SECTION 2

# EPIDEMIOLOGY: DESIGN, METHODOLOGY, AND APPLICATIONS

*Epidemiology is the study of the occurrence of disease in human populations. Nutritional epidemiology is the study of the dietary factors that influence disease frequency and distribution in human populations.*

The *Dictionary of Epidemiology* defines epidemiology as the study of the distribution and determinants of health-related states and events (e.g., death or disease) in specified populations and the application of this study to the control of health problems (Last 2001). Epidemiologic studies provide data on associations between an exposure (e.g., red/processed meat) and a disease (e.g., cancer) among *humans*, while considering important factors that may influence results, such as bias and confounding. It is important to note that there is a distinction between an *association* (a statistical correlation between two variables) and *causation*. Associations may be observed in a single study or several studies; however, these associations may not be indicative of a relationship that is causal. Although a single epidemiologic study (or even a group of studies) is generally not sufficient to make a conclusion of causality, a number of guidelines have been developed that provide a basis to evaluate data from an entire collection of epidemiologic studies in order to determine whether a causal relationship is inferred.

Specifically, epidemiologists commonly apply the guidelines that were proposed by Sir Bradford Hill (1965) to evaluate causality. These guidelines have been refined and expanded by other epidemiologists over the years, although the fundamental framework remains in place (e.g., Gordis 2000; Hennekens et al. 1987). This systematic approach (Sir Bradford Hill guidelines to evaluate causality) emphasizes the use of multiple factors when making interpretations of epidemiologic research, such as the strength of observed associations within and across studies;

*…a single epidemiologic study (or even a group of studies) is generally not sufficient to make a conclusion of causality…*

## FIGURE 2.1
## EXAMPLES OF GENERAL RANGE OF ASSOCIATIONS OF ESTABLISHED CAUSES OF CANCER

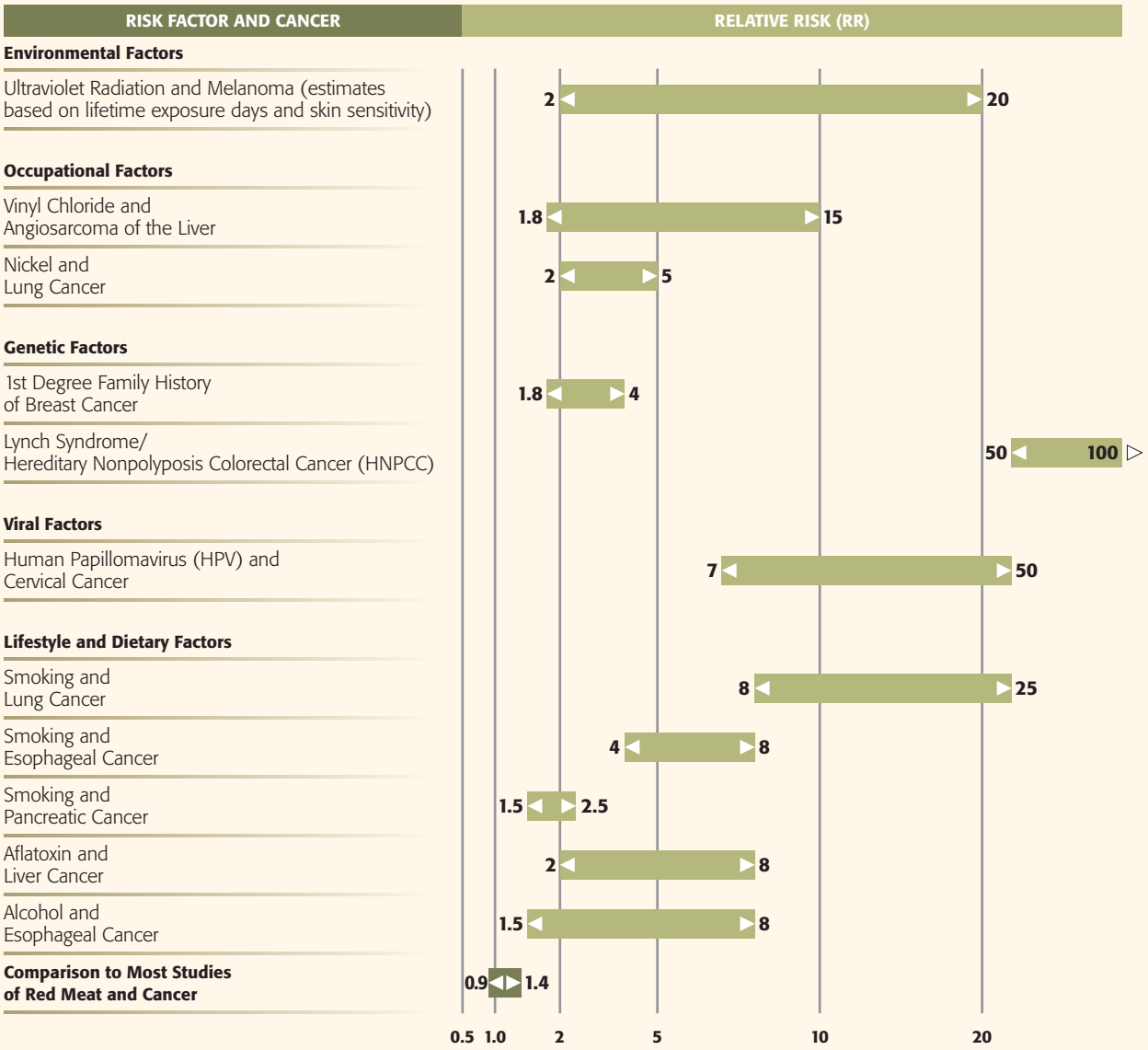
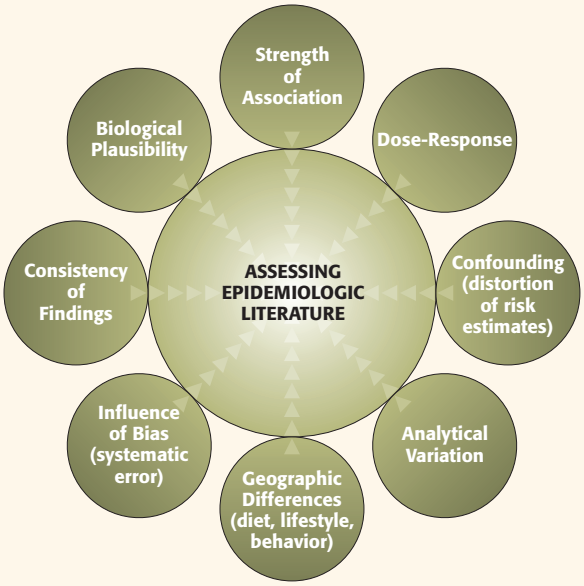


**FIGURE 2.2**
**ASSESSING EPIDEMIOLOGIC LITERATURE**



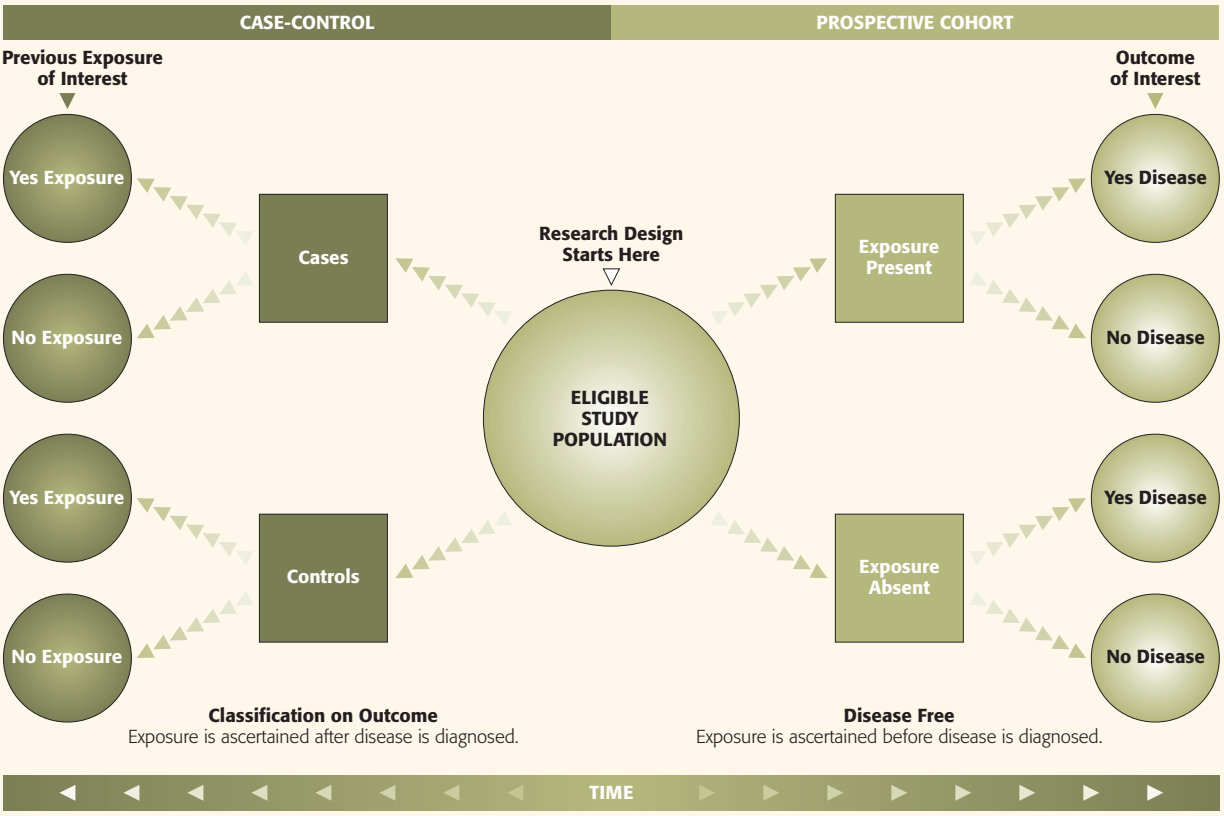

evidence for exposure-response patterns; whether the exposure preceded the disease; consistency of the associations reported across studies; coherence of the evidence; and biological plausibility of the observed associations. Other important considerations when evaluating nutritional epidemiology studies include the variability of food item or food group definitions, how intake is characterized across studies, and differing patterns of intake and/or disease associations by key factors (e.g., gender, tumor site, age, etc.).

The application of the aforementioned guidelines may have some limitations inherent to nutritional epidemiology. For example, most associations between dietary factors and cancer have associations that are not considered strong (i.e., RR < 2.0 for most associations between dietary factors and cancer), and a dose-response gradient may be difficult to achieve. In comparison, the majority of established exposure-disease causal associations are of strong magnitude (i.e., RR > 2.0) as shown in Figure 2.1.

Most epidemiologic studies are observational in design, that is, the number of outcomes (or disease events) is observed among a clearly defined study population consisting of exposed and non-exposed individuals. For example the rate of disease is compared among individuals who consume red meat daily (i.e., the exposed group) to that of individuals who consume red meat infrequently, such as once per week (i.e., the non-exposed group).

There are two general classes of observational studies, *descriptive* and *analytical*. The primary function of a descriptive epidemiologic study is to characterize the distribution and/or occurrence of disease in time (e.g., trends over time), place (e.g., clustering, geographic location), and person (e.g., age, gender, race). Descriptive epidemiologic studies are useful in generating hypotheses about potential exposure-disease relationships; however, descriptive studies do not test these hypotheses and generally do not provide information regarding disease causality. Analytical epidemiologic studies, on the other hand, are conducted to identify associations between factors (e.g., diet, lifestyle factors, etc.) and disease, and are useful for testing hypotheses regarding etiology (causation). The two most commonly conducted types of analytical epidemiologic studies are cohort studies and case-control studies. Indeed, these are the most frequently utilized study designs to examine the association between meat consumption and cancer.

**FIGURE 2.3**
**EPIDEMIOLOGIC STUDY DESIGNS**




*Odds of exposure among those with disease (cases) is compared with the odds of exposure among those without disease (controls)*

*Rate of disease among exposed group is compared with the rate of disease among the non-exposed group.*

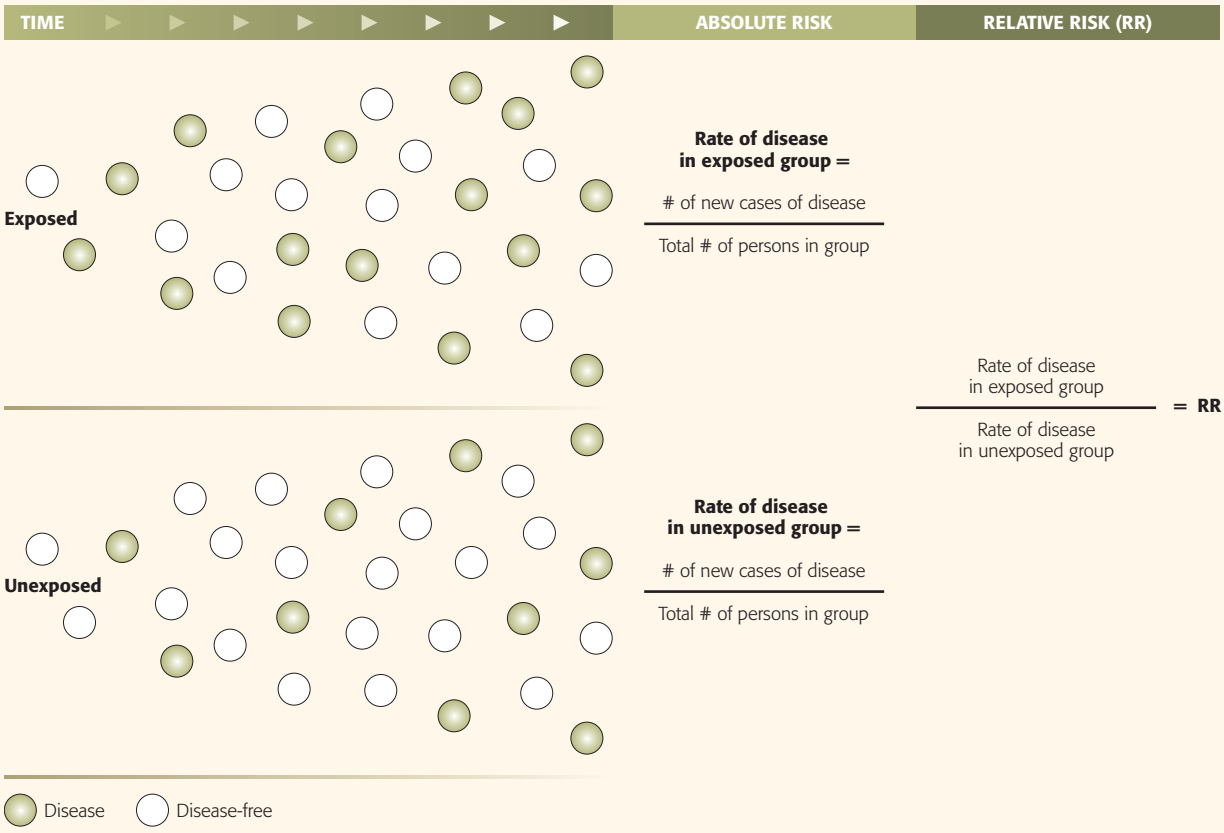
## UNDERSTANDING EPIDEMIOLOGIC STUDY DESIGNS

### Cohort Studies (Follow-Up Studies)

In a *cohort* study, researchers clearly define a disease-free (participants do not have the disease that is the focus of the investigation) study population (e.g., U.S. women aged 50 to 70) and study participants are followed over time to compare the incidence of disease between those who are grouped together based on certain factors, such as quantiles (i.e., intake groups) of meat intake. For example, the rate of cancer is compared between participants who consume meat three times or more per week with the rate of cancer among participants who consume meat one time or less per week. Thus, a cohort study facilitates an estimation of disease occurrence (incidence) because exposure is ascertained prior to the diagnosis of disease. Most cohort studies of diet and cancer are prospective, that is, the study population is defined in the present and then followed into the future to determine disease occurrence. In a retrospective cohort study, the study population is defined in the past and the disease occurrence is determined up to the present time.

Prospective cohort studies are the most methodologically rigorous observational studies and offer the best evidence to evaluate possible cause and effect. As mentioned, dietary information is collected prior to disease diagnosis, thereby decreasing the likelihood that the disease caused a change in dietary intake, or that disease diagnosis influenced the recall or reporting of past dietary habits. Because cohort studies are conducted longitudinally, repeated measurements of diet can be obtained throughout study follow-up and multiple disease endpoints can be evaluated. Cohort studies are less susceptible to bias compared with other study designs,

**FIGURE 2.4**
**ESTIMATING THE RATE OF DISEASE: COHORT STUDIES**




such as case-control studies. However, prospective cohort studies are expensive to conduct as it is often necessary to enroll thousands of persons in the study.

### Case-Control Studies

In a *case-control* study, dietary (and other) information is collected from individuals who have already been diagnosed with the disease of interest (i.e., cases) and the same type of information is collected among a comparison group who does not have the disease of interest (i.e., controls). Case-control studies are generally less expensive to conduct than cohort studies and may be performed more efficiently because fewer participants are analyzed and no follow-up is necessary. However, case-control studies of dietary factors may produce inconsistent results because of the inherent potential for methodological bias, such as differential recall of dietary intake between cases and controls (e.g., cases may tend to over-report consumption than controls) or the selection of an inappropriate control group (e.g., control participants have a tendency to be healthier than eligible controls who choose not to participate) (Willett 2006).

Prospective cohort studies may avoid some of the biases of case-control studies in that dietary information is collected prior to disease; thus, the diagnosis of cancer should not affect the recall of dietary factors (Willett 2006). Despite these limitations, case-control studies may provide some scientific evidence regarding diet and cancer, particularly in the absence of data from prospective cohort studies. The statistic produced in a case-control analysis is referred to as an odds ratio (i.e., OR). Analytically, the odds of the case having a certain exposure factor (e.g., 5 or more servings of red/processed meat per week) is compared with the odds of the control having that same factor.

### Other Study Designs

Many early investigations of diet and cancer, including meat and fat intake, consisted of *ecological* or *correlational* studies. These types of studies compare aggregate, or national-level, data between dietary factors and disease. For example, the average level of fat intake in the United States is correlated with the rates of breast cancer in the United States. Although these studies may be useful in comparing rates between countries, or generating an assessment of trends over time,

LEVEL OF SCIENTIFIC EVIDENCE

| STUDY DESIGN | APPLICATION |
|---|---|
| **Clinical Trials** | Randomized clinical trials are commonly considered the gold standard in establishing a cause-and-effect relationship. However, these types of study designs are difficult (and may not be practical) to achieve for broad food groups, such as meat. |
| **Meta-Analysis*** *(synthesizes data from other study designs)* | A meta-analysis involves systematically combining results data across published studies to produce a summary estimate of relative risk. As more studies of meat intake and cancer are published and as more data become available, meta-analyses offer a systematic methodological approach to synthesize data across studies. A pooled analysis is a type of meta-analysis that incorporates data at the individual level rather than combining results data. |
| **Cohort Studies** | Prospective cohort studies are considered to offer the best evidence of the observational studies of diet and cancer. The exposure information is ascertained prior to the onset of disease, allowing for the calculation of incidence. These designs may overcome some of the bias (e.g., recall bias) inherent to case-control studies. Most commonly cited design when interpreting studies of meat intake and cancer. |
| **Case-Control Studies** | Persons already diagnosed with the outcome of interest are compared with persons without the outcome. Diet is ascertained retrospectively, lending this type of design to information bias (i.e., differential recall of past dietary history between those with and without disease). Although hundreds of case-control studies of meat intake and cancer have been published, the weight of the evidence is usually only considered in the absence of data from prospective cohort studies. |
| **Cross-Sectional Study** | Compares groups in terms of exposure and outcome at a single point in time. Exposure and disease are ascertained contemporaneously, referred to as a "snapshot" of exposure and health status. One-dimensional analysis not useful for examining a cause and effect relationship. |
| **Ecologic Study** | Compares data on the aggregate level, such as the correlation between per capita intake of meat with national rates of cancer. Does not evaluate information at the individual level. May be considered "hypothesis generating." Sometimes referred to as community-based or correlational studies. |
| **Case Series** | A collection of information pertaining to the health status of a series of individuals. These are commonly considered "case-only" evaluations, and no comparison groups are evaluated. |
| **Case Report** | A case report commonly involves a clinical observation of a single patient. Many case reports document a unique clinical circumstance. Not intended for evaluating cause and effect. |

*Of note, results from a meta-analysis are only as valid as the data from the original studies that are included in the analysis. For example, a meta-analysis of 20 case-control studies may offer a lower level of scientific evidence than individually examining five prospective cohort studies. A meta-analysis of clinical trial data may offer the best scientific evidence for causation. Thus, a meta-analysis may be viewed as an analytical technique rather than a study design.

ecologic studies do not evaluate data at the individual level. Therefore, these study designs do not provide valid evidence for making examinations of causality, although they may substantiate scientific evidence from other study designs.

Another study design, a cross-sectional study, ascertains exposure and disease or other health-related characteristics in a defined population at a given point in time. These studies provide a "snapshot" picture of the exposure-disease relationship in a population. Because cross-sectional studies usually do not involve a time component, the dynamic interaction between exposure and disease is difficult to determine. Cross-sectional studies, commonly referred to as cross-sectional surveys, are based on prevalent rather than incident cases. Generally, the results of such studies cannot be used to infer causation.

The study designs that offer the best evidence for evaluating causality are randomized double-blind clinical trials. In these study designs, confounding by extraneous factors is theoretically minimized because study participants are randomly assigned to receive the intervention or the control. Clinical trials are commonly conducted on certain correlates of food, such as vitamins or minerals; however, trials of food items or food groups are not always feasible and are conducted infrequently. Thus, the most abundant scientific evidence surrounding red meat and processed meat intake and cancer come from epidemiologic cohort and case-control studies, which is the focus of this technical summary.

## SYNTHESIZING THE DATA: META-ANALYSIS

A meta-analysis is a systematic quantitative method for which 'results data' from individual studies are combined to produce an overall or weighted summary association (an average relative risk estimate of all studies), commonly referred to as a summary relative risk estimate (SRRE).

In general, there are two types of meta-analysis models, fixed effects and random effects. In a *fixed-effects* model, it is assumed that the underlying effect is the same across studies and that the overall variation is random *within* each study but does not incorporate variation *between* studies. *Random-effects* models account for both within- and between-study variation, and allow for non-homogeneity between the effects of the various studies. Therefore, random-effects models are typically used in observational epidemiologic studies to account for between-study variation resulting from different methodological techniques and study designs. Statistically, confidence intervals are typically wider when using random-effects models because the between-study component is included in the algorithm.

An important function of a meta-analysis is testing for heterogeneity. Heterogeneity reflects unexplained variation between study results in a meta-analysis model, and a model that has significant heterogeneity may not be a valid quantitative summarization of studies. Heterogeneity may be the result of differences in study design, measurement techniques, patterns of associations by gender or race, or a plethora of other

characteristics. A single meta-analysis model will not indicate the exact source of heterogeneity; rather, researchers conduct a variety of sub-group and sensitivity analyses in an effort to identify possible sources of between-study variation. When interpreting findings from a meta-analysis, it is important to consider the studies that were included in the analytical model.

A detailed methodological protocol should be followed when selecting the studies and the data to be included in a meta-analysis. The results of a meta-analysis are only as valid as the studies comprised within the model. For example, if a meta-analysis is conducted on a group of case-control studies for which selection bias may have been an issue, producing a summary association from these studies may not be informative. On the other hand, a meta-analysis of well-conducted prospective studies may produce an accurate and valid summary relative risk and allow for the evaluation of patterns of associations across population sub-groups.

With the increasing number of published studies, more data are available to analyze using a meta-analysis technique. In turn, advanced meta-analytical methods are continually being incorporated.

A pooled analysis is a type of meta-analysis for which the *individual level data* are pooled together across study groups rather than the *results data* across studies. Simply put, a pooled analysis is a way of combining individuals across study centers to produce a larger study sample. This type of analytical methodology is optimum for calculating relative risk estimates. However, this approach may not be practical. For example, researchers from the individual study centers must be willing to share their data and cooperate with the study protocol. In addition, since the data are at the individual level, confidentiality may be a concern. The most comprehensive pooled analysis pertaining to nutritional epidemiology is the Harvard University Pooling Project of Prospective Studies of Diet and Cancer (Pooling Project) [http://www.hsph.harvard.edu/poolingproject/about.html], which is an "international consortium of cohort studies with the goal of analyzing diet and cancer associations using standardized criteria across studies." Their pooled analyses incorporate "individual data as opposed to a meta-analysis of the published literature." To date, few pooling project studies pertaining to red meat and cancer have been published, and these only include breast cancer and kidney cancer. Of note, a pooling project analysis of meat and fat intake and colorectal cancer (no significant associations were reported for red meat, processed meat, or fat intake) was published as an abstract and presented at the American Association for Cancer Research 2004 annual conference but this analysis inexplicably was not published as a full manuscript (Cho & Smith-Warner 2004).

*When interpreting findings from a meta-analysis, it is important to consider the studies that were included in the analytical model.*

Statistical data (RRs and CIs) that are entered into the meta-analysis from each study

Horizontal bars represent the range of the confidence interval (CI).

The relative weights represent how much statistical weight or influence that each study has on the summary association. Large studies with low standard error contribute more weight than small studies with high variability.

Circles represent the point estimates (RRs and ORs from each study).

## FOREST PLOT OF A META-ANALYSIS

| MODEL | STUDY NAME | Rate Ratio | Lower Limit | Upper Limit | FIXED Relative Weight | RANDOM Relative Weight |
|---|---|---|---|---|---|---|
| | Study A | 1.00 | 0.64 | 1.55 | 20.44 | 19.80 |
| | Study B | 0.83 | 0.53 | 1.29 | 19.92 | 19.49 |
| | Study C | 1.07 | 0.58 | 1.97 | 10.54 | 12.59 |
| | Study D | 1.89 | 1.14 | 3.14 | 15.28 | 16.42 |
| | Study E | 0.70 | 0.31 | 1.57 | 6.08 | 8.12 |
| | Study F | 1.20 | 0.82 | 1.75 | 27.74 | 23.59 |
| Fixed | | 1.10 | 0.90 | 1.34 | | |
| Random | | 1.10 | 0.85 | 1.41 | | |

RR AND 95% CI

0.1 0.2 0.5 1.0 2 5 10

Summary associations (SRRE) for all studies included in the meta-analysis model

1.0 is the null value.

Incorporates within- and between-study variability

Diamonds represent the summary relative risk estimate (SRRE). The horizontal tips of the diamonds represent the lower and upper bounds of the confidence interval.

Incorporates within-study variability

## INTERPRETING RESULTS FROM EPIDEMIOLOGIC DATA

In an epidemiologic study, the association between a particular disease and dietary factor is measured using a relative risk (or odds ratio).

- If a relative risk is less than 1.0, the rate of disease is lower among high consumers, and the general interpretation is that there is an ***inverse association*** (i.e. negative association) between the dietary factor and the disease. If, for example, we were studying the association between fruit and vegetable intake and lung cancer, an inverse association would occur if the rate of lung cancer was lower among persons with high fruit and vegetable intake, compared to persons with low intake of fruits and vegetables.
- If a relative risk is equal or close to 1.0, the rate of disease is the same between the high and low consumers, and the general interpretation is that there is ***no association*** between the dietary factor and the disease.
- If a relative risk is greater than 1.0, the rate of the disease is higher among persons with a greater level of exposure, and the general interpretation is that there is a ***positive association*** between the factor and the disease. For example, a positive association would occur if the rate of colon cancer was higher among persons with a higher body mass index, compared to persons with a lower body mass index.

A relative risk is simply an estimate of the association between two factors that is measured from one study. It does not necessarily represent the true association between the disease and dietary factor, nor does it mean that there is a causal relationship between the two. The true association can be affected by numerous methodological and analytical factors, such as chance, bias, and/or confounding. These factors need to be considered and adequately accounted for prior to formalizing conclusions.

An observed association may simply be the result of a chance occurrence. Statistical methods are employed to test for this possibility and, if chance is an unlikely explanation, the relative risk is called 'statistically significant.'

Confidence intervals (CI) are typically reported alongside each relative risk estimate to evaluate its statistical significance. A CI is a range of values for a relative risk that has a specified probability (e.g., 95%) of including the "true" relative risk. If the 95% CI does not include 1.0 (i.e., the null value representing no association), the probability of the association being due to chance alone is 5% or lower and the result is considered statistically significant. If, however, the 95% CI includes 1.0, then the probability that the association is due to chance alone is greater than 5% and the association is not considered statistically significant. For example, if a RR for high meat intake and pancreatic cancer is 1.9 (95% CI = 1.2-3.9), this would indicate a statistically significant positive association. The "best

### INFORMATION BOX 2.1
### INTERPRETING RELATIVE RISKS

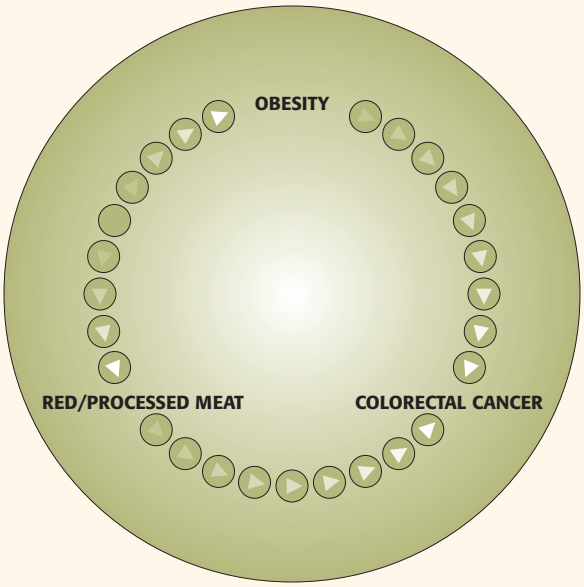
| Direction of Association | Comparison of disease rates between dietary intake groups (i.e., high intake vs. low intake) | ▶ Interpretation |
|---|---|---|
| **RR < 1.0** | Rate of disease is **lower** among high consumers compared with low consumers | ▶ **Inverse Association** |
| **RR = 1.0** | Rate of disease is **the same** between intake groups | ▶ **Null Association** |
| **RR > 1.0** | Rate of disease is **higher** among high consumers compared with low consumers | ▶ **Positive Association** |

estimate" of the data is that persons with high levels of meat intake have a 90% greater risk of pancreatic cancer compared to persons with a low meat intake, although the increase in risk could plausibly be as low as 20%, or as high as 290%, or anywhere in between, based on the 95% CI.

A p-value is another way (and less preferred method) of considering the role of chance. A p-value tests the probability that the observed association is due to a chance finding, i.e., that there truly is no association between the two variables under consideration. Typically, the threshold for reporting a finding as statistically significant is a p-value of 0.05 or less.

**FIGURE 2.5**
**CONFOUNDING EXAMPLE**

*Obesity is independently associated with increasing the risk of colorectal cancer. If the highest consumers of red/processed meat are also obese, the association between red/processed meat and colorectal cancer may be distorted by the confounding effects of obesity if not fully controlled for in the analysis.*




## BIAS AND CONFOUNDING

A confounder is an extraneous variable that may distort the association between a factor under study and the outcome of interest. By definition, a confounder (e.g., total energy intake) is independently associated with both the factor (e.g., red/processed meat) and the outcome (e.g., cancer). Therefore, it is of importance that the potential for confounding be eliminated or mitigated at either the design phase (through restriction, randomization, or matching) or the analytical phase (by statistical adjustment or stratification) of the study.

In epidemiologic parlance, bias is a systematic error that may result in an incorrect estimate of the association between an exposure and risk of disease. Although there are numerous types of biases, two of the most common types inherent to epidemiologic studies are selection bias and information bias. In addition, publication bias may affect quantitative reviews of the literature.

*Selection bias* arises when the exposure-disease association differs between those who participate in the study and those who are eligible to participate but do not. Selection bias can occur in either cohort or case-control studies, and can affect both the internal validity (are the measures of association unbiased?) and external validity (is the study population representative such that results can be generalized?) of a study. The probability of selection bias is theoretically reduced when participation levels are maximized. Furthermore, in case-control studies, it is particularly important that the control group is selected from the same study base as the case group. In this regard, data from hospital-based case-control studies should be interpreted carefully because the control group consists of other hospital patients, typically admitted for a select group of conditions, who may not be representative of the population which gave rise to the cases. Methods to minimize the potential impact of selection bias include clearly defining the study population, maximizing participation rates, identifying study participants without knowing their disease status, and including cases and controls who arise from the same population.

**INFORMATION BOX 2.2**
**COMMON TYPES OF BIAS IN EPIDEMIOLOGIC STUDIES**

| | |
|---|---|
| **Selection Bias** | ■ Occurs when study participants are not representative of the target population upon which the conclusions are to be made<br>■ Bias introduced by the differential selection of participants into the study<br>■ Differential drop-out of study participants during study follow-up (i.e., loss to follow-up)<br>■ Non-responders<br>■ Controls who choose to participate tend to be healthier than controls who are eligible but choose not to participate |
| **Information Bias** | ■ Systematic error in the measurement of information on exposure or outcome<br>■ Recall bias: Occurs retrospectively when the ability to recall an exposure is not equal between the groups being compared<br>■ Interviewer bias: Investigator queries study respondents differently, such as probing |
| **Publication Bias** | ■ Study findings are reported and published differentially, depending on the type and nature of the result<br>■ Positive associations have a tendency to be published in greater frequency than null associations, which may provide an artificial sense of consistency of direction across studies |

*Information bias* is a systematic error in the measurement or ascertainment of exposure and/or outcome information. In case-control studies, dietary (and other) information is collected after the diagnosis of disease; thus, differential reporting of dietary intake between cases and controls may occur, and ultimately produce spurious associations. This is referred to as recall bias, which is a type of information bias. Because dietary data are collected before the onset of disease in prospective cohort studies, this particular type of information bias is considered to be negligible. Another type of bias to be cognizant of when interpreting a body of scientific literature is publication bias.

*Publication bias* occurs when findings from individual studies are differentially published. For example, studies that observe increased risks are more likely to be published (or the authors are more likely to report these data in their article) than studies that do not observe such associations.

*In epidemiologic parlance, bias is a systematic error that may result in an incorrect estimate of the association between an exposure and risk of disease.*

## ASSESSING FOOD INTAKE

Accurate measurement of food intake is paramount in studies of diet and cancer; thus, the interpretation of nutritional epidemiology studies is dependent upon the methods used to estimate dietary intake.

The *food frequency questionnaire (FFQ)* is a method for which participants are asked about the frequency of their food intake over a specified period of time. Some questionnaires may inquire about the amount of food consumed in addition to frequency of consumption. There are a few different variations of FFQs, but they are generally comparable at assessing diet and disease associations (Subar et al. 2001). The FFQ is the most commonly utilized dietary instrument to ascertain red/processed meat consumption across the epidemiologic literature.

Another method is *dietary recall*, in which an interviewer queries participants about the food they have consumed, often within a 24-hour period. The dietary recall method is used to describe actual intake; however, this method typically assesses a single day of intake, which is not representative of long-term intake and less frequently consumed foods are often missed (Willett 1998).

Participants can also keep track of the items that they consume for a period of time; this is known as the *food diary* or *food record* method. Weights and volumes of actual food consumed are recorded using measuring tools or cups. Diary data are commonly used as validation for food frequency questionnaires and have correlations that range from 0.25 to 0.75 indicating considerable variation in accuracy. As a result of these limitations in dietary assessment accuracy, researchers have suggested that relative risks lower than 1.8 may be beyond the statistical power of the study to validly detect a significant effect (Thompson et al. 2008).

A final method is the use of *biochemical indicators* to assess levels of nutrients in the body at a given point in time. Information Box 2.3 summarizes the different methods used to assess food intake.

*The FFQ is the most commonly utilized dietary instrument to ascertain red/processed meat consumption across the epidemiologic literature.*

## INFORMATION BOX 2.3
## ASSESSING FOOD INTAKE

| METHOD | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| **Food Frequency Questionnaire (FFQ)** | ■ Identifies usual food intake patterns<br>■ Low respondent burden, self-administered<br>■ Relatively inexpensive<br>■ May not be as sensitive to recent dietary changes<br>■ Relatively efficient in ascertaining information from a large study population<br>■ Generally effective at ranking individuals by frequency of intake | ■ Possible inaccuracies in:<br>□ Respondent memory of food consumption (differential recall)<br>□ Estimation of portion size<br>□ Estimation of specific food constituents within a mixture |
| **Dietary Recall** | ■ Generally more accurate weights and volumes of food consumed<br>■ Can be administered at various intervals over time<br>■ Can be administered to illiterate persons, thereby increasing eligible participants<br>■ Typically efficient | ■ Assesses a single day of intake which may not be representative of long-term intake<br>■ Less frequently consumed foods often missed<br>■ Typically requires a trained interviewer<br>■ Can be expensive<br>■ Respondents may inaccurately report intake |
| **Food Diary/ Food Record** | ■ Measures intake and portion size over a period of time, usually three days to one week<br>■ Accurate weights and volumes of food consumed; less reliance upon memory<br>■ High level of specificity (e.g., exact food names, brands, cooking methods) | ■ Participants may alter intake to present themselves more favorably<br>■ High level of burden on the participants to measure, weigh, and record; may not be practical for large study populations<br>■ May not be representative of long-term consumption |
| **Biochemical Indicators** | ■ May be a more accurate and reliable indicator of actual intake<br>■ May have less error than other methods<br>■ May be used to more accurately assess micronutrient intake<br>■ May be used to validate self-reporting of food intake | ■ Subject to within-participant variability<br>■ May only indicate short-term dietary intakes<br>■ Biomarker may not be specific to a certain food or food group<br>■ May be expensive |