# TEACHING STATISTICS FOR USE IN EPIDEMIOLOGY

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**Abstract:** The design of educational objectives and learning experiences for statistics courses for students who can be expected subsequently to engage in epidemiologic tasks requires adaptation to epidemiologic uses. Academic epidemiologic researchers generally acquire satisfactory statistical competence during their careers. But the many students whose epidemiologic involvement will be only in the appraisal of published studies or in the performance of epidemiologic studies in order to meet pragmatic ends may fail to acquire the statistical skills required for these purposes and for using findings as a basis for decisions and action in the health care of groups or populations or individual patients. Statistics courses should therefore give due emphasis to concepts and procedures commonly used in epidemiologic contexts. Epidemiologic terms and concepts should be employed, and use should be made of examples and exercises drawn from epidemiology. It may be useful to provide experience in the use of specialized epidemiologic software. Appropriate coordination of statistical and epidemiologic teaching can lead to mutual reinforcement.

**Keywords**:

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I will start with two definitions of epidemiology. The first, from the Dictionary of Epidemiology (Last 1995) is "The study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to control of health problems". Note that this includes both descriptive and analytic elements, and extends to the use of findings as a basis for decision-making and action. The second definition is "Epidemiology is what epidemiologists do".

Many health professionals who engage in epidemiological studies or who use epidemiological findings know - or, what is worse, do not know - that as students they did not acquire enough of the statistical knowledge and know-how that they need for these purposes. One of the reasons for this is that their statistics courses were not adequately adapted to epidemiologic uses.

This is possibly no great problem when it comes to most investigators who conduct epidemiologic research aimed at widening the horizons of scientific knowledge concerning the causes and effects of diseases and other health phenomena. These researchers, who try "to boldly go where no man has gone before" - or (more often) to alter study methods or populations and then follow the trail-blazers' footsteps - generally work in academic settings, and have ample opportunity to obtain advanced statistical training and statistical advice and help. Some have statisticians as collaborators in their research, some become well versed in statistics themselves. This paper is not about the teaching of cutting-edge statistics to prospective cutting-edge epidemiologists involved in etiologic research. But among health professionals who engage in epidemiological studies or use epidemiological findings, these researchers are the minority.

First, there are many, generally working in health departments or health services, who conduct pragmatic epidemiologic investigations that seldom generate publishable papers, but provide a valuable basis for practical decisions concerning health care. These are studies of the health needs of a specific group or population, or the determinants of health service utilization, or of trends in the occurrence of a disease or risk factor is changing, or investigations that provide an epidemiologic basis for evaluation of a specific program's effectiveness or efficiemcy, and so on.

To the extent that these studies are concerned with etiology, they usually endeavour to determine the relative importance and impact of known causal factors in a specific group or population, rather than trying to find new ones. They are generally observational studies - descriptive, analytic, or both. If an experimental or quasi-experimental design is used, the aim is usually to appraise the performance or effect of a curative or preventive procedure or program, rather than to throw light on etiology.

Secondly, there are many more health professionals who may not themselves do epidemiologic studies, but endeavour to use the findings of such studies as a basis for their decisions concerning the health care of groups or populations (in public health, community-oriented primary care, health administration) or the clinical care of individual patients (clinical epidemiology). This requires a capacity for the critical appraisal of studies in general, and epidemiologic studies in particular - an ability to judge their quality, the validity of their findings and the inferences drawn from them, and their generalizability and relevance to the group, population or patient under consideration. Even if an overview of studies is available, the intelligent use of its results requires an acquaintance with the methods and limitations of meta-analysis. In clinical practice, what has come to be called "evidence-based medicine" focuses especially on the use of "research into the accuracy and precision of diagnostic tests ... the power of prognostic markers and the efficacy and safety of therapeutic, rehabilitative and preventive regimens" (Sackett et al. 1997).

It is with the latter two groups of professionals that this paper is mainly concerned. The net is of course a wide one - this paper might as well have been titled "Teaching statistics to students of medicine, dentistry, nursing, health education, public health, health administration, and so on". To students of veterinary medicine also, if we extend from epidemiology to epizootology.

How then, can statistics be taught in a manner that will encourage and facilitate its proper application in these epidemiologic contexts? How should educational objectives and learning experiences be shaped to meet these needs? In the same way as Kahn and Sempos (1988) tried "to write a book about statistical methods for ... epidemiology that could be read and understood by nonstatisticians", the aim, at least in a basic course, is to teach statistical methods for epidemiology in an acceptable and effective way to nonstatisticians,

***Five Approaches***

I will discuss five general approaches. These are not new, and they are already applied in many statistics courses. They are not, however, applied as widely as they could be. Their detailed application - e.g. the specific topics dealt with, and the balance between the teaching of concepts and techniques - must obviously depend on the level, needs and interests of the students, as well as on practical constraints.

***1. Emphasize epidemiological concepts/procedures***

First, the educational objectives should be expanded to give due emphasis to concepts and statistical procedures commonly used by epidemiologists. A survey of current statistics courses for medical students indicated that a syllabus of 36 topics is feasible, including the performance of 14 techniques (Dixon 1994). There should be no difficulty in fitting in epidemiologic topics. Obvious topics include the distinction between statistical significance and importance, the interpretation of a nonsignificant result, the use of confidence intervals, and the statistical elements of the criteria commonly used by epidemiologists when making judgements concerning causality (Rothman and Greenland 1998).

As simple examples of less obvious topics: assuming that exposure to a given factor is a cause of a given disease, the attributable fraction in the population is an easily-computed measure that tells what proportion of the disease rate can be attributed to the factor, and (under certain conditions) would be prevented if the factor were removed.

Similarly, the attributable fraction in people who are exposed to a risk factor can indicate what proportion of their risk of contracting the disease would be removed if they ceased to be exposed. These simple indices are of obvious value as a basis for decisions about care at both a community and an individual level. But they are generally ignored in statistics courses. I have found only two textbooks on statistics in the health field that describe these indices: those by Armitage and Berry (1994) and Kahn and Sempos (1989). There may be others; but these indices are not mentioned in (for instance) the excellent books by Selvin (1996) and Altman (1991), or in Daniel's (1995)_widely-used basic text.

As a third simple example: if people exposed and not exposed to a preventive procedure (such as immunization or screening for disease), a therapeutic regimen, or a risk factor (like smoking) are compared, the inverse of the difference between their risks of disease or death can be used as an indication of the number of people who must be immunized, screened or treated or must stop their exposure in order to prevent one case of disease or death. I have found no mention of this so-called "Number needed to treat" in statistics textbooks. Its computation is simple; but its confidence interval presents difficulties (Altman 1998) that merit discussion by a statistician.

It is of interest that all three of these indices are based on a difference between disease rates. Differences between rates are often particularly useful as a basis for decision-making, because they indicate the magnitude of a public health problem or the cost of its management; but they are often neglected in the teaching of statistics, at the expense of ratios (risk ratios, rate ratios, odds ratios), which have advantages in studies of causal processes. Other examples of the many statistical indices or methods commonly used in epidemiology, but often ignored in statistics courses, are the use of rates with person-time denominators, methods of controlling for confounding, measures of agreement (particularly kappa), indices of the validity of data (e.g. sensitivity, specificity), and other measures applicable to screening and diagnostic tests, such as the likelihood ratio and the predictive value of positive and hegative results.

Students should be warned of flaws, or questionable approaches, commonly seen in epidemiological studies.

One example is the tendency to dichotomize unnecessarily, thereby losing information; many epidemiologists seem to live in a simplistic world in which everything has two faces - diseased or well, smoker or nonsmoker, exposed or not exposed.

As a second example, Mantel-Haenszel and other overall measures of association are often used to combine the findings in different strata so as to control for the confounding effects of the stratifying variables, or (in metanalyses) to bring together the findings in different studies; but this is often done even when the findings in the strata or studies are so heterogeneous that a single overasll measure has little value. Similarly, odds ratios adjusted for other variables are often derived from multiple logistic regression analyses, without including interactions in the model; it is not difficult to find data that illustrate how misleading these odds ratios can sometimes be.

***2. Language of Epidemiology***

A second way of making statistical teaching more relevant to epidemiologic uses is to use the language of epidemiology, both in theoretical teaching and in examples and exercises. The use of epidemiologic terms and concepts, like "prevalence" and "incidence", "rates" and "risks", "case-control studies" and "cohort studies", "confounding" and "effect modification", "multiplicative" and "additive" effects, and "risk factor" and "risk marker" may ease the transition to epidemiologic applications. This may be a way of stimulating interest in statistics, by making it more "relevant". In many instances students will benefit from having these terms and concepts explained by statisticians rather than only by epidemiologists - provided that excessive emphasis on technicalities and formulae is avoided.

***3. Examples from Epidemiology***

Thirdly, use should be made of examples and exercises drawn from epidemiology. Illustrations based on real or simulated epidemiologic studies can be used in the teaching of statistical concepts, and practical exercises in the analysis or interpretation of data can be based on actual epidemiologic findings These exercises can provide experience in the measurement of the strength and impact of associations, in the exploration of modifying and confounding effects, in the control of confounding, in inferences concerning causality, and in prediction of the effects of intervention. Exercises can also serve as launching-pads for discussions of the many kinds of bias (Choi and Noseworthy 1992, Choi and Pak 1998) that may beset epidemiologic studies. If projects are assigned to the students, they should be epidemiologic in nature; and if published papers are critiqued as part of the course, they should include reports of epidemiologic studies, preferably recent papers dealing with live issues. In each of these instances, the choice of topics of interest to the students may be crucial.

***4. Epidemiologic Software***

Fourthly, it may be useful to provide the students with hands-on experience in the use of epidemiologic software - that is, packages that are specifically designed for epidemiologic uses and employ epidemiologic terms. A recent review of 11 such packages, as well as one general-purpose statistical package with specialized routines for epidemiologists, points out that this software "provides output that is almost exactly what an epidemiologist is expecting", as well as analytic techniques that are not included in general-purpose packages (Goldstein 2000). In a basic statistics course, emphasis should be placed on analysis, not on data entry, management, sorting and tabulation. Use of these programs can be a useful learning experience in a statistics course, as it is in epidemiology courses (Abramson, in press). It familiarizes students with statistical procedures, including those used in epidemiology, and facilitates the performance of practical exercises requiring computations. The programs also enable students to do "what if?" exercises (Larson 1985); for example, they make it easy to learn, by manipulating data, how the sensitivity or specificity of measures can alter an odds or risk ratio, how differences in prevalence or the number of controls per case can alter the required sample size, or how exclusion of a single study can affect the results of a meta-analysis. The programs may be helpful not only in the planning and analysis of studies, but also when reviewing a published study, e.g. by permitting appraisal of the effect of misclassification on a published odds or risk ratio. In clinical epidemiology, a program like SCRN, in the public-domain PEPI package (Abramson and Gahlinger 2000) can use the findings of a screening or diagnostic test in groups studied previously (specificity and sensitivity) to compute a patient's probability of the disease and the extent to which performance of the test increases the certainty of diagnosis, as well as permitting choice of the best critical cutting-point for the test, depending on the relative value attached to false positives and false negatives. Familiarity with such software, if it is user-friendly, obviously enhances the probability that the student will continue to use these procedures. If such software is used, the teacher's main task is to explain the thinking behind the procedures, their purposes, how and when they should be employed and when and how they should not, and how to interpret - and how not to misinterpret - the results. Detailed explanations of formulae and their mathematical derivation are less important and may be self-defeating, and it may be best to dispense with them. In the same way as the manual extraction of square roots has been superseded by the use of a calculator or computer, there is no reason, for most users, why significance tests, the estimation of confidence intervals, or other procedures should not be left to a computer, provided that the methods of calculation have received expert approval. The delegation of statistical arithmetic to computer programs can expand the time available for discussing statistical concepts.

These four approaches obviously require the statistics teacher to know something about epidemiology and what epidemiologists do. In a paper on "What statistics should we teach medical undergraduates and graduates", Appleton (1990) ended his conclusions with the question, "What courses should our medical colleagues give us?".

### *5. Collaboration*

This leads on to the fifth approach - collaboration between teachers of statistics and epidemiology. The optimal, if unlikely, situation may be complete integration of the teaching of the two disciplines; after all, they have much in common - both deal with numerical data, and both require the student to think, and not just memorize facts. The minimum level of cooperation is that the teachers of each discipline should know what the teachers of the other are doing, and take account of this knowledge when planning their courses. Overlaps can be avoided, and semantic confusion avoided - the terms "interaction", "dependent variable", "intervening variable", "univariate analysis", and "estimation", for example, may not mean the same to a statistician and an epidemiologist. Effective collaboration, with an ongoing dialogue, may lead to coordination of the sequence and timing of topics, ensure that each course provides the foundations and bolstering that the other needs, and in general have a synergistic mutual-reinforcement effect.

These five simple approaches - emphasis on topics of importance to epidemiologists, the use of epidemiologic language, epidemiologic illustrations and exercises, the use of epidemiologic software, and collaboration with teachers of epidemiology - should, even if they do not turn out accomplished epidemiologists, at least make statistics courses more enjoyable.

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