highest percentage is medium of 10- 20 feet with 167 cases. One hundred and eighteen cases were recorded for high roof buildings that have heights of more than twenty feet. There were 453 cases where no information was provided. This would, in turn, suggest that better definition of roof heights in the report of accidents may enhance the ways of assessing risks and mitigating accidents. Of course, it is possible to have an accident on any roof but working at height always requires certain changes in safety measures.

Statistical Significance: Chi-square tests also exclude conjunction hypothesis on equal frequencies of accidents by seasons, hours and occupations since the test values are higher than the critical values. For instance, the calculated chi-square value of 871.80 for time-based and 8.02 for the seasonal analysis supports the hypothesis that the accidents are occasional and more likely to take place at peculiar temporal sections contributing 85% to the general overall grouping of the occupational categories. The findings of this research therefore call for effective preventive measures that would cover environmental conditions, specific work and time of the day saying that it is more important to prevent accidents during high-risk activities in their high-risk periods. Further studies should focus more on examination of specific programs which can be extremely helpful, such as safety programs and enhanced protective clothing for certain uses, but most importantly for the functions performed outside, as observed here.

Temporal Distribution: To prepare the data for the subsequent analysis, it is possible to differentiate between different time intervals and observing accident rates peaks occurring at certain time points: Most accidents occur between 8:00 AM and 11:59 AM: within this time period, there are 352 accidents, which makes this period the most dangerous for accidents. This pattern suggests that it is active in the mid-morning and early afternoon, which is most probably due to more work, accompanied by Attention Deficit, morning sunlight. Few happen during the night or early in the evening and accidents generally decrease after lunch. This trend indicates that there is a need for improved safety measures in the workplace in addition to having regular breaks in the working day.

Seasonal Variations: The annual accident statistics broken down by season have revealed that summer had the most accidents (225), followed by autumn (209) and then winter (198). The spring season was the least accidental and was involving 170 accidents. Many workplace conditions are likely to be cited for such fluctuations including activity demanding exercise in hot weather, or cold weather in winter, or extended shifts in the fall. That the precaution is taken seasonally, especially when weather is hot is justified by the fact that there are high tendencies of having an accident in summer.

Conclusion

The paper concerning the accidents associated with roofing provides useful suggestions; nevertheless, it has certain shortcomings. It focuses on the problem of analyzing information since the data provided is often insufficient and inaccurate, especially concerning the severity of the injury and the roof's height. However, the paper omits micro-climatic effects; these may affect different accident incidence in different regions, and it lacks an extensive analysis of root

causes of accidents. The study does not consider the effectiveness of safety programs that have been implemented and excludes accident trends by age while including other factors such as experience and training. Moreover, the paper does not analyze which types of accidents are most probable in particular seasons, even though it focuses on the seasonality of the issue. It could therefore be employed in the categorization of safety interventions. Thus, these constraints suggest that further studies should focus on the refinement of data gathering processes, more refined classification and detailed cause analysis in an attempt to increase safety measures within the roofing profession.

Key Recommendations: Peak Hour Interventions: Accidents are less likely to occur when rest breaks are taken, shift changes are made, and supervision is stepped up in the middle of the morning and the early afternoon. Seasonal Campaigns: Implement safety campaigns specific to summer and fall, involved drinking water, heat related illnesses, and increased outdoor awareness. Occupational Focus: Special attention should be paid to increasing the severity of safety requirements for the roofing industry and investing in technology and the training of workers (fall arrest systems such as harnesses, guard rails etc.). Protective Measures: Reduce serious injury by utilizing personal protective equipment more often, especially those protecting the head and spine. Young Worker Safety Programs: Conduct age-sensitive safety programs to meet the accidents rates challenges associated with young generation employees. Improved Reporting: Extend data categories, for example, “Unknown” in roof height and the extent of injuries to provide efficiency in risk evaluation and planning for the interdisciplinary intervention. When the above critical areas are addressed, organizations are in a position to reduce workplace related accidents and also enhance safety of the worker’s wellbeing.

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