

Principles of Epidemiology

COURSE DURATION

June 1 – 30, 2021

INSTRUCTOR

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COURSE DESCRIPTION

This course will provide an in-depth introduction to epidemiologic concepts and methods. Using graphics and visuals as a starting point, we will provide step-by-step instruction on the fundamentals of epidemiologic study design and analysis. For this course we will use the textbook *Epidemiology Matters: a New Introduction to Methodological Foundations*, co-written by course instructors Drs. Keyes and Galea. At its core, *Epidemiology Matters* is concerned with the principles of an epidemiologic science that is consequential for the improvement of human health through the identification of causes of disease while aspiring to the prevention of disease and the promotion of health. The course will be divided into fourteen modules that correspond with the fourteen chapters of *Epidemiology Matters*. Across these modules, *Epidemiology Matters* is organized around seven foundational steps that inform the conduct of an epidemiologic study. The seven steps are: 1) identify a population of interest; 2) measure exposure and health indicators; 3) take a sample; 4) estimate measures of association between exposures and health indicators; 5) rigorously evaluate the associations for internal validity; 6) Assess the evidence for causes working together; and 7) assess the external validity of epidemiologic study results. *Epidemiology Matters* also covers principles of screening for primary and secondary prevention. In addition to comprehensive content within the text, students will find a full compendium of exercises and practice problems, lecture slides, and additional material to enhance and build upon the material in the text at www.epidemiologymatters.org.

PREREQUISITES

None.

COURSE LEARNING OBJECTIVES

- Identify the most appropriate study design for different types of research questions

- Estimate measures of association between exposures and health indicators
- Evaluate the potential for non-comparability compromising our ability to make inference from a study
- Articulate epidemiologic causal theory and how causes work together to produce complex health indicators
- Envision a program of research that has consequence for improving public health

COURSE READINGS

Keyes KM, Galea S. 2014. Epidemiology matters: a new introduction to methodological foundations. New York, Oxford University Press.

COURSE STRUCTURE

The course is divided into fourteen modules. Each Monday throughout the month of June, 3-4 modules will be released. Each module will include a series of 10-15 minute lectures, Power Point slides, and an exercise. Exercise answer keys will be released on Thursdays. Navdep Kaur will also be available to answer questions via email or through the online discussion boards throughout the week.

COURSE SCHEDULE

Module 1 – Introduction to Epidemiology Matters	
Release date: Monday, June 1	<p>Lecture: Epidemiology Matters, an introduction</p> <p>Description: Epidemiology is the science of understanding the causes and distribution of population health so that we may intervene to prevent disease and promote health. In this first chapter we outline the role of epidemiology as a public health science, describe the evolution of epidemiology as a discipline, and explain our philosophy of teaching introductory epidemiologic concepts. We provide an overview of the seven steps for conducting an epidemiologic study, which will form the underlying architecture of the fourteen chapters of the book, including: 1) identify a population of interest; 2) measure exposure and health indicators; 3) take a sample; 4) estimate measures of association between exposures and health indicators; 5) rigorously evaluate the associations for internal validity; 6) assess the evidence for causes working together; and 7) assess the external validity of epidemiologic study results.</p> <p>Required reading: Chapter 1: An introduction</p> <p>Independent practice: Chapter 1 Exercises</p>

Module 2 – Populations and Population Health	
Release date:	<p>Lecture: What is a population and what is population health?</p> <p>Description:</p>

**Monday,
June 1**

This chapter introduces step 1, i.e., identify a population of interest. While illness ultimately occurs within individuals, epidemiologists ask questions about the health of groups, such as whether the illness is common or rare, why illness is more common in one group compared with another, and what are the common causes of illness within a population of interest. To the end, the first step in conducting an epidemiologic study is to conceptualize, define, and operationalize the population of interest. Populations to study are defined by eligibility criteria in three main domains. Populations can be defined by geographic space and time; a characteristic, event, or exposure; or by particular considerations needed to improve compliance and adherence to the study protocol. While human populations are inherently dynamic with a constant influx and outflow of individuals due to birth and death, populations for epidemiologic study may be dynamic or stationary depending on these eligibility criteria. Specific and predetermined criteria that characterize a population of interest are critical to all successful epidemiologic studies.

Required reading: Chapter 2: What is a population and what is population health?

Independent practice: Chapter 2 Exercises

Module 3 – Measuring Exposure and Disease

**Release
date:
Monday,
June 1**

Lecture: What is an exposure, what is a disease, and how do we measure them?

Description:

In this chapter we present step 2, i.e., identify an exposure and health indicators. We review how to conceptualize health status and common ways in which we measure the health status of populations, how to define exposures and other factors that may influence health, and fundamental principles in the measurement of these factors. Health indicators of interest may be any factor that is associated with disease, illness, or adverse health symptoms, as well as well-being and positive health outcomes. We can measure health indicators by their presence or absence, or as gradients. Exposures of interest are any variables that may influence health indicators, and can be innate such as genetics or biological sex, acute one-time events, chronic environmental insults, or time-varying health behaviors such as smoking and diet. Valid and reliable measures are critical to the success of an epidemiologic study for any exposure or specific health indicator of interest. We also review foundational concepts in construct definitions, as well as standard tests of reliability and validity.

Required reading: Chapter 3: What is an exposure, what is a disease, and how do we measure them?

Independent practice: Chapter 3 Exercises

Module 4 – Sampling



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Release date:
Monday, June 8

Lecture: What is a sample?

Description:

This chapter introduces step 3, i.e., take a sample. We review basic principles for taking a sample of a defined population. We review two approaches to sampling: simple random sampling, and purposive sampling. Simple random sampling is required when inference about population parameters is of interest. We review basic approaches to simple random sampling including quantifying sampling variability. Purposive samples are often used in epidemiology when all members of a population cannot be enumerated or when the question of interest is whether a particular exposure is a cause of a health indicator. We review the epidemiologic approach to purposive sampling, which requires us to reconceptualise individuals in the population as quanta of eligible person time. We then review the fundamentals of epidemiologic study design, which include following a sample of individuals free of the health indicator of interest forward in time to determine when cases arise (cohort studies), sampling individuals at a particular point in time and assessing the burden of the health indicator (cross-sectional studies), or sampling individuals with and without the health indicator of interest and assessing history of potential exposures (case-control studies). We emphasize throughout that all of these methods for collecting samples are at core different ways to look at a dynamic population, aiming to capture a piece of that population for the purposes of an epidemiologic study.

Required reading: Chapter 4: What is a sample?

Independent practice: Chapter 4 Exercises

Module 5 – Measures of Occurrence and Frequency

Release date:
Monday, June 8

Lecture: Watching a sample, counting cases

Description:

This chapter reviews foundational epidemiologic measures of health indicator occurrence and frequency. For any epidemiologic study design we need to count cases of the health indicators of interest. Prevalence, risk (also termed incidence), and rate are three central measures of occurrence and frequency that form the foundation of all epidemiologic approaches to understanding the distribution of health indicators. We provide a comprehensive overview into the estimation of these measures and the connections among these measures. We also provide a comprehensive guide to estimating standard errors and confidence intervals for measures of prevalence, risk, and rate. Finally, we guide the reader through estimating conditional risks as we progress toward estimating measures of association.

Required reading: Chapter 5: Watching a sample, counting cases

Independent practice: Chapter 5 Exercises

Module 6 – Measures of Association

Release date:
Monday, June 8

Lecture: Are exposures associated with health indicators?

Description:

How do we know when an exposure of interest is associated with a health indicator? This question is at the heart of step 4, i.e., estimate measures of association between exposures and health indicators. In this chapter we guide the reader through measures of association for multiple types of study design. We cover the risk ratio, rate ratio, and odds ratio, as well as risk and rate difference. We provide special attention to the odds ratio, including what an odds ratio is, when to use an odds ratio, and the connections between odds ratios and other measures of association. The chapter provides multiple examples of when to use each measure, their estimation and the associations among measures. We also provide a comprehensive guide to estimating and interpreting 95% confidence intervals for all measures of association.

Required reading: Chapter 6: Are exposures associated with health indicators?

Independent practice: Chapter 6 Exercises

Module 7 - Causation

Release date:
Monday, June 8

Lecture: What is a cause?

Description:

Identifying factors that cause disease is the central driving force behind the discipline of epidemiology. Having discussed, in preceding chapters, how we can measure associations in epidemiology, this chapter considers how we may think about whether such associations are causal. To do so we articulate a framework focusing on the counterfactual approach to defining a cause. We guide the reader through disease causation at the level of the individual and the population. We present disease causation in the population using the example of a game of marbles, in which each individual has a marble jar through which certain combinations of marbles cause produce disease. Using the metaphor of the marble jar we guide the reader through disease causation across the life course and offer a formulation for expressing disease causation in the context of connected networks of individuals who share exposures and may transmit diseases to one another. We provide the reader with a framework for conceptualizing multiple causes of disease as exposures that interact, and describe why assessment of causes in population is often probabilistic rather than deterministic.

Required reading: Chapter 7: What is a cause?

Independent practice: Chapter 7 Exercises

Module 8 – Non-Comparability

Release date: Monday, June 15	<p>Lecture: Is the association causal, or are there alternative explanations?</p> <p>Description: Associations observed between an exposure and a health indicator can arise because the exposure causes the health indicator of interest, or because there is an alternative explanation for the association. Understanding this lies at the heart of step 5, i.e., rigorously evaluate the associations for internal validity. A fundamental driver of non-causal associations is non-comparability. Non-comparability arises when individuals who are exposed are not comparable to individuals who are unexposed on factors that are related to the health indicator. This chapter introduces the reader to fundamental concepts in non-comparability. Building on the counterfactual framework for conceptualizing a cause introduced in chapter 7 we guide the reader through understanding the causal architecture that underlies non-comparability in epidemiologic studies, providing theoretical frameworks and examples.</p> <p>Required reading: Chapter 8: Is the association causal, or are there alternative explanations?</p> <p>Independent practice: Chapter 8 Exercises</p>
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Module 9 – Non-Causal Associations	
Release date: Monday, June 15	<p>Lecture: How do non-causal associations arise?</p> <p>Description: Non-comparability between exposed and unexposed individuals can compromise causal inference from epidemiologic studies. In this chapter, we guide readers through the four ways in which non-comparability commonly arises in our studies: (1) through random chance in the sampling process; (2) because causes of health indicators tend to cluster; (3) because of systematic differences between exposed and unexposed in the selection and follow-up of the sample; and (4) because of measurement error that is associated with both the exposure and the health indicator. Throughout the chapter we provide quantitative measures assessing the extent of non-comparability through these sources, and also provide multiple examples and graphical illustrations demonstrating how non-comparability arises and can compromise epidemiologic research.</p> <p>Required reading: Chapter 9: How do non-causal associations arise?</p> <p>Independent practice: Chapter 9 Exercises</p>

Module 10 – Mitigating Against Non-Causal Associations	
Release date: Monday, June 15	<p>Lecture: How can we mitigate against non-causal associations in design and analysis?</p> <p>Description: Having explicated how we think of causes in epidemiology, how comparability between exposed and unexposed is an important component of our ability to make strong</p>

conclusions from our data, and the central ways in which non-comparability arises when we conduct epidemiologic studies, in this chapter we detail three foundational ways in which comparability is achieved in epidemiologic studies: (1) randomize individuals to receive the exposure or not; (2) match individuals in the study to each other on variables that are potential causes of non-comparability; and (3) stratify the data to determine whether there is an association between exposure and outcome holding constant variables contributing to non-comparability. We provide a comprehensive overview of randomization and randomized controlled trials in epidemiology, matching and methods for analyzing matched data, and quantitative approaches to stratification for the assessment and removal of non-comparability after the data has been collected.

Required reading: Chapter 10: How can we mitigate against non-causal associations in design and analysis?

Independent practice: Chapter 10 Exercises

Module 11 – Interaction

Release date: **Lecture:** When do causes work together?

**Monday,
June 22**

Description:

This chapter introduces step 6, i.e., assess the evidence for causes working together. For nearly all health indicators that are of interest to public health, our exposures of interest are embedded in a host of other component causes that work together to activate the exposure's effect. In developing and testing hypotheses regarding the potential effects of an exposure on a health indicator, it is critical to conceptualize, measure, and assess the other component causes that may work in concert with the exposure of interest. When multiple component causes work together to produce a particular health indicator, we term this process interaction. In this chapter we provide a conceptual overview of interaction rooted in our metaphor of disease causation through marble jars, providing the reader with a graphical and intuitive understanding of this topic. We then present quantitative approaches to assessing interaction in epidemiologic data, discussing interaction across multiplicative and additive scales as well as modern techniques for quantifying interaction.

Required reading: Chapter 11: When do causes work together?

Independent practice: Chapter 11 Exercises

Module 12 – Generalizability

Release date: **Lecture:** Do the results matter beyond the study sample?

**Monday,
June 22**

Description:

Establishing the external validity (or generalizability) of the study results beyond the study sample is critical if epidemiologic studies will have consequence for public health. In this chapter we discuss step 7, i.e., assess the external validity of epidemiologic study

results. We provide the reader with a quantitative as well as a conceptual overview of external validity. We first place external validity in context by discussing other levels of validity in epidemiologic studies. We then guide the reader through the epidemiologic principle that the result from one study will be externally valid to populations in which the distribution of component causes of the exposure is similar to the study sample. We discuss trade-offs between internal and external validity for the identification of causes of health indicators. We provide the reader with tools to rigorously evaluate the extent to which the results of a particular epidemiologic study will be externally valid, and to whom.

Required reading: Chapter 12: Do the results matter beyond the study sample?

Independent practice: Chapter 12 Exercises

Module 13 – Screening

Release date: **Lecture:** How do we identify disease early to minimize its consequences?

**Monday,
June 22**

Description:

This chapter introduces the reader to foundational concepts in disease screening as well as public health approaches to evaluating screening programs. We discuss central measures in screening including sensitivity, specificity, positive predictive value, and negative predictive value. We discuss how these parameters change when cut-points for screen tests are changed, and discuss the relation between disease prevalence and positive as well as negative predictive values. We then discuss guidelines for screening programs, including the need for early detection to prevent symptoms or slow death. In screening program evaluation, we discuss unique biases that threaten the validity of inference. We provide readers with examples from successful public health screening programs to illustrate the central concepts of screening for public health prevention.

Required reading: Chapter 13: How do we identify disease early to minimize its consequences?

Independent practice: Chapter 13 Exercises

Module 14 – Conclusion

Release date: **Lecture:** Epidemiology and what matters most

**Monday,
June 22**

Description:

Epidemiology has a foundational responsibility to improve the health of populations. In this concluding chapter we advocate for a consequentialist view towards epidemiologic research questions. We explain the consequentialist approach to epidemiology and leave the reader with several key messages from the book overall. We underscore the tradeoff between comparability and external validity that we as epidemiologists must sometime make, we discuss the concept of small effects translating to large improvements in population health and the implications of this for public health

planning and study evaluation, and finally, we discuss epidemiology within the global context of health and disease.

Required reading: Chapter 14: Conclusion: Epidemiology and what matters most

Independent practice: Chapter 14 Exercises