# UNDER PRESSURE

*Thunder players spend a lot of time on their feet, whether they're running, jumping, walking, or even standing. In a game, during practice, or just getting from place to place, athletes' feet sure do a lot of the heavy lifting—literally! Yours do, too. In fact, have you ever taken a great jump and felt a pain in your feet when you landed? How about after a long day of playing sports or running: have you ever noticed that your feet ache more than after just walking around? Use your engineering and math skills in the following activities to see if you can discover just how tough feet are!*

## HERE'S WHAT YOU'LL NEED:

- **Ruler**
- **Book**
- **Marker**
- **Toothpicks**
- **2 pieces of Styrofoam** *(or other stiff foam about one inch thick and at least 4 inches wide and long)*
- **Balloons**
- **Scale**
- **Pencil**
- **Journal**
- **Template A** *(included)*
- **Template B** *(included)*
- **Template C** *(included)*

## WARMUPS

Pull out your copies of Templates A and B and take a closer look at each shape.  How are they similar?

How do you think their areas compare?  **Area** is simply a measurement of the amount of space the surface of the shape covers.  In math, area is expressed in square units.  You can find it by counting the number of squares that make up each shape or you can simply multiply the shape's length by its width.

What is the area of Template A?  What is the area of Template B?

Record the area of both shapes in your journal.

Place Template A on the top of one of the blocks of foam and insert a toothpick into each corner of the square.  Next, take Template B and place it on the second foam block and insert a toothpick into each corner of every small square. You will need 16 toothpicks for this template.

With all those pointy toothpicks lined up so nicely, it's time to invite a few balloons to the party for a little experiment with pressure.  Set your foam contraptions off to the side, take a couple of deep breaths and inflate and tie off two balloons.

What is **pressure?**  It's what happens when you apply a force to a surface and divide it by the area the force is touching. In this case, you are going to be pushing the balloon down onto the surface of the toothpick grids you've just made. Before you try it, predict what you think will happen to the balloons when they come in contact with all those pointy ends.  Do you think the balloon will pop?  Which one will pop with the least amount of force, the balloon against the surface with four toothpicks or the one with sixteen?

Start with Template A.  Balance a book on top of the balloon and then very gently set the balloon on top of the toothpicks.  Watching the balloon closely to observe any changes to its shape, slowly press down on the book increasing the force on the surface below.  What happens?

Repeat the test with Template B.  What happens?  Were your predictions correct?  What do you think the size of the template's area has to do with how much force is needed to pop the balloon?



BOOK

BALLOON

TOOTH PICKS

BLOCK OF FOAM

Now is a good time to do some math to figure the pressure the balloon experiences. Remember our definition of pressure is the force applied to a surface divided by the area the force is touching.

To keep things simple, say you pushed down on the balloon with 20 pounds of force. The area of Template A was 1x1= 1 inch squared, or 1 square inch, or 1 in². You can use this information to figure the pressure exerted.

**Pressure = 20 pounds of force ÷ 1 square inch = 20 pounds per square inch**

Template B is 3 inches wide by 3 inches long. Using the area for Template B that you have recorded in your journal and the same 20 pound of force, calculate the pressure per square inch.

How did it compare to the pressure of Template A? Do you think there is any relationship between the change in pressure and how quickly the balloon popped?

**GAME TIME**

Now, it's time to bring your knowledge of calculating area back to basketball. As we discussed, Thunder players ask and expect a lot from their feet. You do, too, even if you don't realize it! Conduct these experiments and calculations to determine the pressure you and your shoes exert on the ground. Grab a partner to help you with these challenges, and then you, in turn, will help them, too.

Place a copy of **Template C** on the ground and stand on top of it on one foot. Using the squares on the grid, have your partner trace closely around your foot creating a rectangle to collect the area of your shoe.

**PRO TIP: If your foot is too big to fit on a standard 8 ½ x 11 piece of paper, tape two pieces of Template C together! Just make sure that you line up the grids when you tape it together so that you can get an accurate area size.**

Use the skills you learned in Warm Up to calculate the area of your single foot.

What did you notice about the pressure in your foot while standing on only one foot?
Calculate the amount of pressure you're applying to your foot when you stand on just one foot to see if you can find a connection. To do this, you're going to divide your weight (in pounds) by the area of your foot.

$$\text{Pressure} = \frac{\text{Force or your weight in pounds}}{\text{Area of your foot in square inches}}$$

Record this result in your journal.

Compare this result to the amount of pressure exerted on both of your feet when you're just standing normally. To calculate this, begin by multiplying the area of your foot by two. Then, using this new area of both of your feet, calculate how much pressure is always exerted upon your feet using the same formula of your weight divided by the area. Record your results for this in your journal, too. Were you surprised at the outcome?

**ANALYZE THE REPLAY**
What happened?

Compare the amount of pressure under your feet from the data you collected and calculated from standing on one foot as opposed to standing on both of your feet. How does this information you've compiled relate to the Warm Up activity where you explored pressure and force with the balloons and the toothpicks?

Interested in learning more about the pressure applied to your feet and shoes when performing physical activities? Think about the shape your foot makes when you jump. If you're about to try and make the winning dunk in a game, do you jump off your entire foot, or only part of it? Using your partner's help, try to trace on Template C the part of your foot that you use (and therefore, apply the most pressure to) when you're jumping.

**PRO TIP: If imagining how your feet move when you jump, try actually jumping or taking a leap and having your partner carefully watch your feet to see where your take-off point is. You can also go to YouTube, and search for videos of NBA players jumping in slow motion to really see what their feet do when they go in for a shot. (Try searching "slo mo basketball jumping" if you need a starting point.)**

After you've traced the area of your foot shape while jumping, use your formula to calculate the amount of pressure exerted on your foot during this activity.

How does that figure compare to just standing on both feet, or standing on one foot?

What hypothesis could you make about why your feet might be more tired after running around during a basketball game for a couple hours as opposed to just walking around the mall?

How do you think this pressure applied to feet during rigorous basketball activities (such as running or jumping) might relate to foot and ankle injuries that NBA players may experience at a more frequent rate than athletes in other sports?

How do you think the amount of pressure applied to feet during these activities helps designers and engineers make better shoes for players?

This activity introduces students to the concepts of area, force and pressure.
When a force is exerted on a surface, the smaller the area, the greater the pressure will be.  With a larger area, the force is spread out and the pressure becomes smaller.

A common example used to illustrate this is the high pressure seen in women's shoes with high spiked or stiletto heels.  A typical shoe distributes the weight of an average size adult over 20 in$^2$, so if a 100 lb. person is wearing them they apply 100/20 or 5 pounds per square inch on the floor. Compare that to a stiletto heel that is only 0.25 in$^2$ .  That same person would apply 100/0.25 or 400 pounds per square inch on the floor where the heel touches it.

To keep things simple in this activity, instead we only worried about the force of gravity, our weight, when figuring pressure exerted per square inch. When we run and jump we actually use our muscles throughout our body and our legs to apply more pressure to the ground. Additionally, Newton's third law comes into effect here. When our bodies use chemical energy to exert mechanical energy on the ground, the ground exerts an equal and opposite force. Your body pushes down harder to overcome the force of gravity, its own weight, and you are pushed upward off the ground.

Because shoe size is not directly connected to height or weight, students may find that though they are similar in both height and weight to a classmate, the amount of pressure they exert on the ground is vastly different.

**OKLAHOMA ACADEMIC STANDARDS: MATHEMATICS**

| STANDARD | 4TH GRADE | 5th Grade | 6th Grade |
|---|:---:|:---:|:---:|
| N.1.1 - Numbers and Operations | ● | | |
| N.1.4 - Numbers and Operations | | ● | |
| N.1.5 - Numbers and Operations | ● | | |
| N.2.6 - Numbers and Operations | ● | | |
| N.2.7 - Numbers and Operations | ● | | |
| N.4.4 - Numbers and Operations | | | ● |
| GM.2.4 - Geometry and Measurement | ● | | |

**Template A**

**Template B**

**Template C**