Osteoarthritis (OA) is a joint disease that affects 21 million Americans every year. OA occurs when cartilage at weight-bearing joints such as the knees and hips wears down, causing extreme pain and bone damage. OA severity is determined based on degree of bone deformity and joint space. Currently, moderate exercise combined with prescription painkillers are recommended for OA patients in order to counteract the degeneration of cartilage. While exercise may strengthen joints, patients must carefully manage their exercise, as under-exercising will lead to joint stiffness and weakness and over-exercising may damage cartilage and cause severe pain. Unfortunately, clinicians have little quantitative data on how exercise affects joints, making it difficult for them to personalize exercise treatments. As of now, few effective, affordable solutions are available to monitor OA patients’ exercise long-term and relate their physiological condition to their exercise habits.

**Need Statement**

An accessible and accurate way to constantly measure and record knee pressure and pain of arthritis patients in order to help clinicians determine how patient activity correlates with physical joint condition and personalize recommendations for patient exercise based on quantitative data.

**Need Specifications**

<table>
<thead>
<tr>
<th>Must Have</th>
<th>Measurable Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure pressure on knee</td>
<td>Accurate to 1 kPa with range of 15-1200 kPa</td>
</tr>
<tr>
<td>Lightweight and comfortable</td>
<td>Average comfort rating 8/10 or higher from a user survey after wearing device for 1 day</td>
</tr>
<tr>
<td>Patient self-reported pain input capability</td>
<td>Records patient’s pain rating on a scale of 1 to 10</td>
</tr>
<tr>
<td>User-friendly interface</td>
<td>Average UI rating 8/10 or higher from user survey after wearing device for 1 day</td>
</tr>
<tr>
<td>Record/store data continuously long-term</td>
<td>Records data every 500 ms and stores up 1 full day of measurements</td>
</tr>
</tbody>
</table>

**Prototype**

We connected piezoelectric disks and a bluetooth transceiver to an Arduino Lilypad wearable microprocessor with conductive thread, sewing all parts to a foam insole.

**Comparison Analysis**

Moticon® OpenGo
- Expensive: ~$5,000
- Needs additional software
- Not geared towards OA patients

Tekscan® F-Scan System
- Expensive: ~$10,000
- For research purposes only
- Not geared towards OA patients

**Materials**

- Arduino Lilypad Main Board
- Bluetooth transceiver
- 10 kΩ resistors
- Insoles
- Conductive thread
- Piezoelectric sensors (6)

**Concept Analysis**

Piezoelectric pressure sensing insoles and a pain input phone application to monitor OA patients’ exercise and pain, giving clinicians a way to connect patient exercise to disease progression and help them determine acceptable programs of exercise for each patient.

**References**


**Acknowledgements**

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**Future Work**

Our next steps:
1. Improve efficiency of and reduce size of circuit
2. Devise way to power microprocessor for long periods of time
3. Streamline design for thinner insole
4. Add machine learning and pain/activity analysis features to app
5. Broaden scope of device to help patients with a variety of diseases
6. Use device as data collection tool to evaluate different OA treatments

**Testing**

Planned tests of our prototype will:
- Correlate Arduino measurements (0 to 1023) to pressure units (kPa) using a force plate to take control data
- Detect measurable differences in pressure patterns of different activities (running, walking, etc.)

**Conclusions**

The goal of our project was to enable clinicians to find a correlation between exercise and OA progression, which would help them develop and prescribe better exercise programs for OA patients. To do so, we created a piezoelectric insole that sends pressure data via bluetooth to a mobile application for analysis of exercise type, intensity, and resulting patient-reported pain. This prototype serves as a convenient and reliable method to monitor OA patients’ pain and exercise that would allow both clinicians and patients to make more individualized decisions about exercising with OA.

**Results of Comfort Survey**

<table>
<thead>
<tr>
<th>Comfort</th>
<th>Fit</th>
<th>Cushioning</th>
<th>Imperceptibility of Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.4</td>
<td>8.2</td>
<td>6.9</td>
<td>8.1</td>
</tr>
</tbody>
</table>

out of 10