

KERTAS SIMPOSIUM

**EPIDEMIOLOGIC METHODOLOGY IN PUBLIC HEALTH:
NEW FRONTIERS & CHALLENGES***Omar Hasan K ****ABSTRACT**

The paper describes new and innovative applications of the epidemiologic methodology outside the traditional domain of diseases, infectious and non-infectious. Epidemiology, being a methodological discipline, has no coherent subject matter but finds applications in various disciplines. It was used in the study of epidemics of infectious diseases even before the term epidemiology was coined. Over the past 50 years the epidemiologic methodology has been extended to the study of chronic non-communicable disease. The epidemiologic methodology has been extended, over the past 10-15 years, to the study of non-traditional fields that are now designated as sub-disciplines: hospital, drug, radiation, genetic, molecular, nutritional, environmental, occupational, accidental injury, geriatric, and psychiatric, behavioral, and social epidemiology. Beyond these are the new frontiers of health policy, health services planning, health care financing, health care delivery, economic analysis, and health program evaluation that are increasingly relying on epidemiologic data and epidemiologic methodology. These will constitute the main growth area of the discipline in the 21st century. The paper identifies the main elements of the methodology that have remained constant and are likely to guide the growth of the discipline in the next century. The epidemiological methodology in essence is inference on the causal relation between cause and effect while preventing, eliminating, or adjusting for the 3 main types of bias (selection, misclassification, and confounding). Developments in the fields of statistical modeling with the accompanying hard and software will enable a deeper and richer understanding of multi-causal relations by describing interaction effects (synergistic and antagonistic) as well as effect modifications. Intervention, definable as looking at the causal relation in reverse, is the main underlying objective of epidemiological studies and involves interrupting, reversing or mitigating the effect of causes. Epidemiology will continue enjoying pride of place among public health disciplines in being able to devise ways of successful intervention even before the detailed understanding of the causal relation at the molecular level is achieved. The most effective interventions in this regard are those that modify human behavior and lifestyle. A preponderant majority of disease conditions can be either prevented or cured by available medical knowledge and technology. The last frontier that medicine has yet to conquer is changing the human will to adopt healthy life-styles

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and avoid unhealthy ones. Epidemiological studies can link specific life-styles to specific diseases enabling effective interventions even if the mechanisms may not be known fully. It is the considered opinion of the author that the increasing specialisation within epidemiology will not lead to the 'death' of the mother discipline. Neither will the mother discipline turn into theoretical epidemiology. It will remain close to its practical and empirical base. Epidemiologists will continue being involved in the application of their methodology to real-life public health problems unlike theoretical physicists or mathematicians who can afford to keep their hands clean from toiling in the field. Most of the growth forecast in epidemiology will be in the area of applying epidemiologic data to large and detailed data sets on human populations and environmental variables. No spectacular developments are forecast in the methodology of study design or study analysis. Meta or pooled analyses will become more popular as studies and databases proliferate.

Key words: epidemiology, methodology.

EPIDEMIOLOGICAL STUDIES

Basic Characteristics Of The Epidemiologic Methodology

Epidemiology uses the procedures of the scientific method: stating a hypothesis, collecting and analyzing data to test the hypothesis, and reaching conclusions about the hypothesis. The epidemiologic methodology ensures continuous improvement of knowledge by generating and testing new hypotheses. An epidemiological hypothesis is formulated to relate two phenomena: the disease and the putative cause of the disease, the exposure or risk factor. Hypotheses must be specific and testable. Empirical data is from experimentation and observation. The conclusions from testing a hypothesis can be rejection/non-rejection and never acceptance. A new hypothesis is generated from the conclusion and the process is repeated. Use of the scientific method implies among other things that epidemiological knowledge is never stable. It keeps on changing and getting nearer the truth as new information is discovered.

Epidemiological methodology is empirical, inductive, and refutative. Empiricism refers to reliance on physical proof. Epidemiology relies on and respects only empirical findings. There is no room for preventive action being based on pure reasoning, rationalism, not subjected to empirical verification by collection and analysis of data. Both inductive and deductive logic are used in epidemiological reasoning. The inductive is used more because it is more in line with empirical experimental verification. Induction is a type of reasoning that starts from one observation and generalizes. Refutation is a type of scientific reasoning introduced by the philosopher Karl Popper (1) that emphasizes rejection of suppositions rather than accepting them. Rejecting an idea opens the way to test other ideas. Epidemiology can refute a finding but can never offer conclusive proof. This is in line with the spirit of empirical inquiry that knowledge and understanding grow continuously and

facts accepted and interpreted in one way today may be rejected and interpreted in another way tomorrow.

Natural Experiments

Natural experiments are not deliberately designed by humans. They can, however, be analysed to provide insight at little cost to humans because they just involve observation of events. They however are rarely conclusive. Natural experiments can be divided into 2 types. Some involve no human agency at all like earth-quakes, floods, and cosmic radiation. Others involve human action which is not deliberate or planned in any systematic way.

The following are classical examples of natural experiments:

- 1948: Smog episode in Danora, PA. (2)
- 1952: The London fog of 1952 that killed 4000 persons in 10 days (3)
- 1854: Snow's study of the relation between polluted water and cholera in London (4).
- 1929: Occurrence of polio after tonsillectomy (5)
- 1976: Cancer in accidental chemical exposure (6, 7)
- 1945: Cancer in survivors of atomic explosions in Hiroshima and Nagasaki (8, 9, 10)
- 1981: Heart attacks and asthma following the Athens earthquake of 1981 (11).
- 1962: The thalidomide disaster (12)
- 1951: An epidemic of deafness in Australia (13)

True Experiments

True experiments involve deliberate human action or intervention whose outcome is then observed. Their objective is to establish the definitive causal relation. True experiments are more involved and expensive than observational studies or natural experiments but are still cheaper and easier than laboratory-based research. The main strength of experimental studies is good control of extraneous or confounding factors that might make interpretation of study results difficult. The main weaknesses are that well controlled experiments on humans are difficult. It is difficult to put humans under full experimental conditions where they can be observed for 24 hours. Ethical controversies and violation of human rights always arise in such studies.

The following are classical examples of true experiments

- 1747: Lind's trial of fruit juice for scurvy in 1747 (14)
- 1796: Jenner's cowpox vaccination in 1796 (15)
- 1915: Induction of pellagra by Goldberger and Wheeler in 1915 (16)
- 1905: Discovery of the relation between rice and beri-beri by Fletcher in Kuala Lumpur in 1905 (17)

Community Intervention Studies

A community intervention study is designed to test whether a certain public health intervention such as health education or water fluoridation has an effect on a given outcome measure. Two or more similar communities are randomly allocated to receive different interventions and the outcome is then measured. Random allocation ensures comparability. The strength of the community intervention study is that it can evaluate a public health intervention in natural field circumstances. The weakness is that people in the control community may receive the intervention under study on their own because tight control as occurs in laboratory experimental or animal studies is not possible with humans.

Classical examples of community intervention studies are:

- 1970: Tests of the prevention of dental caries by fluoridation carried out by the United States Public Health Service, USPHS, in 1970 (18).
- 1997: Trials of vaccination efficacy (19)

Observational Studies

Observational studies, descriptive or analytic, allow nature to take its course with no human interference. They usually precede and prepare for definitive experimental studies. Cross-sectional (prevalence), case-control, and follow-up studies are the main types of observational studies in epidemiology. The advantages of observational studies are their low cost and lack of ethical controversies. A cheap study is made of a wide variety of human experiences by just observing and recording information. This is much cheaper than experimental studies in which people must be subjected to various treatments and exposures at the experimenter's cost. Ethical problems in observational studies are much less than those in experimental studies because the human subject is not exposed to any major physical risk. Observational studies have three main disadvantages. It is not possible to study etiology directly because the investigator does not manipulate the exposures. Etiology is studied only indirectly by comparing disease experience in the group exposed to a putative risk factor with the group that was not exposed. Information on the variable of interest may not be available recourse being made to surrogate variables. Several unplanned co-factors (giving rise to confounding, interaction, or effect modification) are involved making interpretation difficult. Experimental studies, unlike observational studies, collect systematic information on these co-factors rendering study interpretation easier.

Most of epidemiological study is observational. The following are a few classical examples

- BC: Hippocrates and observations on the relation between disease and environment (20)
- 1652: Observations by Graunt on the London bills of mortality (21)

- 1885: Observations by William Farr based on vital statistics of England and Wales (22)
- 1861: Semmelweiss's observation of the relation between washing hands and child-bed fever (23)
- 1954: Relation between working in the dye industry and bladder tumors (24)
- 1965: Cancer mortality after irradiation for analysing spondylitis (25, 26)
- 1952: Smoking and lung cancer (27, 28)
- 1959: Cancer of the cervix and circumcision (29)
- 1958: Social class and mental illness (30)
- 1955: Neoplasia in children treated with x-rays (31)
- 1965: Cancer in uranium miners (32, 33.)

Confirmatory studies of established knowledge are being carried out in different countries and in different population sub-groups for example the study of cigarette smoking and lung cancer in Spain (34).

New innovative approaches are being used in observational studies with the availability of more detailed information about diseases and exposures from molecular studies. Novel study designs are also tried out; a good example being case-parent studies of genetic diseases that use the parental genotype as a comparison(35).

SUB-DISCIPLINES OF EPIDEMIOLOGY

Infectious Disease Epidemiology

Epidemiology started as a study of infectious diseases first as epidemics and later as non-epidemics. It was assumed that with the discovery of effective anti-microbial agents, access to health care, and improvements in environmental sanitation, infectious diseases would disappear from the industrially-developed countries. This assumption has been proved wrong by the current epidemic of HIV and other sexually-transmitted diseases. Human behavior and life-style are proving to be a last barrier to eradication of infection. In poor developing countries, there are no resources to deal with infectious disease. Some diseases that were controlled before can reappear. TB once virtually banished from industrially-developed countries is spreading now in tandem with the HIV epidemic. Complacency in immunisation against diphtheria led to a resurgence in Europe in the 1980s (36). Measles once controlled by wide-spread childhood immunisation is now appearing as a severe disease of college students (37).

Non-Communicable Disease Epidemiology

Non-communicable diseases, also called chronic or degenerative diseases, have a prolonged course, are generally rare, and have no spontaneous resolution. Data on these diseases is incomplete and search for causes is still in its infancy. There is a general increase in the incidence of these diseases explained by the relative decrease

of infectious disease, increasing life expectancy and longevity, and social and environmental changes. Definitive causes for most of these diseases are not known. The future of cancer epidemiology research lies in the field of chemo-prevention that is witnessing several recent studies (38, 39, 40).

Hospital Epidemiology

Hospital epidemiology traditionally was concerned with surveillance and control of hospital infections. Hospital epidemiologists were employed to study incidence and prevalence of nosocomial infections, their sources, and associated epidemiological factors. They would also plan and implement control measures. Epidemiological surveillance of hospital infections has been made easier by computer programs that systematically search computerised laboratory data for patterns and trends (41). Besides infections, new areas of opportunity are opening up for hospital-based epidemiology. Hospitals collect a lot of medical and social data about healthy individuals and patients. The linkage of records over a region constitutes an epidemiological data bank which if combined with socio-demographic and other computerised data on citizens, provides an opportunity to study many linkages between causative factors and disease outcome while controlling for confounders. Hospital-based cancer registries may in the end prove more effective than national or regional cancer registries. Linkage of such registries in a region provides a very fertile area for cancer epidemiological studies. Epidemiologists can assist hospital administrators in policy-making by studying performance indicators, process and outcome, while relating them to specific determinants and controlling for confounders. The epidemiologists can use their accumulated data on morbidity and mortality to provide hospital administrators with projections of future admission patterns so that forecast of bed capacity and other facilities can be done accurately. Epidemiologists are involved in data analysis for patterns, trends, and determinants of health care for purposes of hospital quality assurance programs.

Clinical Epidemiology

Clinical epidemiology is a bridge between epidemiology and clinical medicine. It applies epidemiological principles in clinical medicine to improve the diagnosis and management of disease. It has a wide scope covering disease definition, diagnostic criteria, risk assessment, prognosis, evaluation of treatment outcome, and prevention. It also helps in the quantitative interpretation of diagnostic and screening tests. The same principles and methodologies used in population-based epidemiology are used in clinical epidemiology with a few necessary modifications

Disease Screening Epidemiology

Screening is a type of secondary prevention targeted at apparently healthy individuals who are at risk of a particular disease. It is defined by the World Health Organisation as presumptive identification of unrecognised disease or defect examination or other

procedures that can be applied easily. Screening programs have three objectives: decrease morbidity, decrease mortality and improve the quality of life. Epidemiologists using available data and knowledge select diseases and screening procedures that are suitable. They also evaluate the cost-effectiveness of the screening programs by using process parameters (sensitivity, specificity, and predictive value) and outcome parameters (morbidity, mortality, and quality of life). Correct interpretation of outcome parameters requires consideration of lead-time and length biases. There is current interest in studying the efficacy of screening programs because this has policy implications. Screening has been shown to decrease breast cancer mortality but more work needs to be done to clarify several outstanding issues (42) to justify the economic investment that has to be made in such screening programs. A new addition to the arsenal of screening is the increasing use of biomarkers for earlier detection of cancer (43).

Drug Epidemiology

Epidemiologists contribute to strategies of both primary and secondary prevention of adverse drug reactions, drug interactions, and drug poisoning by epidemiological surveillance. Their job is made much easier by existence of extensive hospital and prescription data-bases that can be easily linked in an area network. Much work needs to be done in this area given the increasing use of prescription and non-prescription drugs for real and imaginary conditions. Epidemiological studies have to be directed to the study of post-vaccination adverse effects (44) because developments in immunology are putting an increasing number of vaccines on the market. The field of toxo-epidemiology investigates poisoning using a variety of techniques (45).

Radiation Epidemiology

Epidemiological studies over the past half century have raised awareness of health effects of ionising radiation from environmental, industrial, and military sources. The studies take a long time to conclude since radiation effects are usually seen long after the exposure. The studies aim at two main objectives: establish the health effect of the exposure and define the dose-effect relationships. These studies contribute to the determination of safe exposure levels in both the industrial and medical environments. Fear of a nuclear war is receding but nuclear accidents at power plants are likely to increase because more such plants are being built all over the world to provide 'clean' power in place of the fossil-based power generation that pollutes the atmosphere. Studies carried out at the 10th anniversary of the 1996 Chernobyl nuclear accident showed no cancer increase in cancer incidence in the countries that were most heavily exposed (46). The 10-year period of follow-up is perhaps too short; a second look after 20 years may show different results.

Genetic Epidemiology

Recent developments in molecular biology are unraveling the role of genetic disorders in disease. About 5-10% of chronic diseases have a genetic component. Genetic disorders are involved in up to 30% of hospital pediatric admissions in developed countries. Genetics is becoming increasingly important in epidemiological research (47). The interaction between genetic and environmental factors in multi-factorial disorders is also unraveled. The Balkan Endemic Nephropathy is an example of a condition with both genetic and environmental factors (48). Epidemiologists undertake genetic mapping studies relating specific genetic formations to specific diseases. They also compute disease risks for communities using their genetic distribution. Study of the molecular biology of the mutation of the p53 cancer gene can yield important information about the prognosis of breast cancer (49). Gene tests or genetic testing can be used to detect hereditary pre-disposition to cancer (50, 51) and cystic fibrosis (52). More work is needed in this area because the economic implications of such tests may be very far-reaching. Genetic counseling is a growing field (53). This is being driven by rapid advances in molecular biology and the understanding of the human genome.

Molecular Epidemiology

Molecular biology could be considered a part of genetic epidemiology. It can equally well be considered part of toxicology. It has raised the need to cross-train epidemiologists and laboratory scientists (54). Recent advances have enabled epidemiologists to study biological markers of disease that are not necessarily related to genetic factors. Molecular epidemiology is enabling study of the relation between low-dose carcinogens and genetic susceptibility to disease (55). DNA figure printing was used to study TB transmission in the Netherlands (56). This is far more effective than contact tracing using traditional methods.

Nutritional Epidemiology

Diet is thought to contribute to at least 90% of cancers. It is also an underlying contributing factor to many diseases. The dietary mechanisms in particular diseases however remain elusive. Nutritional epidemiology is one of the oldest sub-disciplines in epidemiology. It started as study of diseases related to under-nutrition. It has extended to study of diseases of over-nutrition. One of its earlier concerns was to establish the normal dietary requirements. More work needs to be done in this area. Available dietary guidelines still require further epidemiological, clinical, and laboratory studies because many are not based on rigorous scientific evidence. Another area of concern in nutritional epidemiology is to relate intake of specific nutrients to disease like the study of the relation between anti-oxidants and coronary heart disease (57). There are still unresolved issues in the study of the relation between lung cancer and diet (58) as well as between diet and colo-rectal cancer (59).

Environmental Epidemiology

Environmental epidemiology is a sub-discipline of epidemiology that studies environmental causes of human disease and how to prevent such diseases. It started with infectious diseases but has now expanded to air, water, and soil pollution and contamination. Where causes can not be eliminated, environmental epidemiologists carry out studies to determine and recommend safe exposure levels.

Occupational Epidemiology

The industrial revolution of the mid-19th century gave rise to diseases and conditions that were hitherto uncommon. With more industrialisation and employment in new settings, more physical and psychological effects of the work-place on health are becoming apparent. Epidemiologic studies seek to investigate suspected hazards, determine the quantitative relation between hazard and disease, and assess the effectiveness of intervention programs. Both morbidity and mortality studies are carried out. Most potential exposures at the work-place have not been investigated. Epidemiologic methods are being employed in the study of occupational problems such as ergonomics (60). Not even exotic occupational hazards such as vocal problems of teachers are not neglected by epidemiology (61).

Accidental Injury Epidemiology

Traumatic injury is a rapidly rising cause of morbidity and mortality. Accidental injuries are increasing in developed and developing countries. Most are under-reported in developing countries (62). About 50% of injuries occur in homes affecting mostly young children and the elderly. Behavioral factors, including drugs and alcohol, are involved in road traffic accidents and homicide. The epidemiological study of accidental injury is in its infancy. It seeks to unravel the causative web that is complex and long.

Pediatric Epidemiology

Preventable infant mortality has fallen over the past century due to general socio-economic improvement. There however remain a core of residual causes of peri-natal morbidity and mortality that epidemiologist have to study. These are usually multi-factorial involving environmental and genetic factors. Over the past decades the relation between smoking and bad obstetric outcome has been studied. With development of more detailed investigative techniques these relationships are being revisited for example the relation between smoking and placental calcification has been investigated (63). This will in the end contribute to understanding the causal pathways.

Geriatric Epidemiology

The proportion of the elderly is increasing in all countries of the world due to increasing life expectancy at birth, falling fertility rates, and falling late-age mortality. The elderly are subject to higher disease and disability risk which need to be studied and prevented. Epidemiologists also play a role in forecasting future needs of geriatric care by extrapolating from current morbidity and mortality trends.

Psychiatric Epidemiology

Psychiatric morbidity is on the increase world-wide because of increasingly stressful life-styles and also more awareness by both patients and physicians. Accurate epidemiological data on psychiatric conditions is lacking. Causal associations are poorly understood. Epidemiological study of risk and prognostic factors in psychiatry helps plan preventive and intervention programs (64). Methodological inadequacies limit the use by law enforcement agencies of findings relating major mental disorders and crime (65).

Behavioral Epidemiology

The role of human behavior in disease is taking a center role but rigorous epidemiological studies of the factors underlying human behavior are very few. Part of the difficulty of such studies lies in the definition and quantification of human behavior.

Social Epidemiology

The term social epidemiology is used here to refer to the extension of the epidemiologic methodology from its bio-medical base to the social arena in which the social root-causes of disease are studied. The criticism that modern epidemiology has veered away from the community perspective in favor of the individual (66) has some truth in it but is rather exaggerated. It does not apply to all fields of endeavor in epidemiology. Study of the ecology of human disease focuses on risk factors in the society and not the individual (67).

NEW FRONTIERS IN EPIDEMIOLOGY**Health Policy**

Formulating health policy requires epidemiological data on disease incidence and disease prevalence. For example policy on CHD requires knowledge of correct prevalence data (68). Epidemiologic study relating sexual and racial discrimination to health outcome (69) can guide policy on equitable distribution of health resources. Studies on health effects of alcohol addiction can lead to policies on restriction of intake and punitive sin taxes. Routinely collected administrative data guides policy

makers (70) but will have to be analysed by an epidemiologist to obtain valid unbiased conclusions. Results of analysis of epidemiological data are used to formulate regulations on prevention and compensation of occupational cancers (71).

Health Services Planning

Epidemiological data is used to forecast trends in disease occurrence. This is used to anticipate future demands on health care services. For example it is forecast that by 2020, twenty (20) million cases of cancer will be diagnosed every year (72) Such information helps health planners to project the needs of human and material resources that will cater for that burden of disease

Health Care Financing

Many countries are now moving to some form of health insurance for their citizens. In some cases the premiums are paid by the citizens or there is some government participation. In any case it is important for the right amount of premium to be set so that there are enough resources for all disease conditions and the payers are not overpaying. Setting such premiums requires using epidemiological data on the incidence and prevalence of various disease conditions.

Health Care Delivery

The future trend of health care delivery systems may well be in the preventive arena because curative care has for some conditions reached its last frontiers and can not make major advances in decreasing disease burden because of basic human behavioral and life-style factors that have to be changed first. The introduction of managed care and privatisation of medical services may result in poor health outcome because of short-cuts necessitated by the profit motive. Epidemiologic surveillance of disease prevalence and incidence of complications and side-effects will help assess these forms of health care delivery at the community-wide level. For example measurement of the prevalence of pressure ulcers may prompt changes and improvements in procedures at long-term care facilities (73).

Economic Analysis

In the past there were few questions asked about health economics because the range and cost of medical interventions were limited. With the growth of medical technology, many expensive procedures can be carried out and this is responsible for the sky-rocketing health costs. There is thus increasing interest in the economic impact of medical procedures with the overall aim of cost-containment. The discipline of health economics seeks to find the best ways of using resources to maximize the health of the community (74). Economic factors are considered in deciding treatment approaches (75). Cost-effectiveness and cost-benefit analyses have become very common for example screening for prostate cancer is not popular

because it is thought not to be cost-effective (76). The real interest is aligning financial incentives to health outcomes (77). Assessment of outcome at the level of the community involves epidemiological data collection and analysis. Outcome analysis based on individuals can not be as reliable as that which uses the whole community and compares the outcome to the overall community health expenditure. For example a cost- effectiveness study was carried out to choose between selective and universal hepatitis vaccination in the UK (78). Such studies utilize epidemiologic data.

Health Program Evaluation

Health programs need both process and outcome evaluation. The outcome of evaluation affects decisions (79). Outcome evaluation will require using population-based epidemiological data on disease conditions. The impact of public health interventions is evaluated in a community setting (80). Program evaluation is necessary for re-orientation of programs and for getting the support of stake-holders (81).

OPPORTUNITIES & CHALLENGES

Data Availability

Epidemiologists who worked before the computer age must envy modern epidemiologists. Today's epidemiologist has a wide range of data sources. A lot more data is collected by electronic medical records than could ever be imagined 20 years ago (82, 83). Data routinely collected about citizens in medical care plans can be linked to socio-demographic, birth and mortality data to test many epidemiological hypotheses that before required expensive primary data collection. One study for example linked data from a Group Health Care Co-operative with death records to study mortality of patients treated for depression (84). Racial differences in the incidence of sarcoidosis was studied using HMO data in Michigan (85). The well kept Nordic medical birth registers were used in epidemiological research combined with other data bases (86). The relation between parity and pancreatic cancer was studied by linking the Swedish Cancer Registry with the Swedish Fertility Registry (87). The Vermont Oxford Network has a data-base on low birth weight from collaborating Neo-natal Intensive Care Units that is used in outcome research (88). Some very innovative and imaginative ways of data collection have been used such as collecting saliva samples by mail (89). Human hair has been used as a bio-marker for environmental pollutants (90). Drug prevalence has been monitored by testing urine, saliva, sweat, and hair (91.). Capture-recapture methods, originally used in study of wild-life, have been used in epidemiology to study disease incidence and prevalence (92, 93). Data from previous studies of the same phenomenon are now being combined and re-analysed for example the study of the relation between sun exposure and melanoma (94).

Standardisation Of Methodology

Globalisation in medical research has meant that research findings are rapidly and efficiently exchanged among researchers working in different parts of the world. Epidemiologists are faced with the challenge of standardising the methods of measurement of various exposure variables such as alcohol intake (95) and physical activity (96). Thus it is difficult to make a comparative analysis of different studies or pool their results. Standardisation of methodologies of data collection and handling is also lacking. The profession will have to address these issues to be an effective player on the global scene. Outcome measures in mental health are notoriously difficult to define (97). Comparative evaluation of studies on prevalence of periodontal disease is complicated by inconsistencies in clinical assessment (98). Wide fluctuations in the prevalence data of heart failure reflect vagueness in clinical definition (99). On the other hand, rheumatoid arthritis has such a wide range of outcomes that their measurement is difficult (100). Studies indicating reduction in maternal mortality due to ante-natal care have been criticised as methodologically flawed in their definition of what is ante-natal care (101). Methodological differences explain the wide range in reported prevalence of Alzheimer's disease (102). Variation in reported prevalence of hypertension in the Netherlands was found to be due to methodological variations (103). The use of meta-analysis is being questioned in some quarters because the results are not comparable to those from large trials (104). Methodological innovations in meta-analysis could lead to saving a lot of resources because they would effectively substitute for large trials. Meta-analysis has the advantage of increasing statistical power and the estimate of a properly weighted summary risk ratio (105).

Confounding Bias

Reading scientific literature is like reviewing a litany of methodological flaws. Many studies are not designed or analysed properly. Disentangling the separate effects of several potential causative factors is a daunting task. Many researchers are not aware of the ABC of good epidemiological research, measurement and control for confounding and other types of bias. Without this study results can not be interpreted properly. A good example was the finding of a spurious association between mouth-washes and oropharyngeal cancer due to under-ascertainment of confounders (106).

Miettinen has dealt with the theoretical basis of confounding (107). Confounding bias arises when the disease-exposure relationship is disturbed by an extraneous factor called the confounding variable. The confounding variable is not actually involved in the exposure-disease relationship. It is however predictive of disease but is unequally distributed between exposure groups. Being related both to the disease and the risk factor, the confounding variable could lead to a spurious apparent relation between disease and exposure.

Confounding can be understood by the following example. Alcohol consumption confounds the relation between smoking and lung cancer. There is an indirect relation between alcohol consumption and cancer of the lung. We observe

that those who have lung cancer also consume alcohol. This is because of the non-causal relation between alcohol consumption and cigarette smoking. The two are part of the same lifestyle and tend to occur together. The direct causal relationship between cigarette smoking and lung cancer could be distorted in a study in which alcohol consumption is not balanced between the smoking and non-smoking exposure groups. A negative relationship between cigarette smoking and lung cancer will be seen if study subjects are selected predominantly from the non-smoking population.

Confounding can be prevented or minimised. Prevention of confounding at the design stage by eliminating the effect of the confounding factor can be achieved using 3 strategies are used: pair-matching, stratification, and randomisation. Multivariate techniques can be used to adjust for the effects of confounding at the analysis stage of the study.

THE MEDIA AND THE LAW

Epidemiology is now recognised by the policy-makers, the courts of law, and the general public as a source of valid information on exposures and disease. Epidemiologists are therefore challenged to improve their communication skills to be able to present complex scientific information to their clients in the media, the courts of law, and governmental agencies (108). The presentation must be in an easy and understandable way that does not sacrifice fact for clarity. Any misconception of epidemiological findings could cause mistakes in policy, court decisions, and the behavior of the public.

Training Of Epidemiologists

The needs of epidemiological studies are multiplying several-fold everyday yet the supply of trained epidemiologists is limited. Several university training programs have been stated; the demand still far outstrips the supply. The ideal would be to train physicians to become epidemiologists preferably to work in their own specialty. Since the recruits from this avenue are few, nurses, biologists, and other graduates from health-related disciplines have been recruited. In some situations epidemiology has been taught as an under-graduate course. Despite the many opportunities available in the discipline, many people are reluctant. This may be due to a genuine fear of the mathematics involved since those who are mathematically-inclined select engineering and related quantitative fields quite early in their careers.

CONCLUSIONS

The epidemiological methodology has a lot of strengths as well as some weaknesses. The strengths far out-weigh the weaknesses. In a 1979 seminal discussion of the strengths and weaknesses of epidemiological methodology, Brian McMahon, Professor of epidemiology at Harvard summarised the strengths as obtaining observational data cheaply and with a wide wide range of human exposures. The

humans both choose and pay for the exposures and what the epidemiologist does is to collect the data. He identified the major weakness as inability to offer conclusive proof of the disease-exposure relationship. In this sense epidemiological findings open the way for further work and verification by laboratory science. As more epidemiologic studies indicate the same etiology, increasing convincing evidence is obtained. However the final proof will have to come from the laboratory. In some cases the final proof is never obtained using the limited epidemiological knowledge on causation, public health interventions may be undertaken and they result in elimination of the disease before the laboratory workers have a chance to say their word.

The main elements of the methodology have remained constant and are likely to guide the growth of the discipline in the next century. The epidemiological methodology in essence is inference on the causal relation between cause and effect while preventing, eliminating, or adjusting for the 3 main types of bias (selection, misclassification, and confounding). Developments in the fields of statistical modeling with the accompanying hard and software will enable a deeper and richer understanding of multi-causal relations by describing interaction effects (synergistic and antagonistic) as well as effect modifications. Synergy can be conceptualised as biological and statistical (109). Its importance lies in its preventive potential. A biggest 'bang' can be obtained from the least 'buck' when intervention is against a synergistic relationship.

Intervention, definable as looking at the causal relation in reverse. is the main underlying objective of epidemiological studies and involves interrupting, reversing or mitigating the effect of causes. It is a truism that epidemiology is for prevention (110). Epidemiology will continue enjoying pride of place among public health disciplines in being able to devise ways of successful intervention even before the detailed understanding of the causal relation at the molecular level is achieved. The most effective interventions in this regard are those that modify human behavior and lifestyle. A preponderant majority of disease conditions can be either prevented or cured by available medical knowledge and technology. The last frontier that medicine has yet to conquer is changing the human will to adopt healthy life-styles and avoid unhealthy ones. Epidemiological studies can link specific life-styles to specific diseases enabling effective interventions even if the mechanisms may not be known fully

Epidemiology will continue playing a role in new areas of research that are opened up by changes in medical care systems and availability of large data sets (111). It is the considered opinion of the author that the increasing specialisation within epidemiology will not lead to the 'death' of the mother discipline. Neither will the mother discipline turn into theoretical epidemiology. It will remain close to its practical and empirical base. Epidemiologists will continue being involved in the application of their methodology to real-life public health problems unlike theoretical physicists or mathematicians who can afford to keep their hands clean from toiling in the field. Most of the growth forecast in epidemiology will be in the area of applying epidemiologic data to large and detailed data sets on human populations and environmental variables. No spectacular developments are forecast in the

methodology of study design or study analysis. Meta or pooled analyses will become more popular as studies and databases proliferate.

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