DEPARTMENT OF MECHANICAL ENGINEERING

Remote Deep Tendon Reflex Device
ME Team 33 - Knee Slappers

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Problem Definition

Objective: The solution will perform the deep tendon reflex test and relay information to the doctor in telehealth in the target audience of individuals aged 50 to 55.

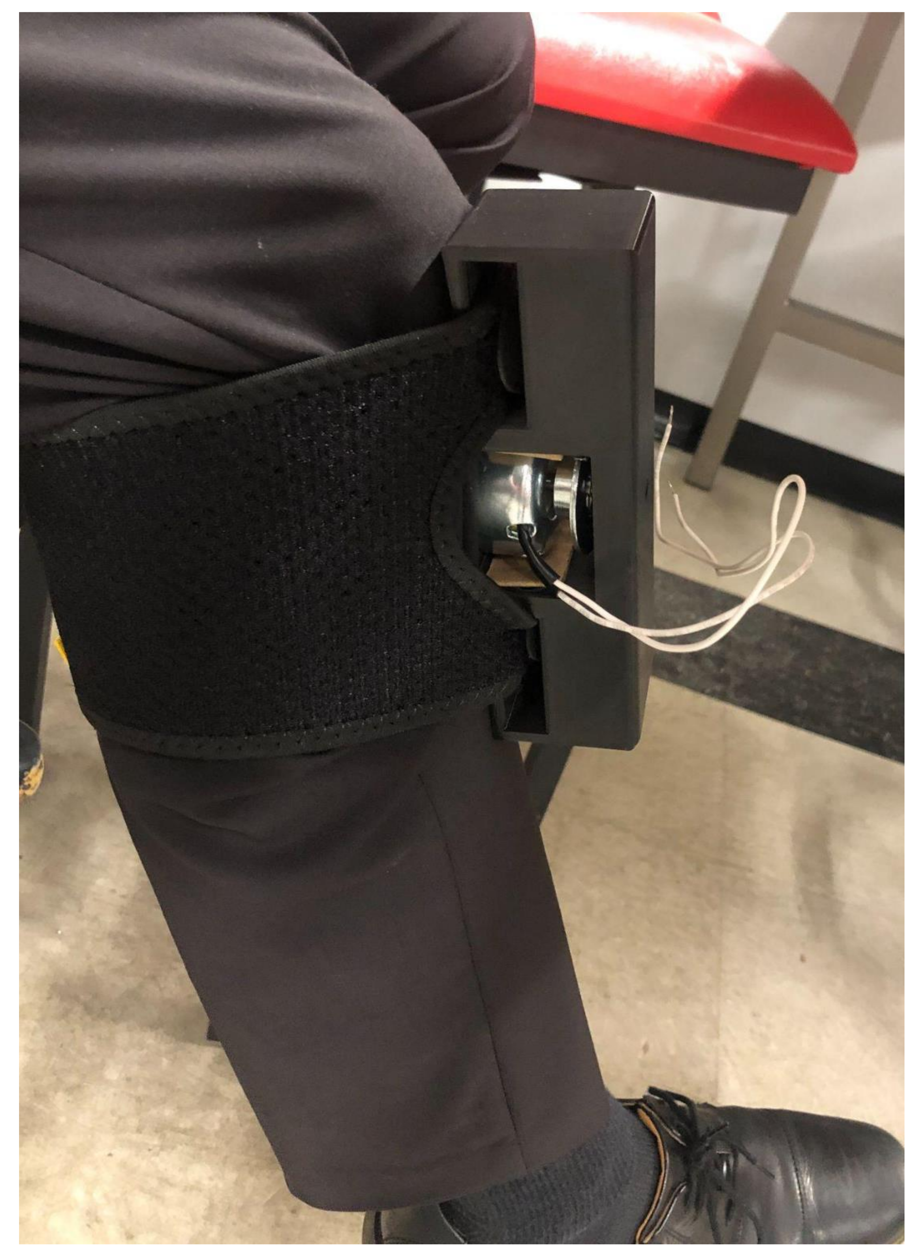
Background: A traditional hammer reflex test is performed on patients who complain of lower-back pain as an assessment of spinal health. The test impacts the patellar tendon to gauge muscle-nerve communication, and the doctor physically inspects the reaction of the knee-jerk reflex in order to give a diagnosis. The need for a remote testing method is crucial, as the cost of chronic pain conditions and lower back pain in the US is between $560 to $635 billion annually. Per AHA statistics, approximately 3.5 million patients go without care because they cannot access transportation to their providers, justifying the need for a remote solution. In the design, stakeholders value reliability of results, a simple user interface, and effective triggering of the deep-tendon reflex.

Design Calculations & Analysis

Maximum and Minimum Impulse Applied (N*s): NIH study indicates tap force range for reflex response to be 12.8 to 85.2 Newtons, resulting in a necessary impulse range of 0.043008 to 0.2772 N*s when multiplied by an expected hammer impact time of 3 milliseconds. Natural internal reaction force on the patellar tendon is approximately 1000 N, providing a safety factor of 11.737 when compared to the maximum tap force found in NIH study.

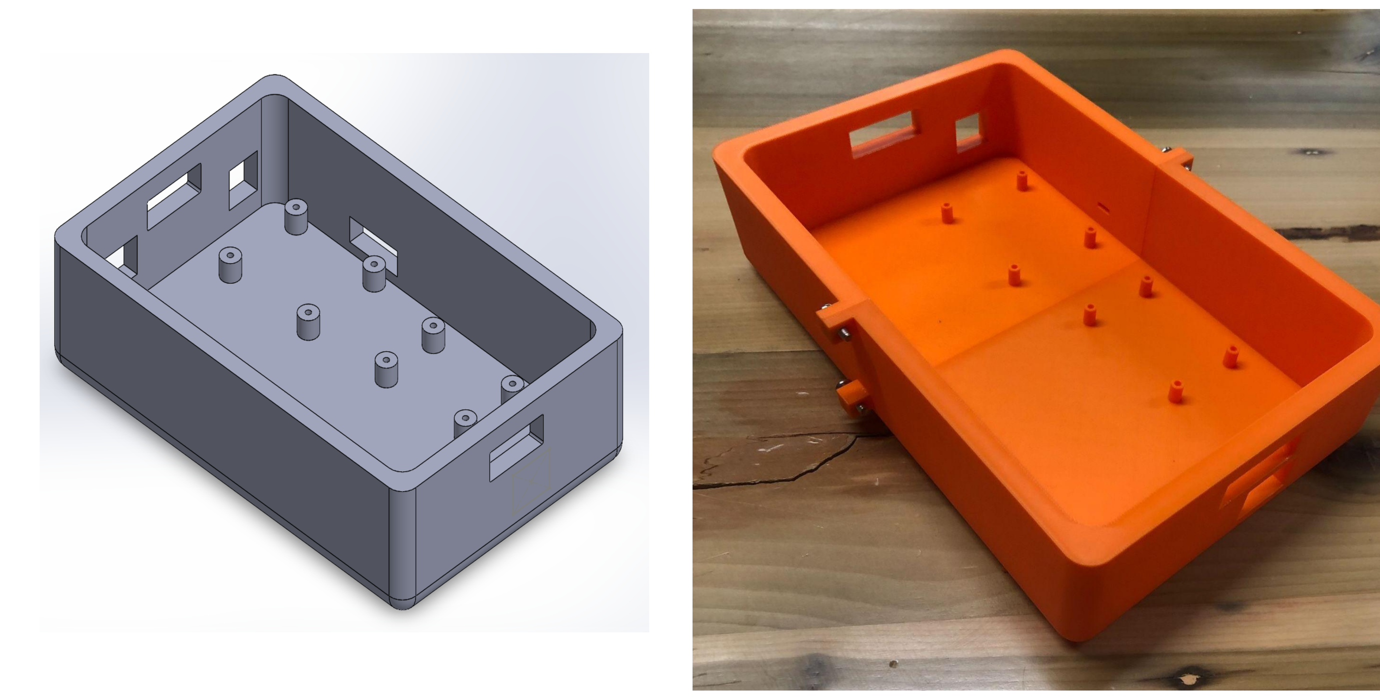
Electronics Housing: Properly managing heat is critical in electronics housing design; goal is to maintain low conductive heat transfer rate while preventing overheating. Using Fourier's Law, calculations based on thermal conductivity and thickness of PLA filament (0.13 W/mK, 1 inch) indicate a heat transfer rate of 3.05 J/s. Despite PLA's insulation properties and heat deflection temperature of 133°F, a cooling system such as a fan or liquid coolant is deemed necessary for effective operation. A cooling system can reduce device temperatures by approximately 25°C, increasing product lifespan by a factor of 5.66, potentially extending device lifespan from 20 to over 110 years and reducing PCB e-waste.

Final Design

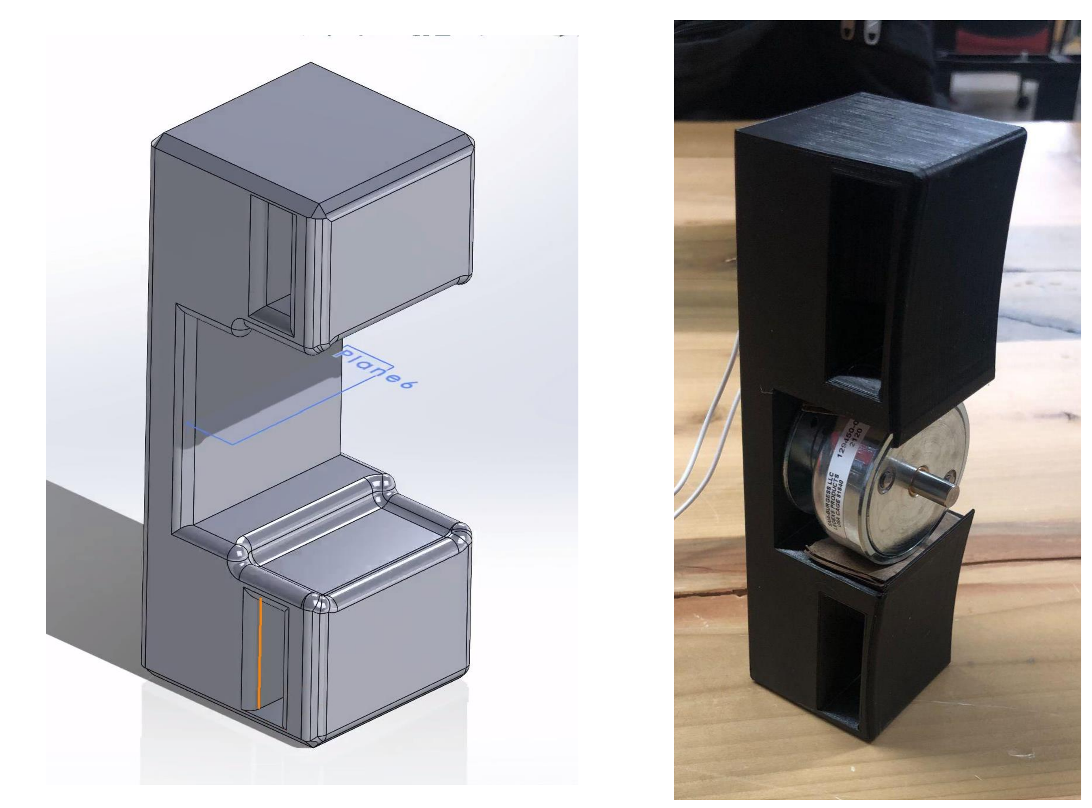


Solenoid Housing Mounted to Leg

The design is composed of a solenoid to impact the knee, an Inertial Measurement Unit (IMU) to measure movement of the leg, and a Raspberry PI to control power and relay data to the practitioner. This required impulse led to the selection of the LEDEX 129450-026 solenoid for impact due to its compact size and ability to produce the required impulse at as low as 12 V. The MPU-6050 is the chosen IMU due to its inclusion of both a gyroscope and accelerometer to simultaneously measure angle and movement of the leg.



Electronics Housing Realization



Solenoid Housing Design into Prototype

Problem (cause):	RPN
MPU gives incorrect data	100
Program relays incorrect data	100
Power and/or microprocessor input is not delivered to solenoid	80
Solenoid plunger is too far away to contact knee	70
Wiring is not done correctly	40
Solenoid and housing not firmly attached to knee	20
Straps do not have provisions for tightening or adjustment	15
MPU is not responding	14

DFMEA Risk Priority Number for Potential Failure Modes

Prototype & Test Results

Prototype: The prototype consists of a housing designed to securely hold a high-wattage solenoid near the patellar tendon for eliciting reflexes. This housing facilitates easy adjustment and alignment with the knee through two straps, ensuring comfort and stability. The solenoid will be powered with a Raspberry Pi 5. The electronics will be encased in a different housing to secure important electronic components in place, as well as to protect them from moisture or physical damage. The housing material for both is currently PLA filament, chosen for its lightweight and compatibility with the solenoid's weight.

Testing: The testing procedure involves setting up the solenoid in a rigid holder to prevent body movement, maximizing energy transfer. A known mass is attached to the end of a rod to create a pendulum, with the solenoid impacting the mass. Marks are made to signify the pendulum's maximum height and to determine the angle, allowing for adjustment of the solenoid's travel distance. Finally, the solenoid is triggered, its path tracked, and its momentum calculated for analysis.