Field Study

A Case-crossover Study of Transient Risk Factors for Occupational Traumatic Hand Injuries in Incheon, Korea

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Abstract: A Case-crossover Study of Transient Risk Factors for Occupational Traumatic Hand Injuries in Incheon, Korea: Won-Jun CHOI, et al. Department of Ocean and Underwater Medicine, Maritime Medical Center, ROK Navy, Korea—Objectives: A case-crossover study was conducted to identify transient risk factors for occupational acute hand injuries. Methods: In total, 98 subjects were recruited from a hospital specializing in occupational accidents and trauma. Patients who had injured fingers, hands or wrists during work were interviewed within 30 days after their accidents. Results: The relative risks for each factor were as follows: 22.9 for unusual or malfunctioning machines (95% confidence interval [CI] 14.4–36.4), 3.3 for wearing gloves (95% CI 1.9–5.7), 5.7 for unusual tasks (95% CI 3.8–8.8), 12.1 for altered work methods (95% CI 8.4–17.6), 4.1 for rushing (95% CI 2.6–6.3), 12.9 for being distracted (95% CI 7.9–20.9), 1.2 for feeling ill (95% CI 0.4–3.6) and 1.0 for working overtime (95% CI 0.6–1.6). Conclusion: The results suggest that some transient risk factors were associated with occupational acute hand injuries. These risk factors are probably preventable, and modifying unsafe or unusual conditions is important to reduce occupational traumatic hand injuries. (J Occup Health 2012; 54: 64–73)

Key words: Case-crossover studies, Hand injuries, Occupational exposure, Risk factors

Most occupational injuries affect the hands1). Based on a survey of the “causes of industrial disasters in Korea” in 2008, when injuries due to occupational cases were divided by injured region, 39.4% of injuries occurred in the upper limbs, with the fingers, hands and wrists accounting for 78.7% of these injuries2). Since occupational hand injuries occur as a result of acute exogenous force, most causes of occupational hand injuries are transient risk factors occurring immediately before injury occurs. Triggers can be reasonably defined as preceding causes in causal relationships3). When many different causes exist causing the same outcome, the probability that a certain outcome will occur can be reduced by finding predictable causes or removing some causal factors. When examining the causes that result in occupational injuries, causes exist that may not be corrected such as gender4, 5). However, causes that can be predicted and prevented to avoid accidents, such as mechanically or physically unsafe states and behaviors, also exist. Finding correctable causes is important to develop preventive measures aimed at reducing occupational acute hand injuries.

Case-crossover studies are suitable to evaluate the effect of rapidly changing factors in sudden accidents because each case becomes its own control; thus, confounding factors that occur from differences between individuals, such as age, gender and work experience, can be eliminated6). In the medical field, the case-crossover design is used in studies related to injuries from traffic accidents7, 8), injuries resulting from drinking9) or factors triggering acute myocardial infarction10) and cerebrovascular events11). Risk factors affecting occupational acute hand injuries are temporary in many cases and are such that the state of exposure changes over time. These risk factors have short time intervals between exposure and the resultant hand injury. Also, because the effect of an exposure acts temporarily, little carryover effect occurs12). The case-crossover design is useful in controlling confounding variables because the design eliminates the effect of variations between individuals, such as work proficiency or past injury.

This study was conducted to identify transient risk factors affecting occupational acute hand injuries
using the case-crossover design to establish strategies to prevent injuries.

**Methods**

**Study subjects**

The study subjects were patients who had visited the hospital outpatient clinic between March and May 2008. The hospital specializes in industrial disasters and is located in the Namdong Industrial Complex in Incheon, Korea. The study examined patients who incurred one or more injuries to the fingers, hands or wrists, including lacerations, avulsions, punctures, contusions, dislocations, fractures or crush injuries. These injuries were caused by external forces according to the International Classification of External Causes of Injuries (ICECI)\(^{13}\). Thermal or chemical burns are classified as a different category of mechanism and were excluded from this study. Sprains and strains are regarded as cumulative injuries, and determining the exact time when these occurred is difficult; therefore, they were excluded. Only those patients who were interviewed within 30 days from the occurrence of their injuries were included. In total, 98 subjects participated.

**Study design**

1) Subject interviews

Data were collected through interviews during patient visits to the hospital for treatment of their injuries. After explaining the purpose and background of the study, those patients who volunteered to participate in the study provided written consent.

The interviews were conducted in a private room in the hospital. The mean and median time elapsed from injury occurrence to the interview was 5.4 and 2.5 days, respectively (standard deviation [SD] 6.3, range 0–29). The mean and median time spent in the interview was 13.1 and 12 min, respectively (SD 4.4, range 7–27). Before starting the interviews, the date and time when each accident occurred and the types of injuries sustained were verified by comparison with medical records. For the purpose of helping the patients improve their recall of the situation at the time of their injuries, the questions used were open-ended, asking subjects to directly describe their situations.

2) Information on exposure to risk factors during the hazard period and control period

Eight risk factors for occupational hand injuries were selected. Overtime or extended work was added to the seven variables known from the literature to be risk factors, such as operating machines/equipment different from those normally used or using malfunctioning equipment, wearing protective gloves, performing a task different from one’s normal work duties, utilizing different methods from those usually used, working hurriedly, working with lower concentration or inattentively and working during illness.

In the case-crossover design, the level or presence of the exposure during the hazard period is compared with that during the control period. Two major methods are the matched-pair interval approach and the usual frequency approach (Fig. 1). These approaches have been conceptualized by others and reported previously\(^{14, 15}\).

The authors asked the subjects whether they had been exposed to each risk factor in the 90 min prior to the injury. If a patient confirmed that he or she was exposed to a risk factor, the time the exposure began and the time the exposure ended were recorded in 10-min intervals using a figure shown in temporal order. The hazard period was set as 10 min prior to the injury. That is, the cases in which exposure to each of the risk factors occurred during the period beginning 10 min prior to the injury were deemed as cases in which the patient was exposed to a risk factor at the time of injury.

Information on exposure during the control period was investigated using two methods. In the first, the control period was set at 90 min prior to injury. In the second, exposure time and control time for each risk factor during the month prior to the injury were recorded. The daily average time of exposure to each of the risk factors during the last month and the number of days of such an exposure were investigated, and the result was converted into the average exposure time during a month and then deemed the gross exposure time during the month. The entire working time during the last month minus the average exposure time was set as the control time.

A structured questionnaire was used to obtain information on exposure. Similar questions were asked by Sorock et al\(^{16}\). Part of the questionnaire is shown in Appendix 1.

**Data analysis**

The data were analyzed in two ways. First, using a matched-pair interval approach, the exposures during the hazard period were analyzed together with the matched case-control data to assess the amount of exposure during the hazard period compared with that during the control period\(^{15, 17}\). Two models were established. In the first model, only one of each risk factor was entered as an explanatory variable. Meanwhile, if there were exposures that were mutually correlated, adjustment was required. For example, if a subject had been doing a task using an altered method while rushing, these two exposure variables were correlated over time. Within-person confounding could occur in this situation. It is possible to control
for multiple correlated exposures by using conditional logistic regression analysis\(^6,14,18\). All eight risk factors were entered into the second model to adjust for temporally correlated exposures, and the model was analyzed using conditional logistic regression for matched pair data.

Second, the incidence-rate ratios and confidence intervals of injuries caused by each of the risk factors were calculated with the usual frequency approach using the Mantel–Haenszel estimates for person-time data. The formulae were presented by Rothman and Greenland\(^{19}\). Sorock et al. gave a practical example in their paper\(^{16}\). The theoretical formulae and interpretations of the sample are presented in Appendix 2. The loss of information is relatively small in the usual frequency approach because the control period for this approach is longer than that for the matched-pair interval approach. Consequently, this method is more efficient than the matched-pair interval approach\(^{15}\). Nevertheless, gathering information about co-occurring exposures during the relatively long control period is much more difficult. In our study, we were unable to adjust for co-exposures in the usual frequency approach.

The SAS software package (version 9.1, SAS Institute, Cary, NC, USA) was used for the statistical analysis. Results were considered statistically significant if \(p\) values <0.05.

**Results**

**General characteristics of the study subjects**

Among the 98 persons studied, 85 were men (86.7%) and 13 were women (13.3%). The mean age of the participants was 39.5 yr old (Table 1). Other general characteristics of the participants are shown in Table 1. Fifteen were office workers. These workers reported that they did not work in the field officially, but if the manufacturers were busy or if someone asked for help, they had to assist. These office workers were working in the field at the time of their injuries and had been exposed to risk. The characteristics of injuries are provided in Table 2. The most common type of injury was laceration (63.3%). Among subjects who injured their phalanges, the most common injury site was the distal phalanges (76.6%). The hand injury severity score (HISs) system, the criterion used to classify the severity of hand injuries, gives weighted values based on the region and scope of the injuries and the existence of accompanying injuries\(^{20}\). The severity is classified as minor, moderate, severe or major. In this study, injuries in 92 subjects (93.9%) were classified as minor, three (3.1%) were classified as moderate, two (2.0%) were classified as severe and one (1.0%) was classified as major.
The proportion of subjects exposed to each risk factor in the hazard period and the average percent-age of person-time exposed to each risk factor in the previous month are presented in Fig. 2. During the hazard period, 39 subjects (39.8%) used unfamiliar or malfunctioning machines/tools. The proportion of the person-time spent exposed to these machines in the month before injury was 5.4%. The proportion of exposure in the hazard period was greater than the usual frequency of exposure for all risk factors, except working overtime. For working overtime, the proportion of exposure in the hazard period was similar to the usual frequency of exposure in the previous month. Remarkably, the proportion of person-time wearing gloves in the hazard period was greater than the proportion of person-time wearing gloves in the month before injury (79.6 and 68.4%, respectively).

Relative risk of injuries by exposure to risk factors

The results using the first method of setting the control period (i.e., the matched-pair interval approach) are shown in the Table 3. When the subjects were assumed to have been exposed to only one risk factor (i.e., in the model in which only one of each of the risk factors was used), the relative risk ratios of the following risk factors were statistically significant: unusual machines, equipment or malfunctioning machines were used; protective gloves were worn; unusual work was being performed; and work was being performed using a different method than usual. For work that was performed more hurriedly, work that was performed with low concentration or inattentively and work that was performed outside
normal working hours, the relative risk ratios were calculated to be infinitely large, as subjects were not exposed to the control period without being exposed to the hazard period. For being sick while working, the relative risk ratio could not be calculated, as the state of exposure to the hazard period and the control period was not different in any of the cases.

When the model in which the subjects were exposed to two or more risk factors at the same time was adjusted (i.e., eight risk factors were used as explanatory variables), the relative risk ratio of "unusual machines, equipment or malfunctioning machines were used" was 10.3 (95% CI 1.9–195.2) and that of "work was being performed using a different method than usual" was 5.2 (95% CI 1.4–33.9).

The relative risk ratios and confidence intervals of injuries for each of the risk factors were calculated by the second method of setting the control period (i.e., the usual frequency approach), and the results indicated significant relative risk ratios for six of the eight variables investigated as risk factors (Table 4). The risk ratios for the following risk factors were statistically significant: unusual machines, equipment or malfunctioning machines used; protective gloves were worn; unusual work was being performed; work was being performed using a different method than usual; work was performed more hurriedly; and work was performed with low concentration or inattentively.

Table 3. Conditional logistic regression analysis for the matched-pair interval approach

<table>
<thead>
<tr>
<th>Transient risk factors</th>
<th>Exposed only in hazard period</th>
<th>Exposed only in control period</th>
<th>Exposed in both periods</th>
<th>RR*</th>
<th>95% CI†</th>
<th>aRR‡</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unusual machine or tools</td>
<td>32</td>
<td>1</td>
<td>7</td>
<td>32.0</td>
<td>6.9–569.1</td>
<td>10.3</td>
<td>1.9–195.2</td>
</tr>
<tr>
<td>Wearing gloves</td>
<td>12</td>
<td>2</td>
<td>66</td>
<td>6.0</td>
<td>1.6–38.5</td>
<td>2.3</td>
<td>0.3–49.9</td>
</tr>
<tr>
<td>Unusual tasks</td>
<td>18</td>
<td>2</td>
<td>10</td>
<td>9.0</td>
<td>2.6–56.6</td>
<td>1.3</td>
<td>0.1–30.3</td>
</tr>
<tr>
<td>Altered work method</td>
<td>27</td>
<td>2</td>
<td>2</td>
<td>13.5</td>
<td>4.0–83.7</td>
<td>5.2</td>
<td>1.4–33.9</td>
</tr>
<tr>
<td>Rushing</td>
<td>23</td>
<td>0</td>
<td>16</td>
<td>Infinite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distracted</td>
<td>28</td>
<td>0</td>
<td>5</td>
<td>Infinite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling ill</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Working overtime</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>Infinite</td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*RR, relative risk (calculated from unadjusted model). †CI, profile likelihood confidence interval. ‡aRR, relative risk adjusted for other transient risk factors (In this model, ‘feeling ill’ was omitted due to the absence of discordant pairs).
Table 4. Transient exposures and relative risks of occupational acute hand injury (usual frequency analysis)

<table>
<thead>
<tr>
<th>Exposure</th>
<th>RR*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unusual machine or tools</td>
<td>22.9</td>
<td>14.4–36.4</td>
</tr>
<tr>
<td>Wearing gloves</td>
<td>3.3</td>
<td>1.9–5.7</td>
</tr>
<tr>
<td>Unusual tasks</td>
<td>5.7</td>
<td>3.8–8.8</td>
</tr>
<tr>
<td>Altered work method</td>
<td>12.1</td>
<td>8.4–17.6</td>
</tr>
<tr>
<td>Rushing</td>
<td>4.1</td>
<td>2.6–6.3</td>
</tr>
<tr>
<td>Distracted</td>
<td>12.9</td>
<td>7.9–20.9</td>
</tr>
<tr>
<td>Feeling ill</td>
<td>1.2</td>
<td>0.4–3.6</td>
</tr>
<tr>
<td>Working overtime</td>
<td>1.0</td>
<td>0.6–1.6</td>
</tr>
</tbody>
</table>

*RR, relative risk. CI, confidence interval.

Discussion

To our knowledge, this is the first study of transient risk factors for occupational hand injuries conducted in Korea. There is a lack of descriptive studies about transient risk factors in Korea. This study examined whether known transient risk factors from foreign studies could be applied to Korean workers.

Considering the risk factors, the highest risk occurred when malfunctioning machines were used. Through a case-control study, Hertz and Emmett reported that the odds ratio of this risk factor for hand injuries was 30 (95% CI 5.0–∞)\(^{21}\). Also, in studies using the case-crossover design, Sorock et al. and Chow et al. reported that the relative risk ratios for the same factor were 11.0 (95% CI 9.4–12.8)\(^{16}\) and 28.3 (95% CI 14.4–55)\(^{22}\), respectively. In addition, this study showed results consistent with those of existing studies for the risk factors that showed statistically significant results\(^{14, 16, 22–24}\).

The relative risk ratio of hand injuries in cases when protective gloves were worn was not statistically significant in the adjusted model. Meanwhile, it was significant in the usual frequency approach. It does not seem logical that the risk of hand injuries increased when gloves were worn. Moreover, previous studies showed that wearing gloves decreased the risk of injury\(^{16}\) or at least did not significantly affect the incidence of injuries\(^{26}\). One possible interpretation is that the gloves workers used were not effective. If the gloves could not adequately protect against excessive external force, the risk of injury might not be ameliorated by wearing gloves. Sorock et al. reported that even protective gloves were not effective in some types of injury\(^{26}\). In this situation, the association between wearing gloves and injury is merely coincidental; although the association is statistically significant, it may not reflect a causal association. Unfortunately, no more detailed information on the properties of the gloves was available. Further evaluations should focus on this point. Another possible interpretation is that an information bias occurred. If the subjects recalled wearing gloves at the time of injury better than they recalled wearing them during typical working time in the last month, an information bias could arise. In fact, the proportion of wearing gloves in the hazard period was reported to be higher than the percentage of total person-time for wearing gloves in the previous month. However, if this was due to information bias, it is still unclear why the direction of the information bias was reversed. Perhaps the subjects wanted to avoid so-called victim blaming. The subjects might regard other risk factors as uncontrollable factors, but they might accept wearing gloves as their own responsibility. To find out whether this proposal is accurate, more objective data on glove-wearing behavior are needed. Information bias in the case-crossover study design is discussed below.

Working while ill did not significantly affect the incidence of hand injuries, as the majority of the study subjects (55%) said that if they were sick, they would apply for sick leave. Therefore, the incidence of injuries occurring in workers who were sick was not statistically significant, as sickness actually made exposure to risk factors less likely to occur.

In case-crossover studies, selection biases, information biases and confounding factors within individuals may occur\(^{26, 27}\). If the possibility of participating in a study varies with the extent of exposure to risk factors, selection biases may occur, and the risk factors relevant to such a case may be over- or underestimated. However, fewer selection biases occur in case-crossover studies compared with conventional case-control studies\(^{69}\). Also, every person in this study who met the selection criteria and agreed to participate was interviewed, lowering the possibility of selection biases.

Information biases occur when the subject’s account of the situation and the actual situation are different. Because subjects remember the situation at the time of injury clearer than the situation prior to injury, the relative risk ratios are likely to be overestimated. Furthermore, a phenomenon called memory decay may occur. This is especially prominent when 2 or more months have passed since the event\(^{26}\). Chow et al. reported that if injuries are examined using a self-reporting method more than 6 wk after injury, maintaining the reliability of the examination is difficult\(^{22}\). In this study, we attempted to minimize information biases by showing a figure drawn in temporal order to encourage the study subjects to describe the time when they were exposed to each of the risk factors. Also, we attempted to minimize information losses due to incomplete recollection by executing interviews.
as soon as possible after injury, and we excluded those cases in which 1 mo or longer had passed.

If a subject is exposed to multiple risk factors at the same time, a confounding effect may occur. In this study, cases in which the subjects were exposed to multiple risk factors at the same time were adjusted through conditional logistic regression analyses to calculate the relative risk ratios. Even after confounders were adjusted, using malfunctioning or unfamiliar machines/equipment (aRR 10.3, 95% CI 13.9–195.2) and using a method different from usual (aRR 5.2, 95% CI 1.4–33.9) showed statistically significant results. Identifying confounding factors in an individual through questionnaires was impossible when the control period established through the usual frequency approach was 1 month before the injuries. If more sufficient information can be obtained, confusion in an individual can be adjusted through the usual frequency approach, and in that case, more stable results can be obtained.

In the case-crossover design, three primary methods can be applied to establish hazard periods. In the case of exposure to temporary risk factors without accumulating effects, the temporal section in which the relevant risk factors affect the incidence of accidents will be divided into a section corresponding to the original risk of accident occurrence and another section in which the risk of occurrence of the relevant accident would increase or decrease because of exposure to risk factors; the length of the section in which the risk of occurrence of the relevant accidents would increase or decrease due to exposure to risk factors will vary based on the characteristics of the risk factors. Among the risk factors investigated, using unfamiliar machines, doing work that had not been performed at normal times and using a different method from usual can be deemed to increase the risk of injuries within a short time from the moment workers are exposed to the relevant risk factors. Thus, establishing the hazard period as 10 min immediately prior to injury was appropriate. However, whether other risk factors would increase the risk of injuries immediately after exposure to the relevant risk factor is unknown. If the duration of a certain exposure was sufficiently long to cover the 90-minute time period before the injury, it would be impossible to detect a change in exposure between the hazard period and the matched-pair interval. This means that the risk ratio would approach toward the null. Additional studies are necessary to determine the length of the hazard periods, along with closer observation of working patterns and those temporal factors that are related to the incidence of injuries.

Methods to establish control periods have been suggested and can largely be divided into matched-pair interval, multiple-interval and usual frequency approaches. The most efficient method is the usual frequency approach because this method establishes long control periods and utilizes information during these periods with relatively fewer losses. The matched-pair interval approach establishes one control period corresponding to the hazard period to compare the state of exposure; thus, its efficiency is relatively low, and the width of confidence intervals for relative risk ratios will become wider compared with the usual frequency approach. The multiple-interval approach corresponds to midway between two methods previously mentioned, but the relative benefit actually produced is in the order of 40–50% compared with the usual frequency approach, even if the number of control periods is increased. In this study, the confidence intervals of the relative risk ratios were more stable in the results produced by the usual frequency approach compared with the matched-pair interval approach. It may seem quite arbitrary to set 90 min before the injury as a control period for the matched-pair interval approach. There is little empirical basis for determining an adequate control period in occupational hand injuries. It would be possible to conduct studies using various control periods if further investigations of Korean workers are conducted.

Making a workplace safe depends on controlling hazards, including unsafe behavior. A successful safety program should include a wide range of organized activities, such as efforts to understand the accident process, field observations, accident investigations and hazard control. These activities are interconnected. Supervisors might identify hazards during an accident investigation or field observation and try to eliminate the hazard. When planning field observations or accident prevention campaigns, both workers and employers should consider transient risk factors as preventable hazards.

Conclusion

The case-crossover design is an appropriate study method to identify the transient risk factors for occupational hand injuries. Most of the risk factors identified in this study can be removed or prevented. Identification of these risk factors can be utilized to reduce injuries through engineering improvement and managerial interventions such as safety education.

References


Appendix 1. Sample questions included in the questionnaire

# If any of the situations described occurred within 90 min before the accident, please record it below.

1) You used any machine, equipment or tools that you do not usually use. (Include breakdowns or malfunctions of machinery or equipment you used)

| 90 min earlier | 60 min earlier | 30 min earlier | Accident |

(At the actual interview, the time at which the accident occurred was recorded, and the time 90 min before the accident was also recorded.)

1.2) Please select from the situations below. If none apply to your accident, please describe the situation on the line for “Others.”

☐ Broken down machines (including malfunction)
☐ Sharper knives or cutters were used than those used normally.
☐ Knives or cutters had more slippery handles than those used normally.
☐ Tools included different parts from those used normally.
☐ Objects with sharp edges other than knives or cutters were used (e.g., steel plate edge).
☐ Others:

1.3) (Make sure to ask regardless of answers to the above questions.)

How often did you do this kind of work during the last month?
Average ( ) days per week, ( ) hours a day or ( ) hours a month on average

2) I was wearing protective gloves.

| 90 min before | 60 min before | 30 min before the accident |

2.2) (Make sure to ask regardless of answers to the above questions.)

How often did you do this kind of work during the last month?
Average ( ) days per week, ( ) hours a day or ( ) hours a month on average

Appendix 2. Usual frequency analysis for five subjects using the Mantel–Haenszel incidence rate ratio

Table A. Example of exposure to unusual machine or tools; data for five subjects from the 98 investigated

<table>
<thead>
<tr>
<th>ID</th>
<th>( A_{i\text{exposed}} )</th>
<th>( A_{i\text{unexposed}} )</th>
<th>( T_{i\text{h exposed}} )</th>
<th>( T_{i\text{h unexposed}} )</th>
<th>( T_{i\text{h total}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
<td>199.5</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>224</td>
<td>232</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>272</td>
<td>272</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>188</td>
<td>188</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>219</td>
<td>220</td>
</tr>
</tbody>
</table>

\( A_{i\text{exposed}} \), If exposed at the time of injuries, 1; if not, 0.
\( A_{i\text{unexposed}} \), If not exposed at the time of injuries, 1; if exposed, 0.
\( T_{i\text{h exposed}} \), Total exposure time during the last month (person-time).
\( T_{i\text{h unexposed}} \), Total control time during the last month.
\( T_{i\text{h total}} \), Total working time during the last month.
Where the Mantel–Haenszel standard weight is

\[ W_{MH} = \frac{T_0 T_i}{T_i}, \]

the Mantel–Haenszel incidence rate ratio \((IRR_{MH})\) is expressed as follows:

\[ IRR_{MH} = \sum W_{MH} I_i \frac{\sum T_0 T_i A_{0i}}{T_i} \frac{\sum T_i}{T_i} \]

Therefore, if the incidence rate is calculated in Table A,

\[
IRR = \frac{1 \times 199.5 + 0 \times 224 + 0 \times 272 + 0 \times 188 + 1 \times 219}{0 \times 0.5 + 1 \times 8 + 1 \times 0 + 0 \times 1 + 220} = 1.993 = \frac{58.6}{0.034} = 58.6.
\]

The estimate of variance is calculated as follows:

\[
Var[ln(IRR_{MH})] = \sum \frac{M_{ij} T_{ij} T_i}{T_i} \frac{A_{0i} T_0}{T_0} \frac{A_{0i} T_0}{T_0} = 0.613,
\]

where \(M_{ij} = A_{ij} + A_{0j}\); thus, it is the total number of cases in the \(i\)th layer.

The 95% confidence interval is

\[
exp[ln(IRR_{MH})] \pm 1.96 \sqrt{\text{var}} = exp[ln(58.6) \pm 1.96 \sqrt{0.613}] = 12.6, 271.9
\]

Since actual injuries occur within a very short time, the incidence rate becomes a nonbiased estimate of the relative risk ratio. The result in the example can be interpreted as indicating that the risk of injuries will be 58.6 times higher if any machine, equipment or tools that had not been used at normal times were used.