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THE TEACHING OF STATISTICS TO UNDERGRADUATE MEDICAL STUDENTS

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There can be no argument about the need for medical students to acquire
some knowledge of the general principles that underline the statistical method
of handling and interpreting biological and medical data. At the beginning
of their training the teaching of anatomy, physiology, and biochemistry will
be seriously deficient if it does not include instruction about the continuous
distribution of biological variables (of physical, physiological and biochemical
measurements) in the general population and make clear that it is rarely possible
to draw a precise line between the normal and the pathological. Their clinical
training will be incomplete unless they are repeatedly reminded that most medical
problems have of necessity to be examined through a grid of interrelated physio-
logical, psychological and social variables, and that numerical statements about
prevalence, prognosis and treatment cannot be accepted at their face value but
must be subjected to statistical scrutiny. Any teaching in preventive medicine
will be valueless if it is not based on statistical statements about current
health problems and statistical evaluation of prophylactic measures.

In what follows I propose to consider briefly what should be the aims
of teaching statistics to medical students, what difficulties lie in the way
of achieving those aims and, in conclusion, to discuss in the light of those
considerations what should be the content and timing of an effective teaching
programme.

I   AIMS OF TEACHING

The purpose of teaching statistics to medical undergraduates is
certainly not to enable them to design their own experiments, conduct their
own surveys or analyse their own research data. Teaching at that level is a
post-graduate matter. So far as undergraduates are concerned, the most that
can be hoped for is that they should learn to recognize when special statistical
advice is needed in those fields. The basic purpose should be to help them
to acquire what Bertrand Russell has described as "the habit of forming
opinions on the evidence and of holding them with that degree of certainty
which the evidence warrants". In less philosophical and less general terms
the aims of teaching should be:

1.   to educate students to think quantitatively about medical and
      biological problems;

2.   to enable them to understand the meaning of the conclusions
      reached by statistical methods;

3.   to demonstrate how statistical methods are used to measure the
     health of populations and to evaluate the effectiveness of health
     and social services;

4.   to train them in the duties and responsibilities they will have,
     when qualified, in relation to the vital and health statistics
     of their own country.

What statistical ground needs to be covered if those aims are to be
achieved?   Most teachers will agree that all the following subjects should
be included, although there are likely to be diferrences of opinion about
the amount of time to be spent on each:

1.   the idea of a frequency distribution, and the need for measures
     of dispersion and summarising indices, and their implication in
     relation to natural variability and to physiological and biochemical
     norms;

2.   the idea of sampling, and the problem of bias, observer variation
     and patient variation in relation to clinical measurements, the
     design of experiments, and population surveys;

3.   the statistical concepts of chance and probability, and the
     rationale of significance tests, and their use and abuse in
     relation to medical problems;

4.   the concept of correlation and of concurrent and causal relationships;

5.   the use of diagrams and their abuse: what diagram is appropriate
     for a given purpose and how to construct it; how to interpret
     diagrams; and how to recognize when they have been misused
     (deliberately or subconsciously) to lend support to doubtful
     arguments;

6.   the use of percentages, ratios, and rates; the sources,
     imperfections, and limitations of official local, national,
     and international medical statistics; and the need for
     standardisation when comparing data from different sources.

II   DIFFICULTIES TO BE FACED

Many difficulties lie in the way of achieving the aims we have defined.
It will help us to plan a more effective and realistic teaching programme
if first we recognize and bring into the open those difficulties.   They are
of two kinds: those relating to the teachers; and those relating to the taught.

1. Difficulties relating to the teachers

a)   Most clinicians have a deep-rooted antipathy to any form of numerical thinking, so that curriculum committees are weighted with members who although they will admit, perhaps under pressure, that statistical methods have made a valuable contribution to clinical as well as laboratory research, consider the claim of statistical teaching to a place in the overcrowded curriculum of low priority.

b)   Many hours of teaching time are needed if instruction in statistics is to be effective, particularly if the students are to be given the opportunity to collect, sort, tabulate and interpret their own data.

c)   In most countries of the world there is an acute shortage of suitably qualified teachers.   There are very few medically qualified statisticians, while non-medical statisticians with a biological background are even more difficult to find.

2. Difficulties relating to the students

a)   In the past, statistics, if taught at all, has been introduced at too late a point in the medical curriculum.   The subject has usually been taught in the fourth or fifth year, by which time the student is too absorbed by the fascinations of clinical practice to pay much attention to or see the relevance of statistics to medicine.

b)   Medicine appears to be selective for students with less than average mathematical ability.   This is in part due to the fact that mathematically gifted students tend to be attracted by the more scientific disciplines.   It is also due to the perhaps unnecessarily high level of knowledge that pre-medical students are expected to acquire in physics, chemistry and biology, which leaves them, even should they have the inclination, with no time to study advanced mathematics.

c)   Teaching becomes unacceptable to most students if too much time is spent on arithmetical and algebraic procedures, on the derivation and learning by heart of formulae (summarising indices and tests of significance).   It is not easy to achieve a satisfactory balance between systematic instruction and intellectual stimulation, but there is no doubt that for medical students the emphasis must be on the understanding of principles and not on the learning by rote of facts and formulae.

d)   It is unrealistic to expect students to pay attention to a subject which most of them regard as marginal unless there is compulsory attendance at lectures or a written examination. Of those two methods of compelling attention, a written examination is both more in keeping with the university idea and more effective.

III CONTENT AND TIMING OF SYLLABUS

In the light of what has been said about the aims of a teaching programme and the difficulties which have to be overcome before the aims can be realised, four general principles can be enumerated as a guide to what is required:

1. medical students must be made familiar with the statistical approach to biological problems as early as possible in their university training;

2. the relevance of statistics to biological and medical problems must be underlined throughout their undergraduate training from the preclinical years onwards;

3. those teaching the subject must have a direct and day-to-day interest in medical problems. This does not mean that the teachers need to be medically qualified. It does mean, however, that their approach must be biological and medical rather than mathematical;

4. because of the limited mathematical ability of many students, sophisticated algebra and too much tedious arithmetic must be avoided and teaching should as far as possible be in small groups.

If these principles are accepted, it will be seen that the subject does not easily lend itself to being taught as a separate discipline but is more readily introduced to medical students in relation to their immediate academic interests at successive stages in their training. To this end, the teaching may conveniently be divided into three parts:

1.   general principles and methods;

2.   the application of statistical methods to medical problems;

3.   vital and health statistics.

1.   <u>General principles and methods</u>

This course should be given at the beginning of the medical curriculum, alongside anatomy, physiology and biochemistry. At least ten one-hour periods of formal teaching are called for, a supplement of practical work is advisable, and there should be a compulsory examination at the end. The following subjects should be dealt with:

a)   general introduction on the variability of biological and medical data;

b)   sources of data (surveys and experiments);

c)   reduction and presentation of data (tabulation, frequency distribution, mean, mode, median and variance etc.);

d)   introduction to the idea of probability;

e)   the concept of population and sample;

f)   sampling problems;

g)   statistical estimation (tests of significance, their application and interpretation);

h)   association and correlation and the concept of concomitant variables and causal relationships.

How the time available for teaching is divided between lectures and practical work will depend on the number of teachers and the amount of equipment available in a medical school, but the value of well-planned practical work cannot be over emphasized.   The practical work must be related to the students work in physiological and biochemical laboratories or dissecting rooms.   In this respect, measurements of arterial pressure taken with the mercury sphygmomanometer and blood counts provide excellent material for illustrating how a biological variable is distributed in a sample of the young adult population and for introducing students to the notion of observer variation in clinical medicine.

2.   The application of statistical methods to medical problems

This part of the teaching should demonstrate the relevance of statistical methods to all branches of medicine.   In it an attempt should be made to discuss and illustrate the following problems:

a)   physiological and biochemical norms;

b)   distribution of symptoms and laboratory measurements in relation to diagnosis;

c)   prognosis and survival rates;

d)   design of laboratory experiments;

e)   design of field surveys;

f)   problem of observer variation;

g)   controlled therapeutic and prophylactic trials;

h)   biological assays of drugs and toxic substances.

It is not possible to suggest how much time should be devoted to this teaching, for certain parts of it will be dealt with much more fully in some medical schools than others, depending on local problems and on the interests of local teachers.

The need for a statistical approach to the design of laboratory experiments can be pointed in biochemistry and pharmacology, and the complications introduced by observer variation illustrated in the context of the students' own laboratory work.   In the teaching of therapeutics, an opportunity is provided to enlarge upon the problem of bias in sampling, to indicate how therapeutic trials are planned, and to explain the rationale of the simpler tests of significance.   At the same time, the student can be taught to regard with a sceptical eye the therapeutic claims made in breakfast-table medical literature.   The need for and value of properly controlled trials of prophylactic therapy can be illustrated during bacteriological teaching with the examples of B.C.G. and the poliomyelitis vaccines.   Clinical medicine presents many opportunities to remind students that in the population biochemical measurements are continuously distributed, and that consequently there is no clearly defined line between the normal and the pathological.   Attention can be also drawn to the complication of observer variation in the interpretation of diagnostic procedures such as chest X-ray and electrocardiography and even in the recording and interpretation of symptomatology.   These ideas are perhaps best imparted at the bedside or in the side ward by means of joint teaching sessions held by the departments of medicine and of social medicine, with active student participation.   In addition, while the student is studying clinical medicine, there is a place for discussion in small groups of selected articles drawn from recent issues of medical journals, to illustrate the use and misuse of diagrammatic and tabular methods of presenting numerical data, the interpretation of tests of significance and, above all, the need for a careful and informed statistical approach to a medical investigation and a logical presentation of its results.

3.   Vital and health statistics

This part of the course forms an important part of the teaching of preventive medicine, public health and allied subjects.   It should include:

a)   size, structure, movement and growth of populations;

b)   definitions of vital events and of commonly used indices (rates, ratios, etc.);

c)   nomenclature and classification of disease, injuries and causes of death;

d)   sources of data on mortality, morbidity and disability (certification of cause of death, notification and registration of diseases, health surveys etc.);

e)   methods of measuring and comparing the health of populations (anthropometry, morbidity, mortality etc.);

f)   study of factors influencing health (biological, social and economic);

g)   numerical description and evaluation of health services and their activities.

There is a tendency in some schools to separate the above material from the main body of instruction under the heading of vital or medical statistics. It is more readily accepted and possibly more effectively presented as illustrative material in the general teaching programme of preventive medicine and allied subjects.   The amount of time given to the component parts of this section will of course depend on the amount of curriculum time allocated to the department of preventive medicine and on the medical needs and problems of the country concerned.

In conclusion it may be said that the teaching of statistics in the manner outlined above has two great advantages: by allowing the subject to permeate the whole of the undergraduate training, it overcomes the difficulty of finding a separate place for it in the already overcrowded curriculum; and by always relating the subject to the students' current biological and medical interests, it makes it easier to hold their attention.   However, the programme has one serious disadvantage: it is difficult to coordinate. Until every medical school has a department of medical statistics, and perhaps even then, responsibility for ensuring that the necessary ground is covered must rest with the head of the department of preventive medicine (or its equivalent) and members of that department should participate in the teaching at every step.