# Chapter 1
# Nonparametric Methods: Schistosomiasis

## Investigation
This chapter asks students to use nonparametric tests to determine if a new drug is helpful in reducing schistosomiasis (shis-tuh-soh-mahy-uh-sis), a disease occurring in humans caused by parasitic flatworms. Schistosomiasis affects millions of people, especially children in developing countries. The disease can cause death, but more commonly results in chronic and debilitating symptoms, caused primarily by the body's immune reaction to parasite eggs lodged in the liver, spleen, and intestines.

## Goals
This chapter introduces randomization tests, permutation tests, and bootstrap methods. We demonstrate that these techniques typically require fewer assumptions and provide results that are often more accurate than those from traditional techniques (especially when the sample data are skewed, the sample size is small or when we want to conduct inference for something other than the population mean). Rank based tests, such as the Wilcoxon Rank Sum Test and the Kruskal-Wallis Test, are also discussed in the extended activities.

This chapter also reviews the key concepts of statistical inference, thus students may feel the material in this chapter moves somewhat slower than other chapters if they are already comfortable with hypothesis tests.

## Suggested Schedule
Below is an aggressive outline that has been used for Chapter 1. This class met three times a week for 50 minute time periods. While it is helpful to teach this chapter in a computer lab, these materials have also been taught in rooms where only the instructor has a computer.

I require students to submit answers to all the questions from the initial activities, but grade only a few problems. Class time is used to discuss (or give solutions to) questions where several students had questions, review key concepts, and provide additional examples (often selected from the homework problems).

**Day 1-2:** Before class the students (often in groups of 2-3) are expected to read the introduction and complete the first two problems. We start the class by discussing the case study, then review the goals of hypothesis testing and discuss why the traditional two-sample t-test is not appropriate for this study. Students (typically in groups) work through Questions 3-6 in class and answers are recorded on the board (or on the instructor's computer) but not graded. *Bring 3x5 note cards to class for students to use.*

While Questions 3-6 are rather simplistic and time consuming, I always take the time to work through these in detail in class. Many students leave the introductory statistics course not clearly understanding the key concepts behind statistical inference. These four questions provide a concrete example that can be referred to throughout the course to reiterate the true meaning of these concepts.

If time allows we will also work through Questions 7-12 in class. Even though step by step instructions are given, *this is one place where students may become easily frustrated*, since many of my students are not familiar with writing even a small computer program. Many students may not complete all the problems in class, so this is one time that I am careful to give time outside of class where I will be available to answer questions.

*Note: If you are starting this chapter the first day of class, it may be best to briefly introduce the research question and have the students work through problems 3-6 in class. Then have the students catch up on the reading before the second day.*

**Day 2:** The second day is used to review the simulation in Questions 7-12. I use the instructor's computer and projector to walk through the meaning of each step in the short program and ask how changing certain aspects of the program will impact the results. Often I will allow 15 minutes at the end of class to help any student groups who could not get their programs to work. If class is conducted in a computer lab, students who did get their programs to work can use class time to continue to work through the rest of the chapter.

**Day 3-4:** Student groups submit Questions 13-18 at the beginning of class. We spend 10-15 minutes comparing and interpreting p-values from their simulations and the two-sample t-tests. I also spend time reviewing the concepts of random allocation and random sampling. If time allows I lecture with new examples (often using one of the end-of-chapter exercises), discuss the extended activities, or allow students to work through a few of the extended activities. At this point I have students read through the gender discrimination research project and have them start collecting data on their university of choice.

**Day 4-5:** I typically allow 1-2 days to discuss a few topics from the extended activities, particularly Section 1.13 (Multiple Comparisons) and Section 1.9 (Using Bootstrap Methods to Create Confidence Intervals). While not required, the multiple comparison activities are helpful for students to work through before they complete the project. I often briefly discuss other nonparametric techniques without requiring students to work through all the questions. While students work on these activities, they are also expected to be collecting data, conducting an analysis and preparing their report.

**Day 6:** Student groups submit their 3-page summary report for their discrimination research project. In addition, at the beginning of class students are expected to submit the first few questions of the next chapter (Chapter 2 or other chapter). Class discussion focuses on Chapter 2.

## Extended Activities

Some of the optional extended activities are more complex than the questions asked in the schistosomiasis study.

- Sections 1.6 and 1.7 can be completed as out of class homework problems.

- Often I lecture through Sections 1.8 -1.10 instead of having students work through these activities on their own. Students tend to struggle with these sections.
- Traditional non-parametric techniques (such as *Wilcoxon* and *Kruskal-Wallis*) are very useful to be aware of because they are often used in research. However, these techniques are somewhat ancillary to the goals of this chapter and after students have completed this course, they usually have little difficulty understanding these techniques on their own.
- Section 1.13 (Multiple Comparisons) is useful to work through before conducting the project, but not required

## Research Project

While a data set labeled `faculty` is available for this project, students are much more interested in this project when they find their own data based on a local university. The `faculty` data set contains messy data. Expect students to ask why particular outliers exist. The one female English instructor earning $178,798 was working as an associate dean while still considered part of her original department. While information on other faculty was not completely available, it seems reasonable that some are emeritus or have part time teaching positions.

Students will find it difficult to limit their report three pages (including graphs); they tend to struggle with succinctly presenting their results. This is a very useful exercise in encouraging students to clearly and concisely communicate key results of a study. I point out that while academics sometimes value very thorough lengthy documents, in my experience working as an industry consultant, all the top executives that I know prefer to be given short summary documents that help them understand the key points on the issue.

Since this is their first project, I tend to make it shorter and worth fewer points than later projects. While it would be useful to give students an opportunity to rewrite this document, instead I often lecture on common errors in the assignment and provide an example of a well written summary paper. The following can be used as a model solution in class.

# SAMPLE PROJECT SOLUTION

## Chapter 1 Project: Faculty Salaries

### Conclusion:

We found no evidence of gender discrimination in the salaries paid to the regular, full-time faculty in the English and statistics departments.

### Method:

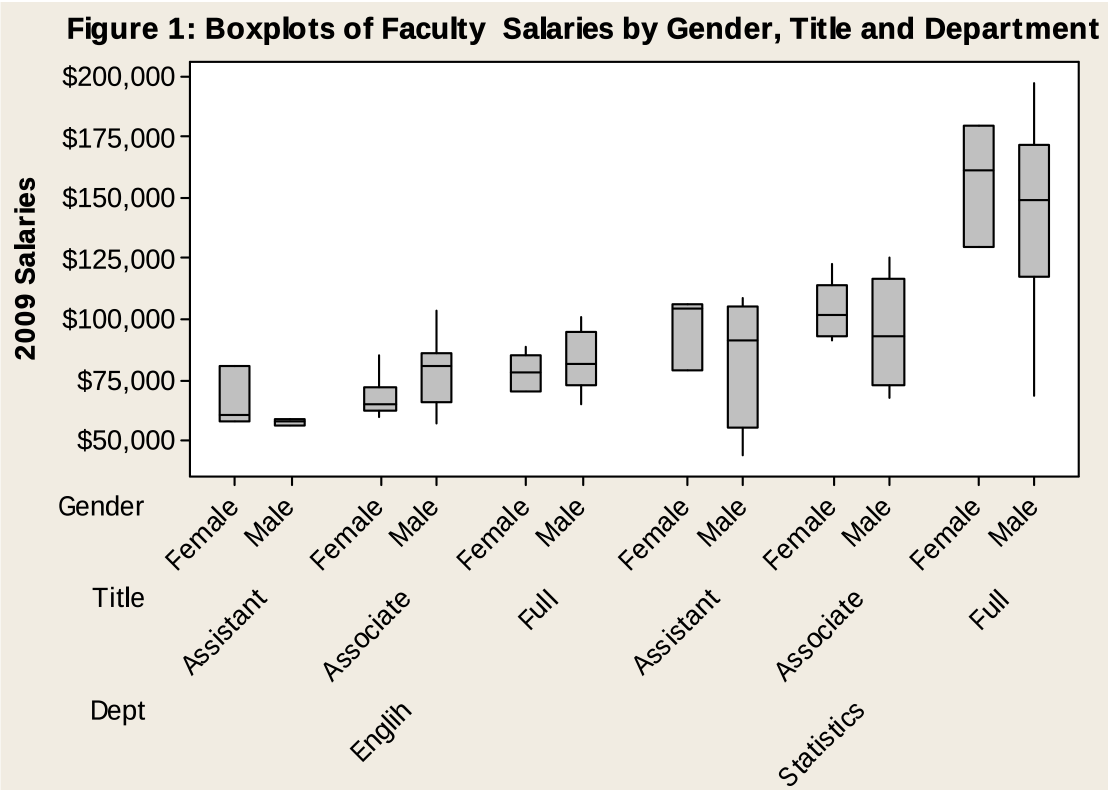
We examined only regular, full-time faculty; the following persons were excluded from the analysis:

- The three lecturers and adjuncts in the English department. Without knowing details about each of these instructors' teaching loads and contracts, it is difficult to determine if there is gender bias in their pay.
- The English professor earning $178,798, although a member of the English department, is currently serving as an associate provost, and presumably her salary reflects her administrative position rather than her role as an English professor.
- Three faculty members (one in statistics and two in English) for whom salary information was not provided.
- The male full professor, whose salary was $21,268. This salary is so low that he was presumably not acting as a full-time member of the faculty.

"Distinguished professors" and "university professors" were grouped with full professors for the purposes of this analysis.

Figure 1 graphs the remaining salary data by gender, faculty rank (title), and department. These categories were chosen because faculty rank and department are likely to explain much of the variations in salaries. It is not valid to compare the salaries of male full professors in the statistics department with the salaries of female assistant professors in the English department, and then conclude that the males' higher salaries are due to gender.

Figure 1 shows that the members of the male-dominated statistics department are paid more than the members of the female-dominated English department, leading to an overall higher average salary for the male professors ($106,040 for male professors versus $90,899 for female professors). However, within the six department and faculty rank combinations there is no clear pattern showing that male professors out-earn the female professors .




Two-sided randomization tests were used to determine if gender differences in average salaries could be explained by random chance. Two-sided tests were chosen to account for the possibility that there may have been gender bias in *favor* of female professors; a one-sided test would only have shown statistical significance in the cases where the male professors' salaries were significantly higher than the female professors' salaries, whereas a two-sided test would also show statistical significance if the female professors' salaries were significantly higher than the males. Randomization tests were chosen because the small number of faculty in each group ruled out the use of a t-test.

Table 1 shows the results of the randomization tests conducted for each of the six department and faculty rank combinations. In each test, the salaries were randomly assigned to either a male or a female (in the same proportion as the actual members of the department), and then the difference between the average male and female salaries were calculated. After this was done 10,000 times, the p-value represents the percentage of times where the absolute value of the difference exceeded the absolute value of the actual difference. This p-value estimates how often the actual difference would have occurred by random chance alone.

**Results:**

Although the average female and average male salaries do differ in each of the six department and faculty rank combinations, the difference was not statistically significant for any of the six. Thus in each test, random chance could have explained the observed differences between salaries for males and females.

**Table 1: Comparison of Faculty Salaries by Department and Rank**

| Department and rank | Average female salary | Female sample size | Average male salary | Male sample size | Difference | *p-value* |
|---|---|---|---|---|---|---|
| English assistant professors | $66,327 | 4 | $57,545 | 3 | $8,782 | .6074 |
| English associate professors | $67,714 | 6 | $77,901 | 7 | -$10,187 | .1885 |
| English full professors | $78,036 | 5 | $82,748 | 7 | -$4,712 | .4929 |
| Statistics assistant professors | $96,464 | 3 | $83,899 | 5 | $12,565 | .6068 |
| Statistics associate professors | $103,184 | 5 | $94,171 | 7 | $9,013 | .4048 |
| Statistics full professors | $157,155 | 3 | $143,875 | 16 | $13,280 | .5276 |

Conclusions should not be drawn about the entire university based on an analysis of two departments that were not randomly selected. Also, this analysis is only able to consider the people who are currently members of these departments at these ranks. This analysis cannot speak to possible biases (including gender biases) in which faculty are hired, which faculty receive tenure, how quickly faculty are promoted, or which faculty choose to leave for higher-paying jobs elsewhere. Any biases such as these, if they exist, might influence the results of this analysis. (For example, if lower-paid female faculty have left the university [voluntarily or through tenure denial], then their lower salaries cannot be included in this analysis, and the average female salary will appear to be higher.)

However, for these two departments, and with the above caveats, there is no evidence of gender discrimination in salaries.