Development of a 'Smart' Resistance Exercise Band to Assess Strength

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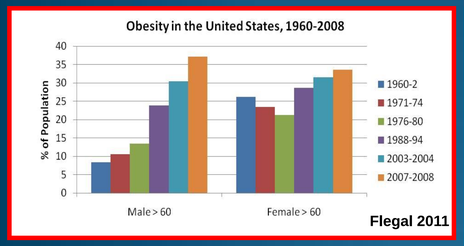
The research reported was supported in part by the National Institute On Aging K23AG051681 and the National Science Foundation CNS-1314281
The investigators retain full independence on the conduct of this research

BACKGROUND



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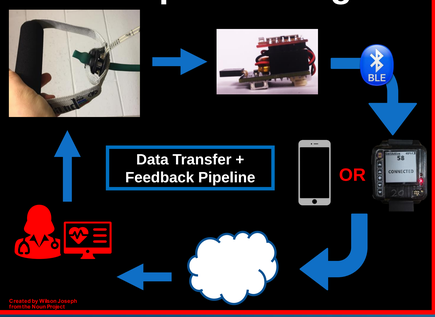
- Conventional clinic-based programs for older obese adults often focus on dietary weight loss, but this can result in muscle and bone loss
- Resistance activity using resistance exercise bands can mitigate muscle/bone loss.
- Mobile technology is emerging as a delivery tool for elder-specific health promotion interventions

HYPOTHESIS

A device can be designed to enable rapid feedback on, encouragement for, and remote monitoring of, elastic resistance exercise via mHealth technology

Conceptual Design



Acknowledgements

The Halter Lab, especially Dennis Wu and Joe Skinner

The Kotz Lab, especially George Boateng and Patrick Proctor

The Aging Resource Center, especially those that helped coordinate clinical studies

Dawna Pidgeon, PT, who selected the four test exercises

The many participants who took part in the clinical studies

My friends who helped me solder late into the night

DESIGN PROCESS

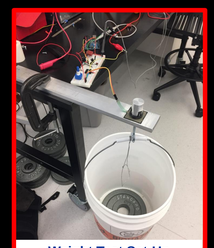
Design Components + Considerations

- ***Tubing vs. Flat Band Style –*** axial force necessary
- ***Sensor selection –*** decision drove most others
- **Handle selection** – connection style and axial force
- **Case design** – minimal form, removable/portable
- **Other hardware design** – ensure sensor repeatability
- **Electronics** – Bluetooth Low Energy, easy switch, low power, small, simple code (Arduino), LED indicators
- **Application design** – off-the-shelf (phone), secure, flexible (Amulet wearable, Amulet OS)

Example – Sensor Selection

- Commercially available sensors were evaluated for:
  - linearity of response to force
  - repeatability of response to force
  - ease of integration with Thera-Band

- Sensors were mounted between 2 washers and placed under a load-bearing standoff. Weights of 0.2, 5, 10 and 15 lb were applied to the sensor
- Supporting electrical circuits were designed
- Sensors were ranked low, medium, or high in each category



Weight Test Set-Up

	Linearity	Repeatability	Ease of Integration
Digital Dynamometer	High	High	Low
Conductive Rubber Cord Stretch Sensor	High	Low	Med
FSRs	Med	Med	Med
Flexiforce A401 Sensor	Med	Low	Med
Flexiforce A201 Sensor	High	High	High

Thera-Band System of Resistance Exercise

Color Progression:

Thera-Band® Band/Tubing Color	Increase from Preceding Color at 100% Elongation	Resistance in Pounds at: 100% Elongation	200% Elongation
Thera-Band Tan	-	2.4	3.4
Thera-Band Yellow	25%	3.0	4.3
Thera-Band Red	25%	3.7	5.5
Thera-Band Green	25%	4.6	6.7
Thera-Band Blue	25%	5.8	8.6
Thera-Band Black	25%	7.3	10.2
Thera-Band Silver	40%	10.2	15.3
Thera-Band Gold	40%	14.2	21.3

BEGINNER → ADVANCED

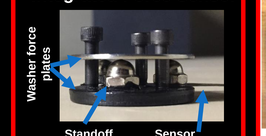
Represents typical values. All products not available in all colors.

FINAL DESIGN

COMPLETE IEB DESIGN

The best design used a single **Tekscan FlexiForce A201** sensor (range 0-25lb) positioned under a standoff that applied uniform pressure to the sensor (**shown below**). The device was placed around the tubing and within the handle. Force was applied between the tube's end and the handle when in use.

Data is ported through a custom PCB to a RedBear Bluetooth Low Energy Nano device powered by Li-Ion battery, then wirelessly visualized in real-time through the nRF Toolbox iPhone application or the Amulet, a wrist-worn smartwatch- , style secure wearable with a custom application (shown at right).



1. Unconnected Amulet – press Button on lower left side to connect; 2. Amulet trying to connect with IEB – Turn IEB on; 3. IEB on (green and red LEDs lit) but Amulet will not connect until non-zero force registered; 4. Amulet connected, exercise summary displayed – press Button to advance; 5. Choose exercise to be performed – Use the slider to scroll to select; 6. "Seated Row" selected – press Button to confirm.

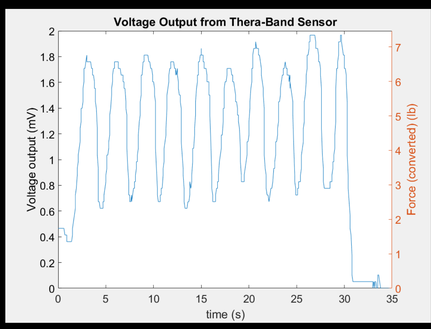
7. Choose band color – scroll to select and press button to confirm; 8. Confirm selections – press button to confirm, or use the slider to go back; 9. Ready to begin exercise – begin using IEB; 10. Amulet reading values – if values are changing, Amulet is working. Press button when exercise complete; 11. Post Exercise summary – bar displays level of highest peak achieved. Press button to continue; 12. Choose another exercise – or hold Button for a few seconds and release to exit app.

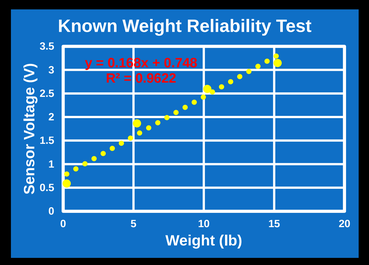
VALIDATION + TESTING

Repeatability of Flexiforce A201 Sensor

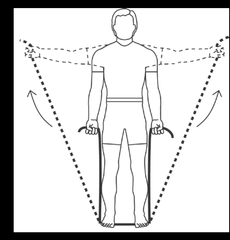
Weight (lb)	Trial 1	Trial 2	Trial 3	Mean	Std Dev	Δ (%)
0.25	0.5	0.62	0.65	0.59	0.08	23.1
5.25	1.64	1.88	2.08	1.87	0.22	21.2
10.25	2.37	2.61	2.81	2.60	0.22	15.7
15.25	3	3.2	3.24	3.15	0.13	7.4

- **Repeatability + Reliability** was assessed for both sensor and custom electronics. The sensor was tested using the "Sensor Selection" procedure, and data is displayed at left and plotted at right. Electronics **Accuracy = 0.3%**; **Precision = 0.0045 V**; **Signal-to-Noise Ratio = 57.6 dB**





- **Calibration** curves were generated for each sensor, as potentiometers are set by hand
- **Range** was assessed and determined to be at least **130 feet**.
- **Interference** was assessed by using multiple IEBs in the same room during a group exercise session. **No missed data values or losses in connectivity were detected**.
- **Power Consumption** was assessed using a Monsoon Solutions High Voltage Power Monitor. Given that we use a 40mAh battery, our expected battery life is **4.38 hours continuous run time**. **$Power_{ave}$ = 33.42 mW**, **$Current_{ave}$ = 9.14 mA**



- **Clinical Trials** were run on young, healthy adults, older adults, and older, obese adults to validate the concept as well as collect preliminary data. It was collected successfully with identifiable peaks in most cases. The example data at left shows voltage output on the left and converted force on the right. The conversion **force = 5.73 x voltage - 3.99** was used (from the calibration graph). Elongation data (length of Thera-Band at maximum stretch) measured from participants was converted to theoretical force using Thera-Band linear fit conversion. The average percent difference between predicted forces from elongation and converted forces from real data is nearly 67% ±79.3%

DISCUSSION

- Device is relatively repeatable and can be used to detect repetitions of resistance exercise.
- The magnitude of force appears to lack desired levels of accuracy. The device design and protocols for exercise may be reviewed to ensure participants are performing uniform exercises.
- Components cost <$100 -- simple to manufacture
- Device can be used in interventions for older adults to help them and their physicians track their fitness, especially those in rural areas who lack access to physical therapists
- A better dynamic measurement system is needed for the device

FUTURE DIRECTIONS

- Integrate peak detection algorithm to measure individual reps automatically
- Refine sensor design to minimize variations in magnitude of force measured, consider custom sensor
- Refine battery design for easier charging, charge level monitoring
- Develop interchangeable band design
- Use ML for automatic exercise recognition