Basic Statistics for the Clinician

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Disclosure

Nothing to disclose
Why do I need to know statistics...?
...and for any other reason…

THEY WILL BE ON YOUR SPECIALTY BOARD EXAM!!!
Learning Objectives

- Review basic study design & levels of evidence common to clinical research

- Review basic applications of hypothesis testing:
  - purpose of \( p \)-value
  - tests for determining difference b/w groups
    - (eg. t- test & ANOVA, etc.)
  - tests for determining relationships
    - (eg. Correlation analysis, regression, etc.)

- Understand difference between prevalence & incidence

- Review & understand results of basic statistical analysis commonly used in clinical diagnostic research:
  - Sensitivity, Specificity
  - Positive Predictive Value, Negative Predictive Value
Common Clinical Research Design Types Study
“…how did dey do dat?”

- **Systematic Reviews/Meta-Analysis**
  - Focused review and synthesis of results from RCTs

- **Randomized Controlled Trial:**
  - Subject randomized into different groups

- **Cohort:**
  - Examine 2 or more groups over time

- **Case Control:**
  - Patients with condition are matched to a control group

- **Cross-Sectional:**
  - Data is collected at a single point in time (prevalence)

- **Case Reports/Case Series:**
  - Medical histories in one or more patients with condition or treatment
Good for rare diseases.

Used to test new intervention/trx

Look back at exposures related to groups that did/didn’t have condition (retrospective)

Look forward at outcomes related to intervention (longitudinal)
STATISTICS
THE DISCIPLINE THAT PROVES
THE AVERAGE HUMAN HAS
ONE TESTICLE
What are these?

- P – value
- T-test
- Analysis of Variance (ANOVA)
- Pearsons Correlation (r)
- Regression (r²)
Error?

- **Type I**: (false ‘+’)  
  Concluding there **IS** a difference between groups when there really isn’t…

- **Type II**: (false ‘-’)  
  Concluding there is **NO** difference between groups when there actually is…

```
\begin{array}{c|c|c|c}
  \text{Measured/Perceived} & \text{Reality} & \text{Reality} \\
  \text{True} & \text{Correct} & \text{False} \\
  \text{False} & \text{Type II} & \text{Correct} \\
\end{array}
```

$$\alpha$$ $$\beta$$
Never confuse Type I and II errors again:

Just remember that the Boy Who Cried Wolf caused both Type I & II errors, in that order.

First everyone believed there was a wolf, when there wasn't. Next they believed there was no wolf, when there was.

Substitute "effect" for "wolf" and you're done.

Kudos to @danolner for the thought. Illustration by Francis Barlow "De pastoris puero et agricolis" (1687). Public Domain. Via wikimedia.org
Significance…?
It’s all about P for “percentage”

**p-value:**
- Probability of committing a type I error
- \( p = 0.05 \)
  - 5% probability that the difference b/w means/groups occurred by chance
  - 5% chance of type I error

Roll a 20-sided die and you’ll notice that any given number comes up pretty often!
How do I know if there is a difference?

**Parametric**
- **T-Test:** means of 2 groups
- **Analysis of Variance (ANOVA):** means of >2 groups

**Non-Parametric**
- **Mann-Whitney U-Test:** means of 2 groups
- **Kruskal-Wallis ANOVA by ranks** ($H$ or $\chi^2$): means of >2 groups
Scenario

- **Aim 1:** To determine the optimal exercise intervention (volitional quad set or electrical stimulation) in improving quad strength 1 week following ACLR.
  - $H_1:$

- **Aim 2:** To characterize the relationship between quad strength and knee effusion following ACLR.
  - $H_2:$
Which statistical tests should be used?

Patients s/p ACLR…

Group A vs. Group B

- Dependent Variable: Quad Strength
- Intervention:
  - Group A → Quad sets
  - Group B → Electrical Stimulation

What test would you use to determine if quad strength was different between the groups A & B following the interventions?
Which statistical tests should be used?

Patients s/p ACLR…

Group A (Males vs. Females) vs. Group B (Males vs. Females)

- Dependent Variable: Quad Strength
- Intervention:
  - Group A → Quad sets
  - Group B → Electrical Stimulation

What test would you use to determine if quad strength was different between groups A, B, males, & females following the interventions?
Which statistical tests should be used?

Patients s/p ACLR…

- Group A
- Group B

- Dependent Variable: Knee Effusion
- Intervention: Group A → Quad sets, Group B → Electrical Stimulation

What test would you use to determine if there is an association between quad strength and knee effusion post ACLR?
Pearson’s Correlation (r)

Fig. 1
IS FACEBOOK DRIVING THE GREEK DEBT CRISIS?

- Number of active Facebook users
- Yield on 10-year Greek government bonds

2005  2011
3.6    16.82
5.5m users  750m users

Fig. 2
IS GLOBAL WARMING A HOAX PROPAGATED BY SCIENTISTS?

- Average global temperature
- National Science Foundation R&D Budget

1993  2009
$69.8m  $146.9m
+0.13C above 1950-1980 avg.  +0.63C

Fig. 3
DID AVAS CAUSE THE U.S. HOUSING BUBBLE?

- Housing price index
- Babies named “Ava”

1991  2009
100  15,826
281 Avas  193.74

Fig. 4
WOULDN'T NITY SHYAMALAN START MAKING GOOD MOVIES AGAIN IF PEOPLE BOUGHT MORE NEWSPAPERS?

- Total newspaper ad sales
- Shyamalan’s movies’ score on Rotten Tomatoes

1999  2010
$46,289m  $22,795m
85% (The Sixth Sense)  6% (The Last Airbender)

http://images.businessweek.com/cms
Pearson’s Correlation (r)

- Direction & strength of linear **relationships**
- Not causative

<table>
<thead>
<tr>
<th>Negative</th>
<th>Positive</th>
</tr>
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<tbody>
<tr>
<td>&lt; .70</td>
<td>&gt; .70</td>
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<tr>
<td>.40-.69</td>
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<tr>
<td>Strong</td>
<td>Strong</td>
</tr>
<tr>
<td>Very Strong</td>
<td>Very Strong</td>
</tr>
</tbody>
</table>

**Notes:**
- Correlation does not imply causation.

# Pearson’s Correlation (r)

## Strong ‘-” relationships

**y**

<table>
<thead>
<tr>
<th>&lt; .70</th>
<th>.40-.69</th>
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## Strong ‘+” relationships

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## Table of Correlation Strength

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*The Ohio State University Wexner Medical Center*
Pearson’s Correlation (r)

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### Pearson’s Correlation (r)

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<tr>
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<td>Very Strong</td>
</tr>
<tr>
<td>≥ .70</td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- **No relationship**
- **Very Strong**
- **Strong**
- **Moderate**
- **Weak**
- **None**
- **Very Weak**
- **Very Strong**

**Graph:**
- **y** vs. **x**
- Scatter plots for different correlation levels.
Scenario

- Aim 3: To predict the contribution of quad strength to IKDC score following ACLR.
  - H₃:
**Linear Regression** \((r^2)\)

**Predict** the value of a dependent variable (**outcome** \(\rightarrow\) **IKDC Score**) based on the value of at least one independent variable (**predictor** \(\rightarrow\) **Quad Strength**)

- Explain the impact of changes in an independent variable on the dependent variable

Regression line summarizes relationship between explanatory, \(x\), & response variable, \(y\)

predict value of \(y\) for a given value of \(x\)
r & $r^2$ (How much explanation of variance?)

- $r = -1; r^2 = 1$
- $r = -0.6; r^2 = 0.36$
- $r = 0; r^2 = 0$
- $r = +0.3; r^2 = 0.09$
- $r = +1; r^2 = 1$
What are these?

- P – value
- T-test
- ANOVA
- Pearsons Correlation
- Regression
Have you had enough yet…?

I can give you my 93.4% assurance that there is less than a 65.6% possibility that this exercise will simply generate 34.8% more meaningless statistics.
### Diagnostic Testing….oh boy…

<table>
<thead>
<tr>
<th>Reference Standard Positive</th>
<th>Reference Standard Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnostic Test Positive</strong></td>
<td></td>
</tr>
<tr>
<td>True + Results</td>
<td>a</td>
</tr>
<tr>
<td>False + Results</td>
<td>b</td>
</tr>
<tr>
<td><strong>Diagnostic Test Negative</strong></td>
<td></td>
</tr>
<tr>
<td>False - Results</td>
<td>c</td>
</tr>
<tr>
<td>True - Results</td>
<td>d</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Accuracy</td>
<td>((a+d)/(a+b+c+d))</td>
<td>Percentage of patients who are correctly diagnosed</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>(a/(a+c))</td>
<td>Proportion of patients with the condition who have a + test result</td>
</tr>
<tr>
<td>Specificity</td>
<td>(d/(b+d))</td>
<td>Proportion of patients without the condition who have a - test result</td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td>(a/(a+b))</td>
<td>Proportion of patients with a + test result who have the condition</td>
</tr>
<tr>
<td>Negative Predictive Value</td>
<td>(d/(c+d))</td>
<td>Proportion of patients with a - test result who don’t have the condition</td>
</tr>
<tr>
<td>Positive Likelihood Ratio</td>
<td>Sensitivity/(1-) Specificity)</td>
<td>If the test is +, the increase in odds favoring the condition</td>
</tr>
<tr>
<td>Negative Likelihood Ratio</td>
<td>((1-) Sensitivity)/Specificity)</td>
<td>If the test is -, the decrease in odds favoring the condition</td>
</tr>
<tr>
<td>Test Outcome</td>
<td>Condition</td>
<td>PPV</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
<td>-----</td>
</tr>
<tr>
<td>Positive</td>
<td>True Positive</td>
<td>TP/(TP+FP)</td>
</tr>
<tr>
<td>Negative</td>
<td>False Positive</td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>TP/(TP+FN)</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>TN/(FP+TN)</td>
<td></td>
</tr>
</tbody>
</table>
SnNOut: High Sensitivity, Negative test, Rule out Condition
SpPIn: High specificity, Positive test, Rule In condition

<table>
<thead>
<tr>
<th>Lachman</th>
<th>ACL Tear</th>
<th>Positive</th>
<th>Negative</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>24</td>
<td>14</td>
<td>24/(24+14)</td>
<td>56/(6+56)</td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>6</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Total = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/(24+6)</td>
<td>56/(14+56)</td>
<td></td>
</tr>
</tbody>
</table>
Example

- Population/Sample: 100
- Torn ACL: 30
- Prevalence: $30/100 = 30\%$
How much is what…?

- **Prevalence:**
  - how much of condition is in population at a particular point in time
  - 30 case in a sample of 100
    - \( \frac{30}{100} = 0.30 \)
    - \( 0.30 \times 100 = 30\% \)
  - % or # cases per 100,000
% of Obesity* Among U.S. Adults

(*BMI ≥30, or about 30 lbs. overweight for 5’4” person)

[Maps showing obesity percentages for 1990, 1999, and 2009 across the United States]

http://cdc.gov/obesity/data/trends.html#State
How much is what…?

- **Incidence:**
  - **Rate** (in month/year/etc.) of occurrence of new cases of a disease or condition
    - (# new cases (over time course) / total population)
    - # cases per 100,000
Sensitivity

- How good a test is at correctly identifying people who have a “disease/condition”
- “…test's ability to identify positive results.”
  - 24 out of 30 → \[ \frac{24}{(24+6)} = 0.80 \]
Specificity

- How good a test is at correctly identifying people who are well
- “...ability of the test to identify negative results.”
  - 56 out of 70 → $[\frac{56}{14+56}] = 0.80$
100% Sensitivity

- “...test's ability to identify positive results.”
Perfect Test

A+
Positive Predictive Value

- The chance that a positive test result will be correct.
- 24 out of 38 positive tests correct: \( \frac{24}{(24+14)} = 0.63 \)
Negative Predictive Value

- The chance that a negative test result will be correct
- 56 out of 62 neg. results correct: \[\frac{56}{(6+56)}= 0.90\]
Ottawa Ankle Rules example…

- Sensitivity ~100%
- Specificity: 48%
- PPV: 15%
- NPV: ~100%
What is the Likelihood Ratio (LR)

The probability of a clinical finding in patients with a condition divided by the probability of the same finding in patients without the condition.

Direct estimate of how much a test result will change the odds of having a disease/condition.

Likelihood of a disorder or condition being present.
Increased diagnostic confidence:
“Probability estimate of presence/absence of the condition of interest”

- **LR+** tells you how much the odds of the condition increase when a test is positive.

- **LR-** tells you how much the odds of the condition decrease when a test is negative.

<table>
<thead>
<tr>
<th>LR -</th>
<th>LR+</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - .1</td>
<td></td>
</tr>
<tr>
<td>.1 - .2</td>
<td></td>
</tr>
<tr>
<td>.2 - .5</td>
<td>2 - 5</td>
</tr>
<tr>
<td>.5 - 2</td>
<td>5 - 10</td>
</tr>
<tr>
<td>&gt;10</td>
<td>Important</td>
</tr>
</tbody>
</table>

- Important
- Unimportant
**Likelihood Ratios**

<table>
<thead>
<tr>
<th>Test</th>
<th>Condition</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>True Positive</td>
</tr>
<tr>
<td>-</td>
<td>False Negative</td>
</tr>
</tbody>
</table>

| Sensitivity | Specificity | Total |

\[
LR^+ = \frac{Pr(T+|D+)}{Pr(T+|D-)} = \frac{\text{True Positive}}{\text{False Positive}} = \frac{\text{sensitivity}}{1-\text{specificity}}
\]

\[
LR^- = \frac{Pr(T-|D+)}{Pr(T-|D-)} = \frac{\text{False Negative}}{\text{True Negative}} = \frac{1-\text{sensitivity}}{\text{specificity}}
\]
<table>
<thead>
<tr>
<th>Lachman</th>
<th>ACL Tear</th>
<th></th>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>24</td>
<td>14</td>
<td>PPV</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>6</td>
<td>56</td>
<td>NPV</td>
</tr>
<tr>
<td></td>
<td>Sensitivity</td>
<td>$24/(24+6)$</td>
<td></td>
<td>Specificity</td>
</tr>
</tbody>
</table>
What is the proportion of patients with an ACL tear who have a “+” Lachman?

\[
\frac{24}{24+6} = 0.80 \text{ (sensitivity)}
\]

What is the proportion of patients without an ACL tear who have a “-” Lachman?

\[
\frac{56}{14+56} = 0.80 \text{ (specificity)}
\]

What is the proportion of patients with a “+” Lachman who have an ACL tear?

\[
\frac{24}{24+14} = 0.63\% \text{ (PPV)}
\]

What is the proportion of patients with a “-” Lachman who don’t have an ACL tear?

\[
\frac{56}{6+56} = 0.90 \text{ (NPV)}
\]

If the Lachman’s is “+”, what are the odds favoring an ACL tear?

\[
+LR = \frac{\text{sensitivity}}{1-\text{specificity}} = \frac{0.80}{0.20} = 4
\]

If the Lachman’s is “-”, what are the odds favoring an ACL tear?

\[
-LR = \frac{1-\text{sensitivity}}{\text{specificity}} = \frac{0.20}{0.80} = 0.25
\]

In other words, a “+” Lachman is 4x’s more likely in a patient who has an ACL tear than a patient who does not have an ACL tear. AND

A “-” Lachman is only ¼ (0.25) more likely in those who have an ACL tear.
What is the proportion of patients with an ACL tear who have a “+” Lachman?

\[
\frac{24}{24+6} = 0.80 \text{ (sensitivity)}
\]

What is the proportion of patients without an ACL tear who have a “-” Lachman?

\[
\frac{56}{14+56} = 0.80 \text{ (specificity)}
\]

What is the proportion of patients with a “+” Lachman who have an ACL tear?

\[
\frac{24}{24+14} = 0.63\% \text{ (PPV)}
\]

What is the proportion of patients with a “-” Lachman who don’t have an ACL tear?

\[
\frac{56}{6+56} = 0.90 \text{ (NPV)}
\]

If the Lachman’s is “+”, what are the odds favoring an ACL tear?

\[
+LR = \frac{\text{sensitivity}}{1-\text{specificity}} = \frac{0.80}{0.20} = 4
\]

If the Lachman’s is “-”, what are the odds favoring an ACL tear?

\[
-LR = \frac{1-\text{sensitivity}}{\text{specificity}} = \frac{0.20}{0.80} = 0.25
\]

In other words, a “+” Lachman is 4 times more likely in a patient who has an ACL tear than a patient who does not have an ACL tear.

And a “-” Lachman is only 0.25 times more likely in those who have an ACL tear.
What is the proportion of patients with an ACL tear who have a “+” Lachman?

\[
\frac{24}{24+6} = 0.80 \text{ (sensitivity)}
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What is the proportion of patients without an ACL tear who have a “-” Lachman?

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\frac{56}{14+56} = 0.80 \text{ (specificity)}
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What is the proportion of patients with a “+” Lachman have an ACL tear?

\[
\frac{24}{24+14} = 0.63\% \text{ (PPV)}
\]

What is the proportion of patients with a “-” Lachman who don’t have an ACL tear?

\[
\frac{56}{6+56} = 0.90 \text{ (NPV)}
\]

If the Lachman’s is “+”, what are the odds favoring an ACL tear?

\[
\text{+LR} = \frac{\text{sensitivity}}{1-\text{specificity}} = \frac{0.80}{0.20} = 4
\]

If the Lachman’s “-” what are the odds favoring an ACL tear?

\[
\text{-LR} = \frac{1-\text{sensitivity}}{\text{specificity}} = \frac{0.20}{0.80} = 0.25
\]

In other words, a “+” Lachman is 4x’s more likely in a patient who has an ACL tear than a patient who does not have an ACL tear.

AND

A “-” Lachman is only \(\frac{1}{4}\) (0.25) more likely in those who have an ACL tear.

<table>
<thead>
<tr>
<th>Anterior Drawer</th>
<th>Actual ACL Tear</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Negative</td>
<td>PPV</td>
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<td>56</td>
<td>(\frac{56}{6+56})</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>70</td>
<td></td>
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</tbody>
</table>

**Sensitivity**

\[
\frac{24}{24+6} = 0.80
\]

**Specificity**

\[
\frac{56}{14+56}
\]
What is the proportion of patients with an ACL tear who have a “+” Lachman?

\[
\frac{24}{24+6} = 0.80 \text{ (sensitivity)}
\]

What is the proportion of patients without an ACL tear who have a “-” Lachman?

\[
\frac{56}{14+56} = 0.80 \text{ (specificity)}
\]

What is the proportion of patients with a “+” Lachman who have an ACL tear?

\[
\frac{24}{24+14} = 0.63\% \text{ (PPV)}
\]

What is the proportion of patients with a “-” Lachman who don’t have an ACL tear?

\[
\frac{56}{6+56} = 0.90 \text{ (NPV)}
\]

In other words, a “+” Lachman is 4x’s more likely in a patient who has an ACL tear than a patient who does not have an ACL tear.

AND

A “-” Lachman is only ¼ (0.25) more likely in those who have an ACL tear.
What is the proportion of patients with an ACL tear who have a “+” Lachman?

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\frac{24}{24+14} = 0.80 \text{ (sensitivity)}
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What is the proportion of patients with a “-” Lachman who don’t have an ACL tear?

\[
\frac{56}{6+56} = 0.90 \text{ (NPV)}
\]

If the Lachman’s is “+”, what are the odds favoring an ACL tear?

\[
+LR = \frac{\text{Sensitivity}}{1 - \text{Specificity}} = \frac{0.80}{0.20} = 4
\]

If the Lachman’s “-” what are the odds favoring an ACL tear?

\[
-LR = \frac{1 - \text{Sensitivity}}{\text{Specificity}} = \frac{0.20}{0.80} = 0.25
\]

In other words, a “+” Lachman is 4x’s more likely in a patient who has an ACL tear than a patient who does not have an ACL tear AND

A “-” Lachman is only \(\frac{1}{4}\) (0.25) more likely in those who have an ACL tear.
| Anterior Drawer | Positive | Negative | PPV  
|----------------|----------|----------|---------
| Positive       | 24       | 14       | 24/(24+14) |
| Negative       | 6        | 56       | NPV 56/(6+56) |
| Total          | 30       | 70       |         |
| Sensitivity    | 24/(24+6) = 0.80 | Specificity | 56/(14+56) |

What is the proportion of patients with an ACL tear who have a “+” Lachman?

\[ \frac{24}{(24+6)} = 0.80 \text{ (sensitivity)} \]

What is the proportion of patients without an ACL tear who have a “-“ Lachman?

\[ \frac{56}{(14+56)} = 0.80 \text{ (specificity)} \]

What is the proportion of patients with a “+” Lachman have an ACL tear?

\[ \frac{24}{(24+14)}=0.63\% \text{ (PPV)} \]

What is the proportion of patients with a “-” Lachman who don’t have an ACL tear?

\[ \frac{56}{(6+56)}= 0.90 \text{ NPV} \]

If the Lachman’s is “+”, what are the odds favoring an ACL tear?

\[ +LR = \frac{\text{sensitivity}}{1-\text{specificity}} = \frac{0.80}{0.20} = 4 \]

**If the Lachman’s “-” what are the odds favoring an ACL tear?**

\[ -LR = \frac{(1-\text{sensitivity})}{\text{specificity}} = \frac{.20}{.80} = .25 \]

In other words, a “+” Lachman is 4x’s more likely in a patient who has an ACL tear than a patient who does not have an ACL tear AND

A “-” Lachman is only ¼ (0.25) more likely in those who have an ACL tear.
<table>
<thead>
<tr>
<th>Anterior Drawer</th>
<th>Actual ACL Tear</th>
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<th></th>
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<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Negative</td>
<td>PPV</td>
</tr>
<tr>
<td>Positive</td>
<td>24</td>
<td>14</td>
<td>$\frac{24}{24+14}$</td>
</tr>
<tr>
<td>Negative</td>
<td>6</td>
<td>56</td>
<td></td>
</tr>
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In other words, a “+” Lachman is **4x’s**

more likely in a patient who has an ACL tear than a

patient who does not have an ACL tear

AND

A “-” Lachman is only \( \frac{1}{4} (0.25) \)

more likely in those who have an ACL tear.
HOLY SHIT, MAN!! LOOK AT THIS!!

“STUDY FINDS 50% OF PEOPLE BORED BY STATISTICS.”
OSU Sports Medicine

sportsmedicine.osu.edu