Study design

Case-crossover designs in occupational health

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Commentary on the paper by Schwartz (p. 956)

The case-crossover design has become an accepted method for investigating acute health consequences of transient exposures, or ''triggers''. This design, originally presented in 1991 by Maclure,[1] can be thought of as a variant of the conventional case-control study with individual (pairwise) matching. The principal difference is that a case-crossover study only includes cases, where each serves as his own referent. This feature has a compelling methodological appeal in that it allows for efficient control of potential confounders that are fixed (for example, genetic traits) or change minimally or slowly over time (for example, socioeconomic status), and are difficult or impractical to measure. Who better to provide control for confounding than the case himself?

To date, the case-crossover design has been applied most often to investigate environmental exposure effects in studies of air pollution, as an alternative to time series analyses. The paper by Schwartz[2] in this issue exemplifies this application, and also illustrates the utility of the case-crossover method for controlling for seasonal and long term air pollution time trends. There have also been several applications to occupational studies of acute outcomes, primarily injuries, such as a recent investigation of risks for acute hand injuries associated with working with malfunctioning tools, accelerated work pace, and distractions.[3] Further applications of this design for investigating acute workplace injuries and illnesses are clearly warranted, as other authors have stated.[4 5]

There are some important practical and methodological considerations for designing and implementing case-crossover studies of workplace hazards. Obviously, data on acute health outcomes need to be recorded and retrievable for this design to be successful. Some workplaces routinely record acute events, such as injuries that require medical treatment. Data reporting is sometimes performed to comply with government regulations, and some industries also maintain illness and injury reporting systems for medical benefits and other internal purposes. Case-crossover analyses of routinely tabulated outcomes, linked with relevant historical exposure data, can then be undertaken fairly expeditiously without large resource expenditures. The validity of these analyses will nonetheless require accurate classification of health outcomes and exposures in order to minimise bias. Data on acute health effects other than injuries, such as symptoms or transient changes in physiological functions, will require specially designed data collection protocols, typically involving detailed, repeated assessments of workers' health and exposure status. This may entail physical examinations or repeated physiological measurements, which will ordinarily be resource intensive and can impose severe limitations on study size. Exposure assessment requirements for transient exposure changes can also engender substantial costs and logistical complexity, beyond what ordinarily are encountered in standard cross-sectional or longitudinal studies. In particular, personal level continuous exposure monitoring or repeated biomonitoring may be necessary for accurate characterisation of short term environmental changes.

There have been some notable advances in case-crossover design methodology since the initial applications in the early 1990s, yet some issues have not been fully resolved. Among these, unbiased selection of the aetiologically relevant and representative time periods for the ''case'' and ''control'' intervals, respectively, has probably received greatest attention. The case interval is generally defined as the time period immediately preceding or in close temporal proximity to the health event. Allowance for a lag period between the case interval and the event will be important when the health outcome of interest is a delayed effect of exposure. The more difficult choice is the selection of the correct control period, which should represent the case's expected exposure profile, much as the exposure experience of a control in a case-control study is assumed to reflect the norm. There is now fairly wide recognition that limiting selection of control periods to times preceding the event can be biased when there are secular exposure trends. Air pollution research provided the impetus for this concern, but it is not hard to imagine the same type of bias occurring in an occupational study. Improved workplace ventilation, introduction of personal protective equipment, and changes in production are all possible sources of secular exposure trends. Accordingly, bi-directional control interval selection, in which control periods are selected from times before *and* after the event, has been shown to be a reasonable strategy for reducing such bias.[6] The validity of this approach requires the assumption that the case event will not influence subsequent exposure. This assumption is certainly likely to hold true for a study of daily counts of mortality or hospital admissions related to daily changes in air pollution (which cannot be modified easily or rapidly), but may not apply in some occupational settings. To illustrate, consider the possible consequences of a limb amputation in a specific workshop on subsequent work and safety enforcement practices. Analogous health event influenced exposure modifications might be instituted following recognition of outbreaks of acute illness or symptom reports. Other nuances of control selection may involve matching case and control times on season, day of week, or work shift if there is prior evidence that these time related factors are potential confounders. Of course, care should be taken to avoid overmatching on an exposure related time factor.

The case-crossover design can offer a versatile approach for studying a range of work related health outcomes. In addition to applications that address illness and injury aetiology, this method may also prove to be advantageous for occupational health surveillance, at the population-wide level and in specific workforces. Newly hired workers without past exposure to agents of concern should be especially valuable groups for case-crossover studies designed for industry specific surveillance programmes. Future, expanded use of this design in occupational epidemiology should be encouraged.

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REFERENCES

1 **Maclure M**. The case-crossover design: a method for studying transient effects on the risk of acute events. *Am J Epidemiol* 1991;**133**:144–53.
2 **Schwartz J**. The effects of particulate air pollution on daily deaths; a multi-city case crossover analysis. *Occup Environ Med* 2004;**61**:956–61.
3 **Sorock GS**, Lombardi DA, Hauser R, *et al*. A case-crossover study of transient risk factors for occupational hand injury. *Occup Environ Med* 2004;**61**:305–11.
4 **Burdorf A**, Sorock GS, Herrick RF, *et al*. Advancing epidemiologic studies of occupational injuries—approaches and future directions. *Am J Ind Med* 1997;**32**:180–3.
5 **Eisen EA**. Methodology for analyzing episodic events. *Scand J Work Environ Health* 1999;**25**(suppl 4):36–42.
6 **Navidi W**, Weinhandl E. Risk set sampling for case-crossover designs. *Epidemiology* 2002;**13**:100–5.

Pain

Work related neck pain: how important is it, and how should we understand its causes?

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Commentary on the paper by Wahlström *et al* (*Occup Environ Med*, June 2004)*

Upper extremity musculoskeletal disorders (MSDs) have been linked to many features of video display unit (VDU) operation, including duration and intensity of use.[1] Neck pain has been less studied than the shoulder and the distal hand-wrist regions; the study by Wahlström and colleagues, published in the June 2004 issue of this journal,[2] is a new and noteworthy exception.

Perhaps the lower level of attention to date is because neck pain is less serious and has less potential to cause disability. How long lasting and important are these symptoms? Do people recover readily, or do they progress to having more frequent and chronic pain? Do the disorders interfere with work or have other social or economic costs? And—especially important for occupational health and safety practitioners and clinicians—do the answers to these questions depend on whether the individuals are continuing to work in the same conditions under which the symptoms first developed?

A few investigations have addressed these questions. For example, among employed persons with neck pain, the proportion with lost work time is similar to those with back pain, which is notorious for high absenteeism costs.[3 4]

*Wahlström J, Hagberg M, Toomingas A, *et al*. Perceived muscular tension, job strain, physical exposure, and associations with neck pain among VDU users; a prospective cohort study. *Occup Environ Med* 2004;**61**:523–8.

Manufacturing workers with neck pain lost, on average, about 14 days from work in one year because of their neck problems. Among nurses, more frequent and severe neck pain was associated with a higher probability of work absenteeism as well as having to modify or restrict work activities.[5] Other outcomes included inadequate sleep, reduced participation in non-work activities and recreation, seeking more medical attention, and greater use of pain medications.

Among people with neck pain severe enough to seek medical care, pain severity predicted decreased mental wellbeing as well as limitations in ability to perform activities of daily living and related functional capacities.[6] The longer the episode had lasted, the worse the expected outcome; a substantial minority were still suffering one year after seeking medical attention.

While healthcare costs are not as high for neck as for low back pain, they may be substantial in patients with neuropathies affecting the neck.[7] Non-surgical treatment of chronic radicular pain is of limited efficacy.[8] These data, although very limited, should nevertheless motivate us to seek effective primary and secondary interventions for preventing work related neck pain and for limiting the duration and progression of those episodes that do occur. There is a need for more prospective data on predictive factors of adverse clinical and employment outcomes. It is to be hoped that populations such as the one described in the current study will be followed up in the future for new information on the natural history of neck disorders and how they can most effectively be addressed in the workplace.

Despite the large literature on work related MSDs, one theme in the recurring debate centres on the possible confounding of physical exposures by psychosocial strain in that literature. While these two types of exposures are often correlated with each other,[9] and while each has physiological effects with biological plausibility for MSD risk, nevertheless ''confounding'' may not be the correct way to frame the issue. Independent variables that share a common causal pathway cannot confound each other, although there may be interaction if, for example, the effect of one is conditional on the other's presence or absence. In addition, if the two variables are measured in such a way that they overlap operationally (if not conceptually), then any attempt to separate their effects may lead to spurious conclusions.

This has important practical implications for the way that MSDs are studied. Given their acknowledged multifactorial aetiology, we need to employ multivariable analytical methods that are consistent with our hypothesised biological models. Standard regression approaches, with main effect terms only, imply control of confounding but do not examine effect modification or other causal pathway structures. At a minimum, stratified analyses or interaction terms are required to examine potential effect modification, and more complex modelling approaches are often justified.

One important domain of psychosocial strain, assessed through any of the commonly used instruments, is job ''demands'', usually representing a combination of time pressure, actual work pace, physical effort, and/or competing demands from multiple supervisors or job responsibilities. Conversely, any operational measure of physical work pace is likely to imply a psychological experience of time pressure. Job ''control'', another important psychosocial feature, generally has a strong inverse relation with the performance of physically repetitive work. Clearly these measurement constructs have both psychological and physical dimensions. Under these conditions, the attempt to partition the risk of MSDs between physical and psychosocial exposures is inherently flawed. The dilemma is especially pronounced in the case of VDU operators because physical force levels are generally low, leaving work pace and repetitive hand and finger motions as predominant physical stressors.

Again, the best approach to resolving this problem is to define clearly the causal pathway in advance of undertaking any data analysis. Identifying factors at different stages along that pathway can provide valuable information about whether or not different exposures have common mechanisms of effect, provided that the statistical analysis is carried out so as to illuminate rather than obscure those mechanisms. In the current study, ''physical exposure'' was assessed in terms of precision and repetition of manual activity, while ''psychosocial strain'' was defined as the combination of high demands and low control. The same questionnaire obtained ''perceived muscular tension'' (PMT)—a likely intermediate variable for both exposures and possibly also a reflection of non-occupational stressors. PMT was treated in the analyses as a risk factor only, even though the authors called attention to the need to determine its position on the pathway(s) of effect. Since we cannot determine that position from the analyses presented, the cause(s) of the tension remain obscure. However, it is evident that if PMT represents the effects of either occupational exposure (physical and/or psychosocial), then those effects are underestimated in the analyses that are adjusted for PMT. Complicating the matter even further, if either physical or psychosocial exposures were assessed incompletely or with error, PMT might be serving here as a proxy for that unmeasured load or strain. Thus, despite the other strengths of this investigation, the results provide less information than we might wish regarding which interventions would decrease that muscle tension and the resulting neck pain.

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REFERENCES

1 **Punnett L**, Bergqvist U. Visual display unit work and upper extremity musculoskeletal disorders. *A review of epidemiological findings.* Solna, Sweden: National Institute of Working Life, 1997.
2 **Wahlström J**, Hagberg M, Toomingas A, *et al.* Perceived muscular tension, job strain, physical exposure, and associations with neck pain among VDU users; a prospective cohort study. *Occup Environ Med* 2004;**61**:523–8.
3 **Burdorf A**, Naaktgeboren B, Post W. Prognostic factors for musculoskeletal sickness absence and return to work among welders and metal workers. *Occup Environ Med* 1998;**55**:490–5.
4 **Cheadle A**, Franklin G, Wolfhagen C, *et al.* Factors influencing the duration of work-related disability: a population-based study of Washington State workers' compensation. *Am J Public Health* 1994;**84**:190–6.
5 **Trinkoff AM**, Lipscomb JA, Geiger-Brown J, *et al.* Musculoskeletal problems of the neck, shoulder, and back and functional consequences in nurses. *Am J Ind Med* 2002;**41**:170–8.
6 **Kjellman G**, Skargren E, Öberg B. Prognostic factors for perceived pain and function at one-year follow-up in primary care patients with neck pain. *Disability and Rehabilitation* 2002;**24**:364–70.
7 **Berger A**, Dukes EM, Oster G. Clinical characteristics and economic costs of patients with painful neuropathic disorders. *J Pain* 2004;**5**:143–9.
8 **Persson LCG**, Lilja A. Pain, coping, emotional state and physical function in patients with chronic radicular neck pain. A comparison between patients treated with surgery, physiotherapy or neck collar—a blinded, prospective randomized study. *Disability and Rehabilitation* 2001;**23**:325–35.
9 **MacDonald LA**, Karasek RA, Punnett L, *et al.* Covariation between workplace physical and psychosocial stressors: evidence and implications for occupational health research and prevention. *Ergonomics* 2001;**44**:696–718.