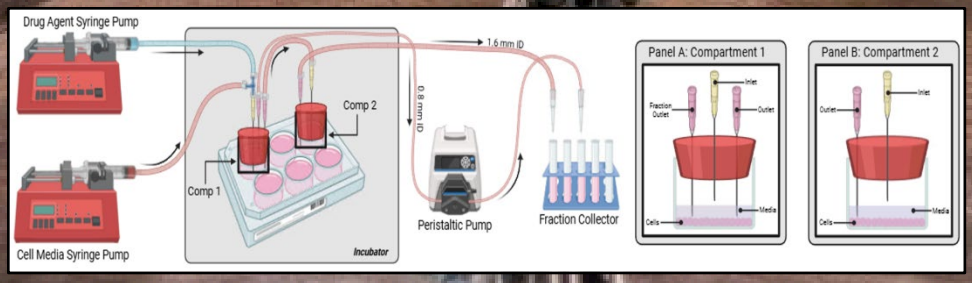
RUTGERS–NEW BRUNSWICK
School of Engineering

SOMJA

ComfortStride

Twenty Fourth Annual Biomedical Engineering Senior Design Conference

May 6, 2025



ModuPhyx

24th Senior Design Conference 2025 Schedule

8:30-9:00	Breakfast	BME Lobby
9:00-9:30	Keynote: Bill Donnelly	BME102
9:30-11:30	3 Minute Pitches	BME 102
11:30-12:15	Group Photo and Lunch	BME Lobby
12:15-1:30	Best-in-class Presentations	BME 102

Biomedical Computing, Imaging and Instrumentation

- SOMJA Instrumented Cane
- Bone Density Instrumentation

Tissue Engineering and Molecular Bioengineering

- Pharmacokinetic Mimicry of Gingival Crevice Tissue Inflammation
- ModuPhyx: A Modular Pharmacology Modeling Solution

Biomechanics and Rehabilitation Engineering

- STEP UP: Sensor Tracking & Evaluation Platform for User Prosthetics
- Pressure Embedded Guiding Alarm Service and User System P.E.G.A.S.U.S

1:30-2:30	Posters, Demos and Prototypes	BME 117, 122
2:30	Announcement of Winners!	BME 102

BME SENIOR DESIGN PROJECTS

Biomedical Imaging, Computing and Instrumentation (BCII)

Androulakis	NHANESConnect
Androulakis	Epitech: Software for Epidemiologic Data
Drzewiecki	HeartSense
Langrana	Bone Density Instrumentation
Li	Mental Stress Heart Monitor
Maikos	SOMJA Instrumented Cane
Tutwiler/Zahn	Quantifying Recirculation Zones in a 3D Carotid Artery Model using Bead-Based Velocity Tracking for Resuscitation Fluid Studies

Tissue Engineering and Molecular Bioengineering (TEMB)

Berthiaume/Cohen	A 3D Printed Solution to Modeling an In-vitro Wound Healing Protocol
Cai	Identifying Dynamic Gene Expression Changes in Retinal Development
Parekkadan	Pharmacokinetic Mimicry of Gingival Crevice Tissue Inflammation
Parekkadan	Engineered Probiotics to Help Promote Weight Loss
Parekkadan	ModuPhyx: A Modular Pharmacology Modeling Solution
Shreiber/Donovan	Pericardiocentesis Simulation Model for Resident Training
Tutwiler/Zahn	Blood Clot Strength Testing Mold

Biomechanics and Rehabilitation Engineering (BRE)

Freeman	3D Printed Soft Robots
Labazzo	Pressure Embedded Guiding Alarm Service and User System P.E.G.A.S.U.S
Labazzo	Stayble
Labazzo	Wheelchair Compatible Vibrational Therapy Device for Children with Disabilities
Labazzo	ComfortStride: Reimagining Mobility with Cushioned Support for Drop Foot Devices
Langrana	Paraswing
Maikos	STEP UP: Sensor Tracking & Evaluation Platform for User Prosthetics
Pierce	AnkleIQ

Biomedical Computing, Imaging and Instrumentation (BCII)

NHANESConnect

Team Members: Conor Burns, Matthew Cipriaso, Widnie Pierre-Louis
Mentor(s): Ioannis Androulakis, Ph.D.

Objective

Our project leverages NHANES, a CDC national health survey, for exploratory population health analysis. Access to the data is currently cumbersome due to the data's XPT format, restricting use to technically skilled users. To simplify this, we developed an API that generates detailed CVS patient profiles, enabling cross-attribute analysis and integration with statistical and machine learning workflows. Success will be measured by cutting data preparation time by at least 50%, supporting extraction from multiple NHANES categories, and achieving over 90% accuracy in variable mapping.

Concept Design and Engineering Constraints

The Flask API allows users to navigate through a streamlined website that enables them to specify demographic and clinical data. The tool meets stakeholder needs by enabling faster data wrangling, increasing accessibility for non-programmers, and seamless integration with machine learning workflows. Constraints included limited development time, human resources, and full-stack expertise. UI improvements and comprehensive documentation are underway.

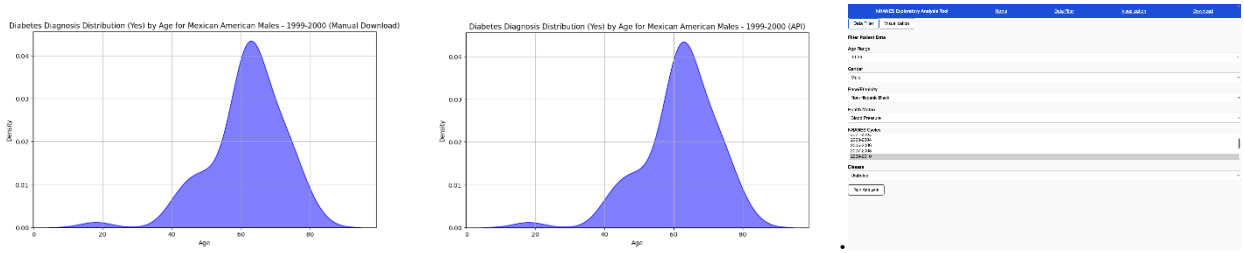
Prototype development

Methods

Our prototype uses Python scripts for the API backend and UI frontend. The API code simplifies NHANES data access by mapping files, converting them into a CSV, compiling into a single data frame, and filtering based on user input.

The UI features drop-down menus for key demographics (age, gender, ethnicity) and health metrics (disease diagnoses), allowing users to select relevant filters. Users can choose the cycle year, run analyses, and generate visualizations to assess potential health risks.

Results



The API visual (right) matches the manual data distribution (left), reducing development time by 62.5%. The UI screenshot highlights dropdown menus and easy NHANES data access.

Conclusion

This project has developed a prototype to improve access to the NHANES database, empowering users across the healthcare spectrum to leverage this information. Future efforts will expand demographic, lab, and disease data to allow for more robust profiles.

Epitech: Software for Epidemiological Data

Team Members: Pratyoy Biswas, Sachi Kurian, Katherine Nguyen, Felix James Vergara
Mentor(s): Ioannis Androulakis, Ph.D.

Objective

Analyzing large-scale health datasets, such as the National Health and Nutrition Examination Survey (NHANES), requires significant manual effort and coding expertise. Thus, there is a need to determine the link between biomarkers and chronic inflammatory diseases with epidemiological data in U.S. adults through an adaptive machine learning system with user inputs in parameters. The objective of this project is to develop Epitech, a user-friendly platform that enables non-coding professionals to analyze large-scale epidemiological data. To evaluate the success of Epitech, feature importance consistency was measured by examining the stability of top-ranked features across various classifiers and preprocessing strategies, while also verifying rankings with established findings in literature.

Compared to existing platforms, such as Weka and AutoML, this product offers significant improvements in customization, scalability, and predictive performance. Existing platforms often limit users to a narrow set of preprocessing methods and machine learning models[1]. Additionally, these platforms tend to struggle with large datasets, facing performance issues related to speed and memory[2].

Concept design and engineering constraints

Epitech provides users with full control over the machine learning pipeline, enabling customization at every stage, from data exclusion to classifier selection. Outputs include feature importance graphs, combined average graphs, and accuracy, recall, and precision tables, allowing users to compare models and select the best approach for their dataset.[1]

Prototype development

Methods: The biggest part of this product was evaluating different imputation methods and classifier models for handling missing data and predicting disease outcomes in large-scale health datasets. Six imputation methods and nine classifier models were first tested on a simpler, well-defined dataset (Iris) to assess the effectiveness of these approaches. The same methods were then applied to a gout case study to simulate a more complex real-world scenario.

Results: For the Iris dataset, accuracy values exceeded 90% across different classifier and imputation combinations. However, recognizing that large health datasets with missing data will yield lower accuracy, testing was in the form of ensuring that varying combinations of classifiers and imputation methods produced distinct results, highlighting the system's adaptability.

Conclusion

Epitech demonstrates the potential for adaptive analysis of health data, offering users customizable options and yielding distinct results. While the Iris dataset showed high accuracy, the gout case study revealed real-world challenges. Future work will focus on refining the interface, optimizing model parameters to improve predictive accuracy, and scaling the platform for large, incomplete datasets.

---

[1] AltexSoft. (2021, December 15). *AutoML: Capabilities and limitations of Automated Machine Le*. https://www.altexsoft.com/blog/automl/

[2] ERP Information. *Weka ML Software (features, advantages, and disadvantages)*. (2024, March 13). https://www.erp-information.com/weka

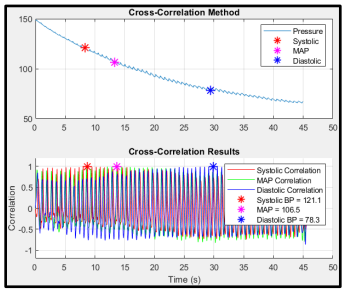
HeartSense

Team Members: Luke Devecka, Aditi Gupta, Rabiya Haque, Sabrina Munir, Ethan Paredes, Himanshi Shetty, Samantha Thai

Mentor(s): Gary Drzewiecki, Ph.D

Hypertension and hypotension affect millions worldwide, with hypertension being a major contributor to cardiovascular disease-related deaths. In underdeveloped communities, limited access to reliable at-home monitoring systems[1] hinders effective blood pressure (BP) management. To address this, we aim to develop a portable, accurate, and user-friendly device that non-invasively measures systolic (SBP) and diastolic (DBP) pressures, integrating advanced cross-correlation software to enhance functionality and empower patients to monitor their health.

HeartSense is a portable BP monitor that uses a pulse transducer to acquire waveforms, processed through a high-pass filter and non-inverting amplifier for real-time visualization. Current solutions, pulse oximeters or cuff-based monitors, lack BP specificity and cause discomfort from inflation. These devices rely on oxygen saturation or manual operation, making them unsuitable for continuous monitoring. HeartSense addresses these limitations by delivering a compact, data-driven alternative with continuous, BP-specific monitoring in a non-occlusive format.



The HeartSense prototype was developed through iterative hardware-software integration to create a compact system for accurate BP monitoring. Two algorithms were used to estimate BP from oscillometric waveforms: an industry-standard fixed-ratio method[2] and a novel cross-correlation approach. The pressure signal was filtered using a 4th-order Butterworth IIR filter to remove low-frequency trends. The fixed-ratio method identified the MAP at the point of maximum oscillation and estimated SBP and DBP using standard ratios. To improve accuracy, a cross-correlation method was developed using representative waveform segments extracted at fixed-ratio estimated SBP, DBP, and MAP locations. These templates were compared to segments of the signal to identify matching patterns based on waveform shape. This approach enables more precise detection of BP points by analyzing waveform morphology rather than relying solely on amplitude.

A pulse transducer was utilized to detect BP differences, with the signal amplified to fit the oscilloscope's display. Gain adjustments were made to ensure visibility by centering the pulse on the screen. To maintain signal integrity and minimize noise, the circuit is housed in a grounded metal enclosure, with low-offset components selected. Power and signal integrity were challenges addressed through the design. The oscilloscope, sensor, and circuit were tested for accurate readings, while the software algorithm focused on creating an efficient reader for the system.

HeartSense has successfully met its goals, with a portable, non-invasive BP device with real-time accuracy and precise BP estimations. Future work includes adding an emergency alert system and mobile app compatibility. We plan to patent our algorithm to protect intellectual property and enhance future developments.

---

[2] Juraschek, S. P., Daya, N., Appel, L. J., Miller, E. R., & Selvin, E. (2024). Use of home blood pressure monitoring and cardiovascular outcomes in the United States. *Hypertension, 81*(3), 623–631. https://doi.org/10.1161/HYPERTENSIONAHA.123.00000

Bone Density Instrumentation

Team Members: Youssef Ibrahim, Trinity Saria, Nabiha Umar, Eric Yan
Mentor: Noshir Langrana

Objective

Osteoporosis and Osteopenia are major, often undetected risk factors for orthopedic surgeries such as total joint arthroplasty (TJA), with 25% of patients having osteoporosis and 39% having osteopenia.These conditions significantly increase the risk of implant failure due to aseptic loosening; osteoporosis increases this risk by 80% [1,2]. Current surgical procedures and practices lack real-time objective tools to assess bone quality during procedures, leading to preventable complications and revision surgeries. The closest existing technologies for this problem are DEXA scans and CT scans, both of which are unsuitable for intraoperative use. To address this gap in technology, our team developed a portable, real-time bone density instrumentation device using microindentation technology and pressure sensing that is easy to use and able to apply a controlled load to determine bone quality intraoperatively. Our key metrics for success included correlating force sensor readings to known density (PCF) values and accurate categorization of bone quality.

Concept design and engineering constraints

Our proposed solution is a microindentation device that integrates a linear actuator, pressure sensor or force-sensitive resistor (FSR), and an Arduino microcontroller. With a single button press, the probe applies a load to the bone tissue, recording the FSR data in order to estimate the density. The device displays the interpolated PCF values and its corresponding diagnosis on an LCD screen.We designed our device to be portable, simple, and accurate, meeting all key user requirements. Constraints included limited lab time, budget, and reliance on non-biological samples for calibration.

Prototype development

Methods

We calibrated the pressure sensor by correlating its readings to sawbone samples of known densities (5, 8, 10, and 15 PCF). Each sample was subjected to mechanical compression testing on an Instron machine to derive elastic modulus values, validating the consistency of our model. Using the elastic modulus values, we developed a linear regression model to interpolate unknown densities based on the FSR outputs. We used Arduino code to control the extension and retraction of the linear actuator and coordinated it with the LCD screen for user interfacing.

Results

The elastic modulus testing indicated a consistent and proportion increase with bone density. The pressure sensor reliably measured resistance across the known PCF samples, and our prototype displayed the correct classification in real-time.

Conclusion

We successfully developed a low-cost, portable, and user-friendly prototype capable of assessing bone density intraoperatively. Initial validation done on sawbone samples supports the feasibility of microindentation-based assessments using FSR data. Future work for this project would include additional bone sample densities for better interpolation, refining the electronic wiring and casing, and integrating more precise force calibration methods for consistent clinical reliability.

---

[1] Al-Huniti MB, DeMeo ML, Wong SE, Moser FW, Glauser JA, Husni ME. Prevalence of osteoporosis and osteopenia in an academic population of patients undergoing primary total hip and knee arthroplasty. Arch Osteoporos. 2021;16(1):1–6. doi:10.1007/s11657-021-01055-9

[2] Nathan SK, Cevallos ND, Bhashyam AR, Sen S, Brant I, Kamath A. A prospective evaluation of preoperative bone health in patients undergoing total joint arthroplasty: Prevalence of osteoporosis and osteopenia and the impact of bone health optimization protocols. J Arthroplasty. 2024;39(3):579–584. doi:10.1016/j.arth.2023.10.059

Mental Stress Heart Monitor

Team Members: Yoon Seok Choi, Shayni Faltings, Maria Reyes Gaspar, Joyce Huang, Luke Marotta

Mentor(s): John K-J. Li, Ph.D

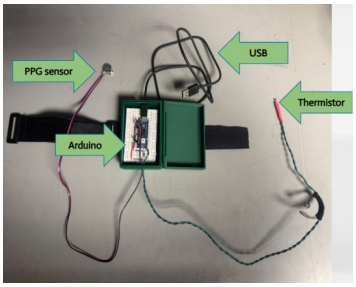
Objective

Mental stress is a significant health concern linked to cardiovascular diseases, weakening immune system, and cognitive function. Current popular wearable monitors, such as the Apple Watch and Fitbit, only focus on tracking physical stress and lack tools for identifying and quantifying mental stress.

Our team designed a wearable device that monitors heart rate, respiration rate, and heart rate variability (HRV) to categorize a user's mental stress level. We aimed for a 5-10% error margin in heart rate, respiration rate and HRV measurements compared to the gold standard, and a greater than 90% agreement with the Perceived Stress Scale (PSS).

Concept design and engineering constraints

Our device uses a PPG sensor and thermistor to measure physiological indicators. The device was designed to meet key customer requirements, including high accuracy, affordability, and real-time feedback. Testing showed that our device had less than 4% error for BPM and HRV measurements. The respiration rate measurements remained consistent with ranges documented in existing literature. Unlike market leaders which track physical stress indicators, our solution is focused on monitoring mental stress.

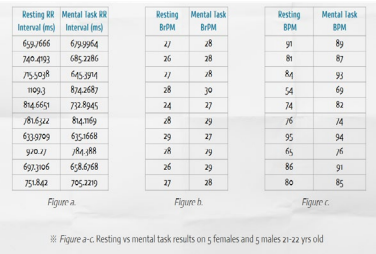


Prototype development

Methods

We collected baseline physiological data, including resting BPM and BrPM, from participants. Device measurements were validated against gold-standard ECG data obtained using the Biopac system. Participants then completed a timed cognitive task designed to induce mental stress, followed by the Perceived Stress Scale (PSS) questionnaire to assess subjective stress levels. Sensor signals were acquired in real time using MATLAB, where filtering was applied, HRV metrics were computed, and mental stress scores were generated based on our classification algorithm.

Results



Resting RR Interval (ms)	Mental task RR Interval (ms)
659.7666	673.9964
740.4193	685.2286
775.3038	645.3911
1109.3	834.2687
814.6651	732.8945
781.6322	814.1169
633.9709	635.1668
900.11	784.388
697.3106	658.6768
751.842	705.2219

Figure a.

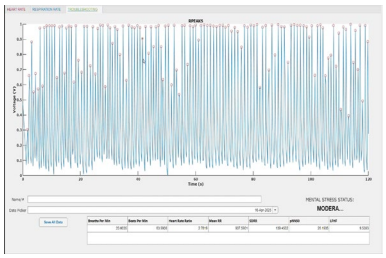
Resting BrPM	Mental task BrPM
17	18
16	18
17	18
18	20
14	17
18	13
19	17
18	19
16	19
17	18

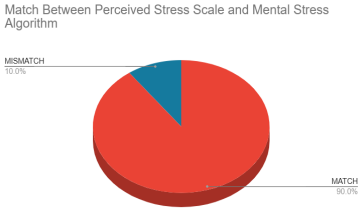
Figure b.

Resting BPM	Mental task BPM
91	89
81	87
84	93
54	69
74	82
76	74
95	94
65	76
86	91
80	85

Figure c.

※ Figure a-c. Resting vs mental task results on 5 females and 5 males 21-22 yrs old





Conclusion

The device successfully categorized mental stress with a 90% agreement with the PSS. Future work includes making the device more ergonomic and further improving the mental stress algorithm by collecting our own data and refining HRV calculations.

SOMJA Instrumented Cane

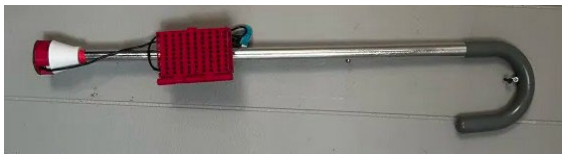
Team Members: Agboola Aishat, Alberto Sarah, Colavito Olivia, Pavel Judy
Mentor(s): Jason Maikos, Ph.D.

Objective

Veterans with lower limb loss often rely on canes during ambulation, yet gait labs currently lack the ability to capture synchronized force data from both the legs and assistive devices. Ground reaction forces are measured via force plates, but any load supported by the cane is unaccounted for, leaving researchers with an incomplete biomechanical profile. While products like the Intellicane exist, they focus on fall detection and navigation features[1] and are often bulky, visually stigmatizing, and not optimized for clinical gait analysis. A lightweight, unobtrusive, and accurate smart cane is needed to capture loading data in real-time during walking, synchronized with motion capture systems. Our objective was to develop the SOMJA Instrumented Cane, a cane capable of measuring axial forces with <5% error.

Concept design and engineering constraints

We integrated a 450 lbf load cell into the shaft of a 3D printed cane tip to measure the axial forces through the cane. An onboard microcontroller with Bluetooth streams data to an Arduino-based interface. Design constraints included a <5% accuracy error, weighing <2 lbs, being <25 in^3, operating wirelessly within 20 meters, and functioning for up to 10 hours on a single charge.



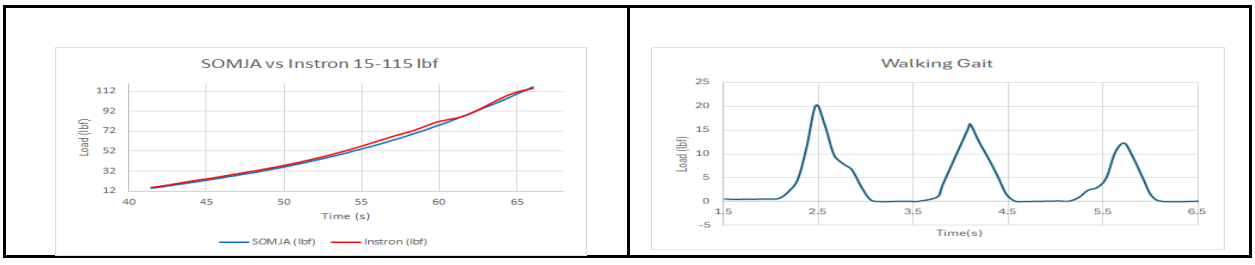
Prototype development

Methods

Different mechanical housing compartments, and cane tips using 3D printing and SolidWorks were prototyped. Microcontrollers like the ESP32-Pico-D4 integrated a load cell and amplifier into the circuit. Calibration and testing were performed using an Instron machine.

Results

The system achieves <4.5% accuracy error (target: ±5%) and reads up to 115 lbf (target: 100 lbf) in a 10.5 in^3 housing unit (target: <25 in^3). Correlation: 0.99565, RMS: 12.364, R^2: 99.13%, Mean Error: 4.512 lbf.



Conclusion

The SOMJA Instrumented Cane prototype successfully met all key benchmarks and provides a novel, lost-cost method to assess the axial load bearing forces through the cane. The device has application in motion capture labs, physical therapy, and clinical diagnostics. Future work will include expanded testing with patient populations to ensure patient comfort and satisfaction, and refinement of data visualizations.

[1] Weber, Gerard. "Intellicane: Intelligent Walking Cane System." *Vanderbilt University*, Vanderbilt University, 20 Sept. 1970, lab.vanderbilt.edu/rasl/past-research/intellicane-intelligent-walking-cane-system/.

Quantifying Recirculation Zones in a 3D Carotid Artery Model using Bead-Based Velocity Tracking for Resuscitation Fluid Studies

Team Members: Cole Burgos*, Michael Lattarulo*, Wilmary Figuereo Objio*, Aarush Sood*, Armando Angelo Sulit*

Mentor(s): Jeffrey D. Zahn, PhD*, and Valerie Tutwiler, PhD*

Objective

Hemorrhagic shock accounts for 30-40% of trauma-related deaths[1]. Hypovolemia occurs when 20% or more of the total blood volume of fluid is lost, causing resuscitation fluids to be administered to restore blood oxygenation[2]. However, current clinical metrics lack a noninvasive and real-time way to assess the effectiveness of resuscitation fluids in restoring the blood flow critical to maintaining organ function, such as the Internal Carotid Bifurcation model by United Biologics and the Starling Fluid Management Monitoring System by Baxter.

Recirculation zones at arterial bifurcations, like the carotid artery, are regions of disturbed flow where vortices form[3]. To address the need to evaluate resuscitation fluid effectiveness, we modeled pulsatile flow through a scaled 3D-printed carotid bifurcation and used bead tracking to quantify vortex formation. Clinical standards indicate that recirculation vortices' sizes are dependent on the flow rate, therefore, data analysis will focus on visualizing the relationship between both factors.

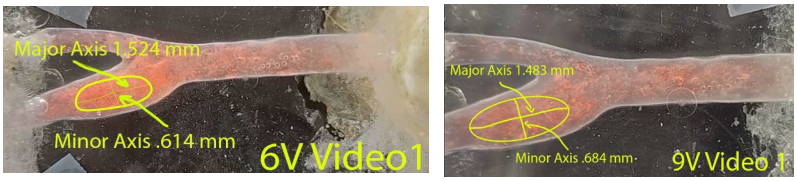
Concept design and engineering constraints

We designed a benchtop system with a 3D-printed Polyvinyl Alcohol (PVA) carotid artery mold embedded in PDMS, using polyethylene beads in Bovine Serum Albumin (BSA) solution for flow visualization. A waveform generator, pump, and power supply created pulsatile flow (6V-12V, 1 Hz). Compared to ultrasound or Computational Fluid Dynamics (CFD), our system enables direct visualization and experimental quantification of recirculation zones. Design constraints included modularity and optical clarity.

Prototype development

In order to determine the vortex properties, flow rates were calculated at varying voltages (6V-12V) to establish the average resting heartbeat flow rate as a clinical outline for our testing. 5% Bead-laden fluid was then perfused through the model while high-speed videos were analyzed using ImageJ. At 6V, average flow rate of 121 mL/min, the vortex width averaged 0.614 mm with a recirculation zone area of 2.94 mm^2. At 9V, average flow rate of 231 mL/min, the vortex width averaged 0.684 mm with a recirculation zone area of 3.09 mm^2.

Conclusion



The system successfully visualized recirculation patterns that correlated with flow conditions. Results show the model's potential for evaluating the organ perfusion effectiveness of resuscitation fluids. Future improvements include physiologic calibration and testing with fluids matching clinical standards.

[1] El Sayad, M., *Emergency medicine international*, *2014*, 638956. (2014).
2. Gagliardi, V., *Medicina*, *60*(12), 1936. (2024).
3. Wallace, H. A., *Fluid Resuscitation*. (2023).

Tissue Engineering and Molecular Bioengineering (TEMB)

A 3D Printed Solution to Modeling an In-vitro Wound Healing Protocol

Team Members: Gennelle Cruz, Khalil Elbrini, Heidi Leung, Allison Li, Connie Lin, Jahnavi Shah
Mentor(s): Francois Berthiaume, Ph.D., and Rick Cohen, Ph.D.

Objective

Chronic wounds affect over 6.5 million people in the US, with healing hindered by hypoxia. Current treatments like Hyperbaric Oxygen Therapy (HBOT) are limited by the lack of scalable, physiologically relevant in vitro models[3]. Existing systems often isolate stressors, lack reproducibility, and are resource intensive.

We developed an in vitro assay that simulates chronic wounds by combining a low-nutrient environment with a 3D-printed stamp to create uniform abrasions in 96-well plates seeded with human keratinocytes[4]. Success is defined by <10% scratch variation and a significant wound closure difference in the control and treatment groups. This system improves reproducibility, reduces resource use, and supports quantitative analysis of hypoxia-driven healing[5].

Concept design and engineering constraints

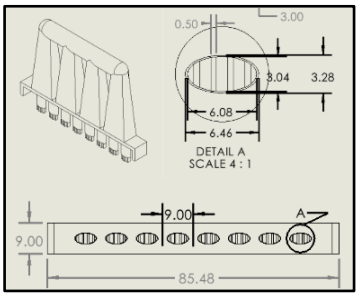
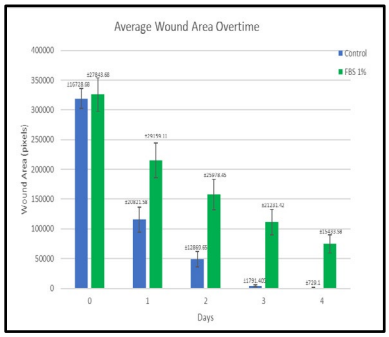


Figure 1: Prototype design of the stamp

To improve chronic wound modeling, we developed a 3D-printed PLA stamp with four elliptical extrusions and plate guides that create uniform scratches across eight wells of a 96-well plate. This design maximizes cell engagement while minimizing cell use, enabling scalable, high-throughput modeling. Unlike inconsistent pipette tip methods, the stamp ensures reproducible mechanical injury. A current limitation is the use of HaCaT cells, which lack full native wound-site fidelity.



Prototype Development

Methods: HaCaT cells were seeded (120,000/well) in a 96-well plate. After confluence, a 3D-printed stamp created four uniform scratches per well. Scratches were verified and imaged via fluorescence microscopy. Wells were treated with 10% (control) or 1% FBS (low-nutrient environment), and closure was tracked every 24 hours. ImageJ and MATLAB quantified wound area and closure.

Results: Control wounds closed significantly faster. Two-way ANOVA showed media type and time were significant ($p < 0.05$), with no interaction ($p > 0.05$). Minimal error bars confirmed reproducibility.

Conclusion

We developed a stamping device that creates four uniform scratches per well in 96-well plates, enabling consistent mechanical injury in keratinocyte monolayers. Future work aims to improve durability, standardize use, and integrate oxygen assays under hypoxic, nutrient-deprived conditions. Additional goals include adding inflammatory markers, optimizing stressors (FCCP, Antimycin A), using a hypoxia chamber, and tracking fluorescence-based metabolic responses.

---

[3] Kang HJ et al. J Control Release. 2021;333:176–187.

[4] Seo MD et al. Biomol Ther (Seoul). 2012;20(2):171–6.

[5] Kosol W et al. Biochem Biophys Res Commun. 2020;522(2):335–341.

Identifying Dynamic Gene Expression Changes in Retinal Development

Team Members: Augustine George, Lekha Rakundlia, Svar Shah, and Kayvus Trajano
Mentor(s): Li Cai, Ph.D

Objective

There is a growing need for scalable, automated tools to annotate cell types in large single-cell RNA sequencing (scRNA-seq) datasets, especially to track gene expression changes in retinal cells across development. Our objective was to develop and validate a machine learning pipeline to identify cell types and classify rod photoreceptor subtypes from C57BL/6 mouse retina scRNA-seq data spanning four time points (P15–P91). We evaluated the pipeline on annotation accuracy, Seurat integration, and visualization quality.

Retinal development involves time-sensitive differentiation of multiple cell types. Manual curation and tools like Monocle are time-consuming and inconsistent for high-dimensional data. Our Random Forest-based method improves speed, reproducibility, and scalability in developmental scRNA-seq annotation.

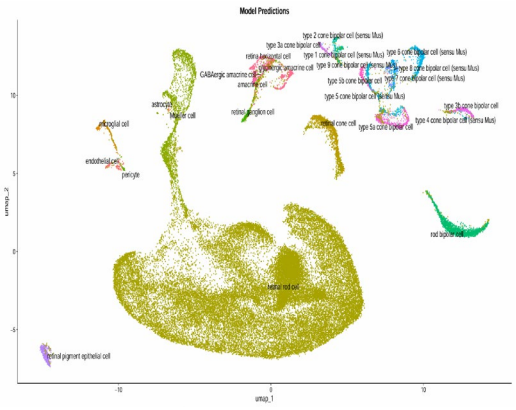
Concept design and engineering constraints

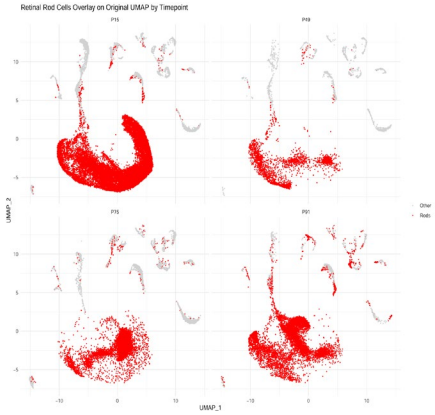
We developed 10 modular R scripts in a Seurat-based workflow for preprocessing, quality control, clustering, and machine learning annotation. The pipeline accepts matrix, barcode, and feature files as input, and outputs UMAP plots, cluster IDs, and gene expression profiles. Compared to existing tools, it requires less manual input, supports batch analysis, and handles biological variation efficiently, making it well-suited for large-scale studies.

Prototype development

Methods: The pipeline filters low-quality cells, normalizes data, and integrates it with the Mouse Retinal Cell Atlas. Using 3,000 shared genes, we trained a Random Forest model (mlr3 package) to predict cell types in experimental datasets and generate annotated visualizations.

Results: Our model processed P15 – P91 data and aligned well with manual annotations based on known cell types and marker genes. It accurately classified major retinal cell types and captured spatial-temporal patterns in rod development. Annotation accuracy exceeded 95%, with 81% gene overlap between datasets.





Conclusion

We developed a scalable, accurate pipeline for automated retinal cell type annotation using scRNA-seq and machine learning. Our results show strong alignment with known developmental patterns and outperform manual annotation in speed and consistency. Future improvements include advanced models for rare cell detection and an intuitive interface for lab users. Our model lays the groundwork for broader applications in neural development and retinal disease research.

PHARMACOKINETIC MIMICRY OF GINGIVAL CREVICE TISSUE INFLAMMATION

Team Members: Kelli Cheng, Sharanya Datta, Vanessa Karayiannis, David Vaysberg, Anjali Viswanathan

Mentor(s): Isabel Brandtjen, Biju Parekkadan Ph.D.

Gingivitis and other periodontal diseases are highly prevalent and pose a growing public health concern.[6] Current in-vitro models of gingival crevice tissue (GCT) are limited in their ability to replicate the pharmacokinetics and inflammatory dynamics of the oral environment, hindering the effectiveness of preclinical testing and slowing development in research.[7] We addressed this need by creating a physiologically relevant assay that better mimics drug diffusion and inflammation dynamics in the GCT. Our assay kit provides sensitive and specific results for permeability and inflammation.

We developed a "Gum Tissue in a Box" assay platform (**Figure 1)**: an in-vitro multicellular tissue model composed of epithelial, fibroblast, and neutrophil-like engineered cells cultured on a 3 µm transwell insert. Engineered cells secrete reporter proteins linked to inflammation pathways (NF-κB-driven Gluc, Cluc & SEAP), which allow for the detection of inflammatory activation via enzyme secretion and fluorescent imaging. The design incorporates a FITC Dextran tracer dye for permeability modeling and offers both qualitative (imaging) and quantitative (spectrophotometry) outputs.

Figure 1: Gum Tissue in a Box

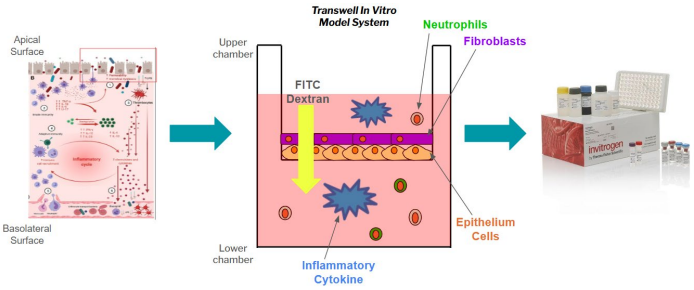
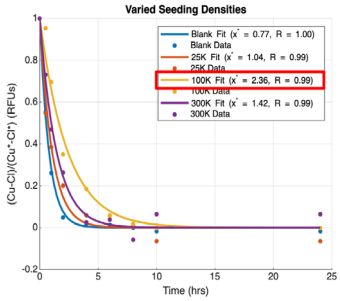


Figure 2: Select Permeability Results



Cells were seeded on 3 µm transwell inserts to form monolayers. We optimized seeding densities and stabilization times to ensure tight junction formation. Inflammatory stimulation was induced using a relevant cytokine, and FITC Dextran tracer dye (70 kDa) was added for permeability. Samples were taken over 24 hours from the apical and basolateral sides. Engineered cells were characterized using fluorescence microscopy and flow cytometry. Enzyme secretion was measured to quantify inflammatory signaling.

We found that our TIGK epithelial cells at 100K density formed a tight barrier preventing FITC passage (**Figure 2)**. 2-day incubation yielded optimal permeability control. An 8-hr cytokine stimulation increased permeability and GLuc secretion. In a co-culture assay, simulated inflammation unexpectedly reduced permeability, potentially due to ECM production by fibroblasts. This result highlighted the system's ability to capture complex tissue behavior compared to current competitor products.

We successfully developed a dynamic in-vitro assay to simulate gingival inflammation and drug permeability. Our engineered cell lines and transwell system allow for controlled modeling of the GCT environment. Future direction could integrate fluid flow and clinical samples to enhance translational relevance, but our system lays a strong foundation for standardized oral care testing platforms.

---

[6] Oral diseases: a global public health challenge; Peres, Marco A et al., The Lancet, Volume 394, Issue 10194, 249 - 260

[7] Wang Cong , Xu Tian , Seneviratne Chaminda Jayampath , Ong Louis Jun Ye , Zhou Yinghong; Modelling periodontitis in vitro: engineering strategies and biofilm model development; Frontiers in Biomaterials Science; 2024;

Engineered Probiotics to Help Promote Weight Loss

Team Members: Sarah Shenouda, Michael Zaki, Parth Patel
Mentor(s): Biju Parekkadan, Ph.D.

Objective

Obesity is a major global health crisis and leading risk factor for several chronic diseases.[8] Current treatments on the market like Ozempic, are effective but often expensive, require frequent injections, and can cause adverse gastrointestinal effects[9]. Additionally, they suffer from lower patient compliance and carry a higher risk of user error compared to more convenient oral capsule forms. To address this, we aim to engineer a probiotic strain to constitutively express and secrete glucagon-like peptide-1 (GLP-1) within the gastrointestinal tract, providing a novel and non-invasive therapy for weight management.Our project involves designing a plasmid with a codon-optimized GLP-1 gene, transforming a probiotic bacteria (*Lactobacillus*) and validating protein expression. Success will be measured by achieving GLP-1 concentrations of at least 50 pM in culture supernatants as quantified by ELISA.

Concept design and engineering constraints

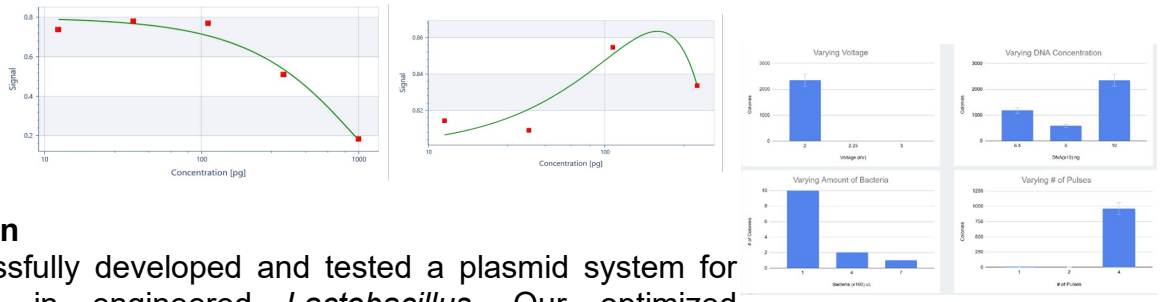
We developed a probiotic containing the codon-optimized GLP-1 gene to address key user needs- non-invasiveness, safety, and affordability- and compares favorably to injectable GLP-1 therapies. Constraints included a limited timeline, which prevented testing of bioactivity, and in vitro gut simulation.

Prototype development

Methods

To optimize transformation efficiency, we first tested electroporation using RFP- expressing plasmid. We varied electroporation parameters- voltage, pulse number, bacterial concentration, and DNA amount- and assessed fluorescence by colony counting, microscopy, and Celigo imaging. Using these optimized conditions, we transformed *Lactobacillus* with pMAL-c5X-GLP-1[10], a plasmid encoding GLP-1. Transformed cells were grown in liquid culture and tested for GLP-1 secretion via ELISA.

Results



Conclusion

We successfully developed and tested a plasmid system for GLP-1 expression in engineered *Lactobacillus*. Our optimized electroporation method enabled reliable transformation, and initial ELISA data confirmed GLP-1 secretion. While further validation is needed, this work demonstrates the potential for probiotic-based GLP-1 delivery and opens avenues for developing accessible, non-invasive obesity treatments.

---

[8] World Health Organization. Obesity and overweight. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

[9] Wilding, J. P. H., et al. (2021). Once-Weekly Semaglutide in Adults with Overweight or Obesity. New England Journal of Medicine, 384(11), 989–1002.

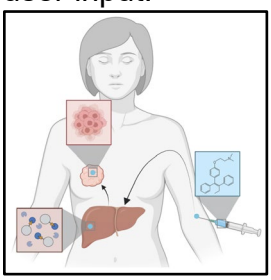
[10] pMAL-c5X-GLP-1 was a gift from Ashutosh Chilkoti (Addgene plasmid # 66997 ; http://n2t.net/addgene:66997 ; RRID:Addgene_66997)

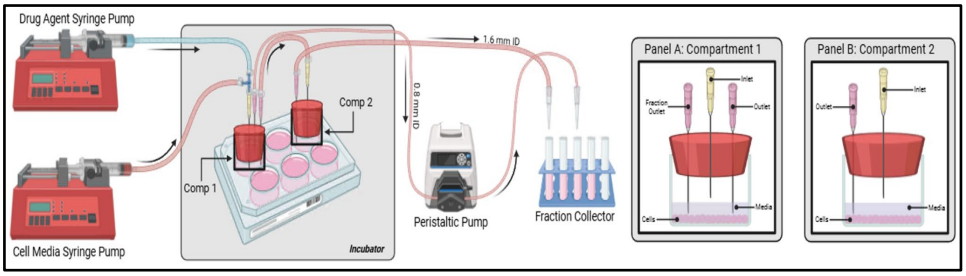
ModuPhyx: A Modular Pharmacology Modeling Solution

Team Members: Diya Chengappa, Rudra Joshi, Aum Patel, Soha Patel, Sughosha Rao
Mentor(s): Biju Parekkadan, Ph.D.

Pharmacology testing is complex, and many potentially life-saving drugs fail to reach clinical trials due to the gap between in-vitro and in-vivo testing. This disconnect limits the ability to predict patient treatment response, contributing to the $1–2 billion annual cost of pharmaceutical R&D. This project aims to bridge that gap by developing a platform that enables efficient testing and extraction of key parameters to better characterize pharmaceutical drugs and reduce resource strain.

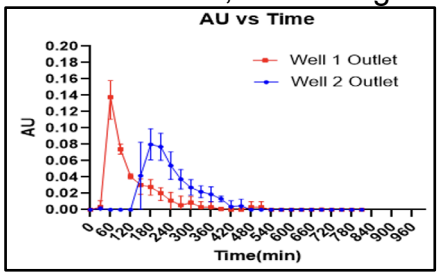
To address this, our team proposes ModuPhyx—a modular, two compartment flow-based in-vitro/in-vivo system featuring integrated cell culture, automated sampling, and easy assembly. Using syringe pumps, the tested drug is delivered to the first and second well compartments. These compartments are regularly sampled by an automated fraction collector. Engineered with standard lab supplies and commercially available parts, ModuPhyx is a low-cost system capable of high degrees of user input.





Our model drug of interest was the development of prodrugs, an effective alternative to chemotherapy with less adverse effects. Prodrugs are metabolized by the liver, and move to a treatment region through the bloodstream. To determine ideal flow rates, a tracer dye was run through the system at a given flow rate in triplicate. The system's automated fraction collector sampled the working fluid in both the first and second compartments.

The absorbance of these samples was measured and plotted to characterize the amount of dye in both compartments at multiple time points. Through the use of an in-house developed mathematical model of the system, we are able to extract parameters for any substance of interest which can be quantified in the samples. This is integral since in the case of prodrugs it allowed us to further characterize metabolite formation over time. In the case of dye, we determined the highest areas under curves to decide optimal flow-rates, correlating to the best potential treatment exposures.



Parameter	Estimated Value	Units
k_{12}	0.050203	mg/kg/h
k_{elim_C1}	0.0082231	1/h
k_{elim_C2}	0.0048695	1/h
V_{max_met}	10.368	mg/h
K_{m_met}	11.356	mg/L
K_{max}	0.61707	1/h
K_{C50}	5.4029	1/h
k_{growth}	0.27717	mg/L
$k_{transform}$	0.054057	mg/L

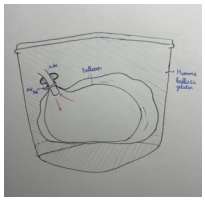
In summary, our senior design group helped develop a two compartment perfusion platform with high levels of user control. We also successfully developed and validated a mathematical model of our system capable of extracting key drug parameters. The groundwork for the development of ModuPhyx has been laid, allowing for a wide range of potential solutions.

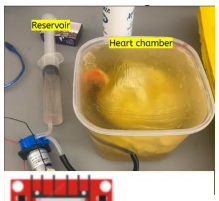
Pericardiocentesis Simulation Model for Resident Training

Team Members: Shayan Ali, Anmarie Aquino, Skyler Faltings, Yessenia Leon, Vy Nguyen
Mentor(s): David Shreiber, Ph.D., Colleen Donovan, MD.

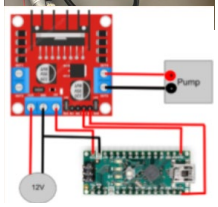
Objective: Cardiac tamponade is a life-threatening condition caused by fluid buildup in the pericardium, potentially leading to cardiac arrest if untreated. It is one of the few reversible causes of arrest when managed emergently with pericardiocentesis, an ultrasound-guided procedure using a needle to remove the fluid. As a high-acuity but low-frequency procedure, hands-on experience is limited, so RWJ medical students and residents rely on simulation training. The current model requires two people to operate, and ultrasound imaging is difficult due to unclear fluid pockets and balloon ridges. Our goal is to develop a reusable, anatomically accurate model with automated heartbeats and improved ultrasound clarity.

Concept design and engineering constraints: The mechanical components, consisting of the model heart and ballistic gel encasing, allow the product user to visualize an ultrasound and extract pericardial fluid.





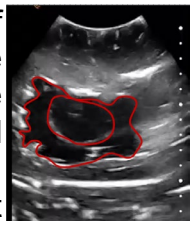
The electronic subsystem, on the other hand, will consist of a peristaltic pump, motor driver, and Arduino Nano microcontroller. The peristaltic pump will push fluid in and out of the inner balloon, simulating a heartbeat. The Arduino Nano will control the motor driver supplying the peristaltic pump with alternating DV voltage (+12V/-12V), pushing fluid in and out of the balloon, effectively controlling the heart rate.



Prototype development

Methods: To determine the needs of the model, we conducted a survey with current RWJUH residents for feedback on the previous year's model. The survey results indicated that while the simulation replicated the procedure well and was ultrasound compatible, it was difficult to visualize the heart and to exhibit an accurate heart rate; additionally, turbulent flow was easily mistaken for representing blood clots. We focused on three main areas of improvement: anatomical accuracy, an automated heartbeat beat and cost efficiency. To automate the model, we chose to use a peristaltic pump to provide flow to the inner balloon, a motor driver to supply power to the pump, and an Arduino Nano to control the motor driver. Initially, we purchased an inexpensive low flow rate(70mL/min) peristaltic pump to estimate the flow rate required for adequate heart rate simulation. Additionally, the melting temperature of the gel was causing ridges in the ballon which hindered ultrasound visibility, we lowered the temperature to 90C.

Results: Our testing showed that the inexpensive peristaltic pump was only capable of achieving a maximum heart rate of 4 beats per minute. Programming a higher heart rate with the inexpensive pump would not provide an adequate amount of deflection in the inner membrane to simulate a heartbeat. Consequently, we purchased a more powerful pump (1200mL/min), allowing us to achieve a realistic range of heart rate of 30 BPM.



Conclusion: Our project aimed to develop a cost-effective, anatomically accurate heart model with an automated heart rate. We successfully reached a heart rate of approximately 30 beats per minute. Lowering the gel melting temperature preserved the balloon's round shape and improved ultrasound clarity. We started the polycarbonate casing and testing viscous fluids to reduce turbulent flow. Future work for this project includes finishing the casing, surveying RWJ residents, adding a user-controlled system for heart rate adjustment, and making the inner balloon shape similar to a heart.

Blood Clot Strength Testing Mold

Team Members: Mendel Aizikovitch, Riley Englehart, Oyakunle Oyedele, Arya Patel, Javier Piedrasanta

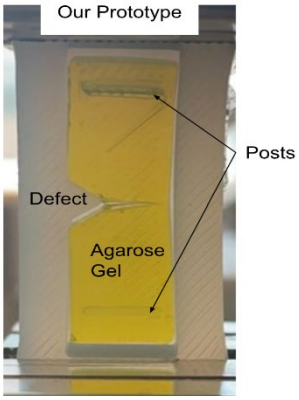
Mentor(s): Valerie Tutwiler, Ph.D., Jeffrey Zahn, Ph.D.

Objective

Thrombotic embolism is the rupture of an intravascular blood clot (thrombus) releasing a smaller clot (embolus) travel downstream and block smaller blood vessels, leading to pulmonary embolism and ischemic stroke. The conditions of thrombotic rupture are poorly understood, necessitating research into clot compositions and fracture circumstances. Current clot testing methods require a 4 mL[1] to 6 mL[2] clot, requiring pooled donor samples. There is need for a method or device to test smaller volume clots allowing for patient-specific clot testing. Our project aims to fill this need by designing a device that allows for viable testing and fracture strength calculations of a 1 mL blood clot.

Concept design and engineering constraints

We designed a rectangular device with a 1 mL chamber, meeting requirements for testing a reduced volume clot. Our chamber features two symmetrical posts and a wedge-shaped protrusion. Tension on the device causes the deflections of the posts proportional to the force in the clot. Most validation testing used agarose gels due to a temporary blood shortage.



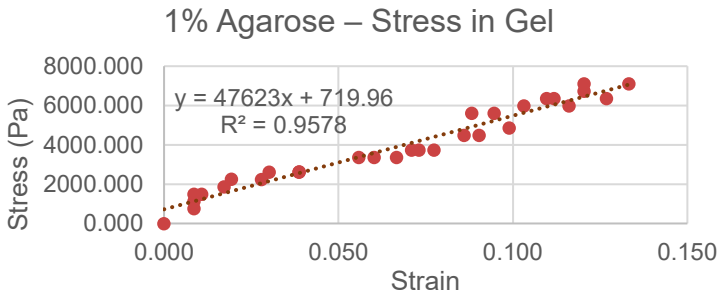
Prototype development

Methods

We first simulated the deflection of various posts dimensions. We used that data to print a thermoplastic polyurethane mold and cast RTV2 silicon. The device was demolded and the chamber was loaded with agarose. A Biomomentum Mechanical Tester equipped with a 10N load cell was used for tensile testing. Video records were taken by a mounted phone and video analysis employed to obtain post deflection and total displacement of the gels.

Results

Initial testing of our device with agarose gels yielded little to no post deflection, however posts were redesigned until deflection was observed. Agarose gels were determined to have elastic moduli of 43-48 kPa which fall within the order of magnitude suggested by literature[3]. The limited testing of platelet-poor-plasma clots was inconclusive with minimal post deflection observed. Clots did not fracture when tested.



Conclusion

We obtained mixed success with our project. Our device was able to accurately measure the internal force of agarose gels when subjected to tensile strain. However, it was not able to measure the force within platelet-poor-plasma clots, most likely due to the low elastic modulus of the PPP clots. Future work, including research into materials more compliant than RTV2 silicon and further reduction of the post spring constant, will be necessary to determine clot fracture strength.

[1] Fereidoonnezhad, B., Moerman, K. M., Johnson, S., McCarthy, R., & McGarry, P. J., Blood clot fracture properties are dependent on red blood cell and fibrin content. *Acta Biomaterialia*, 127 (2021), 213–228. https://doi.org/10.1016/j.actbio.2021.03.052

[2] Tutwiler, V., Singh J., Litvinov R., Bassani J., Purohit, P., & Weisel, J, "Rupture of Blood Clots: Mechanics and Pathophysiology," *Science Advances* 6, no. 35 (2020): eabc0496, https://doi.org/10.1126/sciadv.abc0496.

[3] V. Normand, D. L. Lootens, E. Amici, K. P. Plucknett, and P. Aymard, "New Insight into Agarose Gel Mechanical Properties," *Biomacromolecules* 1, no. 4 (2000): 730–738, https://doi.org/10.1021/bm005583j.

Biomechanics and Rehabilitation Engineering (BRE)

3D Printed Soft Robots

Team Members: Kiara Alvarez, Imran Attarwala, Alma Bautista, & Matt Parchment
Mentor(s): Joseph Freeman Ph.D

Objective

We hope to develop a biocompatible, electroactive scaffold system—compatible with commercial 3D printers—that enables skeletal muscle cell differentiation for tissue engineering and transplantation research to treat individuals with Volumetric muscle loss (VML). VML is the loss of over 20 % of skeletal muscle that can cause permanent functional impairment if untreated. Current clinical solutions such as autologous grafting are invasive, inconsistent, and limited in accessibility.[11] Our prototype is designed to address the loss by differentiating stem cells in vitro that can be implanted to encourage muscle growth.

Concept design and engineering constraints

To address current treatment limitations, we aim to develop a hydrogel solution capable of crosslinking with commercially available digital light processing printers(DLP) for accessibility. A hydrogel consisting of PEGDA(Polyethylene Glycol Diacrylate), Acrylic Acid(AA) and LAP photoinitiator were proposed. PEGDA is a synthetic UV-crosslinkable polymer that forms a stable and elastic network, while AA enhances hydrophilicity & improves swelling. LAP significantly reduces crosslinking time. When electrically stimulating a hydrated hydrogel in a high concentration salt water, it will swell. This movement will cause contractile motion on a sheet of muscle stem cells to encourage differentiation. Implanting the cells into the region of the muscle loss helps medical professionals to treat and rehab patients with ease.

Prototype development

The bioreactor prototype was fabricated using a DLP 3D printer to crosslink a PEGDA:AA(1:4)& LAP based hydrogel under 405nm UV light in less than four minutes.The final structure featured a curved electroactive top and bottom walls with rigid borders designed to anchor a suspended, cell-laden gel insert in a basket. Carbon grease was applied externally along the hydrogel surface to help with conductivity without affecting the formulation due to its hydrophobic nature. To test electroactivity, hydrogel strips were hydrated and submerged in PBS while being stimulated with 20 volts via platinum wire electrodes running along the hydrogel length. Consistent bending angles exceeding 20 degrees were observed. Mechanical testing was conducted using both an Instron system and a Dynamic Mechanical Analyzer (DMA). The Instron provided stress strain behavior under tensile loading, while the DMA was used to assess viscoelastic properties under oscillatory loading.

Conclusion

The team successfully developed a 3D printable, electroactive hydrogel bioreactor capable of delivering compressive and tensile stress. The prototype demonstrated consistent bending in response to electrical stimulation, maintained structural integrity during mechanical testing, and was fabricated entirely using low cost materials and accessible printing methods. Future work will focus on seeding the system with myoblasts, optimizing stimulation parameters, and exploring its potential for eventual implantation as a dynamic tissue scaffold.

---

[11] Grogan BF, Hsu JR; Skeletal Trauma Research Consortium. Volumetric muscle loss. J Am Acad Orthop Surg. 2011;19 Suppl 1:S35-7. doi: 10.5435/00124635-201102001-00007. PMID: 21304045.

Pressure Embedded Guiding Alarm Service and User System P.E.G.A.S.U.S

Team Members: Aditya Desale, Dev Hudson, Eric Quartey, Lakshita Sharma, Maxwell Tran
Mentor(s): Kristen Labazzo Ph.D., MBA, Mark Pierce Ph.D., Gary Drzewiecki Ph.D, John Reck, Christine Horvath

Objective:

Matheny's patients encounter significant communication barriers, complicating caregivers' ability to address developing musculoskeletal issues. These patients are fitted for customized wheelchairs, making it imperative to understand pressure placement. This insight is vital for assessing skeletal issues related to posture. Currently, wheelchair technicians cannot determine the effectiveness of their customizations due to a lack of knowledge about the pressure applied to specific areas.

This project aims to mitigate the improper posture problems that can arise from individuals with complex communication needs and physical disabilities who are at risk of musculoskeletal complications. Delayed responses to these events lead to injuries, highlighting a need for a pressure-based, time-sensitive alarm to notify caregivers, ensure patient safety by minimizing harm, and address a critical gap in patient care for those with complex needs.

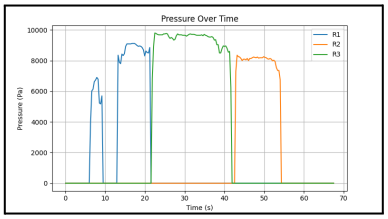
Concept design and engineering constraints:

Methods

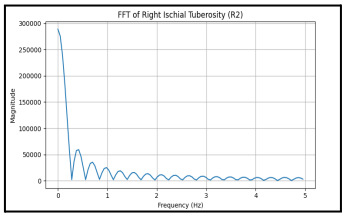
Our solution addresses key design specs and customer needs, such as tracking pressure on/off and benchmarking well over 70% as opposed to 30-50% pressure change, immediate notification through minimized delay from 5-30 seconds to 5 seconds, and false alarm percentages from 10% to 5%. This solution fills the critical gap for Matheny for a pressure sensor correlating with time, specifically how long pressure is being applied to a region, and classifications of normal vs abnormal. Thus, they would be able to make adjustments to the wheelchair design for each patient using this data.

Prototype development: We created three interactions for our device. Prototypes 1 and 2 used force sensor resistors to detect the pressure force applied at distinct points/areas. Incorporating the Arduino R4 Wifi's real-time clock feature, we collected how long the pressure was applied to the FSR. And find out what time of the day the pressure changes. Prototype 3 collects pressures using an electrical conductive fabric, increasing the number of inputs to 15.

Results



Pressure vs time Graphs generated for all three sensors (R1, R2 and R3)



FFT Display on Pressure sensor R2 corresponding to Right Ischial Tuberosity

Conclusion

The prototype results indicate that the device successfully detected pressure applied to the FSRs and correlated it with the duration and time of day the pressure occurred. Using predefined parameters, the device's GUI generated timely alerts by identifying significant shifts in pressure, thereby supporting effective and responsive care.

Stayble

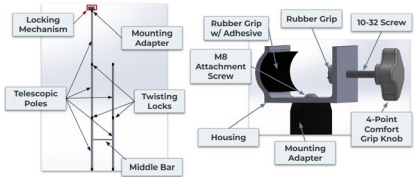
Team Members: Srijan Parikh, Monit Patel, Ethan Rodrigues Prabhu, Emily Sullivan, and Ria Suresh
Mentor(s): Kristen Labazzo, Ph.D.

Objective

Stayble looks to improve the safety, comfort, and independence of ambulatory disabled individuals using public transportation. Public buses often lack accessible seating and support for passengers who do not use wheelchairs, but still require assistance with balance and stability.

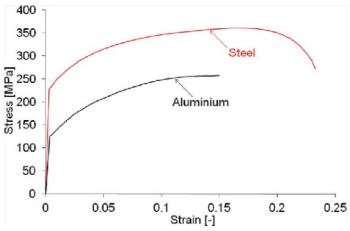
Concept design and engineering constraints

Stayble is aimed to be a strong, weight-bearing device for passengers, as well as easy to install for bus drivers. The design features telescopic poles, which allow for adjusting the height of the device to reach the overhead bar in the bus. A middle bar is welded in between the poles to both connect the poles together and provide a space for the user's backpack. The locking mechanism found on top of one of the telescopic poles is used to secure the device in place. This custom-designed steel mechanism features rubber grips that attach to the overhead bar and can be adjusted using the grip knob found on the side of the housing. Stayble provides an ergonomic, durable, and easy-to-use solution to making transportation in our university more accessible.



Prototype development

The development of the Stayble prototype was focused on user-centric design. Stayble aims to increase comfortability with proper hand placement, reduce blood pressure and heart rate, remain compact, and allow for easy installation. Our product went through multiple rounds of iterations, based both on our research and manufacturer feedback. Ultimately, we widened the locking mechanism housing to properly account for both the thickness of the overhead bar and the rubber grips inside the locking mechanism. At our metalworker contact's suggestion, we used steel for the housing; this both increased the strength of the device (as shown by the higher Young's modulus)[12] and reduced costs by eliminating the anodizing step that would be required for aluminum. In order to increase the longevity of our device and ease manufacturing, we introduced round fillets in our design, which prevent bending and cracking. The mechanical performance of this device would be evaluated by any signs of slippage of the footing mechanism at different speeds, instability of the locking mechanism, and wear and tear after prolonged use. Our experimental procedure enabled us to optimize the design of our device.



Conclusion

Ultimately, Stayble is the result of a user-centered design process focused on improving accessibility in public transportation. Through iterative prototyping, collaboration with various departments, and testing, we developed a strong, ergonomic, and easy-to-use device for ambulatory disabled individuals. Our future work includes enhancing the portability of the device, increasing its structural security and stability by anchoring the feet of the device to existing bus fixtures, and ensuring that our device is in compliance with DoT standards for implementation.

---

[12] Failure characteristics of strength-equivalent aluminium and steel plates in impact conditions - Scientific Figure on ResearchGate.

Wheelchair Compatible Vibrational Therapy Device for Children with Disabilities

Team Members: Allison Bierly, Melanie Gonzalez, Kelvin Guzman-Baez, Rachael Kim, Abigail Wasielewski

Mentor(s): Kelly Kyker-Snowman, PhD.; Kristen Labazzo, Ph.D.; Michael Pierce, Ph.D.

Objective

Whole-body vibration (WBV) therapy has demonstrated benefits including improved bone density, circulation[13], cognitive function[14], and pain management[15]. However, current WBV platforms are designed for standing users and are inaccessible to those in wheelchairs. In partnership with the Matheny School and Hospital, our team met the need for an accessible, safe, and effective WBV therapy option for wheelchair users.

Our goal was to design a vibrational therapy device tailored for wheelchairs that replicates the benefits of standing vibration therapy equipment. Our success metrics included ensuring safety based on ISO-2631 standards[16], falling within the range for therapeutic effect (acceleration 1.6–25.7 m/s^2 and frequencies 5–25 Hz)[17], and matching the acceleration and frequency of Matheny's WBV device.

Concept design and engineering constraints

Our prototype features a modular vibrating cushion with embedded motors, a control interface, and a 3D-printed enclosure for protection. This system was built from a disassembled commercial WBV device, modified to operate within wheelchair constraints. It sits atop existing wheelchair cushions for ease of use and cleaning. Constraints included budget limits (<$200), motor limitations, and safe vibration exposure.

Prototype development

Methods: Acceleration data was gathered from three participants using a 3-axis accelerometer placed on the foot, thigh, and chest. The raw data was converted to total acceleration which was then converted to the frequency domain using fourier transform. The peaks of the frequency domain correlated to the frequency of the vibration. Statistical comparisons were performed using t-tests between the Matheny device and our prototype for mean total acceleration and frequency data.

Our Results: The mean acceleration of our prototype was 11.04 m/s^2 and the mean frequency was 8.86 Hz. According to the ISO guidelines, our device is safe to use for under 1 minute. Both values are within the range for therapeutic effect. The t-tests show that there is no significant difference between the mean accelerations ($p = 0.6297$), but the frequency of our device is significantly higher ($p = 3.27*10^{-15}$).

Conclusion

Overall, our device can safely be used for under 1 minute according to ISO guidelines, is within the effective therapeutic range, and matches the Matheny vibrational device's acceleration. For the future, we aim to create more sensitive vibrational frequency and acceleration adjustment controls to have lower acceleration and frequency options.

---

[13] Li S, Yu W, Li W, et. al. The Impact of Whole-Body Vibration Training .... 2022 Feb 15;9(2):266. doi: 10.3390/children9020266.

[14] Fuermaier AB, Tucha L, Koerts J, et. al. Good vibrations--effects of whole body vibration on attention in healthy individuals and individuals with ADHD. PLoS One. 2014 Feb 28;9(2):e90747. doi: 10.1371/journal.pone.0090747.

[15] Newhart S, Pearson A, Salas E, Jones C, Hulla R, Gatchel R. Whole Body Vibration: Potential Benefits in the Management of Pain and Physical Function. Pract Pain Manag. 2019;19(1).

[16] Muir, Jesse et al. "Safety and severity of accelerations delivered from whole body vibration exercise devices to standing adults." Journal of science and medicine in sport vol. 16,6 (2013): 526-31. doi:10.1016/j.jsams.2013.01.004

[17] Godley D, Csongradi J. Whole Body Vibration Therapy for Children with Disabilities. Arch Rehabil Res Clin Transl. 2023 Sep 29;5(4):100298. doi: 10.1016/j.arrct.2023.100298.

ComfortStride: Reimagining Mobility with Cushioned Support for Drop Foot Devices

Team Members: Aldwyn Porter, Ariana Gartenstein, Shoshana Blech, Surya Prabakaran Gopinath Thangamani
Mentor(s): Kristen Labazzo, Ph.D.

Objective

Drop foot devices often cause discomfort, leading to non-compliance. [1] ComfortStride addresses this by providing a comfortable, adjustable, breathable, antimicrobial cushioning system. Our objective was to design, prototype, and test a multi-layer pad, aiming for an increased comfort rating, air permeability, bacterial reduction, and decreased compression set.

Concept design and engineering constraints

ComfortStride uses a three-layer design: antimicrobial bamboo [2], breathable muslin [3], and memory foam. This addresses comfort, included breathability, and hygiene. Specifications efficacy, comfort, breathability, antimicrobial limited and durability. Constraints include a integration. budget, timeline, and seamless

Figure 1: Decomposition Diagram of ComfortStride Design

A decomposition diagram illustrating the design elements is shown in Figure 1.

Prototype development

Methods

Methods included material selection, prototype fabrication, user testing, adjustability efficacy, and standardized tests for comfort, breathability, antimicrobial efficacy, durability, and adhesion.

Results

User testing yielded a high comfort rating of 4.75/5 (Figure 2). Air permeability exceeded 200 $L/m^2/s$ for all materials, achieved a demonstrating excellent breathability. The prototype durability 99.99% reduction in bacterial growth, indicating strong antimicrobial efficacy. While adhesion was strong, testing revealed some further improvement.

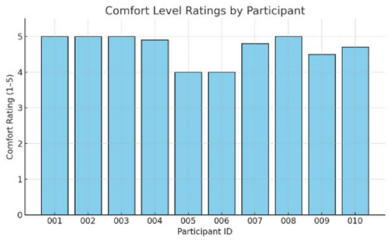


Figure 2: User Comfort Ratings for ComfortStride

Conclusion

ComfortStride successfully provides a comfortable, breathable, adjustable and antimicrobial cushioning system. Future work will focus on improving durability and optimizing for mass production.

ParaSwing

Team Members: Ryan Kim, Adrienne Lota, Smriti Mumudi, Farah Nisar
Mentor: Noshir Langrana, Ph.D

Objective

Tetraplegia, or quadriplegia, is one of the most common outcomes of spinal cord injuries(SCIs). In America alone, more than half of the estimated 291,000 individuals who live with SCIs experience incomplete or complete tetraplegia.[1] A significant number of SCIs are caused by sports injuries[18], and those affected lose the ability to partake in the activities they once enjoyed. Thus, we need to increase accessibility to hobbies and sports for quadriplegic individuals to improve quality of life. Our focus is to make one of such activities, golf, more accessible.

Quantitative metrics of our success include the success rate of hitting a golf ball with our device and the consistency of the output user-defined velocity. While there are golf robots and swingless golf clubs on the market that complete swings with minimized effort from the user, these are not fully accessible to quadriplegic individuals. Our solution will integrate digital and software elements to better adapt golf to their needs.

Concept design and engineering constraints

We designed a wheelchair-mounted apparatus that would swing a golf club controlled through an accessible mobile app. Overall, there are three prototypes that we developed: the device, the electronics, and the application. The device uses a motorized gripper that pulls back a club into a spring-loaded piston for variable power. An Arudino circuit controls the gripper's motion, and a bluetooth and camera module for ball alignment were also implemented. The app was also designed to include features such as camera feed access, swing power settings, and an AI chatbot for extra assistance. While some electrical parts, such as our motor, were limited by cost and the fact that the device had to be mobile, we iteratively redesigned our device and circuit to combine what we had and what needs had to be met.

Prototype development

Methods

Due to motor constraints, we experimented with various motors and iteratively redesigned our device according to each DC motor. We also experimented with different voltage and current settings for optimization of the motor performance. Once we found the most optimal motor we had available, we finalized our device design and circuitry according to that motor and tested various rotational speeds to explore the power limits of the device.

Results

With our finalized device, we found that it consistently hits a golf ball with a motion similar to putting. The electronics also run with minimal incidents of current issues which persisted with previous motors. Additionally, the app's camera feed and features run with minimal bugs and respond to the Arduino in a consistent manner. In any given run of the device, the three prototypes work interact smoothly to deliver a swing.

Conclusion

Overall, our device is able to deliver a golf swing consistently with optimized performance from our app and electronics. While we aimed to have more power in the swings, we constructed a solid foundation for light to medium swings. In the future, we would like to collect more data on the device's performance and optimize it further.

---

[18] National Spinal Cord Injury Statistical Center, Facts and Figures at a Glance. Birmingham, AL: University of Alabama at Birmingham, 2019.

STEP UP: Sensor Tracking & Evaluation Platform for User Prosthetics

Team Members: Anisha Jackson, Bhakti Ramani, Parbeen Swaich, Ruchi Vora
Mentor(s): Jason Maikos, Ph.D., John Chomack, M.S., David Herlihy

Objective

The gold standard Optical Motion Capture (OMC) system used to assess gait and provide personalized prosthesis fitting for veterans with lower limb loss requires a lab setting, limiting application in community ambulation. We aim to enable veterans with lower limb prostheses to achieve better mobility by developing a device that is portable up to 30 feet, costs less than $100 and measures gait parameters during real world ambulation to within 5% of OMC, while achieving a 5/5 usability score. Unlike costly and/or lab based devices on the market, like Reev Sense, RunScribe and Kinesis Gait, our device provides accessible and real-world gait analysis.[19]

Concept design and engineering constraints

STEP UP is a wearable device designed to measure knee angles using Inertial Measurement Units (IMU) sensors and an Arduino microprocessor (Figure 1A). It is affordable, costing $40, portable up to 35 feet, and accurate, with ~5% error compared to OMC.

Prototype development

Methods

STEP UP was validated against the gold standard, OMC. The subject performed stand-to-sit (SS) and walking tests while wearing STEP UP and the 46 markers of OMC. Motion data was sampled via an Arduino and IMU, converted to knee angles using trigonometry, and filtered with a low pass Butterworth filter to reduce noise. Measurements were taken in the sagittal plane to maximize accuracy.

Results

STEP UP produced percent gait cycle graphs showing motions like heel strike and toe off, aiding gait assessment. Stand-to-sit (SS) graphs (Figure 1B) closely matched OMC, with knee angles from ~10° to ~100°, with an average error of 5.46%. Gait cycle trends (Figure 1C) resembled OMC, with some peak variation due to STEP UP's lower sampling rate. These results demonstrate STEP UP's potential for real-world, low-cost gait monitoring outside the lab.

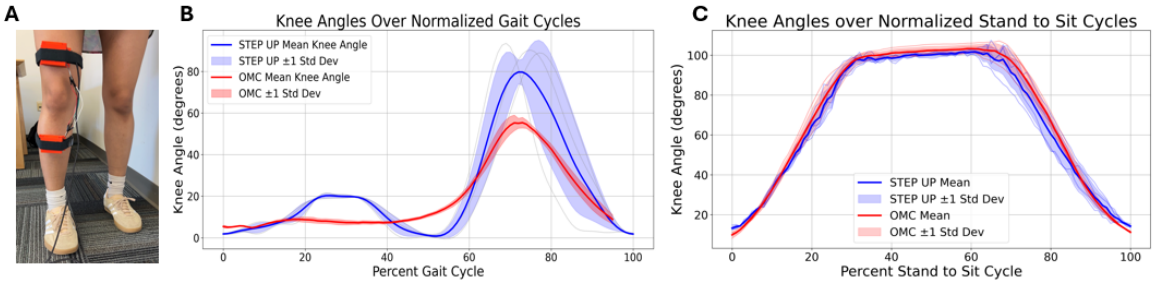


Figure 1: Comprehensive Prototype (A), Motion Test Data (B), SS Data (C)

Conclusion

STEP UP captured accurate knee angle with low error (5.46%) during SS tests, validated against OMC. STEP UP is a cost-effective ($40), portable (35 ft) solution for real-world gait analysis. Future work includes customizing STEP UP to measure gait parameters at other joints and developing a mobile app for enhanced data visualization.

---

[19] Hulleck, A. A., Menoth Mohan, D., Abdallah, N., El Rich, M., & Khalaf, K. (2022). Present and future of gait assessment in clinical practice: Towards the application of novel trends and technologies. Frontiers in medical technology, 4, 901331. https://doi.org/10.3389/fmedt.2022.901331

AnkleIQ

Team Members: Laura Agolli, Veronica Antonov, Antonio Coelho
Mentor(s): Mark Pierce, Ph.D.

Objective

Ankle injuries impact nearly 2 million people annually in the U.S., with up to 40% being sports related. Poor rehabilitation monitoring often leads to chronic issues. To address this, our team developed the AnkleIQ, a multi-functional smart ankle brace providing real-time recovery and injury monitory data through integrated sensors that measure key rehabilitation metrics. Success of the device relies on achieving less than 10% error in inversion-eversion detection, accurate visualization of weight bearing area, and cardiovascular monitoring aligned with gold standard devices.

The main competitor, the DynoBrace1, uses MEMS technology to provide adaptive stability control, however, lacks real time, objective data, limiting patient and clinician insight into ankle recovery.

Concept design and engineering constraints

The AnkleIQ is designed to be worn during physical therapy and light exercise. Data is collected through dual IMUs to track inversion and eversion angles, weight distribution across 3 force-sensitive resistors (FSRs) in the sole of the shoe, and a PPG for heart rate and blood oxygen saturation. Wi-Fi connection to an app allows for visualization of recovery metrics. Despite budget and hardware limitations, the AnkleIQ meets key customer needs for an optimized recovery,

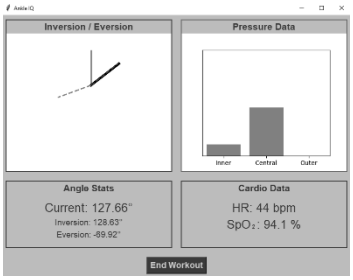
combining multiple rehabilitation tools into a wearable solution.

Prototype development

Methods

The purpose of our work has been to develop and test a smart ankle brace capable of integrating sensors to monitor key rehabilitation metrics in real time. Our approach consisted of analyzing off-the-shelf sensors to determine which provided the most reliable data, followed by optimizing their functionality. Experimental methods included configuring dual IMUs, assembling an FSR array, and validating a PPG sensor. We conducted tests comparing sensor outputs to gold-standard tools to validate success.

Results



Our results validated the effectiveness of the AnkleIQ in tracking rehabilitation data with reliable accuracy. IMU inversion-eversion sensing falls within 10 percent. FSR weight distribution in the inner, outer, and central foot regions is displayed on a dynamic bar graph. The PPG provides HR and SpO2 readings relatively matching those of a gold standard pulse oximeter. These results confirm the device's ability to

deliver accurate, real-time insights that supports patient recovery and decision making.

Conclusion

Through AnkleIQ, we have introduced a new approach to improving patient care through personalized rehabilitation plans and preventing injuries. Future work includes implementing inversion-eversion warnings, expanding motion monitoring capabilities, and integrating a swelling detection cuff.

1 K. A. Norbaka, A. M. Rishmany, J. J. O'Hara, P. V. Filippone, C. -H. Yu and A. Kiapour, "DynoBrace: Stability Control of Ankle Joint Using a Mobile App Controlled Smart Brace Device," 2018 IEEE MIT Undergraduate Research Technology Conference (URTC), Cambridge, MA, USA, 2018, pp. 1-4, doi: 10.1109/URTC45901.2018.9244784. keywords: {wearable;MEMS;ankle;adaptive}