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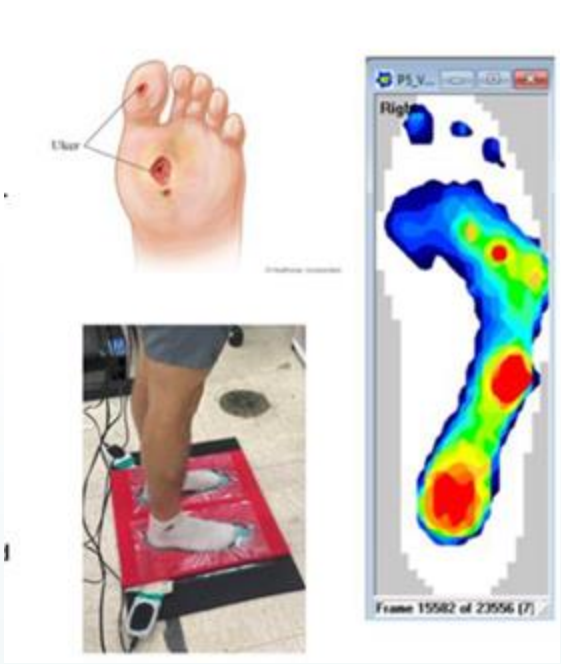
Sole Survivors:

A Biomedical Engineering Project

U.S. National Science Foundation

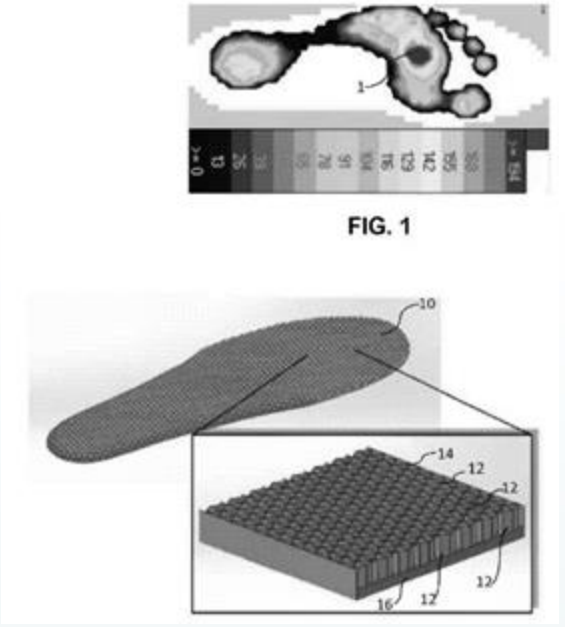
Engineering & Applied Science
UNIVERSITY OF COLORADO BOULDER

Doctors are doing this in real hospitals



Trio of photos showing a foot with an ulcer, a multi-colored foot pressure scan, and a patient standing on a foot pressure mat.

A doctor in a hospital viewing patient results on a computer while a nurse stands by.



A graphic showing a black and white foot pressure scan and another showing an orthotic that has foam density matching the high pressure areas of the scan.

Understanding the Medical Impacts

Did you know that people with serious foot ulcers have about a 30% chance of not surviving five years, which is about the same rate as many common cancers? - *NIH.gov*

Each year, more than 100,000 people in the U.S. need serious foot treatment like surgery or special boots because of complications such as diabetes. - *The Guardian*

4 to 6 out of every 10 patients don't wear their special medical boots as often as they should.
- *NIH.gov*

If the boots or inserts don't feel good, patients often stop using them, and their foot injuries don't heal properly. - *Milford Podiatry*

Parts of the Foot

Phalanges

Toes 2-5

Lateral arch

Outer Foot

Calcaneus

The heel region

Hallux

The big toe

Metatarsal Heads

Make up the ball of the foot

Medial arch

Inner curve of the foot

Engineering Solutions: A Case Study

Subjects: Employees who stand 6-8 hours per day
Problem: 32% have foot pain
Solution: Orthotics made 67% of people feel better

Weight Distribution

- Employees are tested to see where they put the most pressure on their feet.

Material Testing

- Materials are tested to see what is most comfortable and durable.

Pressure Mapping

- Orthotic prototypes are tested to see if they improve pressure.

BMW Logo

The Physics of Kinetic Energy

Kinetic Energy Formula: KE = ½mv²

- This means that moving things have energy.
- The heavier something is (mass = m) and the faster it's going (speed = v), the more energy it has.

Force and Pressure on the Foot

- When something hits your foot, it creates a force (like a push).
- Force = mv ÷ change in time — the faster something moves or heavier something is, the more force it hits with.
- If all that force is in one small spot (like under your heel), it hurts more.
- Pressure = Force ÷ Area — so bigger insoles help spread that force out and reduce pain.

What Orthotics Do

- Energy dissipation = spreading out pressure and reducing force.
- Energy absorption = spring-like recovery of the material.
- In diabetic orthotics, dissipation is key for reducing pressure hotspots.

The Engineering Design Process

1. Research

- Learn about the foot condition.
- Study existing solutions.
- Think about what the patient needs.

2. Design

- Pick foam types.
- Plan where support is needed.
- Build your prototype.

3. Test

- Drop test and collect data.
- See what works (or doesn't!).
- Improve your design.

4. Communicate

- Make a poster of your design.
- Share your results with the class.
- Use data to convince others your orthotic works.

Foam Types and Material Science

Soft Foam

Feels really squishy and comfy. Used where you want more cushioning.

Medium Foam

A balance between soft and firm. Good for support and comfort.

Hard Foam

Feels stiff. Used to hold up heavy parts of the foot like the arch.

How We Test Our Orthotics

Variables:

- Independent – Drop height (30–150 cm)
- Dependent – How deep the ball sinks in the dough
- Controls – Ball weight

Data Collection:

1. We drop a metal weight onto kinetic sand with and without an orthotic.
2. We measure how deep the weight goes.
    a. Deeper mark = less pressure dissipated
    b. Shallower mark = more pressure dissipated (better protection)

Kinetic Energy Review

Formula:

$$KE = \frac{1}{2} m v^2$$

(m = mass, v = speed)

The faster something moves, or the heavier it is, the more kinetic energy it has. That's why a bowling ball rolling fast is harder to stop than a tennis ball at the same speed.

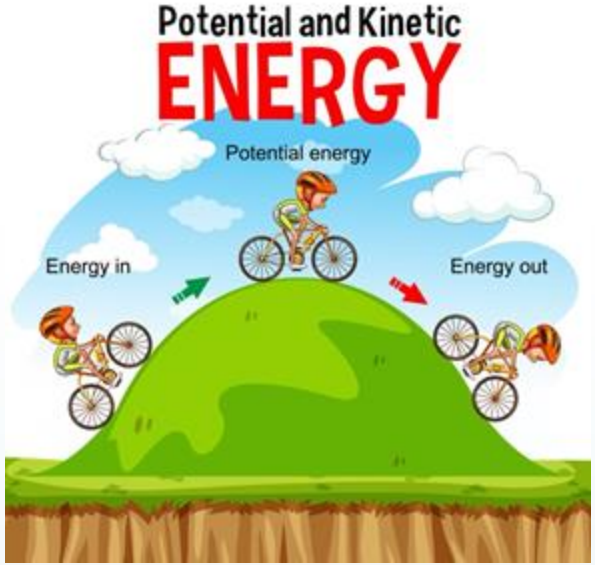
For example:

Mass of object = 2 kg, Speed = 1 m/s

$KE = \frac{1}{2} \times 2 \times (1^2) = 1$ Joule

When we drop weights from different heights, we're changing how much kinetic energy they have when they hit the orthotic.

That's why the force on the orthotic is different depending on the height of the drop.



Infographic explaining that a bike going over a hill gains potential energy as it goes up and kinetic energy as it goes down

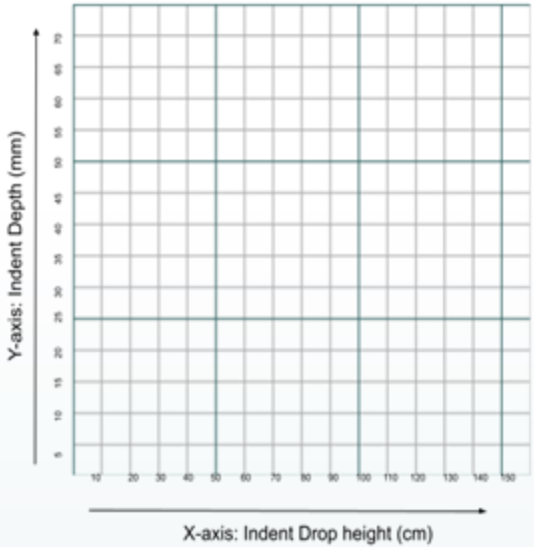
Graphing Your Data

What to compare

- With vs. without your orthotic
- Drop height vs. impact depth
- How much energy the orthotic stops from reaching the dough

Graphing Focus

- Look for trends or patterns.
- Use your graph to explain whether your design worked.
- Include error bars if you've learned how.



Graph with indent depth on Y axis and drop height on X axis

Real-World Applications

Current Impact

40% fewer foot ulcers -
60% more patients using their orthotics -
Saves about $4,000 per patient -
Source: NIH

Future Ideas

3D-printed custom insoles -
Smart pressure sensors -
New, high-tech materials -
Source: NIH

World Map in black and white

Career Options

Manufacturing Assembler: Build medical supplies in a factory - no education needed
Advanced Manufacturing Machinist: Produce supplies with a machine - trade school
Manufacturing Engineer: Design medical products - college degree needed