Visualizing the Daily Physical Activities and Nutrition Information of High School Athletes in WAVE~Ripples for Change: Obesity Prevention in Active Youth

AN ABSTRACT OF THE PROJECT OF

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Title: Visualizing the daily physical activities and nutrition information of High School Athletes in WAVE~Ripples for Change: Obesity Prevention in Active Youth

Abstract approved: Christopher Scaffidi

Uploading everyday information about food intake, sleep, number of steps and then generating consolidated peer visual reports for participants in large-scale health studies, often divided into multiple treatment groups, can be challenging.

This challenge is even bigger if subjects are young teenagers between the age of 14-19 active in sports, as in the case of Oregon State University's WAVE project, an intervention health study involving 24 teams with 750 teenagers from 13 schools in Oregon, as it becomes difficult for scientists to monitor information from all subjects and consolidate it into the database. This Master's project extends the WavePipe system, a two-year integrated health study dashboard that enables scientists to create studies, enroll subjects and their health tracking devices, create web-based surveys, collect and analyze data from these devices and surveys to upload each subject's sleep, nutrition, physical activity information and generate health reports for all the subjects under each group for any specified date range. The project also provides a feature for the scientist to edit already existing subject's demographic information by just uploading a Comma Separated Value (CSV) file.

An evaluation of the sub-system with the main user found it to be both usable and effective. Moreover, it has been in use since Fall 2014 and six rounds of reports have been generated for all the students participating in the study (subjects).

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1. Introduction

1.1 Background: The WAVE Project and WavePipe

"The Wave ~ Ripples for Change: Obesity Prevention in High-School Soccer Players research project is a 5-Year USDA[1] funded project focused on building healthy nutrition, physical activity (PA) and life skills for healthy weight maintenance. The intervention includes face-to-face sport nutrition, PA and life-skills lessons, assessments of diet, body composition and PA on/off the soccer field, and on-line immersive learning to reinforce the lessons." [1]

One of the components of the WAVE project is WavePipe, a system that allows WAVE scientists to create studies, enroll subjects, assign Fitbit trackers [2], send them periodic surveys to fill, retrieve the results of these surveys as well as information obtained from subjects' devices (steps taken and calories burned per minute), and finally to export or analyze these results. [3]

As explained above, subjects are high school soccer players (aged 14–19) from different schools located in Oregon, coordinated through their coaches [4]. WAVE researchers constantly collect information from participants for a period of time, generally seven days and it is called the 7-Day Challenge, and manually update it in the WavePipe. For example, they collect the nightly survey from all participants after a week and extract the required information from the survey for each participant and update it in the database and generate reports for each group. Support for such a system has been lacking which saves manual work hours for the scientists. Additionally, the users needed a visual representation of all the student attributes using different colored charts and graphs for the study period.

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[1] U.S. Department of Agriculture

2. Related Work on visual reports in health studies

Visual reports are a longstanding method for enabling students to compare themselves to one another in an academic setting. For example, one literature review examined the usage of data visualizations to help instructors understand activities about whole class or focus on a particular student in an environment where instructors use Course Management Systems (CMS) to manage or distribute course materials and conduct online learning activities [1]. CMS logs can be used to track the learning activity of the students, and, analogous to use cases supported by WavePipe, the students can also use CMS functionality to understand how their own progress compares to others in the class. For instance, one study with such a system collected data from 71 participants of 11th grade at a small public high school for a period of six weeks to study "how students developed an understanding of chemical representations with the aid of a computer-based visualization tool" [2].

As systems for tracking PA and nutrition have become widespread, visual reporting has become a common method for depicting personal changes over time. It is recognized that "visualizations are important in personal informatics tools because they help users reflect on and gain insights about their eating, sleeping and exercise patterns which encourages them to continue tracking," and particularly in the context of physical activity tracking noted that many consumer-oriented devices (e.g., Fitbit, Dailyburn and Runkeeper) use visualizations (e.g., bar, line and pie charts) to represent PA as a form of feedback to users [3]. Beyond the use of such visualizations in consumer-oriented systems, research studies have presented data to users as a means of providing feedback. For instance, one research study uses visualizations to help diabetic patients explore the relationship between their blood glucose level, their diets, and their daily routines [5]. Another study used visualizations to "aid physiotherapists in interpreting and understanding accelerometer data from patients in communication with patients and other healthcare workers."

They used data gathered by a sensor called activePAL and classified into periods spent walking, standing and sedentary. These classifications were used to create visualizations just like in the WavePipe we classify data into sleep, steps, and nutrition intake [6].

Visualizations in such systems are often designed with the intent of influencing users to engage in healthy behaviors. For instance, a study with the goal to develop a "system to promote an active lifestyle for individuals and to recommend to them valuable interventions by making comparisons to their past habits" developed a prototype system "to promote an active lifestyle and a visual design capable of engaging users in the goal of increasing self-motivation." [7]. The main idea was to use visualizations to study past habits to improve a person's health and well-being in a proactive manner. They used a platform called ATHENA (activity-awareness for human-engaged wellness applications) to visualize a subject's daily, monthly and weekly physical routines. These visualizations can be shared with social media so the subject can earn appreciation and be motivated [7].

The primary limitation of systems, to date, is that they provided limited information to users about how they compare to others in their peer group. This contrasts with academic visualization systems which, as noted at the outset of this section, commonly compare students to their peers. This comparison to peers across a breadth of different indicators (diet, exercise and sleep) is a distinctive new feature of WavePipe developed as part of this Master's project. For example, FoodWatch [8] is a mobile app for recording food. It analyzes and depicts the user's intake of carbohydrates, fats and proteins but does not compare these to other users, nor does it track sleep or physical activity. Shut Eye [9] is a similar app that is focused on sleep-tracking, but it does not compare with other users, nor does it track diet or activity. Likewise, Fitbit [10] and Google Fit [13] track activity, MyFitnessPal [12] tracks diet and exercise, Apple Health [11] tracks all three—

but none of these provide a means of comparing to peers. Healthwatch 360, is a mobile application that incorporates Dietary Guidelines for Americans medical nutrition therapy for major chronic diseases and provides personalized dietary and nutritional recommendations according to an individual's health goals and personal profile. It analyzes over 30 nutrients in the diet, from both foods and supplements, and generates a daily nutrition report with a detailed breakdown of how well the user's choices combine to meet personal nutritional requirements [14].

3 Work Done

The main objective of this project was to create Visual Reports of participant's daily nutrition intake, sleep and physical activities. The generation of Visual Reports needed new features to upload participant's information collected through surveys into the system and also edit the demographical information of the existing subjects. Also, subject's attributes like weight and height were needed. To support all these requirements new features were added to the system.

The following Menu Options were added to the existing Wave System.

1) New Data Editing Features
2) New Data Upload Feature
3) Daily Fitbit Summary
4) Visual Reports

3. 1 Data Editing Features

3.1.1 Adding Fields to Study Enrollment

The Visual Reports displays the age, height, weight, average hours of sleep, average steps per day, average nutrition intake for a specified time range for every study group. Earlier, there were no fields to enter the date of birth, height, weight, the mailing address and parent's contact information in the WAVE system. This led to the addition of new fields in the study enrollment form. Also, a new field Notes was added to add some related information about the participant. The following fields were added:

Date of Birth
Gender
Height (Centimeteres)
Weight (KG)
Parent's Name
Parent's Email Address
Parent's Phone Number
Mailing Address
State
Zip Code

Notes

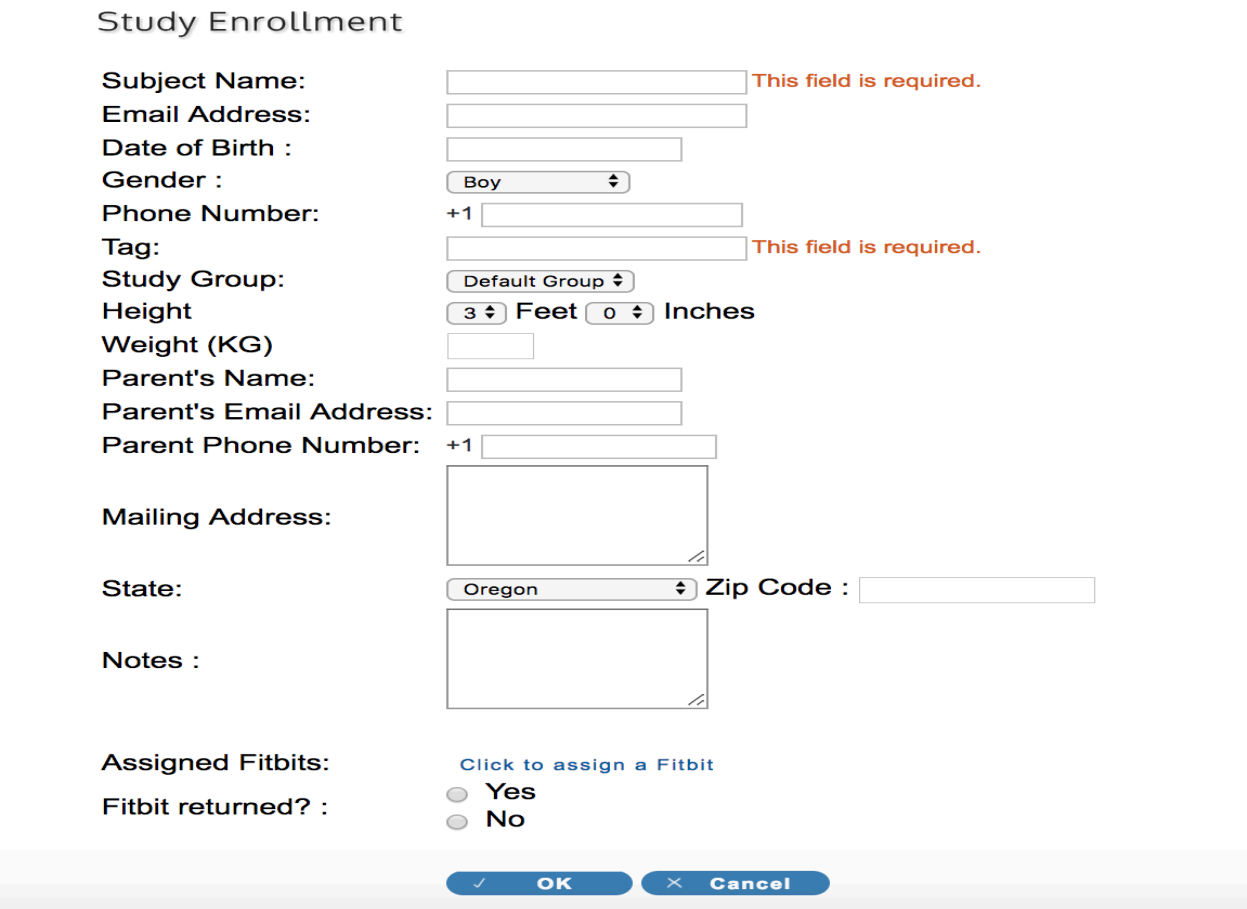


Figure 1 – Study Enrollment Form

3.1.2 Edit Subjects

Earlier, the details of a subject had to be manually edited. For example, if a subject's phone number changed or address had changed, then the user had to manually edit the phone number or address for that particular subject. But now, the user can edit all the details of a subject or all subjects by just uploading a Comma Separated Value(CSV) file with all the new details. This saves the users a lot of time and effort of doing things manually. Also, the details for the newly added fields can be uploaded to the system using this feature.

Now, with this feature, to add new subjects, the only required fields to enter are `Subject Name`, `Secondary ID` and select the `Group` subject belongs to. All the other details can be added or modified with this menu option.

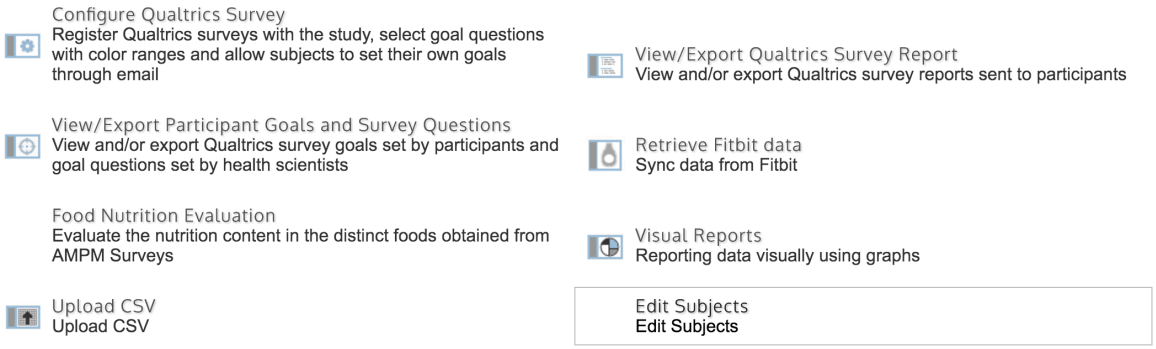


Figure 2 – Edit Subjects menu option

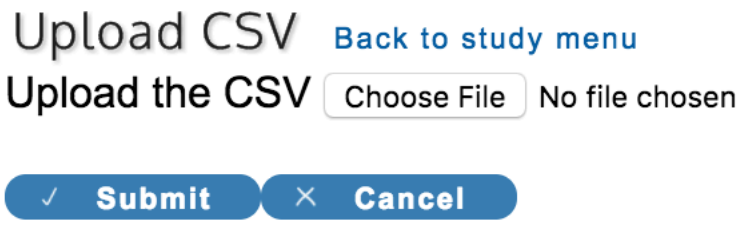


Figure 3 – Edit Subjects Upload CSV option

This feature only accepts a file with .csv extension.

The fields that can be edited using this feature are

1. Subject's email address
2. Subject's phone number
3. Parent's Name
4. Parent's email address
5. Parent's phone numbers
6. Mailing address
7. Date of Birth
8. Height

9. Weight

This feature also throws an error if a file with wrong extension or wrong csv format is uploaded.

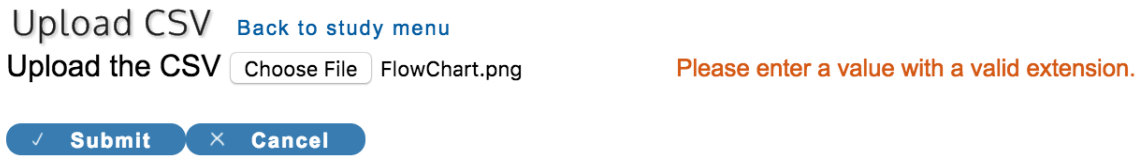


Figure 4 – Edit Subjects Upload CSV invalid file format error

If the CSV contains the details of subjects that are not in the WAVE system or the values in the fields are not as expected, then all the errors from the CSV will be thrown on the screen.

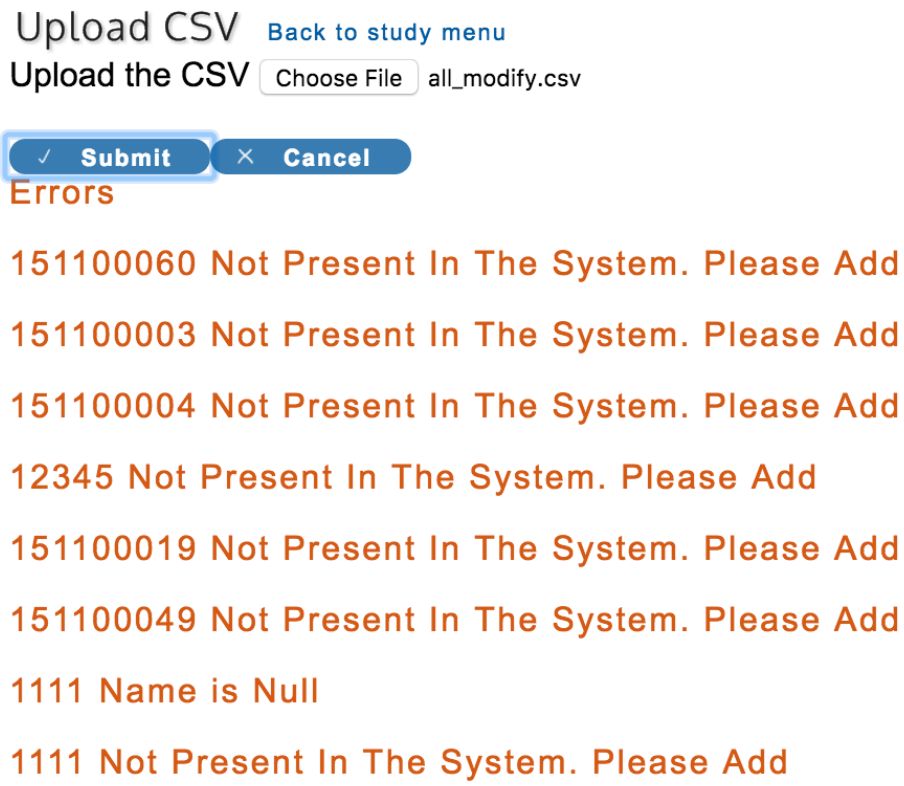


Figure 5 – Edit Subjects Upload CSV option errors

If all the subjects in the CSV are successfully modified, then a success message would be displayed.

3.2 New Data Upload Feature

3.2.1 Upload CSV

'Upload CSV' menu option is the first step in generating Visual Reports. The CSV contains subject's nutrition, sleep, injury and daily activity for all the days the subject participated in the study.

The fields in the CSV are :-

`YID,YthName,School,date.start,day.rec,gotobed,outofbed,fitbit,sportactivity,injured,injpreventact,GrainConsume,FruitConsume,VegetableConsume,ProteinConsume`

Each line in the CSV belongs to a subject with all the information for that day. This data is persisted into the database.

The `gotobed` and `outofbed` fields from the CSV are used to calculate the sleeping time by taking the difference of the minutes between them.

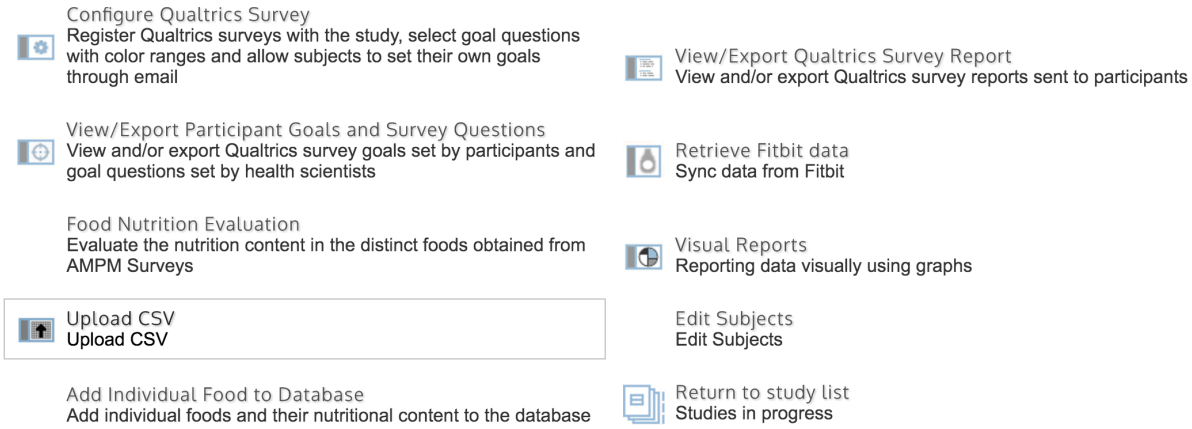


Figure 6 – Upload CSV menu option

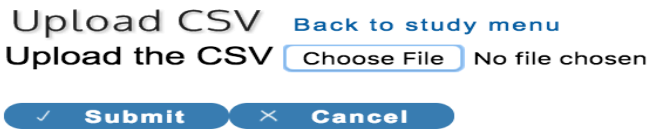


Figure 7 – Upload CSV menu option Upload CSV page

If the fields in the CSV do not follow the specified standards, then the system throws errors.

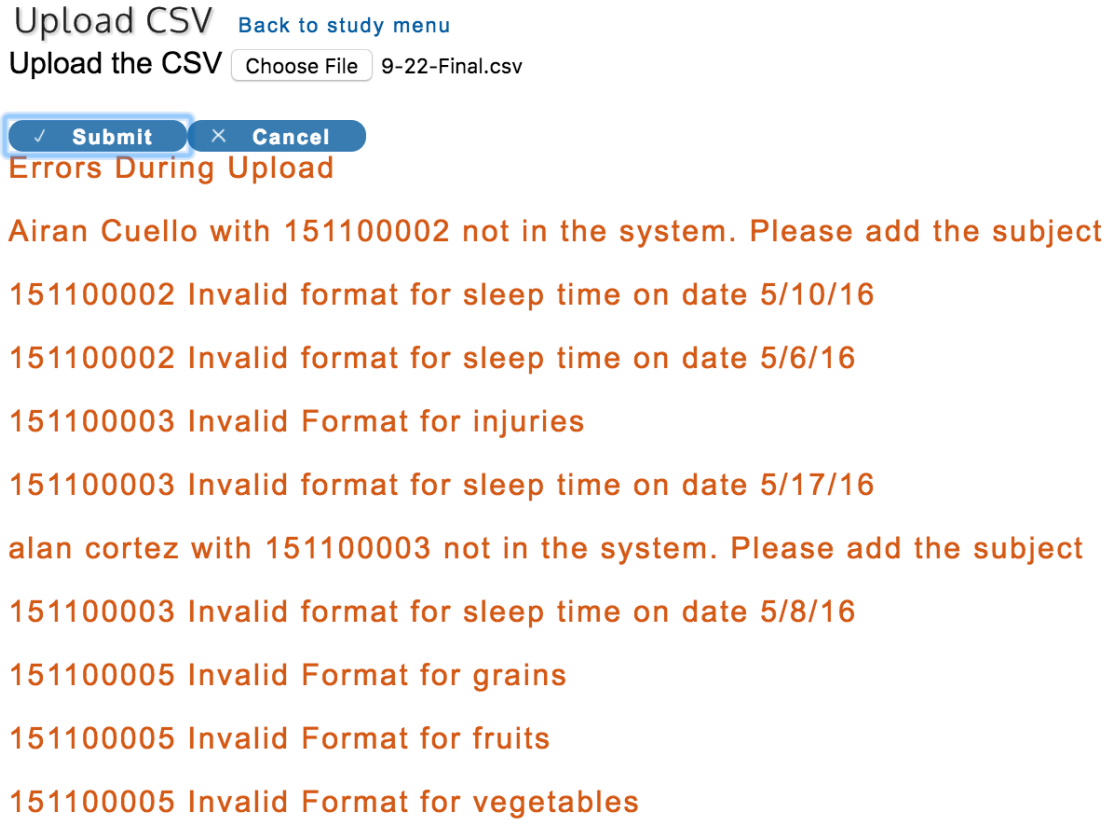


Figure 8 – Upload CSV errors

3.3 Daily Fitbit Summary

Every subject is assigned a Fitbit. The Fitbit data is synced periodically from the server and persisted to the database. It contains information for every minute in a day. (1440 entries/per day). So, if there are more than 180 minutes of zero steps then those entries are purged and only the zero step minutes not within consecutive 180 minutes of zero steps are considered to be categorized into different bands.

For every subject, the Fitbit information for was categorized into different bands for the number of steps taken per day and the amount of time the Fitbit was worn every day. Both the steps and time were categorized into seven different bands and these bands are displayed under 'View Data' Menu option by selecting the time range, the subject and the group.

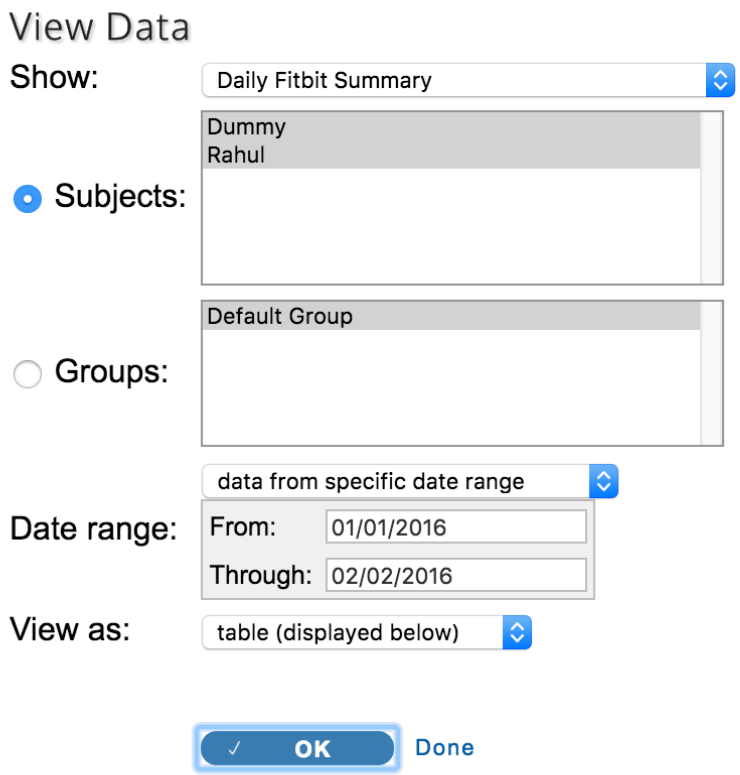


Figure 9 – View Data page

Daily Fitbit Summary Data — Hide headers

Subject	When	TimeBandOne	TimeBandTwo	TimeBandThree	TimeBandFour	TimeBandFive	TimeBandSix	TimeBandSeven	StepsBandOne	Steps
Rahul	1/1/2016 12:00 am	0	0	0	0	0	0	0	0	0
Rahul	1/2/2016 12:00 am	177	4	4	1	4	20	0	83	132
Rahul	1/3/2016 12:00 am	0	0	0	0	0	0	0	0	0
Rahul	1/4/2016 12:00 am	12	0	2	3	1	9	0	31	0
Rahul	1/5/2016 12:00 am	287	11	15	6	14	62	1	272	321
Rahul	1/6/2016 12:00 am	22	6	8	4	1	33	1	81	179
Rahul	1/7/2016 12:00 am	349	10	14	7	7	15	29	175	311
Rahul	1/8/2016	0	0	0	0	0	0	0	0	0

Figure 10 – Daily Fitbit Summary Data results page

3.4 Visual Reports

The first step in generating the Visual Reports is to use the `Upload CSV` menu option to upload subject's information. After that, the user has to choose the 'Visual Reports' menu option. The user has to select the start date and end date from the calendar that appears on the screen and select the study group and click on Save to generate the visual reports. This displays visual reports for all the subjects in the study group.

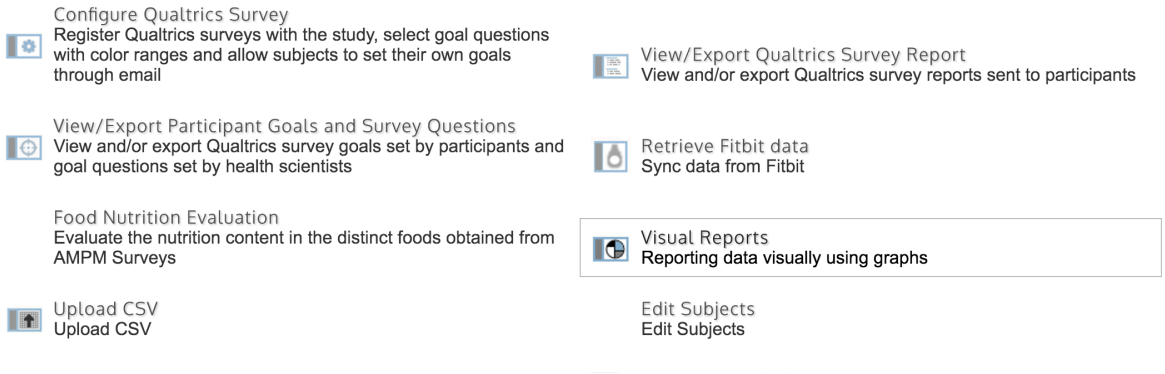


Figure 11 – Visual Reports menu option

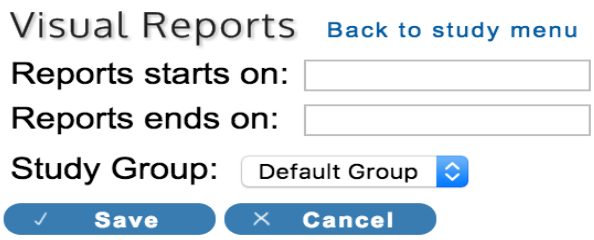


Figure 12 – Visual Reports page

The 'Visual Reports' generates reports for every subject in the group by aggregating all the information for that subject for all available dates in the database that fall within the user specified time period. The 'Visual Reports' is useful to show comparisons for different attributes between the subject and the peers in that group. It also aggregates the available data for all the subject's attributes into a CSV which can easily be used as a future reference document by the users. The reports can easily be exported to a PDF or printed and distributed directly to the subjects. For visualizations a JavaScript library called d3.js was used along with Handlebars.js to develop templates for generating web pages for all the subjects in a group.

There are four main sections in the 'Visual Reports' :-

i) Title

ii) Physical Activity

iii) Nutrition

iv) Sleep

3.4.1 Report Title

The title includes the logo of the WAVE project, the name of the subject and the name of the group.

3.4.2 Physical Activity

The Physical Activity part includes the age, height, weight, body mass index of the subject. It contains total number of steps the subject took for the 7-day period and also the injuries sustained along with the average steps per day and the day with the best steps.

It contains a bar chart that provides information about the total time where the steps were greater than 100 steps per minute. It is calculated for all the subjects in the group and it is represented in the 'Peers' bar. There is also a 'Recommended' bar. If there is no information of the subject regarding this field, then it is represented as 'N/A'.

3.4.3 Nutrition

The Nutrition portion of the 'Visual Reports' uses pie charts to represent the intake quantities of 'Whole Fruits', 'Whole Grains', 'Proteins', and 'Vegetables'.
From the database the values for grains, fruits, proteins, and vegetables are retrieved for the subject and divided by the number of days where the subject has had valid values. To calculate the nutritional values for all the peers, the values for all the subjects are added and then divided by the total number of subjects in the group. It has three pie charts –

i) YOU - This pie chart aggregates the nutritional intake values for a subject for the specified time duration.
ii) RECOMMENDED - This pie chart contains the recommended nutritional values for the subjects.
iii) WAVE PEERS - This pie chart contains the average nutrition values for all the subjects in the group combined.

3.4.4 Sleep

This section contains a set of circles. Each circle represents an hour of sleep. It also contains three columns. One for the subject, one for recommended sleep and one for the sleep of all the subjects in the group. The peer sleep is calculated in the same way the nutritional peer values are calculated.

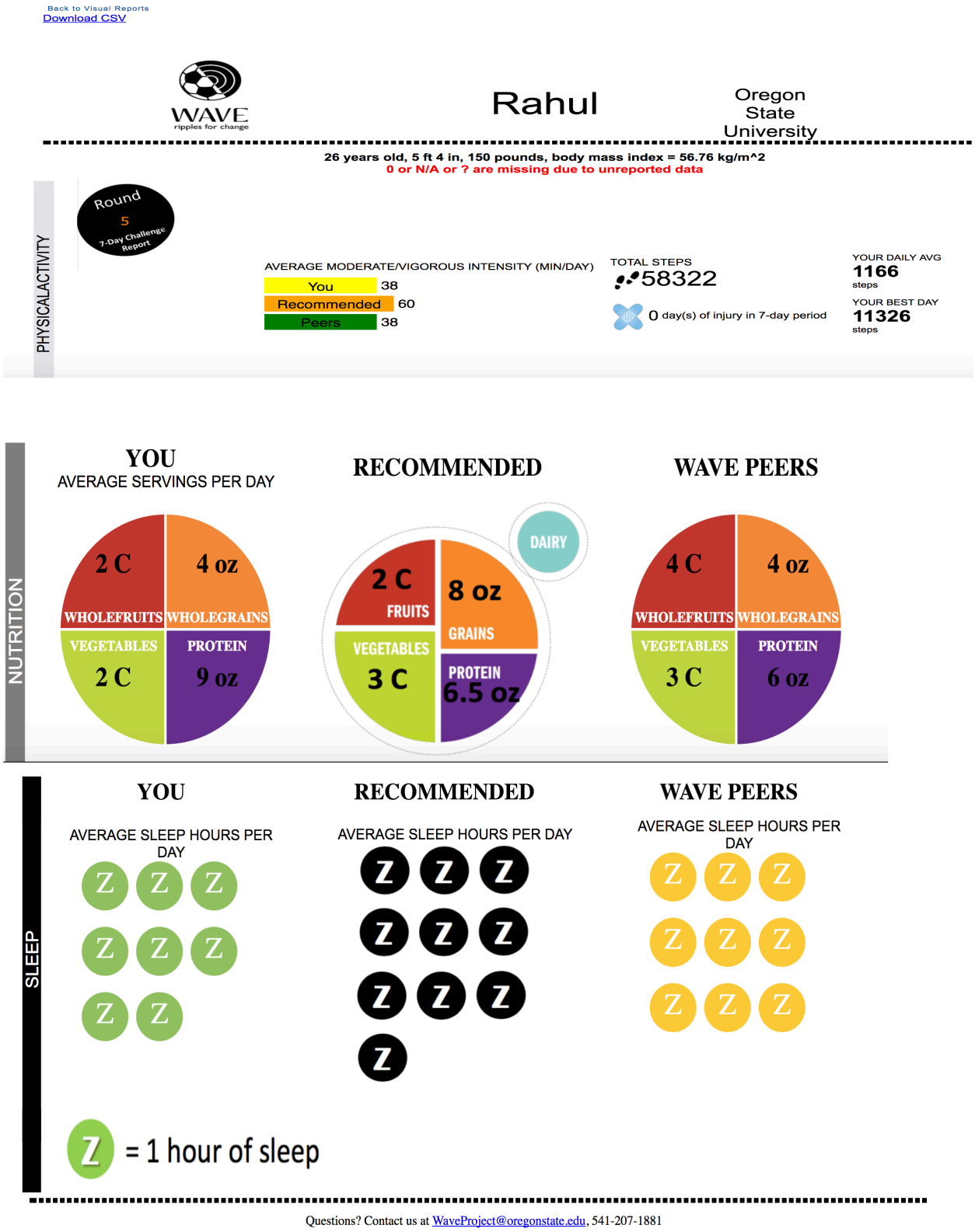
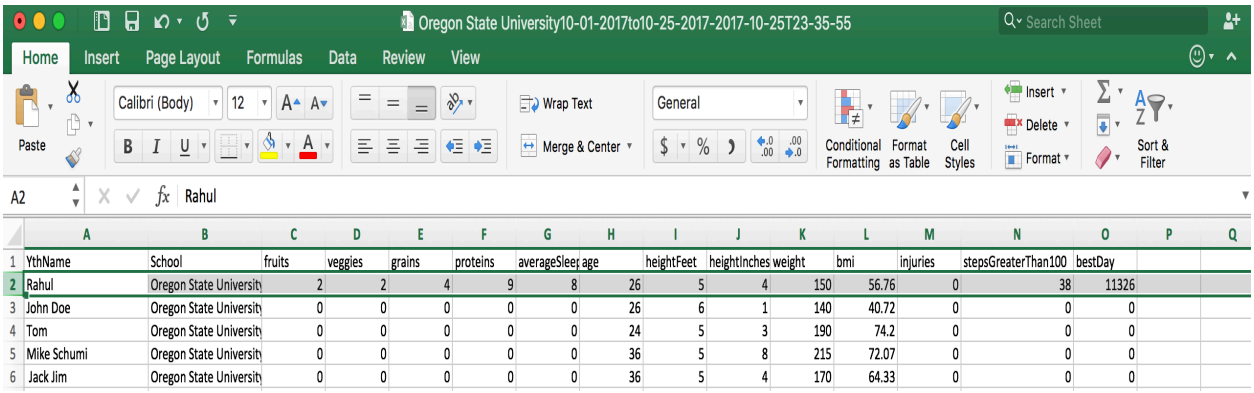


Figure 13- Visual Reports results

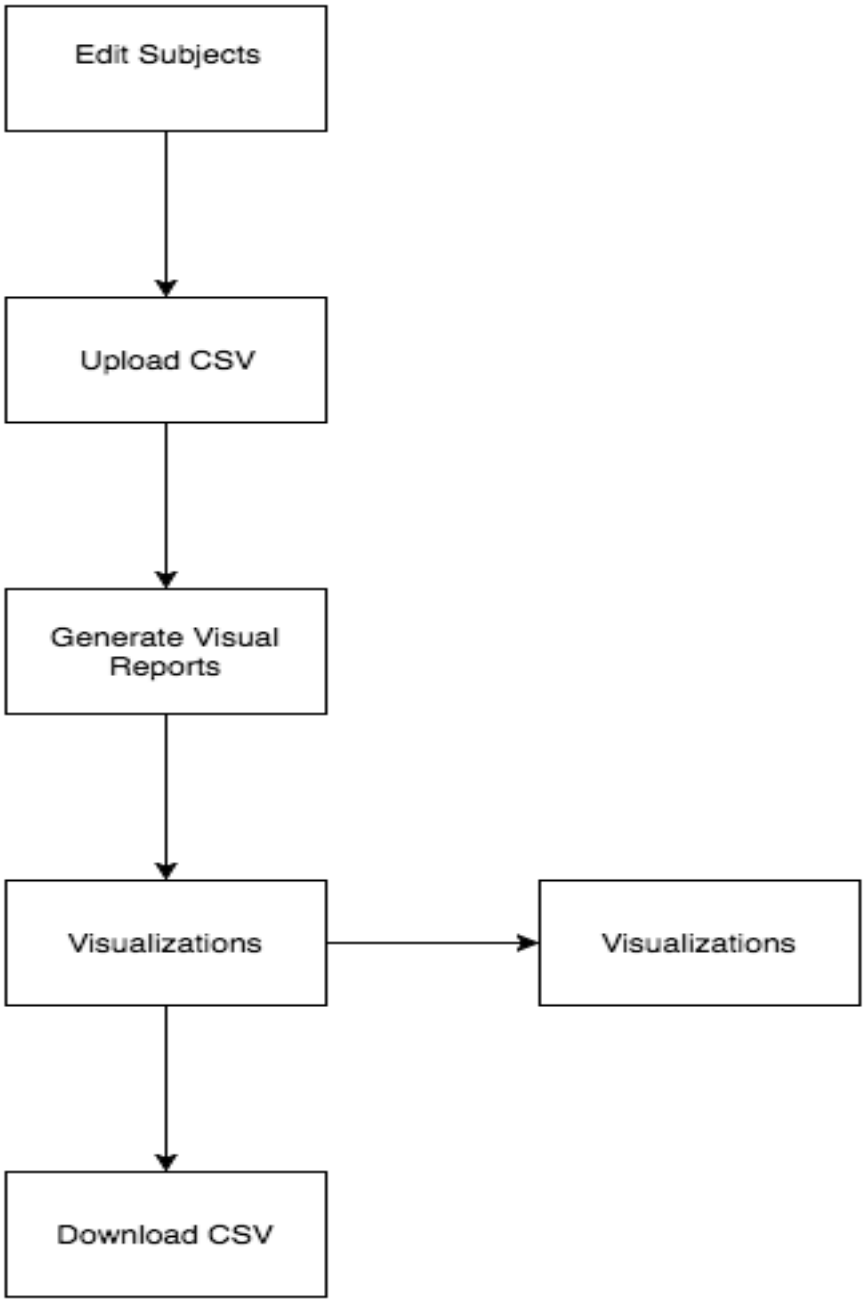
The ‘Visual Reports’ contains a ‘Download CSV’ option on top of the page to download the generated visual report information into a CSV for all the subjects in the group. The CSV’s name has the Study Group along with the date range selected and the current time so it can be easily identified from a group of CSVs.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	YthName	School	fruits	veggies	grains	proteins	averageSleep	age	heightFeet	heightInches	weight	bmi	injuries	stepsGreaterThan100	bestDay		
2	Rahul	Oregon State University	2	2	4	9	8	26	5	4	150	56.76	0	38	11326		
3	John Doe	Oregon State University	0	0	0	0	0	26	6	1	140	40.72	0	0	0		
4	Tom	Oregon State University	0	0	0	0	0	24	5	3	190	74.2	0	0	0		
5	Mike Schumi	Oregon State University	0	0	0	0	0	36	5	8	215	72.07	0	0	0		
6	Jack Jim	Oregon State University	0	0	0	0	0	36	5	4	170	64.33	0	0	0		

Figure 14 – Visual Reports Download CSV result

Figure 15 - Block Diagram describing the steps to generate Visual Reports



4 Testing

4.1 Unit Testing

Unit Testing is the process of testing the smallest parts of the application, called units, individually and independently to scrutinize for proper operation. As a part of this project, testing was done to check whether the methods that helped in creating 'Visual Reports' generated the expected results or not.

Test cases were written for three modules.

i) VisualReports

ii) UploadCSV

iii) FitbitDataSync

4.1.1 Visual Reports

This Java class includes a method called 'returnDate' which accepts the user specified date as a string and returns the date in the numerical format for processing. So, this method was tested by passing null values, an invalid date format, and a valid date format to check if the result is being generated as expected. For null and invalid values, the code correctly threw an error "Please check the date format". For valid values, the code returned correct output.

4.1.2 Upload CSV

This Java class contains a method called 'totalSleep' which returns the total time the subject had slept when the 'bed time' and 'wake up time' are passed to it as arguments. The bed time and wake up time are each provided by the user in "hour:min" format. (Example – "06:00pm" or "6:00 am"). This method was tested by passing null, invalid and valid values. The method

should calculate the difference between number of minutes between both the times. The wake up time is considered to belong in the succeeding day, so 1440 minutes are added to it and subtracted by the number of minutes of the 'bed time'. This calculation was tested in the test case by passing different combinations of 'bed time' and 'wake up time'. All the results of the test cases were as expected.

The other methods in the class were manually tested by uploading test CSVs. The Upload CSV option was tested by uploading both valid and invalid CSVs. The feature displayed errors when CSVs with invalid fields was uploaded. Also, when a file without the .csv extension was tried to upload, it displayed an error to upload only files with CSV extension.

A test CSV was uploaded which had real user data. The aggregated expected results were calculated by hand correctly and were compared against the results displayed by the system for the same users by using the Visual Reports tool. The values calculated by hand matched the values displayed by the tool. So, this proved that the system behaved as expected and was producing correct results. All these tests were repeated again in a common testing server which produced the same results.

4.1.3 FitbitDataSync

This class includes a method called 'removeSequencesOf180orMoreZeros'. This method takes the list of the Fitbit measurements for a day and returns a list by stripping the sequence of consecutive zeros which last more than 180 minutes.

This method was tested by six different sets of values:

1) It was tested by passing a list of 1440 measurements with nonzero values at index 1, 182 and 363 and zeros in all other indexes. The output for this list is 0, 1, 1, 1 after stripping

all 180 consecutive zeros. The test outputted the expected set after stripping all consecutive zeros.

2) A sequence with 1440 0s was passed and the test case returned an empty set. As the method strips of all the zeros the empty set was expected.
3) A sequence with alternate 1s and 0s was created and the test case returned the entire set without stripping any zeros because there was no sequence of 180 or more zeros.
4) A sequence with 1440 1s was passed and the test case returned the entire set of 1s as there were no zeros to be stripped and this was the expected behavior which was correctly tested by the test case.
5) A sequence with numbers from 1 to 1440 was passed to the test case and the test case returned the entire set as expected.
6) Finally, a sequence was passed with all negative values and an empty set was returned by the test case because we don't handle negative values in any of the daily summary steps bands.

Also apart from these automated test cases, test data was used to manually test this feature. One of the members on the team used a Fitbit. This Fitbit's data was synced into the system and the numbers of steps taken and time the member wore the Fitbit were manually calculated. These results were compared by generating the Daily Summary report from the Wave System. The results matched and this proved that the feature was working perfectly as expected.

5 Evaluation

5.1 User study

A short user study, involving six graduate students from the College of Public Health and Human Sciences at Oregon State University, was performed to evaluate the effectiveness and usability of the sub-system. The graduate students did not have any programming experience. The study was designed to be completed in 30 minutes, but was completed under 20 minutes. The OSU IRB protocol number for the research study is 6317.

- **Prior to start**

Before starting, a user was created in WavePipe and two groups were added under the user. Each group had 10 subjects and each subject had data about nutrition, physical activity and sleep.

- **Recruitment of participants**

An email with the description of the user study was broadcasted to the graduate students in the College of Public Health and Human Sciences at Oregon State University. Out of all the respondents to the email, six English speaking students above the age of 18 years were selected.

- **Filling out the consent form**

Every test users was emailed a copy of the consent form to read. The study began only after the participants signed the consent form.

Introduction

The test users were given a brief introduction about the user study and its benefits. They were also given an opportunity to ask questions. Then a sheet with instructions was handed over to the participants.

- **Task**

  Each task had three steps. The tasks were as follows:

  1. Fill a survey on Qualitrics
  2. Generate Visual Reports for the two groups
  3. Download CSVs for each group and compare the results in CSV with the Visual Reports

Test users finished all three tasks within 20 minutes.

Feedback

After finishing the tasks, the test users were asked to fill a questionnaire based on they usage of the system.

The questions were as follow:

- **Q1:** What is your job or year at OSU?
- **Q2:** What is your field or major?
- **Q3:** What is your experience with collecting data, analyzing data, or doing other research related to the following?

Research on…	None	Less than 1 year	1-2 years	More than 2 years
Nutrition	o	o	o	o
Exercise	o	o	o	o
Sleep	o	o	o	o
Other health	o	o	o	o

Table 1 – Experience with collecting data or other related research

- **Q4:** Did the survey enable you to effectively record information?
- **Q5:** One key purpose of the system is to speed up the creation of a report that summarizes diet, PA and sleep. Do you think the goal is achieved?

- **Q6:** How easy was it to understand the Nutrition, Exercise and Sleep parts of the report?
- **Q7:** What aspects of the software or the report do you like the most?
- **Q8:** What suggestions do you have about improving the software or the report, if any?

- **End of user study**

  Finally, the test users were paid $25 for participating in the study and sharing their feedback about the system. A confirmation of payment (signature and data) was collected from them.

- **Results**

  The evaluation of the user study was based on the ease of use of the system and the feedback submitted by the test users.

  The following feedback was obtained for the questions from which the results were obtained:

Q1: Did they survey enable you to effectively record information?

Four out of the six test users responded that the survey enables to record information efficiently and only two test users felt that the survey records information "Mostly" as the participants felt the fields used to represent physical activity information was insufficient.

Q2: One key purpose of the system is to speed up the creation of a report that summarizes diet, physical activity and sleep. Do you think the goal is achieved?

Five of the six test users agreed that the goal was achieved and only one test user felt that the goal was mostly achieved as the test user felt there were also other ways to

report exercises like the number of calories burnt besides steps count and injuries. The test user also added that steps count is not always represents good work out as a person can walk slowly a lot and not get a lot of exercise.

Q3: How easy was it to understand the Nutrition, Exercise and Sleep parts of the reports?

Nutrition: Five out of the six test users mentioned that it was very easy to follow nutrition data on the report while only one test user mentioned it was somewhat difficult to understand the nutrition data as other nutrients like fiber, fats and dairy were not considered which could make the nutrition information more informative.

Exercise: Three test users reported that it was very easy to follow exercise data in the visual reports and 2 felt it was somewhat easy while the remaining one participant felt it was difficult to follow from the report. The feedback the participants had about exercise data was that the data was insufficient. Some subjects having a lot of steps over long time might not have the same level of activity as a subject running for a short time.

Sleep: Four test users agreed it was very easy to follow sleep data and 2 participants agreed it was somewhat easy while 1 test user felt it was somewhat difficult to follow sleep data as there were many circles representing average hours of sleep for every subject.

Q4: What aspects of the software or the report do you like the most?

Response of Participant 1: Easy to follow nutritional and sleep habits.

Response of Participant 2: Graphics makes things clear

Response of Participant 3: Summary in a visual format

Response of Participant 4: Graph + Charts

Response of Participant 5: Color-coding was helpful. Slide-scale for “Number of Servings” in food categories worked well.

Response of Participant 6: I like that it summarizes the data in a friendly-visual manner through the colors and graphs for each category. It makes it easy to read and understand.

Q5: What suggestions do you have about improving the software or the report, if any?

Response of Participant 1: Additional exercise/PA information.

Response of Participant 2: There are other ways to record exercise.

Steps is good, but some one can walk a lot but not really get a lot of exercise.

Response of Participant 3: None

Response of Participant 4: Make wording bigger on age, height,

weight + BMI. Charts + graphs wording is too big. For sleeping, putting the number of hour will be easier to understand. For physical activity, relating steps to Moderate to Vigorous Physical Activity (MVPA) might help easier to understand the recommendation

Response of Participant 5: Sleep question layout was odd. Difficult to see separate questions. Does not account for non-sport exercises (example: individual training/activity),

Response of Participant 6: I think knowing the time frame this data is for would be helpful. Is this on a daily basis? If so, maybe expanding it to a weekly basis would be helpful too.

5.2 Usage of sub-system

The sub-system was used to generate visual reports for six rounds so far starting from Fall 2016. In each round, reports were generated for approximately 750 subjects in 24 groups.

5.3 Critical Thinking

The following conclusions can be drawn from the evaluation of the system by the test users.

1. All the test users were from HDFS, Public Health, Nutrition and Kinesiology majors and two-thirds felt the visual reports met its goals of speeding up the creation of summarizing PA, nutrition and sleep data. This implies that users experienced in those fields would probably find the visual reports effective.
2. The results clearly show that it was easy to follow nutritional and sleep habits
3. All the test users mentioned that summarizing data in friendly-usual manner through colors and graphs for every category was visually appealing
4. Also the data that was collected from multiple sources (Fitbit server and Qualtrics responses) was clearly represented in the visual reports.
5. The study was designed to be completed within 30 minutes but all test users completed the study under 20 minutes and this implies that the interface is probably very user friendly and easy to use.
6. Users with more than two years of experience in data collection or research in exercise felt the PA data represented was insufficient and including suggested additional methods for physical activity (e.g. biking distance, flights climbed, swimming time etc.) might make the reports more informative and liked by everyone

6 Conclusion and future work

The master's project presented a sub-system allowing health scientists to upload everyday information about food intake, sleep, number of steps and generate consolidated peer visual reports for the participants.

The overall goal of this sub-system is monitor information from all subjects and consolidate it into the database and evaluate the progress of each subject using visualizations.

The peer comparison feature can be extended for use in popular systems like Apple Health app. The Apple Health app, available on Apple iPhones, displays information about nutrition, physical activity, mindfulness and sleep. It is similar to WavePipe Visual Reports tool. But it doesn't provide peer to peer comparison. The app can use the peer comparison feature available in WavePipe Visual Reports. It can provide an option of comparing the phone owner's physical activity, nutrition and sleep data with other users of the application and display relative results. It also be extended to compare phone owner's values with a group of user's values. This will give the phone owner an idea of how he/she is performing compared to his peers or friends. It would also motivate the person to focus on his/her personal health better, just like WavePipe is used to prevent obesity among high school students. The main user (owner) of the mobile app can send requests to his friends in his phone contacts. When the receiver (friend of owner) accepts the request, his/her data will be shared with the main user's application and comparison reports can be generated. To address security, the app can have an option to generate 'Comparison Reports'. When the

main user selects the 'Comparison Reports` option, he/she has to enter a passcode to open it.

Also the data of the friend is visible only to the main user. If the friend also wants to generate comparison reports, he/she has to follow the same steps as the owner as sending a request and securing the part of application with a password. The table holding information of each user can have a one to many relationships with a 'Friends' table. Whenever the user requests a friend to join the comparison reporting tool, the friend's data would be added to the table with the unique id of the user as foreign key to the table.

The following sections, provide a list of potential future work that can enhance the current sub-system or other parts of the WavePipe project.

6. 1 Different method to represent PA Data

Although**,** there are several attributes to access physical activity data, currently, the system only utilizes steps. The system can be improved for displaying physical activity data by including distance covered by a subject or number of calories burnt. Flights climbed and biking distance can also be considered.

6.2 Provide Statistics

Based on the visual reports, a statistical conclusion can be extracted and displayed as a separate page at the end of the reports. This would give the users an insight into overall progress of the study.

6.3 Email Reports

A feature can be added to the system to directly email the report of a subject to the subject's registered email address in the system.

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