Case-crossover studies of occupational trauma: methodological caveats

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Abstract

Objectives—The case-crossover study design was developed to examine triggers for the onset of myocardial infarction. This paper seeks to examine selected methodological issues when applying the case-crossover method to the study of traumatic injuries in the work environment.

Methods—Researchers known to be working on occupational case-crossover studies were invited to present at a workshop held at the National Occupational Injury Research Symposium in October 2000. Data from ongoing studies were used to illustrate various methodological issues involved in case-crossover studies of occupational injury.

Key findings and issues identified—To utilize the case-crossover design, investigators must clearly define the time during which a worker is at risk of injury, the period of time during which a particular transient exposure could cause an injury and carefully select control time periods that estimate the expected frequency of exposure. Other issues of concern are changing work tasks over time, correlated exposures over time and information bias.

Conclusions and future research needs—More case-crossover studies of occupational injury are needed to compare results from multiple studies. The validation of the timing of transient exposures relative to injury onset, whether done in a laboratory or field setting, should be conducted. Nested case-crossover designs in other epidemiological studies (case-control or cohort) can examine both transient and fixed risk factors for occupational injury, and should be attempted.

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Methods

Researchers known to be working on occupational case-crossover studies were invited to present at a workshop held at the National Occupational Injury Research Symposium in October 2000. The workshop sought to examine the issues involved in using case-crossover methods to study injury in the workplace. Data from three ongoing studies were used to illustrate various methodological issues involved in case-crossover studies and each one is described in more detail elsewhere. The first study examined the risk of sharps related injuries to health care workers. The second study evaluated transient risk factors for occupational traumatic hand injury in patients presenting to occupational clinics in New England. The last study was a cross sectional study of risk factors for animal related injuries to practicing veterinarians in Minnesota, which included a case-control and case-crossover study nested within it.

The findings from the above studies were used to illustrate some key issues to consider when planning a case-crossover study of occupational injury. The issues include (1) determining the person-time at risk of injury and exposure, (2) defining the transient exposures and the hazard and control periods, (3) considering the correlation of work related exposures over time, (4) controlling for potential confounding by between and within subject...
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factors, (5) considering how changing tasks in the work environment may influence the study results, and (6) taking into account potential recall bias. Finally, the study of temporal factors in occupational injury using this design and nesting case-crossover studies in other epidemiological designs are discussed. Some suggested areas for future research are noted in the conclusion.

Key findings and issues identified

PERSON-TIME AT RISK OF INJURY AND EXPOSURE
In conducting an empirical study of occupational injury, exposure and injury must be ascertained during person-time at risk of an injury. Whether conducting a cohort, case-control or case-crossover study, only person-time during which an individual is at risk of the outcome ought to be considered. Unlike chronic disease outcomes, which can occur at any time, occupational injuries require special circumstances. Consider a study of rushing as a transient risk factor for sharps related injuries in healthcare workers. Because the worker is only at risk while handling sharps on the job, exposure (rushing or not) while handling sharps when working, is the only person-time that is relevant. For instance, sharps related injuries or episodes of rushing outside of work should be excluded. Whether the subject was rushing during the hazard period (shortly before the injury) also needs to be ascertained. Finally, the expected frequency of rushing while performing medical procedures with a sharp instrument needs to be determined. Rushing while not handling a sharp instrument should not be counted in the study base. The person-time at risk needs to be worked out during the planning phase of a case-crossover study of occupational trauma.

TRIGGERS (EXPOSURES) AND HAZARD PERIOD: DEFINITIONS
Injury is associated with multiple component causes, some of which are present for a relatively long time period, and others occur just before it and are thought to trigger the onset of the injury producing event. A trigger (exposure) may be transient in nature and have a short effect period (such as an object falling near a worker) or can be transient but have longer effects (such as a disturbing telephone conversation that distracts a worker for hours afterwards). The hazard period is the time segment during which the exposure is likely to have its etiological effect on the injury, and must be carefully specified to capture the etiologically relevant exposures. The hazard period can vary depending on the nature and duration of the exposure under study. For example, on the one hand, malfunctioning equipment can influence injury risk during the entire period of the malfunction, lasting several seconds up to several hours. On the other hand, the sedating effects of antihistamines may have their onset of effect after 30–60 minutes of ingestion and can be expected to affect injury risk for several hours. Misspecification of the hazard period is likely to lead to null biased results, for example, antihistamine use in the past month may be less relevant to the risk of injury than its use in the four hours before the injury.

EXPECTED FREQUENCY OF EXPOSURE AND SELECTION OF CONTROL TIME PERIODS
The extent to which an exposure is “unusual” can be estimated using various control time periods during which an injury is not reported to have occurred. These time periods may be sampled from other workers, such as in a case-control study, or from the previous exposure experience of the injured worker (case-crossover study). An investigator might choose the average frequency and duration of reported transient exposures in the work-month before the injury. This approach is termed the usual frequency of analysis (UFA). Other control time periods however could also be used, such as an earlier equivalent time period one hour before the injury (pair matched interval approach) (fig 1). The UFA approach is more powerful for finding effects if they exist than is the pair matched interval approach. The UFA is comparable to a retrospective cohort study that is highly stratified (each subject forms his or her own stratum).

CORRELATION OF WORK RELATED EXPOSURES OVER TIME
The correlation of exposures over time is also a concern. For example, in the study of transient risk factors for hand injuries, four of eight factors were correlated over the 90 minute exposure window before the injury (table 1). That is, the median duration of these four exposures, when they did occur, covered almost all of the 90 minute time period before the injury (working overtime, wearing gloves, rushing, and feeling ill). Thus, it was not possible to detect a change in these four exposures between the hazard period 10 minutes before the injury and the 60–70 minute pair matched interval period before the injury. In choosing

Figure 1  Case-crossover study design (* = episode of exposure).
Adapted from Sorock transient risk factors. For instance, 118 subjects reported a median of 8 minutes of distraction.

<table>
<thead>
<tr>
<th>Factor</th>
<th>No exposed†</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working overtime</td>
<td>160</td>
<td>90</td>
<td>180</td>
<td>390</td>
</tr>
<tr>
<td>Wearing gloves</td>
<td>155</td>
<td>60</td>
<td>258</td>
<td>480</td>
</tr>
<tr>
<td>Rushing</td>
<td>151</td>
<td>60</td>
<td>120</td>
<td>300</td>
</tr>
<tr>
<td>Distracted</td>
<td>118</td>
<td>2</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Unusual task</td>
<td>86</td>
<td>18</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Equipment/materials or performed differently</td>
<td>71</td>
<td>1</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>Feeling ill</td>
<td>65</td>
<td>60</td>
<td>240</td>
<td>480</td>
</tr>
<tr>
<td>Different work method</td>
<td>64</td>
<td>9</td>
<td>30</td>
<td>120</td>
</tr>
</tbody>
</table>

†Number of subjects (n=232) reporting any exposure during the past work-month to each of eight transient risk factors. For instance, 118 subjects reported a median of 8 minutes of distraction, on average, during episodes of distraction in the month before the injury.

Before injury shown as the 25th, 50th, and 75th percentiles in hand injured subjects.

Had it been possible to use the pair matched interval approach, an evaluation of the relationship between glove wearing and other transient exposures that may be correlated and change over time (within subject confounding) could have been made. For example, since data were collected on the temporal relationship between wearing gloves and rushing within the 90 minute period before the injury, we could control for within subject confounding of these two variables using conditional logistic regression. This would be more likely to go undetected while utilizing the usual frequency approach since data were not collected on the co-occurrence of rushing while wearing gloves in the past work month, only the average frequency and duration of glove use. Because of the difficulties mentioned above, it is important to carefully consider the choice of control period selection, and take into account correlation of transient exposures over time and the need to control for within person confounding.

CHANGING TASKS IN THE WORK ENVIRONMENT

One major challenge in conducting case-control or case-crossover studies in the work environment is identifying control periods that are similar to the time at which the injury occurred. For instance, workers may change tasks considerably over a 90 minute time period. If the work task done 10 minutes before the injury is vastly different from the task(s) done over the previous 80 minutes, then the nature of the work has changed and perhaps the risk of injury as well. This would affect the pair matched analytic approach if one used the 60–70 minute earlier period as the control period. However, when considering traumatic hand injury, there are many ways that a laceration, crush, or puncture can occur so excluding certain tasks as “zero risk” may be ill advised.

RECALL BIAS

The reliability and validity of self reported transient exposures has been another important criticism of case-crossover studies. For the hand injury study, there are now test-retest reliability data available which may suggest that injured subjects can reliably report the frequency and duration of transient exposures in the month before the injury up to four days after the initial interview. This implies that recall of such exposures may be reliable, but does not answer the question of the validity of the recall, that is: can the timing of the transient exposure in the hazard period be recalled correctly? Was the subject truly rushing in the 10 minute interval before the injury or was it 20–30 minutes before the injury? Answering this question may require methods such as sampling observation periods for factors such as rushing or working with malfunctioning machinery. This may not be feasible however given the infrequent nature of exposures and work injuries. Another example might be to use the occurrence of documented assembly line speed-ups seen in manufacturing production as a gold standard for rushing with respect to the recalled period of rushing.
Table 2

Comparison of case-crossover and case-control features for examining sleep deficit as a risk factor for animal related injuries to veterinarians, Minnesota

<table>
<thead>
<tr>
<th>Study type</th>
<th>Case definition</th>
<th>Exposure assessment</th>
<th>Control selection</th>
<th>Factors potentially evaluable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case-crossover</td>
<td>Animal related injury in past year</td>
<td>Hours of sleep the night before the injury</td>
<td>Usual hours of sleep at night the month before the injury for the injured vets</td>
<td>Transient factors like hours of sleep</td>
</tr>
<tr>
<td>Case-control</td>
<td>Animal related injury in past year</td>
<td>Hours of sleep the month before the injury</td>
<td>Hours of sleep for a randomly selected month for uninjured vets</td>
<td>Transient factors like hours of sleep and fixed factors like age, gender, practice style, etc</td>
</tr>
</tbody>
</table>
tandem with case-control studies, the results have been consistent in the direction of effects. Furthermore, this approach would allow the investigator to also conduct a case-time-control study to adjust for possible temporal trends in exposure.

Conclusions and recommendations for future research

The following recommendations for future research were made based on our analyses and discussions with workshop participants.

(1) More case-crossover studies of occupational trauma should be conducted that compare results for the same injury type and across injury types, especially where and when

(2) The examination of the validity of exposure timing should be given high research priority. This may be most feasible for transient factors that are external such as malfunctioning equipment, or wearing gloves, compared with internal factors such as distraction due to thinking about other people or rushing where there are no witnesses or external processes to corroborate or refute the self reported exposure.

(3) In work settings, where it is possible, an effort should be made to launch cohort studies perhaps using pre-employment data or new baseline data on fixed risk factors such as age, gender, work tasks, occupation, job experience, and safety training. A case-crossover study nested in a cohort could evaluate both fixed and transient risk factors. A study in a large manufacturing company that targets all acute traumatic injuries might be successful, provided adequate pilot studies were done first to help identify appropriate person-time at risk, hazard period duration, and eligible control periods.

In summary, the case-crossover design is useful for the evaluation of transient risk factors that may trigger injury at the workplace. This approach leads to freedom from confounding by differences between workers that would be difficult if not impossible to overcome with more traditional approaches. Implementing such studies involves overcoming several important challenges just as in any other observational design.

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