How does intensity and frequency of exercise affect cholesterol levels? The November 7, 2002 issue of *The New England Journal of Medicine* contains an article by Kraus *et al.* in which the authors report the results of a prospective, randomized trial to study the effects of the amount and intensity of exercise on lipoproteins.

Volunteer subjects were between the ages of 40 and 65, sedentary, overweight or mildly obese (body-mass index 25 to 35), and had dyslipidemia (defined by having LDL or HDL cholesterol levels in certain ranges). Subjects were randomly assigned to one of four exercise groups: control, low-amount/moderate-intensity, low-amount/high-intensity, and high-amount/high-intensity. Exercise sessions were supervised. Subjects gradually increased exercise for a couple months before entering a 6-month exercise program. Of 159 subjects initially enrolled, 48 dropped out of the study, 15 had excessively low adherence to the assigned exercise program, 10 had incomplete lipid data, and 2 had excessive weight loss, leaving 84 subjects for the analysis.

The study examined several outcome variables, one of which is HDL cholesterol concentration (mg/dl). Each subject for which there was compete data had HDL measurements taken before and after completing the exercise program and at similar times for controls. Here is one summary (means $\pm$ SE).

Group	n	Base line	End of study	Change
Control	26	42.7 ± 2.7	42.1 ± 2.2	-0.6 ± 1.7
Low-amount/Moderate-intensity	19	40.3 ± 2.2	41.0 ± 2.6	0.7 ± 1.0
Low-amount/High-intensity	17	46.6 ± 3.7	46.9 ± 3.4	0.3 ± 1.8
High-amount/High-intensity	26	44.3 ± 2.9	48.6 ± 3.3	4.3 ± 1.4

(a) Select a method from the course that would be appropriate to address the question, "Do different exercise programs affect HDL cholesterol concentration differently?"

Solution: The problem is to compare four different exercise programs. ANOVA is the appropriate method to use. (Note that each exercise program could be studied separately with a paired t-test, but this does not address the question of comparing the exercise programs. This is similar to problems at the end of Chapter 9 in which you could do separate paired t-tests for each of two treatment groups and then use an independent sample t-test to compare the groups.)

(b) For the method you selected in part (a), state null and alternative hypotheses, both in the context of the problem and using statistical notation. Define any statistical notation you introduce.

Solution: *In the context of the problem:*
H_0: The different exercise programs have the same effect on HDL cholesterol concentration.
H_A: The different exercise programs do not have the same effect on HDL cholesterol concentration.

Let μ_i for $i = 1, 2, 3, and 4$ be the population mean changes in HDL cholesterol concentration for the population from which the volunteers come for the four treatments in the order listed above.

Using statistical notation:
$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$
H_A: The μ_i are not all equal.

(c) For the method you selected in part (a), describe how the p-value would be calculated. (For example, you might answer something similar to "the p-value would be the area to the right of the test statistic under a t distribution with 17 degrees of freedom".)

Solution: The p-value would be the are to the right of the test statistic undeer an F distribution with 3 and 84 degrees of freedom.

(d) What parts of the summary data above could be used to compute the test statistic and what parts would not be necessary? (You do not need to make any calculations.)

Solution: The sample sizes and the means and SEs of the changes in HDL cholesterol concentration could be used to calculate the ANOVA table and the F statistic. The other data is not relevant for this purpose.

(e) Suppose that your method produced a p-value of 0.088. Write a summary of your conclusions in the context of the problem. (Assume that your audience has limited statistical knowledge but understands the scientific content very well.)

Solution:

There is slight evidence to suggest that the different exercise programs affect HDL cholesterol concentration differently ($p = 0.088$, F-test, one-way ANOVA). A larger study would be necessary to be more certain that the observed differences between treatment groups are due to different treatment effects and not just sampling variation.

(f) Explain how the large amount of dropout in the study might affect interpretation of the results in your previous response.

Solution: If the people who dropped out of the study would have had substantially different HDL cholesterol changes than those who remained in the study, the results of the study could be biased and invalid.

(g) Suppose that the study had only contained two groups, control and high-amount/high-intensity exercise. Using just data from these groups, find a 95% confidence interval for the change in HDL cholesterol concentration that might result from the exercise program. Interpret this confidence interval in the context of the problem. (You may assume 50 degrees of freedom.)

Solution: First, note that the data reports SEs, not SDs. The SE for the difference in sample means is $\sqrt{(1.4)^2 + (1.7)^2} = 2.20$. With 50 degrees of freedom, the critical t value is 2.009. The confidence interval is 4.9 ± 4.4. We are 95% confident that the mean change in HDL cholesterol concentration for people from the volunteer population who undertake the high-amount/high-intensity exercise program will be between 0.5 and 9.3 mg/dl higher than those who follow the control exercise program (of continuing sedentary life).

(h) In the article, three pairwise comparisons were made: each exercise group was compared with the control group. Bonferroni's correction is invoked to explain why 0.0167 was used as the level for statistical significance. Briefly explain why this was done.

Solution: Bonferroni's correction is used so that the probability of at least one Type I error in a set of hypothesis tests is controlled and no more than a given significance level. In this study, there were three comparisons of interest, which is why a significance level of $0.05/3 = 0.0167$ was selected.