Using a Wireless Electronic Platform as Part of a Smart Knee Brace to Aid Rehabilitation and Prevent Anterior Cruciate Ligament Reinjury in Athletes

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Clinical Background

- 80,000-250,000 ACL injuries in the US per year [1]
- 10% reinjury rate [2]
- Mechanics of non-contact injuries (70%) [3]:
  - Rapid acceleration/deceleration
  - Quadricep dominance
  - Quadricep contraction combined with internal rotation
- The cost of surgery and rehabilitation is 17,000-25,000 USD per injury [4]

Unmet Clinical Need: A cost-effective sensing platform designed to continuously monitor knee joint angle and linear acceleration used to inform the user of potential risk of reinjury and rehabilitation progress.

State of the Art

Goal: To recreate these devices in a simpler and highly cost-efficient way.

Product Architecture

<table>
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<tr>
<th>IMUs</th>
<th>Microcontroller</th>
<th>SD-card Breakout Board</th>
<th>SD-card</th>
<th>MATLAB Analysis</th>
</tr>
</thead>
</table>

Virtual Prototype

Adafruit FLORA (wearable microcontroller)

Virtual prototype of design created with Fritzing software.

Figure 1: Position of ACL in the knee joint. [5]

Figure 2: A wireless multi-sensor platform designed by a team of researchers to support functional monitoring and knee rehabilitation. [6]

Figure 3: Commercial device utilizing accelerometers to record raw data for research purposes. [7]

Figure 4: Block diagram for the designed wireless monitoring platform.

Physical Prototype and Output

Figure 5: Output while at rest (round 1).

Figure 6: Physical prototype.

Figure 7: Output while at rest (round 1).

Figure 8: Output while walking roughly in the x-direction (round 2).

Figure 9: Output while running roughly in the x-direction (round 3).

Virtual Prototype

3.7 V battery

Real-time clock

SD-card breakout unit

Virtual prototype of design created with Fritzing software.

Figure 10: One-way ANOVA for x-direction data. Significant difference between walking and the other two groups (p=0.001).

Figure 11: One-way ANOVA for x-direction data. No significant difference between any of the groups (p=0.06).

Figure 12: One-way ANOVA for x-direction data. No significant difference between any of the groups (p=0.816).

Data Analysis

As the two IMUs had to be in series to establish 123 connection, the microcontroller was unable to differentiate between the two sensors. Hence, while the prototype was functional at recording linear acceleration, it failed to determine knee flexion angles.

Moving forward, my research team would like to pair a similar, but more advanced sensing platform with an active movement damping mechanism. Theoretically, the output of certain IMUs could scale the torque of a low-voltage motor in order to actively prevent ACL overloading. This technology could be incorporated into a novel knee brace and marketed to athletes around the country.

Limitations and Future Work

Acknowledgements

I would like to thank my research peers Daniel Gaytan-Jenkins, Fernando Rangel, and Wesley Groves for their contributions to the product concept generation and selection process. Furthermore, I would like to thank Rodolfo De La Cruz electrical engineer for his help with troubleshooting the prototype and teaching me about SPI and I2C. Finally, I would like to thank my faculty mentor, Dr. Schaefer, for her continued support exploring my personal interests.

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