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AOGS REVIEW

Cross-sectional studies – what are they good for?

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Abstract

Cross-sectional studies serve many purposes, and the cross-sectional design is the most relevant design when assessing the prevalence of disease, attitudes and knowledge among patients and health personnel, in validation studies comparing, for example, different measurement instruments, and in reliability studies. This paper describes the use of cross-sectional studies and provides examples within obstetrics and gynecology. Caveats are also described; for example, when cross-sectional data is used for analytical purposes of associations between an exposure and an outcome, authors and readers should be careful not to make causal inferences, unless the exposure may safely be assumed to be stable over time and not influenced by experiencing the outcome. In such cases, analyses are also subject to selection and information bias as well as confounding.

Abbreviations: IVF, in vitro fertilization; SET, single embryo transfer.

Introduction

Cross-sectional studies are characterized by the collection of relevant information (data) at a given point in time. Hence, there is no time dimension involved in cross-sectional studies, as all data are collected and mostly refer to the time at or around the time of the data collection.

While it is often mentioned that information in cross-sectional studies is collected at a given point in time, what is meant by "a point in time" is usually not described or defined. The time dimension may depend on the study question. The time dimension must be defined clearly for each study component, i.e. the selection of study participants, the collection of data and the definitions of the disease or traits measured. In a study on alcohol intake among pregnant women, the relevant study question was: what is the prevalence of alcohol intake in the early second trimester? The data collection lasted three months (specified in the paper), but the relevant "point in time" in this case would be the gestational age at data collection, which on average was 15.0 weeks (also specified in the paper) (1), rather than the calendar time used to collect the data.

Sometimes it makes little sense to report the prevalence of an outcome within a few days or a week. If the data collection covers a long period of time, for example, a year, the term 'period prevalence' may be used. For

Key Message

A cross-sectional design is relevant when assessing the prevalence of disease or traits, attitudes and knowledge, in validation and in reliability studies. When cross-sectional data is used for analytical purposes, authors and readers should be careful not to make causal inferences, unless the exposure may safely be assumed to be stable over time.

example, the prevalence of preterm birth is usually reported on an annual basis (2) and this may be regarded as a period prevalence. Timewise, there is no specific cut-off between a prevalence based on information collected at a point in time and a period prevalence based on information collected over an extended period of time.

Cross-sectional studies may be either descriptive or analytical. Descriptive studies mostly aim to provide estimates of prevalence of disease, traits such as smoking behavior, people′s attitudes, knowledge or health behavior, whereas analytical studies aim to assess associations between different parameters.

When performing studies on the prevalence of particular diseases or traits such as overweight and alcohol intake, the term 'prevalence study' is often used, and when, for example, attitudes and opinions are assessed, the term 'survey' is sometimes used.

Cross-sectional studies may be based on data on the entire population from national registers (3) or on a sample of the relevant (sub)population (4). Most cross-sectional, descriptive studies, whether based on data on the entire population or on a representative sample, aim to provide estimates of prevalence in the entire population under study. While representativeness may be a lesser problem in for example, cohort studies assessing the association between an exposure and an outcome, representativeness is paramount in studies of prevalence (5). Therefore, selection bias is an obvious issue in cross-sectional studies on the prevalence of disease, traits or other issues. Information bias, i.e. inaccurate measurement or recording of a disease or characteristic, is also a key problem that needs to be addressed in cross-sectional studies as in any other study design. Please refer to Nøhr & Liew (5) and Kesmodel (6) for details on selection and information bias, resepctively.

Sometimes the difference between an ecological study using only data at the aggregate level and a cross-sectional study based on data from individuals may be subtle (3). In a recent study showing that the prevalence of births remains constant in the Nordic countries in spite of high rates of contraceptive use and liberal access to abortion on women's request (3), the study design was correctly specified as cross-sectional. The paper also stated that only aggregated data on a group-level were used, which might suggest an ecological design. However, many data from the Nordic registries are linked to a unique personal identifier, and it is clear from the paper that data showing the distribution of hormonal methods by age were available only because of this linkage at the individual level (3). Hence the data used were not aggregate data in the sense used for ecological data, where each person is completely untraceable, but were aggregated so that no individual was recognizable, even though the original data were based on information at the individual level.

Prevalence studies

Prevalence of disease

The prevalence of a given disease is often used as a measure of the burden of disease for society.

For example, the prevalence of symptomatic pelvic organ prolapse among women >40 years has been estimated at 6% in an American cohort (7). The fact that only those with symptoms of any given disease are counted is quite common, as asymptomatic cases are usually only discovered in relation to screening programs.

The prevalence of any disease depends on the incidence of the disease, whether the disease is chronic or acute, the survival, whether it is assumed that most cases are in fact diagnosed, and whether women who have received treatment and who are potentially cured are included. For example, most cancers will not be diagnosed during the latent preclinical phase with no symptoms and will therefore not contribute to the estimated prevalence in a cross-sectional study, nor will the many cases with undiagnosed diabetes. When estimating prevalence of specific cancer types, often all those diagnosed and alive will contribute to the estimate of prevalence, irrespective of whether they have been treated and potentially cured, and hence no longer have the disease.

In some papers, the development over time of a given condition is described, for example, the change in preterm birth in Denmark 1995–2003 based on national registry data, theoretically including all births (2). Although the prevalence of preterm birth each year is easily seen as a period prevalence estimated within a cross-sectional design, the description of development over time is in fact also based on consecutive cross-sectional studies (one each year) (Figure 1). The difference from a cohort study is that in a cohort one would be following the same group of women (cohort) over time, whereas the presented data in Langhoff-Roos et al. (2) do not represent the same women over time (although each woman may contribute information on more than one birth). The difference from an ecological (or macro-epidemiological) study is that in ecological studies data are analyzed at the aggregate level, as are potential confounders, whereas in the consecutive cross-sectional studies, data are available at the individual level (2). Only few such studies describing development or change in the prevalence of a certain disease or procedure in a population are explicitly described as cross-sectional (8).

The prevalence of congenital malformations at birth constitutes a special case, as the prevalence at birth depends not only on genetic disposition and relevant prenatal exposures but also on the proportion of women who are offered ultrasonographic assessment of potential

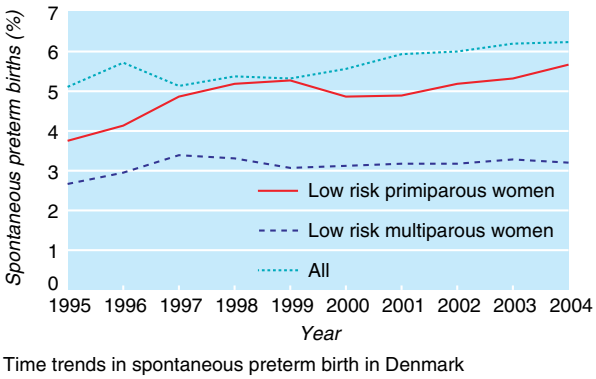

Figure 1. Time trends in spontaneous preterm birth in Denmark, 1995–2004. Reproduced with permission from Langhoff-Roos et al. (Spontaneous preterm delivery primiparous women at low risk in Denmark: a population based study. *BMJ*. 2006;332:937-9). [Color figure can be viewed at wileyonlinelibrary.com].

malformations in pregnancy and the subsequent proportion who choose to have an induced abortion, which again may reflect legal issues in different countries. The true incidence of malformations remains unknown.

Prevalence of traits

Cross-sectional studies are also used to estimate the prevalence of traits such as alcohol intake and smoking habits in women (and men). Interview and questionnaire surveys have shown that the prevalence of alcohol binge drinking in very early pregnancy seems to peak around the time of conception and then drops off, reaching a low level around the time of recognition of pregnancy (9); the prevalence has also been shown to change over time in consecutive cross-sectional populations (4).

Analytical studies of association

Although the majority of analytical observational studies assessing the association between an exposure and an outcome are cohort or case-control studies, cross-sectional studies may be used for analytical purposes provided that authors and readers are careful not to make causal inferences except in special circumstances.

Generally, as there is no time dimension involved in cross-sectional studies and therefore no time interval between "exposure" and "outcome", causal inferences should not be made. For example, in a study on characteristics of women who engage in alcohol binge drinking during pregnancy, it was shown that while binge drinking before and after recognition of pregnancy was associated with weekly alcohol consumption before pregnancy, single status and tobacco smoking, binge drinking after recognition of pregnancy was associated with multiparity, being unintentionally pregnant, an unskilled worker, unemployed for more than one year and having a mental/neurotic disorder (9), as opposed to women who engaged in binge drinking before recognition of pregnancy. The authors correctly made no claim that, for example, being unmarried or with an unintended pregnancy caused alcohol binge drinking, because such claims would be unfounded in a cross-sectional design. They simply concluded that to prevent binge drinking during pregnancy, healthcare providers should target their efforts toward pregnant women as well as pregnancy-planners and that it is important to be aware that women who binge drink before vs. after the pregnancy are recognized to have different social characteristics (10).

Many characteristics of, for example, pregnant women change over the course of a pregnancy. Nausea is a prevalent symptom in early pregnancy and may influence the intake of coffee and alcohol; if nausea ceases because of, for example, a missed abortion, coffee intake may change. Cross-sectional data might in this case lead to the conclusion that coffee increases the risk of miscarriage, whereas in fact the coffee intake increased only after the miscarriage, leading to inverse causation.

Under certain circumstances a cross-sectional design may still be a valid design when studying potentially causal associations. For example, if the exposure is assumed to be stable over time, a cross-sectional design may be valid. Stable exposures would include most genetic exposures, as seen in a study on the association between specific alcohol gene variants and alcohol intake among pregnant women (11). The alcohol intake was measured during pregnancy as intake before and during pregnancy, and samples of peripheral blood was also sampled during pregnancy (11,12). In this case, blood samples were not taken before alcohol intake during pregnancy was measured, but even so the underlying question in the analyses was whether gene variants could influence alcohol consumption. However, assuming that the gene variants measured are stable over time, the lack of a proper time dimension with exposure (gene variants) being measured before the outcome (alcohol intake before and during pregnancy) is irrelevant.

When cross-sectional data is used for analytical purposes, assessing the association between an exposure and an outcome, measures of prevalence are compared, theoretically creating ratios of prevalence, but usually data are dealt with in regression analyses providing odds ratios etc. (10). This should not lead the reader to think in terms of cohort or case-control studies. The analyses of association in cross-sectional studies are evidently subject to the common types of bias in cohort and case-control studies: selection bias (5), information bias (6) and confounding (13).

Attitudes, knowledge and health behavior

Studying the attitudes of patients and health professionals toward health behavior and treatment is important from a public health and organizational point of view.

Patients' attitudes

When performing fertility treatment the overall aim is to achieve one or more pregnancies in a woman. For many years it has therefore been common practice to transfer two or more embryos when performing in vitro fertilization (IVF). However, in recent decades, practice in, for example, the Nordic countries has moved toward single embryo transfer (SET) as the routine procedure (14), mainly because of the reduced risk of multiple pregnancies and the associated risks during pregnancy and birth. Even so, although the chance of pregnancy may not be substantially reduced with SET compared with transfer of more than one embryo (15), patients undergoing IVF may be reluctant to choose a procedure that is potentially less effective, especially if they have to pay for the treatment. Cross-sectional studies would contribute to the understanding of patients' attitudes, and it has been shown (16) that the majority of both women and men undergoing IVF treatment do in fact prefer to have twins for various reasons, irrespective of medical risks. Hence, a general policy of SET might be in conflict with patient interests and wishes, and this knowledge has been suggested to be useful in everyday clinical practice when explaining the rationale for choosing SET as an option, as choosing something less effective as a minimum requires sufficient and objective information and discussion (16,17).

Health professionals' attitudes

From a health professional's point of view the main reasons for not offering elective SET have been shown to be the belief among doctors that patients prefer optimal pregnancy rates irrespective of the potential complications (17), and therefore the development of more formal decision-aid tools has been advocated to help with counseling.

Patients' and health personnel's knowledge of health behavior and official recommendations

In most countries health authorities recommend not to drink alcohol during pregnancy. Even so, in many countries many pregnant women drink alcohol after conception (4). Such observations may lead health authorities to launch campaigns against alcohol drinking, but is this the right choice? Cross-sectional studies among pregnant women in different continents have shown that many women consider some alcohol drinking during pregnancy acceptable, at least in small amounts (18,19). These attitudes were not associated with knowledge of the official recommendation or with discussions between the woman and her general practitioner or midwife about alcohol during pregnancy (18). At the same time, up to half of health professionals on three continents – doctors, midwives and nurses alike – have been shown not to provide information to pregnant women in accordance with the official recommendations, even if they know the recommendations; their recommendations are in accordance with their attitudes (20–22).

The above information on attitudes, knowledge and information practice, which is available only from cross-sectional studies, is useful for planning health interventions. In the case of SET it would seem relevant to develop decision-aid tools to help with counseling as suggested, and in the case of alcohol in pregnancy, yet another campaign directed toward pregnant women may have little impact if the women receive different advice from health professionals.

Validation studies

Validity of the data used in any study design is paramount. While validity is used with slightly different meanings in different areas of research, generally validity of a measurement instrument is considered to be the degree to which the instrument measures what it purports to measure, and the validity of available data refers to the degree to which the data correspond accurately to the real world. A detailed description of different types of validity is beyond the scope of this paper.

The usual study design for validation studies is a cross-sectional design, even if it forms part of, for example, a larger cohort study (23). Examples may include:

Comparison of register-based data with information from medical records; when studies are, for example, based on data from national or other registers it may be useful to compare the information in the register with that available from the medical records (24,25), as the latter information is assumed to be the gold standard. As is often the case, operation and other procedure codes are often shown to be valid, whereas information on specific diagnoses may turn out to be less valid, especially for conditions such as miscarriage (25).

Comparison of one instrument with a gold standard; comparison of self-reported and directly measured weight and height among women of reproductive age is an example where an obvious gold standard exists (26). In

other studies, where an objective biomarker is used as a reference for self-reports of, for example, dietary components among pregnant women (27), the biomarker may not be a direct measure of that component or participants may not complete all biological sampling procedures (27), potentially causing some selection bias and/or information bias.

Comparison of one instrument with another – relative validity; in many situations there is no real gold standard. When measuring, for example, alcohol intake in pregnancy, one must rely on self-reports, as no objective biomarkers exist. Cross-sectional validation studies therefore tend to compare different instruments such as questionnaires, interviews and diaries (9) measuring the validity of one instrument relative to another, the assumption usually being that the method that yields the highest intake is the most valid, although such assumptions can be challenged. Another example would be comparison of different measures of gestational age calculated from either the last menstrual period or from ultrasound measurements. This problem is dealt with elsewhere (6,28).

Reliability studies

Reliability refers to the repeatability of findings. If, for example, ultrasound measures used in fetal medicine (29) or the monitoring of endometriosis (30) can be reproduced by the same observer (intraobserver variability) or by different observers (interobserver variability) the measures are reliable. Such studies are inherently also cross-sectional in nature, even if they form part of larger cohort studies (29), and the only study design mentioned in a given paper may be the longitudinal design (29).

Conclusion

Cross-sectional studies serve many relevant purposes, and the cross-sectional design is the most relevant design when assessing the prevalence of disease or traits, prevalence of attitudes and knowledge among patients and health personnel, in validation studies comparing, for example, different measurement instruments, and in reliability studies. However, when cross-sectional data are used for analytical purposes, authors and readers should be careful not to make causal inferences, unless the exposure may safely be assumed to be stable over time and not influenced by experiencing the outcome.

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