Exercise Band Monitoring

Qarch Hawk, Maddie Manning, Matthew Salvino, Agoston Walter

BME 462L - Design for the Developing World

November 5, 2019

I. Abstract

A number of patients in the rural town of Welch and Williamson suffer from an array of physical ailments. These communities rely heavily on the coal mining industry and suffer from local economic hardship. Residents in these areas present with symptoms of congestive heart failure, diabetes, hypertension, and even chronic obstructive pulmonary disorder (COPD). Moderate exercise is recommended for these patients from healthcare professionals, focusing on strength and resistance training exercises. For many of the patients with congestive heart failure, a specific exercise plan using resistance bands with 30 minutes per day is developed.

Previous groups were tasked with creating a device to accomplish the goals of detecting the frequency of stretches and the number of exercise sessions in order to provide data to improve compliance. The device is tailored specifically for exercise bands as the majority of exercises for the patients are executed using resistance bands. The prior teams developed a board with a processor and microswitch that can register stretches and can store this data on the pyboard's internal memory. In addition, the past teams designed a board that fits the shape of the band and implemented small batteries to power the device. However, the device frequently slips down the band when used during exercise, there are problems related to powering the board and time stamping the data, and the data cannot be downloaded and stored in a readable fashion.

Based on these current problems, the goal of this current project has four aspects. The first goal is to reduce slippage of the device on the band. In order to accomplish this goal, the device will be converted into a handle and attached to one end of the band rather than the middle. The second goal is to improve the power management of the board. This will be achieved through implementing a standby system to place the device in a low power mode when not in use. The third goal is to implement a real time clock of the device in order to timestamp the data. This will be performed by updating the code and therefore the functionality of the microprocessor. The last goal is to introduce a method of downloading and storing the exercise data so that it can be accessed by community health workers. This will be executed with a microUSB connection and the implementation of CSV files.

The expected results of the modifications to this device are as follows. The device will no longer slip on the band during a regular session of exercise. In addition, the device should be able to be powered for a week without having to replace the battery. This will allow for the community health worker to replace the battery during visits and eliminate intervention by the patient. Moreover, the device should be able to accurately timestamp the exercise sessions to the nearest minute. Finally, the exercise report should be accessible and operational by the majority of community health workers.

Table of Contents

II. Clinical Need

Historically, the Central Appalachia region of the United States has been plagued with abnormally high levels of chronic diseases and are overwhelmingly underserved. The Appalachian Regional Commission (ARC) is the longest standing organization federally assigned to alleviate these disparities. Despite these conditions being acknowledged dating back to the 1980's, thorough research on the health and wellbeing of these communities has only been conducted over the last ten years [1].

This project focuses on two coal-based communities, Welch and Williamson, in rural West Virginia. Welch is located in McDowell County, which has a reported median income of $25,595 with 31.7% of residents living in poverty [2]. Williamson is located in Mingo County, which has a reported median income of $31,27 with 31.0% of residents living in poverty [3]. These numbers fall below the reported median income of $57,652 and above the reported 11.8% of people living below the poverty line across the country [4]. These census results highlight the discrepancy in living conditions between rural, coal towns and the rest of the United States.

These communities, like other towns in Appalachia, are riddled with health issues, such as congestive heart failure (CHF), diabetes, obesity, and chronic obstructive pulmonary disease (COPD), as a result of the dominance of the coal mining industry. As far as treatment, the American College of Sports Medicine and physicians recommend daily sessions of mild strength training as a way to mediate these conditions [5]. A 2014 study showed significant improvement in symptoms from low-resistance, high repetition elastic band exercises over 8 weeks [6].

Despite physician direction to complete 20-30 minutes of daily resistance band training, most patients diagnosed with CHF, diabetes, obesity, COPD, or some combination of the four neglect to do their exercise. Community health workers visit patients in home weekly, but are unable to monitor the true degree to which they are complying with doctor's orders. Currently, the exercise bands provided to patients are unable to record the frequency at which exercises sessions are completed nor the number of exercises done per session.

The lack of nearby medical facilities, low number of healthcare workers in these communities, and geographic sprawl of population, make assigning a daily, in-person monitor to each patient unrealistic. In order to monitor patient compliance, a device to measure and store exercise data from each session would be sufficient. Due to the daily nature and amount of prescribed exercise, the device must be able to register each motion, record length of exercise session, store data in an accessible form, and retain battery for a specified amount of time.

Previous iterations of this device have not been distributed to patients. The earlier generations of this project evolved into a switch and microprocessor on a plastic board. However, these designs were unable to be implemented due to issues with device placement stability- meaning the device slipped down the elastic band during prescribed exercises, power management- meaning the device could potentially die prematurely and fail to record data, lack of real-time clock function- meaning there is no time related information in the data, and no program to download the stored data to allow health workers to verify compliance. To remedy these issues and prepare the device for distribution, this iteration of the device will be designed to stay in place on the band through all exercises, record time information, maintain battery level, and store data in an accessible file format. It is intended that these adaptations will enable the device to be used to improve records of compliance in Welch and Williamson.

III. Specifications

Specification	Minimum	Typical	Maximum
Ease of Use: attaching the device to the exercise band	After 10 non-engineering Duke students are trained for one minute, the students can attach the device to the band, on average, in less than two minutes	After 10 non-engineering Duke students are trained for one minute, the students can attach the device to the band, on average, in less than one minute	After 10 non-engineering Duke students are trained for one minute, the students can attach the device to the band, on average, in less than 30 seconds
Ease of Use: downloading data	After five minutes of training, 10 Duke students are able to download stretch data from one training session with the device, on average, in less than three minutes	After five minutes of training, 10 Duke students are able to download stretch data from one training session with the device, on average, in less than two minutes	After five minutes of training, 10 Duke students are able to download stretch data from one training session with the device, on average, in less than one minute
Durability	The body of the device does not crack or break after being dropped 10 times on a vinyl surface from four feet in the air	The body of the device does not crack or break after being dropped 20 times on a vinyl surface from four feet in the air	The body of the device does not crack or break after being dropped 30 times on a vinyl surface from four feet in the air
Durability	The device is able to meet all possible performance specs after 100 stretches are performed	The device is able to meet all possible performance spec after 200 stretches are performed	The device is able to meet all possible performance spec after 400 stretches are performed
Weight	The device, without being attached to the exercise band, does not exceed a weight of one pound.	The device, without being attached to the exercise band, does not exceed a weight of eight ounces.	The device, without being attached to the exercise band, does not exceed a weight of four ounces.
Accuracy: time stamping	Time stamps of stretch data including year, month, and day fall on the actual day 90% of the time	Time stamps of stretch data including year, month, day, and minute fall within 30 minutes of the actual minute of recording 90% of the time	Time stamps of stretch data including year, month, day, minute, and second fall with 30 seconds of the actual second of recording 90% of the time

Accuracy	Out of 120 stretches performed, 70% of the stretches performed are detected	Out of 120 stretches performed, 80% of the stretches performed are detected	Out of 120 stretches performed, 95% of the stretches performed are detected
Reliability: time stamping	After 50 stretches are performed, 70% of the stretches are accurately time stamped (based on time stamping specification)	After 50 stretches are performed, 80% of the stretches are accurately time stamped (based on time stamping specification)	After 50 stretches are performed, 95% of the stretches are accurately time stamped (based on time stamping specification)
Reliability: downloading data	After downloading 25 stretch data files, 70% of the files are not corrupted and are able to be opened	After downloading 25 stretch data files, 80% of the files are not corrupted and are able to be opened	After downloading 25 stretch data files, 95% of the files are not corrupted and are able to be opened
Maintenance	The device meets all specifications with need for battery replacement no less than every 14 days	The device meets all specifications with need for battery replacement no less than every 28 days	The device meets all specifications with need for battery replacement no less than every 42 days
Storage Space / Acceptance	Seven out of ten stretch data files are stored as a CSV file from the device and is able to be read from a laptop or iPad 70% of the time	Eight out of ten stretch data files are stored as a CSV file from the device and is able to be read from a laptop or iPad 80% of the time	Nine out of ten stretch data files are stored as a CSV file from the device and is able to be read from a laptop or iPad 95% of the time
Budget	Each device costs less than $100 to produce	Each device costs less than $200 to produce	Each device costs less than $300 to produces
Power Management	After more than 30 minutes but less than an hour of not being used, the device turns off and stops using the battery	After more than 20 minutes but less than 30 minutes of not being used, the device turns off and stops using the battery	After more than 10 minutes but less than 20 minutes of not being used, the device turns off and stops using the battery
Public Acceptance	After being used by 10 Duke students, the product received an average score of 2.5 out of 5, with 1 being	After being used by 10 Duke students, the product received an average score of 3.5 out of 5, with 1	After being used by 10 Duke students, the product received an average score of 4.5 out of 5, with 1

	the device’s presence made their exercise experience frustrating and unbearable, and 5 being there was no noticeable difference in their exercise with the device present	being the device’s presence made their exercise experience frustrating and unbearable, and 5 being there was no noticeable difference in their exercise with the device present	being the device’s presence made their exercise experience frustrating and unbearable, and 5 being there was no noticeable difference in their exercise with the device present

IV. Design Descriptions

Three Designs Built:

Design Option One

This proposed design alteration focuses on the method of device attachment to the band. This design maintains all components from the previous iteration with the addition of a clip or two clips that hold the band to the device board, as shown below. The method for using the band will be unaffected and the user will only need to interact with the device when switching between exercise bands.

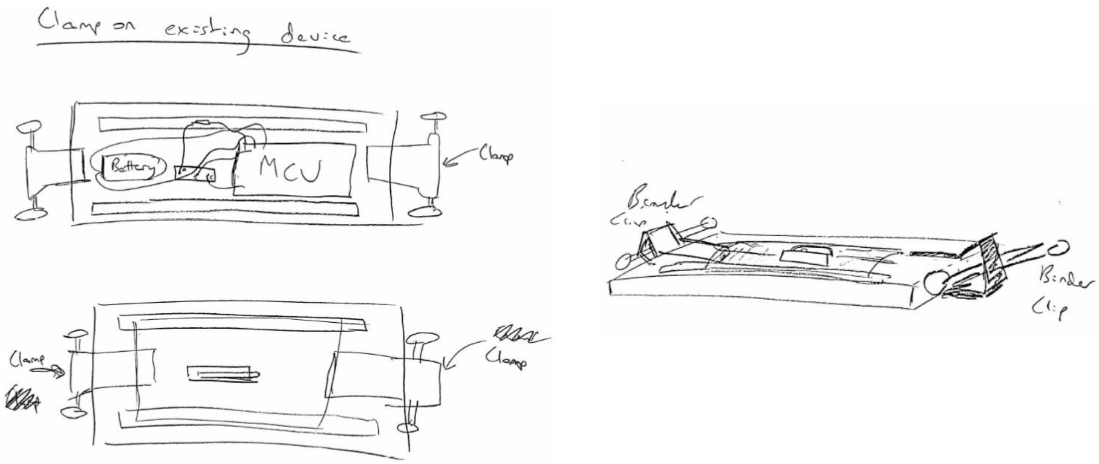


Figure 1: Drawn Design change utilizing clips from top, bottom, and angled view

Design Option Two

This proposed design change focuses on device attachment to the band. This design alters the device location on the band; the previous design could be put on any part of the band, while this design has the device function as a handle to be placed at one end of the band. The method for using the band is slightly altered, as now the patient will grip the band in one hand and the handle in the other - instead of both hands on the band itself.

Figure 2: Sketched design change utilizing attached handle and clamp, from top, side, and angled view

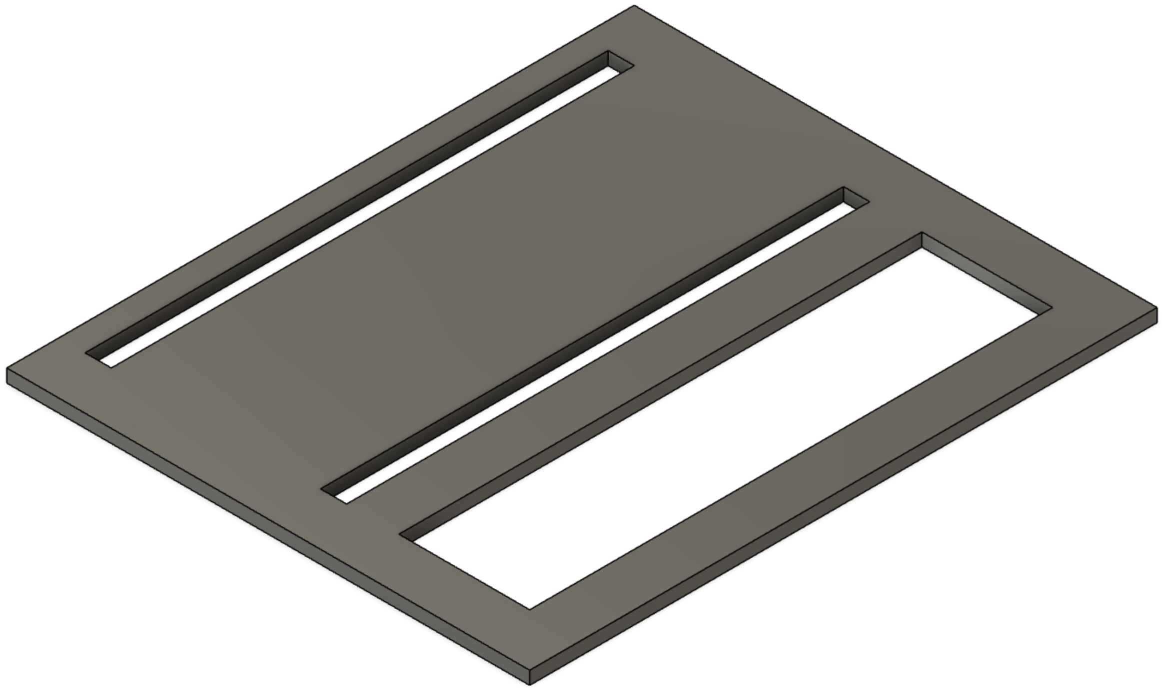


Figure 3: CAD model of design change, from angled view

Design Option Three

This proposed design changes the device attachment to the band. Instead of an addition to the device board, this design proposes increasing the number of slats the exercise band goes through on the board. The method for use is unchanged, as the user will still hold exclusively the band in either hand. However, switching the band that the device is on will require more effort as there is an additional slit on either side.

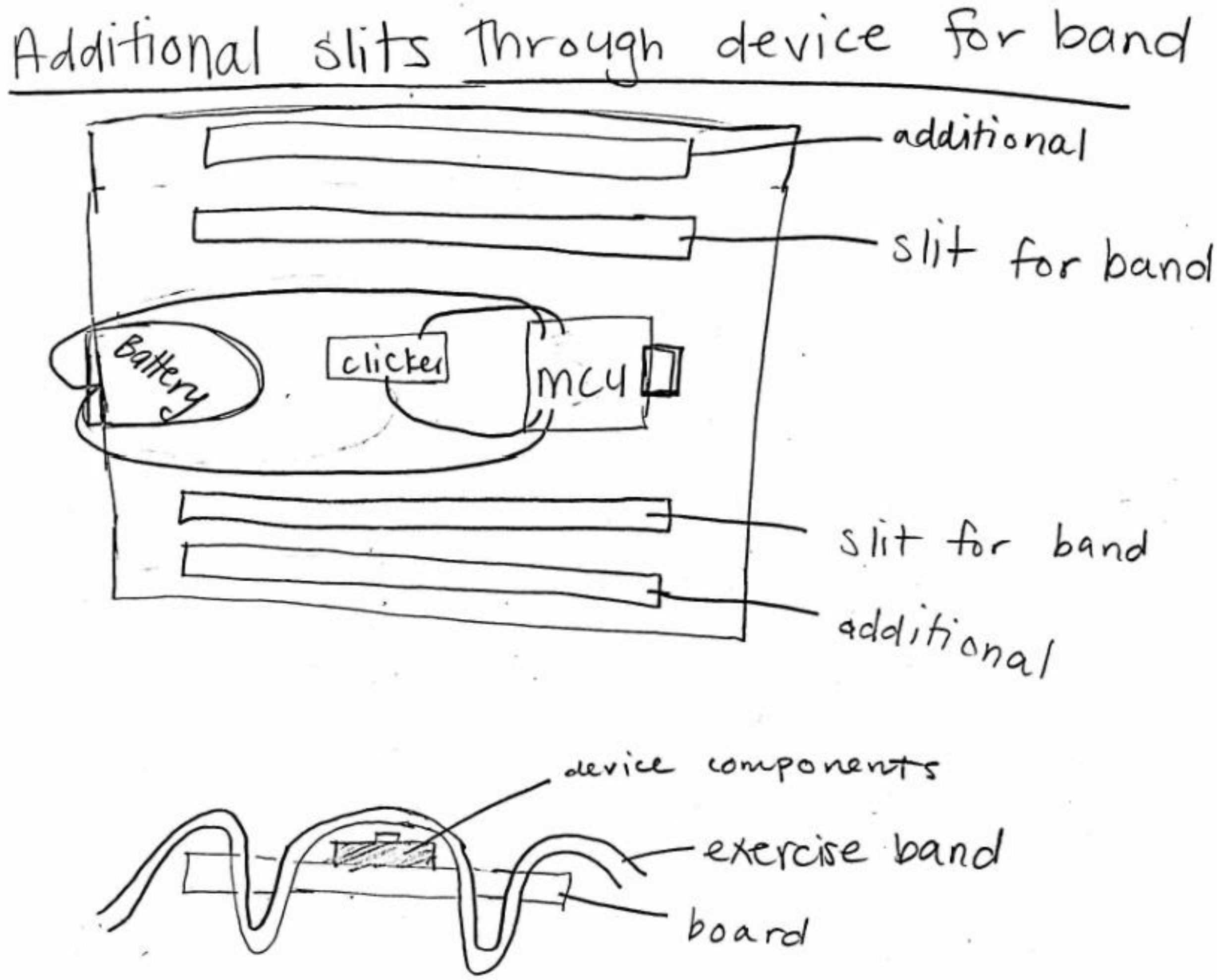


Figure 4: Design change with additional slits from top and side view

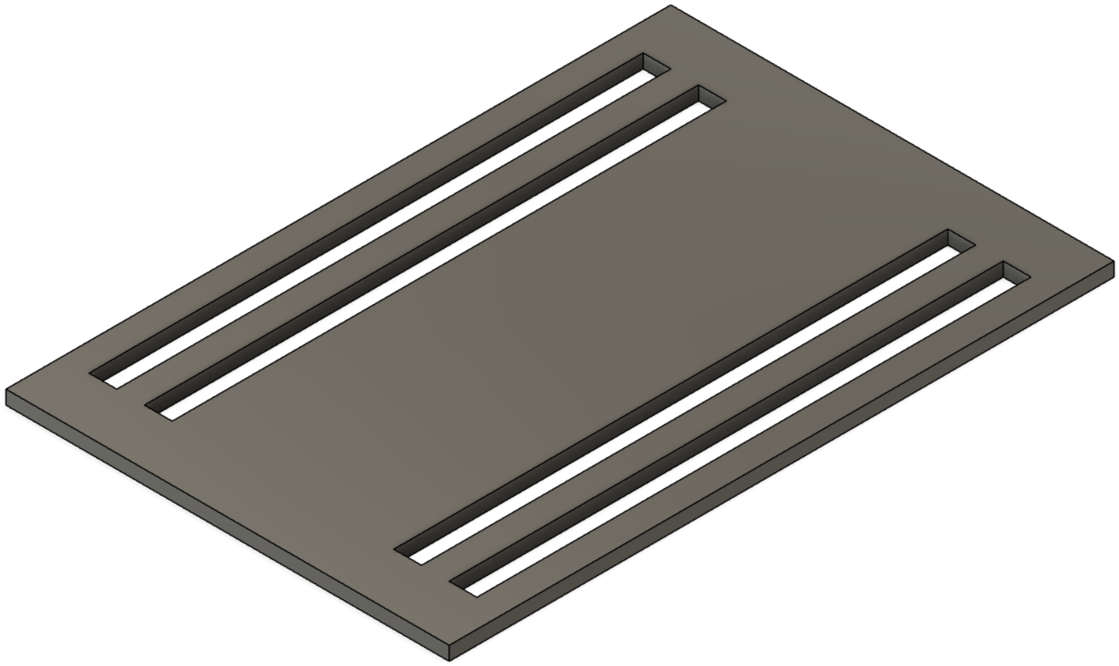


Figure 5: CAD model of design, from angled view

Design Choice:
From the accuracy testing, the double slit design was eliminated because it registered zero stretches. Both the handle and the clamp designs performed the same, so we conducted additional testing to inform our decision.

Our group chose to move forward with the handle design over the clamp design for three reasons. One, the handle had no damage from the drop tests done for the durability testing, but the clip design was chipped starting from the first trial. Two, the handle gives our team more room to play with in arranging the components. Since the user is holding the handle, the device can have a higher weight than a device that rests in the middle of the band such as the other two proposed design solutions. Two, the handle design is a more enjoyable experience. Based on the team's and ten Duke student's experiences while testing, it was uncomfortable how the clip and slit designs rotated and moved around and rotated on the band while the exercise was being performed. The swinging of the device interfered with the exercise and was a potential safety hazard for the user. For example, during testing it hit the user's face and torso several times. The ten users grading the designs gave the clip design an average score of 3.2, while the handle design received an average score of 4.0. For these three reasons, we decided the handle was the superior design.

V. Testing Methods

We needed to address four problems to finish the monitoring device for exercise bands.

First, the device previously slipped down the band when it was being used, especially when used vertically, such as for a bicep curl. This was inconvenient for the user because it prevented them from completing the exercise, and the device no longer registered stretches when it had slipped all the way down the band.

Second, there is no time stamp attached to the data when it is recorded. The health workers need the device to know if their patients are complying with their prescribed exercise routines. A time stamp attached to each data recording will inform the health worker of when their patient performed the exercises.

Third, there is no power management for the system. The current iteration device is powered by two CR2032 batteries, which provide enough power for thirty hours of use of the device. Our goal is to turn the microprocessor off or switch it to low power mode when the user has forgotten to turn the device off, so that the battery's charge will not run out.

Fourth, there is no method to extract the stored data on the pyboard. The visiting health worker needs to be able to view the saved patient exercise data. Our goal is to write a program to extract the saved exercise data to a .csv file using a microUSB connection to the device.

At this point in the design process, we have tackled and completed testing on the first problem- as well as other concerns that developed over the design process. We have tested the three initial designs, described previously, against five of the specifications defined in Section III and selected one design to pursue for the rest of the course.

To test the first specification of durability, we dropped the device from four feet in the air above a vinyl floor in increments of ten drops. After each set of drops, we inspected the body of the device for cracks or breakage. To decide which design to pursue for the rest of the course, we planned to compare how each of the design casings performed against the standards - as in which level the design passed out of the minimum, typical, or maximums defined in Section III.

To test the second specification of durability, we performed over four hundred fly stretches with the devices, with each member of the team completing one hundred. After each set of one hundred, we checked the device to ensure it was still registering stretches with minimum accuracy outlined in the second accuracy specification. To decide which design to pursue for the rest of the course, we planned to compare each of the resulting accuracies against the specification - as in which level the design passed out of the minimum, typical, or maximum values defined in Section III.

To test the specification of weight, we put each device, without the band, on a food scale and measured their masses in pounds. At this point in the process, we were only able to measure the mass of the device casings - as the board is not finalized. This aspect does not affect our decision making, as the board will be the same weight regardless of which casing is chosen. To decide which design to pursue for the rest of the course, we planned to go with the design that passed the highest level of weight specification defined in Section III - though would default to other factors if multiple designs reach the same level.

To test the second accuracy specification, of stretch detection, each device was used while band was stretched 120 times, divided up into 30 stretches per person for 4 different users. Each user performed 15 fly motions and 15 bicep curls using the device with the band. We measured how many stretches were detected and counted how many stretches were actually completed. To decide which design to pursue for the rest of the course, we planned to go with the design that achieved the highest percent of stretches recorded out of completed.

To test the public acceptance specification, we had ten random Duke students to perform two regiments of exercise with the band with and without the device (5 stretch sessions), and then rank experience on a scale of 1-5. 1 was defined as “the device’s presence made the exercise experience frustrating and unbearable” and 5 defined as “there was no noticeable difference in their exercise with the band present.” To decide which design to pursue for the rest of the course, we planned to select based on the average score received, and compare the averages for eac design with the scores listed in Section III.

VI. Testing Results

Durability Testing: Drop Testing

Results from three sets of ten drops from 4 feet above a vinyl floor; inspection of casing after each set. Pass is defined as no cracks, chips or break damage; fail is defined as acquisition of any type of the previously mentioned damage.

	Clips	**Handle**	**Double Slit**
Set 1	Pass	Pass	Pass
Set 2	Pass	Pass	Pass
Set 3	Fail	Pass	Pass
Specification Met	**Typical**	**Maximum**	**Maximum**

Durability Testing: Stretch Registering

Results from testing if stretches are registered after 100, 200, and 400 stretches. Pass is defined as if the device registers stretches to the minimum level defined in accuracy specification - as 70% of 120; fail is defined as recording less than 70% of 120 stretches.

	Clips	**Handle**	**Double Slit**
After 100	120/120	120/120	0/120
After 200	120/120	120/120	0/120
After 400	120/120	120/120	0/120
Results	**Pass**	**Pass**	**Fail**

Weight Testing

The weight of the casing, from food scale, is less than the values specified for each level of specification.

	Clips	**Handle**	**Double Slit**
Weight	1.2 oz	1.3 oz	1.5 oz
Specification Met	**Maximum**	**Maximum**	**Maximum**

Accuracy Testing: Stretch Registering

Results of stretch registering for each design with all four members of the team performing 15 fly and curl stretches using each of the designs; registering defined as a click from microswitch.

	Clips		Handle		Double Slit	
Stretch Type	Fly	Curl	Fly	Curl	Fly	Curl
Group Member 1	15/15	15/15	15/15	15/15	0/15	0/15
Group Member 2	15/15	15/15	15/15	15/15	0/15	0/15
Group Member 3	15/15	15/15	15/15	15/15	0/15	0/15
Group Member 4	15/15	15/15	15/15	15/15	0/15	0/15
Total Results	120/120		120/120		0/120	
Specification Met	**Maximum**		**Maximum**		**None**	

Public Acceptance Testing: Feedback after use
Results from ten Duke students rating their experience using the band with device casing compared to using the band without device present. 1: "presence made the exercise experience frustrating and unbearable" through 5: "there was no noticeable difference."

	Clips	**Handle**	**Double Slit**
Subject 1	5	4	1
Subject 2	3	4	3
Subject 3	4	3	2
Subject 4	3	4	1
Subject 5	3	4	2
Subject 6	4	3	3
Subject 7	3	5	3
Subject 8	2	5	3
Subject 9	2	3	4
Subject 10	3	5	1
Average Score	**3.2**	**4.0**	**2.3**
Specification Met	**Minimum**	**Typical**	**None**

After our testing, we've decided that the handle design is the best to pursue for the rest of the course. The results of the durability drop testing, with Clips design passing typical specification and the other two designs passing maximum specification, led us to have a preference for the Handle and Double Slit designs. The results of the durability stretch registration testing, with the Double Slit design failing and the other two designs passing, led us to have a preference for the Clips and Handle designs. The weight testing, with all three designs achieving the maximum specification, did not cause us to favor any designs over the others. The results of the accuracy testing, with the Double Slit failing to reach any specification and the other two reaching maximum, led us to favor the Clips and Handle designs. The results of the public acceptance testing, with Clips reaching minimum specification, Handle reaching typical specification and Double Slit reaching no specification, led us to favor the handle design. Overall, the optimal design, meaning passed the testing with the best specification levels reached and tests passed, is the handle design.

VII. Applicable Standards Analysis

The standard which we will be following for our project is ISO20957-2: Stationary Training Equipment - Strength training equipment, additional specific safety requirements and test methods.

Substandard	**Inclusion**
Intrinsic Loading: Each piece of the device can be loaded with the user's body mass and withstand its forces	This substandard will be considered for our design as our design must be able to withstand any application of the user's body weight onto the device and still function properly.
Extrinsic Loading: When loaded with the user's body mass and/or reaction forces or moments of the user, each piece of equipment should withstand the load without breaking	This substandard will be considered in the design of our device as the user is intended to apply generated forces to the exercise band which will in turn apply forces to the monitoring device. Therefore, the device must be able to load and unload these forces and still function in a way that meets all specifications.
Endurance Load: When tested under a vertical force of 2-2.5 times the maximum specified load, the device should be capable of normal functioning	This substandard is not being considered as the majority of the forces applied will be applied to the exercise band which is dependent upon the needs of each individual patient. Therefore, as the resistance of the band changes, the maximum specified load will also change so a vertical force would only need to be supported by the band rather than the monitoring device.
Access to Squeeze and/or Shear Points: The uncontrolled access by a third party to a squeeze and/or shear point on the device should be prevented	This substandard is not being considered as any of the squeeze and/or shear points located on the device to not generate enough force or squeeze tight enough to harm an individual.
Weight Discs: The maximum load ability of each weight support should be indicated on the device	This substandard is not being considered as different bands and band strengths may be prescribed to a patient using the device based on that individual patient's needs. Therefore, the band may change and the weight or force need to stretch the band would change as well.
Minimum Achievable Training Loads: The device should meet certain torque values depending upon the various biomechanical	This substandard is not being considered, since the patients who will be performing exercises with this device have very severe

functions which are performed	health conditions, the force and torque values generated on the device will be extremely low and there will not be a large variety of biomechanical functions performed.

References

[1] Meacham, S., Sukpraprut, S., Taber, T., & Metzger, D. (2012). Publications on Chronic Disease in Coal Dependent Communities in Central Appalachia . *Journal of Health Disparities Research and Practice*, *5*(3), 62–79.

[2] US Census Bureau. (n.d.). United States Census Bureau. Retrieved from https://www.census.gov/quickfacts/fact/table/mcdowellcountywestvirginia/IPE120218#IPE120218

[3] US Census Bureau. (n.d.). United States Census Bureau. Retrieved from https://www.census.gov/quickfacts/fact/table/mingocountywestvirginia/LFE305217

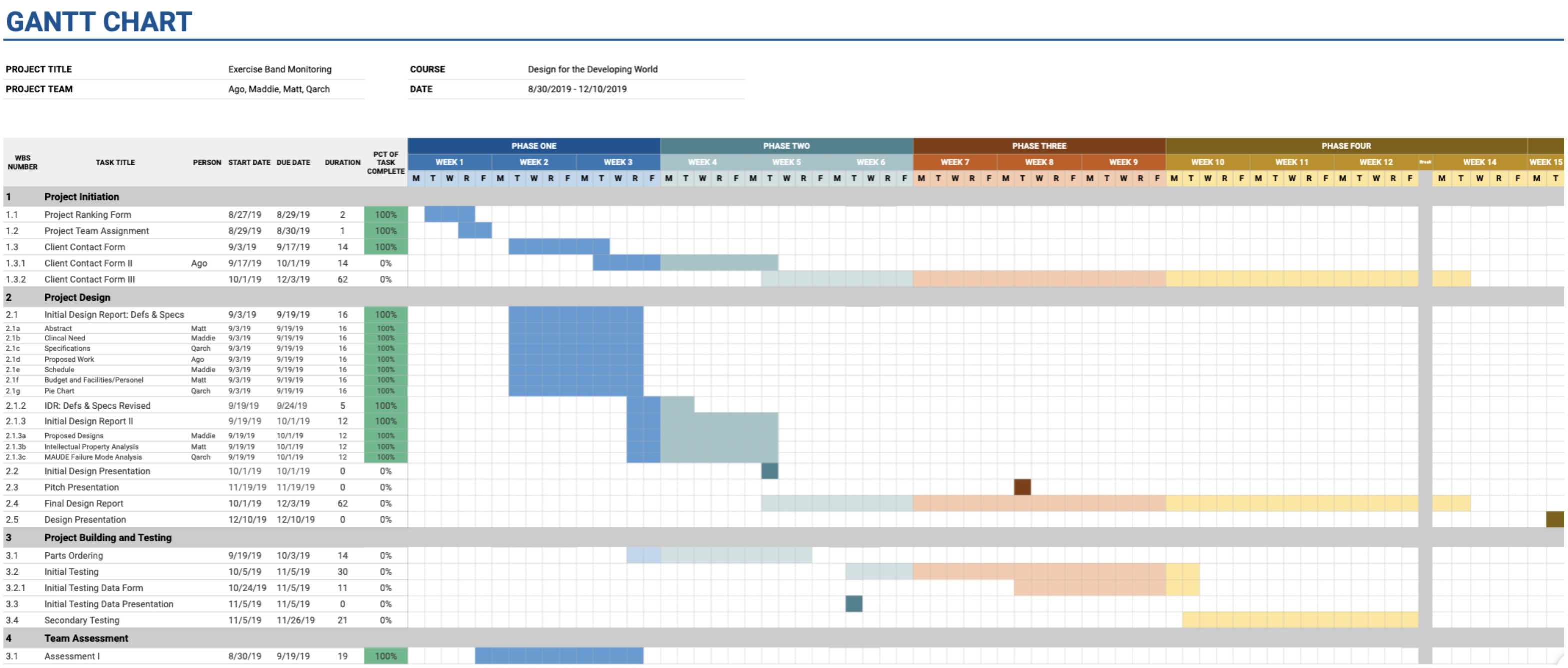
[4] US Census Bureau. (n.d.). United States Census Bureau. Retrieved from https://www.census.gov/quickfacts/fact/table/US/PST045218

[5] Dressendorfer, R. H., Haykowsky, M. J., & Eves, N. undefined. (n.d.). *American College of Sports Medicine*, PDF. Indianapolis, IN.

[6] Nyberg, A., Lindström, B., Rickenlund, A., & Wadell, K. (2014). Low-load/high-repetition elastic band resistance training in patients with COPD: a randomized, controlled, multicenter trial. *The Clinical Respiratory Journal*, *9*(3), 278–288. doi: 10.1111/crj.12141

Appendices

i. Schedule



The lightest color in each phase represents planned tasks, the medium color represents completed tasks, and the darkest color represents presentations. Sequential tasks are represented by overlapping end and start dates. The gray bar for Week 13 labeled “BREAK” represents the week off for Thanksgiving.

ii. Budget

Prototyping Budget

Category	Component	Manufacturer	Unit Price	Total Cost (3 Prototypes)
Salaries	--	--	--	--
Equipment/Supplies	Computer	--	--	--
	Exercise Band	TheraBand	$10.51	$10.51
	3D Printer	--	--	--
	LED/Resistors/ Wires	--	--	--

	Pyboard v1.1	MicroPython	$34.97	$104.91
	MicroSwitch	Omran Electronics	$1.35	$4.05
	Battery Pack (Rechargeable)	Adafruit	$14.95	$44.85
Machining Facilities	--	--	--	--
Consultants	--	--	--	--
Operations	--	--	--	--
Travel to Welch/Williamson	Car Ride	--	$2.50/gallon	$50
	Hotel (1 night)	--	$65/night	$65
	Food		$30	$30
TOTAL				**$309.32**

Budget for 500 Devices

Category	Component	Manufacturer	Unit Price	Total Cost
Manufacturing	--	Group	--	--
Equipment/Supplies	LED/Resistors/ Wires	--	--	--
	Pyboard v1.1	MicroPython	$34.97	$17,485
	MicroSwitch	Omran Electronics	$1.35	$675
	Battery Pack (Rechargeable)	Adafruit	$14.95	$7,475
Machining Facilities	--	--	--	--
Operations	--	Group	--	--
TOTAL				**$25,635.00**

iii. Facilities and Personnel

Facilities:

Facilities needed for this project include:

- Duke Co-Lab
- Duke Student Shop
- Duke BME Student Lab

Personnel:

Personnel needed for the project include:

- Matthew Salvino, BME student
- Qarch Hawk, BME student
- Maddie Manning, BME student
- Agoston Walter, BME student
- Dr. Allan Shang, Adjunct Assistant Professor of the Duke BME Department
- Dr. Robert Malkin, Professor of the Practice in the Duke BME Department
- Matt Brown, the BME Senior Laboratory Administrator
- Steven Earp, the Manager of the Pratt Student Shop

Agoston Walter

agoston.walter@duke.edu | +1 (757) 553 4281 | linkedin.com/in/agostonw | github.com/agodoggo

OBJECTIVE

I love tackling engineering design problems using my unique background in software development, embedded circuit design, and understanding of human-machine interfaces.

EDUCATION

Duke University May 2020

BS Triple Major: Biomedical Engineering, Electrical & Computer Engineering, and Computer Science
Awards & Honors: Dean's List, 2x All-ACC Academic Team, 2x ACC Honor Roll

Georgia Tech Lorraine, Metz, France August 2018 - December 2018

EXPERIENCE

Edwards Lifesciences | Critical Care Operations Intern June 2019 – August 2019

Project 1

- Enabled GUI development and EMC/Drop testing for by approving 20 modules through a testing and calibration protocol that I revised
- Approved production of the next line of CSM Modules through a Gage R&R, a statistical analysis of the test protocol

Project 2

- Searched for discrepancies in circuit board design and presented a post-manufacturing test strategy to senior managers
- Designed the electrical test fixture, the backend, and frontend of a post-manufacturing test
- Collaborated with multiple branches of the Edwards Critical Care Team and international manufacturers based in the Netherlands, Puerto Rico, the Dominican Republic, and China

Karra Research Lab | Research Assistant January 2017 – May 2019

- Used R with Ilastik, a machine learning software, to identify regeneration markers, automating data acquisition
- Searched for biomarkers of cardiac regeneration, bringing science closer to heart disease therapies
- **Coauthor of publication**: Journal of Clinical Immunology – "The relationship between cardiac endothelium and fibroblasts: It's complicated" (Vol 127, Issue 8, p. 2892-2894)
- Constructed mouse viral vectors containing growth factors to investigate gene therapies

Boussert Research Lab | Software Engineering Intern August 2018 – December 2018

- Used Python and LabView to create a GUI used to control multiple instruments for a spectral energy experiment; resulting in improved solar cell efficiency for Georgia Tech Lorraine

PROJECTS

Heart Clearing Chamber | *Fusion360, Solidworks, 3D Printing*

- Designed and 3D printed innovative electrophoretic chambers to clear and stain mouse hearts, reducing the time needed to stain hearts from days to hours

Cardiac Function Simulator | *MATLAB*

- Modeled cardiac pressure loops using Windkessel models of increasing complexity
- User input of patient's heart rate and vascular properties allows predictions of cardiac pressures, informing the physician of the patient's health if they lack a sphygmomanometer

ECG Waveform Study | *LabView*

- Built an ECG monitoring system from scratch using leads, a biopotential amplifier, and displayed the waveform onscreen using LabView
- Using the system, conducted a study that found that a patient's gender and level of exercise affects the ECG waveform collected, justifying physicians' normalization of ECG data to accurately measure patient health

SKILLS

Coding: Python, Java, C, R, MATLAB, Assembly (MIPS), HTML/CSS
Experience with Linux, Git, Arduino Dev, LabView, Fusion360, Solidworks, Keil uVision, Minitab, 3D Printing
Languages: English, Hungarian, Spanish, French

LEADERSHIP AND INTERESTS

Division I Varsity Fencing

Awards: ACC 2018 Champions, 3rd place ACC Championship 2017, 2019 NCAA Championship finalist
Training Regimen: 15 hours / week with competition travel on weekends

Resident Assistant of 2 years managing 60+ residents acting as a liaison between university and student body

Madeline Claire Manning

EDUCATION

Duke University **Durham, NC**
Bachelor of Science in Biomedical Engineering August 2016 – May 2020
Campus Involvement: Tour Guides, Club Soccer, Society of Women Engineers, Autism Awareness

WORK EXPERIENCE

Engineering World Health **Arusha, Tanzania**
Program On-the-Ground Coordinator May 2019 – August 2019

- Provided the sole support for 20 volunteers and local technicians in rural hospitals to repair 600+ pieces of equipment and complete hospital specific initiatives with a budget of $3,000
- Crafted and instructed labs for troubleshooting and repairing over 25 types of medical equipment and the interpersonal skills necessary for working effectively in low-resource settings despite cultural and language barriers
- Orchestrated 10 hospital placements with the Ministry of Health and an intensive Swahili beginner language course with 20 homestay placements in conjunction with MS-TCDC Action Aid Denmark

Duke Engage – Engineering World Health **Moshi, Tanzania**
Volunteer Biomedical Engineering Technician June 2018 – August 2018

- Repaired 150+ pieces of hospital equipment in Marangu Lutheran Hospital as the only biomedical technician in the area
- Prepared and ran training sessions of 30+ hospital staff on preventative maintenance and common repairs of indispensable hospital equipment in the local language, Swahili, and English
- Utilized the Human Centered Design process to identify needs and renovated the Children's Ward with a budget of $200

Duke University Pratt School of Engineering **Durham, NC**
Teaching Assistant, Department of Civil and Environmental Engineering June 2018 – Present

- Collaborate with course professor to develop and grade homework sets, weekly problem solving sessions, and exams
- Design and supervise 5 engaging laboratory sessions to demonstrate mechanical properties of materials taught in class

Duke University Disability Management System **Durham, NC**
Student Assistant August 2016 – Present

- Accommodate students registered with the Disability Access Office by assisting in typing notes, papers, and projects

LEADERSHIP EXPERIENCE

Duke Line Monitors, Men's Basketball Operations **Durham, NC**
October 2017 – Present
Head Line Monitor May 2019 – Present
Head of Gameday Operations May 2018 – May 2019

- Facilitate meetings with Duke Athletics and Administration to ensure safety of 1400+ students over a 2 month period of camping out for entrance to the largest on-campus athletic event each year: the Duke-UNC game
- Lead a team of 30 students who handle all operations for 20 home basketball games and the 2 month period of camping with 130+ attendance checks at random periods throughout night and day hours
- Penned an original contract to outline expectations and performance benchmarks for members to ensure accountability, equal work distribution, and completion of essential tasks

Duke University First Year Advisory Council **Durham, NC**
Undergraduate Orientation Leader April 2018 – Present

- Facilitate conversations on topics including acclimating to college, race, gender and sexual identity, socioeconomic status, and gender violence for group of 10 first year students of different backgrounds upon arrival on campus

Duke University Student Dining Advisory Committee **Durham, NC**
Senior Board Member September 2017 – Present

- Work in conjunction with Dining Administration on all dining decisions, brought a local Latinx restaurant to campus to fill the need highlighted by student groups in 2018

PROJECTS

Laundrometer: Application proposal and design for monitoring laundry machines on campus. 1st place in semester long Startup Pitch Competition with goal to fill a need on campus, absorbed and integrated each team defeated in previous round

Low-Resource Setting Light Source: Designed and built a waterproof, buoyant lantern for a client living on the North Carolina coast in the aftermath of Hurricane Florence

Synthetic and Organic Material Testing: Developed Matlab code to process 1M+ raw data points and analyzed results to determine materials best suited to replace specific tissues in the body

Head Acceleration Testing: Developed Matlab code to process 500K+ raw, Wii-mote accelerometer data points to calculate force experienced in daily life to compare and find concrete values for diagnosing whiplash resulting from vehicle accidents

Qarch Wyatt Hawk

qarch.hawk@duke.edu

EDUCATION

Duke University — **Durham, NC**
Bachelor of Science in Biomedical Engineering — Expected May 2020
Minor: Chemistry

H.B. Plant High School — **Tampa, FL**
Valedictorian — May 2016

WORK & LEADERSHIP EXPERIENCE

Trinity Life Sciences — **Waltham, MA**
Associate Consultant Intern — June 2019 – Aug. 2019

- Profiled market landscapes for medical device and medical specialty areas utilizing primary and secondary market research
- Developed a comprehensive asset list and prepared an asset scan for strategic asset acquisition
- Performed top-down and bottom-up data analysis for a ten-year forecast culminating in presentation of a deliverable to internal company leadership

Duke University Hospital — **Durham, NC**
Researcher, Thoracic Surgery Research Group — Feb. 2018 – Jan. 2019

- Investigated outcomes of non-small cell lung cancer patients who underwent traditional pneumonectomy compared to video-assisted thoracoscopic pneumonectomy
- Utilized the National Cancer Database and Stata 13.0 software to perform statistical analysis on cancer data from over 1,500 facilities representing 70% of new cancer cases across America

Duke University Sports Information Department — **Durham, NC**
Student Assistant — Aug. 2016 – Present

- Assist in office with department compliance and athletic competition tracking
- Compute statistics for Duke sporting events and maintain official statistics for Duke Wrestling

Duke University Housing and Residence Life — **Durham, NC**
Resident Advisor — Aug. 2017 – May 2019

- Responsible for the safety, community engagement, and living circumstances of 31 residents
- Served on-call shifts for the entire residence hall of 450 students to assist in emergencies

Engineering World Health — **Kampala, Uganda**
Biomedical Engineering Technician — June 2018 – July 2018

- Repaired and serviced over 65 pieces of medical equipment for eight national hospital locations
- Created inventories of biomedical devices and prepared operating rooms, coordinating with United States and Ugandan students and professors

Duke University Hospital — **Durham, NC**
Volunteer, Intensive Care Unit — Aug. 2017 – May 2018

- Communicated with patients, patient families, nurses, doctors, and the charge nurse in the Medical Intensive Care Unit to assist, improve efficiency, and raise morale of the unit
- Accumulated over 90 hours of experience interacting with patients, nurses, and doctors

SKILLS, ACTIVITIES, & INTERESTS

Volunteering: Pinellas Park Signature Care nursing home activities center, Muscular Dystrophy Association summer camp, Metropolitan Ministries kitchen
Activities: Under the Lights youth flag football coach
Interests: Exercise & Weightlifting, Football, Tenor Saxophone, Paddle Boarding, Fantasy Sports

Matthew Salvino
matthew.salvino@duke.edu

education

2016-2020 **DUKE UNIVERSITY** **DURHAM, NC**
Bachelor of Science in Engineering in Biomedical Engineering; Minor in Chemistry.

experience

2018-Present **PRATT SCHOOL OF ENGINEERING** **DURHAM, NC**
Pratt Research Fellow
Intensive research experience under the direction of the Vice Provost of Research, Dr. Larry Carin. Applying machine learning and convolutional neural networks to ophthalmology and pathology. Includes paid summer internship component.

2018 **ACCENTURE** **MADRID, SPAIN**
Intern
Paid summer internship in Health and Public Services Management Consulting. Worked on data analytics projects for healthcare clients, both in English and in Spanish.

2018-Present **DUKE HOUSING & RESIDENCE LIFE** **DURHAM, NC**
Resident Assistant
Ensure student safety and the security of a first-year dormitory. Help first-year students integrate to campus life.

2016-2017 **DUKE MEN'S BASKETBALL** **DURHAM, NC**
Assistant to Director of Basketball Operations
Worked on social media research, content, and communications. Aided with player logistics and class, practice, travel, and community event schedules.

2014-2015 **LEVINE CANCER INSTITUTE** **CHARLOTTE, NC**
Intern
Focused on gene progression and biomarkers in Bladder Cancer Lab. Research published in 2015 and presented at the American Society of Clinical Oncology Annual Meeting.

impact

2018-Present **DUKE UNDERGRADUATE CONDUCT BOARD** **DURHAM, NC**
Elected Member
Composed of elected undergraduate students and appointed faculty members who conduct disciplinary hearings and issue sanctions in cases of Duke policy violations.

2016-Present **DUKE CATHOLIC CENTER/DUKE UNIVERSITY HOSPITAL** **DURHAM, NC**
Eucharistic Minister
Active member of Duke Catholic Center. Have responsibility during Masses as a Eucharistic Minister. Also administer Communion to patients at Duke University Hospital.

2017-2019 **DUKE HONOR COUNCIL** **DURHAM, NC**
Finance Chair
Championed the Duke Community Standard and promoted integrity in all aspects of student life at Duke. Elected for additional responsibility as the Finance Chair, overseeing a $12,500 annual budget.

2017-2018 **DUKE STUDENT CONDUCT** **DURHAM, NC**
Disciplinary Advisor
Consulted and advised students who were under investigation for a possible violation of university policy.

iv. Intellectual Property Analysis

Patent	Description
10,426,991 Exercise Device	An exercise device for performing multiple exercise movements. The device includes a track, a track carriage, and a variable resistance system so that users can exercise multiple muscle groups. The resistance system provides assistance to the user during certain exercise movements and increased difficulty during other exercise movements.
10,427,000 Exercise and rehabilitation device	The exercise and rehabilitation device of the present invention includes a telescopic tube, having a first tube with upper and lower ends, and a second tube, having upper and lower ends, telescopically received in the upper end of the first tube. The lower end of the first tube has a base plate secured thereto by a joint which may be flexible or rigid. An open hand support may be secured to the upper end of the second tube by a flexible joint. A closed hand support may be secured to the upper end of the second tube by a double-ball mounting assembly. A forearm support may be secured to the upper end of the second tube by the double-ball mounting assembly.
9,914,005 Apparatuses and methods for exercise using circular bands	An exercise apparatus is provided, the exercise apparatus including a circular elastic band and a handle attached to the band. Also provided is an exercise apparatus comprising a circular elastic band and an anchor device attached to the band. Also provided is a method of exercising the human body with a circular elastic band is provided, the method including exerting a force in one or more planes to stretch the elastic band and releasing the force exerted in one or more planes to allow the elastic band to retract. The method of claim 1, wherein the first force is exerted using an attachment, where the attachment is a handle, a carabiner, or a gripping device. The method of claim 2, wherein the attachment is a gripping device.
9,795,198 Band and slider	A wearable or stationary cognitive reminder for mechanical and electronic tracking of highly repeatable actions represented by selectable indicia on a band performed by moving a slide-able "window" frame and a bezel ring slider. Examples of use are: pill dosage counter, golf bracelet scorer, and bracelet voting device. Chosen indicia position and clock time are recorded and transmitted to non-included electronic device for further characterization or action. Non-included data receivers include cell phones, data tracking devices, or electronic games. Transferred data is available for continuous tracking, compilation, additional action, and verification of selected indicia.
10,429,822 System and method for building activity-based data collection devices	A grip interface is used to provide information about a user to a range of connected devices and applications based on the users' interactions with the grip. By embedding into the grip an array of sensors for motion, health, environmental and other data using embedded microcontroller network technology, and focusing on the grip as the interface between the physical and virtual worlds, applications and services to existing grip-based devices are enabled. Applications for the grip include as sports, fitness equipment, health monitoring, activity tracking, coaching, physical therapy, mobility aide and virtual entertainment, among others.
10,420,486 Promoting	Methods, computer systems, and computer readable media are provided for promoting positive activity patterns for users and facilitate long-term adherence to

positive activity patterns	the activity patterns, such as by providing alerts or electronic reminders to ambulate in a fashion that is responsive to an individual's actual activity patterns and behaviors and compatible with routine activities in the workplace and home. In particular, embodiments of the present invention are directed to (1) measuring physical activity patterns during the waking hours of a human, and in some embodiments continuously measuring these activity patterns; (2) automatically ascertaining whether the patterns exhibit sufficient frequency and variability of activity such as confers certain health benefits; and (3) if the patterns do not manifest such features, to adaptively provide sensible reminders at irregular within-day intervals such as are likely to establish healthy patterns of ambulation and other light activity.
10,413,250 Method and apparatus for generating assessments using physical activity and biometric parameters	The methods and apparatuses presented herein determine and/or improve the quality of one or more physiological assessment parameters, e.g., response-recovery rate, based on biometric signal(s) and/or motion signal(s) respectively output by one or more biometric and/or motion sensors. The disclosed methods and apparatuses also estimate a user's stride length based on a motion signal and a determined type of user motion, e.g., walking or running. The speed of the user may then be estimated based on the estimated stride length.
10,411,066 Athletic activity monitoring device with energy capture	Aspects relate to an energy harvesting device adapted for use by an athlete while exercising. The device may utilize a mass of phase-change material to store heat energy, the stored heat energy subsequently converted into electrical energy by one or more thermoelectric generator modules. The energy harvesting device may be integrated into an item of clothing, and such that the mass of phase change material may store heat energy as the item of clothing is laundered.
10,390,755 Monitoring body movement or condition according to motion regimen with conformal electronics	Systems and methods are described for monitoring an individual subject and facilitating a motion regimen of the individual subject. In an aspect, a system includes, but is not limited to, a deformable substrate; a sensor assembly configured to generate one or more sense signals based on detection of at least one of a movement of the body portion or at least one physiological parameter of the body portion; a processor configured to receive the one or more *sense* signals, the processor including circuitry configured to identify a physiological state of the individual subject based on at least one of the movement of the body portion or the at least one physiological parameter of the body portion; and an effector operably coupled to the processor and configured to effect at least one predetermined motion of the body portion corresponding to a motion regimen responsive to control by the processor.
10,376,184 Apparatus and method for patient activity estimation and classification	A medical device includes a housing and an electrode arrangement coupled to the housing and configured to sense an electrical physiologic signal from a patient. The device also includes detection circuitry coupled to the electrode arrangement and configured to obtain a cardiac signal component and a non-cardiac signal component from the physiological signal. A processor is coupled to the detection circuitry. The processor is configured to detect patient activity using at least the non-cardiac signal component and discriminate between voluntary and involuntary

	activity of the patient based on a comparison of temporally aligned cardiac and non-cardiac signal components.
9,707,433 Exercise handles and band	A pair of exercise handles includes one handle that can fasten one end of an exercise band in a fixed position and another handle that can secure the other end at multiple locations, allowing a user to vary the resistance level for different exercises. The band may be marked with a sequence of numbers along its length to help the user establish particular resistance levels. The exercise handles include rigid connectors inserted through the interior of handholds, which retain the handholds and allow them to freely rotate.

First Author	Title	Journal and Year	Relevance
Minvielle	Monitoring Elderly Levels of Activity with a Piezoelectric Floor	Sensors; 2019	The relevance of this journal article is the focus on patient care by non-physician healthcare providers and in-home treatment. Also, the sensors described are able to minimize the main limitation, that this project faces as well, which is recognizing only relevant, patient manufactured signals.
Roell	Validation of Wearable Sensors during Team Sport-Specific Movements in Indoor Environments	Sensors; 2019	The aim of this study was to determine the accuracy of motion detecting, wearable sensors. The relevance is the focus on detecting motion in indoor settings, as well as the validity of data collection from wearable sensors. The sensor used in this project is similar to a wearable device in that it attaches externally to the band, though different because it does not attach to the user directly.
Compagnat	Validity of the Walked Distance Estimated by Wearable Devices in Stroke Individuals	Sensors; 2019	The relevance of this journal article is the need for accurate data collection on patient use to be reviewed by healthcare professionals. Additionally, this study focused on the interference of the attached device on the patient experience - a specification included in this project as well.

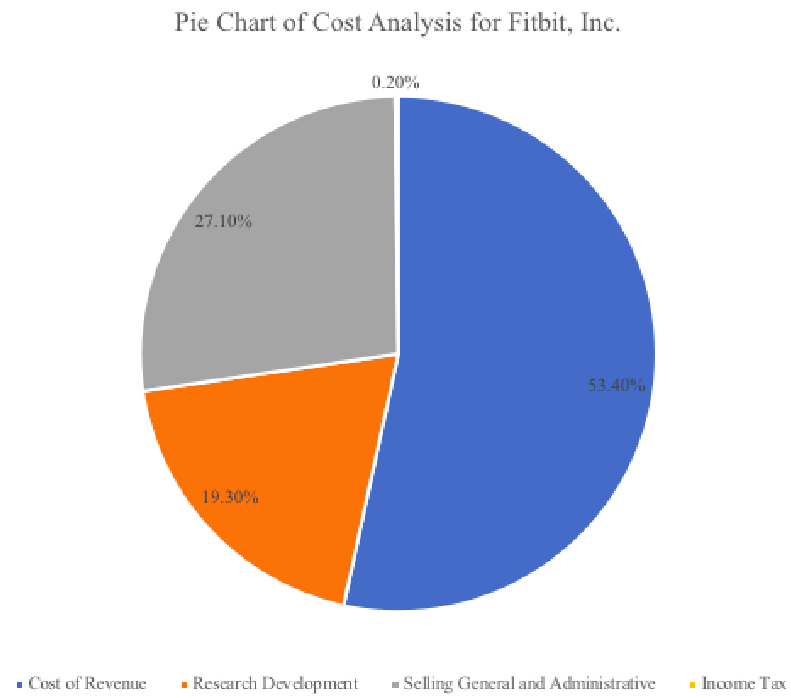
Sáez de Asteasu	Physical Exercise Improves Function in Acutely Hospitalized Older Patients: Secondary Analysis of a Randomized Clinical Trial	Journal of the American Medical Directors Association; 2019	The study conducted focuses on function of patients with prescribed physical exercise. This is relevant to the minimal exercise prescribed by physicians that is monitored by the device designed and implemented in this project. Additionally, the patients are classified as minimally active - essentially equal to the status of patients involved in the exercise band treatment.
Straczkiewicz	On Placement, Location and Orientation of Wrist-Worn Tri-Axial Accelerometers during Free-Living Measurements.	Sensors; 2019	This article focuses on the variability of wearable activity sensors and their application to free living. Relevance to this project is further support for choosing a button-clicker sensor for reliable stretch count rather than motion detecting, accelerometer based sensors.
Perez-Castilla	Reliability and Concurrent Validity of Seven Commercially Available Devices for the Assessment of Movement Velocity at Different Intensities During the Bench Press.	2019; Journal of Strength and Conditionin g Research	This article details the accuracy of velocity measurements for restricted linear motion through acceleration monitoring sensors. For this project, the design utilizes the clicker as a result of constant questionable results of motion sensors beyond basic movements - as elaborated on in this article.
Sarsfield	Segmentation of Exercise Repetitions Enabling Real-Time Patient Analysis and Feedback Using a Single Exemplar.	2019; IEEE Explore	This article presents a method for grouping data using an algorithm capable of segmenting exercise repetitions in real time. The relevance is the ability to correctly segment repetitions from subjects, including those of limited mobility, which is the basis of the goal for data storage and battery life conservation in this project.

Bowler	Real-world use of rescue inhaler sensors, electronic symptom questionnaires and physical activity monitors in COPD.	2019; BMJ Open Respiratory Research	The relevance of this article is the study focus on physical activity monitors in patients with Chronic Obstructive Pulmonary Disorder. This disorder is one of the main health ailments that plague patients who are prescribed resistance band exercises (physical activity).
Bavan	Adherence monitoring of rehabilitation exercise with inertial sensors: A clinical validation study.	2019; Gait & Posture	This article describes how it is difficult to measure adherence for self-directed home exercises in patients who are recovering from various ailments. If adherence rates were known, it would be much easier to determine the effectiveness of these in-home exercises. Since the device in this project attempts to measure in-home exercise adherence, it could show the effectiveness of such exercises.
Papagiannaki	Recognizing Physical Activity of Older People from Wearable Sensors and Inconsistent Data.	2019; Sensors	This article describes the potential of wearable sensors to benefit the lives of elderly people, especially when monitoring physical activity and exercise. It shows that these sensors improve health status and quality of life. While the sensor created in this project is not wearable, it measures activity in a similar fashion as a wearable and could produce similar health outcomes.

v. Pie Chart Analysis

Fitbit, Inc.

Price / Cost Ratio	$1,511,983,000 / $908,404,000 = 1.66
Profit %	-$185,829,000 / $1,511,983,000 = -12.3%



vi. MAUDE Failure Mode Analysis

Device	Device Problem	Event Type	Description
Resist-A-Band (Resistance Band)	Fracture	Injury	Person was using the resist-a-band during a group exercise class (barre-fusion) at a sports club. The band broke and the person fell and broke her wrist.
Theraband (Resistance Band)	Fracture	Injury	Hygenic was notified of a claim alleged against theraband for a loss of an eye. The only information received was a poor quality

			photo of what appears to be a red theraband exercise band.
Theraband (Resistance Band)	Split	Injury	Patient's red theraband broke during an exercise, causing her to fall and injure her finger tips, neck and back. She had the theraband around a giselle machine-stationary part. She pulled in to build her forearm and bicep, held for 3 seconds, and the band "split" which caused her to lose her balance and fall backward and down. She landed on her right side wrist/arm and forearm and is having loss of grip strength.
Theraband (Resistance Band)	Snapping	Malfunction	The patient had a velcro strap headband secured around her head, the theraband was tied to the band at an attachment point. The band was secured around a pole on the other end. The patient was facing the pole and was instructed to step backwards to increase tension on the band while maintaining proper head posture. The band snapped in the mid-section. The end still attached to the headband hit the patient in the right side of her face, just below her eye. A small 1 inch area below her right eye was reddened.
Theraband (Resistance Band)	Snapping	Injury	At the time the subject incident occurred, she was using 2 exercise bands in an attempt to strengthen her shoulders. As she was leaning back, one of the bands snapped and she fell to the floor. She landed on her left hip. She was taken by ambulance to the hospital where she underwent an open reduction and internal fixation of a left hip fracture.
Theraband (Resistance Band)	Material Integrity Problem	Injury	As patient was pulling back, the theraband broke and with the force sent his arm back to over a 90 degree angle and caused severe injury to his shoulder. He had to have surgery on his shoulder to repair the injury. The MRI showed a complete rip to his shoulder.
Theraband (Resistance Band)	Material Integrity Problem	Injury	Patient was at a physical therapy session where he was performing exercises with a theraband. The band broke and struck him in the eyes and face causing severe pain, injuries to face & eyes, & injury to left shoulder.
Theraband	Material Integrity	Injury	Patient was using the exercise band in the

(Resistance Band)	Problem		bathroom on new years eve when it either broke or slipped from his hand causing him to spin and fall, blinding him in one eye.
Lifevest WCD 4000 (Wearable Cardioverter Defibrillator)	Button Registration	Malfunction	A US distributor reported that a patient's response buttons were not able to activate the device.
MP5 (Patient Monitor)	Wrong Signal	Death	The customer reported that "the monitor continued to display an ECG wave and a numeric value for the heart rate, but the patient was dead". The device was used for monitoring at the time of the alleged malfunction.

vii. Applicable Standards List

- International Organization for Standardization
    - ISO 20957-2:2005 - Strength Training Equipment (Elastic Cords)