The Effects of Firm Size on Risks and Reporting of Elevation Fall Injury in Construction Trades

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Abstract

Although many occupational safety programs are targeted towards large firms, the construction industry is dominated by smaller firms. This study examines the differential effect of firm size on the risk and the reporting of over 3,000 serious and minor nonfatal elevation fall injuries in Danish construction industry trades (1993-1999). Small firms (<20 employees) accounted for 93% of all firms and 55% of worker-years. There was an inverse relationship between firm size and serious injury rates, and a direct relationship between firm size and minor injury rates. An inverse relationship between firm size and injury severity odds ratios (serious versus minor) was found for carpentry, electrical work, general contracting and the remaining other trades. Health and safety issues, legislation and enforcement in the construction industry should, to a greater degree, be focused on smaller firms.

Introduction

Building and construction industries (referred to in this study as construction) are unique and challenging to study due to the temporary and transitory nature of construction workplaces and the construction workforce. 1,2 Epidemiological analyses of construction injury surveillance data are instrumental in contributing to an understanding of the extent and rates of injury risks. Many studies of construction industries have identified falls from heights as the most common incident leading to fatal injury. 3-6 One of the studies 6 found that a focus on falls from heights is also relevant when looking at serious nonfatal injuries as opposed to minor nonfatal injuries. Interest in this area is reflected by a number of focused studies on falls in construction. 7-12

The literature on firm size and fatal or nonfatal injuries in construction shows varying patterns, 13-18 and only two studies make any mention of elevation fall injury rates in relation to firm size. 8,19 None of the above studies differentiated between serious and minor nonfatal injuries, nor mentioned trade-specific (e.g., carpentry) or source-specific (e.g., scaffold or ladder) analyses of injury rates in construction in relation to firm size.
Purpose

The purpose of this study was to assess the differential effect firm size had on the risk and the reporting of serious and minor nonfatal elevation fall injuries in selected construction trades and in relation to the sources of elevation falls. The study builds on earlier research on the effects of firm size on injuries in construction in three ways: 1) it focuses on one specific hazard — elevation falls, 2) it differentiates between reported serious and minor nonfatal injury incidents, and 3) it applies construction trade- and source-specific analyses.

Materials and Methods

Data sources

This study is based on males’ nonfatal elevation fall injury incidents (accidents) reported to the Danish Working Environment Authority (DWEA) during the seven-year period between 1993 and 1999. The reporting of lost-time-injury incidents in Denmark is compulsory, and requires a minimum of one lost workday beyond the day of injury. Nonfatal injuries are divided into serious and minor. Serious injuries, as used in this study, are pre-defined by DWEA as lost-time-injury incidents resulting in amputations, bone fractures, or multi-trauma injuries. Minor injuries include all other reported nonfatal lost-time-injury incidents. Injuries are categorized into serious and minor irrespective of their social and economic consequences. Firm size was coded as 'not given' in 15% and 13% of the reported serious and minor injuries, respectively, and these injuries were excluded from the study.

DWEA has estimated that the proportion of underreporting of injury incidents in construction in general is approximately 50%, and across all economic sectors there is an estimated underreporting of amputations (10%) and bone fractures (40%). The proportion of underreporting in respect to firm size was not analyzed in the DWEA study. The effect of underreporting of injury incidents probably has a major effect on the absolute rates of serious and minor injuries. However, the effect on the ratio between serious and minor injuries, as used in this study and described below, will likely be negligible — assuming the patterns of underreporting are similar from year to year.

Denominator data for this study encompassed the entire Danish construction workforce in relation to firm size and construction trade, and were obtained from Statistics Denmark for the period between 1993 and 1999. Each year, Statistics Denmark registers Danish residents’ primary employment information as of the last week of November. Firm size is determined according to the number of male and female employees as follows: 0 employees (self-employed), 1-4, 5-9, 10-19, 20-49, 50-99, and ≥100 employees. These classifications are similar to those used by the United States Census Bureau.

The data are analyzed for construction as a whole, as well as for four selected trade groupings: general construction contracting, carpentry, electrical work, and the remaining other trades combined (i.e., glazier work, insulating, scaffolding, painting, masonry, plumbing, and miscellaneous remaining construction trades). The study mentions general construction contracting, carpentry, and electrical work because, as far as construction is concerned, these trade groups comprise the greatest percentage of worker-years (68%), and serious (73%) and minor 74% elevation fall injuries. The construction trade classifications were taken from the Danish Branch Codes of 1993, which are based on the European Union’s NACE (Revision 1) classification system. NACE conforms somewhat to the United Nations’ ISIC (Revision 3) classification system.

Statistical Analyses

The statistical and risk analyses carried out in this study included calculations of proportions (%), nonfatal injury incidence rates per 1,000 worker-years, relative rates (RR), and injury severity odds ratios (OR). Weighted (by worker-years) linear regression analyses were performed on the injury severity odds ratios across firm sizes – that is, the injury severity odds ratios for each trade group were modeled as a line with an estimate for the line’s intercept with the Y-axis (i.e., the level
of injury severity odds ratio) plus an estimate of the line’s slope (i.e., the effect of the firm size by category — the X-axis). To see whether the effect of firm size could reasonably be described to be equal for all trades, a likelihood ratio test was used to compare the above model with a model where the estimate for the line’s slope was forced to be the same. Further, to see whether the level of injury severity was similar across trade groups, another likelihood ratio test was used to test if the trade-specific intercepts could be modeled as a common intercept.

It could be anticipated that firms with no employees (self-employed) had a level of injury severity odds ratio that might differ significantly from what would be expected — extrapolating from the association between firm size and injury severity odds ratios for firms with one or more employees. Therefore, the above analyses were repeated allowing an extra estimate for firms with no employees.

Results

Firm size and the Danish construction industry

There is an inverse relationship between firm size and serious fall injury rates, and a direct relationship between firm size and minor injury rates (Table 1). The weighted linear regression shows an inverse relationship between injury severity odds ratios and increasing firm size, with a trend slope per category of firm size equal to -0.51 (95%CI: -0.071 to -0.032)

Firm size and construction trades

With minor variations, the patterns of relative injury rates and injury severity odds ratios for the four trade groupings mentioned above reflect that of the construction industry as a whole (Table 1) – with two exceptions: (i) an inverse relationship between minor injury rates and firm size in the electrical work trade group, and (ii) a direct relationship between serious injury rates and firm size in the other trades group.

Firms with no employees (self-employed) differed significantly from what would be expected — extrapolating from the association between firm size and injury severity odds ratios for firms with one or more employees. Carpenter and general construction contractor firms with no employees differed significantly in this respect, with higher and lower injury severity odds ratios than expected, respectively.

<table>
<thead>
<tr>
<th>Firm size (employed)</th>
<th>Firms %</th>
<th>Worker years %</th>
<th>Serious injuries %</th>
<th>Relative rate</th>
<th>Minor injuries %</th>
<th>Relative rate</th>
<th>Injury severity odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>36.4</td>
<td>6.3</td>
<td>4.3</td>
<td>0.68</td>
<td>3.6</td>
<td>0.57</td>
<td>1.18</td>
</tr>
<tr>
<td>1-4</td>
<td>28.2</td>
<td>15.8</td>
<td>20.4</td>
<td>1.29</td>
<td>14.2</td>
<td>0.90</td>
<td>1.43</td>
</tr>
<tr>
<td>5-9</td>
<td>18.3</td>
<td>15.7</td>
<td>18.0</td>
<td>1.14</td>
<td>18.1</td>
<td>1.15</td>
<td>1.00</td>
</tr>
<tr>
<td>10-19</td>
<td>10.4</td>
<td>17.5</td>
<td>17.3</td>
<td>0.99</td>
<td>14.0</td>
<td>0.80</td>
<td>1.23</td>
</tr>
<tr>
<td>20-49</td>
<td>5.1</td>
<td>19.9</td>
<td>16.3</td>
<td>0.82</td>
<td>18.0</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>50-99</td>
<td>1.1</td>
<td>10.3</td>
<td>10.0</td>
<td>0.97</td>
<td>11.7</td>
<td>1.13</td>
<td>0.86</td>
</tr>
<tr>
<td>100+</td>
<td>0.5</td>
<td>14.4</td>
<td>13.6</td>
<td>0.94</td>
<td>20.3</td>
<td>1.41</td>
<td>0.67</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>1.00 (ref)</td>
<td>100</td>
<td>1.00 (ref)</td>
<td>1.00 (ref)</td>
</tr>
</tbody>
</table>

Data source: Danish Working Environment Authority and Statistics Denmark
Serious injuries: Amputations, fractures or multitrauma; Minor Injury: all other nonfatal injuries
IRt = Serious and minor injury incidence rates for each group total are per 1,000 worker-years
*Injury severity odds ratio = Odds of the number of serious to minor injuries of a subgroup divided by the same odds for the reference group

Table 1. Lost-time elevation fall injuries and size of construction firms - Danish males 1993-1999
In firms with one or more employees, the likelihood ratio test showed that the trend slopes per category of firm size, from the weighted linear regression model, did not differ significantly from the trend for all construction trades combined. A further likelihood ratio test for an equal intercept showed that the intercepts differed significantly by trade group, with carpentry and electrical work having a higher and lower level of injury severity odds ratio than the other trades group, respectively.

**Firm size and sources of elevation falls**

In all construction trades combined, distinct patterns in relation to firm size were found for serious injuries in relation to the source of the elevation falls, whereas there were no distinct patterns for minor injuries. Firms with less than 20 employees had greater proportions of serious injury falls involving ladders and roof surfaces, whereas larger firms had greater proportions of serious injury falls involving stairs and other sources.

**Discussion**

The Danish construction industry, as well as other construction industries around the world,\textsuperscript{14,21,22} are dominated (in number) by smaller firms, with self-employed firms accounting for the greatest proportion of firms. This study reveals that over 93% of firms have less than 20 employees (Table 1), yet they account for 55% of worker-years. In the United States,\textsuperscript{23} the ten states with the highest rates of fatal injury were predominantly rural states. For example in Iowa, firms with fewer than five employees dominate construction.\textsuperscript{24}

This study has also revealed that for construction as a whole the risk of a serious elevation fall injury is greatest in firms with less than 20 employees, whereas the risk of minor fall injuries is greatest in firms with 20 and more employees. Although the levels of injury severity odds ratio in different construction trade groups vary, the effect of firm size on the odds ratios was similar for them all when looking at firms with one or more employees. A previous study\textsuperscript{6} includes a discussion of interpreting injury severity odds ratios in terms of relative injury risks and relative reporting.

One of the possible explanations for the lower injury severity odds ratios in larger firms is that they often have greater internal and external expertise and resources that can be invested in health and safety issues, allowing for a greater degree of organization, planning, education, and training. Consequently, large firm are capable of investing more in proper equipment and reliable personal protective equipment. In addition, large firms can have a greater vested interest in safety (e.g., image, economy). Low injury rates of large firms may also be due to their ability to outsource potentially hazardous tasks, such as scaffolding, to other and often smaller firms. Larger firms are more often involved in large construction projects, which, to a greater degree, may be inspected by work environment officials than smaller firms and smaller construction projects. Large construction projects often have the added advantage of on-site health and safety organization and expertise, with the possible inclusion of on-site medical care. When an injury has occurred, larger firms are also better able to provide other types of work, thereby preventing or reducing the number of lost workdays. On the other hand, larger firms tend to be better organized in terms of reporting injuries and consequently have a higher number of reported minor injury incidents.

One of the main biases when looking at firm size is that larger firms have more employees involved in relatively safe office work. The employment data used in this study was based on employment figures in November, providing an additional bias, as construction is particularly susceptible to seasonal employment patterns. Furthermore, the trade groups used in this study, such as carpentry, involve smaller firms engaged in potentially more hazardous tasks, for example roofing. This may also represent a bias with regard to the results for a trade group.
Conclusions and recommendations

Differentiating between serious and minor injuries across firm size allows for the assessment of relative hazards and reporting of injury incidents. In comparison with firms with less than 20 employees, workers in firms with over 20 employees have a lower risk of serious injury elevation falls. If a nonfatal elevation fall does occur in the larger firms, there is a lesser risk of it being serious. This may be explained partly by the fact that falls in larger firms involve mainly stairs and other sources, whereas falls in smaller firms involve mainly ladders and roof surfaces. The results for construction as a whole revealed a direct relationship between minor injury rates and firm size, and an inverse relationship between serious injury rates and firm size. Although individual construction trade groups had different levels of injury severity odds ratios, there was a similar decrease in injury severity odds ratios with increasing firm size for all the trade groups when looking at firms with one or more employees.

The results in this study point to a number of recommendations and areas of further research in terms of firm size and the prevention and control of elevation fall injuries. Firstly, health and safety issues, legislation and enforcement should, to a greater degree, be focused on firms with less than 20 employees, and particularly elevation falls involving ladders and roof surfaces. Secondly, firms with 20 or more employees should, to a greater degree, focus on falls involving stairs and other sources. Other sources do not seem to provide such obvious elevation fall risks as ladders and roofs, which appear to be appropriately addressed. In relation to the trade-specific analyses carried out in this study, the first recommendation is particularly relevant for carpentry, where 74% of worker-years are carried out by firms with less than 20 employees. On the other hand, focus on stairs and other sources of falls is particularly relevant in general construction contracting, as the majority of this trade group’s worker-years are in larger firms.

Acknowledgements

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References


Occupational elevation fall injuries referred to an emergency department, 1990-1999

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Abstract

Introduction: This study assesses the utility of emergency department surveillance data in contributing to targeting primary injury prevention of males' occupational elevation falls.

Methodology: A Danish hospital's register (1990-1999) was analysed with the use of statistical and descriptive methods, using acute hospitalisation rate ratios in relation to referrals as a measure of injury severity. Elevation falls were divided into high (≥1 meter) and low (<1 meter) level falls.

Results: Males accounted for a majority of occupational injury incident referrals (79%), admissions (83%), and high-level falls (94%). The acute hospitalisation rate ratio was greatest for high-level falls (RR = 4.31, 95% CI: 3.75 – 4.95), and in particular for falls involving roof surfaces. An increasing trend for acute hospitalisation rate ratios was found for both high and low-level (< 1 meter) falls over the ten–year period, and acute hospitalisation increased with increasing age. There was a proportional increase in high-level falls, yet a decrease in low-level falls over the ten-year period. The majority of high-level falls involve ladders. Workers aged 20-24 had the greatest proportion of high-level scaffold falls, whereas workers aged 30-34 had the greatest proportion of roof and ladder falls. The estimated heights of the falls were reported in only 13% of cases, and large fall heights were presumably overrepresented.

Conclusions: Male occupational high-level fall injuries are a significantly increasing local public health problem. Emergency department surveillance systems need to be expanded or to improve the recording accuracy of workers' occupation, to allow for more precise targeting of primary injury prevention.

Introduction

Occupational injuries are a significant and largely preventable public health challenge around the world. Denmark has one of the lowest occupational fatal injury incident rates in the world (1) and, as in many countries, falls from heights are one of the primary causes of on-the-job fatal and serious injuries (2). The majority of occupational injury incident statistics, however, are based on lost-time-injury incidents reported to national authorities, which require a minimum of one-to-three days sick-leave beyond the day of injury. Underreporting of injury incidents cause biases in these national registers, and in Denmark it is estimated that 50% of reportable incidents go unreported (3). This study looked at the utility of an emergency department register in targeting injury prevention, with a focus on injury incidents involving falls from heights.

Although there is a rather extensive body of literature characterizing emergency department referred falls, there are a number of areas that simultaneously require focused attention, to allow for improved targeting of primary injury prevention. First, due to etiological, gender and age biases,
there is a need for a discrepancy between falls on the same level and falls from heights. There is a great deal of literature dealing with the prevention of trips, slips and falls on the same level and on stairs, often focusing on the friction of working surfaces and footwear. In falls from heights, however, risk taking in the form lack of barriers or fall protective equipment, is an additional aspect that needs to be dealt with by both managers and workers. Falls from heights are a predominantly male phenomenon due to exposure to working at hazardous heights, particularly in the construction industry (2). Females and elderly workers are to a greater degree involved in falls on the same level, due to increased exposure to hazardous (i.e., slippery) floor surfaces, and age related physiological fragility, respectively. Secondly, a differentiation between low-level elevation falls and high-level elevation falls is required, to avoid fall height biases. No studies were found in the literature that made a distinction between low-level and high-level elevation falls. Elevation falls from very low heights can create biases when grouped together with elevation falls from greater heights, as they contribute to underestimating the seriousness of elevation falls. Thirdly, gender differences in fall injuries and hospitalization of falls injuries are also required, to avoid gender biases in injury experience. As mentioned above, falls from heights are predominantly a male phenomenon, yet most studies provide combined results for males and females.

This study, therefore, focused on males' falls from heights, and differentiated between high-level and low-level elevation falls. The purpose of the study was to assess the utility of an emergency department surveillance system in contributing to identifying high risk areas, e.g., worker age and working surfaces of falls, with increased probability of falls from heights, for use in targeting areas for primary occupational injury prevention.

Material and Methods

Study design, setting and population
The study population for this retrospective, descriptive study consisted of a register of victims of physical trauma seeking medical attention at the emergency department of Odense University Hospital in Denmark, during the period 1990-1999. It was not possible to identify the population at risk, as there were four other emergency departments in relative close proximity to the one in Odense on the island of Funen. These emergency departments may also receive patients from the mainland (Jutland) and/or from some of the surrounding islands. This limitation is however not uncommon, as the majority of similar studies using emergency department surveillance data provided only numbers and proportions of injuries, but not incidence rates, e.g., (4-8). Very general and approximate fall injury rates, however, have been shown in other studies, e.g., (9-11).

Measurements, definitions and data analysis
The content of the register included amongst other data, the reason for contacting the emergency department (i.e., illness, accident, violence, self-inflicted, late-effects), age, gender, type of activity (e.g., sport, leisure, paid work, unpaid work, vital activities), mechanism of injury (e.g., fall on same level, fall/hop to lower level, struck or hit), injury incident causing product or working surface (e.g., ladder, scaffold, roof), and outcome category (e.g., no referral – treated and discharged, referred to family physician, acute admission, died during admission).

The focus of this study was on male injuries sustained from occupationally related falls from heights. Falls from heights were differentiated in the hospital register into high-level falls (≥1 meter), and low-level falls (<1 meter). An injury was considered occupationally or work-related if a referring person reported that an injury occurred while at work involving gainful- or self-employment. Further attention in the analyses was focused on patients who were acutely hospitalised in connection with their fall injuries.

Unfortunately no injury classifications (e.g., AIS, ISS, ICD) were included in the register for occupational injuries, unless they were sustained in a road traffic incident. An acute hospitalisation rate ratio was therefore derived as a measure of injury severity, whereby the proportion (%) of acute hospitalised injuries of a subgroup was divided by the proportion of referrals of the subgroup.
Classification of the working surface or source of the falls (e.g., ladder, scaffold, roof) were derived by analyses of information in the register variables 'product type' and 'free text'. The working surfaces were manually collapsed across ladders (portable/movable and permanent), scaffolding, roof surfaces (roof/loft/ceiling/rafters), other, and not otherwise classified (missing).

Results

Emergency department referrals
There were 456,017 emergency department referrals (first treatment visits) registered between 1990 and 1999. Approximately 71% (N=324,790) of the contacts were for treatment of accidental injuries, 23% were for acute sickness, and 4% for violence related injuries. Occupational injuries accounted for approximately 16% (N=52,711) of all accidental injury referrals. Males were involved in the overwhelming majority of the occupational injury referrals (79%; N=41,813), and accounted for 94% and 80% of the high level (≥1 meter) and lower level (<1 meter) fall referrals, respectively.

Hospitalised referrals
Approximately 4% of all male referrals resulted in acute hospitalisation. The greatest proportions of injuries and acute hospitalisations were due to crushing/cutting/stinging and struck/hit injuries (Table 1). High-level falls (≥1 meter) accounted for 3.44% of referrals, yet 14.86% of acute hospitalisations. This produced the highest acute hospitalisation rate ratio of 4.31 (95% CI: 3.75 - 4.95), compared to the acute hospitalisation rate ratio for all injury mechanisms combined (RR = 1.00).

<table>
<thead>
<tr>
<th>Injury mechanism</th>
<th>Acute Hospitalisation (N=1622) %</th>
<th>Acute Referrals (N=41813) %</th>
<th>Acute hospitalisation rate ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crush, cut, sting</td>
<td>32.49</td>
<td>35.94</td>
<td>0.90 (0.83 - 0.99)</td>
</tr>
<tr>
<td>Struck or hit</td>
<td>22.19</td>
<td>23.01</td>
<td>0.96 (0.87 - 1.07)</td>
</tr>
<tr>
<td>Fall &gt;=1 m</td>
<td>14.86</td>
<td>3.44</td>
<td>4.31 (3.75 - 4.95)</td>
</tr>
<tr>
<td>Chemical effect</td>
<td>8.88</td>
<td>2.33</td>
<td>3.80 (3.17 - 4.53)</td>
</tr>
<tr>
<td>Acute over-exertion of body</td>
<td>5.61</td>
<td>7.68</td>
<td>0.73 (0.59 - 0.90)</td>
</tr>
<tr>
<td>Falls on same level</td>
<td>5.55</td>
<td>4.54</td>
<td>1.22 (0.98 - 1.51)</td>
</tr>
<tr>
<td>Thermal, electric, radiation effect</td>
<td>4.69</td>
<td>4.31</td>
<td>1.09 (0.85 - 1.37)</td>
</tr>
<tr>
<td>Fall &lt;1 m</td>
<td>4.13</td>
<td>2.83</td>
<td>1.46 (1.12 - 1.87)</td>
</tr>
<tr>
<td>Fall on stairs</td>
<td>1.23</td>
<td>0.86</td>
<td>1.43 (0.86 - 2.24)</td>
</tr>
<tr>
<td>Foreign bodies</td>
<td>0.25</td>
<td>14.99</td>
<td>0.02 (0.01 - 0.04)</td>
</tr>
<tr>
<td>Suffocation</td>
<td>0.00</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>0.12</td>
<td>0.03</td>
<td>3.97 (0.43 - 17.5)</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.00</td>
<td>0.03</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Acute hospitalisation rate ratio: %hospitalisation divided by %referrals

Working surfaces
The type of working surface or source of high-level falls was available in 95% of referrals (N = 1378) and acute hospitalised cases (N = 229). The distribution of the three main sources of high-level falls - ladders (41% referrals; 39% hospitalised), scaffolds (11%; 12%), and other surfaces (40%; 38%) did not vary considerably depending on whether they resulted in acute hospitalisation or not. However, in high-level fall injuries involving roof surfaces (8% referrals; 11% hospitalised),
there was a 38% greater risk of acute hospitalisation, compared to the hospitalisation risk for all the known sources of high-level falls.

The sources of low-level fall referrals were recorded in 80% of referrals (N = 948), and 61% of acute hospitalised cases (N = 41). They primarily involved 'other' sources (79% referrals; 76% hospitalised) than ladders (15%; 22%), scaffolds (5%; 2%) and roof surfaces (1%; 0%). A 48% greater acute hospitalisation rate ratio was found for low-level falls involving ladders, compared to the risk for all the known sources of low-level falls.

**Age**

In terms of age, a Kruskal-Wallis non-parametric equality of populations rank test found that the distribution of low-level and high-level fall injuries did not differ significantly from the distribution for all male occupational injuries. In spite of a decreasing proportion of injuries with increasing age, the acute hospitalisation rate ratio increased with increasing age for both high and low-level falls. Cross-tabulation analyses of age and working surface of falls from high levels for age groups 15-59 showed that workers aged 20-24 had the greatest proportion of scaffold falls (18%), whereas workers aged 30-34 had the greatest proportion of roof (22%) and ladder falls (16%).

**Fall heights**

A non-standardized short text description was provided in 637 of the 1440 high-level fall cases, of which 186 contained information regarding the height fallen (mean 2.7 meters, range 1-10 meters). The height fallen was more often given in acute hospitalised injury cases (46/241=19%, mean=3.3 meters, range=1-10 meters), than for the other high-level fall injury cases (145/1199=12%, mean=2.5 meters, range=1-10 meters). From this it can be assumed that it was the more extreme fall heights that were reported. Thus, the average fall height in both groups, were presumably overestimated. As the heights fallen in non-acute hospitalised cases were less often reported than the acute hospitalised cases, then they were likely the most overestimated. Therefore, the difference in mean fall heights between the two groups was assumed to be underestimated.

**Trend**

A log linear Poisson regression revealed that there was a decreasing trend (Figure 1) in the number of low-level falls from 1990-1999 (change in log injury rate per year = -0.04, 95% CI: -0.06 – -0.02), and an increasing trend in the number of high-level falls (change in log injury rate per year = 0.04, 95% CI: 0.03 – 0.06). There was an increasing trend in acute hospitalisation of both high and low-level fall injuries over the ten-year period.

Figure 1. Trend in male low-level (<1 meter) and high-level (≥1 meter) occupational elevation falls recorded at Odense University Hospital, 1990-1999
Discussion

A number of previous studies based on emergency department surveillance data, e.g., (5-14), hospitalised patients (15, 16), or on Doctor's First Reports (4) have directly or indirectly dealt with occupational falls or, more specifically, falls from heights. The results in these and other studies, e.g., (17), harmonize fairly well with results from this study. The lengths of the above studies however, have varied widely from as little as 27 days (9), to lengthier and more focused studies over a seven (7) and nine (5) year period.

The emergency department surveillance data for the ten-year period in this study show the seriousness and resource intensiveness of occupationally related high-level fall injuries in terms of increasing proportions and acute admissions over the ten-year period. Reported lost-time-injury data from the National Working Environment Authority in Denmark show a similar increase in elevation fall injuries in the county where the emergency department was located. These increases may be explained in part by the increase in building and construction activity over the same ten-year period in both the city and county where the emergency department was located. This is based on construction activity data collected by Statistics Denmark, and was measured by the gross number of completed square meters of building floor space. This particular result lends some support to a Finnish study (18) in which they found a direct and statistically significant relationship between non-fatal construction injuries and the number of cubic meters under construction.

In the current study, the approximate distance fallen was provided in only 13% (191/1440) of the high-level fall cases, and analyses showed that the given heights were likely overestimated. Several studies have found that the height fallen is a poor indicator or predictor of the seriousness of the ensuing injuries (see review in Goodacre et al. (13)). If acute hospitalisation is used as an indicator for the seriousness of the fall injuries, then the results found in this study reflect those of the earlier studies showing that the mean height of high-level falls increases with increasing injury severity. However, the results in this and the previously mentioned studies also show that there is great variation in injury severity at each fall height, or, vice versa, that major injuries (or no injury at all) can occur from both low-level and high-level falls.

Limitations and future research

One of the limitations of the surveillance data used in this study was the lack of an occupation category, which would allow for more precise targeting of primary injury prevention. This limitation is not uncommon for emergency department surveillance systems, and surveillance systems that do include job information are often found to have deficiencies (5-7, 11). For example, Zwerling et al. (11) found in their preliminary analyses that 19% of patients with work-related injuries did not provide an occupational title. Studies that have recorded occupational category and/or economic sector find that construction workers are often involved in elevation falls, e.g., (9), particularly in elevation falls resulting in hospitalisation (16). Hunting et al's (6, 7) studies focused on construction worker injuries, where 61% (17/28) and 51% (52/101) of hospitalised occupational injuries were from falls respectively. Of the 52 hospitalised construction workers with fall injuries in the 1994 study, 21 fell from scaffolds and 15 from ladders. In trade specific analyses of construction worker injuries, Hunting et al. (7) found that electricians and plumbers mostly fell from ladders. Four of the five hospitalised ironworkers with fall injuries were due to falls from heights, and half of the hospitalised carpenter injuries were due to falls from heights.

An additional limitation of using emergency department surveillance data is, as has been mentioned in other studies, e.g., (6, 11) that it does not allow for detailed analyses of contributing causes of the injury incident. For example, in terms of workers' blood alcohol concentration, Mosenthal et al. (16) found that 7% (5/68) of workers hospitalised for occupational fall injuries were intoxicated with alcohol. Likewise, Alleyne et al. (19) reported that 18% (N=10/57) of workers with fatal fall injuries had elevated alcohol levels. However, testing for alcohol has a number of ethical and practical limitations, e.g., Little (20), who found that practically all (700/702) people seeking emergency room treatment at a Scottish hospital were willing to take a breathalyser
test if they had been involved in a road accident, whereas no one was willing to take a breathalyser
test in connection with a work-related accident. This was in spite of the fact that they were assured
confidentiality, and that it was for research purposes only.

The emergency department database used in this study was much like the one described by
Hunting et al. (6), which contained information that primarily dealt with the treatment of injuries
and illnesses. Other than identifying general demographic data of the types of occupational falls
from heights, Hunting et al. judged that the information was inadequate in contributing to the
understanding of immediate and underlying contributing factors. Short text descriptions of the
circumstances varied greatly in quality and quantity of content, and were only available in 40%
(1042/2622) of the cases. A typical short description found in this and Hunting et al's study such as
"fell from scaffold, landed on back", is of limited value in identifying primary injury prevention
measures.

Conclusions

The results show that a focus on male occupational high-level fall injuries referred to a local
emergency department is legitimate, in terms of both increasing proportions and increasing
hospitalisation trends over the ten-year period. The emergency department surveillance data used in
this study is suitable for identifying general mechanisms of injury and sources of injury, as well as
providing general epidemiological data that are most useful for treating injuries (secondary and
tertiary injury prevention), and in identifying areas for more in-depth focus (primary injury
prevention). Targeting of local fall prevention was possible using worker age and sources of falls.
High-level scaffold fall prevention should be directed towards young workers, whereas falls
involving ladders and roofs should, in particular, be directed towards middle-aged workers. Low-
level falls involve, to a much greater degree, other surfaces than ladders, scaffolds and roofs, and
seldom result in hospitalisation. The current emergency department surveillance system, as well as
many of the emergency department surveillance systems mentioned in this paper, need to be
expanded and/or to improve their accuracy in recording workers' occupation, trade, and the
circumstances surrounding an injury incident, if the data is to be useful in improved targeting of
local primary injury prevention.

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Case studies of occupational falls from heights: Cognition and behavior in context

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Abstract

Problem: The aim of this study was to examine individual workers’ cognitive, behavioral and motivational processes leading up to occupational falls from heights. Method: The study is based on 26 semi-structured personal interviews and on-site investigations with male workers who reported to an emergency department for treatment of injuries due to falls from heights. Results: A greater number of workers carrying out non-routine compared to routine tasks perceived, identified, interpreted, and attempted to control a fall hazard. Two cases are presented illustrating how cognition and behavior in context progresses from a lesser to a greater active role in the incident processes. Summary and Impact on industry: The addition in full-scale investigations of an understanding of how and why a worker thought and behaved the way she/he did in a particular situation, can give important clues as to whether preventive measures will be effective in a similar situation in the future.

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1. Introduction

Occupationally related falls from elevated work surfaces, e.g., ladders, scaffolds and roofs are often cited as one of the main causes of male fatal occupational injuries (Bailer, Stayner, Stout, Reed & Gilbert, 1998). Kines (2001) also found that falls from heights were the leading type of males’ reported lost-time serious injury (i.e., amputation, fracture, multi-trauma) incidents in Denmark. Analyses carried out in connection with this study, of data from a Danish university hospital’s emergency department register and the lost-time-injury registry of the National Working Environment Authority in Denmark, show significant increasing numbers and rates of falls from heights over the past several years. In addition, the hospital registry reveals that male falls from heights accounted for 3% of occupationally related injury referrals, yet 15% of occupationally related hospital admissions. The prevention of falls from heights is, therefore, of interest not only for workers and employers, but also for the health sector, health and safety professionals and insurance companies.
Many of the studies in the literature on occupational falls from heights are statistical in nature, which, in themselves, are inadequate sources in attempting to understand the underlying processes of an incident. Studies as well as in-depth investigations of fatal injuries (Bradee, Hause & Pratt, 2000; Feyer & Williamson, 1991; Copeland, 1989) begin to provide important information for use in identifying preventive measures; however, cognitive information from the deceased victims is lost. A few studies have looked more in depth at underlying factors in nonfatal injury incidents, including falls from heights (Salminen, 1994), particularly in the construction industry (Cattledge, Schneiderman, Stanevich, Hendricks & Greenwood, 1996), as well as cross-industry studies on falls involving specific types of elevation work surfaces such as ladders (Björnstig & Johnsson, 1992). For example, in a case-control study of falls involving ladders, Cohen & Lin (1991a) found that factors immediately preceding an injury incident, such as ladder use behavior and factors in the working environment, were more important than individual characteristics.

Common for many retrospective studies is that investigations are often initiated relatively long after an incident (Cattledge et al., 1996), and results are often judgmental and counterfactual (Dekker, 2002), focusing on what an individual or organization did not do (omissions), rather than on what they did do (commissions) (Swain, 1963). Establishing guilt, error or failure is often the case not only for authorities (police, health/safety officials, etc.), but also for some of the models and categorizing systems of incident causation, e.g., error and failure models. This study looked at the contribution to full-scale investigations of including a focus on worker ‘commissions’ in the investigation and analysis process, as well as in the identification of preventive measures.

Workers are able to consider more factors that may influence the outcome of a task when they are more knowledgeable of the context within which the task is performed (Yates & Stone, 1992). The current study sought to investigate and analyze the processes leading to elevation fall incidents - seen from the individual worker’s point of view - by looking at cognition in context, and how and why decisions and behaviors were carried out, and why they made sense at the time. Attaining this type of data from subjects requires prompt (without delay) interviews, as well as documenting the site of the injury. Conducting interviews promptly is crucial, for as time passes details of the incident fade or are distorted by recall bias, e.g., aspects or gaps in the process are filled in with logical, legal and/or more socially acceptable aspects.

This study sought to overcome limitations with previous studies in the literature regarding elevation falls by: a) utilizing prompt personal interviews with victims, b) investigating and analyzing the incident process from a retrospective inside view of the individual workers’ cognitions in context, and c) not involving investigative authorities or insurance companies.

The paper is structured as follows: The materials and methods section is supplemented with descriptive data of the study group, as well as a presentation of the model of investigation and analysis used in the study. The subsequent result section begins with some cases, followed by some general patterns of information processing and a discussion of the results.

2. Methods

2.1. Terminology

The elevation fall incidents in this study are referred to as ‘incidents’ or ‘cases’, rather than ‘accidents’ (Davis & Pless, 2001), ‘injury incidents’ or ‘lost-time-injury incidents’, as not all the incidents result in injury and/or lost working time.
2.2. Population

The study population consisted of workers with possible physical trauma seeking medical attention at an emergency department. The emergency department of Odense University Hospital in Denmark was chosen, in 2002, for a four-month period. Based on the hospital registry for the previous twelve years, it was expected that approximately 48 males would seek treatment for injuries that were sustained from occupational falls from the height of one or more meters ($\geq 3.2$ feet).

2.3. Attendance at the emergency department

During the four-month study, 41 male workers were recorded to have reported to the emergency department in connection with falls from heights that the workers said (or were estimated by the emergency department registry personnel) were from a height of one or more meters. Workers were to be informed of the study during registration at the emergency department, and were asked to fill in a form providing their name, address and telephone numbers. This information was then telephoned to the interviewer (author) either immediately, or the next weekday morning.

Of the 41 workers, 26 (hereafter referred to as the study group) gave their informed consent to be interviewed. Of the 15 remaining workers, two were informed of the study, but declined to participate, one worker was excluded due to language barriers, and 12 either did not return their contact information, or were unintentionally not informed of the study. The 15 workers not included in the study did not differ statistically significantly ($p>0.05$) from the study group in terms of age, economic sector (e.g., construction, manufacturing), type of working surface, nor height of fall (as recorded in the registry). No information was provided regarding the 15 workers' professions; however, they were from significantly smaller firms ($p=0.03$).

2.4. Interviews

Semi-structured personal interviews regarding the processes leading up to the fall (see model of investigation and analysis section below) were carried out with the study group. Interviews were carried out by an experienced interviewer (background in clinical psychology and in-depth road traffic ‘accident’ investigations), who was able to deal, sensitively and constructively, with such phenomena as post-traumatic stress disorder. In some cases interviewees were also informed of the relevant options available for dealing with post-traumatic stress disorder. The workers were all informed that the interviews were confidential, and that sensitive information would be published anonymously.

The widespread use of cell phones by the workers provided quick access to the workers. In some cases, introductory interviews were carried out by cell phone while the workers awaited further medical attention at the emergency department. Interviews took place in the workers' homes ($n=20$), workplace ($n=3$) or at the hospital ($n=3$), and varied from one to three hours in length. Ten workers were interviewed personally within 32 hours of the incident, a total of 70% were carried out within three days, 88% within six days, and the three remaining interviews within 10, 16 and 20 days. The relatively lengthy delays between the incidents and interviewing were primarily due to weekends and holidays, delays in returning the contact information, as well as workers waiting a day or more before attending the emergency department. In the study group, 17 of the workers went to the emergency department immediately after the incident. In the remaining nine cases, the workers either continued working or went home after the incident, and first went to the emergency department a few hours later ($n=5$), the day after the incident ($n=3$) or, as in one case, six days after the incident.
2.5. Company visits and photo documentation

Either during or before the main interview, the interviewer asked the worker for permission to contact the workplace where the incident occurred, and to take on-site photos and measurements of the site and working surface. This would allow the interviewer to collect, verify and/or clarify information regarding each incident, such as the background of the equipment. Five of the 26 workers did not give their permission to contact a workplace. The reasons given were primarily the workers’ feeling of job insecurity, as well as a general company restriction on visits and taking photos at the particular work site.

2.6. The study group

Descriptive data regarding the study group is provided in Table 1. The occupations represented in the 26 cases varied from truck drivers (n=5), carpenters (n=4), masons (n=2), auto mechanics (n=2), metal processors (n=2), a crane operator, welder, manager, baker, emergency rescuer, industrial cleaner, butcher, farmer, curtain fitter, salesman, and warehouse worker. In all but the five cases involving truck drivers, the workers were working together with or close to other colleagues. Seven workers had over thirty years experience in their trade, five had ten or more years, eight had 1-9 years experience, and six less than one year. Six of the workers had experience as safety representatives or on safety committees, and four were involved as representatives or on committees at the time of the incident. A few workers had, upon joining their firm, been given introductory courses in, among other things, occupational safety, but this had rarely been followed up by any further formal training. In the 26 incidents, obligatory use of protective footwear (n=16) and clothing (n=3), e.g., steel toed footwear and fire resistant clothing, was required and followed by all the workers in conditions that required it, whereas obligatory helmet use was followed in only three of six cases.

Many of the workers were active in sports in their leisure time, with one worker, who was used to climbing, working, and falling from heights, involved in repelling and skydiving. On the other hand, one worker admitted to being afraid of working at heights, and always hired someone else if his own roof or rain troughs needed maintenance. Another worker, who professionally did not normally work at heights, had, only a few days before the incident, worked with ladders while repairing the roof of his summerhouse.

2.7. Working surface

The heights of the working surfaces involved in the falls (Table 1) were measured using a tape measure during on-site investigations in 19 of the cases. Estimates were provided by the workers in the remaining seven cases, as visits to the work site were denied, or the equipment had been dismantled or removed at the time of the investigation. Upon investigation, one incident turned out
to involve a working platform less than one meter high (0.6 meters) – this was included in the study, as it had initially fulfilled the inclusion criteria (was reported to have been from one or more meter’s height).

2.8. Model of investigation and analysis

The investigative and analytical method applied in this study is aimed at understanding the complex processes involved in an incident, taking a retrospective inside view of the individual workers’ perspective of the incident. The purpose was to study the complexity of workers’ cognition in an often dynamic context, by analyzing what they did, rather than what they or an organization did not do (Dekker, 2002). Focusing on what they did not do may be fruitful in identifying countermeasures, but does not contribute to an understanding of how or why the worker did something at a particular moment. During a work process, a worker often has many dynamic goals, which may be perceived as unclear and contradictory, e.g., production versus safety. The perception of contradictory goals produces cognitive dissonance (Festinger, 1957), of which, possibly due to economic or time restrictions, one or more of the goals is often disregarded or played down. The worker is not knowledgeable or focused on all the surrounding circumstances, and based on past experience and current knowledge, is likely expecting a successful outcome. Retrospective mapping (seen from an investigator’s outside view) may give the impression that the worker had a number of choices, whereas from the inside (from the workers’ point of view in context), it may have seemed as if there were few or no practical or ‘logical’ alternatives.

The challenge in these investigations and analyses is to understand the individual worker’s processing of information, and how and why their decisions and behaviors made sense or were chosen at the time and place. Individual information processing (Surry, 1969; Anderson, 1996) in this study deals with the cognitive and physiological responses involved in the detection and control of hazards, based on the following interrelated questions:

- Is the persisting or periodically occurring hazard detectable?
- How and when is the hazard detected?
- How is the hazard interpreted?
- How and when is the need for hazard control(s) recognized?
- How and when is hazard-control(s) responsibility allocated and accepted?
- How is hazard-control(s) applied?
- How is the hazard-control(s) appropriate in terms of type, time and place?
- How effective is/are the hazard control(s)?

Categorization of cognitive processing and/or physiological responses, including Rasmussen’s (1982) skill, rules and knowledge categories, is adapted in this approach in looking at commissions, what and how something is done, rather than not done. Inquiry into the workers’ information processing (cognition) and behavior in context is supplemented by information regarding their knowledge, training, experience, expectations, motivations, goals, goal trade-offs (e.g., production/safety), focus of attention, information overload/underload, physical characteristics and abilities, as well as the workers’ risk assessments of the probabilities and consequences of their decisions and behaviors.
3. Results

The distribution of how far along in the hazard detection and control process the 26 workers progressed is presented in Table 2, along with a differentiation between routine and non-routine tasks. In principle, all 26 cases involved hazards that were detectable, ten of which resulted in recognition of a need to control the hazards. The results show that a greater number of workers carrying out non-routine compared to routine tasks perceived, identified, interpreted, and attempted to control a fall hazard.

<table>
<thead>
<tr>
<th>Task (n)</th>
<th>Routine</th>
<th>Non-routine</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is a hazard(s) detectable?</td>
<td>13</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td>Is a hazard detected?</td>
<td>10</td>
<td>11</td>
<td>21</td>
</tr>
<tr>
<td>Is it interpreted as a hazard?</td>
<td>7</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Is the need for hazard control(s) recognised?</td>
<td>3</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Is a hazard control applied?</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Is the control effective?</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. Hazard detection and control in 26 hospital referrals of male occupational falls from heights

Half (n=13) of the workers were carrying out routine work tasks (Table 2), all involving familiar work surfaces/equipment. In 12 of the 13 cases the workers were carrying out a routine, daily task, whereas the last case involved a task that was carried out at least once a week on a stepladder. Five of the 13 workers chose a method that was different from their normal way of doing things, such as facing away from a work surface while descending it, pushing instead of pulling an object, or temporarily standing on a surface that they normally would not work from, but they chose it “to be more efficient” as it appeared to “save time” (n=3). In the 11 cases where the workers worked from their normal work surface, they had all very recently worked on the surfaces without incident. So what was different? In three cases the worker had consciously altered the setup to adapt to the context (e.g., folding a trestle ladder), which immediately increased the risks of a fall. In two cases the workers were concentrating on the task at hand, and were temporarily inattentive to the boundaries of the work surface. In two other cases the work surfaces had, unknown to the worker, been altered by others.

In the 13 cases where tasks were non-routine (Table 2), this was due to the worker being new to the job or to organizational shortcomings, e.g., work scheduling, as well as the tackling of temporary (one-time) tasks that arose unexpectedly. In the 13 cases the workers’ decisions were, to a greater degree than in the routine tasks, influenced by the workers either seeing or knowing that the working surface (e.g., ladder) had been previously used (within hours of the incidents) by another worker. The workers were, to a lesser degree, working on the surfaces but rather used them as a form of transport from one area to another, and the incident occurred more often on the worker’s first attempt at using the equipment. In the cases where the worker had previously (within hours/minutes/seconds) used the working surface without incident, the surface had subsequently become slippery due to water and grease (n=3), or the worker released his handgrip on a permanent surface so both hands were free to pull on an object.

The following cases provide examples where technical hazards were not detected, as well as a complex case where a need for hazard control was recognized and applied. This is followed by characteristics of the 26 cases by type of working surface.

3.1. Case 1: technical factors

There were three cases where information processing played a minor role in the incidents, as technical factors with equipment were judged to be the primary immediate contributing factor. In principle, these technical hazards were ‘detectable’. There had not been any previous incidents involving the equipment in the three incidents, and the workers, their colleagues and managers had not anticipated any complications with the equipment. In all three cases the equipment had been
used by the company for at least 15 years, and appeared in good shape, as structural weaknesses (e.g., fatigue of welded joints) were not, without closer inspection, immediately perceptible to the worker. Two cases involved structural collapse primarily due to wear and tear of equipment, and occurred when the worker was working while standing on the equipment. In the one case (Figure 1), a worker with 35 years experience in the trade was aware that some of the stepladders (used daily) in the workplace had been subjected to extreme weight overload, but he did not perceive the stepladders as having any structural weaknesses. The worker had seen the stepladder in question being used by another worker a few minutes before he himself used it. While working from the 1.6-meter (5 foot) high platform section, it suddenly broke away from the supporting legs at the welding joints resulting in both the stepladder and the worker falling to the floor.

3.2. Case 2: a network of factors

The complexity of a process leading to an incident is exemplified in the next case (some details have been altered to maintain anonymity). The incident directly involved three workers from a large construction company with an active safety program, including a detailed incident investigation and prevention plan. A mason was descending a scaffold in an elevator erected on the side of the scaffold structure, when, due to a site-specific power outage, the elevator stalled four meters (13 feet) from the ground. The mason phoned the electrician at the site, who then drove from his workshop to the elevator in a compact company car. The electrician normally drove in a company van, which was equipped with an extension ladder. Upon reaching the site, the electrician first decided to help the mason down from the elevator car. He searched and found a long but visibly weathered, damaged, straight wooden ladder in the vicinity of the elevator, which he leant up and held against the elevator car. The electrician warned the mason that the ladder appeared unstable. The mason climbed out of the elevator car and descended the ladder without incident, but had left some tools on the floor of the elevator car. One of the mason’s colleagues, wearing safety boots and a helmet, walked over to them, as he had been waiting to borrow the tools. The first mason told him where the tools were, and warned him that the ladder was unstable. With the electrician still holding the ladder, the second man ascended the ladder to retain the tools. When the mason had climbed half way up the ladder, it snapped in half just above the area where the previous damage had occurred (Figure 2), and the mason fell two meters (6.5 feet) onto the cement sidewalk below.

The inside view of the incident process for the injured worker reveals a person in a situation with immediate and simultaneously conflicting goals. He was a 26-year old with four years experience in the industry, and had been given an introductory course in safety upon joining the company. He trained regularly with weights at a gym in his leisure time, had returned the day before from a three-week vacation, and he was eager to begin work again. In terms of information processing in context, he had come over to his colleague with the goal of borrowing his colleague’s tools, as there was only one set of them at the site, and he needed them in order to complete a task. He was the third person at the time and place to ascertain that the ladder was damaged, and he was warned of its instability. He considered shortly the production versus safety goal conflict in the situation, quickly identified and weighed his options, i.e., either finding a safer ladder or waiting for
the electrician to reestablish electricity to the elevator, both of which would delay him in finishing his task. Knowing his colleague had climbed down the ladder without incident, and with the electrician holding the ladder, he chose to ascend the ladder. He did not remember feeling any non-verbal group pressure (social cohesion) at the time, but was motivated only by a desire to acquire the tools so he could finish his task.

3.3. Hazard recognition and attempted prevention

The above case was one of ten cases where the worker detected a potentially hazardous situation and thought of taking preventive action. In two of these cases, both involving tall folded (closed) trestle ladders, the workers had thought of but decided not to ask one of their colleagues for help with holding the ladders, as their colleagues were busy with their own tasks. The remaining eight cases were distributed between more safety conscious behavioral adaptations (\(n=7\)) and a technical preventive measure (\(n=1\)), all of which were ineffective in preventing the fall incidents from occurring (such as in Case 2). The case with a technical preventive measure was the only one where the worker acted proactively, out of routine, by placing wedges under the legs of a ladder to prevent slippage. The worker, in this latter case, would have preferred to have used a job-made scaffold, however, this option was abandoned, as it had been in previous tasks, due to “time and cost restrictions” and “organizational deficiencies”. In two of the eight cases the workers overestimated their own physical abilities in non-routine tasks of climbing on objects not designed for climbing on. Two other cases involved the workers concentrating on their routine tasks and being unaware of the restricted dimensions of the working surface (\(n=2\)), off which they subsequently fell.

3.4. Accepted hazardous work conditions

Case 2 was also one of five cases in the study where the workers described accepted risk-taking by employees and/or managers, even in cases where there were written rules or guidelines on how to handle the particular situation. Although acknowledging that other methods were preferable, the current methods were adopted for lack of convenient alternatives. They were perceived to be time saving (\(e.g., \) Case 2), or were deemed necessary to overcome technical shortcomings (\(e.g., \) Case 3 - below). These cases also involved such practices as consciously not securing a truck ramp and removing perimeter railing on an elevated platform. In the latter example, an employee was, due to a holiday staff shortage, set to work for the first time with a conveyor belt system along with an experienced colleague. The workers removed the perimeter railing on the work platform, as the conveyor belt mechanism was perceived as inadequate. A few hours into his shift the worker thought he would make use of the extra space on the platform perimeter where the railing was removed, as well as to add a little variation to a physically demanding and repetitive movement. While immersed in his task, his foot slid off the perimeter of the platform, and he fell through the hole in the railing. In this case, as well as three others, the working surfaces were subjected to water and/or greasy materials.

Another case (Case 3) where water and greasy material played a role involved a truck trailer that was equipped, by the manufacturer, with a built-in, small and narrow metal ladder (Figure 3). The worker found this ladder to be impractical, as it required both hands and good balance to climb. The worker had to wash down the inside of the trailer...
with a high-pressure hose that could only be turned on at the source next to the truck. He found a wooden ladder in the area, and assuming it was there for other workers to use, he decided to use it. After ascending the ladder and washing the inside of the trailer, the worker, realizing that the cement surface, ladder and his footwear had subsequently become slippery, began descending the ladder, which then slid out beneath him.

This latter case is the only one where a worker had, through previous experience, avoided using an immediately available working surface (the small metal ladder), as he judged it to be hazardous. As in Case 2, the wooden ladder was simply that which was closest at hand, and in Case 3, it appeared as though it was designed for the current task. The worker assumed that it successfully had been used by others, in spite of there not being any mechanisms on the ladder to secure it to the trailer.

3.5. Ladders, scaffolds and vehicles

In the 11 cases involving ladders (Table 2), only one of the ladders was secured to a permanent object. In the latter case, the worker, working under what he felt was a strict time-schedule, was climbing down a ladder from a cramped working area, when he noticed he had missed spraying an area. While standing on the 90° angled ladder, he turned on his hand-held high-pressure hose, the pressure of which threw him backwards. In the ten other ladder fall cases, the majority involved the ladder feet gliding backwards (as in Case 3), two ladders toppled, and two collapsed (Cases 1 & 2).

Scaffolds were involved in four falls, two of which involved workers losing their balance on relatively low (under two meters; 6.5 feet) scaffolding, the one being wet and slippery, the other where the worker was inattentive as to the edge of the scaffolding. In the other two cases the workers admitted to what they considered ‘time saving risk taking’. The one case involved a worker building a mobile, hanging scaffold from the slanted ceiling beams/trestle of a relatively low building. He had previously used a mobile lift when carrying out similar tasks, but the current building was too low to allow for effective use of the lift, and stationary obstacles on the floor restricted the use of a mobile scaffold. At one point the end of one of the scaffold floorboards hung over the edge of the scaffolding frame and was not fastened. Thus, when the worker stood on the end of the floorboard, it tipped, and he fell to the cement floor below.

Four of the five truck or trailer fall incidents involved daily, routine behavior with the vehicles. The only deviation from the workers’ normal behavior was that one of the drivers decided to climb down forwards, whereas he normally would have descended backwards. The fifth case involved a worker, in a non-routine task, who attempted to jump 2.3 meters (7.5 feet) from a trailer into a pile of corn. This latter case was the only one of the 26 cases where a worker attempted to jump down from an elevated height.

Finally, two cases involved workers with 33 and 38 years experience, respectively, standing on materials that were not in any state to support the weight of the worker. The workers had been preoccupied with their task, and had not realized that the materials they were standing on were unstable.

4. Discussion

The 26 cases in the study group are not meant to be representative for occupational fall incidents, and the relatively few cases do not necessarily allow for generalizations. The focus of this explorative study was to look at the information and resources workers had to deal with in context, and how they were motivated to behave the way they did, given these conditions. Many of the incident (accident) models that have been developed have their roots in complicated interdependent worker-machine-organization environments, for incidents that are infrequently occurring, yet with the potential for extensive and disastrous consequences. Common, everyday incidents, such as falls
from heights, involve relatively simple worker-machine-organization environments, and yet it appears that it is in this simplicity that much of the origin of falls rests. There is often a mistaken impression that no special knowledge or skill is required to use ladders, scaffolds, etc. (e.g., securing them), which is exacerbated by the restricted area on which to move and/or work on (Cohen & Lin, 1991b).

This and other studies (Zimolong, 1985) have shown that there is a mismatch between subjective risk estimates (probability and consequences) and objective risks, with risk estimates often being based on “informal group communication, second hand information and hearsay” (Zimolong, 1985, p. 468). The falls in the current study all occurred from relatively low heights, thus showing that injury incidents occur even in situations perceived as non-hazardous. In all but the five cases involving truck drivers in the current study, workers interacted with colleagues, and, as Case 1 & 2 illustrate, the interaction between the workers can provide a situation where norms and social pressures may occur. Moreover, experience often shows that so-called ‘unsafe’ behavior is rarely ‘punished’ – on the contrary – it is often rewarding, e.g., time, money, social acceptance etc. (Hofman & Stetzer, 1996).

The potential benefits of including an investigative element of a worker’s cognition and behavior in context in a full-scale investigation, is in when considering whether factually or contrafactually identified preventive measures would have been effective for the worker should he/she find himself in a similar situation. All 26 hazards were, in principle, detectable and, ideally, also preventable. In addition to the typical equipment (design/purchase) and organizational remedies, safety measures are often proposed towards influencing human factors such as workers’ skills, rules and knowledge. This is often in a direct form of education and training, or indirectly through diverse information sources (e.g., campaigns). However, in half of the cases in this study, the workers were not usually exposed to fall situations, and elevation fall-prevention training would not likely be a ‘logical’ aspect of their safety education and training. Nor might it be expected that their companies invest in equipment and organizational scenarios for every possible non-routine (one-time) task that, theoretically, might arise. Even if they did, the workers would not necessarily have the skills, rules, knowledge or motivation to think and behave ‘safely’, nor to judge realistically the risks (probability and consequence) involved in various contexts.

It is essential to reinforce the need to always have someone hold a straight or extension ladder while it is being used, or at least until the ladder is safely secured to an object. In applying the lessons of risk compensation theory (Wilde, 2001), users of ladders with slip-resistant feet are probably better off not knowing of this added safety feature, as it should not rule out the need to secure the ladder. The prevention of ladder fall injury incidents is equally relevant in non-occupational settings (Faergemann & Larsen, 2001). Combined with the results in the current study, they point to a need for widespread and early education and training in ladder safety, such as in primary and secondary school programs.

When some workers began multitasking, their information processing and behavior in context became complex, by having to deal simultaneously with perceived conflicting goals, not to mention the complex biomechanical activity involved. Applying combinations of skills (e.g., walking, climbing), rules, knowledge (Rasmussen, 1982) and motivation to unique situations, as in the 13 non-routine tasks, and the five routine tasks involving contextual specific abnormal routines, requires a greater degree of mental energy (e.g., problem solving) through the cognitive processing of knowledge and rules. This is in contrast to routine tasks, which, to a greater degree, rely on established skill-based behavior, which is relatively more difficult to alter (Feyer & Williamson, 1991).

With the exception of the six workers with backgrounds as safety representatives or on safety committees, none of the workers had received further formal safety training after being hired. The workers in the study group that were most embarrassed about their incidents were, in fact, the four workers currently holding positions as safety representatives or on safety committees. Their primarily non-routine tasks resulted in incidents that gave them first hand experience in understanding the complexity of what they perceive as a “simple” incident.
The 26 workers had no shortages of suggestions for what could have prevented the incidents, attributing preventive measures fairly equally among organizational, technical and human factors. In at least seven cases retroactive prevention was taken following the fall incidents by purchasing or building an appropriate new work surface, as well as effectively securing or strengthening the current work surface. In one case, this occurred within minutes of the incident occurring, and in another case, word was quickly sent around to the company’s other shops to cease work immediately with similar work platforms (see Case 1, Figure 1), until an effective solution could be found and implemented.

The method used in this study is intended as a supplement to full-scale investigations. The method could have been even more efficient, minimizing recall bias to an even greater degree, had interviews been initiated at the emergency department either during or immediately after medical attention. This, however, would be even more resource intensive than the current method. Future studies may want to take the current method further in drawing causal inferences using more stringent designs such as the case-crossover design (Maclure, 1991; Maclure & Mittleman, 2000). Although the recall bias in a case-crossover study will play an even greater role than in this study, the design has many advantages that may outweigh the use of a case-reference design.

5. Conclusions

Many of the incident (accident) models that have been developed have their roots in complicated man-machine environments for incidents that occur infrequently, yet have the potential for extensive and disastrous consequences. Common, everyday incidents, such as falls from heights involve relatively simple man-machine environments. Prompt in-depth interviews with victims of incidents can provide an understanding of the interaction between cognitive (including risk assessment), behavioral and motivational aspects of human behavior in context, which is relevant in identifying where effective preventive measures could be targeted, given the dynamics of human variability, workplaces and work tasks. In the future, a more stringent approach such as the case-crossover design could be considered.

6. Impact on industry

The study has identified the benefit of supplementing traditional objective incident investigative interviews with an understanding of the workers mental processes and behaviors during the incident, allowing for evaluating whether preventive measures actually would have been effective in a similar situation.

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