What is a cut-off frequency and how can it be calculated?
Which statistical tests are used to evaluate biomechanics data?
What is the purpose of IRB?
Feb 6 - Monday - Proposals due (see course website)

Feb 8 - Exam - Covers through IRB

Feb 10 - Lab 1 assignment due

HW 2 -> IRB training
Statistical analysis

(a really brief and incomplete tutorial on paired sampling tests)
Paired samples testing

• A way to compare results from the same subject that was exposed to two different testing conditions to see if there is a statistically significant difference between conditions

• Possible Methods

1) Paired t-test (if results are normally distributed)

2) Non-normal: Wilcoxon's signed ranks test OR Kstest

Kolmogorov- Smirnov
What does normal vs. non-normal data mean?

Plot histogram of values

Probability Distribution Function

Non normal

Median absolute deviation

Test for normality: kstest in Matlab

Check the data for normality!
But first some fundamental concepts…

- Hypothesis testing
  - Null hypothesis ($H_0$): 2 conditions are the same and any difference between conditions is due to chance. $\text{mean}(A) = \text{mean}(B)$
  - Alternate hypothesis ($H_A$):
    - 2 conditions are different and there is a real effect.
    - $\text{mean}(A) > \text{mean}(B) \Rightarrow 1$-tailed test
    - $\text{mean}(A) < \text{mean}(B) \Rightarrow 1$-tailed test
    - $\text{mean}(A) = \text{mean}(B) \Rightarrow 2$-tailed test
P-value

- If \( H_0 \) were true, what is the probability of observing a test statistic at least as extreme as the one we observed?

\[ p\text{-value} \Rightarrow \begin{aligned} &\text{stronger evidence against } H_0 \\ &\text{or} \\ &\text{strong evidence towards accepting } H_a \ (\text{differences exist}) \\ \end{aligned} \]

Small p-values ⇒ good! How small is small enough?
Significance level (α)

- Cut-off point below which we agree that an effect is “statistically significant”.

\[
\text{If } p \leq \alpha \implies \text{reject } H_0, \text{ accept } H_A \text{ that there are differences}
\]

Typically, \( \alpha \approx 0.05 \) or 0.01

\[\uparrow\]

5% chance of rejecting \( H_0 \)
Type I and Type II errors

Type I error: Probability of rejecting $H_o$ given $H_o$ is true = $\alpha$

Type II error: Probability of accepting $H_o$ given $H_A$ is true = $\beta$

<table>
<thead>
<tr>
<th>True state</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_o$</td>
</tr>
<tr>
<td>Accept $H_o$</td>
</tr>
<tr>
<td>Reject $H_o$</td>
</tr>
</tbody>
</table>

Type I: testing on different days, times, unknown bias in data

Type 2: noise in data, low statistical power
Statistical Power

"power analysis"

Power = 1 - \( \beta \)

\( \beta \): probability of accepting \( H_0 \) given \( H_A \) is true

Should \( \beta \) be \( \uparrow \) or \( \downarrow \)?
Test statistic

- The numerical value that is calculated after performing a specific statistical method (test) that is used to assess the hypotheses.

Examples:

- Student’s $t$-test ($t$ or $T$)
- Unpaired and paired versions
- F-test ($F$)
- used for ANOVA (ANalysis Of VAriance) when comparing 2 or more groups
- Non-parametric tests (eg. $W$)

Non-parametric data can either be variables that are non-normally distributed, or the data are organized by ranking observations.
Paired $t$-test

- Null hypothesis ($H_0$): mean difference between paired observations is zero.
  - mathematically equivalent to: means of the groups are equal

- Test statistic:

\[ t = \frac{\overline{X}_D}{S_D} \sqrt{N} \]

\[ t = \frac{\text{Mean differences}}{\text{SE of differences}} \]

SE = standard error = \( \frac{\text{standard deviation}}{\sqrt{\text{number of subjects}}} \)

- Where the differences between all pairs must be calculated. The average ($\overline{X}_{D, \text{bar}}$) and standard deviation ($s_D$) of those differences are used in the equation.

\[ N = \text{number of samples (number of subjects)} \]
Paired $t$-test

- Excel built-in function for paired $t$-tests.

- TTEST(array1, array2, tails, type) function, where array1 is the first column of data, array2 is the second column of data, tails is normally set to 2, and type is set to 1 for a paired $t$-test. The result of this function is the P-value of the paired $t$-test.

- See the following webpage for added explanation

Wilcoxon's signed-ranks test

- Non-parametric equivalent to paired $t$-test
- Null hypothesis ($H_0$): median difference between paired observations is zero.
  - median of a finite list of numbers is the middle value after arranging all the observations from lowest to highest value
- See the following webpage for added explanation
### Traditional COP measures (mm) of Standard Deviation for AP and ML directions for Case and Control conditions

<table>
<thead>
<tr>
<th>subject</th>
<th>SD_AP_Case</th>
<th>SD_AP_Ctrl</th>
<th>SD_ML_Case</th>
<th>SD_ML_Ctrl</th>
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<td>4.64</td>
<td>1.77</td>
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<td>2</td>
<td>3.45</td>
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<td>3</td>
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<td>SD</td>
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<td>1.24</td>
<td>0.40</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Perform paired testing to see if SD_AP and SD_ML are significantly different due to Case or Control

Plug numbers into own Excel program using TTEST(array1, array2, tails, type) function

Or use for example: [http://www.fon.hum.uva.nl/Service/Statistics/Student_t_Test.html](http://www.fon.hum.uva.nl/Service/Statistics/Student_t_Test.html)
Writing up the results

- Report the $p$-value for each COP parameter that you are testing
  - Creating a table with the mean, SD, and $p$ values is often a good starting point.
  - Here is one example of how to write up the results.

  The average (and standard deviation) AP velocity for the case and control conditions were 1.5 (0.1) m/s and 2.8 (0.2) m/s, respectively. Using a paired $t$-test, this result suggests that the case condition significantly reduced AP velocity compared to the control condition ($p = 0.003$).
Human Subject Testing Considerations

- Protection of Human Subjects
- Ethics
  - The Belmont Report
  - Declaration of Helsinki
  - The Nuremberg Code
  - Recent cases
- Institutional Review Board (IRB)
- Informed Consent
- When is IRB approval necessary?

http://irb.illinois.edu/
- Animal testing considerations

- Animal Welfare Act
- Public Health Service Policy on the Humane Care and Use of Animals
- Institutional Animal Care and Use Committee (IACUC)

http://iacuc.research.illinois.edu/

- Does a non-livethe “model” exist?
- Vertebrates vs Invertebrates?

↑

cute + fuzzy factor
Three basic principles: respect for persons, beneficence, and justice. (Belmont Report)

**Respect for Persons:**
- Individuals are autonomous agents
  - Informed consent, privacy, confidentiality
- Those w/o autonomy should be protected

**Beneficence**
- Do not harm
- Maximize benefits + minimize harm

**Justice**
- Fair distribution of research burdens + benefits
  (why test only males, Hispanics, etc)
Milgram experiment

- 1961 Yale Psychologist
- in response to the Nuremberg Trials
- "Obedience to Authority Study"
Tuskegee syphilis experiment

- Conducted between 1932 and 1972
- 600 African-American sharecroppers
  - (400 with disease, 200 controls)
- Natural progression of untreated syphilis
- Tuskegee Institute, U.S. Public Health Service
Stanford prison experiment

- 1971

24 male students; randomly assigned roles of prisoners and guards

- Mock prison situated in the basement of the Stanford psychology building

- [http://www.prisonexp.org/](http://www.prisonexp.org/)

- US Office of Naval Research
The Immortal Life of Henrietta Lacks

- Henrietta Lacks poor black tobacco farmer
- 1951
- HeLa cell line—taken without her knowledge
- Vital for developing the polio vaccine, cloning, gene mapping, in vitro fertilization, and more..

Friday

- Kinematics
- Gait cycle
- Determinants of gait