INJURIES ON OFFSHORE OIL AND GAS INSTALLATIONS: AN ANALYSIS OF TEMPORAL AND OCCUPATIONAL FACTORS

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Offshore Technology Report: OTO - 1999 097

A report prepared under HSE-OSD contract: Project number 3516
Date of issue: February 2000

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Injuries on offshore oil and gas installations: An analysis of temporal and occupational factors

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SUMMARY

This report examines injuries on offshore oil and gas installations in relation to temporal and occupational factors. Three databases were analysed. One data set was provided by the HSE Offshore Safety Division, while the two additional data sets were made available from the records of large multi-national oil and gas companies.

The data sets provided information about the nature and severity of injuries incurred by offshore personnel in the UK sector of the North Sea, together with details of temporal aspects of the accident (e.g. clock time, hours-into-shift, days-into-tour), the work area involved, and the body part injured. The HSE data included only three injury severity categories (fatality, serious injury, 3+ day injuries), whereas the company data included additional minor injury categories. Recoding of information was carried out where necessary to produce variables that, as far as possible, corresponded across databases.

The data were analysed to identify temporal and occupational trends in the occurrence of injuries. In carrying out the analyses, it was necessary to take into account that the numbers of personnel exposed varied across times and in different jobs. As no exposure rate data were available, to examine factors such as time-into-tour, day vs. night shifts, and work area, fatalities and severe injuries were analysed in relation to less serious injuries, the latter being taken as a proxy measure of exposure rates.

The main findings from analysis of the HSE database (which were generally consistent with findings from the two company databases) were as follows:

- *Days-into-tour*. For tour durations longer than two weeks, the ratios of fatalities and severe injuries to 3+ day injuries increased markedly, relative to tour durations of one and two weeks. This pattern was evident in each of the three work areas examined, although it was more marked in production/maintenance and construction/ deck work than in drilling (for which the ratio was relatively high during both the first and second weeks).

- *Day vs. night shifts.* The distribution of injury severity differed significantly across day and night shifts, night shifts showing higher rates of fatalities and serious injuries relative to less serious injuries. This effect was independent of days-into-tour.

- *Hours-into-shift.* The total number of injuries reported differed across successive one-hour time periods during 12-hour shifts. Injuries tended to be more frequent during the first half of the shift than the second half; there was also a reduction in frequency in over the mid-shift break (reflecting fewer personnel exposed). For work extending beyond the normal shift duration of 12 hours, the proportion of fatal/severe injuries relative to less serious ones was significantly higher than between 0-12 hours. This pattern was particularly marked in the drilling work area.

- *Clock hours.* The distributions of severe injuries and 3+ day injuries differed significantly across the 24-hour cycle. Severe injuries were relatively more frequent in the time periods 06.00 - 08.00 hours, and 00.00 - 02.00 hours.

- *Injured body part, nature of injury, and incident type.* Injuries to the hand, shoulder or arm were most frequent, and were particularly associated with crush incidents. Legs were the next most frequently affected body part, accounting for a relatively high proportion of strain/sprain injuries. Different types of incidents showed different distributions across work areas; slips/trips/falls were predominant in production/ maintenance work, while ‘use of machinery’ was the major factor in drilling injuries.

The implications of these findings for work schedules on North Sea installations are discussed in relation to other published findings, and the importance of recording additional details of work patterns in accident reports is noted.

CONTENTS

1. INTRODUCTION

In any organizational setting, and particularly in industries carrying out potentially hazardous operations, it is important to identify environmental and job-related characteristics associated with increased risk of accidents and injuries. In this context, shift work (especially if night work is involved) and working hours are two important factors.

In an earlier study (Parkes, Clark, & Payne-Cook, 1997), patterns of alertness were examined in relation to offshore shift rotation schedules and time-into-shift using both objective and subjective measures of alertness. A preliminary investigation of the effects of duration of offshore tour was also carried out (Parkes & Clark, 1997). However, the design of these studies did not allow the impact of night work, time-into-shift, or time-into-tour on accidents and injuries to be investigated. The work reported here seeks to address this issue by analysis of archival data. First, however, relevant material from the literature on accidents and injuries in relation to shift work is briefly reviewed.

1.1 SHIFT-WORK, ACCIDENTS AND INJURIES: RESEARCH APPROACHES

Numerous studies have examined the effects of shift patterns and hours of work on outcomes such as mood, sleep, mental health, physical complaints, and absenteeism (e.g. Frese & Semmer, 1986; Gillberg, 1998; Jaffe, Smolensky & Wun, 1996; Parkes, 1999; Rosa, 1991; Tenkanen, Sjöblom, Kalimo, Alikoski & Härmä, 1997). These studies depend primarily on self-report data, although studies of physiological responses to shift work have also been reported (e.g. Hennig, Kieferdorf, Moritz, & Weise, 1998).

The literature also includes analyses of self-reported accidents and injuries at work in relation to personality, stress, environmental factors, and day work vs. shift work (e.g. Iverson & Erwin, 1997; Parkes, 1999; Sutherland & Cooper, 1991; Savery & Wooden, 1994). Such studies tend to be based on survey data from relatively small samples. Much larger samples are available if national or industry-wide databases of accidents (including those collated by government agencies from formal accident reports) are analysed. The information in such records tends to be more limited than in survey data, but usually includes the time of the incident, the activity involved, and the nature of the injury sustained.

These large data sets provide a valuable basis for research; however, relatively few studies have used formal records of this kind to investigate accidents and injuries in relation to shift patterns and hours of work. The main difficulty in carrying out such research lies in the problem of estimating the size of the exposed working population in relation to factors such as times of day, hours of work, and work activities. Some reported studies have relevant exposure data (e.g. Laundry and Lees, 1991; McNabb, Ratard, Horan, & Farley, 1994; Forbes, 1997), and can thus calculate absolute accident rates directly. Without such exposure rate data, it is not possible to evaluate the risk of an accident occurring during, for instance, day shift hours as compared with night shift hours, as the number of people working at different hours of the day and night varies widely. Two main approaches to overcoming this problem have been reported.

- Survey data from large samples (usually derived from government statistical publications) can be used to derive estimates of numbers of employees working particular hours (e.g. day work or night work) or particular shift durations. These data can then be applied to estimate exposure rates for the particular study population concerned over the time periods involved. One drawback of this approach (noted, for instance, by Hänecke, Tiedemann, Nachreiner and Grzech-Šukalo, 1998) is that different exposure models can lead to widely different estimates of accident risk, as relatively small variations in exposure estimates may give rise to disproportionately large differences in calculated accident rates.

- If no appropriate exposure data are available to correspond to a particular study population, exposure can be estimated by treating the rate of minor injuries as a proxy for the numbers of personnel at work, and using this rate as a basis against which to evaluate the incidence of serious injuries and fatalities at different times of day. The major limitation of this approach is that it is not possible to analyse absolute accident rates, only ratios of fatalities or serious injuries to lesser ones.

As illustrated by the studies reviewed below, each of these approaches to estimating exposure rates in studies of accident risk is represented in the literature on temporal aspects of work (e.g. shift patterns, time-into-shift) in relation to accidents and injuries.

1.2 ACCIDENTS/INJURIES IN RELATION TO TIME OF DAY, TIME-INTO-SHIFT, AND HOURS OF WORK

Offshore work schedules are based on 12-hour shifts as the remote location of most offshore installations, and the limited accommodation, allows only two crews on board at any one time to cover 24-hour operation. Consequently, only data relating to 12-hour shifts are directly applicable to the offshore context. Nonetheless, some findings from studies comparing accident risks for 8-hour and 12-hour shifts are relevant to the present review. For instance, Laundry and Lees (1991) examined accident records of a company operating a continuous production process, comparing the period ten years before and ten years after a change from 8-hour shifts (starting at 08.00, 16.00 and 24.00 hours) to 12-hour shifts (starting at 08.00 and 20.00 hours).

Company employment records were used to establish the total number of employees exposed each year. The analyses included only minor injuries; lost time injuries were too few to be included. Age/sex standardised injury ratios were calculated to examine differences in injury rates across shift systems. Overall, on-the-job injuries decreased with the introduction of 12-hour shifts but, more directly relevant to the present study, two significant peak periods for accidents (apparent in both the 8-hour and the 12-hour shift data) were identified, 08.00 - 10.00 hours and 14.00 - 16.00 hours. For both the 12-hour and the 8-hour shift systems, accidents during night shifts were significantly less frequent than during the day, although neither production rates nor work practices differed across shifts. However, no evidence was found that injury incidence was related to the time-into-shift, or to the time from the end of the shift, for either shift system. In interpreting these results, it is important to note that they relate only to *minor work-related injuries*.

In contrast, Williamson and Feyer (1995) examined times of day in relation to *work-related fatalities* in Australia from 1982-1984. The fatalities examined included 1020 cases for which information about time of day, together with other details of injuries and contextual factors, was available. Rates of exposure were derived from a government statistical survey; the authors emphasise that the resulting estimate of the proportion of fatalities occurring during night work may have been a conservative one.

The results indicated that 25% of fatal injuries occurred to the 11.2% of the employed population estimated to work at night; in contrast, 75% of the fatal injuries were experienced by the 88.8% employed during the day. Thus, work-related fatalities were more than twice as likely at night as during the day. This result conflicts with that reported by Laundry and Lees (1991) who found no increase in accidents during night work; however, this difference may be attributable to the fact that the two studies examined injuries very different in severity (i.e. minor injuries vs. fatalities).

In a more recent and extensive study, Hänecke et al. (1998) analysed 1.2 million accidents in 1994 from German data, all recorded in relation to time of day and hour at work. Two different exposure models were estimated from the available survey data; in general, they showed fairly good agreement. Relative accident risk for any particular time period was calculated as the ratio of 'Accidents in percent x 100 / Working population in percent'. Both percentages were based on relative distributions (i.e. hour of work or time of day). For example, if 5% of the accidents recorded occurred between 06.00 and 07.00 hours (relative to the total over all hours of the day) and 25% of the working population was at work between those hours, the relative accident risk is 20.

For *number of hours of work per day*, the results showed a gradual upward trend in accident risk from 1-5 hours, relatively low rates between 6 and 7 hours, and an exponential increase beyond the 8th or 9th hour at work. In relation to this finding, the authors note that the directive of the European Union which allows extension of daily work hours up to 10 hours cannot be regarded as not increasing the risk of accidents. In the offshore environment 12-hour shifts are the norm; thus, the implications of the findings reported by Hänecke et al. are particularly salient.

For *time of day*, two different exposure models produced rather different profiles of accident risk, one (based on the minimum exposure estimate) showing high relative rates in the early morning (06.00 - 09.00 hours) and mid-afternoon (15.00 - 17.00 hours), while the other (based on the maximum exposure estimate) showing relatively high rates between 10.00 - 15.00 hours. Neither model showed an increase in risk for night work.

The authors also examined accident risk in relation to the interaction between *time of day and hours at work*; the results showed a clear and highly significant interaction, indicating that the risk of having an accident at the *x th* hour of work depended on the starting time of work. These data were used to estimate the relative accident risks for shifts starting at 06.00, 14.00, and 22.00 hours, the traditional starting times for a three-shift system. The results suggested that the exponential increase in accident risk with hour of work was especially apparent for shifts with starting times further displaced from the normal working day, i.e. 14.00 hours and 22.00 hours.

Again, these findings merit particular attention in the offshore environment; on oil and gas installations, 24-hour operation requires a relatively high proportion of personnel to work night shifts, usually starting between 18.00 - 19.00 hours. Furthermore, drillers traditionally change shifts at noon and midnight; thus, in this case, the work period is displaced from the normal work day for both shifts.

A different approach to estimating exposure rates was used by Jeong (1999) in his examination of fatal and non-fatal accidents in Korean manufacturing industry for the years 1991-1994. He analysed fatal accidents in relation to non-fatal ones, rather than attempting to estimate directly the numbers of employees exposed at any particular time. A non-fatal accident was defined according to the formal reporting requirements in Korea, that is, as an accident resulting in more than four days absence from work. During the four-year period, there was a total of 189,259 work-related injuries (of which 2533 were fatal) in a population of 12,950861 employees.

The results showed significantly different distributions of fatal and nonfatal injuries over the different time periods within the 24-hour day. Thus, the night shift (18.00 - 08.00 hours) accounted for 29.5% of the total deaths in contrast to only 17.9% of non-fatal injuries. These results indicate that an injury sustained during night work is more likely (by a factor of 1.65) to be fatal than one sustained during day-shift work. Within the 24-hour work cycle, the highest proportions of injuries occurred between 08.00 and 10.00 hours, i.e. the first two hours of the day shift, but this was true of both fatal (21.0%) and non-fatal injuries (15.1%).

This study did not include any data on hours of work or time-into-shift in relation to accidents, but it did compare fatal and non-fatal accidents in relation to the work activity involved and the type of accident sustained. The distributions of fatal and non-fatal accidents across both activity and type of accident were significantly different, although in each case several common factors were apparent for both fatal and non-fatal injuries.

Thus, working with machinery, materials handling, and maintenance activities, were the leading factors associated with both fatal and non-fatal outcomes. Similarly, ‘caught in or between objects’ was the most common type of accident for both outcomes. The main factor that distinguished fatal and non-fatal injuries was that in both the ‘activity’ and the ‘accident type’ analyses, fatalities were more likely to be ascribed to the ‘other’ category (i.e. not to fall within the six most common categories) than non-fatalities. In particular, 37.4% of the fatal injuries (as compared with 20.3% of the non-fatal injuries) were not classified in terms of any of the six most frequent accident types.

More directly relevant to the present work are two studies of injuries occurring among oil and gas drilling personnel. McNabb et al. (1994) analysed incidents reported to a world-wide association of drilling contractors between 1988 and 1990; of 5251 incidents, 99.4% were non-fatal. Exposure data were available for each job category and each year in the study. Three job categories (floormen, roustabouts, and derrickmen) accounted for 74% of the non-fatal injuries and 64% of fatal injuries, corresponding to rate ratios (compared with all other occupations) of 10.5, 8.5 and 7.0 for non-fatal injuries, and 5.0, 9.4, and 4.0 for fatal injuries. The most frequently injured body part was the upper extremity; these injuries accounted for 31% of the total. However, this study did not provide any information about accidents in relation to shift patterns or time into shift.

Forbes (1997) analysed accidents occurring on the drill floor of offshore installations operated by a major company. For the more recent years in the data, measures of exposure hours (ie. the total number of driller hours worked per year) were available for the shift patterns examined; thus, for these years, it was possible to calculate accident rates relative to actual exposure hours for the two shift schedules. The analyses indicated a relatively high frequency of injuries between 00.00 and 04.00 hours, but this pattern was largely restricted to personnel working the traditional 7 days / 7 nights 'rollover' pattern (with shift changes at 00.00 and 12.00 hours), rather than those working a fixed pattern of 14 days alternating with 14 nights (with shift changes at 06.00 and 18.00 hours).

Forbes' study also provided some information about the relationship between accidents and hours-into-shift among drillers; the results indicated a tendency for injury rates to decrease over the successive 12 hours of the shift, although there was also some evidence of a disproportionately elevated rate in the first hour of the shift. There was no evidence of a marked increase in accidents beyond the 8 or 9 hour at work such as that reported by Hänecke et al. (1995).

In relation to days-into-tour, the data showed that there were more accidents in the first week of the tour than in the second week; there was also some evidence of a sharp increase in accidents on Day 8 (ie. the first day after the shift change) among those working rollover patterns and, less explicably, on Days 5 and 6 for those working fixed shifts.

Against this background, the present study sought to make use of available accident data from the oil and gas industry to identify injury patterns in relation to relevant temporal and occupational factors.

2. AIMS OF THE PRESENT WORK

The present report documents and analyses injuries reported by the offshore oil and gas industry to the Health and Safety Executive as part of the normal monitoring process. In addition, similar analyses are carried out on accident and injury databases provided by two large multi-national oil and gas companies. In the light of the literature reviewed above, there were two main aims of the work reported here.

- First, factors that predict the **frequency and/or severity of injury** are examined, with particular emphasis on the temporal variables, '*days-into-tour'* and *'hours-into-shift'*. In addition, the roles of two other important predictors are evaluated, *day versus night shifts*, and the *type of work* being carried out at the time of the incident.

- Second, factors associated with particular **injury characteristics** are analysed. Thus, the *body part* involved and the *nature of the injury*, are examined in relation to the *work area* in which the incident occurred.

As no 'exposure rate' information was available for several of the predictor factors examined (time-into-tour, day vs. night shifts, and work area), the approach adopted in these instances was to analyse the relative proportions of different categories of injury rather than absolute incidence rates.

3. DATA USED IN THE ANALYSES

The data used in the analyses reported here originated from three different sources. One data set was obtained from the Health and Safety Executive (HSE); the other two data sets were provided by multinational oil and gas companies (designated Company A and Company B) from their own records. The HSE database related to the oil and gas industry as a whole, including the two specific companies that provided data directly. Thus, there is a degree of overlap between the HSE data and those obtained from Companies A and B.

The data sets recorded injuries incurred by personnel working on offshore installations, and a number of details concerned with the circumstances of the incident. However, the three sets of data did not record identical information, either in terms of the nature of information included (for instance, the clock time of accident was present in two of the data bases but was absent in the third), or with respect to the categorisation within a specific factor (for instance, injury severity contained three categories in one data set, and five and seven categories respectively in the two remaining data sets).

Recoding of information was carried out where necessary, in order to produce categorisations which were, as far as possible, similar across databases. Details of the recodings are provided in Section 4 or at the relevant part of the report. Where possible, analyses are reported for all three data sets, but if this is not possible (e.g. when the necessary information was not available in a particular data set), analyses are reported for the relevant data only.

The time periods covered by the three data sets also differed. The HSE data set covered incidents which occurred between January 1990 and July 1998 inclusive. The Company A data set covered the years 1995-98 inclusive. The Company B data set covered the time period between January 1990 and July 1998 inclusive. The sizes of the databases were 3452 cases (HSE), 1090 cases (Company A) and 2961 cases (Company B), but not all cases provided complete data; consequently the numbers that could be included in any particular analysis were smaller these total samples.

4. RECODING OF INJURY SEVERITY, AREA OF WORK, INJURED BODY PART, AND NATURE OF INJURY

4.1 INJURY SEVERITY

The coding of injury severity differed across the three data sets. The categories used by HSE and Companies A and B are shown in Table 4.1. Injuries at the bottom of the table are the least severe, and those at the top are the most severe. Injuries in adjacent categories of the table are of approximately similar severity.

Table 4.1
Categorisation of injury severity by HSE, Company A and Company B respectively

<table>
<tr><th>HSE</th><th>Company A</th><th>Company B</th></tr>
<tr><td>Fatality</td><td>Fatality</td><td>Fatality</td></tr>
<tr><td>Serious injury</td><td rowspan="3">Lost time injury</td><td>Permanent total disability</td></tr>
<tr><td>3+ day injury</td><td>Permanent partial disability</td></tr>
<tr><td rowspan="4">(Dangerous occurrence; Occupational illness)

(End of reporting)</td><td>Lost workday</td></tr>
<tr><td>Restricted work case</td><td>Restricted work case</td></tr>
<tr><td>Medical treatment</td><td>Medical treatment</td></tr>
<tr><td>First aid case</td><td>First aid case</td></tr>
</table>

The range of injury severities recorded in the databases of Companies A and B is greater than that recorded in the HSE database. In addition to information about serious incidents, the individual companies provided data relating to minor injuries, which necessitated medical treatment or first aid, but did not result in lost time. These data are useful because they provide an approximate 'exposure rate' against which the incidence of the more serious injuries can be compared.

The categories used by Companies A and B allowed a comparison to be made between the distribution of incidents across injury severity. The categories 'permanent total disability', 'permanent partial disability' and 'lost workday' were collapsed in the Company B data set in order to produce a single category which mirrored the 'lost time injury' category of Company A; the distributions of injury severity could be compared across the two companies. Table 4.2 shows the distribution of incidences by severity for Companies A and B.

Table 4.2
Distribution of incidences across injury severity (Companies A and B)

COMPANY	INJURY SEVERITY					TOTAL
	Fatality	Lost time injury	Restricted work case	Medical treatment	First aid case	
Company A	0 *0%*	177 *16.4%*	40 *3.7%*	816 *75.4%*	49 *4.5%*	1082 *100%*
Company B	26 *.9%*	830 *28.1%*	436 *14.7%*	808 *27.3%*	857 *29.0%*	2957 *100%*
TOTAL	**26** ***.6%***	**1007** ***24.9%***	**476** ***11.8%***	**1624** ***40.2%***	**906** ***22.4%***	**4039** ***100%***
$\chi^2 = 801.9$, d.f. = 4, $p<0.0005$						

Companies A and B differed in the total number of injuries recorded (consistent with the longer time period involved for Company B), and in the distributions across injury severity ($\chi^2 = 801.9$, d.f. = 4, $p<0.0005$). The data are shown graphically for each company in Figures 4.1 and 4.2. It can be seen that the great majority of injuries in Company A fall into the 'medical treatment' category, whereas those in Company B are more evenly distributed across categories with relatively large proportions falling in the 'lost time' or 'restricted work' categories. The reason for this marked variation in the two distributions is unclear, although differences in recording and coding injury categories may have contributed to the discrepancy.

In the remainder of the analyses presented in this report, injury severity was classified as follows:

HSE: As the number of incidences falling into the 'dangerous occurrence' and 'occupational illness' categories of the HSE data set were extremely low (5 and 34 respectively), these categories were excluded from further analysis, leaving the first three categories only:

1. Fatality
2. Serious injury
3. 3+ day injury

Company A: The injury severity categories used by Company A were collapsed into the following three categories:

1. Fatality; lost time injury
2. Restricted work case
3. Medical treatment only; first aid (not OSHA recordable)

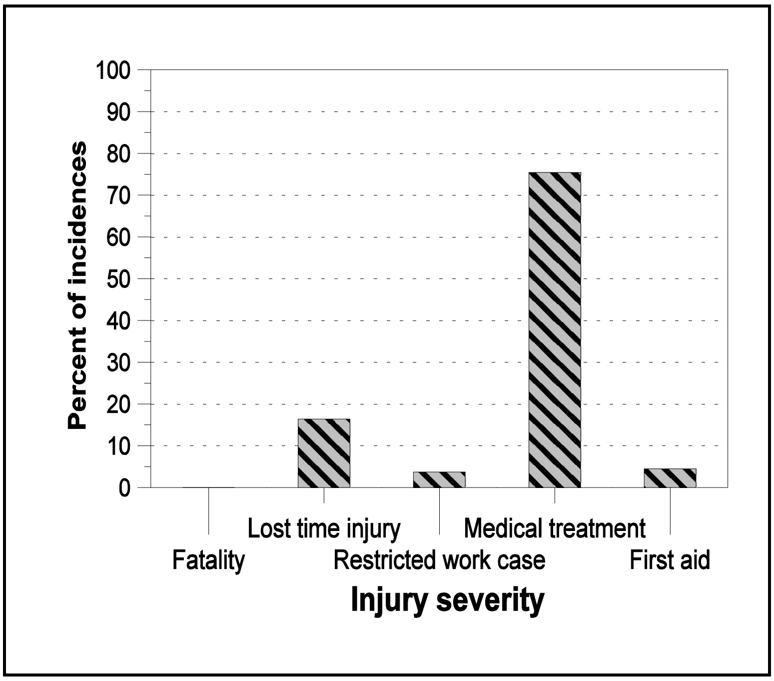


Figure 4.1
Distribution of injury severity (Company A)

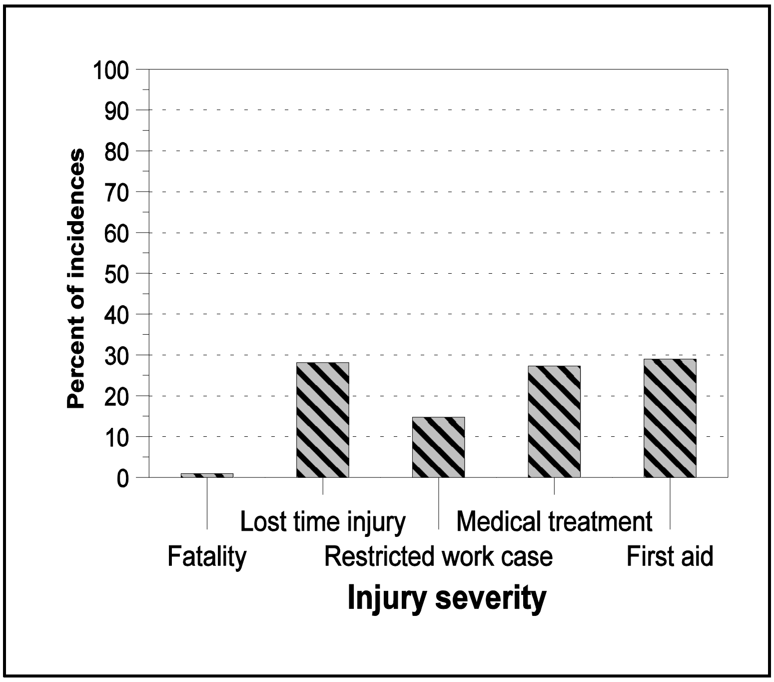


Figure 4.2
Distribution of injury severity (Company B)

Company B: The injury severity categories used by Company B were collapsed into the following three categories:

1. Fatality, permanent total disability, permanent partial disability
2. Lost workday case, restricted work case
3. Medical treatment case, first aid case

4.2 JOB AT INCIDENT

The HSE database provided information about the type of work being carried out by the injured worker at the time of injury. There were ten categories:

1. Production
2. Drilling
3. Maintenance
4. Diving
5. Construction
6. Deck
7. Domestic/Catering
8. Modifications
9. Transport
10. Other

The ten categories were combined into three main *areas of work*, as shown below; the remaining categories were excluded from the present analyses.

1. Production and maintenance
2. Construction, modifications, and deck
3. Drilling

These work areas were chosen to reflect the differing activities carried out by personnel included within each category. Thus, production and maintenance personnel work predominantly within the plant area, while personnel involved in construction, modifications and deck activities frequently work outdoors and are involved in a wider range of tasks.

The work of drilling personnel is generally of a more physically demanding nature than either of the other two job groups; they are also subject to noise, vibration and other physical environment hazards, and might thus be expected to experience injuries of a more serious nature than personnel in other job categories.

Data relating to work area or job type in Companies A and B were not analysed. The number of categories in the Company A data set was insufficient to mirror those of the HSE data, while those in the Company B data were too numerous and specific to allow recoding into the work areas defined for the HSE data.

4.3 INJURED BODY PART

The three databases varied in the specificity with which they recorded the body part injured. For instance, the database of Company B included the following hand/arm-related categories:

1. Arm
2. Hand
3. Shoulder

4. Finger
5. Elbow
6. Hands/finger
7. Shoulder/arm
8. Upper arm
9. Whole arm.

The HSE and Company A databases included only a subset of these types of hand/arm categories. Assuming that a given injury category of the HSE/ Company A data sets would incorporate more than one of the more precise categories of Company B, the general recoding principle used was that an injury was placed in a given category if it involved any of the body parts shown in the following classifications. Six categories of injured body part were created that could be applied to each of the three data sets.

1. Arm, shoulder, hand *(including arm, hand, shoulder, finger, elbow, etc.)*
2. Leg, foot *(including leg, ankle, foot, knee, toe, shin/calf, thigh, etc)*
3. Back
4. Head
5. Eyes
6. Other

4.4 NATURE OF INJURY

The three databases also differed in their categorisation of injuries. In the present work, the following recodings were used to classify the nature of injury.

HSE
1. Crush
2. Break/fracture
3. Sprain/strain
4. Cuts/abrasions
5. Burns (scald, chemical)
6. Amputation
7. Bruise
8. Other

Company A

1. Crush
2. Fractures
3. Sprain
4. Graze/cut
5. Burns (heat/chemical)
6. Amputation
7. Other

Company B

1. Crush/contusion
2. Fractures
3. Open wounds
4. Sprains/strains
5. Superficial
6. Burns (heat/cold/chemical)
7. Amputation
8. Other

The injury categories in each data set are not identical; however, they are sufficiently similar to enable comparisons between the data in most cases.

5. DATA ANALYSES

5.1 DAYS INTO TOUR

All three data sets included the number of elapsed days into the tour at the time the incident occurred. Figures 5.1 - 5.3 show injury severity as a function of days into tour. It is evident from these graphs that the numbers of injuries decrease with increasing tour length. However, this finding does *not* imply that personnel become less likely to have an accident as tour length increases as the number of personnel on board decreases with increasing tour length.

Although the majority of personnel work two-week tours, some spend just one week offshore, and a smaller number work more than two weeks; thus, the numbers of personnel exposed decreases with increasing tour length. As discussed in the Introduction, when no information about exposure rates is available, *relative* frequencies of the various degrees of injury severity, rather than absolute frequencies, must be analysed when examining the effects of 'days-into-tour', and other factors linked to varying exposure rates. Expressed another way, injuries in each category should be analysed in terms of their *relative proportions* of the total number of injuries within any given time period.

In order to ensure the validity of the statistical tests to be carried out on these data, it was necessary to collapse the 'days into tour' variable into a smaller number of categories, thus producing cells which contained sufficiently high expected frequencies for the statistical tests to be used.

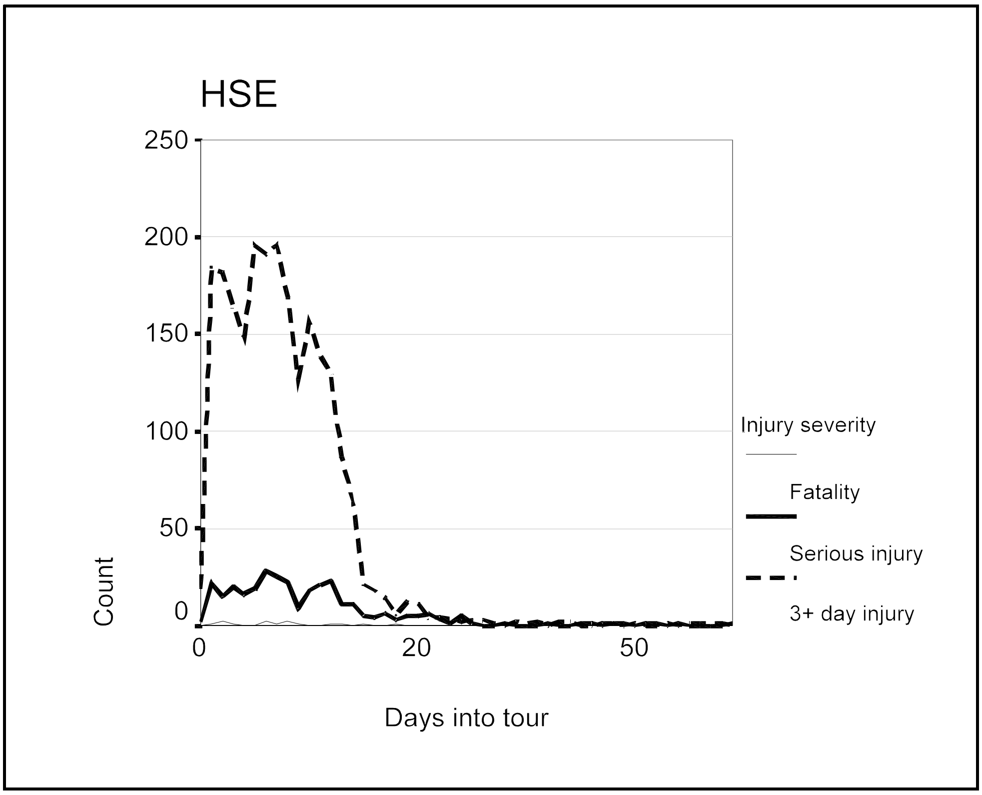


Figure 5.1:
Injury severity as a function of 'days into tour' (HSE)

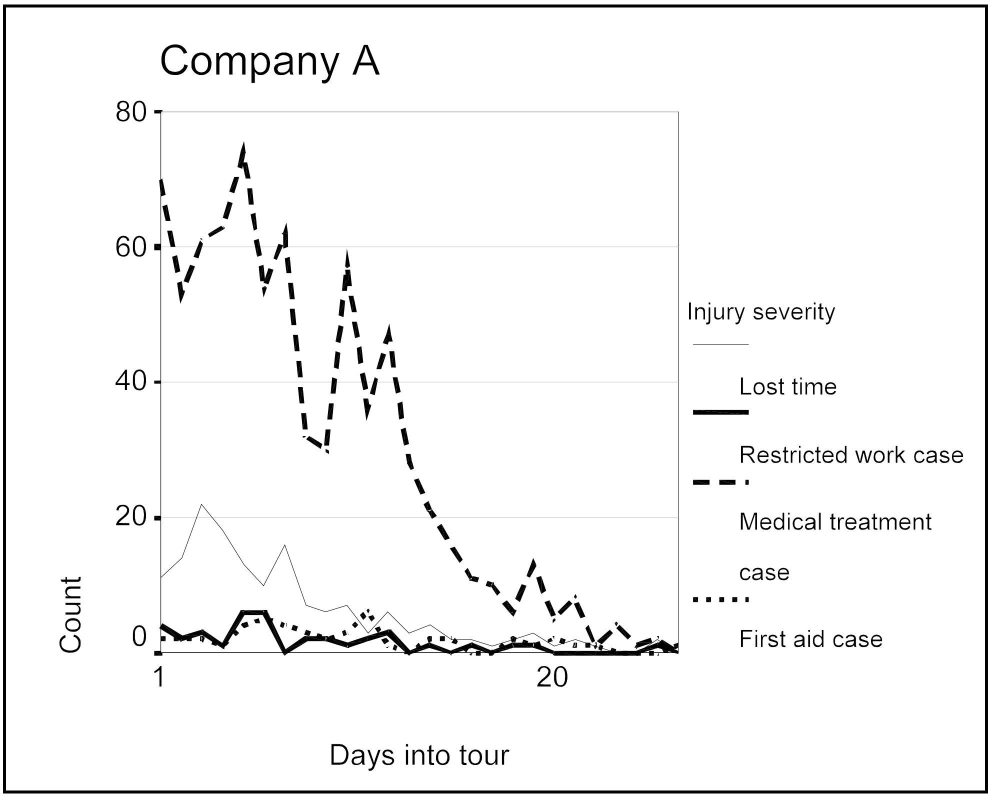


Figure 5.2
Injury severity as a function of 'days into tour' (Company A)

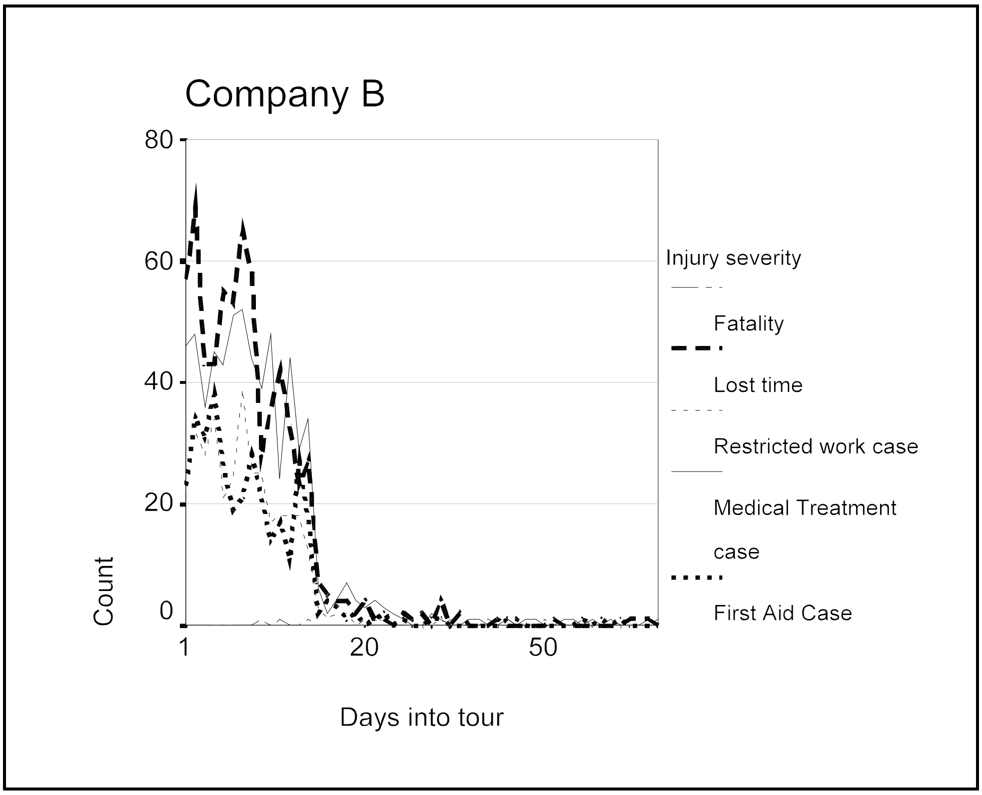


Figure 5.3
Injury severity as a function of 'days into tour' (Company B)

Accordingly, as shown in Table 5.1, the 'days into tour' variable was collapsed into three categories which corresponded to the natural range of tour durations for offshore workers.

Table 5.1
Classification of 'days into tour', and size of database in each category

Range	Total number of injuries		
	HSE data	Company A	Company B
Less than 7 days	1435	583	1097
8 - 14 days	991	315	780
15 or more days	176	107	134
TOTAL	2602	1005	2011

5.1.1 Injury frequency as a function of days into tour

HSE data

Table 5.2 shows the number of incidents falling into each of the three injury severity categories for each of the days-into-tour levels for the HSE data set. The numbers of incidents are also expressed as a percentage of the total within the given time period.

Table 5.2
Injury severity in relation to 'days-into-tour': HSE data

DAYS INTO TOUR	INJURY SEVERITY			**TOTAL**
	Fatality	Serious Injury	3+ Day Injury	
Less than 7	7 *.5%*	147 *10.2%*	1281 *89.3%*	**1435** ***100.0%***
8 - 14	5 .5%	115 11.6%	871 87.9%	**991** ***100.0%***
15 or more	3 *1.7%*	54 *30.7%*	119 *67.6%*	**176** ***100.0%***
TOTAL	**15** ***.6%***	**316** ***12.1%***	**2271** ***87.3%***	**2602** ***100.0%***
$\chi^2 = 66.97$, d.f. = 4, $p<0.0005$				

The significant *chi-square* statistic in Table 5.2 indicates that injury severity is not independent of days-into-tour; thus, the relative proportions of each injury category (as shown in the percentages across rows) do not remain constant across days-into-tour. The percentage of fatalities and serious injuries increased with increasing tour length, while the percentage of 3+ day injuries decreased.

This result indicates that, given the occurrence of an accident, there is an increased risk of serious injury relative to the lesser 3+ day injury with increasing days into tour. It is notable that a steep increase in the percentages of fatalities and serious injuries occurs as the tour length increases beyond two weeks. Indeed, if the 15+ days-into-tour category is removed from analysis, there is no significant difference between the distributions of injury severity in the first and second weeks of the tour ($\chi^2 = 1.13$, d.f. = 2, n.s.).

Figure 5.4 plots the ratio of serious injuries to 3+ day injuries as a function of days into tour. The distribution of these injury categories differed significantly across days into tour ($\chi^2 = 63.43$, d.f. = 2, $p<0.0005$). This figure makes explicit the substantial increase in the ratio of serious injuries to less serious injuries as the tour length increases beyond two weeks. The distribution of the fatalities and 3+ day injuries also differed significantly across days into tour ($\chi^2 = 6.43$, d.f. = 2, $p<0.05$), with an increasing ratio of the former to the latter as days into tour increased. However, this effect was less marked than that shown in Figure 5.4.

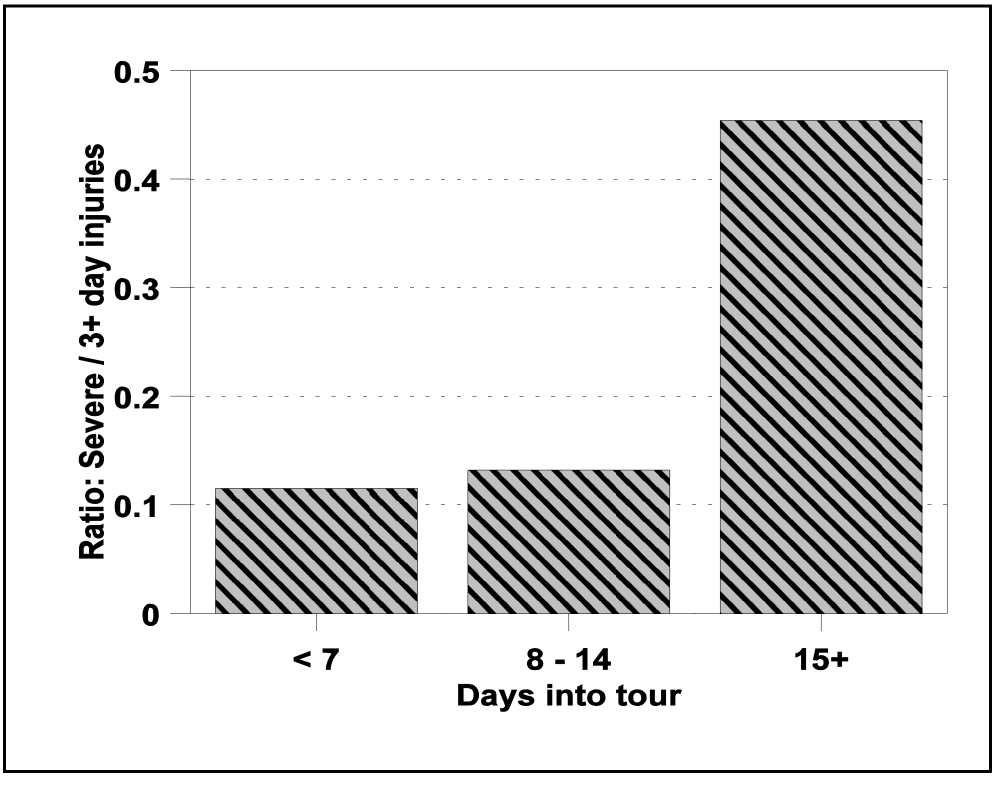


Figure 5.4
Ratio of serious injuries to 3+ day injuries as a function of days into tour for HSE data

Company A data

Table 5.3 shows the Company A data for the number of incidents falling into each of the injury severity categories at each of the days-into-tour levels. Again, incidents are expressed both as frequencies and as percentages of the total number of incidents within each days into tour period. In contrast to the analysis of the HSE data set, the distribution of injury severity (as divided into the three categories shown) did not differ significantly across days into tour.

Table 5.3
Injury severity: Breakdown by days into tour (Company A)

DAYS INTO TOUR	INJURY SEVERITY			TOTAL
	Fatality/ Lost time injury	Restricted work	Medical treatment/ Not OSHA recordable	
< 7	99 *18.4%*	16 *3.0%*	422 *78.6%*	**537** ***100.0%***
8 - 14	56 *13.9%*	16 *4.0%*	330 *82.1%*	**402** ***100.0%***
15+	22 *15.4%*	8 *5.6%*	113 *79.0%*	**143** ***100.0%***
TOTAL	**177** ***16.4%***	**40** ***3.7%***	**865** ***79.9%***	**1082** ***100.0%***
χ^2 = 5.55, d.f. = 4, n.s.				

Company B data

Table 5.4 shows the corresponding results from the analysis of the Company B data. Again, frequencies of incidents are also expressed as percentages of the total number of incidents within each days into tour period. The distribution of injury severity differed significantly across days into tour (χ^2 = 11.50, d.f. = 4, $p<0.05$). The proportions of fatalities/permanent disabilities increased with increasing days into tour. The proportions of lost workdays/restricted work decreased, however, and there was a corresponding increase in the proportion of medical treatment/first aid cases. Again, no significant difference was found between the distributions of injury severity when the first week offshore was compared with the second week (χ^2 = 4.39, d.f. = 2, n.s.). The significant adverse effect of tour length on fatalities/serious injuries was apparent only for the longest 'days-into-tour' duration (15+ days).

Table 5.4
Injury severity: Breakdown by days into tour (Company B)

DAYS INTO TOUR	INJURY SEVERITY			TOTAL
	Fatality/ Permanent Disability	Lost workday/ Restricted Work	Medical treatment/ First aid	
< 7	8 *.7%*	576 *52.5%*	513 *46.8%*	**1097** ***100.0%***
8 - 14	9 *1.2%*	374 *47.9%*	397 *50.9%*	**780** ***100.0%***
15+	4 *3.0%*	58 *43.3%*	72 *53.7%*	**134** ***100.0%***
TOTAL	**21** ***1.0%***	**1008** ***50.1%***	**982** ***48.8%***	**2011** ***100.0%***
$\chi^2 = 11.50$, d.f. = 4, $p<.05$				

The fact that the proportion of injuries in the most severe category increased with increasing tour length is consistent with the trends in the HSE data set. However, the percentages of lost workday/restricted work, and medical/first aid treatment, respectively decreased and increased with increasing tour length. These results, taken in conjunction with the HSE data, suggest that it is only the conditional probabilities of the most *severe* injuries that increase with increasing tour length.

However, as shown in Table 1.1, injury categories do not match exactly across data sets; thus, the 'serious injury' category of the HSE data set corresponds to the 'permanent total/partial disability' category of the Company B data set, while the HSE '3+ day injury' category corresponds to a subset of the Company B 'lost workday' category. If analysis is restricted to the 'fatalities', 'permanent disabilities' and 'lost workday' categories of Company B, then the pattern largely mirrors that of the HSE data set. That is, the percentages of fatalities and permanent disabilities increases with increasing tour length, while the percentage of lost workdays decreases. This finding must, however, be treated with caution because of the low frequencies of these injury categories in the Company B data.

Also consistent with the HSE data, the present analysis suggests that the risk of serious injury increases sharply if the length of tour extends beyond two weeks. The differences in the injury severity classification of the HSE, Company A and Company B databases preclude a direct comparison of these data. As noted above, however, these differences imply that the similar trends observed in the first and third data sets are complementary and thus strengthen the evidence suggesting that the probability of experiencing an injury of a more serious nature (given the occurrence of an injury) increases with increasing time into tour.

5.1.2 Injury severity in relation to days into tour and work area

The HSE data set identified the type of work being carried out at the time of the incident (corresponding information was not available for Companies A and B). As described in Section 4.2, in the HSE data set, three main work areas were identified for analysis: (I) *Production / maintenance;* (i) *Construction / modifications / deck*; (iii) *Drilling*. As numbers of fatalities were relatively small, data from this category were combined with those from the 'serious injury' category to ensure that the expected frequencies were sufficiently high to allow valid statistical tests.

Preliminary analyses showed that these three work areas differed significantly in the proportions of fatal/serious injuries relative to 3+ day injuries. Thus, 17.6% of injuries to drillers were in the fatal/serious injury category, as compared with 14% for construction / modification /deck work, and 8.4% production / maintenance work. The data are shown in Table A-1 (Appendix) together with a detailed breakdown by injury severity and time into tour.

Figure 5.5 shows the distribution of injury severity across days into tour for each of the three work areas. To determine whether the distribution of injury severity differed significantly over days into tour for the three work categories, separate analyses were carried out. The results were significant for the production / maintenance area of work ($\chi^2 = 32.05$, d.f. = 2, $p<0.0005$) and for construction /modifications /deck work ($\chi^2 = 20.68$, d.f. = 2, $p<0.0005$), but not for drilling ($\chi^2 = 4.12$, d.f. = 2, n.s.) although, as shown in Table A-1 (Appendix), the trend was in a similar direction.

Figure 5.6 shows the ratios of fatalities/serious injuries to 3+ day injuries as a function of days into tour for each of the three work areas. The sharp increase in this ratio for tour lengths of 14+ days is evident for the job categories of production /maintenance and construction /modification /deck. The increase is less marked for the drilling category, but the ratio for drilling is higher than the those of the other two job categories during the first two weeks, indicating the more dangerous nature of this work. Indeed, for work in the drilling area, the trend is a near-linear increase across the three levels of the days-into-tour variable (≤ 7 days, 8-14 days, and 15+ days). In interpreting these findings, it is important to note that the actual numbers of incidences occurring 15+ days into tour is small relative to the numbers in the ≤ 7 days and 8-14 days categories, reflecting the fact that relatively few personnel work tours of duration more than two weeks.

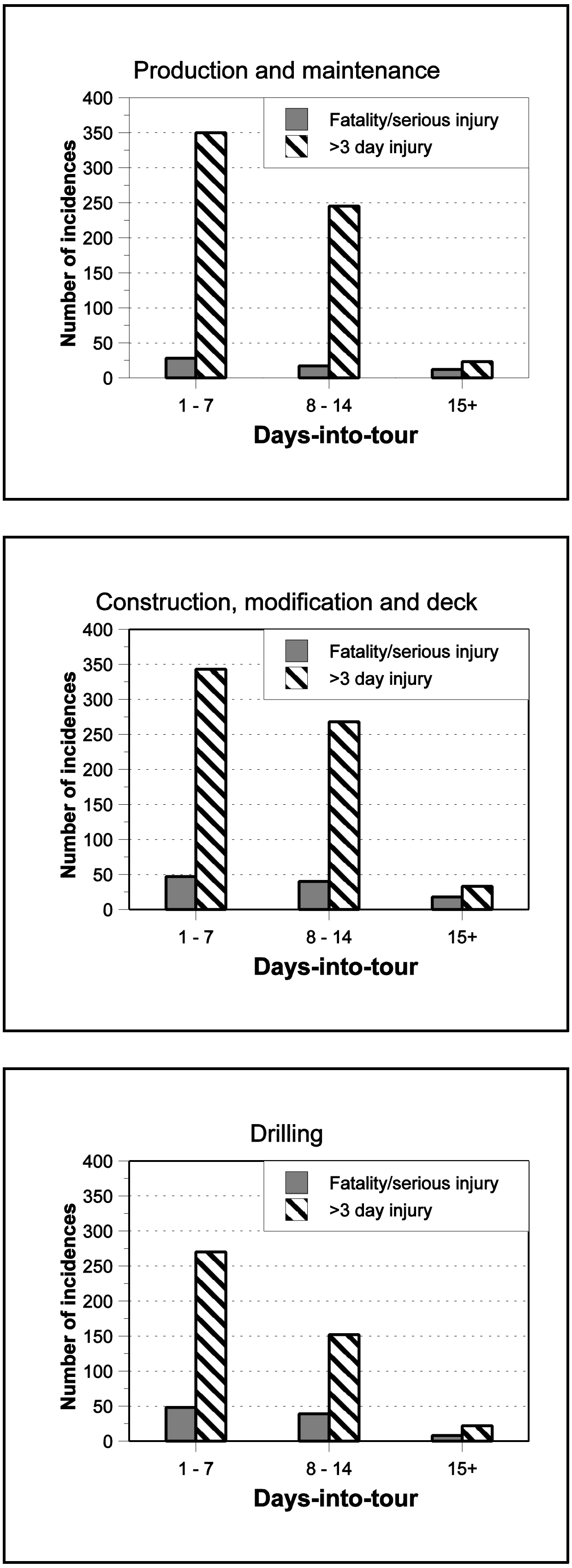


Figure 5.5
Distribution of injury severity across days into tour for the three areas of work

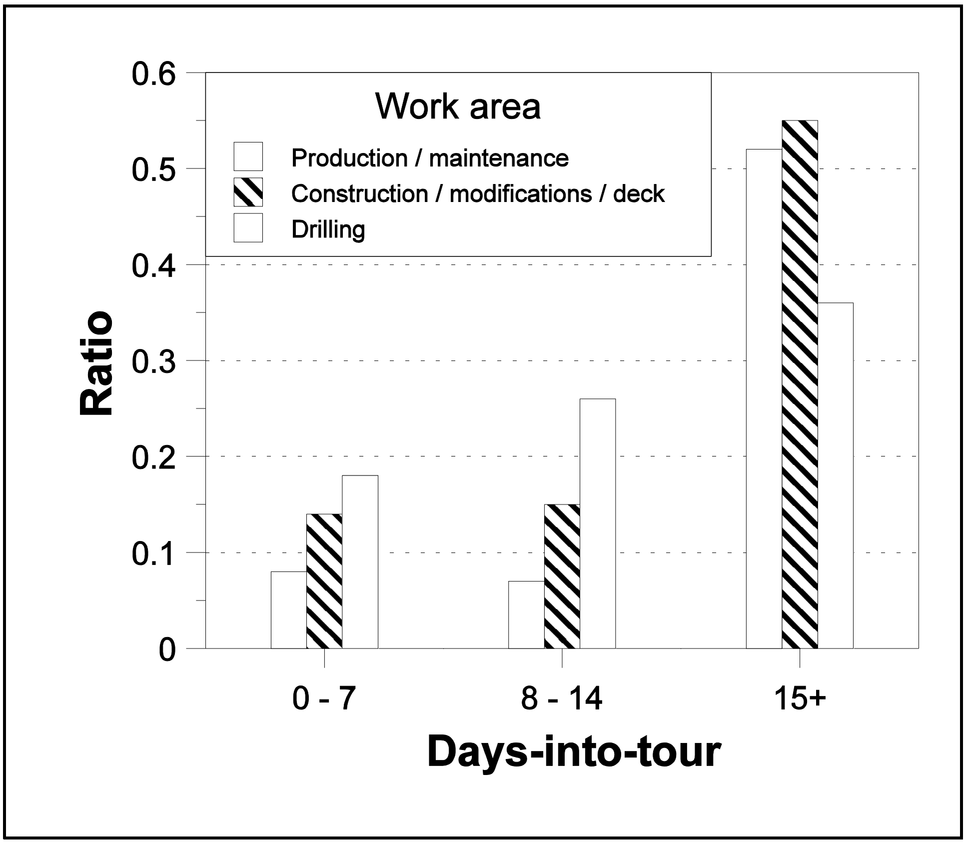


Figure 5.6
Ratio of fatalities/serious injuries to 3+ day injuries as a function of days into tour, for the three areas of work

5.1.3 Injury severity as a function of shift

Figures 5.7 and 5.8 show the distribution of injury severity across day and night shifts, for the HSE and Company B data respectively. Shift information was unavailable for Company A. The numerical data are given in Tables A-2 and A-3 (Appendix).

It is evident from Figures 5.7 and 5.8 that the total number of incidents is greater during the day shift than during the night shift. However, this finding primarily reflects the larger number of personnel on duty during the day shift. The main point of interest in these graphs is the *relative proportions of each injury severity within each shift.*

The distribution of injury severity differed significantly across shift in both the HSE data ($\chi^2 = 25.13$, d.f. = 2, $p<0.0005$) and Company B data ($\chi^2 = 19.77$, d.f. = 2, $p<0.0005$). In the HSE data, fatalities accounted for 2.8% of the total number of injuries which occurred during the day shift, as compared with 3.9% of those which occurred during the night shift. Similarly, serious injuries accounted for 24.7% of the total number of injuries experienced during the day shift, as compared with 31.7% of those experienced during the night shift. Conversely, the percentages of 3+ day injuries were lower for the night shift than the day shift.

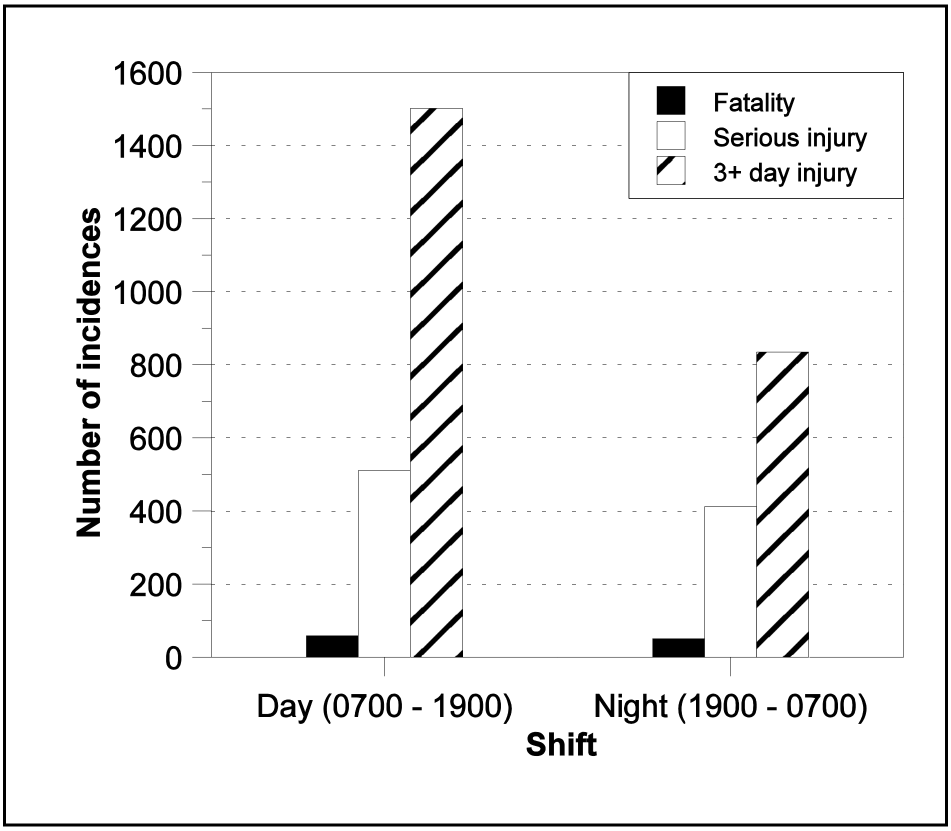


Figure 5.7:
Distribution of injury severity across shift (HSE)

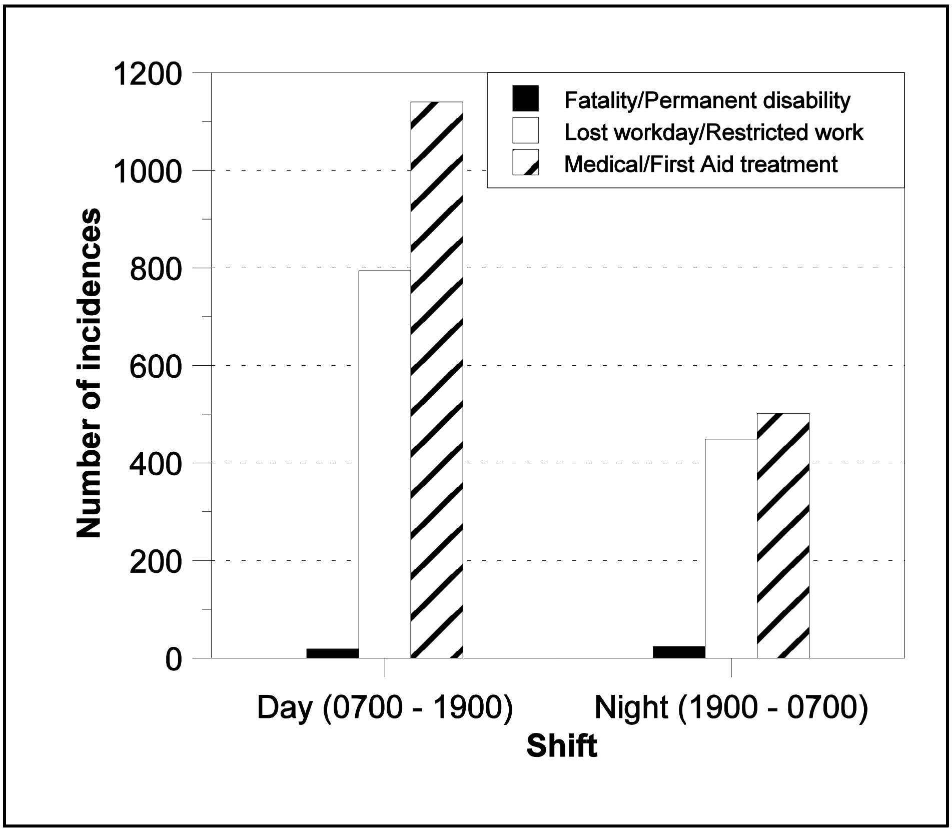


Figure 5.8:
Distribution of injury severity across shift (Company B)

The Company B data show the same trend: fatalities and permanent disabilities accounted for a higher percentage of the total number of injuries experienced during the night shift (2.5%) than during the day shift (1.0%). Similarly, injuries resulting in lost workdays/restricted work account for a greater percentage of the night-shift injuries (46.1%) than day-shift injuries (40.7%). Correspondingly, the percentage of medical treatment/first aid cases is lower for the night shift (51.5%) than for the day shift (58.4%).

Again, as the injury severity categories of HSE and Company B are not identical, direct comparisons cannot be drawn between the two data sets. However, as noted in Section 5.1, the information available in the two data sets is complementary and thus provides strong evidence to suggest that injury severity is greater during the night shift than the day shift.

5.1.4 Injury severity as a function of days into tour and shift

In the HSE data set, the distribution of incidences across injury severity differed significantly over days into tour, both for injuries which occurred during the day shift (χ^2 = 41.75, d.f. = 4, p<0.0005) and for those which occurred during the night shift (χ^2 = 25.25, d.f. = 2, p<0.0005). For both the day-shift and night-shift injuries, the percentages of fatalities and serious injuries increased with increasing tour length, with corresponding decreases in the percentage of 3+ day injuries. Tables A-4 and A-5 (Appendix) show the distribution of injury severity across shift and days into tour for the HSE data and the Company B data respectively.

The similarity of the patterns observed in the day shift and night shift data suggests that the increased likelihood of a worker incurring a serious injury (given the occurrence of an accident) with increasing days-into-tour is independent of whether the data relate to day shifts or night shifts. However, this does not of course mean that the risk of serious injury is the same for both shifts at any given time-into-tour; the analysis in Section 5.1.3 showed that the number of serious/fatal injuries, expressed as a proportion of the total number of injuries incurred during the night shift, was significantly greater than the corresponding proportion of the day shift injuries.

This result is shown in Figure 5.9, which plots the ratio of fatalities/serious injuries to 3+ day injuries across days into tour, for day and night shifts respectively. In addition to the observed increase in this ratio with increasing days into tour, it is evident that during any time period the ratio is higher for night shifts than for day shifts.

The pattern of results for Company B contrasted with those reported above. The distribution of incidences across injury severity differed significantly over days into tour, both for day shift injuries (χ^2 = 16.66, d.f. = 4, p<0.01) and for night shift injuries (χ^2 = 12.56, d.f. = 4, p<0.05). However, inspection of Table A-5 (Appendix) reveals that, although the percentages of fatalities/permanent disabilities for night-shift injuries are greater during the second week of the tour than during the first week, they decrease again for tour lengths of 15 days or more. Furthermore, the percentages of lost workdays/restricted work cases decrease with increasing tour length, for both night shift and day shift injuries.

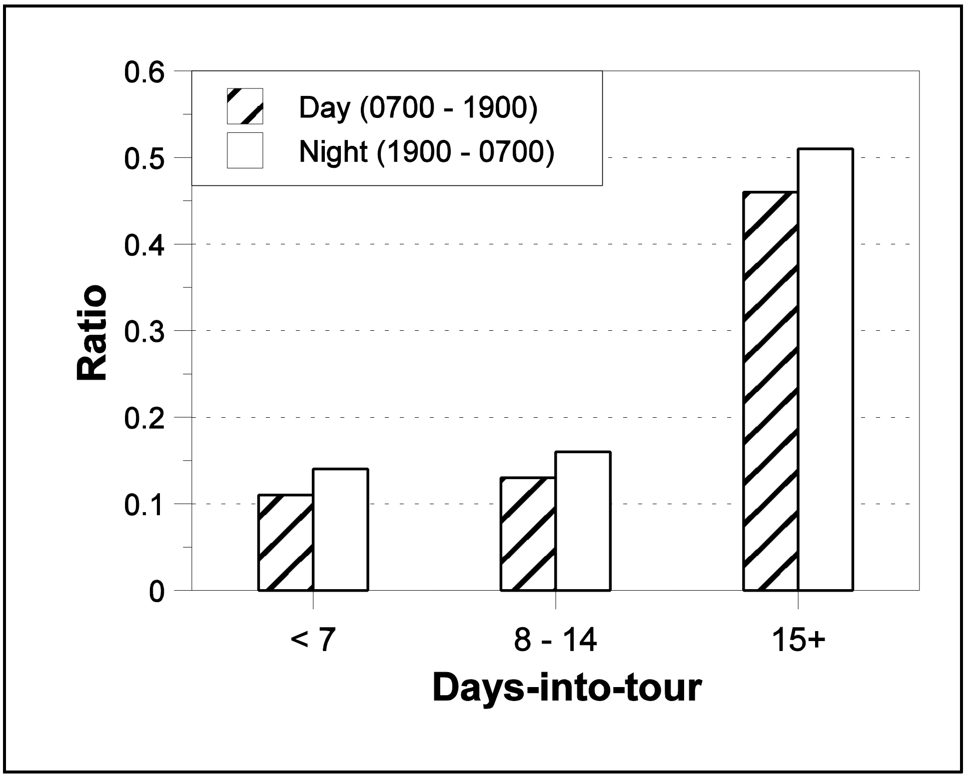
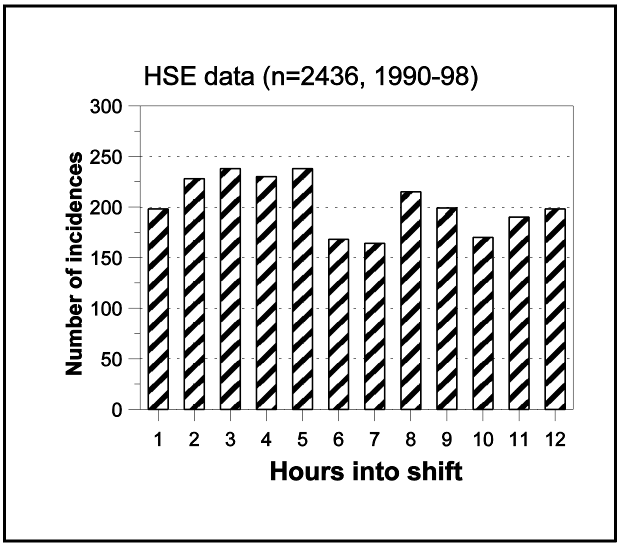


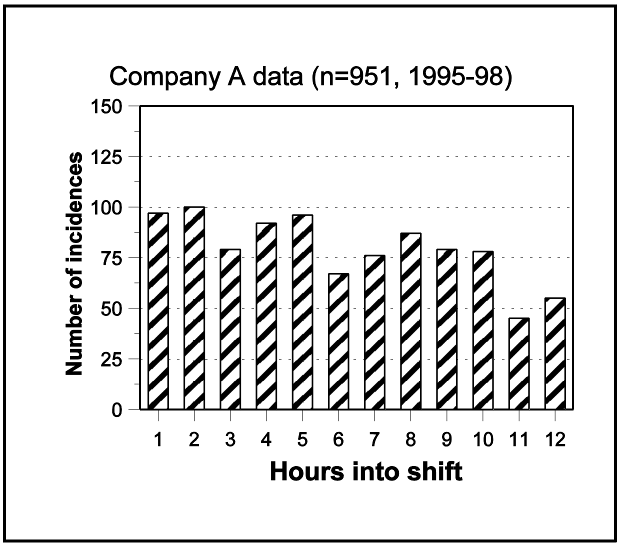
Figure 5.9
Ratio of fatalities/serious injuries to 3+ day injuries as a function of days into tour, for night-shift and day-shift injuries (HSE)

5.2 HOURS INTO SHIFT

The data sets included information about the number of hours into shift at which the injury occurred, divided into hourly intervals. Over the standard 12-hour shift, it could be assumed that exposure rates did not differ across the 12 hours (except at the meal break, see below); however, this exposure base could not be assumed for longer time-into-shift values as relatively few personnel worked for periods in excess of 12 hours. The initial analyses therefore excluded shift durations of more than 12 hours.

For each of the data sets, it was found that the total number of incidences differed significantly across the 12 one-hour intervals of a normal shift (HSE: χ^2 = 39.5, d.f. = 11, p<0.001; Company A: χ^2 = 40.0, d.f. = 11, p<0.001; Company B: χ^2 = 140.9, d.f. = 11, p<.001). It can be seen from Figure 5.10 that, in each case, the number of incidences falls over the mid-shift break (when fewer personnel are at work) as compared with the first half of the shift. Also, in each case, incidences tend to be more frequent during the first half of the shift than during the second half of the shift. This pattern was particularly marked in the Company B data; in the Company A data the reduction in injury frequency was primarily apparent in the last two hours of the 12-hour shift.





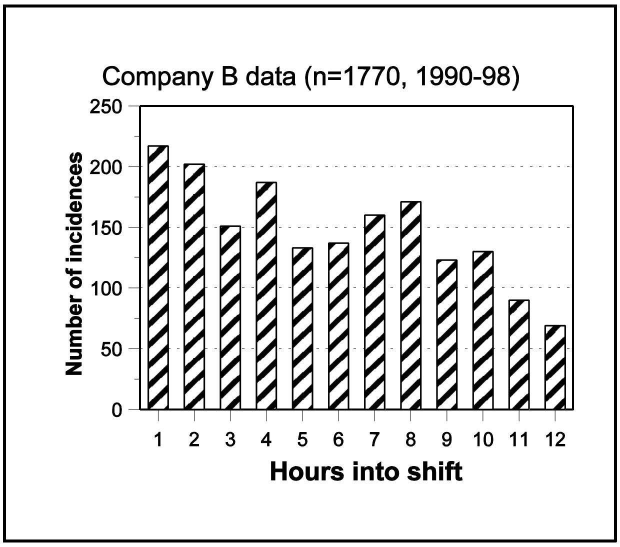


Figure 5.10
Distribution of incidences across hours into shift for HSE, and Companies A and B

Hours-into-shift by *day vs. night shifts*. The analyses of hours-into-shift shown above did not distinguish between day shifts and night shifts. The HSE data were further examined to determine whether day (07.00 - 19.00 hours) and night shifts (19.00 - 07.00 hours) differed significantly in the pattern of injuries over time-into-shift (shifts with midday/midnight changeovers were excluded from this analysis). The difference in the distributions fell short of significance when one-hour time intervals were examined. However, when the hours-into-shift measure was divided into two levels (0 - 6 hours, and 6 - 12 hours), the results showed a significant difference between day and night shifts in the relative numbers of incidences in these two time periods ($\chi^2 = 5.92$, d.f. = 1, $p<0.015$).

Consistent with the greater number of personnel on duty during the day, overall, there were more incidences during day shifts than during night shifts; as noted above, there were also fewer incidences in the second half of the shift than in the first half. However, this further analysis showed that the difference in frequencies from the first half of the shift to the second half was less for day shifts than for night shifts (see Figure 5.11). Thus, for night shifts, the second 6 hours had a lower incidence of injuries relative to the first 6 hours than would be expected from the relative levels during day shifts.

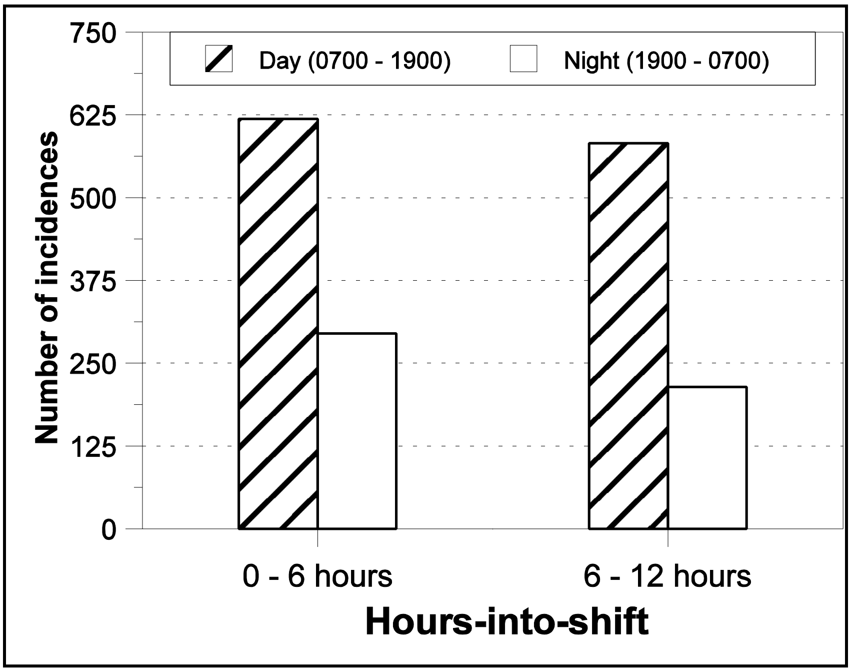


Figure 5.11
Number of incidences during first half and second half of 12-hour shifts for day and night shifts (HSE data)

5.2.1 Injury severity as a function of hours-into-shift

12 hour shifts. Tables A-6 to A-8 (Appendix) show the number of incidences falling into each injury severity category for each one-hour interval over the 12-hour shift for the HSE data set and for Companies A and B respectively. The distribution of injury severity over hours-into-shift was not significant for any of the three data sets, indicating that injury severity was independent of hours-into-shift over standard shift durations of 12 hours.

Shift durations in excess of 12 hours. In addition to the analyses reported above, information was also available about injuries occurring when shifts of more than 12 hours duration were worked. A comparison of injury severity during the first 12 hours of a shift, and injury severity during longer shift durations was carried out. In interpreting the findings, it should be noted that personnel working longer than 12 hours were more likely to be specialists (e.g. wire-liners), managers, or others for whom only day shifts are scheduled, rather than those working rotating shifts (e.g. drillers, or production personnel), who usually work for a fixed 12-hour period, before being replaced by the 'back-to-back' crew.

The distribution of injury severity differed significantly for incidences in the first 12 hours of the shift as compared with longer durations for the HSE data set (χ^2 = 14.77, d.f. = 2, p<0.01) but not in the data for Companies A and B (χ^2 = 1.25, d.f. = 2, n.s.; χ^2 = 2.72, d.f. = 2, n.s.).

Table 5.5
Distribution of injury severity over hours into shift (HSE)

HOURS INTO SHIFT	INJURY SEVERITY			TOTAL
	Fatality	Serious injury	3+ day injury	
0 - 12	12 *.5%*	297 *12.3%*	2112 *87.2%*	**2421** ***100.0%***
12+	3 *3.8%*	12 *15.2%*	64 *81.0%*	**79** ***100.0%***
TOTAL	**15** **.6%**	**309** ***12.4%***	**2176** ***87.0%***	**2500** ***100.0%***
χ^2 = 14.77, d.f. = 2, p<0.01				

The analyses presented at the start of this section indicated that, up to a shift duration of 12 hours, injury severity was independent of time-into-shift. However, in the HSE data set (as shown in Table 5.5 and Figure 5.12), when shift duration extended beyond 12 hours, more severe injuries were disproportionately frequent. However, it should be noted that this finding was based on the relatively small number of incidences occurring at time-into-shift levels greater than 12 hours.

Figure 5.12
Distribution of injury severity over hours into shift (HSE)

5.2.2 Injury severity in relation to hours-into-shift and work area

Table 5.6 shows a breakdown of work area, injury severity, and hours into shift (categorised as ≤ 12 hours vs. 12+ hours) for the HSE data set (corresponding data from the two individual companies were unavailable). To determine whether the distribution of injury severity differed significantly for shift durations of up to 12 hours as compared with those of more than 12 hours for each job category, three separate *chi-square* tests were carried out. As the numbers of fatalities were relatively low, this severity category was combined with the serious injury category for these analyses. The resulting severity categories were therefore 'fatalities and serious injuries' and '3+ day injuries'.

Injury severity did not differ significantly over hours into shift for the production/maintenance work area ($\chi^2 = 0.92$, d.f. = 1, n.s.), or for the construction /modifications /deck area ($\chi^2 = 1.67$, d.f. = 1, n.s.). However, injury severity did differ significantly over hours-into-shift for drilling ($\chi^2 = 4.45$, d.f. = 1, $p<0.05$), suggesting that personnel in this particular area of work are at increased risk of serious injury if their shift extends beyond 12 hours. Figure 5.13 shows the distribution of injury severity over hours into shift for drilling personnel.

Table 5.6
Distribution of injury severity across hours into shift and job at time of incident

JOB AT TIME OF INCIDENT	INJURY SEVERITY	HOURS INTO SHIFT		
		0 - 12	12+	TOTAL
Production Maintenance	Fatality	1 .2%	2 6.7%	3 .4%
	Serious injury	52.0 8.2%	2 6.7%	54 8.1%
	>3 day injury	584 91.7%	26 86.7%	610 91.5%
	TOTAL	637 100.0%	30 100.0%	667 100.0%
Construction Modification Deck	Fatality	5.00 .7%	0% 0%	5 .7%
	Serious injury	91.0 12.8%	6 22.2%	97 13.1%
	>3 day injury	616 86.5%	21 77.8%	637 86.2%
	TOTAL	712 100.0%	27 100.0%	739 100.0%
Drilling	Fatality	3 .6%	1 11.1%	4 .7%
	Serious injury	88.0 16.8%	3 33.3%	91 17.0%
	>3 day injury	434 82.7%	5 55.6%	439 82.2%
	TOTAL	525 100.0%	9 100.0%	534 100.0%

Figure 5.13
Distribution of injury severity across hours into shift for drilling personnel

5.3 INJURY SEVERITY AS A FUNCTION OF CLOCK HOURS

Figure 5.14 shows the distribution of injury severity over clock hours (split into two-hour blocks) for the HSE data. Only serious injuries and 3+ day injuries were included in this analysis as the numbers of fatalities were too low for analysis in relation to clock hours. Both serious and 3+ day injuries were more frequent in daytime hours, reflecting the higher number of personnel working day shifts as compared with night shifts. However, the distributions of injuries in the two categories differed significantly over clock hours ($\chi^2 = 16.65$, d.f. = 11, $p<0.02$).

Overall, serious injuries made up approximately 26.5% of the total, 3+ day injuries accounting for the remaining incidences, but there was significant variation across successive two-hour time periods. In particular, serious injuries were relatively more frequent in the time periods 06.00 - 08.00 hours (the morning shift handover period for personnel working shift patterns with a morning/evening shift change), and 00.00 - 02.00 hours (the midnight handover period for personnel working shift patterns with a midnight/midday shift change). During these periods the proportions of serious injuries were 39.2% and 35.5% respectively.

No clock time information was available for Company A, but a similar analysis was carried out for the Company B data. In this analysis, injury severity was divided into three categories (fatalities and permanent total/partial disability;

lost workday/ restricted work; and medical treatment/first aid). The overall pattern was similar to that shown in Figure 5.14; thus, injuries were more frequent during dayshift hours, except for the reduced frequency during the mid-shift meal break. The distributions of injuries severities differed over the 12 two-hour periods of the day (χ^2 =67.00, d.f. = 22, p<0.0001), but the significance of this effect was due to the distribution of the relatively small proportion (1.5% of the total) of injuries in the most severe category. The two categories of less severe injuries did not show significantly different distributions over the 24 hour day.

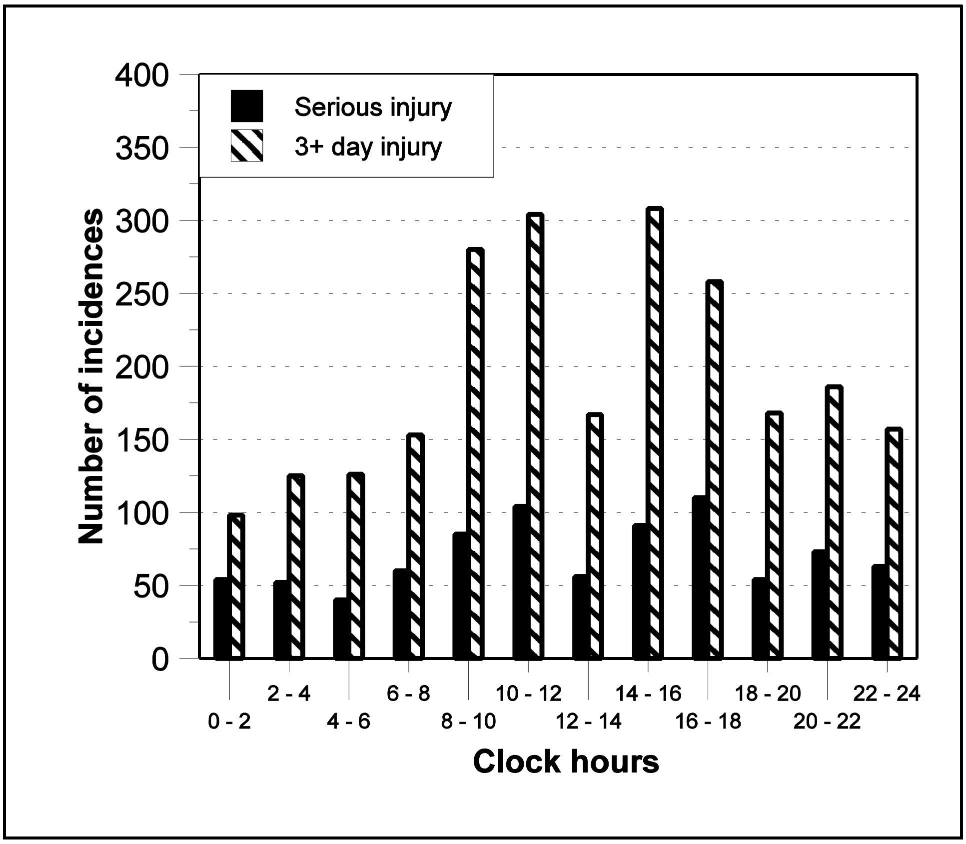


Figure 5.14
Distribution of injury severity (serious injury and 3+ day injury only) over clock hours (HSE data)

5.4 DISTRIBUTION OF INJURIES ACROSS BODY PART

The distribution of injuries across body part was examined in the HSE data set and in those for Companies A and B. As shown in Figures 5.15, the patterns of data for injuries to arm (including hand and shoulder), leg (including foot), back, head, and eye, were similar in each case, although the proportion of injuries assigned to the ‘other’ category varied across the data sets. The most frequently injured body parts were those assigned to the ‘arm, shoulder, and hand’ category (accounting for 32%, 38.6% and 31.4% of the total injuries in the HSE, Company A and Company B data sets respectively).

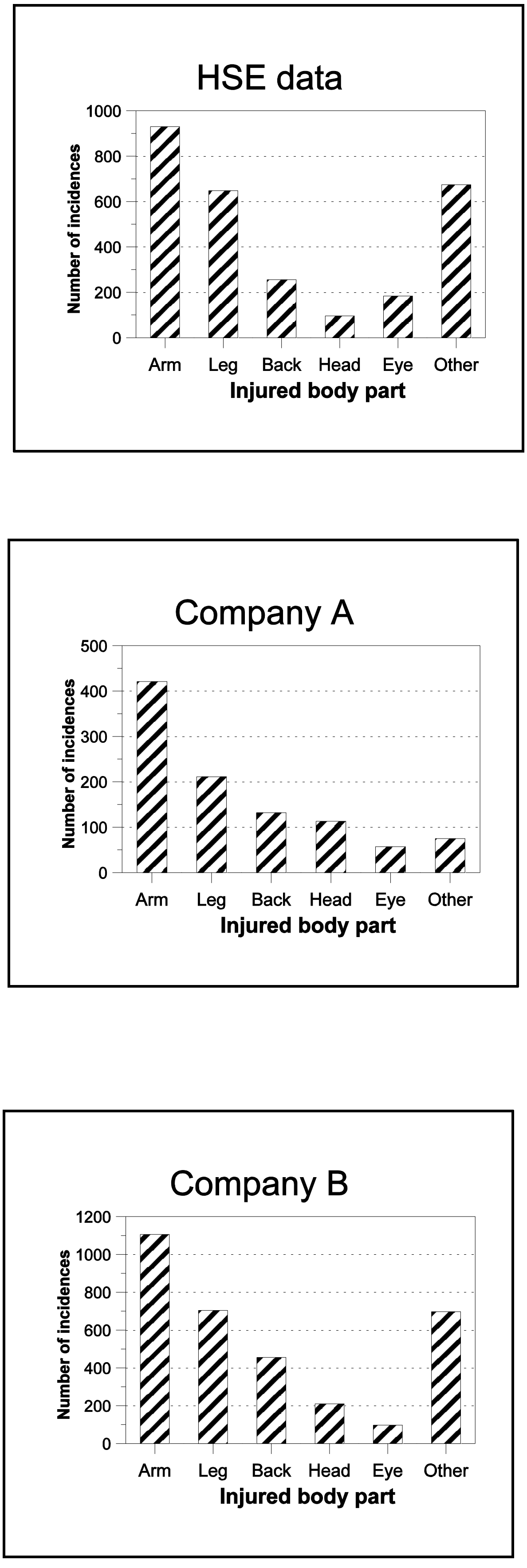


Figure 5.15
Distribution of injuries across body part

5.5 NATURE OF INJURY

5.5.1 Nature of injury as a function of injured body part

Nature of injury was classified into major categories of crush, break/fracture, sprain, cuts/abrasions, burns (including both heat and chemical), and bruises. In each data set, it was found that the relative frequencies with which different body parts were injured differed significantly for different types of injury ($\chi^2 = 1632.37$, d.f. = 35, $p<0.0005$; $\chi^2 = 501.29$, d.f. = 30, $p<0.0005$; $\chi^2 = 1480.63$, d.f. = 35, $p<0.0005$). Table A-9 (Appendix) shows a detailed breakdown of injury type by injured body part for the HSE data.

Injuries to the hand, shoulder or arm accounted for 65.3%, 70.9% and 37.5% of the total number of crush injuries in the data for HSE, Company A and Company B respectively. In contrast, the majority of the strain/sprain injuries involved the leg or foot (25.3%, 40.5% and 45.2%, in the data for HSE, Company A and Company B respectively), and the back (43.7%, 38.6% and 32.5% respectively).

5.5.2 Nature of injury in relation to work area

The distribution of nature of injury also differed significantly across different work areas in each data set (HSE data, $\chi^2 = 182.55$, d.f. =14, $p<0.001$). In particular, crush injuries predominantly occurred in the work areas construction/ deck/modification and drilling, while burns were largely associated with production/maintenance work. Bruises were more equally distributed between the three work areas. The data are shown graphically in Figure 5.16.

5.6 INCIDENT TYPE

5.6.1 Incident type in relation to work area

The HSE data also included information about incident type. The main categories of incident relevant to the present work were: loss of containment, fire/ explosion, electrical, falling objects, slips/trips/falls, handling materials, lifting/ crane operations, use of hand tools, use of machinery, and exposure to harmful substances. These incident types were distributed significantly differently across the three work areas ($\chi^2 = 314.05$ d.f. =18, $p<0.001$).

Full details of the distribution of incident types in relation to work area are given in Table A-10 (Appendix). For the four most frequent types of incidents (slips/trips/falls; handling goods/materials; use of machinery; and lifting/crane operations), the data are also shown graphically (Figure 5.17). It can be seen that in the category 'slips/trips/falls', 41.0% of the injuries occur in production/ maintenance work, but only 23.2% in drilling. Conversely, in the category 'use of machinery', 61.7% of the injuries occurred in the drilling area, while only 16.2% of injuries were associated with construction/modification/deck operations, and 22.1% with production/maintenance activities.

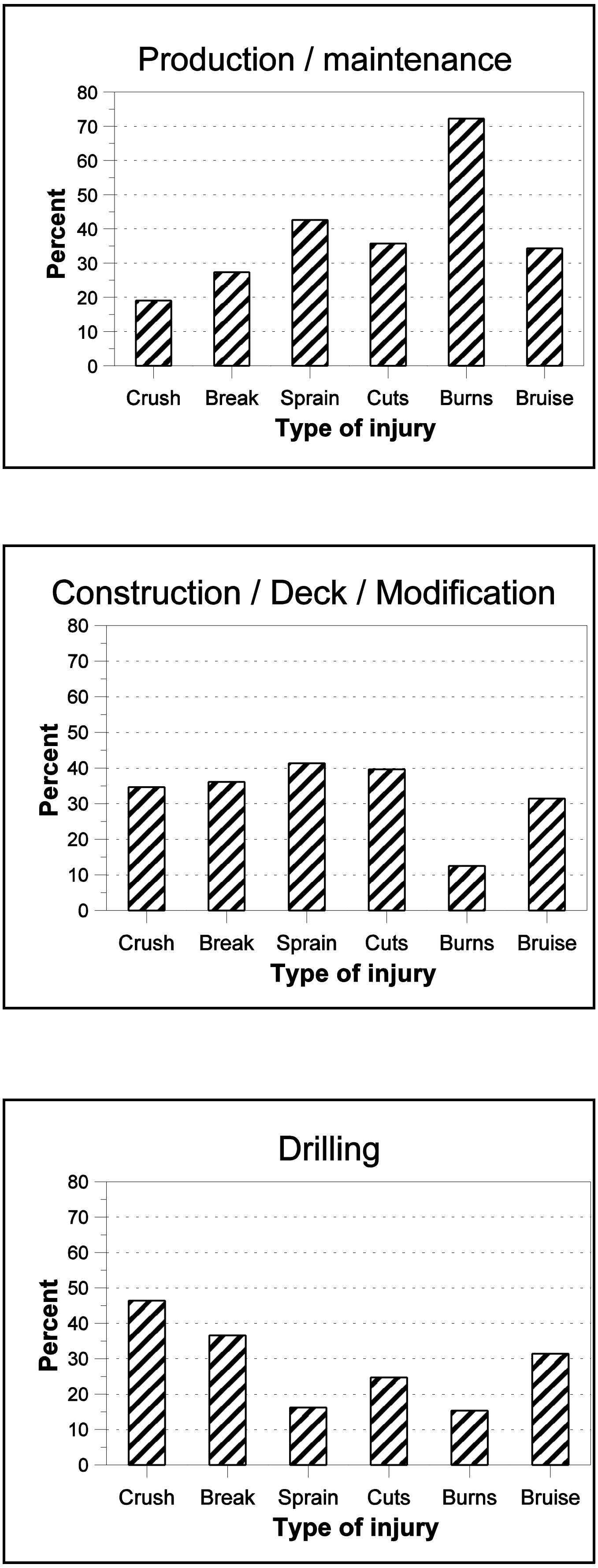
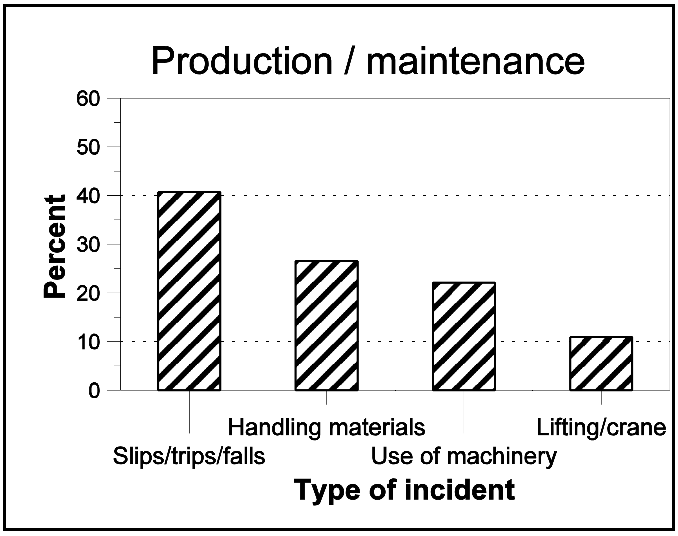
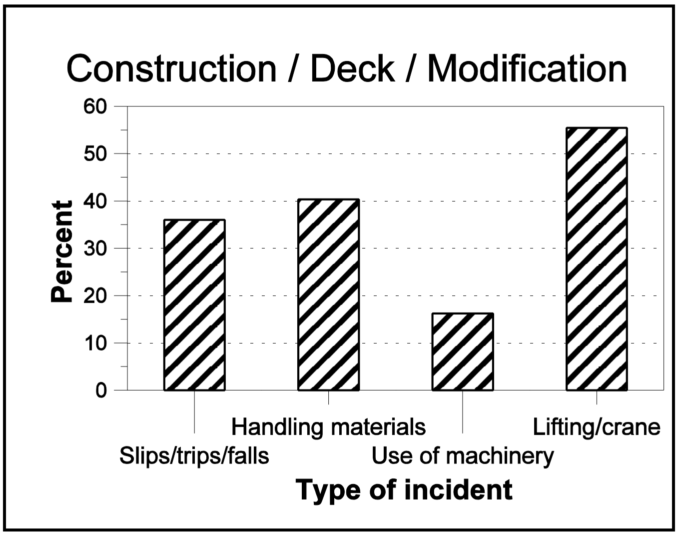


Figure 5.16
Types of injuries in different work areas: Percentages relative to total injuries of each type





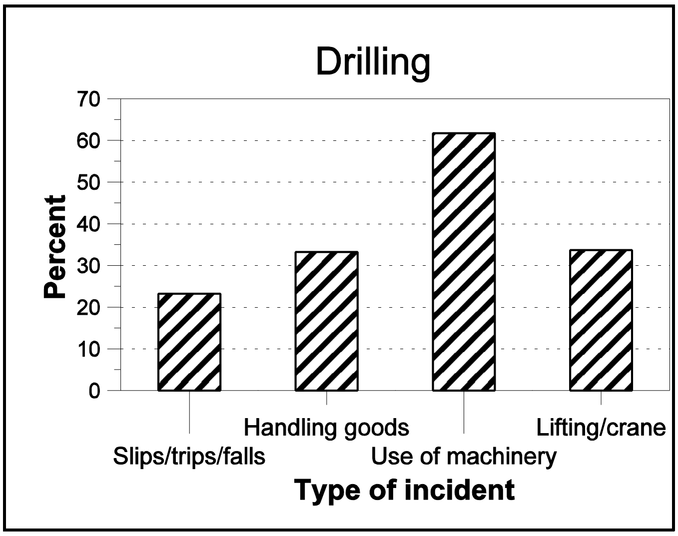


Figure 5.17
Percentages across work areas for the most frequent types of incidents

5.6.2 Incident type in relation to injury severity

The four most frequent incident types were also examined in relation to the severity of injury. The three injury categories were found to be significantly differently distributed across the incident types (HSE data, $\chi^2 = 182.55$, d.f. =14, $p<0.001$). In particular, the percentage of incidents involving 'use of machinery' that resulted in a fatality was 6.8% as compared with 1.2% for 'slips, trips, falls' and 1.5% for 'handling goods and materials'. As shown in Figure 5.18, the relative severity of incidents involving 'use of machinery' is also reflected in the higher proportion of serious injuries relative to other types of incidents.

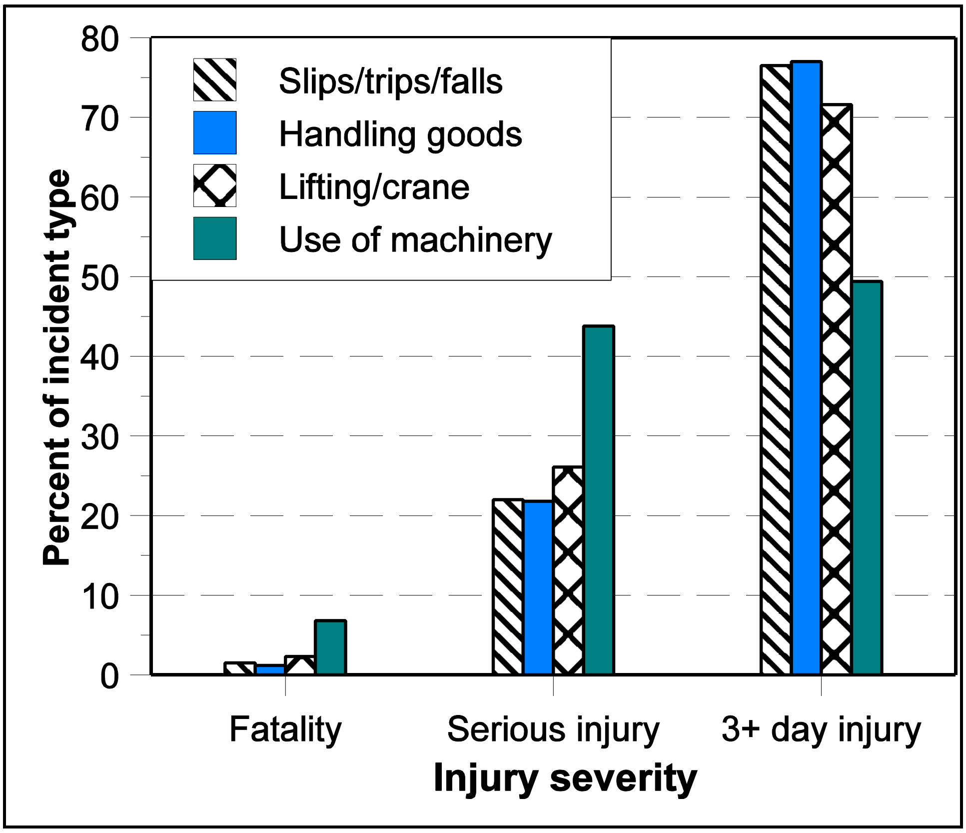


Figure 5.18
Injury severity in relation to incident type (HSE data)

6. CONCLUSIONS

The results presented in this report demonstrate that it is possible to obtain valuable findings from analyses of accident databases, even when the available data are incomplete and information about exposure rates associated with, for instance, different tour durations, is not available. Moreover, when comparisons were possible, findings from the three databases with differently recorded injury categories and predictor variables were generally consistent.

However, a limitation of the present work was that, because of the lack of exposure data, absolute injury rates could not be examined in relation to the days-into-tour variable; instead, it was necessary to analyse ratios of fatalities/ severe injuries to less severe injuries, on the assumption that the lesser injuries were an indirect measure of exposure rates. Thus, the basis of the analyses was that an increase in this ratio would reflect more hazardous conditions. Similar problems were encountered in analyses relating to work area and to shift durations of greater than 12 hours, although it could be assumed that exposure rates were constant (other than during the mid-shift meal break) over the successive hours of a normal 12-hour shift.

In general, the results obtained were consistent with other findings reported in the literature. In particular, the distribution of injury categories differed significantly over days-into-tour. Although there was no significant difference between one-week and two-week tours in the ratio of serious injuries to less serious injuries, the ratio increased markedly as tour length increased beyond two weeks. This finding highlights the potentially adverse effects of tour durations of longer than the normal pattern of two weeks.

When data relating to time-into-tour were analysed separately for three major areas of work, similar patterns were found for the *production/ maintenance* and *construction/deck/ modification* categories, ie. a sharp increase in the ratio of serious to less serious injuries for tour lengths of more than 14 days. Although the increase in the ratio for longer tour durations was less marked for *drilling,* in this work area the ratio was greater than that for the other job groups in the first two weeks of the tour. Thus, consistent with other data (e.g. Hellesøy, 1985; Forbes, 1997; McNabb et al.1994) the present findings highlight the relatively high risks associated with drilling activities during a normal two-week tour.

Although the results relating hours-into-shift to injury rates were less marked, there was evidence that the frequency of injuries varied across time within the normal 12 hour shift duration, the hours from 02.00 -06.00 tending to show the highest rates. Similarly, Forbes (1997) found that accidents among drillers tended to decrease over successive hours of the 12-hour shift. Thus, the present findings for shift durations up to 12 hours did not support the model put forward by Hänecke et al. (1998) which suggested that work periods longer than 9 hours were associated with a marked increase in accident rates relative to shorter durations.

Moreover, the present results did not suggest that, within the normal 12-hour shift duration, the pattern of fatal/serious incidents was significantly different from that less serious ones. Nonetheless, as compared with shift durations of less than 12 hours, durations greater than 12 hours (which were relatively infrequent) were associated with an elevated ratio of fatal/severe to less severe injuries.

This pattern was significant overall, but when analysed separately for the three work areas, it was found that only the data for drillers showed significant results. Thus, shift durations of greater than 12 hours appeared to put personnel working on the drill floor at particular risk. In addition, consistent with the findings of Williamson and Feyer (1995) and Jeong (1999), there was evidence of an overall higher rates of fatalities and serious injuries during the night shift as compared with the day shift.

Thus, both the days-into-tour data and the hours-into-shift data identify work durations extending longer than normal (whether in terms of offshore tours of more than 14 days, or shifts of more than 12 hours), and work taking place at night, as carrying a higher risk in terms of the likelihood that an injury sustained is a serious one. Moreover, as compared with work in other areas, there was evidence of the particular hazards associated with drilling work.

McNabb et al. (1994) reported findings from a study of injuries to petroleum drilling workers which included information about the frequencies with which different body parts were injured, the nature of the incident leading to the injury, and the work activity involved. In general, their findings were consistent with those reported here.

Thus, in the present data, the upper extremities were the most frequently injured body part, and crush injuries were particularly associated with drilling activities. In the present data also, the most common incident types were slips/trips/falls, handling goods and materials, use of machinery, and lifting/crane operations; however, these different types of incidents were significantly differently distributed across work areas.

Whilst the findings presented contribute to our understanding of incidents leading to injury among offshore personnel, they also point to deficiencies in the recording of injury data. In particular, the data available for these analyses did not allow examination of days-into-tour or hours-into-shift in relation to day work vs. day/night rotating shift work. Thus, for instance, a day-shift accident recorded as occurring, say, 9 hours into Day 8 of a two-week tour might represent either a day-shift worker, or a day shift worked by a day/night shift worker; if the latter, it was also not possible to determine whether the individual concerned worked a rollover shift pattern (and might therefore have just experienced a 12-hour shift change) or a fixed-shift pattern.

These issues are crucial in allowing a better identification of risk factors for offshore accidents, and point to the need for more complete recording of accident and injury data. Specifically, rather than only recording days-into-tour, accident records should also include details of the pattern of day and night shifts worked throughout the tour prior to the accident. Also, as some personnel (mostly those involved in drilling services, and other specialist jobs) may be sent successively to several different installations by contracting agencies, it would be useful for accident records to include information about duration of leave prior to arriving on the installation.

Forbes (1997) highlights the importance of education and training to increase the awareness among offshore personnel of the dangers associated with the first days of a tour or hours of shift. He also notes the potential value of long-term contractual arrangements which serve to integrate drilling contractors more closely into the health and safety regime of the operating company. Whilst these issues are outside the immediate focus of the present report, there is clearly a need to take all possible measures to reduce accidents and injuries in the oil and gas industry, particularly at times (e.g. extended duty periods) and in work areas (e.g. drilling) identified as disproportionately hazardous. The findings outlined in the present report contribute to this process.

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APPENDIX

Table A- 1
Breakdown of incidents by injury severity, days into tour and job at time of incident (HSE)

JOB AT TIME OF INCIDENT	INJURY SEVERITY	DAYS INTO TOUR			
		1 - 7	8 - 14	15+	**TOTAL**
Production, Maintenance	Fatality	1 0.3%	1 0.4%	0	**2** **0.3%**
	Serious injury	27 7.1%	16 6.1%	12 34.3%	**55** **8.1%**
	>3 day injury	350 92.6%	245 93.5%	23 65.7%	**618** **91.6%**
	TOTAL	**378** **100%**	**262** **100%**	**35** **100%**	**675** **100%**
Construction, Modification, Deck	Fatality	2 0.5%	1 0.3%	3 5.9%	**6** **0.8%**
	Serious injury	45 11.5%	39 12.7%	15 29.4%	**99** **13.2%**
	>3 day injury	343 87.9%	268 87.0%	33 64.7%	**644** **86.0%**
	TOTAL	**390** **100.0%**	**308** **100.0%**	**51** **100.0%**	**749** **100.0%**
Drilling	Fatality	3 0.9%	1 0.5%	0 0%	**4** **0.7%**
	Serious injury	45 14.2%	38 19.9%	8 26.7%	**91** **16.9%**
	>3 day injury	270 84.9%	152 79.6%	22 73.3%	**444** **82.4%**
	TOTAL	**318** **100.0%**	**191** **100.0%**	**30** **100.0%**	**539** **100.0%**

Table A- 2
Injury severity as a function of shift during which accident occurred (HSE)

SHIFT	INJURY SEVERITY			**TOTAL**
	Fatality	Serious Injury	3+ Day Injury	
Day (0700 - 1900)	59 *2.8%*	511 *24.7%*	1502 *72.5%*	**2072** ***100.0%***
Night (1900 - 0700)	51 *3.9%*	412 *31.7%*	835 *64.3%*	**1298** ***100.0%***
TOTAL	**110** ***3.3%***	**923** ***27.4%***	**2337** ***69.3%***	**3370** ***100.0%***
$\chi^2 = 25.13$, d.f. = 2, $p<0.0005$				

Table A- 3
Injury severity in relation to the shift in which accident occurred (Company B)

SHIFT	INJURY SEVERITY			**TOTAL**
	Fatality/ Permanent Disability	Lost workday/ Restricted Work	Medical/ First Aid Treatment	
Day (0700 - 1900)	19 *1.0%*	794 *40.7%*	1140 *58.4%*	**1953** ***100.0%***
Night (1900 - 0700)	24 *2.5%*	449 *46.1%*	502 *51.5%*	**975** ***100.0%***
TOTAL	**43** ***1.5%***	**1243** ***42.5%***	**1642** ***56.1%***	**2928** ***100.0%***
$\chi^2 = 19.77$, d.f. = 2, $p<0.0005$				

Table A- 4
Distribution of injury severity across shift and days into tour (HSE)

SHIFT	DAYS INTO TOUR	INJURY SEVERITY			TOTAL
		Fatality	Serious	3+ day	
Day (0700 - 1900)	0 - 7	4 .5%	85 9.6%	795 89.9%	884 100%
	8 - 14	2 .3%	73 11.3%	569 88.4%	644 100%
	15+	1 1.0%	32 30.8%	71 68.3%	104 100%
	TOTAL	7 .4%	190 11.6%	1435 87.9%	1632 100%
Night (1900 - 0700)	0 - 7	3 .6%	62 11.5%	474 87.9%	539 100%
	8 - 14	3 .9%	41 12.7%	280 86.4%	324 100%
	15+	2 2.8%	22 31.0%	47 66.2%	71 100%
	TOTAL	8 .9%	125 13.4%	801 85.8%	934 100%

Table A- 5
Distribution of injury severity across shift and days into tour
(Company B)

SHIFT	DAYS INTO TOUR	INJURY SEVERITY			TOTAL
		Fatality/ Permanent disability	Lost workday/ Restricted work	Medical/ First Aid treatment	
Day (0700 - 1900)	1 - 7	3 0.4%	365 49.7%	366 49.9%	734 100%
	8 - 14	4 0.8%	225 47.2%	248 52.0%	477 100%
	15+	4 4.5%	41 46.6%	43 48.9%	88 100%
	TOTAL	11 0.8%	631 48.6%	657 50.6%	1299 100%
Night (1900 - 0700)	1 - 7	5 1.4%	211 58.9%	142 39.7%	358 100%
	8 - 14	5 1.7%	147 49.5%	145 48.8%	297 100%
	15+	0 0%	17 37.0%	29 63.0%	46 100%
	TOTAL	10 1.4%	375 53.5%	316 45.1%	701 100%

Table A- 6
Distribution of injury severity across hours into shift (HSE data)

HOURS INTO SHIFT	INJURY SEVERITY			TOTAL
	Fatality	Serious injury	3+ day injuries	
0 - 1	1 *.5%*	27 *13.8%*	167 *85.6%*	195 *100.0%*
1 - 2	1 *0.4%*	26 *11.5%*	200 *88.1%*	227 *100%*
2 - 3	0 0%	25 *10.5%*	212 *89.5%*	237 *100.0%*
3 - 4	0 0%	27 *11.7%*	203 *88.3%*	230 *100.0%*
4 - 5	2 *.8%*	34 *14.3%*	202 *84.9%*	238 *100.0%*
5 - 6	1 *.6%*	23 *13.7%*	144 *85.7%*	168 *100.0%*
6 - 7	2 *1.2%*	22 *13.6%*	138 *85.2%*	162 *100.0%*
7 - 8	1 *.5%*	26 *12.1%*	187 *87.4%*	214 *100.0%*
8 - 9	1 *.5 %*	23 *11.6%*	175 *87.9%*	199 *100.0%*
9 - 10	1 .6%	16 *9.6%*	149 *89.8%*	166 *100.0%*
10 - 11	1 *.5%*	24 *12.7%*	164 *86.8%*	189 *100.0%*
11 - 12	1 *.5%*	24 *12.2%*	171 *87.2%*	196 *100.0%*
TOTAL	**12** *.5%*	**297** *12.3%*	**2112** *87.2%*	**2421** *100.0%*
χ^2 =8.90, d.f. = 22, n.s.				

Table A- 7
Distribution of injury severity across hours into shift
(Company A)

HOURS INTO SHIFT	INJURY SEVERITY			TOTAL
	Fatality/ Lost Time Injury	Restricted Work	Medical Treatment/ not OSHA recordable	
0 - 1	11 *11.3%*	3 *3.1%*	83 *85.6%*	97 *100.0%*
1 - 2	9 *9.0%*	9 *9.0%*	82 *82%*	100 *100%*
2 - 3	15 *19.0%*	3 *3.8%*	61 *77.2%*	79 *100.0%*
3 - 4	11 *12.0%*	2 *2.2%*	79 *85.9%*	92 *100.0%*
4 - 5	16 *16.7%*	4 *4.2%*	76 *79.2%*	96 *100.0%*
5 - 6	14 20.9%	5 7.5%	48 71.6%	67 *100.0%*
6 - 7	11 *14.7%*	2 *2.7%*	62 *82.7%*	75 *100.0%*
7 - 8	12 13.8%	3 3.4%	72 82.8%	87 *100.0%*
8 - 9	16 *20.3%*	2 *2.5%*	61 *77.2%*	79 *100.0%*
9 - 10	17 21.8%	2 2.6%	59 75.6%	78 *100.0%*
10 - 11	7 *15.6%*	3 *6.7%*	35 *77.8%*	45 *100.0%*
11 - 12	7 *13.0%*	0 *0%*	47 *87.0%*	54 *100.0%*
TOTAL	**146** ***15.4%***	**38** ***4.0%***	**765** ***80.6%***	949 *100.0%*
χ^2 = 25.8, d.f. = 22, n.s.				

Table A- 8
Distribution of injury severity across hours into shift
(Company B)

HOURS INTO SHIFT	INJURY SEVERITY			TOTAL
	Fatality/ Permanent total/partial disability	Lost workday / Restricted work	Medical treatment/ First aid	
0 - 1	1 *.5%*	116 *53.5%*	100 *46.1%*	217 *100.0%*
1 - 2	2 *1.0%*	110 *54.5%*	90 *44.6%*	202 *100%*
2 - 3	1 *.7%*	64 *42.4%*	86 *57.0%*	151 *100.0%*
3 - 4	1 *.5%*	96 *51.3%*	90 *48.1%*	187 *100.0%*
4 - 5	4 *3.0%*	61 *46.2%*	67 *50.8%*	132 *100.0%*
5 - 6	3 2.2%	62 45.3%	72 52.6%	137 *100.0%*
6 - 7	0 *0 %*	90 *56.3%*	70 *43.8%*	160 *100.0%*
7 - 8	1 .6%	78 45.9%	91 53.5%	170 *100.0%*
8 - 9	2 *1.6%*	68 *55.3%*	53 *43.1%*	123 *100.0%*
9 - 10	2 1.5%	64 49.2%	64 49.2%	130 *100.0%*
10 - 11	0 *0%*	39 *43.3%*	51 *56.7%*	90 *100.0%*
11 - 12	0 *0%*	39 *56.5%*	30 *43.5%*	69 *100.0%*
TOTAL	**17** ***1.0%***	**887** ***50.2%***	**864** ***48.9%***	**1768** *100.0%*
χ^2 = 29.1, d.f. = 22, n.s.				

Table A- 9
Breakdown of type of injury by injured body part (HSE)

TYPE OF INJURY	INJURED BODY PART						
	Arm, hand	Leg, foot	Back	Head	Eye	Other	**Total**
Crush	162 *65.3%*	42 *16.9%*	6 *2.4%*	5 *2.0%*	0 *0%*	33 *13.3%*	**248** ***100%***
Break	406 *45.1%*	255 *28.3%*	19 *2.1%*	65 *7.2%*	3 *.3%*	153 *17.0%*	**90** ***100%***
Sprain	61 *8.4%*	184 *25.3%*	318 *43.7%*	5 *.7%*	1 *.1%*	159 *21.8%*	**728** ***100%***
Cuts	114 *47.3%*	45 *18.7%*	3 *1.2%*	40 *16.6%*	15 *6.2%*	24 *10.0%*	**241** ***100%***
Burns	35.0 *32.7%*	12 *11.2%*	0 *0%*	15 *14.0%*	15 *14.0%*	30 *28.0%*	**107** ***100%***
Amputation	91 *83.5%*	10 *9.2%*	1 *.9%*	2 *1.8%*	0 *0%*	5 *4.6%*	**109** ***100%***
Bruise	127 *26.8%*	117 *24.7%*	76 *16.0%*	35 *7.4%*	1 *.2%*	118 *24.9%*	**474** ***100%***
Other	88 *21.9%*	31 *7.7%*	22 *5.5%*	40 *10.0%*	61 *15.2%*	159 *39.7%*	**401** ***100%***
Total	**1084** ***33.8%***	**696** ***21.7%***	**445** ***13.9%***	**207** ***6.5%***	**96** ***3.0%***	**681** ***21.2%***	**3209** ***100%***
χ^2 = 1632.37, d.f. = 35, p<0.0005							

Table A- 10
Distribution of main incident types across work area (HSE data)

INCIDENT TYPE	WORK AREA			TOTAL
	Production / maintenance	Construction/ modification/ deck	Drilling	
Loss of containment	18 *2.4%*	9 *1.2%*	3 *.5%*	30 *1.4%*
Fire/ explosion	42 *5.7%*	1 *.1%*	4 *.6%*	47 *2.2%*
Slips/trips/ falls	305 *41.0%*	270 *36.0%*	174 *26.6%*	749 *34.9%*
Falling objects	53 *7.1%*	63 *8.4%*	56 *8.5%*	172 *8.0%*
Handling goods/materials	130 *17.5%*	198 *26.4%*	163 *24.9%*	491 *22.9%*
Lifting/ crane operations	21 *2.8%*	107 *14.3%*	65 *9.9%*	193 *9.0%*
Use of hand tools	75 *10.1%*	48 *6.4%*	41 *6.3%*	164 *7.6%*
Use of machinery	49 *6.6%*	36 *4.8%*	137 *20.9%*	222 *10.3%*
Exposure to harmful substances	17 *2.3%*	13 *1.7%*	7 *1.1%*	37 *1.7%*
Electrical	33 *4.4%*	5 *.7%*	5 *.8%*	43 *2.0%*
TOTAL	**743** ***100%***	**750** ***100%***	**655** ***100%***	**2148** ***100%***
χ^2 = 314.05, df = 18, p<.0001				