FitFormula

ECE1778 Final report

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Contents

1.0 Introduction

Regular aerobic exercise such as jogging is important for preventing health problems and improving overall fitness level. However, many individuals do not know the optimal exercise duration (how long), intensity (how hard), or frequency (how often) they should be doing in order to receive the maximum amount of health benefits. Current mobile fitness apps available do not take the user's initial fitness level into consideration when recommending exercise programs. This may result in injury or lack of results, leading to discouragement.

FitFormula is the first mobile app that is able to design a personalized exercise program based on the user's initial fitness and health level. This app will target users who are just starting to exercise regularly; it is also designed to be a motivation tool for 'non-fit' users.

The goals of FitFormula are:

I. Assess the user's current fitness and health level
II. Recommend a personalized aerobic program based on the initial assessment.
III. Guide the user throughout their workouts and to track progress.

2.0 Overall Design

FitFormula is designed into three modules (figure 1): i) pre-fitness assessment, ii) workout recommendation and iii) after-fitness assessment.

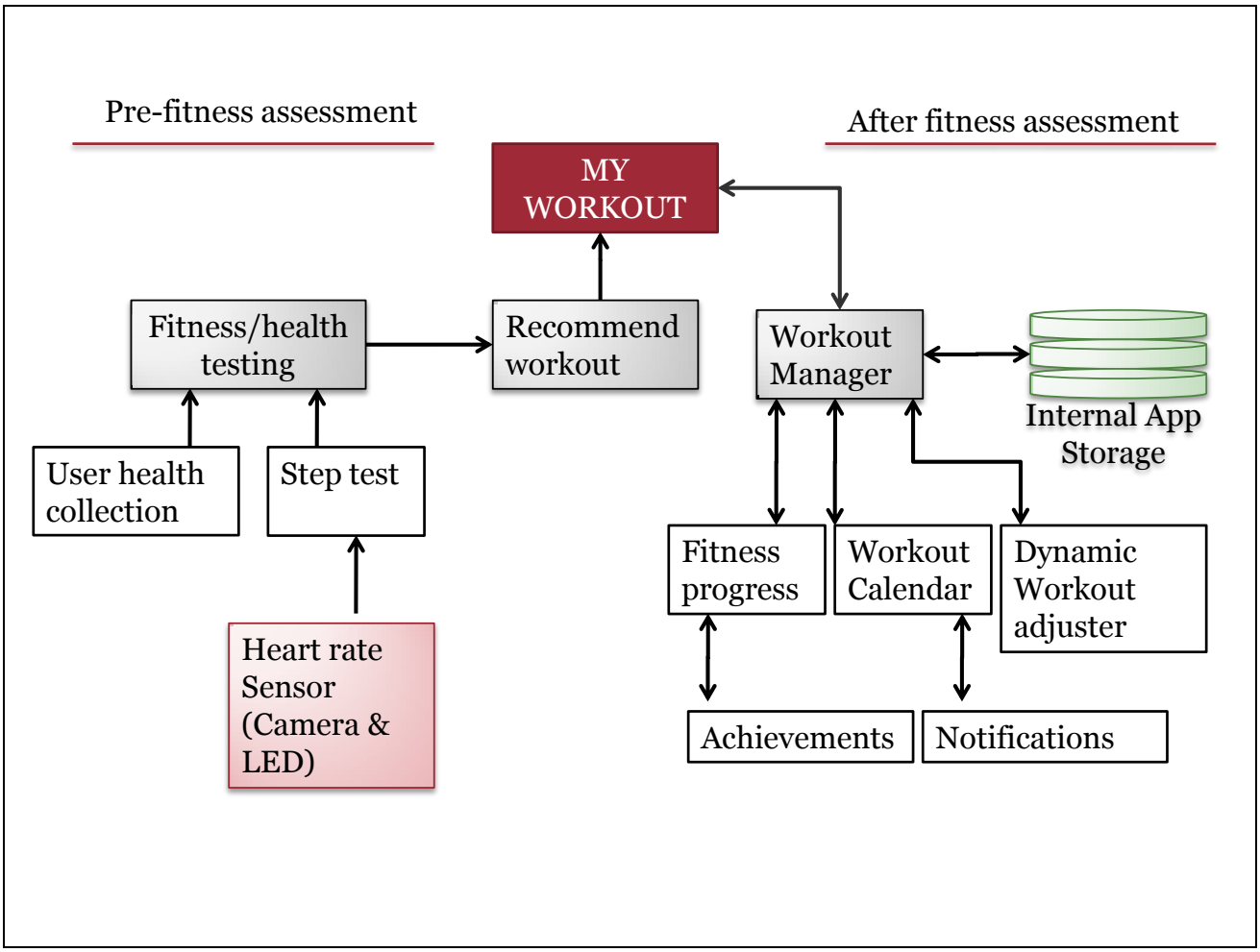

Figure 1: *Block diagram for the overall design.*

2.1 Pre-fitness assessment

- **Fitness and health testing** will be conducted in following way:

    - User health collection: The health information entered is used to calculate body mass index (BMI) and risk for cardiovascular disease (CVD) using the algorithm published by the Framingham Heart Study (1). See appendix for algorithms. The BMI is used to determine the user's risk of developing weight-related health problems.

- Step Test: The Canadian Home Step Test is a validated fitness test which lasts about 6-minutes (3). The fitness test theory states: the lower your heart rate on completion of activity, the higher your aerobic fitness. Instructions on how to conduct the test are presented to the user through an instructional video demonstration (figure 5). Audio cues to denote the stepping rhythm are provided during the test. The user's heart rate is measured at the end of the test, which is used to calculate the fitness level (2). See appendix for the algorithm.

- Heart Rate Sensor: The heart rate sensor makes use of the mobile phone's camera and adjacent LED light. The user takes their heart rate by placing their finger on the camera while the LED light is on. The theory is that light from the LED will illuminate the inside of the finger; the rhythmic fluctuation in (red) light received by the camera corresponds to pulsatile blood flow in the finger, which represents the user's heart rate. To accomplish this, the red (RGB) values from a section of the camera view are averaged together. This average is normalized (brought around 0) then put through a band-pass filter. The band-pass filter consists of a 3rd order Butterworth low-pass filter (cut-off frequency = 4 Hz) and high-pass filter (cut-off frequency = 0.8 Hz). These filters attempt to remove noise and fluctuations that occur beyond our expected heart rate range. After filtering, this data is put through a beat-detection algorithm that looks at peaks and valleys in the signal. The time between consecutive beats is then used to determine the user's heart rate in beats per minute.

2.2 Workout recommendation

A 6-week personalized exercise program will be recommended based on the individual's fitness and health condition; specifically 1) BMI 2) CVD risk factor and 3) fitness level. The individual will be considered as having a poor BMI if the value is greater than 28. A high risk for cardiovascular disease is defined as when the individual has a greater than 10% chance of developing heart disease in the next 10 years or when their heart age is 5 years older than their actual age. Finally, poor fitness level is defined when the individual's fitness level is 30% or lower compared to their age-matched norm. Depending on which of the areas that the user needs

improvement on, a specific tailored workout is recommended. See figure 2 for the possible combinations of programs. The exercise intensity, duration, and frequency are different for each program. See figure 3 sample programs.

Poor BMI	High CVD risk	Poor Fitness level	Program name	Program goal
X			**Slim & Trim**	• Fat Burning and Toning
X	X		**Cardio Metabolic Boost**	• Toning • Improve Heart age and decrease CVD risk factor
X	X	X	**Health Makeover**	• Fat Burning and Toning • Improve fitness level • Improve Heart age and decrease CVD risk factor
X		X	**Fit & Tone**	• Fat Burning and Toning • Improve fitness level
	X	X	**Fit Heart**	• Improve fitness level • Improve Heart age and decrease CVD risk factor
		X	**Fit Boost**	• Improve fitness level
	X		**Cardiac Wellness**	• Improve Heart age and decrease CVD risk factor
No risk	No risk	No risk	**Fit ultimate**	• Keep fit and toned • Prevent cardiovascular illness

Figure 2: *A list of the types of programs offered by FitFormula. The "x" presents the areas that the user needs improvement on.*

The workout difficulty is also matched to the user's fitness level to help avoid exercise burnout and injury. For example, if the user's fitness level is "average", then the user is placed at Level 2 with the specified intensity, duration, and frequency (see figure 2). The user will progress to the next level every 2 weeks only if the user is ready, which is determined through a post workout questionnaire.

	Level 1 Below average fitness	**Level 2** Average fitness	**Level 3** Above average fitness	**Level 4** Good Fitness	**Level 5** Excellent Fitness
Slim & Trim	3 times/week; 25 min/ session, 60% of heart rate reserve (HRR)	3 times/week; 25 min/ session, 65% of HRR	4 times/week; 30 min/ session, 70% of HRR	4 times/week; 40 min/ session, 70% of HRR	5 times/week; 45 min/ session, 70% of HRR
Fit Ultimate	2 times/week; 25 min/ session, 60% of HRR 1 time/week interval exercise; 20 min/session; 2 min at 50% of HRR, 2 min at 60% of HRR.	1 time/week; 25 min/ session, 65% of HRR 2 times/week interval exercise; 25 min/session; 1min at 55% of HRR, 2 min at 65% of HRR.	2 time/week; 30 min/ session, 70% of HRR 2 times/week interval exercise; 30 min/session; 2 min at 60% of HRR, 2 min at 80% of HRR.	2 times/week; 40 min/ session, 75% of HRR 2 times/week interval exercise; 40 min/session; 2 min at 65% of HRR, 3 min at 85% of HRR.	3 times/week; 45 min/ session, 80% of HRR 2 times/week interval exercise; 40 min/session; 2 min at 65% of HRR, 3 min at 85% of HRR.

Figure 3: *Workout schedule for the various fitness levels. See Appendix for Heart rate reserve (HRR) calculation.*

2.3 After fitness Assessment

- **The Workout Manger** is the central hub that will organize and store all health, fitness and workout information.
    - **Internal App Storage –** User's information and the different workout programs are stored locally on the mobile phone in a database. This includes the user's biometrics, calculated risk factors, prescribed workout program with scheduled dates, resting heart rate and weight over time, and achievements. All workout information including duration and target intensity at different time points is also stored in the database for each program and level.
    - **Workout Calendar and Notifications –** The 6-week exercise program is synced to the user's Google calendar. The user will be notified about their workouts.
    - **Fitness Progress and Achievements –** During each workout, fitness progress will display the exercise duration and intensity. Weight and resting heart rate can be tracked throughout the training. The achievement badges will be awarded to increase motivation.

- **Dynamic Workout Adjuster –** At the end of each workout session, the user can rank their perceived workout difficulty. If the user is consistently finding the workout too easy or too hard, FitFormula will automatically increase or decrease the workout difficulty level by one. Additionally, if the user consecutively misses their workouts, Fitformula will lower the user's exercise level and thus lower exercise intensity, duration, and frequency to take detraining into consideration.

3.0 Statement of Functionality and Screen Shots

All functionality proposed for FitFormula worked in the final product; please see below for screen shots and description.

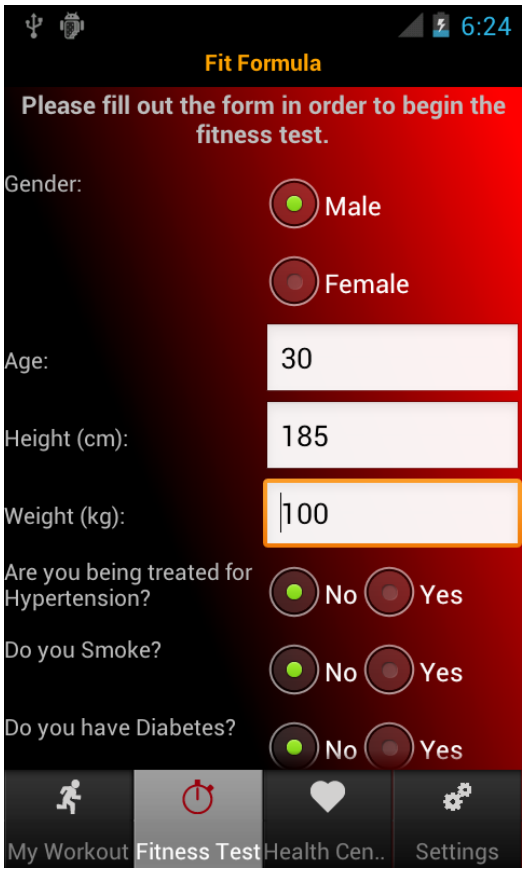

Figure 4. *The user is asked to input their health information to determine the user's BMI and CVD risk factor.*

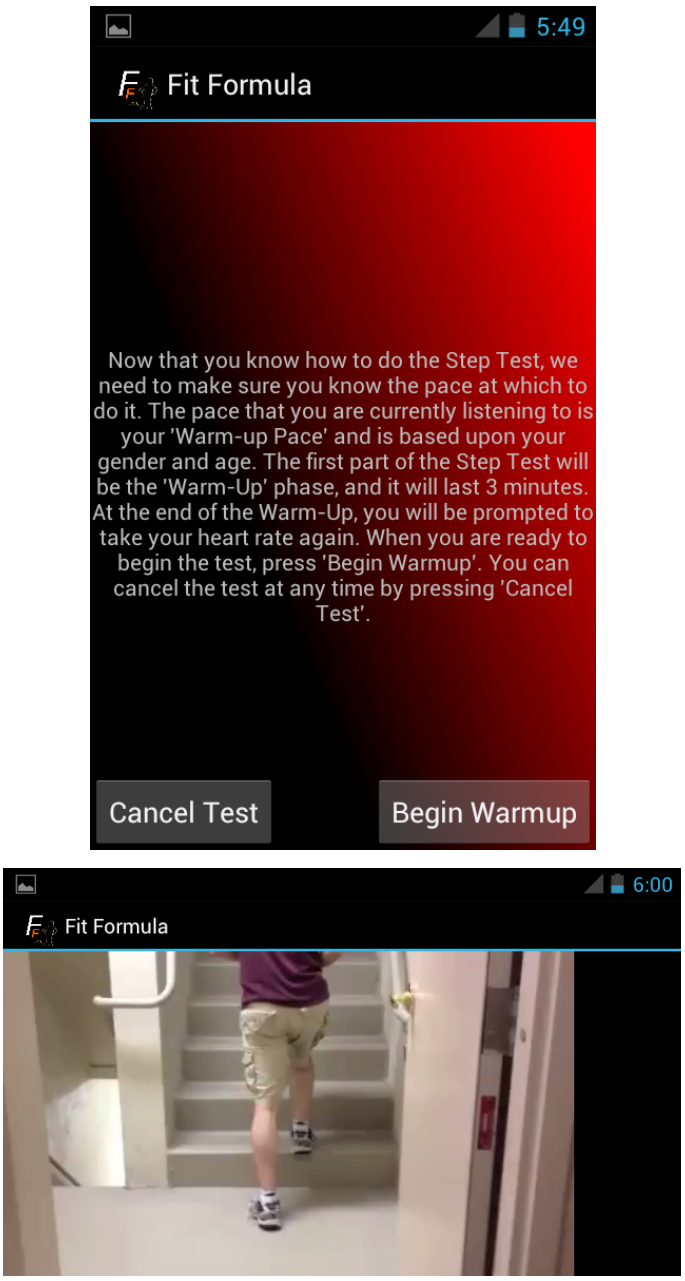

Figure 5. *Video and written instructions are shown before the step test. Audio cues are provided during the step test to help guide the user to the proper step rate.*

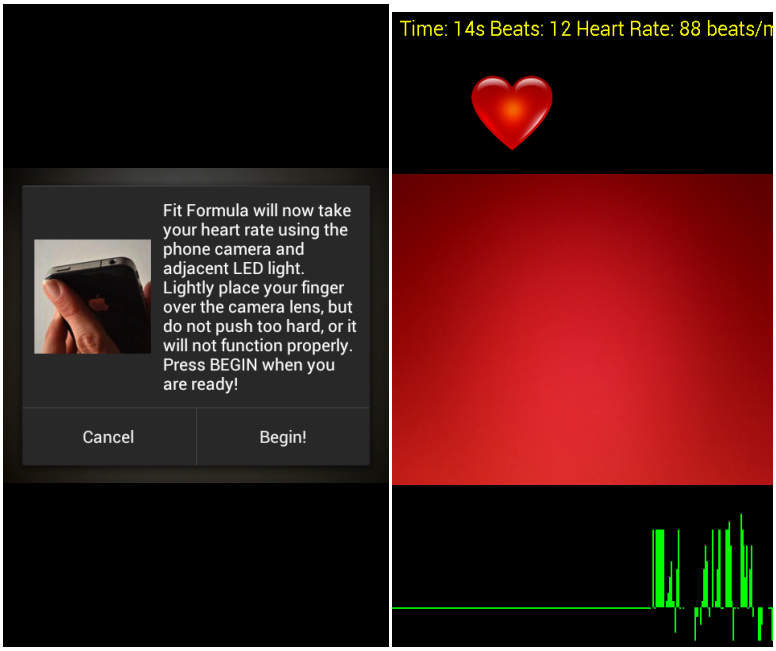

Figure 6. *Heart rate will be measured before and after the step test to calculate fitness level and workout intensity.*

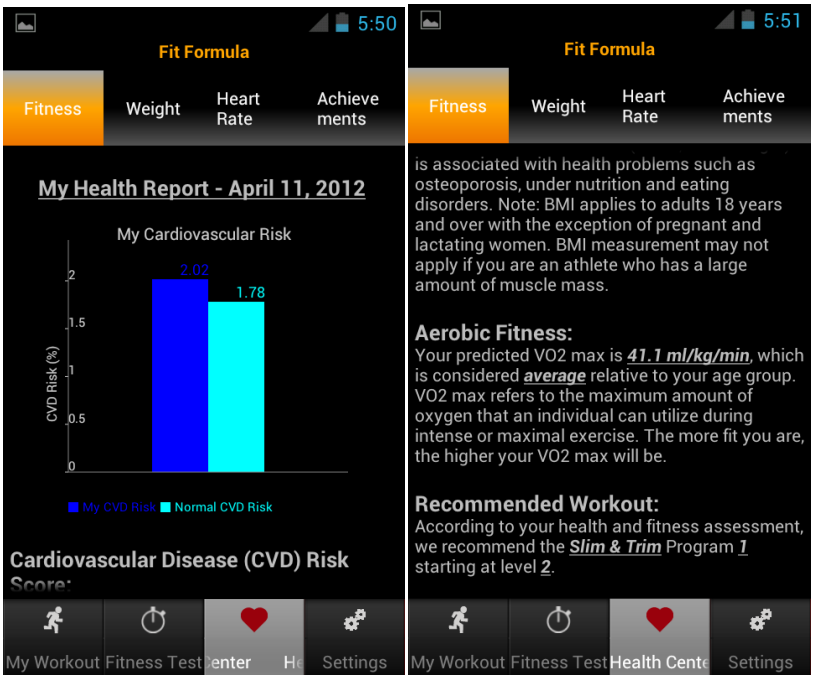

Figure 7. *Health report along with the recommended exercise program is presented post fitness assessment. The health report contains the user's BMI, CVD risk and fitness level.*

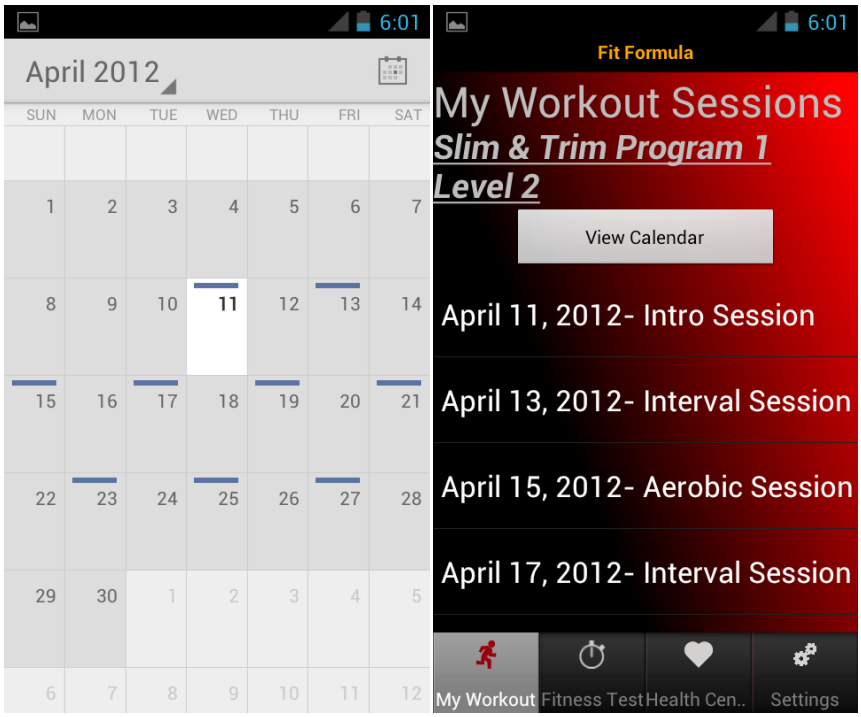

Figure 8. *The 6 week workout plan is saved and displayed to the user's calendar.*

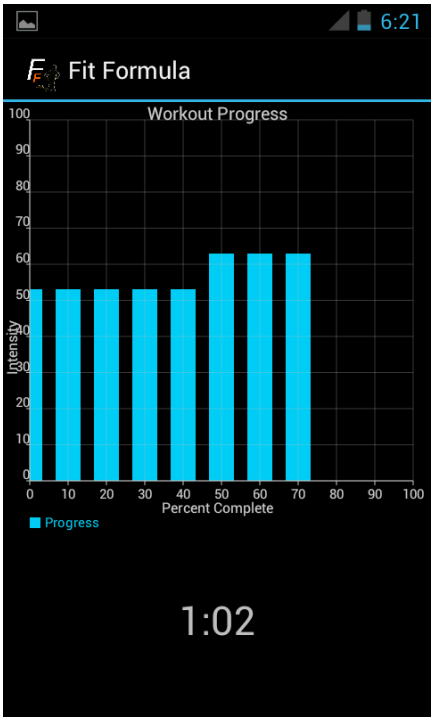

Figure 9. *Workout progress tells the user their exercise intensity and duration.*

4.0 Learning Experience

- **Technical knowledge:** This project provided a wonderful opportunity for inter-disciplinary collaboration. The programmers were able to learn about exercise training and the Android SDK. The apper was able to learn about the designing principles and capabilities of mobile applications.

- **Communication between Appers and Programmers:** There were many discipline-specific principles that the apper and the programmers had to understand in order to construct the app. For example, heart age and CVD risk vs. normal CVD risk. Several of the algorithms and documents provided by the apper also required further clarification. For instance, a BMI range of 18.5-25 was given as "normal" and a BMI of 25-30 was "overweight"; this leaves ambiguity surrounding the value of 25: is a BMI of 25 normal or overweight? This was eventually clarified by the apper: a BMI under 25 was normal and a BMI greater than or equal to 25 was overweight. Thus, a clear outline of what information is required from the apper will help increase development efficiency in the future.

- **Validation before implementation:** One of the key lessons learned was that validation of each new component is required before adding it to the app. There were many algorithms implemented in this app and some of them were not tested for errors before coding them into the app. Thus, when mistakes in the formulas were discovered, it was much more difficult to find and fix them in the code, than if the mistakes had been caught beforehand. In the future, each new component needs to be tested in advance before it is implemented into code.

5.0 Group Contribution

- **Sam Liu (Apper):** I contributed to the project by providing my knowledge regarding fitness testing, health assessments, and exercise prescription. I recommended the fitness test (The Canadian Home Step Test) and health assessments (Framingham Cardiovascular risk) that are easy to perform, and have a low risk of injury. I have provided the specific instructions on how to perform the assessments, interpret the results and use the result to design an exercise program. Finally, I contributed to designing the algorithm that has the ability to recommend the optimal exercise intensity, duration, and frequency depending on the user's initial fitness level and health status.

- **Simran Fitzgerald (Programmer):** I created the user interface and I was responsible for almost all components that the user actually sees. I designed and created the entire step test phase, excluding the heart rate sensor. I also was responsible for creating the "During Workout" Activity. I was responsible for the audio and video playback, as well as all the graph views spread throughout our application, including the "current progress" graphs seen by the user during their workout. I worked with Jonathan on the heart rate sensor, although Jonathan is the signal processing expert in our group. Finally, I was also involved in the database population process.

- **Jonathan Tomkun (Programmer):** I developed the LED and camera-based heart rate sensor including the signal filtering, beat-detection algorithm, and heart rate calculation. I designed the storage database by specifying the necessary tables, fields, and field types. I translated the algorithms and formulas supplied by our apper to calculate risk factors and recommend an exercise program into code. I developed the Health Center information including the fitness health report, weight-loss tracking, resting heart rate history, and achievements. I also implemented the workout schedule integration with Google Calendar.

6.0 Apper Context

FitFormula is the first app that can recommend exercise programs based on an initial health and fitness assessment. This app improves the way users get their workout program as well as stimulates new research questions for mobile exercise interventions.

Initial fitness and health assessments conducted by exercise trainers help determine the personalized exercise program for their clients. However, the challenge for many individuals is the cost associated with trainers and their availability. Thus, many companies created pre-packaged or "one-size fits all" exercise programs for users at a lower cost; but the limitation is that exercise programs must be tailored to the user in order to receive maximum benefits. FitFormula is able to create personalized exercise programs based on the user's own fitness and health level in an affordable way. The app can help keep the users on track with their exercise program by notifying them of their next workout. Additionally, FitFormula will monitor the user's exercise intensity and duration to avoid overtraining. FitFormula is also able to dynamically adjust the workout schedule and difficulty level if the user misses a workout or if they find the workout is not matched to their fitness level. This app reduces the gap in creating a fully automated exercise trainer.

FitFormula also raises many interesting research questions. For example, can FitFormula effectively evoke long-term health benefits for the user? Is there enough motivational feedback and support built into the app to help the user achieve long-term behavioural changes? These are important questions to consider, as there are many different exercise and fitness apps published in the app market every month. Thus, it is important to determine what functionalities in the app will help the user achieve the best results and to help the user stay motivated. I am planning to incorporate FitFormula into my thesis and to examine the effectiveness in helping individuals achieve better health through exercise training.

7.0 Future Work

Alternative Fitness assessments and Additional workouts – Alternative fitness test options using questionnaires will be implemented for individuals who do not wish to, or are physically unable to perform the Step Test. Additional workout programs including 5km and marathon training will be available in the future. This will provide the user with more training choices, and will attract a broader range of users. Future workout programs will also include a variety of training lengths that will last 8, 12 and 16 weeks depending on the user's fitness goal.

Integrate external heart rate monitor – Obtaining the user's heart rate during the workout will allow the app to accurately track the user's exercise intensity in real time. The current heart rate sensor using the phone's camera and LED flash is most accurate when the user is stationary/resting. Measuring heart rate during fatigue and movement is quite difficult. Integrating an external heart rate sensor will be beneficial for determining the user's optimal exercise intensity.

Graphics & User Interface – Currently there is only audio feedback during the step test to ensure correct stepping rate. Future versions will display a graphic animation of the step rate.

8.0 Business School Interest

We are not interested in having a Business School marketing/entrepreneurship student(s) take up FitFormula.

References

1. **D'Agostino RB S, Vasan RS, Pencina MJ, Wolf PA, Cobain M, Massaro JM and Kannel WB.** General cardiovascular risk profile for use in primary care: the Framingham Heart Study *Circulation* 117: 6: 743-753, 2008.

2. **Jette M, Campbell J, Mongeon J and Routhier R.** The Canadian Home Fitness Test as a predictor for aerobic capacity *Can.Med.Assoc.J.* 114: 8: 680-682, 1976.

3. **Shephard RJ, Bailey DA and Mirwald RL.** Development of the Canadian Home Fitness Test *Can.Med.Assoc.J.* 114: 8: 675-679, 1976.

Appendix

Calculating body mass index (BMI):

BMI= weight (kg) / height^2 (m)

Calculating 10 years General Cardiovascular Risk Prediction (1)**:**

Variable input:

1) Treatment for hypertension
2) Gender
3) Age
4) Systolic blood pressure(SBP)
5) Do you smoke (yes = 1, no = 0)
6) BMI
7) Do you have diabetes (yes = 1, no = 0)

Males with No treatment for hypertension

$$Risk = (\ln(age) * 3.11296) + (\ln(SBP) * 1.85508) + (Smoke * 0.70953) + (\ln(BMI) * 0.79277) + (Diabetes * 0.5316)$$

$$CVDRisk = \left[1 - 0.88431^{e^{(RISK - 23.9388)}}\right]$$

$$Heart\ Age = \frac{e^{(RISK/3.11296)}}{\ln 0.8843^{(\frac{1}{3.11296})}} \times (-\ln(1 - CVDRisk)^{1/3.11296})$$

Males with treatment for hypertension

$$Risk = (\ln(age) * 3.11296) + (\ln(SBP) * 1.92672) + (Smoke * 0.70953) + (\ln(BMI) * 0.79277) + (Diabetes * 0.5316)$$

$$CVDRisk = \left[1 - 0.88431^{e^{(RISK - 23.9388)}}\right]$$

$$Heart\ Age = \frac{e^{(RISK/3.11296)}}{\ln 0.8843^{(\frac{1}{3.11296})}} \times (-\ln(1 - CVDRisk)^{1/3.11296})$$

Females with No treatment for hypertension

$$Risk = (\ln(age) * 2.72107) + (\ln(SBP) * 2.81291) + (Smoke * 0.61868) + (\ln(BMI) * 0.51125) + (Diabetes * 0.77763)$$

$$CVD\ Risk\ \% = \left[1 - 0.94833^{e^{(RISK - 26.0145)}}\right]$$

$$Heart\ Age = \frac{e^{(RISK/2.72107)}}{\ln 0.8843^{(\frac{1}{2.72107})}} \times (-\ln(1 - CVDRisk)^{1/2.7207})$$

Females with treatment for hypertension

$$Risk = (\ln(age)\times 2.72107) + (\ln(SBP) * 2.88267) + (Smoke * 0.61868) + (\ln(BMI) * 0.51125) + (Diabetes * 0.77763)$$

$$CVDRisk = \left[1 - 0.94833^{e^{(RISK-26.0145)}}\right]$$

$$Heart\ Age = \frac{e^{(RISK/3.11296)}}{\ln 0.8843^{(\frac{1}{3.11296})}} \times (-\ln(1 - CVDRisk)^{1/3.11296})$$

NORMAL Cardiovascular risk factor for males

$$NormRisk = (\ln(age)\times 3.11296) + (\ln(125)\times 1.85508) + (\ln(22.5) * 0.79277)$$

$$Normal\ CVDRisk = \left[1 - 0.88431^{e^{(NormRISK-23.9388)}}\right]$$

NORMAL Cardiovascular risk factor for females

$$NormRisk = (\ln(age)\times 2.72107) + (\ln(125)\times 2.81291) + (\ln(22.5) * 0.51125)$$

$$CVD\ Risk\ \% = \left[1 - 0.94833^{e^{(NormRISK-26.0145)}}\right]$$

Fitness calculation: VO2 calculation (2)

Predicted VO_{2max} = 42.5 + 16.6 (Energy cost) - 0.12 (weight, kg) - 0.12 (heart rate) - 0.24 (Age)

Note: VO_{2max} is the aerobic power in ml.kg-1.min-1 VO2 max refers to the maximum amount of oxygen that an individual can utilize during intense or maximal exercise. The more oxygen you can use during high level exercise, the more energy you can produce.

Age	Rhythm for Women (count/min)	Energy Cost (l.min-1)	Rhythm for Men (count/min)	Energy Cost (l.min-1)
Warm-Up	66	0.94	66	1.14
15-19	120	1.63	144	2.28
20-29	114	1.49	144	2.38
30-39	114	1.49	132	2.01
40-49	102	1.32	114	1.83
50-59	84	1.05	102	1.63
60-69	84	1.05	84	1.35

Heart Rate Reserve (HHR) Calculation

HHR = (220-age-resting HR) x intensity% + resting HR.

Note: Intensity% is the percentage specified in the table above.