Bone Fracture Risk and Big Data

Core Concepts:

- Big data sets include information collected from many individuals and a variety of sources over an extended period of time.
- Big data sets provide better evidence for health risk claims than small data sets.
- Analysis of big data sets may reveal factors associated with increased risks for health problems.

Class Time Required:

2-3 forty-minute class periods

Teacher Provides:

For each student:

- 1 copy of student handout entitled **Bone Fracture Risk and Big Data**

For each pair of students:

- ** **Bone Density T-Scores** sheet
- ** **Hip Bone X-ray Images** sheet
- ** **Graphs: Bone Fracture Risks** sheet (print in color)
- Opaque envelope (such as a manila envelope) labeled "**Do NOT open until Part 2**." Put the ****10 Years Later—Additional Data from a Variety of Electronic Sources** sheet into this bag.
- 4 test tubes or 2 mL microtubes labeled and prepared as per chart below:

** If these sheets will be used in multiple classes, consider laminating them or putting them in sheet protectors.

Label on Tube	Contents of tube: 2 mL of
Woman 1 Plasma	pH 3 buffer
Woman 2 Plasma	pH 5 buffer
Woman 3 Plasma	pH 7 buffer
Woman 4 Plasma	pH 9 buffer

- ****Instructions for Plasma Tests** (Print in color and cut sheet into 4 sections – each pair gets 1 section.)

This lesson was developed with support from the National Institutes of Health under Award Number R25OD010494-03S1. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

- Small plastic bag labeled "**Plasma Test Strips**" containing 4 three-pad pH test strips. Use a permanent marker to number these 1, 2, 3, and 4. Order from Precision Laboratories https://preclaboratories.com/product/ph-1-14-test-strips-3-pad/

- ****Instructions for Bone Marker Test** (Print in color and cut into 4 sections – each pair gets 1 section.)

- 5 small labeled droppers:
    - **Woman 1**
    - **Woman 2**
    - **Woman 3**
    - **Woman 4**
    - **Bone Marker Test Solution**

- A test tube or microtube labeled **Bone Marker Test Solution** containing 0.5 mL of 0.1% bromothymol blue solution

- **Bone Marker Test Sheet** - print on transparency film and cut to size. Alternatively, print the test sheet on regular paper and insert into a plastic page protector.

Teacher Resources:

- Additional activities related to osteoporosis and big data are available online from University of Rochester's Life Sciences Learning Center. www.urmc.rochester.edu/life-sciences-learning-center/lessons.aspx

- **Big Data, Big Knowledge: Big Data For Personalized Healthcare** http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7047725

- **The Role of Big Data In Medicine** http://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/the-role-of-big-data-in-medicine

- **How Big Data is Changing Healthcare** https://www.forbes.com/sites/bernardmarr/2015/04/21/how-big-data-is-changing-healthcare/#75f5c6692873

- **The Big Data Conundrum: How to Define It?** https://www.technologyreview.com/s/519851/the-big-data-conundrum-how-to-define-it/

- **Big Data Coming In Faster Than Biomedical Researchers Can Process It** http://www.npr.org/sections/health-shots/2016/11/28/503035862/big-data-coming-in-faster-than-biomedical-researchers-can-process-it

- **The Power of Big Data Must Be Harnessed for Medical Progress** http://www.nature.com/news/the-power-of-big-data-must-be-harnessed-for-medical-progress-1.21026

- **Millions of Tweets Are a Goldmine for Data Mining** (*NOTE - This article has links to other articles)* http://www.rochester.edu/newscenter/twitter-provides-a-rich-vein-of-data-218722/

- **How Target Knew a High School Girl Was Pregnant Before Her Parents Did** http://techland.time.com/2012/02/17/how-target-knew-a-high-school-girl-was-pregnant-before-her-parents/

One advantage to big data research is that it may uncover new associations that would not have seemed to be logical associations. However, you need to be cautious about interpreting these apparent associations. For example some scientists claim there is an association between birth month and certain diseases. There are conflicting options about whether evidence supports these claims. If you're curious, take a look at these web sites:

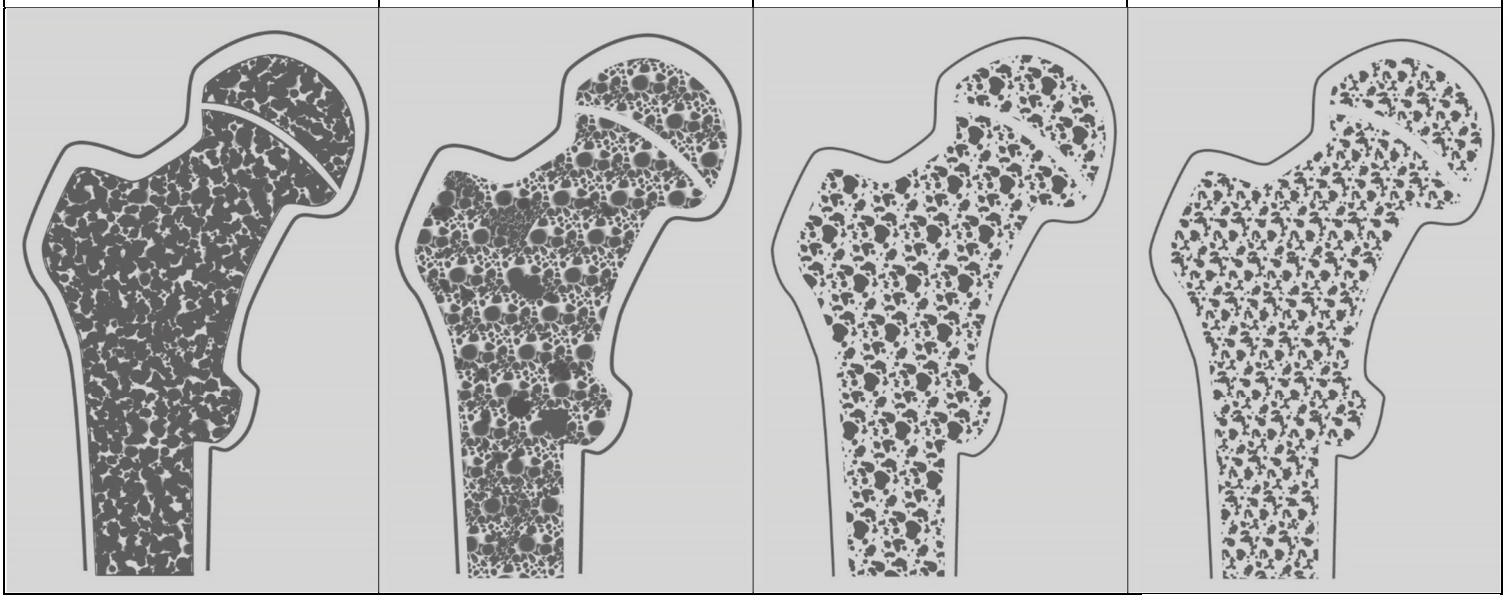
- **Is your health written in the stars?** http://www.express.co.uk/life-style/health/819685/health-horoscopes-birth-month-affect-diseases-you-could-get
- **Statisticians ridicule study aligning month you were born with diseases you are likely to catch** http://www.independent.co.uk/news/health/health-month-born-diseases-probability-study-alicante-statisticians-ridicule-asthma-depression-a7800646.html

Suggested Class Procedure:

1. Give each student a copy of the **Bone Fracture Risk and Big Data** student handout.
2. Assign students to work with a partner.
3. Read the first paragraph in Part 1 aloud to the class.
4. While students answer the questions on page 1, distribute to each pair of students the materials needed for Part 1:
    - **Bone Marker Test Sheet**
    - **Hip Bone X-Ray Images**
    - **Bone Density T-Score** sheet
    - **Graphs: Bone Fracture Risks**
    - 4 labeled droppers - Woman 1, Woman 2, Woman 3, Woman 4, Bone Marker Test Solution
    - Tubes of plasma for women 1-4
    - **Instructions for Plasma Tests**
    - Bag of 4 "**Plasma Test Strips**"
    - **Instructions for Bone Marker Test**
    - Tube of **Bone Marker Test Solution**
5. Students work with their partner to complete Part 1. Instruct students to clean up and return the materials when they are done with Part 1.
6. When students are ready to begin Part 2, distribute the opaque envelope labeled **Do NOT open until Part 2** containing **10 Years Later— Additional Data from a Variety of Electronic Sources** sheet**.**
7. Students work with their partner to complete Part 2.
8. Ask students to share some of their examples of types of data from their chart.
9. Ask students to share their answers to questions 14-16
    - What is meant by the term "Big Data"?
    - Why might analysis of "Big Data" be more effective than traditional controlled experiments in identifying factors that affect women's risk for bone fractures?
    - How is "Big Data" research different from the controlled experiments typically associated with traditional science research?

Bone Density and T-Scores

Standard Scale of Hip Bone Density T-Scores

T-Score -3	T-Score -2	T-Score -1	T-Score 0
			

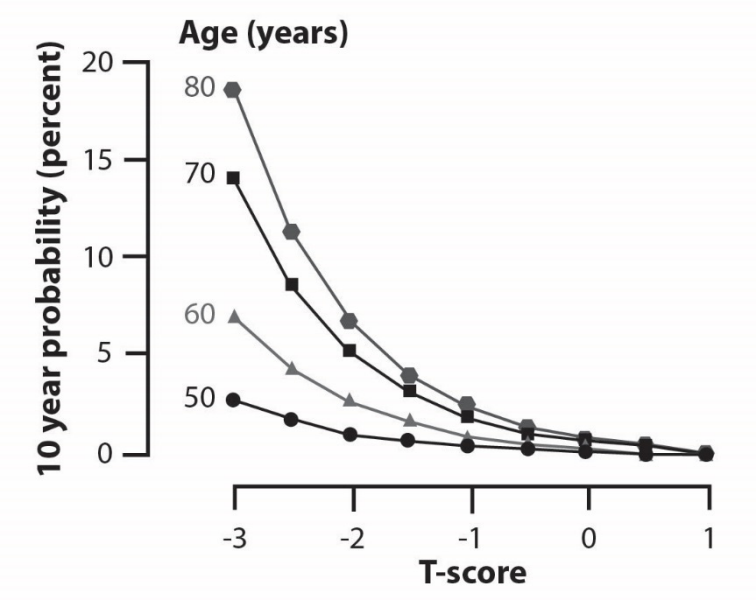
Bones with more black areas are:

- **Low Density**
- **Weak**
- **More Porous**

Bones with more gray areas have more calcium and are:

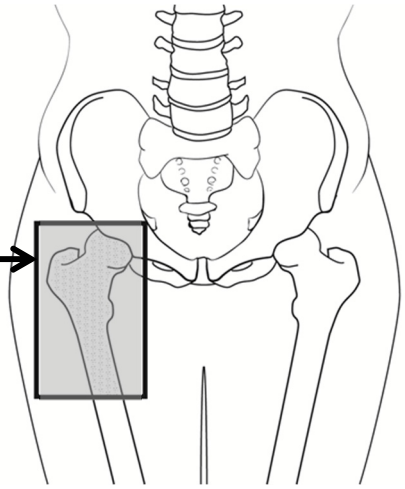
- **High Density**
- **Strong**
- **Less Porous**

Bone Density (T-Scores) and 10 Year Probability of Bone Fracture



Hip Bone X-Ray Images

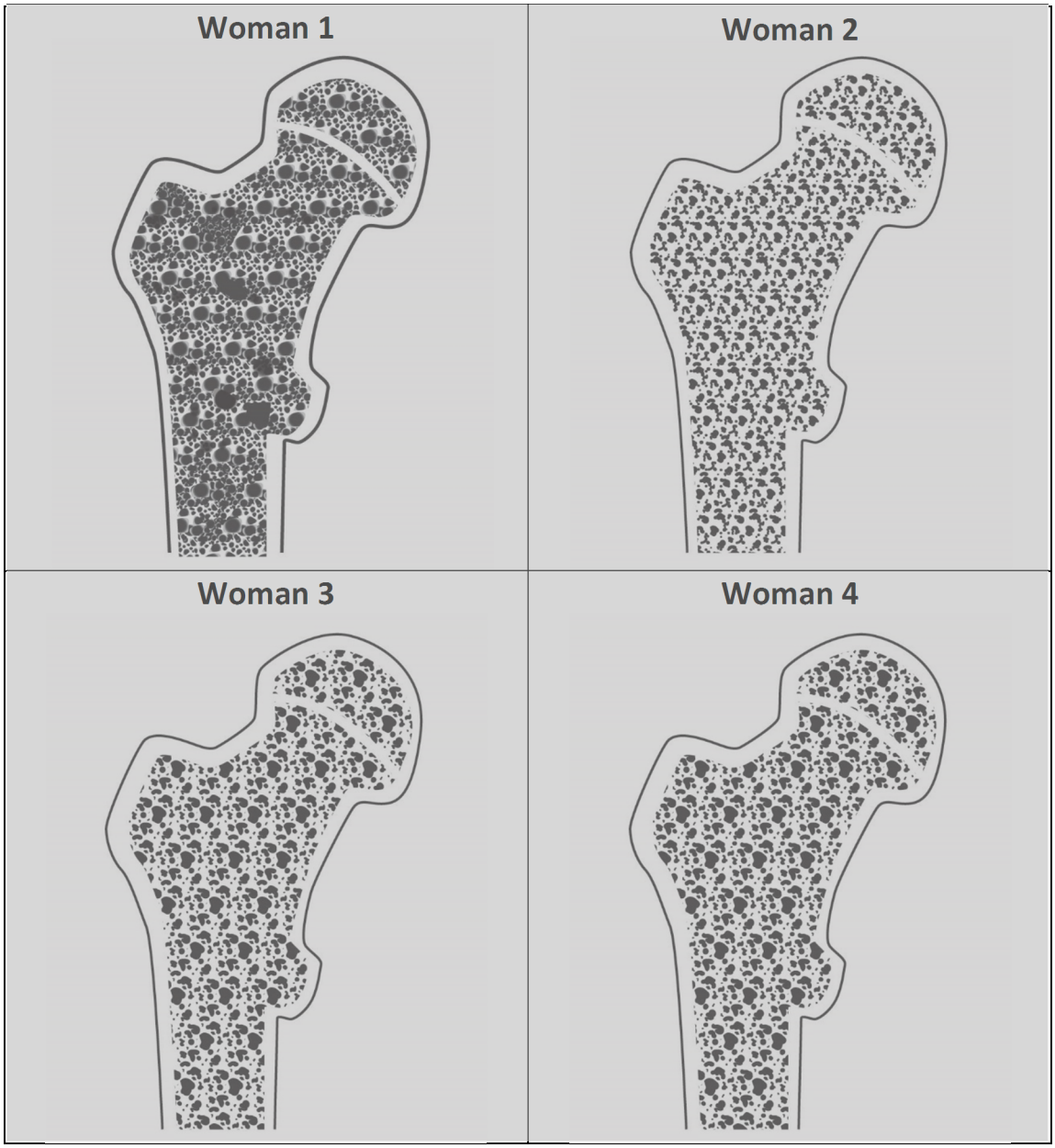
Area of hip bone in X-ray images below



KEY for x-ray images:

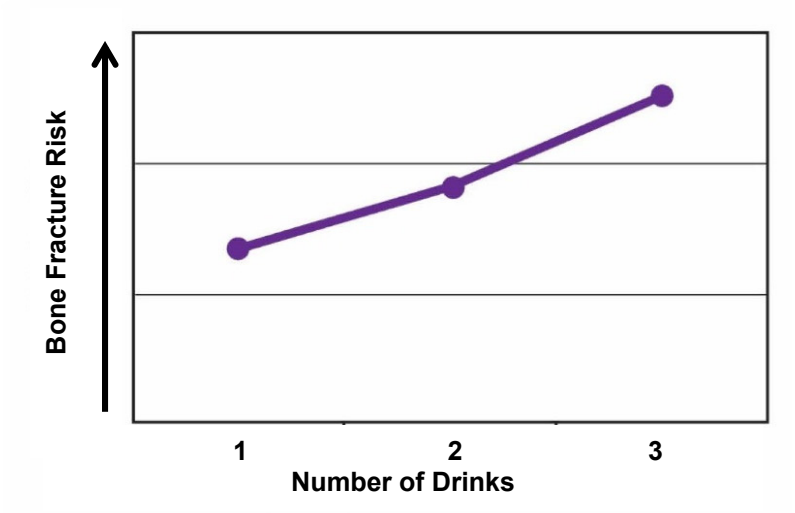
Pores that weaken bone and make it less dense

Hard bone made of calcium and collagen protein



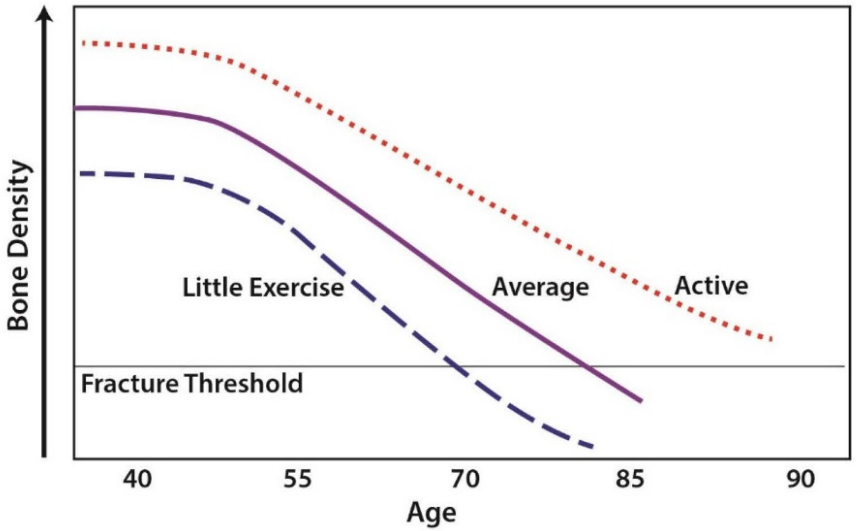
Graphs: Bone Fracture Risks

Alcohol Consumption and Relative Bone Fracture Risk

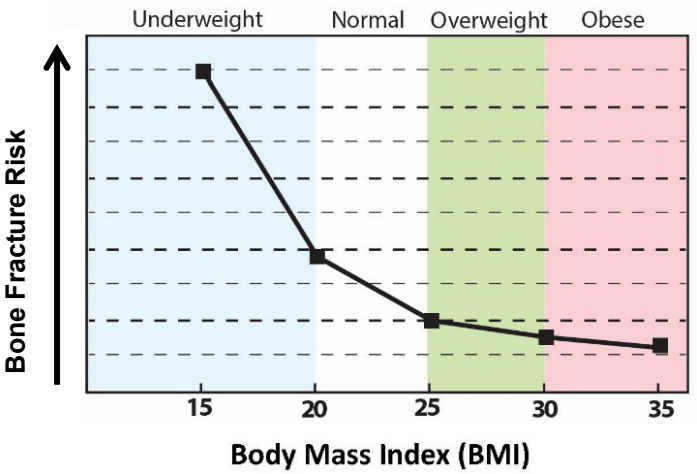


Exercise and Bone Fracture Risk

The middle line shows the bone density of women who have an average amount of exercise. The top line shows the bone density of women who are more active. The bottom line shows the bone density of women who get little exercise. When bone density falls below the fracture threshold line, bone fractures are more likely.



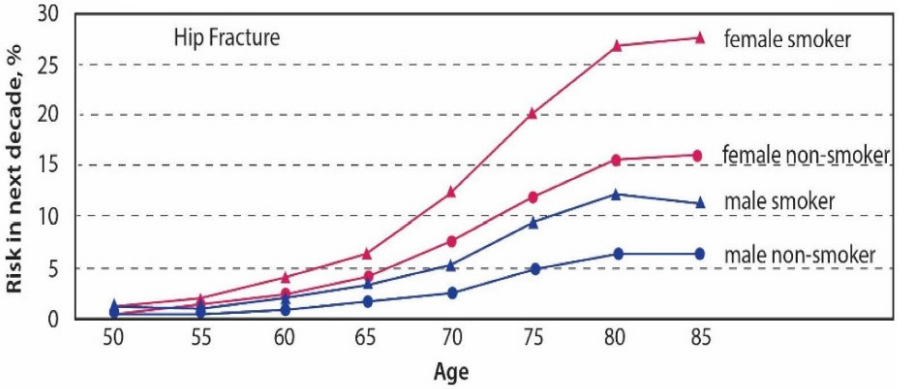
Body Mass Index and Relative Bone Fracture Risk



BMI = body mass in kilograms / height in meters squared

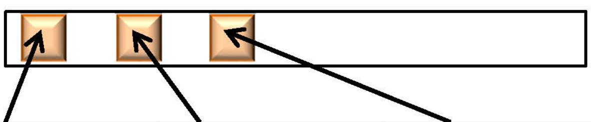
Smoking and Hip Fracture Risk

Risk in next decade is the probability that a person will have a hip fracture in the next 10 years



Instructions for Plasma Tests
Estrogen, Vitamin D, and Calcium

1. Dip the plastic test strip into the tube of plasma so that all 3 pads are submerged. Wait 2 seconds and then remove the test strip from the tube of plasma.
2. Match the color of the <u>bottom</u> pad to the estrogen color chart below.
3. Match the color of the <u>middle</u> pad to the vitamin D color chart below.
4. Match the color of the <u>top</u> pad to the calcium color chart below.



Estrogen (bottom pad)		Vitamin D (middle pad)		Calcium (top pad)	
Low		Low		Low	
Normal		Normal		Normal	
High		High		High	

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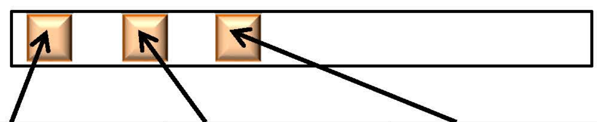

Estrogen (bottom pad)		Vitamin D (middle pad)		Calcium (top pad)	
Low		Low		Low	
Normal		Normal		Normal	
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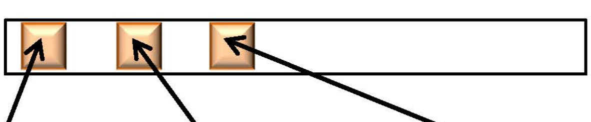

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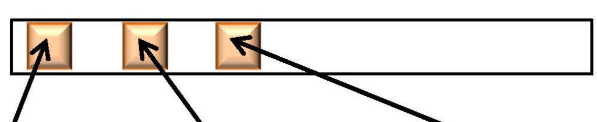


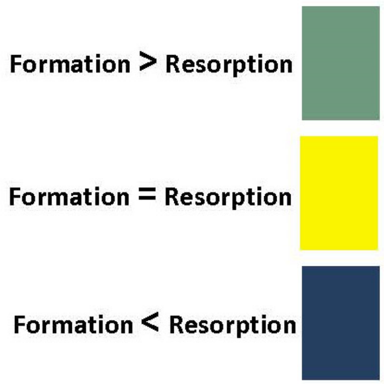
Estrogen (bottom pad)		Vitamin D (middle pad)		Calcium (top pad)	
Low		Low		Low	
Normal		Normal		Normal	
High		High		High	

Instructions for Bone Marker Test

1. Place one drop of Bone Marker Test Solution in each circle on the Bone Marker Test Sheet.

2. Use the labeled droppers to put two drops of plasma from each woman in the appropriate circle on the Bone Marker Test Sheet. *Be sure the label on the dropper matches the label on the tube of plasma.*

3. Match the color of the liquid in each circle with the color chart on the right.



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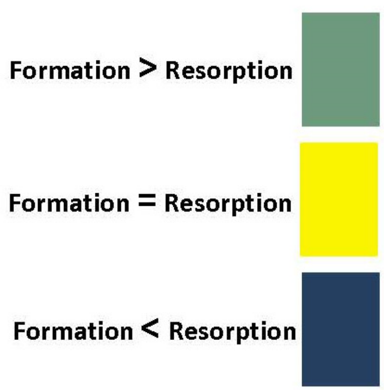

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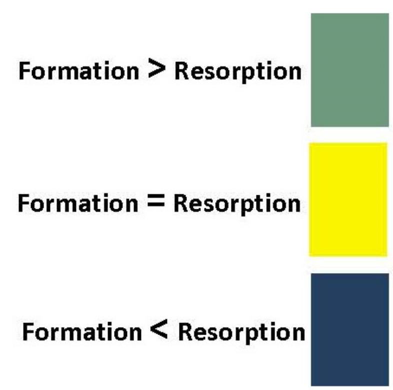


Bone Marker Test Sheet

Woman 1	Woman 2	Woman 3	Woman 4

Bone Marker Test Sheet

Woman 1	Woman 2	Woman 3	Woman 4

Bone Marker Test Sheet

Woman 1	Woman 2	Woman 3	Woman 4

Bone Marker Test Sheet

Woman 1	Woman 2	Woman 3	Woman 4

Bone Marker Test Sheet

Woman 1	Woman 2	Woman 3	Woman 4

Bone Marker Test Sheet

Woman 1	Woman 2	Woman 3	Woman 4

10 Years Later - Additional Data from a Variety of Electronic Sources

Woman 1 Age 60	• **Bone Fractures - none** • Race - White • 3 children • Retired • Osteoporosis - low bone density indicating weak bones • Recent BMI = 15 • Lactose Intolerance - dairy products cause digestive system problems • Grocery loyalty card shows purchase of probiotics to promote digestive system balance • Online purchase of herbal supplements to boost bone health and immunity • Gym membership paid through health insurance • 8 friends on Facebook
Woman 2 Age 65	• **Bone Fractures - hip bone fracture due to fall when getting out of the shower** • Race - American Indian • Widowed • Employed - pre-school teacher • 2 children • Father has osteoporosis - low bone density indicating weak bones • Recent BMI = 25 • Osteoarthritis that causes breakdown of cartilage in joints • Online purchases of multivitamins and calcium supplements • Prescription steroid medicine to reduce joint pain • Physical therapy paid through health insurance • Does not use Facebook
Woman 3 Age 68	• **Bone Fractures - multiple small fractures in spine (neck and lower back region)** • Race - Asian • No children • Osteoporosis - low bone density indicating weak bones • Gene test indicates gene associated with osteoporosis • Emphysema that interferes with getting oxygen into the blood • Prescription steroid medicine to reduce lung inflammation • Health App on iPhone indicates she walks less than 3000 steps per day • 43 friends on Facebook
Woman 4 Age 63	• **Bone Fractures - none** • Race - Black or African-American • Married • 2 children • Employment - Graphic Artist • Heart disease and high blood pressure • Prescription medication to treat high blood pressure • Health App on iPhone indicates she walks an average of 5000 steps per day • Sleep disorder causes difficulty getting need amount of sleep each night • 10 friends on Facebook

Bone Fracture Risk and Big Data

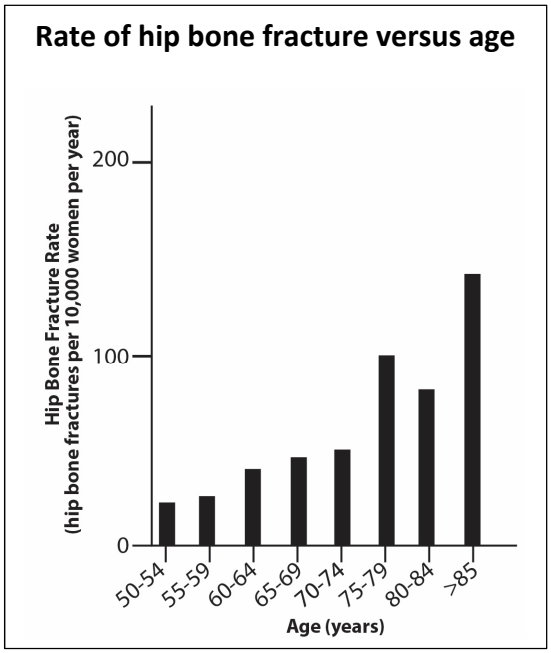
Part 1: Predicting Bone Fracture Risk

Your laboratory has been asked to conduct medical tests and collect data to determine if the data could be used to predict a woman's risk for bone fractures (breaks) when she gets older. Four women (1, 2, 3, and 4) have volunteered to be subjects in the research study that will collect data about possible risk factors for bone fractures.

Woman 1	Woman 2	Woman 3	Woman 4
50 years old	55 years old	58 years old	53 years old

1. Describe the association between age and the rate of hip bone fracture shown in the graph on the right.

   As age increases, bone fracture rate increases.



2. Record the ages of the four women on the **Data Set for Bone Fracture Risk** sheet on the last page of this handout. *You should tear this sheet off to make it easier to record your data.*

3. Which of the four women (1-4) is most at risk for hip bone fractures? Support your conclusion with specific information from the graph.

   Woman 3 because she is the oldest participant in the research project. As age increases, bone fracture rate increases.

A. Bone Density Test

A bone density test uses a low dose X-ray machine and a computer to determine how much calcium and other bone minerals are contained in a segment of bone. The bones that are most commonly tested are in the spine, hip and forearm. Denser bones have higher bone calcium content and are usually stronger.

Bone density test results are reported as "T-scores." Low T-scores indicate bones have low bone density. Bones with low density are porous (have many pores or open spaces). Porous bones are weak and more likely to fracture.

1. Put an X in front of all the characteristic of strong bones that are less likely to fracture.

   _X_ High T-Score ___ More porous _ X_ High bone density ___ Less calcium

2. Use the sheet that shows simulated **Hip Bone X-Ray Images** for the four women. Refer to the **Bone Density T-Scores** sheet**.** Compare the hip bone X-ray images from each of the four women (1, 2, 3 and 4) with the "Standard Scale of Hip Bone Density T-Scores."

3. Record the T-scores for each of the women in the appropriate column on the **Data Set for Bone Fracture Risk** sheet.

4. Based only on the **bone density test results** which woman (1, 2, 3, or 4) would you predict is most at risk for bone fractures when she gets older? Support your conclusion with evidence from the bone density test results data and the "Bone Density and Bone Fracture Probability" graph.

   Woman 1 because she has the lowest T-Score. As T-Scores decrease the probability for bone fractures increases.

B. Blood Plasma Tests for Calcium, Vitamin D, and Estrogen

Normal levels of calcium, vitamin D, and estrogen (female sex hormone) are thought to play an important role in a bone health. The levels of these chemicals in the body can be tested in blood plasma (the clear watery part of blood). Because calcium, vitamin D, and estrogen are essential for normal bone health, low levels of these chemicals can lead to decreased bone density and increased fracture risk.

1. Test the blood plasma from each of the four women (1, 2, 3, and 4) by following the **Instructions for Plasma Tests: Estrogen, Vitamin D, and Calcium**.

2. Record the results of the plasma tests for estrogen, vitamin D, and calcium in the appropriate columns on the **Data Set for Bone Fracture Risk** sheet.

3. Based only on the **plasma test results**, which woman (1, 2, 3, or 4) would you predict is most at risk for bone fractures when she gets older? Support your conclusion with evidence from the plasma testing data.

Woman 4 because she has low levels of estrogen and Vitamin D.

C. Bone Marker Tests

Bone is living tissue that is constantly being formed (built up) and resorbed (dissolved). Bones are **strong** when:

- F = R Bone **F**ormation is equal to Bone **R**esorption
- F > R Bone **F**ormation is greater than Bone **R**esorption

Bones become **weak** when:

- F < R Bone **F**ormation is less than Bone **R**esorption

Bone markers are substances in blood plasma that indicate the relative activities of bone forming cells and bone resorbing cells. Bone marker tests measure enzymes and proteins released into the blood plasma during bone formation and during bone resorption. Bone marker tests are done to determine if the rates of bone resorption and bone formation make bone stronger or likely to fracture.

1. Test the plasma from the four women (1, 2, 3, and 4) by following the **Instructions for Bone Marker Test.**

2. Record the results of the bone marker tests in the appropriate column on the **Big Data Set for Bone Fracture Risk** sheet by writing "Strong" or "Weak".

3. Based only on the **bone marker test results**, which woman (1, 2, 3, or 4) would you predict is most at risk for bone fractures when she gets older? Support your conclusion with evidence from the bone marker testing data.

Woman 4 because bone marker tests indicate that her bone formation is less than her bone resorption.

4. Can you use the results of a woman's bone marker test to **accurately** predict her bone density? Support your answer.

No, some women have marker tests that show strong bones but had a T score that showed low density.

Follow your teacher's instructions for clean-up before you go on to the next part.

D. Medical Records Information

The **Graphs: Bone Fracture Risks** sheet summarizes other factors such as exercise, body mass index, smoking, and alcohol consumption that affect a woman's risks for bone fractures.

1. Describe the association between **alcohol consumption** and bone fracture risk.

   Increasing alcohol consumption is associated with increased bone fracture risk.

2. Describe the association between **body mass index** and bone fracture risk.

   Increasing BMI is associated with decreased bone fracture risk.

3. Describe the association between **exercise** and bone fracture risk.

   Women who are more active have higher bone densities which decreases their risk for bone fractures.

4. Describe the association between **smoking** and bone fracture risk.

   Smokers have a higher risk for bone fractures.

5. The Medical Records Information for the four women has already been entered on the **Data Set for Bone Fracture Risk** sheet. Circle the data for each factor (alcohol, BMI, exercise, and smoking) that puts women at risk for bone fracture. *See the example for Alcohol Consumption in the data set.*

6. Based only on the **Medical Records information** and the **Graphs: Bone Fracture Risks**, which woman (1, 2, 3, or 4) would you predict is most at risk for bone fractures when she gets older? Support your conclusion with evidence from the medical records data.

   Woman 4 because she smokes, consumes alcohol and has a low BMI.

E. Considering All of the Information

1. Based on **all of the information in the data set**, which woman (1, 2, 3, or 4) is most likely to have a bone fracture during the next 10 years? Support your answer with evidence from all of the information that you collected.

   Woman 4 because her estrogen level is low, vitamin D level is low, bone markers indicate bone formation is less than bone resorption, and BMI is low, and she consumes alcohol and smokes.

2. Based on **all of the information in the data set**, which woman (1, 2, 3, or 4) is least likely to have a bone fracture during the next 10 years? Support your answer with evidence from all of the information that you collected.

   Woman 2 because all of her tests were in normal range and she does not smoke. Her only risk factor is 1 unit of alcohol consumption.

Part 2: "Big Data" to Predict Women's Bone Fracture Risk

It is now 10 years after you collected the original data set from the four women. Since then, additional information (data) that may be related to the women's bone fracture risks has become available from a variety of electronic source such as health records, insurance records, online purchase activity, and social media.

1. Open the envelope labeled "DO NOT OPEN until Part 2". This envelope contains information that may be related to the bone health of the four women 10 years later.

2. According to the **10 Years Later – Additional Data from a Variety of Electronic Sources**, which of the four women had bone fractures? ___*2*_____ and ____*3*____

3. Was the data that you collected and analyzed in Part 1 (on the previous page) accurate in determining which of the four women were likely to have bone fractures when they were 10 years older? Support your answer with evidence.

   No. Based on the tests and medical information, woman 4 was predicted to be at high risk for bone fractures. However, she did not have any bone fractures. Woman 1 did not appear to be at risk for bone fractures but she had bone fractures.

4. If a researcher conducted the same experiment with four other women, do you think that the results would be similar or different?

   The results would probably be different if other women were used in the study.

5. How could the experiment be improved to provide more reliable data?

   You could increase the number of research subjects.

6. Why is having reliable data from an experiment important if researchers are trying to make accurate predictions about a woman's risk of bone fractures?

   Having accurate data is important because it will allow researchers to draw accurate conclusions or make accurate predictions. OR You cannot make accurate predictions using false or unreliable data.

The data from a research study is **reliable** if it would yield the same or very similar results when done a second time. One way to increase reliability in an experiment is to increase the number of research subjects.

Imagine what a data table would look like if you combined the data you collected from four women with data collected from thousands of other people. This would create a "**big data"** set that could be analyzed to determine which factors (bone density, bone markers, calcium levels, exercise, etc.) are reliable for predicting bone fractures. The data table would have thousands of rows (one for each person). Computers would be needed to record and analyze the data.

7. Collecting data from thousands of people would be time consuming and expensive. Why is creating a "big data set" from thousands of people worth the effort?

Big data (a larger sample size) allows more reliable statistical analysis of data.

Big data research goes beyond simply including a large number of people. A big data research study includes many different **types of data** from many different **data sources**. Analyzing additional types of data increases the likelihood that some of the factors (types of data) might affect bone fracture risk.

Look at the **10 Years Later – Additional Data from a Variety of Electronic Sources.** Notice that most of this data could be "collected" automatically from electronic sources such as phones, computers, medical records, home control devices, and wearable devices. There would be no need to enroll the women in a research study and remain in contact with them over a 10 year period.

8. If you were able use additional factors (types of data), do you think that would improve the ability to predict a woman's bone fracture risk? Explain why or why not.

Yes because it increases the likelihood that some of the factors might affect bone fracture risk.

9. List at least 10 other factors (types of data) that <u>might</u> have influenced the women's bone fracture risk.

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Student answers will vary. Some examples might include: gym membership, lactose intolerance, probiotics, etc!

10. What is the advantage to collecting many different types of data for the people in a "big data" research study?

More types of data increase the chance that some will be factors that affect bone fracture risk.

It is likely that you are already a part of big data studies without even knowing it. There are many data sources that could already be providing different types of data (information) about you! This data could automatically be added to big data sets without your knowledge.

11. The chart below describes some data sources and examples of types of data from those sources. Complete the chart:
    - Provide two additional examples of **types** of data about you that could be obtained from each source.
    - Suggest another data source, and provide two examples of types of data that could be obtained from this source.

Data Sources	**Types of Data (Factors)**			
Medical records	Birth month	Blood pressure		
Social media	Appearance	Number of friends		
Home monitoring devices (Alexa/Dot)	Time at home	TV shows watched		
Mobile Devices (phone/activity tracker)	Locations visited	Hours of sleep		
Credit card purchases	Medicines purchased	Clothing styles		

12. The types of data in the chart above are not necessarily related to bone density, osteoporosis, or bone fracture risk.
    - Circle three types of data on the chart that might be associated with bone fracture risk.
    - Draw an X over three types of data on the chart that are unlikely to be associated with bone fracture risk.

The data table you used for the four women only included eleven types of data (information) about the four women. Imagine what the "big data" set would look like if you added all of these types of data:

- data from thousands of people
- types of data (factors) listed in question 9
- types of data from the chart in question 11

13. How would the data table from the "big data" set be different from the data table that you made for the four women?

It would include more research subjects and more factors (different kinds of data)

14. What is meant by the term "big data"?

Student answers will vary but should include using data from many people and collecting many different types of data.

15. Why might analysis of "big data" be more effective than traditional controlled experiments in identifying factors that affect women's risk for bone fractures?

Student answers will vary but should include that research is more reliable when sample size is large and more types of data increase the chance that some will be factors that affect bone fracture risk.

16. How is "big data" research different from the controlled experiments typically associated with traditional science research?

Student answers will vary but should state that controlled experiments typically only include a smaller number of research subjects and only analyze a few dependent variables.

Data Set for Bone Fracture Risk

Woman	Age	Bone Density (T-Score)	Plasma Tests			Bone Marker Test	Medical Records Information			
			Estrogen	Vitamin D	Calcium	Indicates that bones are… (Strong or Weak)	Alcohol Consumed (Drinks per Day)	Exercise Amount	Smoker	BMI (Body Mass Index)
1	*50*	*-2*	*Normal*	*High*	*Normal*	*Strong*	1	Little	Yes	30
2	*55*	*0*	*Normal*	*Normal*	*Normal*	*Strong*	1	Active	No	25
3	*58*	*-1*	*Normal*	*Low*	*Normal*	*Strong*	3	Average	No	20
4	*53*	*-1*	*Low*	*Low*	*Normal*	*Weak*	1	Average	Yes	15