2. Multiply the five estimated parameters to derive the measure of community effectiveness (CE), also a proportion between 0 and 1

\[ CE = E \times Se \times C_{hw} \times C_p \times C_v \]

a. Example - *Malaria*

(1) Policy is to identify all persons in the community with acute, febrile illnesses and then treat them with chloroquine

(2) Community Effectiveness (CE)

\[ CE = E \times Se \times C_{hw} \times C_p \times C_v \]

\[ CE = .90 \times .80 \times .90 \times .70 \times .60 = 0.27 = 27\% \]

3. Another view of CE

a. The prevalence of the disease in the community after a successful prevention or treatment program, \( P_1 \), is …

\[ P_1 = P_0 \times (1 - CE) \]

where \( P_0 \) = the prevalence of the disease in the community prior to the prevention or intervention program

(1) Example

Assume: \( P_0 = 0.02 \) or 20/1,000 and CE = 0.60 or 60% effective

\[ P_1 = 0.02 \times (1 - .60) = 0.008 = \frac{8}{1,000} \]
b. The potential proportionate reduction of the disease in the community is…

\[
\frac{P_0 - P_1}{P_0} = \frac{.020 - .008}{.020} = 0.60 = 60\%
\]

Note: This is the same value as \( CE \)

VI. DETERMINE PROBABLE COST OF EACH STRATEGY (STEP 5)

A. Estimate budget in terms of…
   1. personnel
   2. facilities/equipment
   3. supplies
   4. time

B. Consider both the political and financial costs
   1. Short-term solutions versus long-term solutions

VII. RECOMMEND PREFERRED CONTROL STRATEGY (STEP 6)

A. Estimate cost-effectiveness of each strategy

\[
\frac{\text{financial cost}}{\text{reduction in morbidity}} \quad \text{or} \quad \frac{\text{financial cost}}{\text{reduction in mortality}} \quad \text{or} \quad \frac{\text{financial cost}}{\text{disability-adjusted life-years (DALY)}}
\]

B. Compare various disease control strategies
   1. Objective is to maximize return on the financial investment
      a. Outcome is improved health for the most people
   2. Derive the optimum resource allocation decision
      a. When comparing many control strategies, objective is to maximize the potential marginal returns on the health investment for the most people
         (1) Definition - marginal return on health investment
            (a) The per unit improvement in the health outcome (i.e., more DALYs) associated with the per unit increase in cost for the prevention or intervention program
b. Steps for optimum resource allocation decision-making

(1) First determine, and fund, the program that provides the greatest potential reduction in the health outcome

(a) For example, disability-adjusted life-years (DALY)

(2) Increase the level of funding until the marginal improvement in the health outcome for the initial selected disease is less than the marginal improvement for the next most important disease associated with the same level of funding

(3) Switch the additional funding from the first disease to the second disease
(4) Increase the funding of the second disease control program until the marginal return is exceeded by the third disease

(5) Repeat the process until all of the available funds are spent

C. Compare the advantages and disadvantages of the proposed optimum resource allocation plan
   1. How accurate are the estimates
   2. Are there political or scientific reasons for selection one disease program over another

D. Establish targets for the disease outcome of interest
   1. The expected impact in the community

E. Present recommendations to decision-makers
   1. Written report with tables and graphs
   2. Oral presentation with slides or transparencies

VIII. MONITOR PROGRAM ACTIVITIES (STEP 7)

A. Establish a management information system
   1. Components
      a. Similar to a disease surveillance system

![Diagram of health care delivery system]

1. Sensor
(a) Identifies the flow of patients through the health care system, the use of drugs and other supplies, and activities of health workers

(2) Reference signal

(a) The output from the sensor

(3) Monitor

(a) Compares the reference signal with expectations

(4) Expectations

(a) Policies and standards for performance established by the program administrator

(5) Error signal

(a) Output of the monitor which measures difference between performance and expectation

(6) Controller

(a) Takes corrective action aimed at reducing the error signal

2. Typical functions

a. Part of the Health Information System

(1) Systematic data collection

(2) Centralized processing and analysis of data

(3) Feedback of information

(4) Stimulates further action aimed at increasing efficiency

3. Can also be used for evaluation studies

IX. REASSESS IMPACT ON BURDEN OF ILLNESS (STEP 8)

A. Close the measurement loop by evaluating what progress has been made and determine if other health needs of the community are being met

B. Revise funding and programmatic activities to maximize long-term impact on burden of illness

1. Education and training
2. Research and development

X. CONTINUE WITH MEASUREMENT ITERATIVE LOOP

```
STEP 1
Identify burden of illness

STEP 2
Determine probable causal mechanisms

STEP 3
Identify possible control strategies

STEP 4
Determine potential effectiveness of possible control strategies

STEP 5
Determine probable cost of each strategy

STEP 6
Recommend preferred control strategy

STEP 7
Monitor activities of control program

STEP 8
Reassess impact on burden of illness

PROGRAM IMPLEMENTATION
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APPENDIX

QUANTITATIVE MEASURES FOR ASSESSING THE IMPACT OF INTERVENTION OR PREVENTION PROGRAMS/PROCEDURES

This Appendix is intended as either a review of previously presented material for Epidemiology Majors or an introduction to the six measures of effect (i.e., PF_u, PF_p, RD, AF_e, AF_p, and PER) for Non-majors. While the material will not be presented in class, feel free to ask Dr. Frerichs for a more detailed explanation either during office hours (Tuesdays, 10-Noon; Rm 71-236B; 825-3286) or after class.

In order to determine the potential impact that a given health policy may have on a disease outcome, various study designs can be employed to assist the policymaker. The most objective is the randomized clinical trial. Unfortunately, clinical trials are often expensive and complicated to carry out. Yet if we know something about the natural history of the disease and pay special attention to various sources of bias, other study designs can also be of considerable use to the program administrator. Several quantitative measures of effect will be presented in this Appendix; the use of the measures for decision making will be emphasized in the course.

I. RANDOMIZED CLINICAL TRIAL (AN EXPERIMENTAL STUDY)

A. Objective: to test if training auxiliary midwives to cut umbilical cords with a razor and tie the stumps with a piece of thread saves lives during the neonatal period (i.e., the first 27 days of life)

B. Procedure: randomly assign 50 midwives to each of two groups, one trained to cut the umbilical cord with a razor and tie the cord stump with a thread and the second told to continue with their usual practice (in this case, not using a razor or thread)

<table>
<thead>
<tr>
<th>Died during the neonatal period</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Razor and thread</td>
<td>75</td>
<td>2,425</td>
</tr>
<tr>
<td>Usual practice</td>
<td>125</td>
<td>2,375</td>
</tr>
<tr>
<td>Randomly assigned to each training group</td>
<td>200</td>
<td>4,800</td>
</tr>
</tbody>
</table>

Assume: infants delivered by both groups of auxiliary midwives would have had the same probability of death if neither group would have received any special training (i.e., both groups would have the same inherent risk of death independent of the new procedure).

C. Policy-related questions to be answered

1. How many deaths were prevented in this experiment among those births delivered by auxiliary midwives trained to use a razor and thread?
2. What proportion of all neonatal deaths could be prevented if auxiliary midwives changed their usual practice and instead, used a razor and thread at the time of delivery?

D. Preventable Number Approach

<table>
<thead>
<tr>
<th>Death or illness</th>
<th>Yes</th>
<th>No</th>
<th>Number assigned to each group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomly assigned to each group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New treatment/procedure</td>
<td>A</td>
<td>B</td>
<td>A + B</td>
</tr>
<tr>
<td>Usual treatment/procedure</td>
<td>C</td>
<td>D</td>
<td>C + D</td>
</tr>
<tr>
<td>Both groups (i.e., total population being studied)</td>
<td>A + C</td>
<td>B + D</td>
<td>A + B + C + D</td>
</tr>
</tbody>
</table>

1. Considering further the bottom row of the table...

![Diagram showing Usual treatment/procedure with C₀ and C₁]

Where $C₀ = \text{cases not preventable by the new treatment/procedure (i.e., background cases or the non-preventable number)}$

$C₁ = \text{cases preventable by the new treatment/procedure (i.e., the preventable number)}$

2. Non-preventable number ($C₀$)

$$ C₀ = \frac{A}{A+B} \times (C + D) $$

$$ C₀ = \frac{75}{2,500} \times 2,500 = 75 $$

3. Preventable number ($C₁$)

$$ C₁ = C - C₀ $$

$$ C₁ = 125 - 75 = 50 $$
4. Preventable Fraction in the unexposed (i.e., unexposed to the procedure) \([PF_u]\)

\[
P_{F_u} = \frac{\text{preventable number of deaths or illnesses}}{\text{total number of deaths or illnesses among the unexposed}} = \frac{C_1}{C} = \frac{50}{125} = 0.40 = 40\%
\]

5. Preventable Fraction in the total group (i.e., those receiving and not receiving the treatment/procedure) \([PF_p]\)

\[
P_{F_p} = \frac{\text{preventable number of deaths or illnesses}}{\text{total number of deaths or illnesses in the population}} = \frac{C_1}{A + C} = \frac{50}{200} = 0.25 = 25\%
\]

II. COHORT STUDIES

A. Objective: to determine if malnourished children are more likely to develop pneumonia than non-malnourished children

B. Procedure: observe a population over time comprised of both malnourished and non-malnourished children and record the onset of pneumonia

<table>
<thead>
<tr>
<th>Developed pneumonia during following year</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malnourished</td>
<td>900</td>
<td>1,100</td>
</tr>
<tr>
<td>Not malnourished</td>
<td>290</td>
<td>7,710</td>
</tr>
<tr>
<td>Total</td>
<td>1,190</td>
<td>8,810</td>
</tr>
</tbody>
</table>

\(I_p = 0.11900\)

1. Assume that malnourished children would have had the same probability of developing pneumonia as the non-malnourished children if they, the malnourished group, had not been malnourished (i.e., both groups have the same inherent risk of pneumonia independent of their malnutrition status)

2. If this assumption cannot be made due to the presence of other confounding factors (a common problem), then the "pure" effect of malnutrition status can only be estimated after first controlling, via stratification or some other statistical technique, for the effects of these confounding variables

C. Policy-related questions to be answered

1. How many cases of pneumonia in the children in this study are attributed to their being malnourished?

2. What proportion of pneumonia cases among the malnourished children (i.e., among those "exposed" to the effects of malnutrition) could theoretically have been prevented if they had not been malnourished?

Establishing Program Priorities 23
3. What proportion of pneumonia cases in the total population (i.e., those malnourished plus those not malnourished) could theoretically have been prevented if none of the children would have been malnourished?

4. What reduction would you expect to have observed in the annual rate of pneumonia in the total child population if none of the children had been malnourished?

D. Attributable Number Approach

<table>
<thead>
<tr>
<th>Factor of interest</th>
<th>Death or illness</th>
<th>Number observed in each group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>Yes</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>B</td>
</tr>
<tr>
<td>Unexposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both groups (i.e.,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>being studied</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                | A + C           | B + D                       | A + B + C + D              |

a. Considering further the upper row of the table...

Where \( A_0 \) = cases not attributable to the exposure factor (i.e., background cases or the non-attributable number)

\( A_1 \) = cases attributable to the exposure factor (i.e., the attributable number)

1. Non-attributable number (\( A_0 \))

\[
A_0 = \frac{C}{C+D} \times (A+B)
\]

\[
A_0 = \frac{290}{8,000} \times 2,000 = 72.5
\]

2. Attributable number (\( A_1 \))

\[
A_1 = A - A_0
\]

\[
A_1 = 900 - 72.5 = 827.5
\]
3. Attributable Fraction among the Exposed (i.e., exposed to the harmful effects of the factor under consideration) \([ A_{Fe} ]\)

\[
A_{Fe} = \frac{\text{attributable number of deaths or illnesses}}{\text{total number of deaths or illnesses among the exposed}} = \frac{A_1}{A} = \frac{827.5}{900} = 0.92 = 92\%
\]

4. Attributable Fraction in the total Population (i.e., those exposed and unexposed to the factor of interest) \([ A_{Fp} ]\)

\[
A_{Fp} = \frac{\text{attributable number of deaths or illnesses}}{\text{total number of deaths or illnesses in the population}} = \frac{A_1}{A + C} = \frac{827.5}{1,190} = 0.70 = 70\%
\]

E. Incidence/Mortality Rate Approach

<table>
<thead>
<tr>
<th>Death or illness</th>
<th>Number observed in each group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Exposed</td>
<td>A</td>
</tr>
<tr>
<td>Unexposed</td>
<td>C</td>
</tr>
<tr>
<td>Both groups (i.e., total population being studied)</td>
<td>A + C</td>
</tr>
</tbody>
</table>

\[
A + B + C + D
\]

\[
I_e = \frac{A}{A + B}, \quad I_u = \frac{C}{C + D}, \quad I_p = \frac{(A + C)}{\text{Total}}
\]

1. Risk Ratio (RR; also termed "relative risk")

   a. Measures how many times greater is the incidence/mortality rate among the exposed than the unexposed (multiplicative)

   \[
   RR = \frac{I_e}{I_u} = \frac{.45}{.03625} = 12.4
   \]

2. Risk Difference (RD; also termed "attributable risk")

   a. Measures how much greater is the incidence/mortality rate among the exposed than the unexposed (additive)

   b. Among the exposed, identifies the rate of death or illness attributed to the exposure

   \[
   RD = I_e - I_u = .45 - .03625 = 0.41375 = 41.4\%
   \]
c. The RD can also be derived if you know the $I_p$, RR, and $P_e$ (i.e., the proportion of the population which is exposed; (A+B)/ total) using the following formula:

$$RD = \frac{I_p (RR - 1)}{P_e (RR - 1) + 1} = \frac{.119 (12.4 - 1)}{.2 (12.4 - 1) + 1} = 0.414 = 41.4\%$$

3. Attributable Fraction among the Exposed ($AF_e$; also termed "etiologic fraction among the exposed")

a. Measures the proportion of illnesses or deaths among the exposed attributed to the exposure

$$AF_e = \frac{I_e - I_u}{I_e} = \frac{.45 - .03625}{.45} = 0.92 = 92\%$$

b. The $AF_e$ can also be derived if you know only the RR using the following formula:

$$AF_e = \frac{RR - 1}{RR} = \frac{12.41 - 1}{12.41} = 0.92 = 92\%$$

4. Attributable Fraction in the Total Population ($AF_p$; also termed "etiologic fraction in the population")

a. Measures the proportion of illnesses or deaths in the total population attributed to the exposure

$$AF_p = \frac{I_p - I_u}{I_p} = \frac{.119 - .03625}{.119} = 0.70 = 70\%$$

b. The $AF_p$ can also be derived if you know the RR and $P_e$ using the following formula:

$$AF_p = \frac{P_e (RR - 1)}{P_e (RR - 1) + 1} = \frac{.20 (12.41 - 1)}{.20 (12.41 - 1) + 1} = 0.70 = 70\%$$

5. Population Excess Risk (PER)

a. Measures the incidence or mortality rate in the total population which is attributed to the exposure

$$PER = I_p - I_u = .119 - .03625 = 0.08275 = 8.3\%$$
b. The PER can also be derived if you know the $I_p$, RR, and $\rho$ using the following formula:

\[ PER = \frac{P_e I_p (RR - 1)}{P_e (RR - 1) + 1} = \frac{.2 (.119) (12.41 - 1)}{.20 (12.41 - 1) + 1} = 0.08275 = 8.3\% \]

c. Furthermore, the PER is related to the RD as follows:

\[ PER = P_e (RD) = .2 (.4137) = 0.08275 = 8.3\% \]

III. CASE-CONTROL STUDIES

A. Case-control studies are a very efficient means for obtaining etiologic information in a developing country. For any given disease of interest, case-control studies utilize information on the presence of risk factors among persons who died or developed an incident illness (termed "cases") to compare with the presence of risk factors of the disease among persons who either did not die or did not develop the incident illness (termed "controls"). The studies can be used to estimate the RR, $AF_e$, $AF_p$, and if $I_p$ is known, RD and PER. While efficient, requiring small sample sizes to provide estimates of the relative likelihood of illness or death associated with a given risk factor, case-control studies are more complicated to analyze and are subject to numerous sources of bias, known to Epidemiology students who have taken EPI 200A, 200B and 200C.

IV. CROSS-SECTIONAL STUDIES

A. Health surveys conducted at one point in time are among the most common sources of information on the health status of the population in much of the technologically less-developed world. Information may be provided by members of the community (e.g., perceived morbidity), by trained observation of a health professional (e.g., signs and symptoms) or by direct measurement using mechanical instruments (e.g., anthropometric measurements). Information is usually presented describing the occurrence of either the disease or risk factors (i.e., the point prevalence). Yet cross-sectional studies can be used for investigating etiologic relationships if the correct form of analysis is employed and special attention is given to several sources of potential bias. As with case-control studies, cross-sectional studies can be used to estimate the RR, $AF_e$, $AF_p$, and if $I_p$ is known, RD and PER. Cross-sectional studies of etiologic relationships require a different form of analysis than do clinical trials or cohort studies (e.g., the prevalence odds ratio rather than the RR) and are subject to various sources of bias. The methodology for cross-sectional studies (and for that matter, health surveys in general) will not be presented here, but rather, is covered in EPI 200A, 200B and 200C. A special type of survey using portable microcomputers to quickly conduct, process, analyze and present survey findings will be featured next quarter in my course, Rapid Epidemiologic Surveys in Developing Countries (EPI 418).