The Design and Development of a Framework to support Ergonomics Professionals and General Users

by

Onyinye Rosemary Asogwa

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Approved by

Cheryl Seals, Chair, Associate Professor of Computer Science and Software Engineering
Dean Hendrix, Associate Professor of Computer Science and Software Engineering
Bo Liu, Assistant Professor of Computer Science and Software Engineering

ABSTRACT

Poor ergonomics in many industries expose workers to risk. Improving the productivity of an organization is as important as the welfare of the employees that work hard to achieve the results. We are in a digital world where advanced learning systems can be developed to provide better risk assessment in these working environments. The American Industrial Hygiene Association (AIHA) Toolkit is a compilation, which comprises 19 ergonomic assessment tools. This Toolkit was created so that users in ergonomics industries can analyze task for a variety of ergonomic risk factors. Unfortunately, it is less engaging and tedious because most of the tools are still paper-based. The purpose of this research is to transform the already existing information into an application based on user interface design principles to increase user experience, flow, usability, and user interaction. Therefore, the ergonomic specialist and general users can be assisted in selecting the best tool for risk assessment based on a given scenario.

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1. INTRODUCTION

The primary goal of this framework is to assist ergonomic professionals with assessing and mitigating risk by connecting them with easy to use ergonomics tools. This is performed by walking a professional through a short survey with meaningful but straightforward questions. In the end, the professional is suggested specific tools that are then used to help protect company workers from dangers in their workplace. In practice, there are extreme dangers when humans are in the workplace which is an unhealthy lifestyle that can lead to death and ill health [2]. Many of these tasks are rudimentary (lifting, running, bending over) and the associated risk can be measured using tools. There exist many ergonomics assessment tools that can be used to assess Low back disorder [5]. This means that with the variety of available software applications that exist for risk assessment, finding the appropriate tool can make a tremendous difference when connecting professionals and novices to the right resources, and this difference is not limited to one field of work or physical area. The risks that workers face are widespread and are ubiquitous throughout industrialized nations. In countries like Spain and France, work-related musculoskeletal disorders are responsible for over 50% of occupational injuries [9]. These people must then leave work, have lower standards of living, and not be able to perform all the physical functions they once possessed. Home healthcare workers also experience more difficult working conditions [1] since they must lift and move patients without any assistance [7]. It is therefore essential to identify and reduce work-related musculoskeletal disorders (WMSDs) [6]. Therefore, this application exists and aims to help mitigate this extensive and widespread problem by assisting ergonomics professionals to do a better job and allow them to discover resources that they need quickly.

2. LITERATURE REVIEW

2.1 Ergonomics Tool Assessment

2.1.1 Ergonomic Methods for Assessing Exposure to Risk Factors for Work-Related Musculoskeletal disorders (WMSDs).

This literature by G. C. David (2005) provides some methods for risk assessment associated with work-related musculoskeletal disorders. Since most Musculoskeletal disorders (MSDs) are characterized as multifactorial [21], ergonomists are continuously researching to determine accurate methods for measuring risk [4] and providing better working environments for workers in their workplace [3]. The author explains that the mechanical exposure during physical work should be described by the intensity of force, frequency of shifts between force levels and the time the material activity is performed [4]. The author mentions that the methods developed for risk assessment associated with work-related musculoskeletal disorders are grouped into three categories:

A. Self-reports

Self-reports are reports collected directly from the workers concerning physical and psychosocial factors they face at their workplace. These workers can be interviewed or given paper/online questionnaires to fill out. This is a direct way of collecting vital information from large sample size and at a low cost.

B. Observational techniques

These reports are gotten by either an observer assessing the workers or by dedicated software. The observer collects data using varieties of tools and is common in so many workplaces. This is a better approach compared to direct reports which can be unreliable because of varying levels of worker literacy, comprehension or question interpretation [22].

C. Direct methods

This method of assessment involves attaching sensors to the workers to measure body movements. Data can either be collected continuously or at intervals. This gives accurate results, but these sensors can be worn at different parts of the body and come in various sizes which can cause discomfort and interfere with their work. It also expensive because it requires highly skilled people to interpret the results, cost of maintenance and purchasing the product [4]. In conclusion, there is no appropriate method for risk assessment and, various workplaces use a collection of these methods to ensure a healthy working environment for their workers.

2.1.2 A System to Test the Ground Surface Conditions of Construction Sites.

There is an underlying problem of poor soil on many construction sites, which are hazardous to construction workers. Besides the slippery and muddy nature of the terrain is disgusting to look at, these can also cause fatal injuries. This makes the job more demanding whereby the workers must walk with loaded boots, walk on slopes, sink into the soil, slip and sprain their joints, etc. The author concludes by offering solutions, which include applying grid plates to bridge specific areas, constructing paving early and the use of suitable transport facilities on the construction sites [16].

2.1.3 Initiating an Innovative Change Process for Improved Working Conditions and Ergonomics with Participation and Performance Feedback.

In 1997, H. Laitinen et al., describe the development of a new modification programme in Finland called TUTTAVA which is a Finnish acronym that means “safe and productive work habits” [13]. The objective of this paper is to determine the extent how the management’s involvement in the welfare of their workers can increase productivity. It is common for every workplace to urge its workers to maximize time towards productive output, but sometimes, the health of its workers is not being considered. Other times, there might exist disagreement between the workers and the management on safety issues, which can create a divide between them. The management and workers should have a good a friendly relationship to ensure progress and maximum productivity, but it is not easy to achieve.

2.1.4 Comparison of Ergonomic Risk Assessment Outputs from RULA and SI for Tasks in Automotive Assembly Plants.

The goal of this paper was to measure ergonomic tools' effectiveness in practice and give some insight on when some tools should be used. The two primary tools they go into detail about are Rapid Upper Extremity Assessment (RULA) and Strain Index (SI). They then do a head to head comparison of the two.

The first tool that the paper goes into detail about is RULA and how it is applied. The article states that the purpose of RULA as, "1) provide a method of screening a working population quickly, for exposure to a likely risk of work-related upper limb disorders. 2) identify the muscular effort which is associated with working posture, exerting force and performing static or repetitive work, and which may contribute to muscle fatigue." A RULA analysis involves taking notes on the work postures, repetition, and forces involved with the subject. These factors are then used to generate a numerical score to determine the risk of the issue. In addition to RULA, the paper goes into details about SI.

SI is described by the paper as a "methodology that accurately identifies jobs associated with distal upper extremity disorders versus jobs that are not." The tool uses six different parameters to assess risk: Intensity of Exertion, Duration of Exertion, Efforts/Minute, Hand/Wrist Posture, Speed of Work, and Duration per Day. These factors are estimated to determine a multiplier for each one and, the product of all these multipliers is the result. After a brief description, the tools are put up in a head to head analysis.

The researchers use both RULA and SI in an automotive plant to assess and compare the results of these two tools. The results of the two tools were very different. RULA ranked over half of the tasks as low risk and SI ranked over half of the functions as high risk. This is because each tool is not applicable to every situation. RULA is described as more posture based while SI is more intensity driven. This leads me to believe that IErgo has a place in the industry to help ergonomic professional determine the right tool for the job [15].

2.1.5 Risk Assessment in Construction

Often in industry, it is challenging to assess risk and is extremely time consuming. The author then creates a tool called RAM (Risk Assessor Model) that will more effectively assess risk in significant construction activities. The RAM tool determines the risk associated with a particular activity and the justification factor for a remedy to the problem. The tool is menu-driven and only requires knowledge of activities and work activities. This allows the user to not rely on recalling formulas or mathematical operations, but instead use a friendly graphical interface.

The author follows an eight-step approach to assess the risk of the user's situation.

1. Select the activity that will be analyzed.
2. Conduct a pre-analysis inquiry on the selected activity by asking for:

   a. The equipment used in the operation.
   b. The materials and hazardous substances used.
   c. The working environment.
   d. Use of protective equipment.
3. Specify the severity of an accident for the selected activity.
4. Specify the amount of human exposure to the situation.
5. The tool determines the risk score of the activity
6. If the risk is high enough, the tool recommends corrective actions to the user.
7. The tool will calculate the justification factor based on the corrective action.
8. The tool will determine if the corrective action is justifiable. [12]

2.1.6 The Development of a Measure of Safety Climate and the Role of Safety Perceptions and Attitudes

This study aimed to implement a measure of perception and attitudes about the culture of safety in workplaces. The opinions and views of the workforce are essential factors in assessing safety needs. Safety solutions may fail if they do not take into consideration of these prevailing attitudes and perceptions. Safety climate has been researched for nearly 25 years, and there have been many attempts to develop methods which can be used to measure the concept. The two factors that were interpreted to affect the safety are identified as to be management, commitment to safety and workers' involvement in protection. The main idea was to develop a tool that measures attitudes, perceptions, and awareness of safety that are considered to be related to safety climate in workplaces. The approach used was to implement an initial pool of items and then use factor analysis and an item analysis approach to develop scales to measure workplace perceptions and attitudes about safety [14].

Methods

1. Development of an item pool. Eight aspects were identified to form an item pool by considering one or more studies of safety climate.

    1. Safety awareness
    2. Safety responsibility
    3. Safety priority
    4. Management safety
    5. Safety control
    6. Safety motivation
    7. Safety activity
    8. Safety evaluation

2. Determining the format for measuring visual analog scale with descriptors like (True/False or Always/Never)
3. Administering the questionnaire to a development sample

Results

By using all these methods for ensuring the safety of workers these three rules are formed by following these rules the worker's safety can be guaranteed.

1. Safety is the responsibility of both management and the worker's together.
2. Management should be as concerned with people's safety as how it is with profits.

3. Workers should wear safety equipment when required.

Conclusion

Two important considerations can be formed from this study about the concept of safety climate. The first consideration is that it is necessary that, we should not confuse separate approaches to the idea. Approaches differ on what it is assumed to be the components of safety climate. One method assumes that the actual characteristics of the workplace generate safety culture and that they can be discovered by questioning workers about their thoughts regarding the status of these characteristics. The item pool used in this approach consisted of questions about attitudes to safety as well as questions about perceptions of security in the worker's workplace. The use of these both types of items provides an advantage of giving insight into the worker's orientation towards safety from two points. These questions reveal aspects of worker's beliefs about safety which are mostly developed through experiences inside and outside the workplace [16].

2.1.7 Development of Toolkits for Hazard Identification, Risk Assessment and Prevention of WMSDs based on a Collaborative Platform

In addition to discussing the development of various toolkits for identifying hazards, assessing risk and preventing Work-related Musculoskeletal Disorders (WMSDs) this paper also describes a strategy to uphold the application of the existing European Standards (EN) towards mitigating risk in industrial countries.

In countries like Spain and France, work-related musculoskeletal disorders are responsible for over 50% of occupational injuries [9]. These people must then leave work, have lower standards of living, and not be able to perform all the physical functions they once possessed. A workplace with no WMSDs will significantly increase productivity, and so many ergonomists have been working to make it a possibility. The author also states that it is difficult to find the perfect tool for assessing the risk associated with WMSDs and there exists a “big gap between applications and EN standards within European regions” [9].

2.2 Responsive User Interface Design

2.2.1 Proceedings of the Human Factors and Ergonomics Society: Developing Schemas for the Location of Common Web Objects

When designers are developing websites, the layout of elements is left to the designers’ intuition and the guidelines that they follow. This paper explores web-users’ mental models and examines whether it is beneficial to capitalize on user’s pre-existing mental models to aid their design. It argues that by developing for this and incorporating into the design process, the resultant product will be more usable and accommodating of human factors. Further, it raises the question as to when these shared mental models are ingrained in the user to determine if there a difference between the expectations of long-time users compared to users that have only been using the web for less than a year.

To conduct this study, a total of 346 participants were examined; 109 of which were novices, and 237 were experienced users. To ensure that results weren’t biased in the case where users spent more time on a particular site, and more influenced by one design philosophy, participant’s responses to a ‘most visited site’ questionnaire signified that no site had been visited a significant degree over any others. Participants were given a depiction of a web browser that had eight horizontal and vertical grid lines and a set of cards representing common web UI elements. Participants had freedom and flexibility to place them wherever they saw fit. The researchers then evaluated and calculated the percentages of how often UI elements were placed where and normalized across the ranging experience of the participants. The results suggest that users do have perceived expectations concerning the placement of web objects and that these expectations tend to be created and standardized within one year of web use. [17]

2.2.2 The Essential Guide to User Interface Design

The author explains that proper design of user interfaces is essential. A user interface is a means by which users interact with a computer system which comprises of the user input (example typing with the keyboard, clicking with the mouse, etc.) and output (voice, screen, etc.) via the use of software. The screen is what enables you to view objects, colors, text, etc. on computer devices. For example, on visiting a website, the first thing a user observes is the color, font, and layout. A well-built website increases productivity, saves time and attracts more users. Guidelines for interface design process states that you must know your users to suit their needs better, satisfy their requirements and goals for building the system, use good fonts, sizes, colors, and have well-designed layout, navigation buttons, controls, menus, etc. and finally test the system [23].

2.2.3 Responsive web design: A new type of design for web-based instructional content

With the increasing number of people that use mobile devices instead of desktop computers, there is a need for responsive web design. Ethan Marcotte is an independent designer that coined the term “Responsive Web Design” (RWD) in 2010, which describes a way of designing for various screen sizes and resolutions and till now, many developers have adopted this technique. [24]. RWD has many advantages of web contents easily displayed on any mobile device as it will on a desktop computer, it removes the need for a zoom and left-right scroll bar since every content fits the size of the mobile screen. It also prioritizes the display of texts and images as the screen sizes change and it saves time and cost of building a mobile-friendly site.

Figure 1: Screen display on different screen sizes - desktop, laptop, tablet and mobile phone

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2.2.4 Research through Design in HCI

This paper focuses on connecting Research and Design. “Research through Design (RtD) is an approach to conducting scholarly research that employs the methods, practices, and processes of design practice with the intention of generating new knowledge” [8]. They explain that the practice of RtD in HCI makes researchers more active and creative of the “world that they believe to be better than the one that currently exists” [8]. Christopher Frayling coined RtD in

1993 and he provides three frameworks for research: Research into Design which deals with research into design activities [10], Research for Design which deals with researching how to improve design [11] and Research through design which focuses on developing the already existing model thereby building for the future [25].

3. METHOD

This chapter introduces the research problem, questions and the hypotheses of the study.

3.1 Study of the Problem

Over the years, there have been many publications about risks associated with workers in various companies. A survey conducted by the faculty of Manufacturing Engineering, Universiti Malaysia Pahang, Malaysia among workers at core assembly production of electronic components manufacturing company was done to assess the work-related musculoskeletal disorders (WMDs). There were 30 out of 36 respondents that suffered from WMDs mostly at shoulder, wrists and lower back [18]. Low back pain (LBP) is a common and significant musculoskeletal disorder (MSD) with a lifetime prevalence of 84% [19]. LBP ranked highest in global disability and sixth in overall burden [20]. Most of the time, workers are not aware of the risk they face at their workplace and are overwhelmed with all the available applications to help assess that risk. Therefore, IErgo is essential. It supports novice ergonomists in selecting the appropriate tool that can evaluate the risk and help them have a healthy working environment.

3.2 Hypotheses

The usability of the IErgo application will be evaluated based on ease of use, effectiveness, aesthetics, efficiency, and satisfaction. A 5-point rating scale will be used, and the benchmark is a rating of greater than 4. The survey will be conducted on a population of 34 students in a computer science class and evaluations above the baseline is considered satisfactory. These are the areas that will be assessed:

A. Ease of Use:

This application was built with the end users in mind. It is direct and easy to use.

B. Effectiveness:

The web pages are fast and direct. It has a definitions page and a set of questionnaires to help the user assess his/her risk. It will provide immediate feedback to the user.

C. Aesthetics:

The color and font size of this application were carefully chosen. The layout was carefully designed with an appealing interface.

D. Efficiency:

The code complexity used for this application was the best approach, and it is also swift.

E. Satisfaction:

This application is designed to satisfy the end users completely.

3.3 Specification

The Specification depends on the Wireframe and the Software & Hardware requirements.

3.3.1 Wireframe

The wireframe was built to navigate through the web pages quickly. The first page welcomes users, and there is a start button in the middle of the screen to click as shown below. That page takes you to where you click to see all the available tools to glance through and learn or take a quick questionnaire which will suggest some tools at the end. The interface is neat, and there are no confusions of what (or what not) to click or what to do. It was designed to give the users fast feedback as they advance through the pages. There is also a back button in case the user makes a mistake or decides to start over.

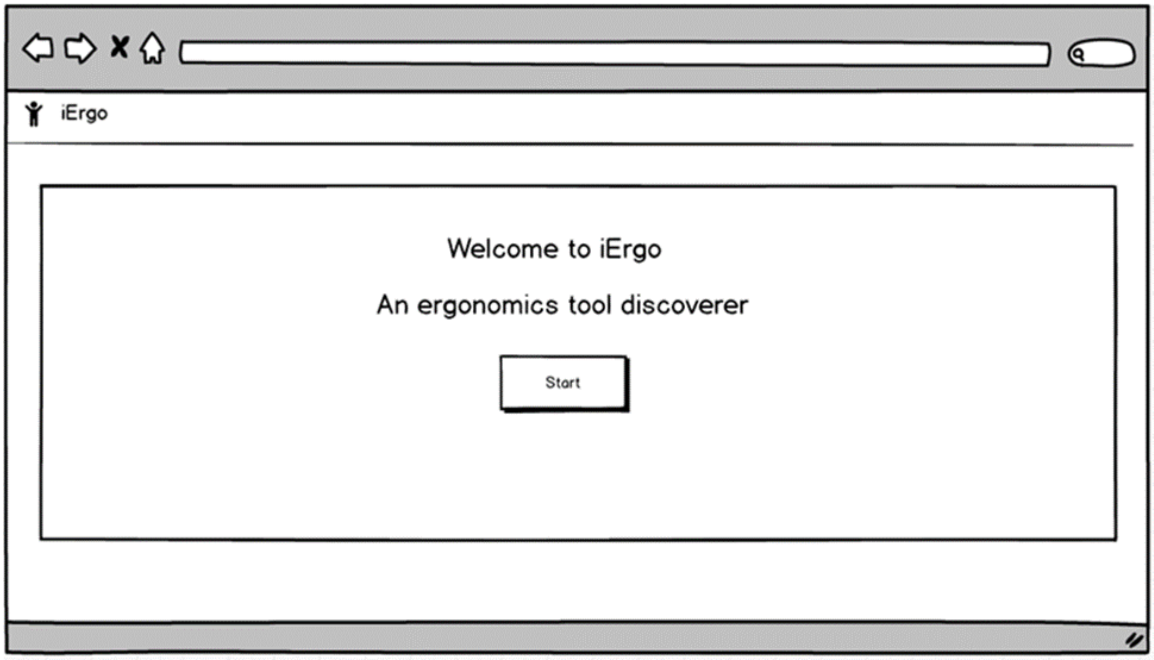


Figure 2: Initial Wireframe for the home page

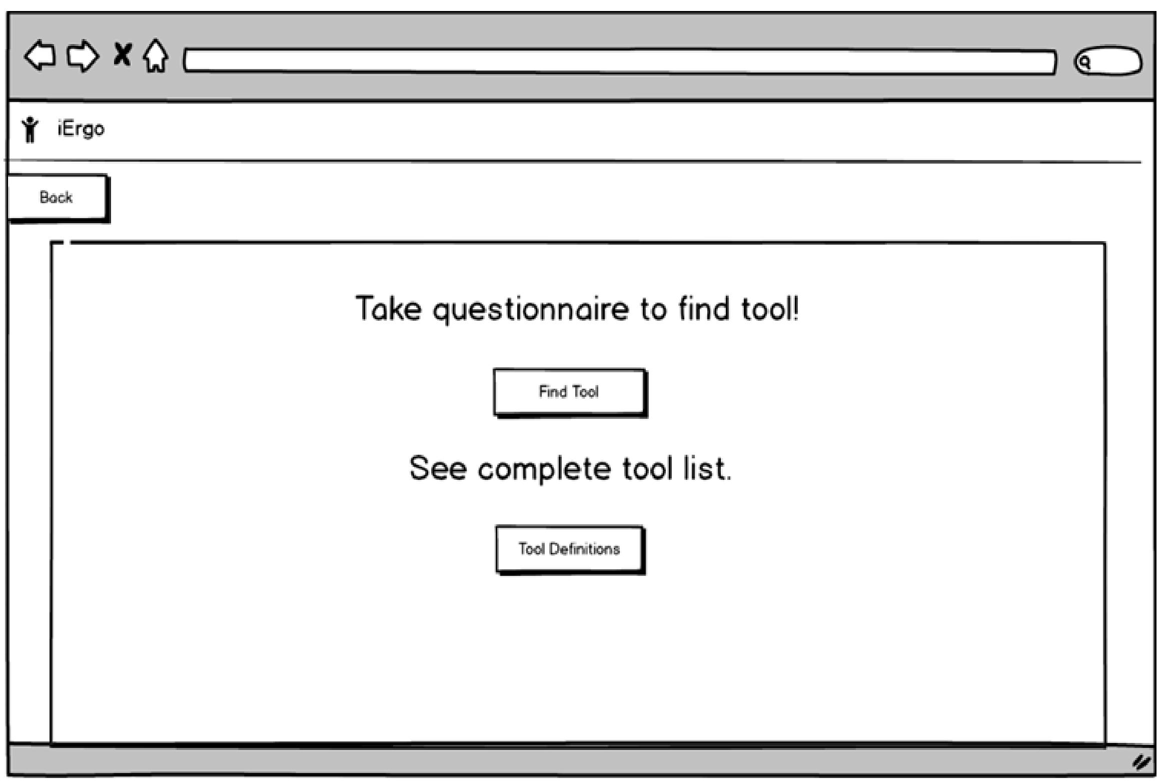


Figure 3: Initial wireframe for questionnaire and definitions page.

3.3.2 Software & Hardware Requirements

With the technological advancement today, most people use their mobile devices for day to day activities. This web application was built to be used on a desktop or mobile device without any difficulties. The software requirement is a modern web browser such as Google Chrome, Mozilla Firefox, Safari, Opera, Microsoft Edge and Internet Explorer. The hardware requirement is a desktop, tablet or mobile device that that supports internet access.

3.4 Conceptual Model

The Conceptual Model specifies the flow chart for the application, lexicon, software development process, functional requirements, and scenarios.

3.4.1 Flowchart

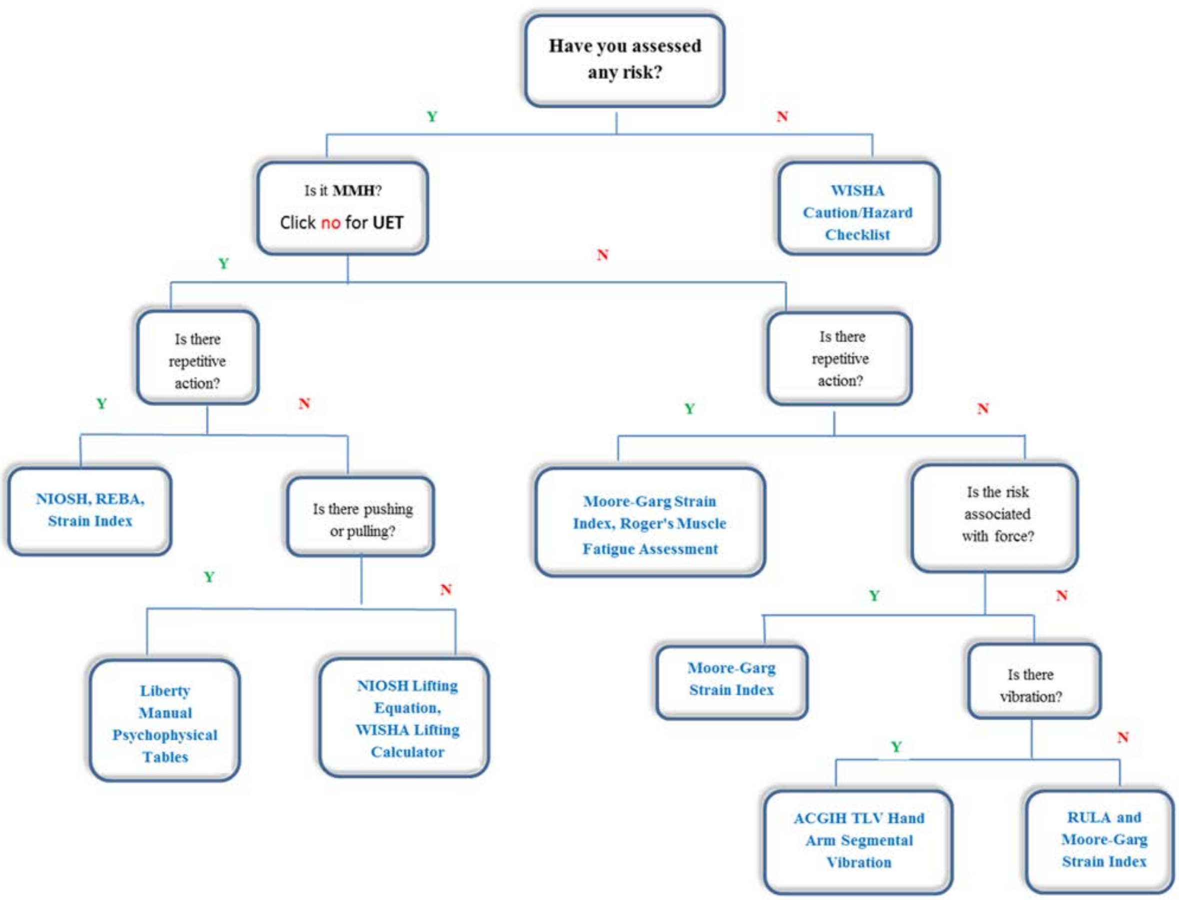


Figure 4: Flowchart for IErgo

The above picture is the flowchart used to build the questionnaire pages for the IErgo application. It first asks whether you have assessed any risk. If “No” then the suggested ergonomics tool is the Washington Industrial Safety and Health Act (WISHA) checklist which is used to perform a quick analysis of a lifting job to determine the need for more detailed analyses. If “Yes” then the next step is to determine whether it is Manual Materials Handling (MMH) or Upper Extremity Tendinitis (UET). Depending on the response of the user, a tool is suggested at the end of the questionnaire.

3.4.2 Lexicon

There are a lot of terms concerned with this ergonomics web application. They are all listed below:

- MMH: Manual Materials Handling (MMH) means moving or handling things by lifting, lowering, pushing, pulling, carrying, holding, or restraining.
- UET: Upper Extremity Tendinitis is a condition affecting the tendons of an upper extremity (limb) which include the shoulder, upper arm, elbow, forearm, wrist, hand, and fingers.
- NIOSH (National Institute for Occupational Safety and Health): NIOSH is a federal agency that research about work-related injuries and their prevention.
- OCRA (Occupational Repetitive Action Index): This is a measurement tool that measures workers’ risk by comparing repetitive actions of their upper limbs which include the shoulder, upper arm, elbow, forearm, wrist, hand, and fingers to the recommended actions.
- OSHA: Occupational Health and Safety Administration
- REBA (Rapid Entire Body Assessment): A tool designed for the general users to

develop a postural analysis system sensitive to musculoskeletal risk in a variety of jobs. This is based on body segment specific ratings within specific movement planes, using a scoring system for muscle activity including static, dynamic, rapidly changing or unstable postures, and provide a benchmark for the urgency of action.

- LBP: Low Back Pain
- RULA (Rapid Upper Limb Assessment): A tool designed for the general users to investigate the exposure to risk factors for upper limb disorders and provide a method of screening work population quickly so the results that could go into a broader, more versatile ergonomic assessment, while eliminating the need for assessment equipment.
- Rodger's Muscle Fatigue Assessment: A tool designed for the professional users to measure the amount of fatigue that accumulates in the muscles within five minutes during an activity.
- Strain Index: An index used to provide a relatively simple risk assessment method designed to evaluate a job's level of risk for developing a disorder of the distal upper extremities.
- Moore-Garg Strain Index: The Strain Index proposed by Moore and Garg to assess jobs for risk of work-related musculoskeletal disorders (WMSDs) of the shoulder, upper arm, elbow, forearm, wrist, hand, and fingers.
- WISHA (Washington Industrial Safety and Health Act): This empowers Department of Labor & Industries (L & I) to create and enforce safety and health regulations. It allows Washington rules/laws to be more stringent than OSHA's if needed.
- Force: This is a push or pull associated with performing a task. Increased force leads to increased risk which is a high factor of work-related musculoskeletal disorders such as

low back pain and injuries to the shoulder, upper arm, elbow, forearm, wrist, hand, and fingers.

- Load: The weight of the object lifted.
- Washington State (WISHA) Lifting Calculator: This tool is designed for the professionals trained in ergonomics and general users to perform a quick analysis of a lifting job to determine the need for more detailed reports.
- NIOSH Lifting Equation: This tool is designed for the professionals trained in ergonomics and general users to provide an easy-to-use and simple job analysis tool to control overexertion injuries associated with manual material handling and lifting.
- Posture: This is the way the body and muscles are positioned while at work. Awkward posture is associated with an increased risk for injury. It is the angle formed during a work activity which may create injuries to the body.
- Repetition: Repetition is the number of similar exertions performed during a task. Repetitive motion has been associated with injury and worker discomfort.
- Risk Factors: These are characteristics that can create or aggravate work-related musculoskeletal disorders. Some examples include lifting heavy boxes, repetitive actions, bending, stress, strain, etc.
- Musculoskeletal Disorders (MSD): Injuries and disorders of the muscles, nerves, tendons, ligaments, joints, cartilage and spinal disc; examples include carpal tunnel syndrome, rotator cuff tendonitis, and tension neck syndrome.
- WMDs: Work-related musculoskeletal disorders.
- AIHA: American Industrial Hygiene Association.

3.4.3 Software Development Process

The Scrum process was used to coordinate development efforts. Each member met up regularly to report our progress, the next phase, and any blocking issues. At the end of our sprint, we had our sprint review and performed all compelling presentations and deliverables. Our sprint lasted for six weeks with each member working on tasks to iteratively and incrementally improve the product. Each task included analysis of the problem, designing a solution, implement the solution, and testing. The sprint began with an analysis of the functional requirements and deliberating on changes to be made to the existing software. After that, we worked on design portions of the software, implementing features and testing them. These processes were repeated until all functional requirements were fulfilled.

3.4.4 Functional Requirements

The project began with a few pre-existing functional requirements, and after that, additional requirements were made in the next development iteration of the IErgo project.

1. Assist with choosing a tool for risk assessment
2. Link to the selected assessment.
3. Adaptively help the specialist with his choice.
4. Help the specialist to read the description of the tools.
5. Help the specialist review the tools.
6. Explain the significance of a chosen tool.
7. Improve aesthetics, reduce and condense descriptions.
8. Improved and add navigation tools to assist the user in choosing the correct tool.
9. Help users navigate questions better by quickly being able to browse past questions.

3.4.5 Scenarios

This is a low-fidelity prototype of the application. The wireframes will be used to describe two scenarios. In the first scenario, a newly employed construction worker is curious about the IErgo app and decides to test it out. On accessing the web app, the home screen welcomes him and asks if he wants to complete a questionnaire to help him choose a tool or if he wants to read about all the available tools. He clicks the “Tool Definitions” button to view all the available tools, and then he clicks “Find Tool” button to assess his risk. See figures below:

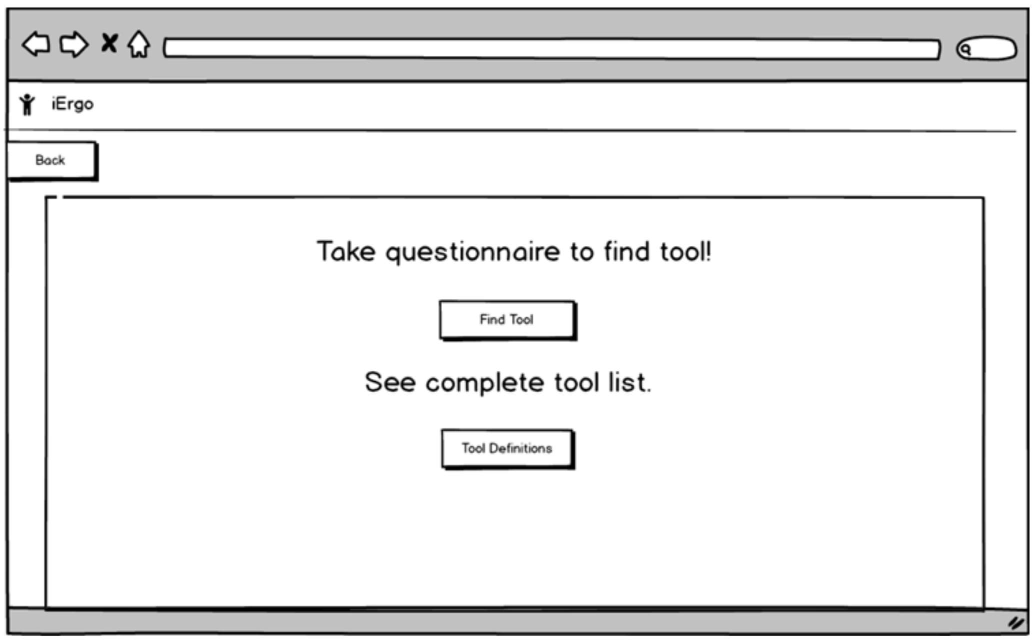


Figure 5: Scenario to click definitions or questionnaire.

The first question on clicking the “Find Tool” button is to know if the user has assessed any risk. Subsequent queries will adaptively help the user choose a tool based on his responses.

Figure 6: Scenario asking if you assessed any risk

In this scenario, the employee is still new and has not assessed any risk yet. He is suggested to use the Washington State Lifting Calculator (WISHA) for quick detailed analysis of lifting jobs which can help mitigate risks. After that, the user can decide to start over or exit the application.

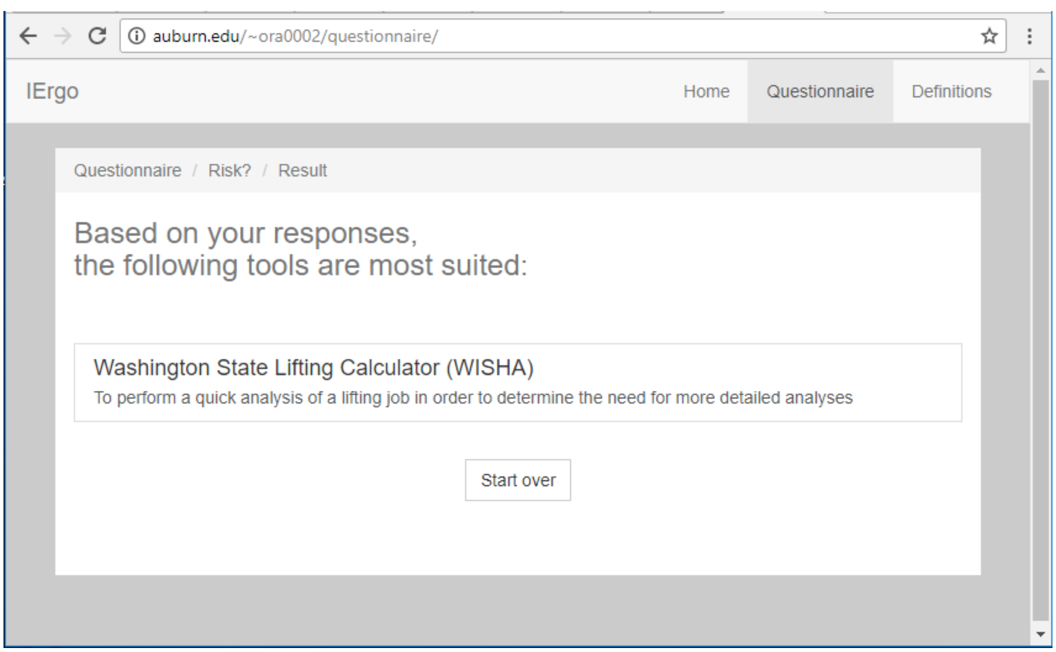


Figure 7: Suggested ergonomics tool 1

In the second scenario, a young man Robert is loading boxes to a big truck and is required to lift approximately 15 boxes a day. Because he bends and carries a lot, he has started feeling pain around his waist, shoulders, and arm. He uses the IErgo app to help him choose the best tool for the risk assessment of MMH (Manual Material Handling) with repetitive action. He is suggested three tools: NIOSH, REBA and Moore-Garg Strain Index which are best for his scenario.

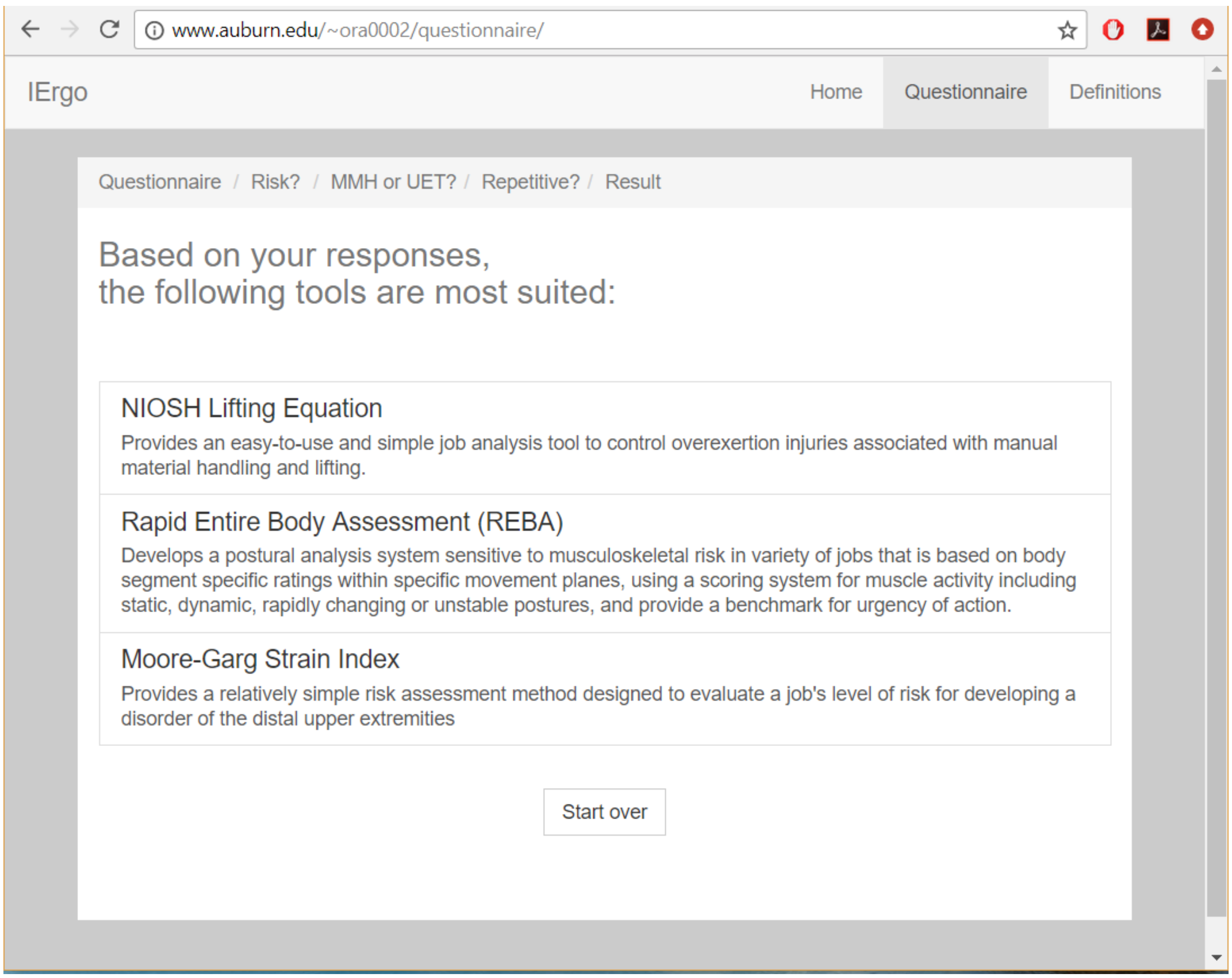


Figure 8: Suggested ergonomics tools 2

3.5 High-fidelity Prototype

The focus of the conceptual model is to make the application the most accessible, aesthetically pleasing, and helpful to provide the best experience possible for our users. At the very beginning of this application, a straightforward way to access the main functionalities of the product was being provided.

3.5.1 Home Page

This welcomes the users by providing an initial home page that acts as a "home base" and gives them a sense of a place they can always return to when reassessing their options.

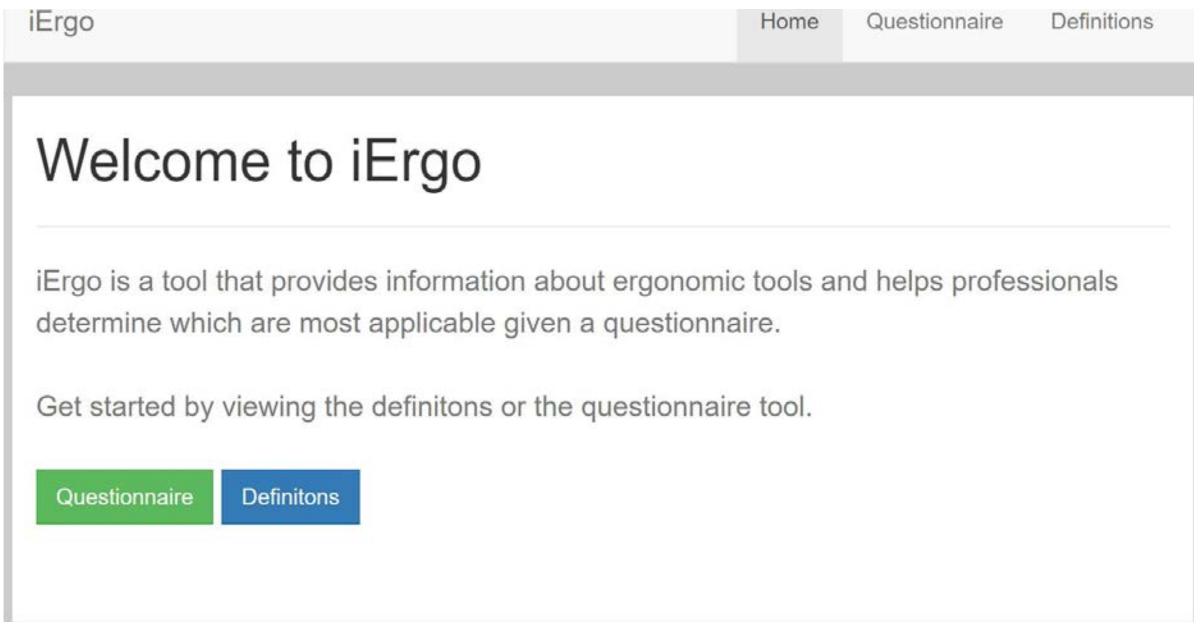


Figure 9: Home page

At the very beginning, the user is introduced using a straightforward message that identifies the central purpose of the product and gives the user two options: to discover a tool utilizing the questionnaire or to list the tools that IErgo supports. This brings the primary two functionalities front and center to the user. From the very beginning, the user understands IErgo's purpose as a software that is used to discover the most applicable tool for ergonomics professionals or general users and be able to access it from the very beginning. At the top of the figure, you will also notice a navigation bar. This contains a link to the questionnaire, all the tool definitions, and two links to the homepage: the IErgo text in the top left, and the "Home" button on the right. This is to give people instant access to these core features at any point the product is being used.

3.5.2 Questionnaire Pages

The questionnaire pages aim to provide a means for users to discover the proper ergonomic tool that they need through taking a short survey. See below:

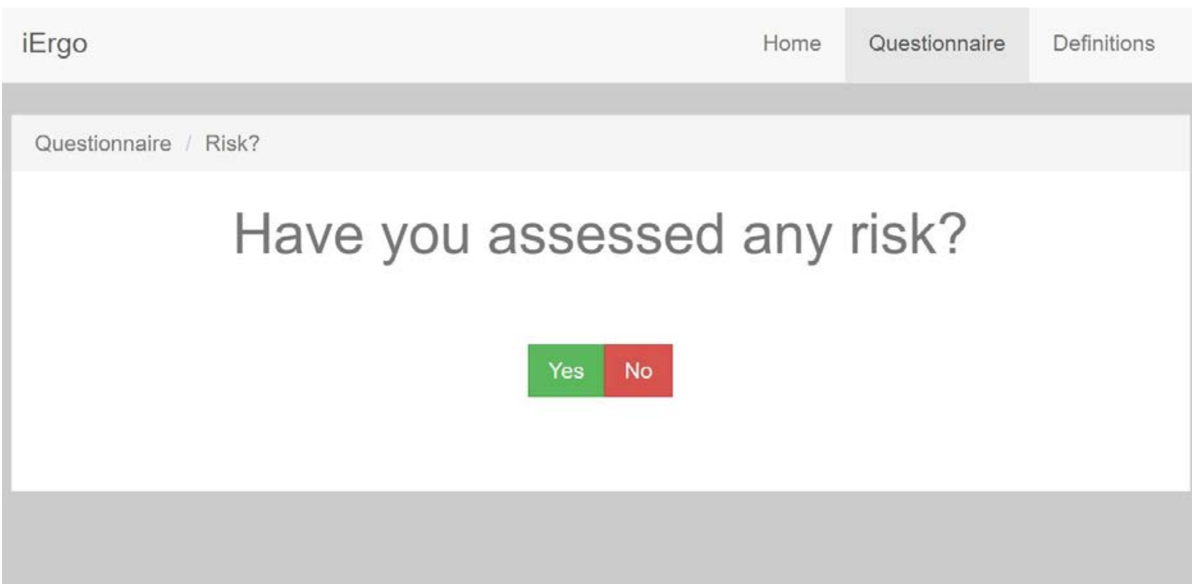


Figure 10: Questionnaire page

One clicking the "Questionnaire" button, the user immediately starts the survey. This was a deliberate decision to connect users to content within the webpage quickly. This was built in a way as not to waste the user's time with an introduction to the quiz. The questions are simple enough to begin discovering the tool the user desired immediately. This is believed to be especially true when the user repeats a survey and already understands the process.

3.5.3 Text and Mappings

When taking the questionnaire, the user is asked short and simple questions. This aims to help rid any confusion that the user may have when making a decision. One of IErgo's primary goal is to remove ambiguity from the very technical task of choosing an engineering tool. The simple questions are aimed to guide the user efficiently, quickly, and confidently through the quiz so that they can feel assured that their decision making was correct.

Each decision path is taken by pressing a button that corresponds to the user's choice. Looking at the buttons, we see there is a clear difference between the options. The "Yes" button is colored in green to accentuate an affirmative choice while the "No" button is colored in red to represent a negative response. The text on the button is printed in white which is aimed to contrast from the red or green background, and the font is Helvetica which seeks to provide a clear, readable font for a user interface. The coloring and the text on each button gives the user more confidence in the choice decided while taking the questionnaire.

The order of the buttons was also tactical. The best way to order the buttons was starting with the positive choice on the left and then the negative on the right. This is believed to be the best choice because of a human's natural tendency to say "Yes/No" and to start with a positive button rather than a negative. If there is not a yes or no answer, the choices are colored green and are presented in the most sensible order to answer the question.

3.5.4 Chosen Tool Pages

Once the user has answered all the necessary questions to determine a result, they are directed to a page with all the possible tools that may be apply to their situation. See below:

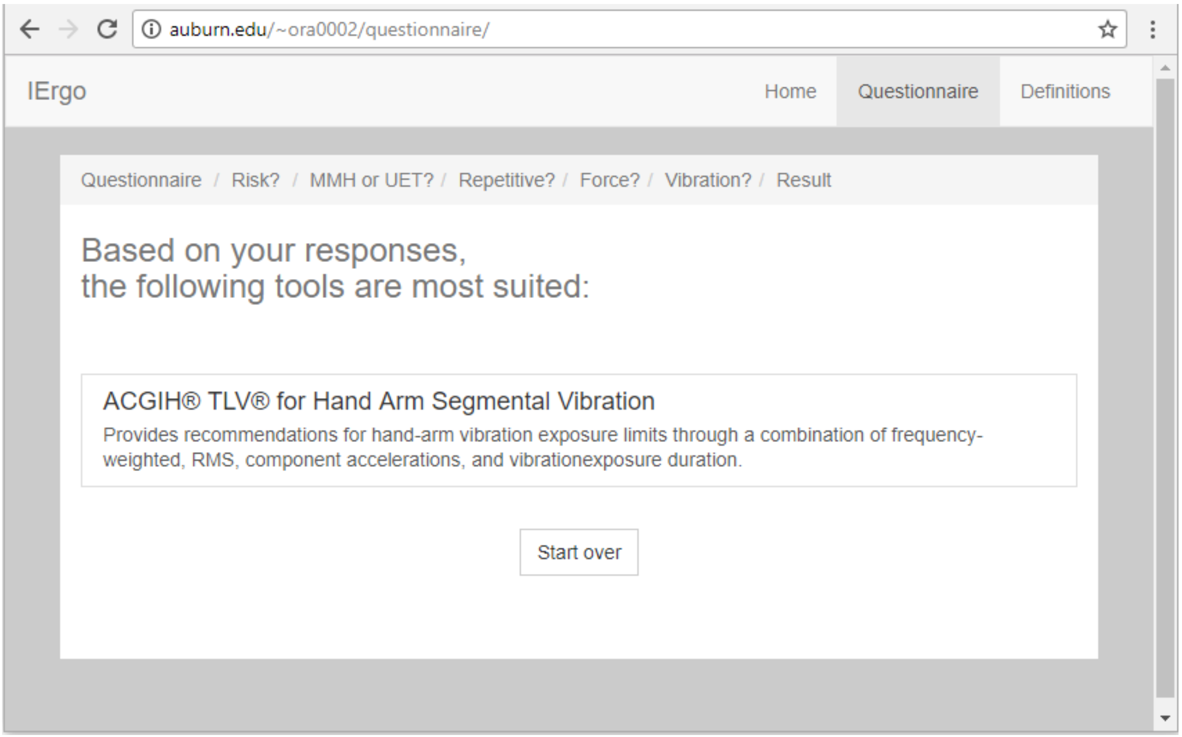


Figure 11: Possible Applicable Tools Page

The user then selects a tool from the list and is directed to a page about the tool. At the top of the page, the title font is in large Helvetica which is easily readable by the user. Immediately under this, the data concerning the tool is sectioned into three different sections: “Overview”, “About”, and “References.” The “Overview” section contains the essential information about the tool and is brought to the user’s attention first. Within the “Overview” section we are presented with an electronic version of the tool, what are inputs/outputs of the tool, and details on the situation where the tool is appropriate. The “About” and “References” section contain more supplementary information about the tool and are initially collapsed not to overload the user with too much information. The “About” section contains further information about the tool such as:

who developed the tool, whether it is copyrighted, and the resources needed to use the tool. The "References" section contains information about journal or articles that may provide validation to the tool as well as some additional locations to find supplementary information. See figure below:

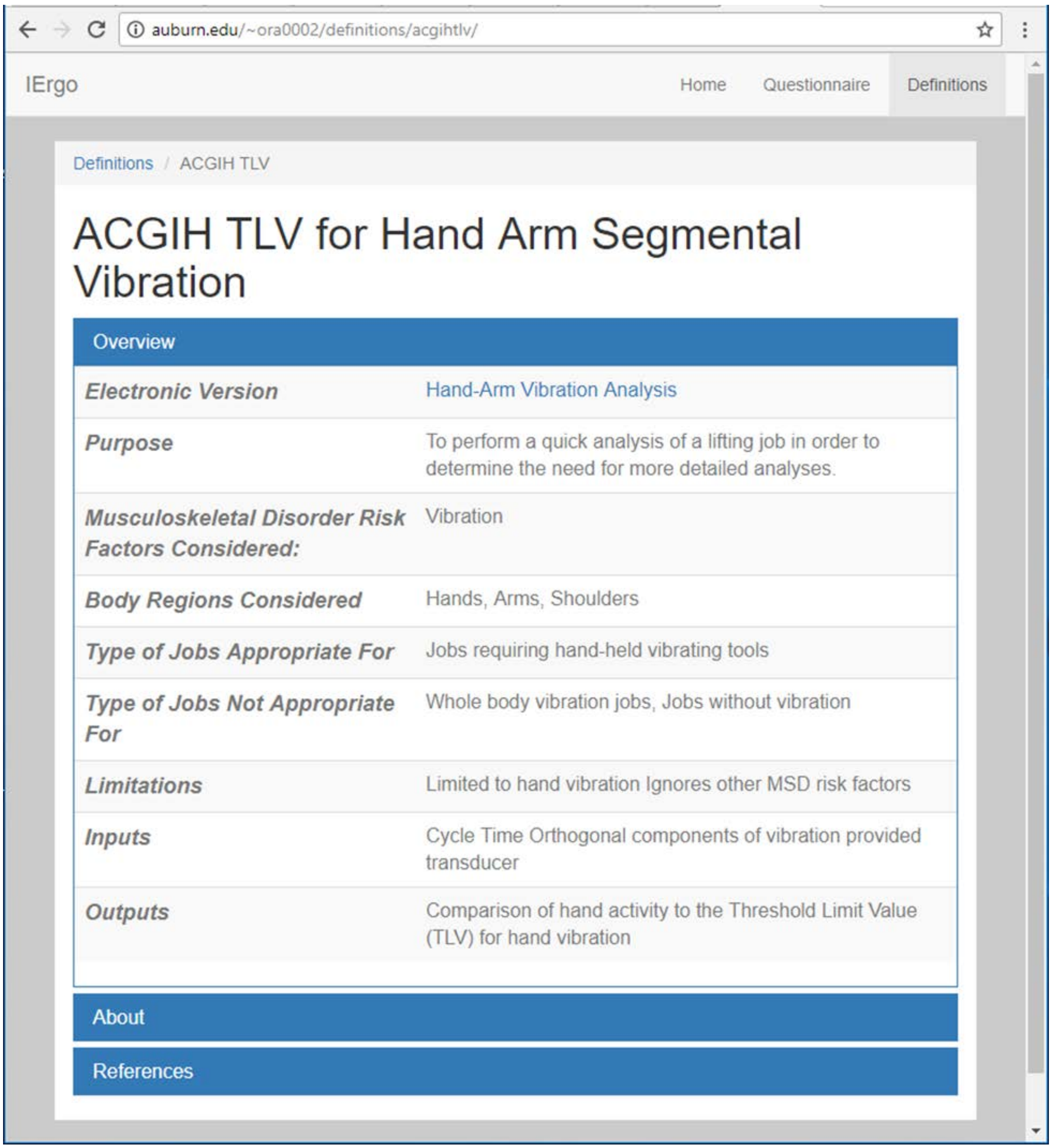


Figure 12: Tool Description Page

3.5.5 Tool Definitions Page

The tool definitions page contains every tool that IErgo provides in one list. This gives the user access to the tools outside of having to take the questionnaire. Here the user can survey all the possible means and get an overview of all the tools. See figure below:

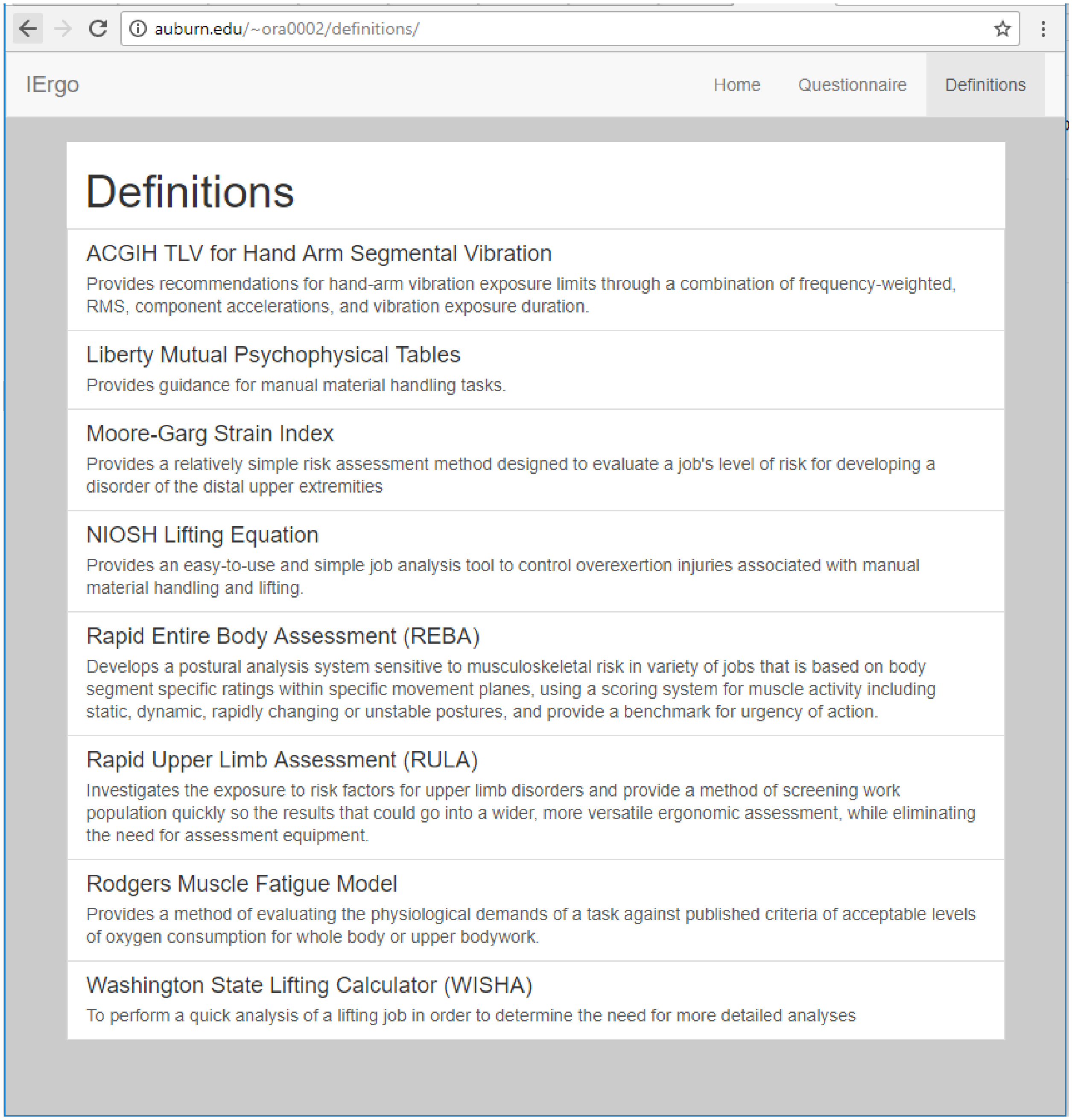


Figure 13: Tool Definitions Page

The tools are provided in a neat, orderly list and are in alphabetical order. The name of each tool method is displayed in large, Helvetica font to make each tool easily identifiable. Each title is accompanied by a description of each technique that gives a summary of what the tool does. This avoids creating the user select each tool to discover how it is meaningful and determine whether it can benefit them.

4. IMPLEMENTATION

This describes how IErgo application was implemented. The source code is written in HTML, CSS, and JavaScript. The Scrum process was used to coordinate development efforts. Each member met up regularly to report our progress, the next phase, and any blocking issues. At the end of our sprint, we had our sprint review and performed all compelling presentations and deliverables. Our sprint lasted for six weeks with each member working on tasks to iteratively and incrementally improve the product. Each job included an analysis of the problem, designing a solution, implementing the solution, and testing. The sprint began with an analysis of the functional requirements and deliberating on changes to be made to the existing software. After that, we worked on design portions of the software, implementing features and testing them. These processes were repeated until all functional requirements were fulfilled.

4.1 Functional Testing

The purpose of this test is to ensure that it conforms to the user's requirements. The functionality testing of IErgo was done using Selenium. It is one of the most popular browser-based functional test automation tool compatible with a wide range of browsers. One of its components - Selenium IDE was used as a plugin for Google Chrome for record and playback of the IErgo web application. All the links were tested and verified to be working correctly. The figure below shows a replay of the questionnaire button, every response, mouse over and click actions which completed successfully.

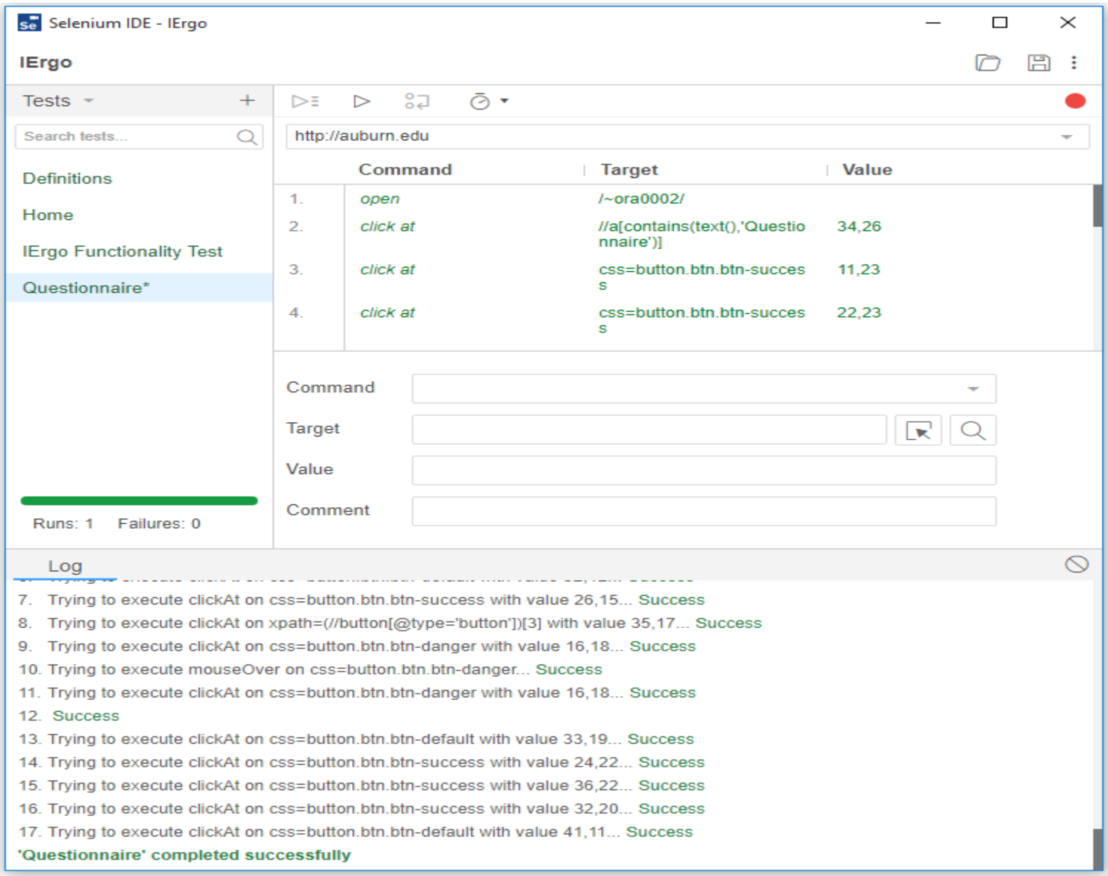


Figure 14: Functional testing of questionnaires

The picture below shows the playback of the overall functionality of the web application. All the buttons and links were tested and verified to be working correctly. Results show that the IErgo web application is fully functional.

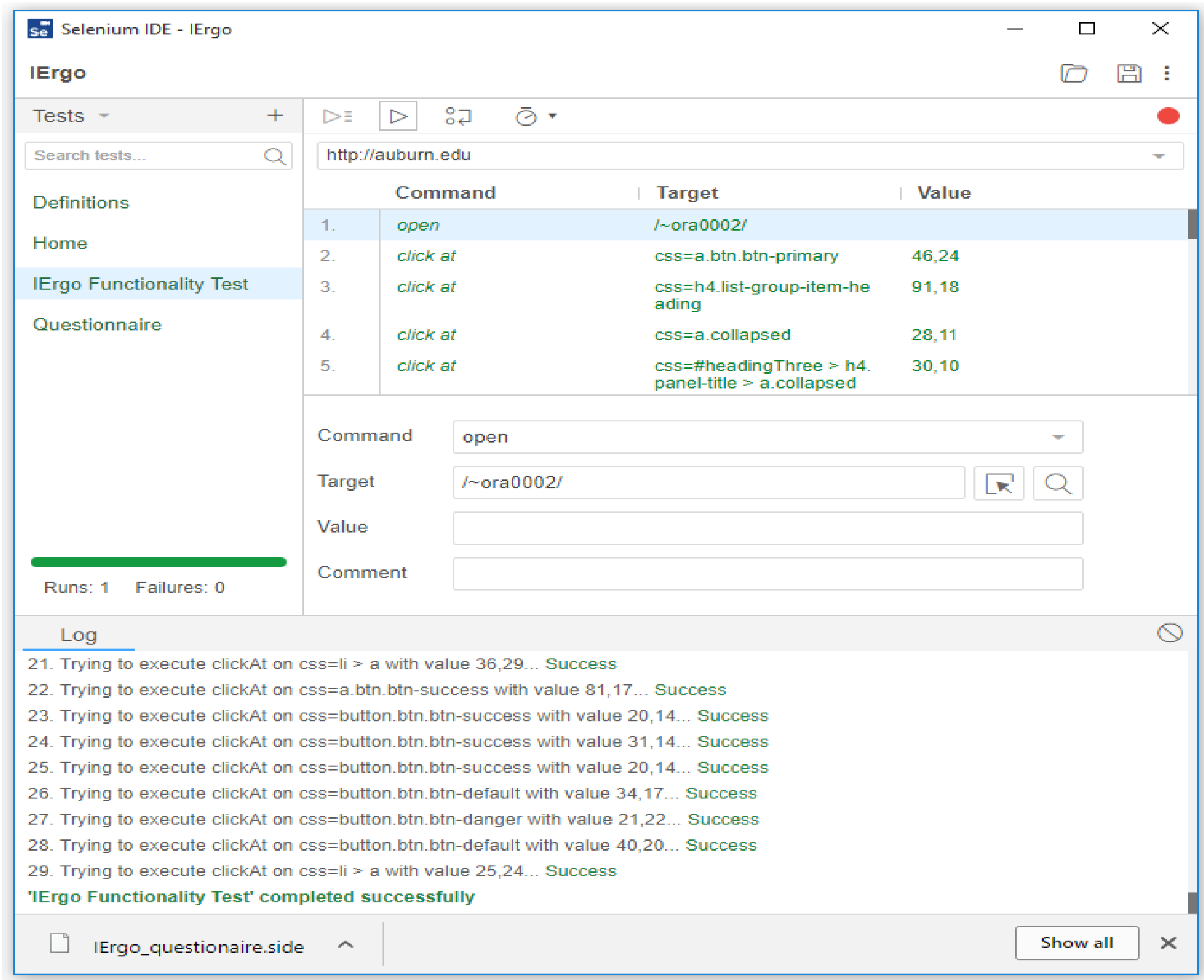


Figure 15: Functional testing of IErgo website

4.2 Performance Testing

This is done to check the speed of the system, its capacity, stability, accuracy, endurance, etc. The performance testing for IErgo was done using JMeter. It is an open source testing tool that runs on Java. This test is a virtual representation of real users under different conditions like the number of requests made by a single user or multiple number of users making one request. The KPI (Key Performance Indicators) like response time, latency, render time, maximum concurrent virtual users and throughput were also determined.

4.2.1 Load Test

In this test, the number of concurrent virtual users and number of iterations are fixed. In JMeter, users are referred to as threads, requests as samples and reports as listeners. The first test was with 1 thread, 1ramp-up period and 1 loop count which was successful. I also increased the loop count to 3 for a single user which was also successful as shown below.

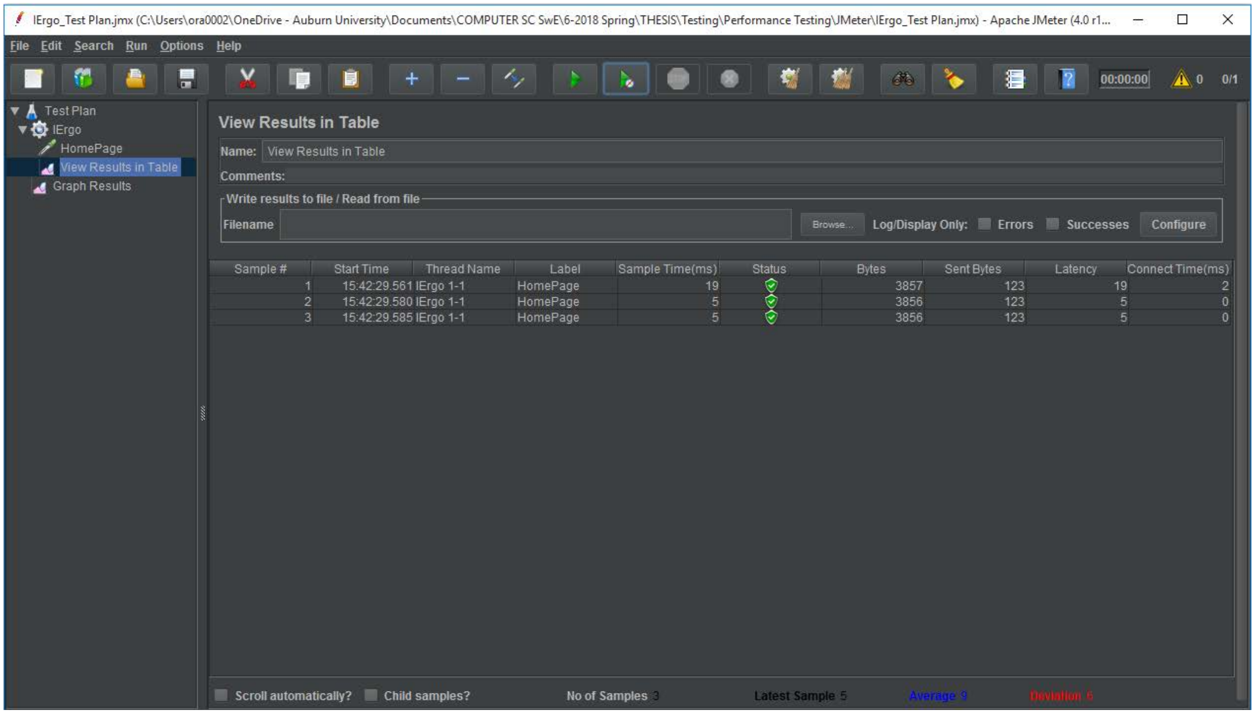


Figure 16: Load test for 1 virtual user with 3 loop counts

In the above figure, I created a test plan containing 1 thread group by the name IErgo. The IErgo application is currently hosted on my Auburn University web space, and the testing was done on the IErgo homepage: auburn.edu/~ora0002 as an HTTP request. It shows the number of samples to be 3 because there are 3 iterations for a single user. The thread name IErgo 1-1 means that it's the first thread group with 1 user. The sample time also known as the response time, latency and connect time are in milliseconds. The response time is the entire time it took JMeter to send the request over the internet, the time taken to process the request and to send the response back.

The number of bytes in the response is approximately 3857, and the latency of 19 ms is the time taken to send the first byte of response back to JMeter. The status is a green check which shows it was successful.

Furthermore, increasing the users to 50 and 100 were also successful as shown in the GUI and non-GUI figures below.

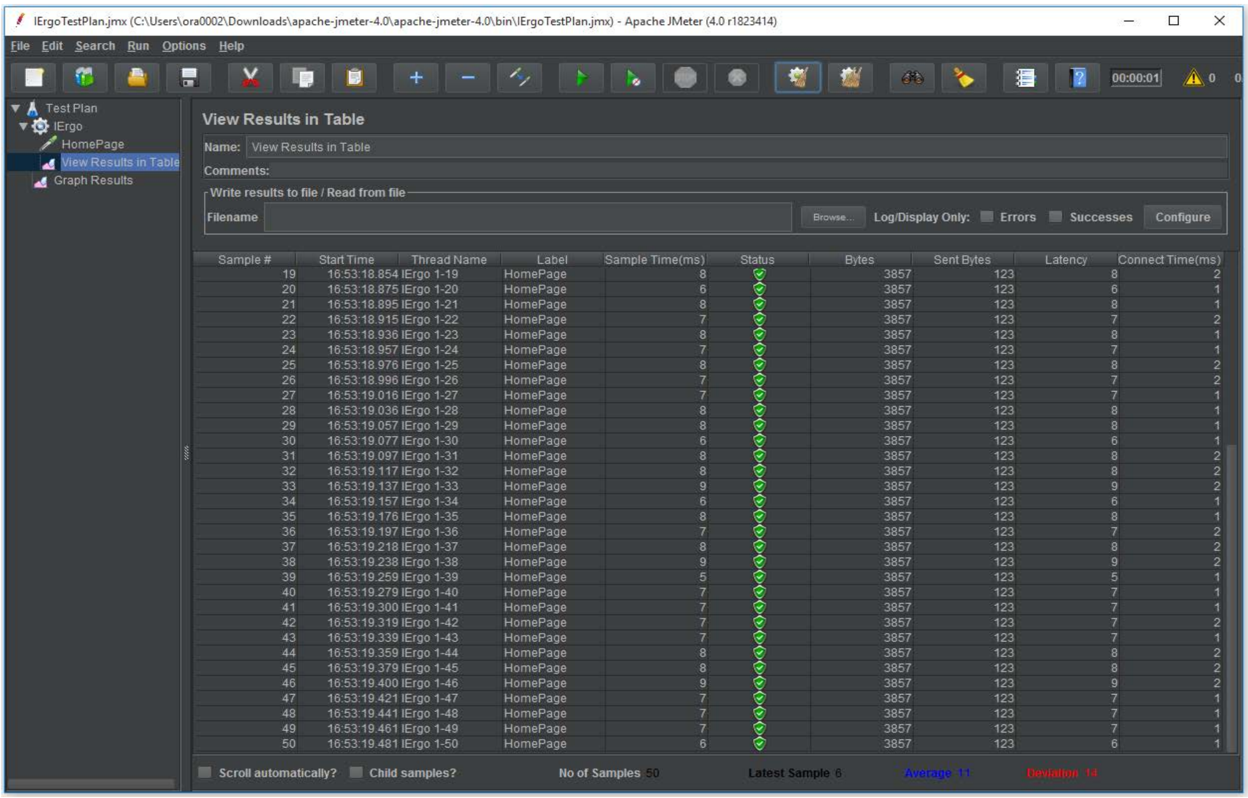


Figure 17: Performance testing for 50 virtual users on GUI

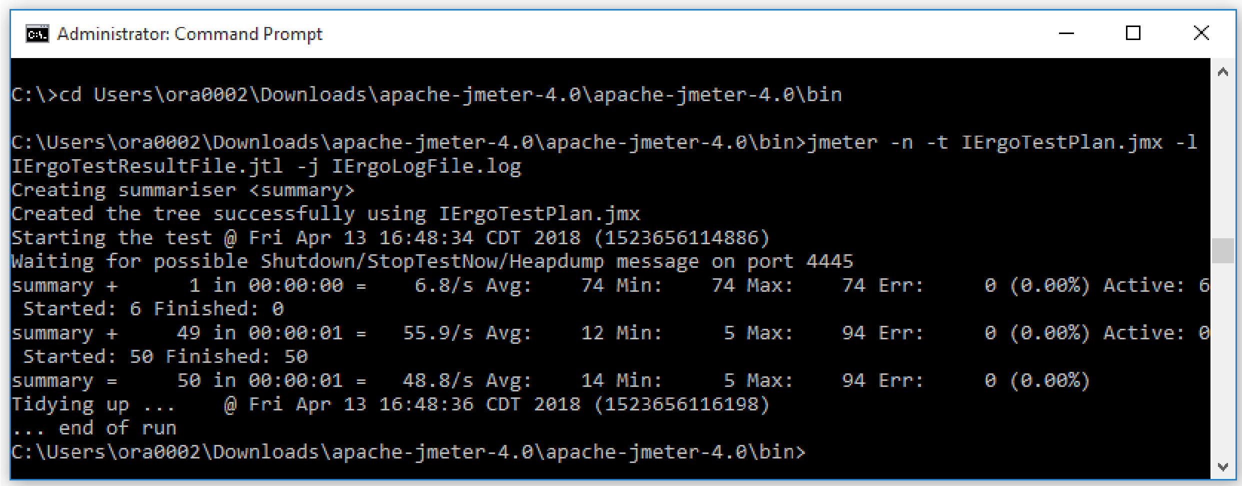


Figure 18: Performance testing for 50 virtual users on command prompt.

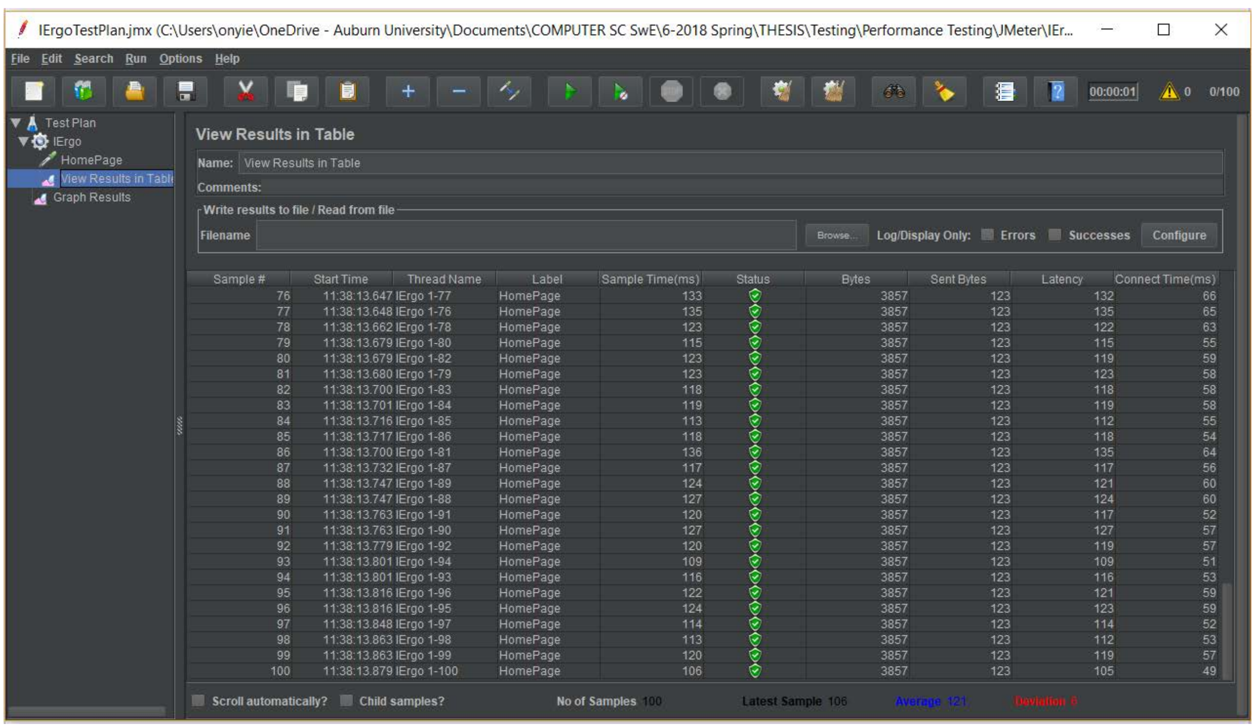


Figure 19: Performance Testing for 100 virtual users

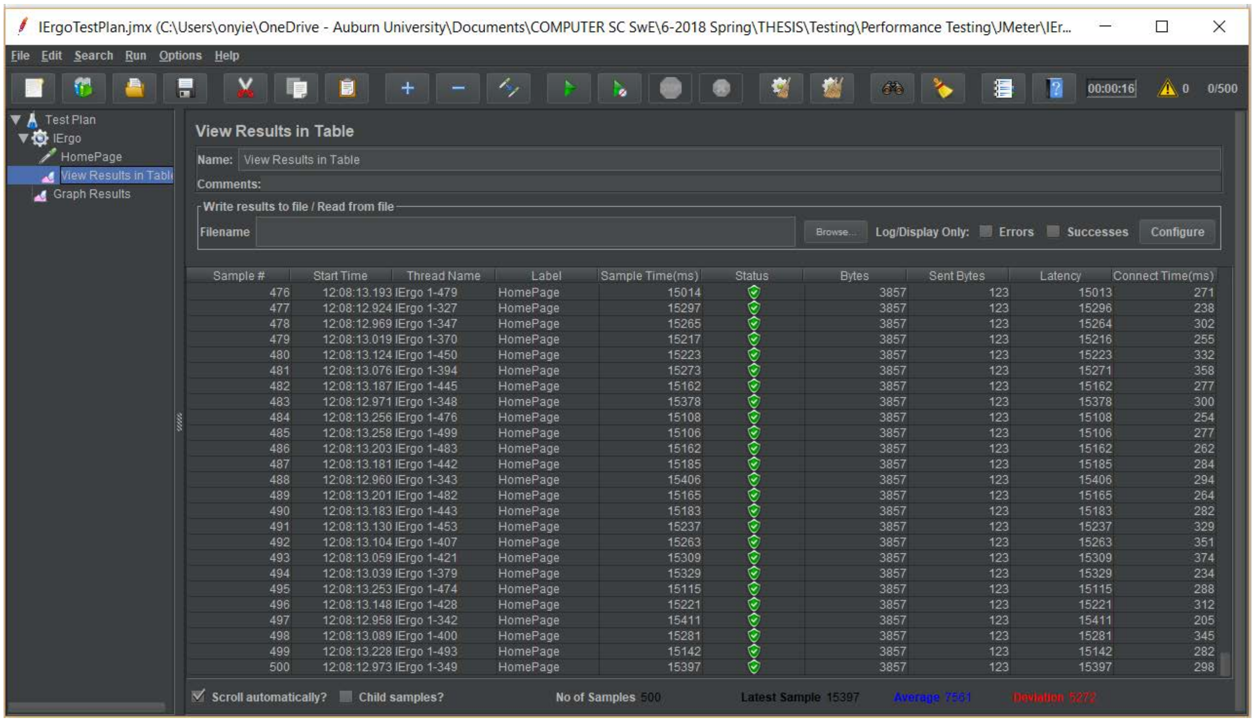


Figure 20: Testing for 500 virtual users

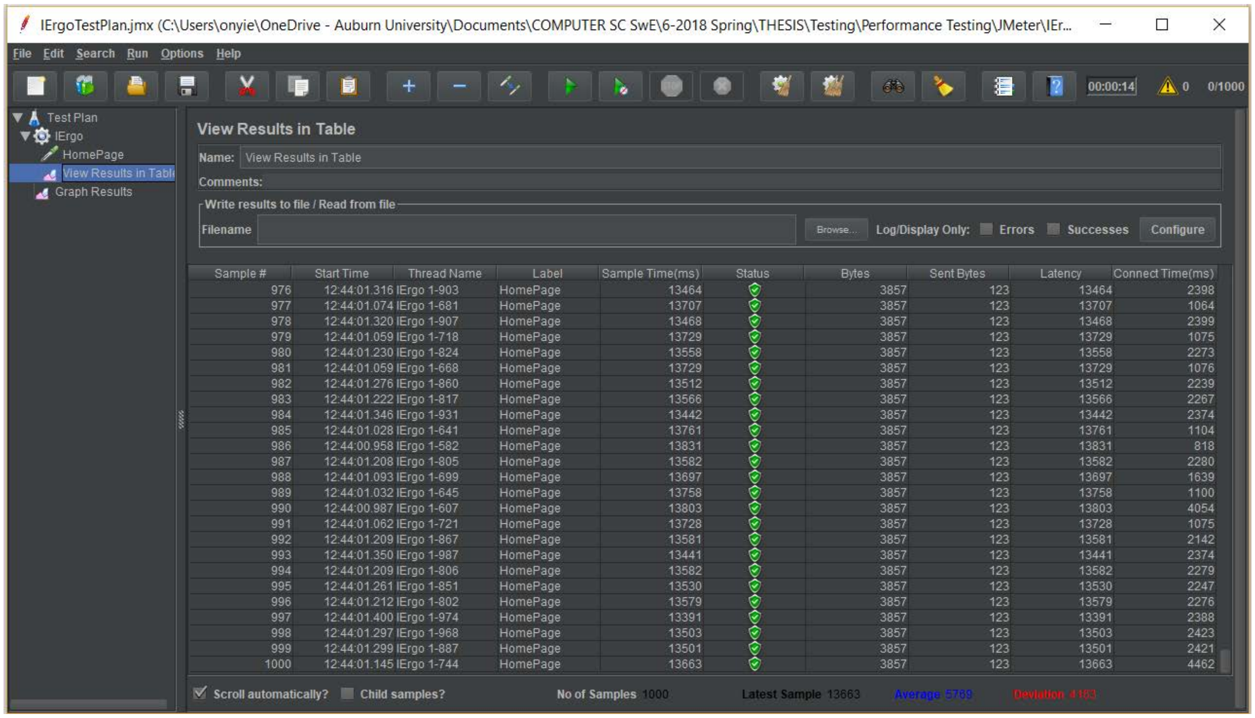
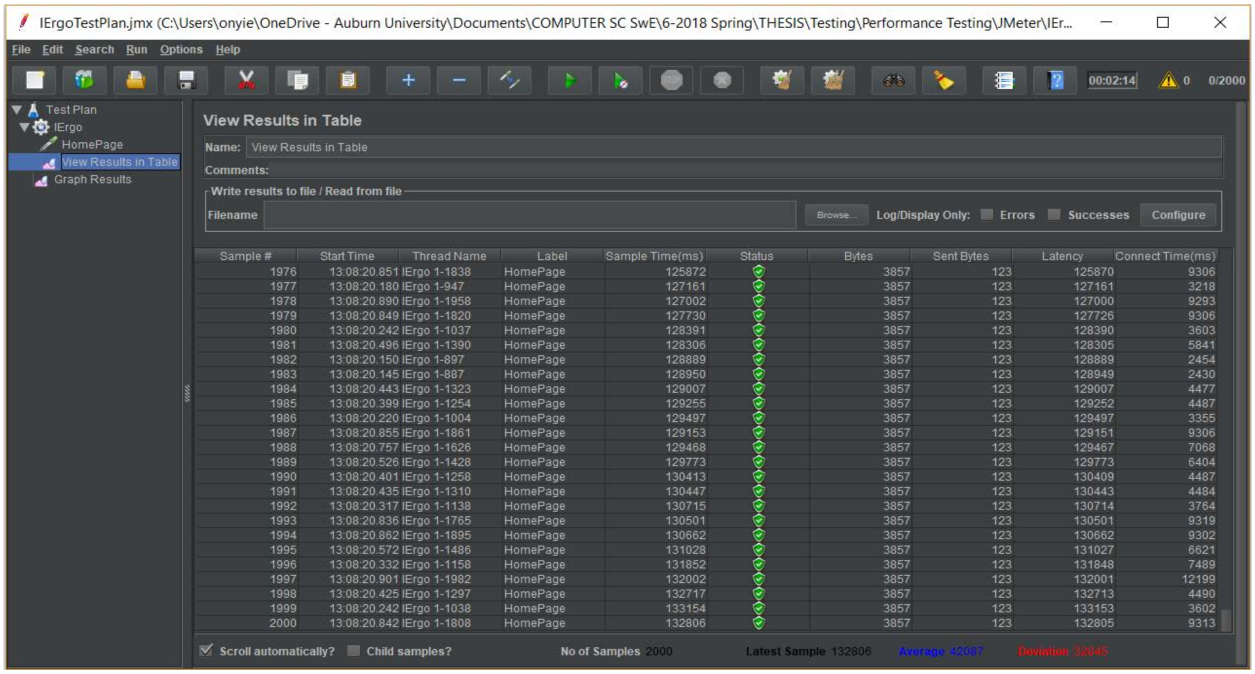


Figure 21: Testing for 1000 users



Sample #	Start Time	Thread Name	Label	Sample Time(ms)	Status	Bytes	Sent Bytes	Latency	Connect Time(ms)
1976	13:08:20.851	IErgo 1-1838	HomePage	125872		3857	123	125870	9306
1977	13:08:20.180	IErgo 1-947	HomePage	127161		3857	123	127161	3218
1978	13:08:20.890	IErgo 1-1958	HomePage	127002		3857	123	127000	9293
1979	13:08:20.849	IErgo 1-1820	HomePage	127730		3857	123	127726	9306
1980	13:08:20.242	IErgo 1-1037	HomePage	128391		3857	123	128390	3603
1981	13:08:20.496	IErgo 1-1390	HomePage	128306		3857	123	128305	5841
1982	13:08:20.150	IErgo 1-897	HomePage	128889		3857	123	128889	2454
1983	13:08:20.145	IErgo 1-887	HomePage	128950		3857	123	128949	2430
1984	13:08:20.443	IErgo 1-1323	HomePage	129007		3857	123	129007	4477
1985	13:08:20.399	IErgo 1-1254	HomePage	129255		3857	123	129252	4487
1986	13:08:20.220	IErgo 1-1004	HomePage	129497		3857	123	129497	3355
1987	13:08:20.855	IErgo 1-1861	HomePage	129153		3857	123	129151	9306
1988	13:08:20.757	IErgo 1-1626	HomePage	129468		3857	123	129467	7068
1989	13:08:20.526	IErgo 1-1428	HomePage	129773		3857	123	129773	6404
1990	13:08:20.401	IErgo 1-1258	HomePage	130413		3857	123	130409	4487
1991	13:08:20.435	IErgo 1-1310	HomePage	130447		3857	123	130443	4484
1992	13:08:20.317	IErgo 1-1138	HomePage	130715		3857	123	130714	3764
1993	13:08:20.836	IErgo 1-1765	HomePage	130501		3857	123	130501	9319
1994	13:08:20.862	IErgo 1-1895	HomePage	130662		3857	123	130662	9302
1995	13:08:20.572	IErgo 1-1486	HomePage	131028		3857	123	131027	6621
1996	13:08:20.332	IErgo 1-1158	HomePage	131852		3857	123	131848	7489
1997	13:08:20.901	IErgo 1-1982	HomePage	132002		3857	123	132001	12199
1998	13:08:20.425	IErgo 1-1297	HomePage	132717		3857	123	132713	4490
1999	13:08:20.242	IErgo 1-1038	HomePage	133154		3857	123	133153	3602
2000	13:08:20.842	IErgo 1-1808	HomePage	132806		3857	123	132805	9313

Figure 22: Test for 2000 virtual users

The response time (sample time) measured in milliseconds increases with increasing virtual users though each request completed successfully. The maximum users to complete successfully with 1 loop count is 2000.

4.2.2 Stress Test

I further increased the number of virtual users and the loop count. Results show that the IErgo website can handle many users with a maximum of 2 loops and it starts to fail with as little as 50 users and 3 loop counts as shown below:

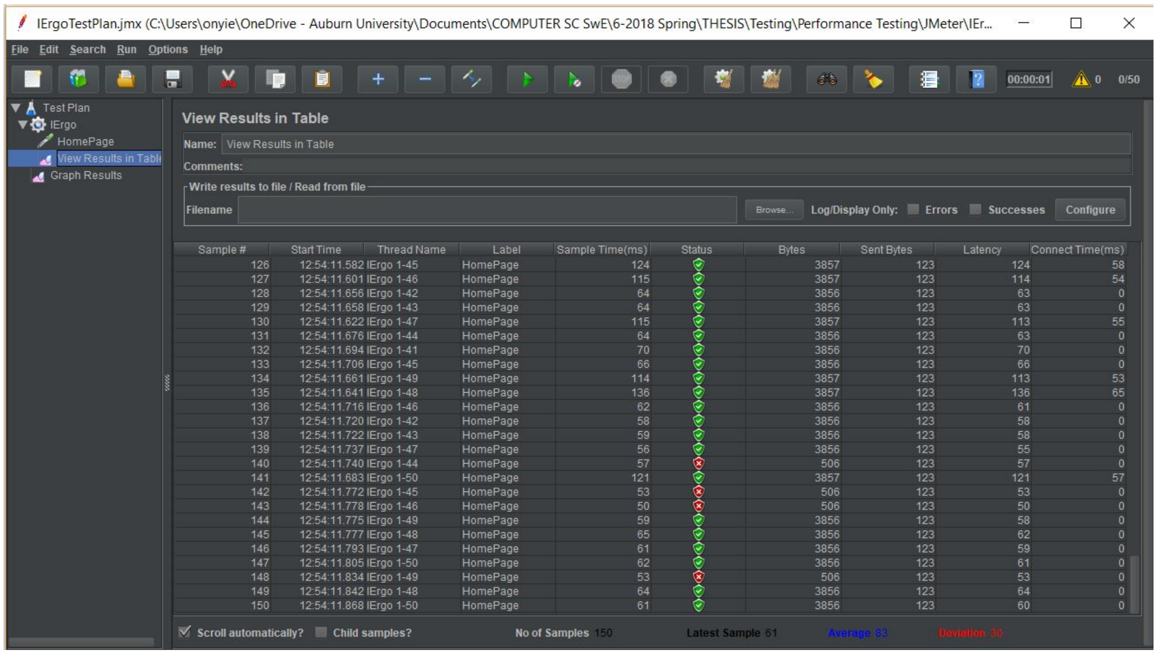


Figure 23: Stress test for 50 users with 3 loop counts

Also, increasing the loop count to 2 for 2000 did not complete successfully and took a very long time to complete. This is shown below:

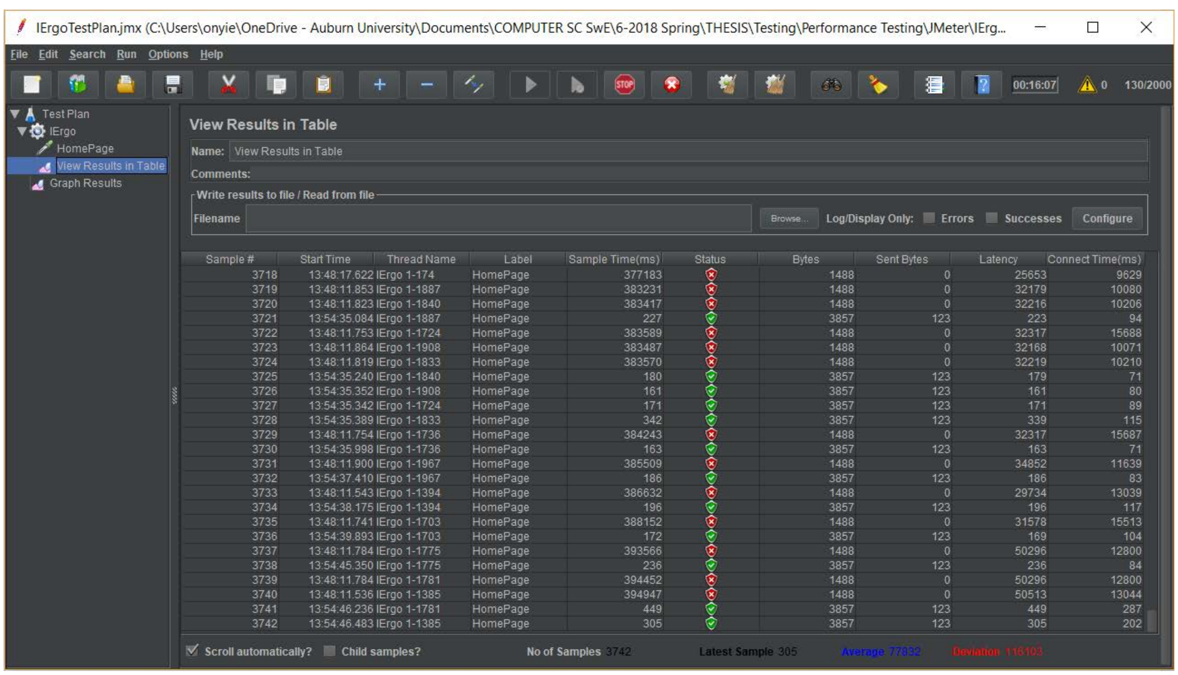


Figure 24: Stress test for 2000 users and 2 loop counts

4.3 Usability Testing

4.3.1 Pre-Survey

This testing was carried out by 34 students in a computer science class mainly undergraduates and graduates. A pre-survey was first conducted to know more about the testers. Below are the results gotten:

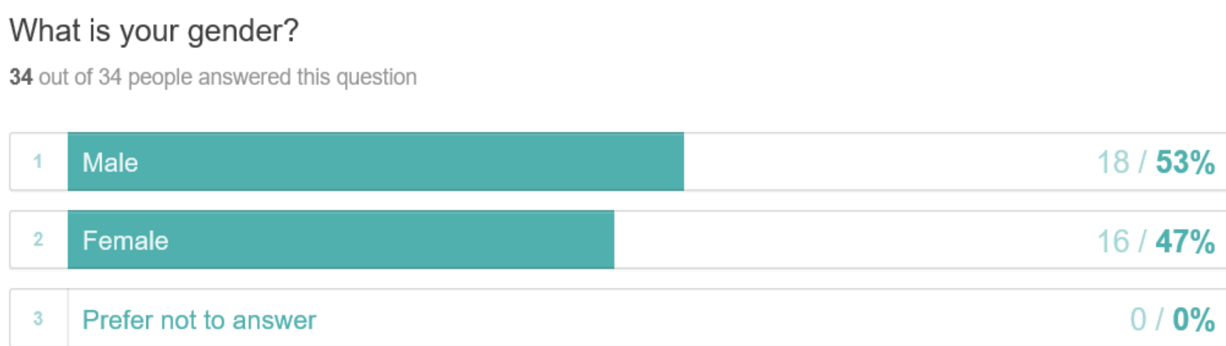


Figure 25: Survey result about gender

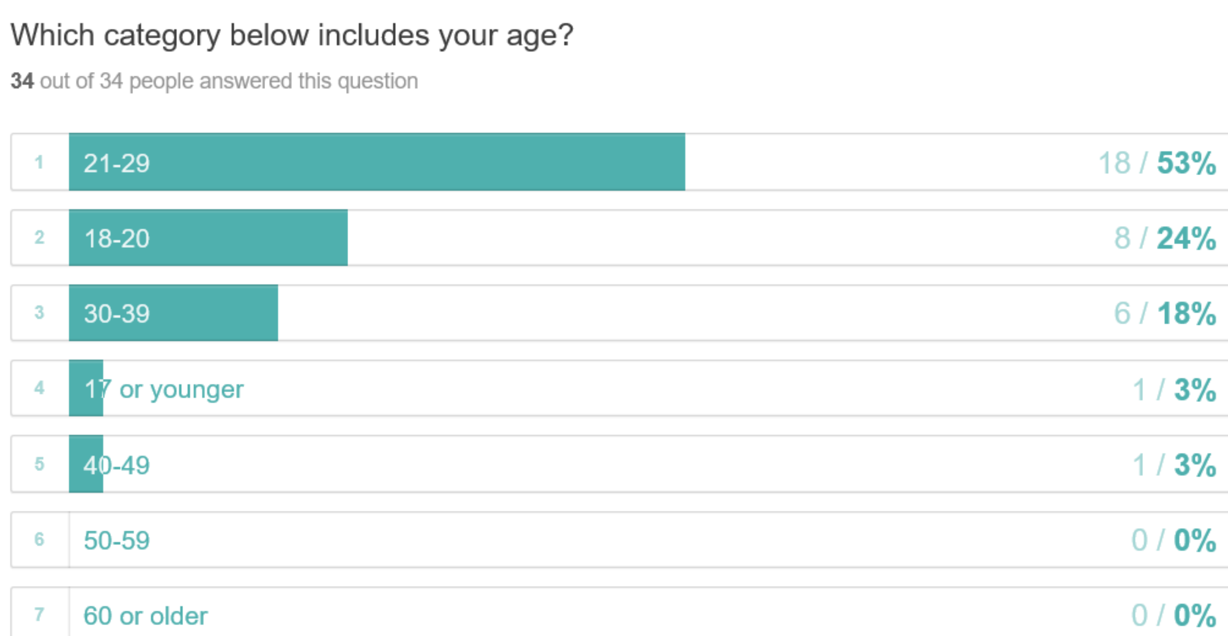


Figure 26: Survey result about age

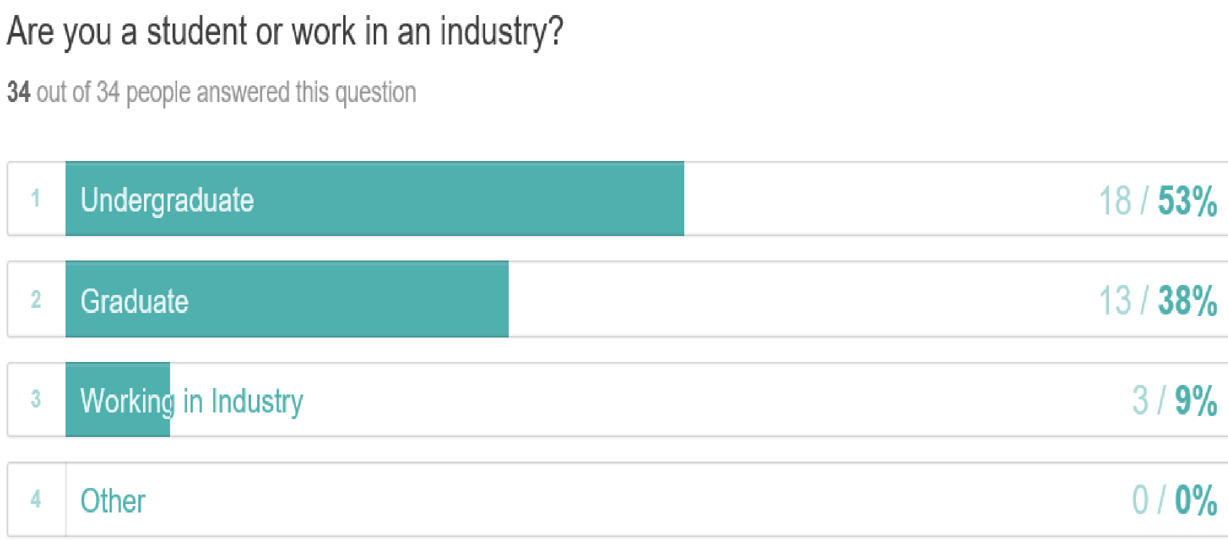


Figure 27: Survey result about being a student or working in an industry

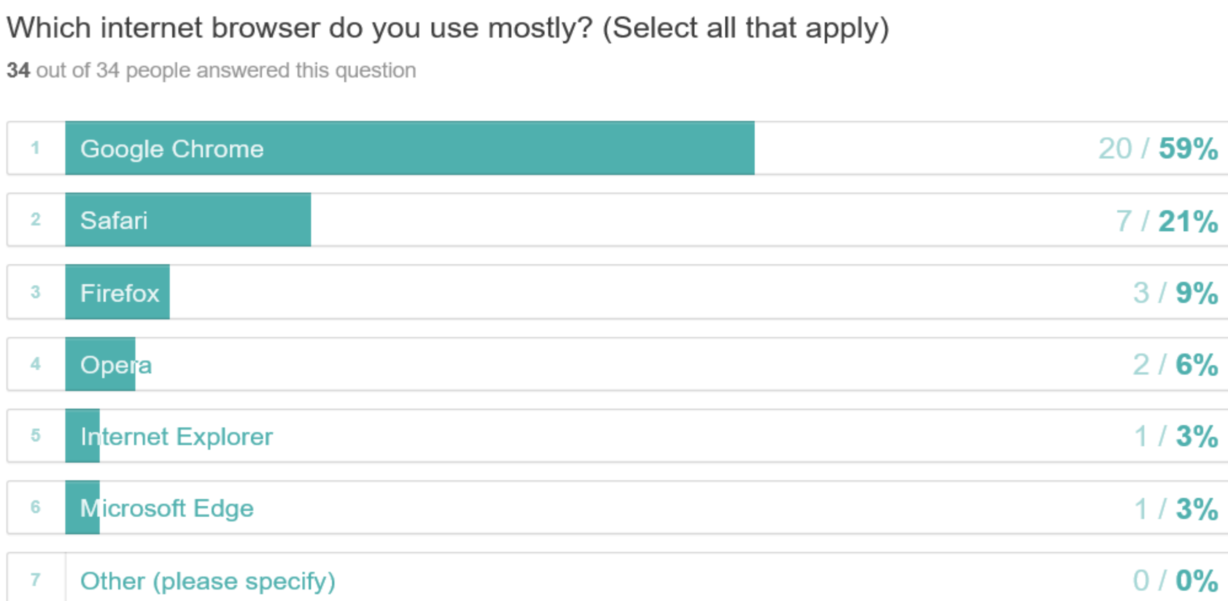


Figure 28: Survey result about their primary browsers

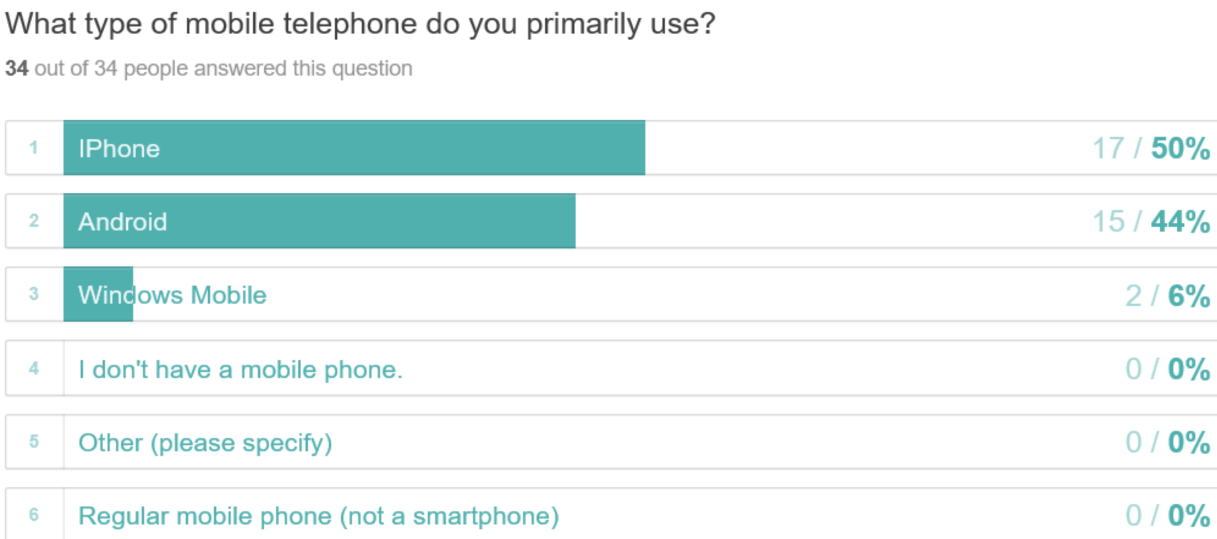


Figure 29: Survey result about their primary phone type

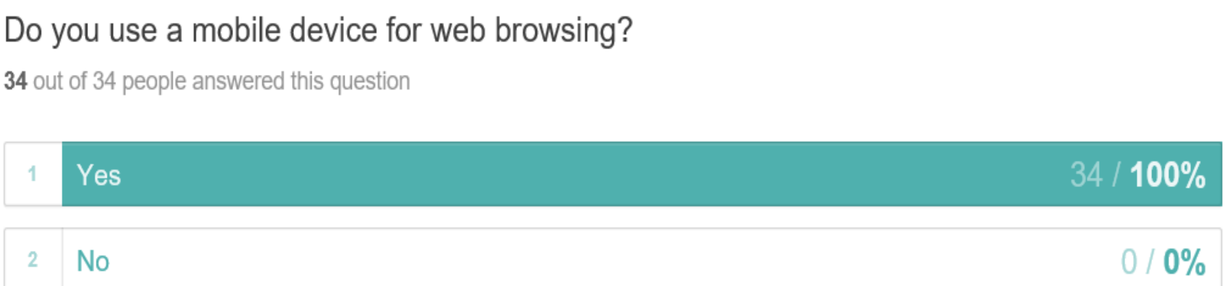


Figure 30: Survey results about using a mobile device for web browsing

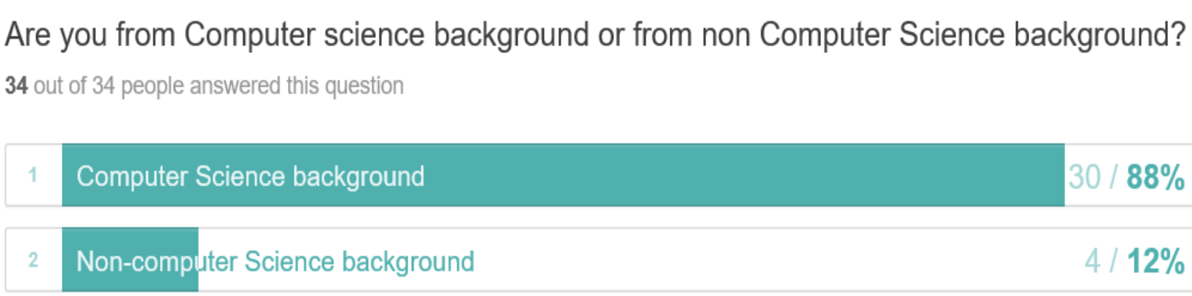


Figure 31: Survey result about computer science background

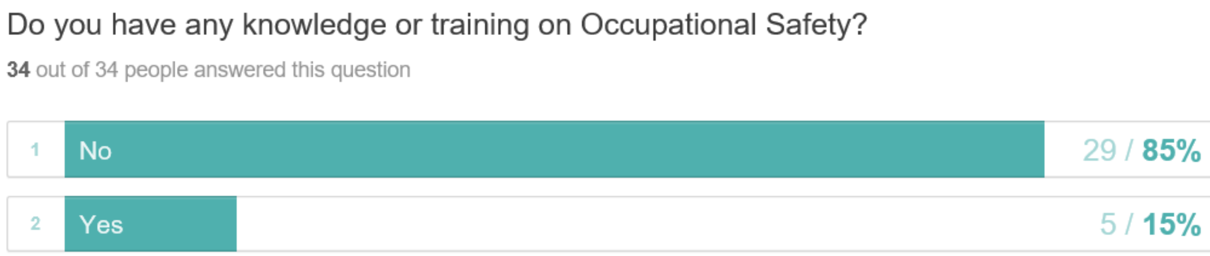


Figure 32: Survey result about knowledge/training on Occupational Safety

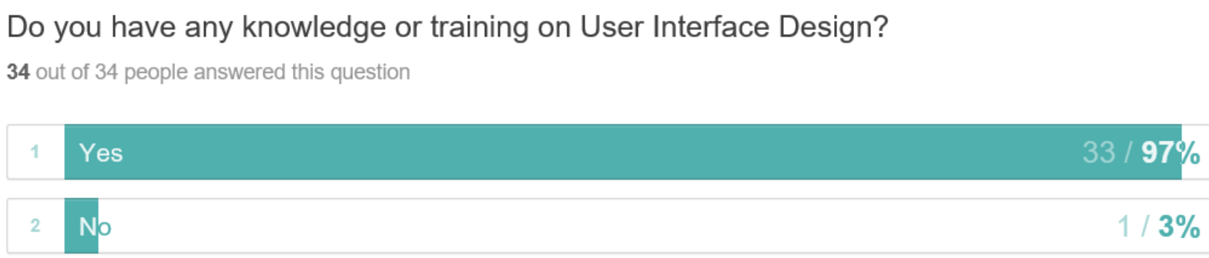


Figure 33: Survey result about knowledge/training on UID

From the results above, 52.9% of the testers were male, 52.9% are of ages between 21 and 29, 52.9% were undergraduates with 8.8% working in the industry, a majority of the testers use Google Chrome, and 100% of the testers use a mobile device for web browsing. This is another reason why IErgo application is responsive and can resize itself to fit a phone, tablet or desktop.

4.3.2 Post-Survey

These sample of people used their devices to test the IErgo application on these factors: screen layout, terminology and system information, learnability, system capabilities, system specifics and overall reaction. The rating was on a scale of 5 (100%), and the benchmark is a score of greater than 4 (80%).

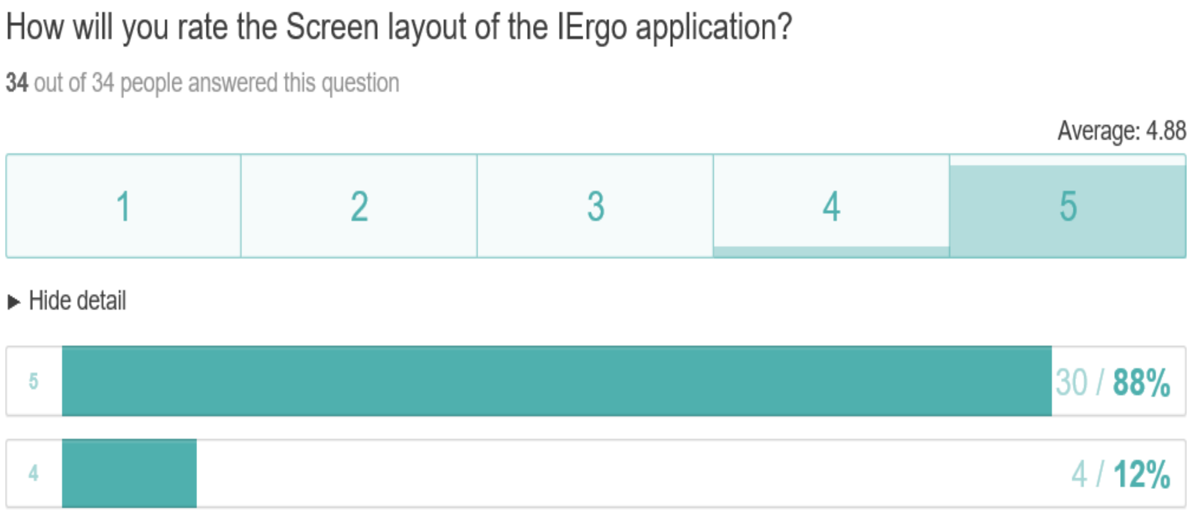


Figure 34: Rating for Screen layout of IErgo

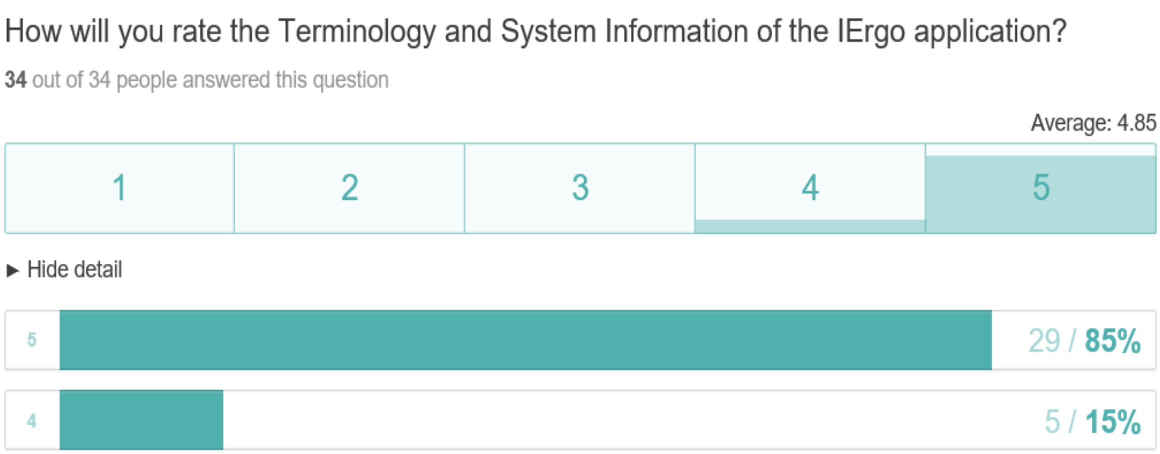


Figure 35: Rating for Terminology and System Information

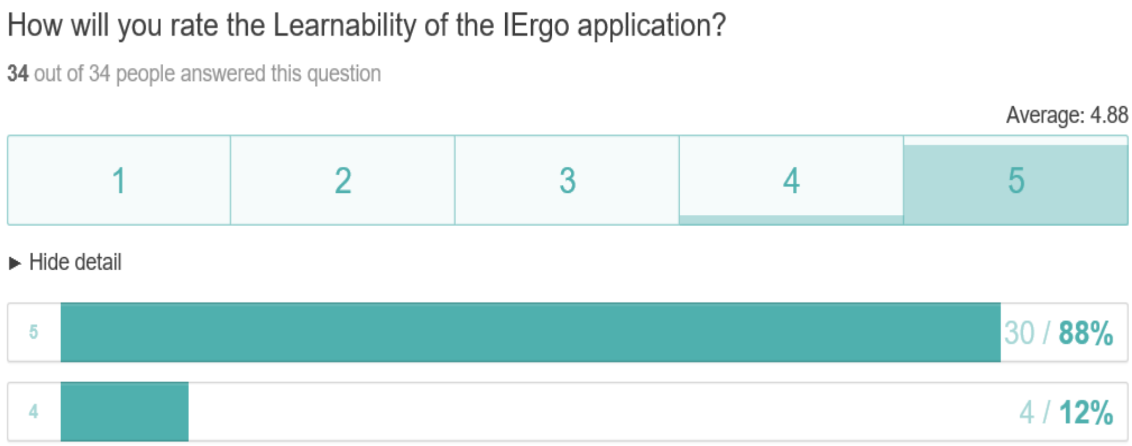


Figure 36: Rating for Learnability

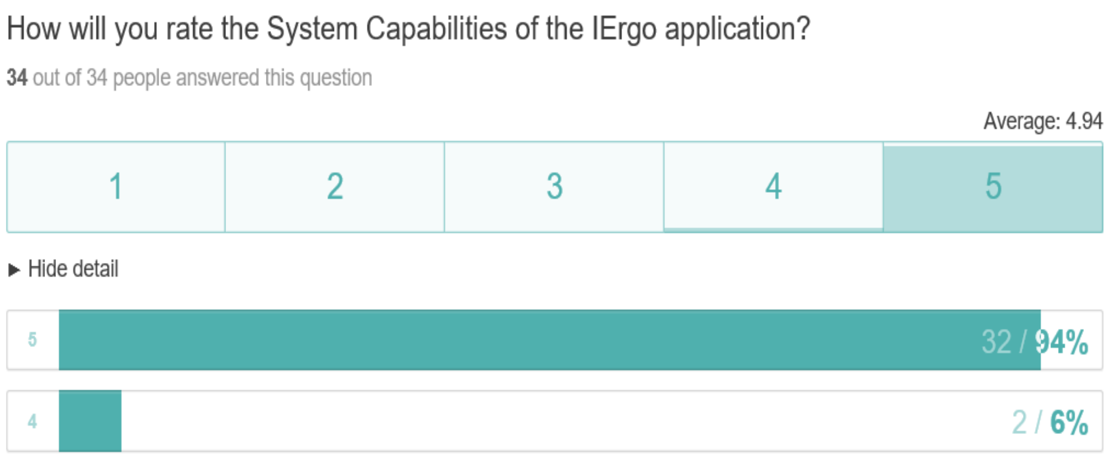


Figure 37: Rating for System Capabilities

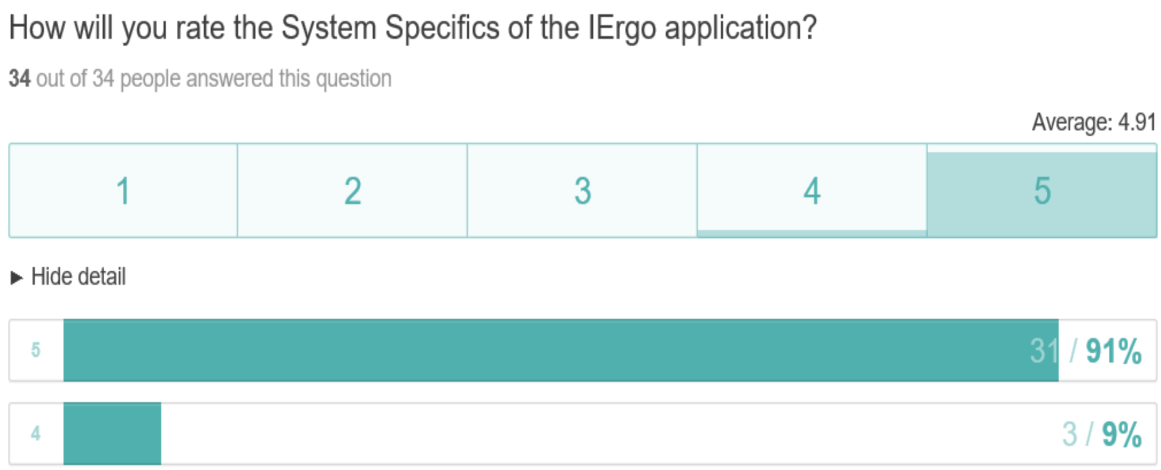


Figure 38: Rating for System Specifics

Figure 39: Rating for Overall reaction to IErgo

5. EVALUATION, RESULTS, AND CONCLUSION

5.1 Evaluation

To evaluate the usability of the IErgo project at a high level, evaluation techniques like interaction study was used. This gives us an opportunity to interact with various users and to collect different feedback regarding the usability of the project. Some small surveys were also conducted through which information regarding several critical qualities for IErgo application were received.

5.1.1 Ease of overall navigation

Does the user find it easy to navigate through the application and are they facing some problems while using IErgo? Navigation was introduced as part of the new functional requirement and desire to know users' thoughts on this subject.

5.1.2 Effectiveness of the Questionnaire

IErgo was built to lead ergonomics professionals and general users to appropriate solutions quickly. This was also measured this during the evaluation.

5.1.3 Satisfaction of the Users

The survey also determines whether the users are satisfied with the results and the product. This should indicate if there is a need to provide more extensive details about the tools and improve the overall flow of the project.

Feedback was also accepted from customers (who are supposed to be end users) to meet their usability demands. There were regular meetings with clients, collecting feedback, and continuously trying to improve the project as per client's requests so that the system meets their standards. This review-based evaluation is an expert-based evaluation method that relies on experimental results and empirical evidence from the literature to support or refute parts of the user interface design. This is believed to be a promising method for usability testing. Cognitive walkthroughs were also conducted. This is a usability evaluation method in which one or more evaluators work through a series of tasks and ask a set of questions from the perspective of the user. The focus of the cognitive walkthrough is understanding the system's learnability from new or infrequent users while improving the usability, look, and feel of the project.

5.2 Results from Evaluation

An online survey was created, and users tested IErgo and expressed their opinions on the finished product. The overall results from the surveys signaled that a high-quality product was produced for the users. Below is a graph of the polls.

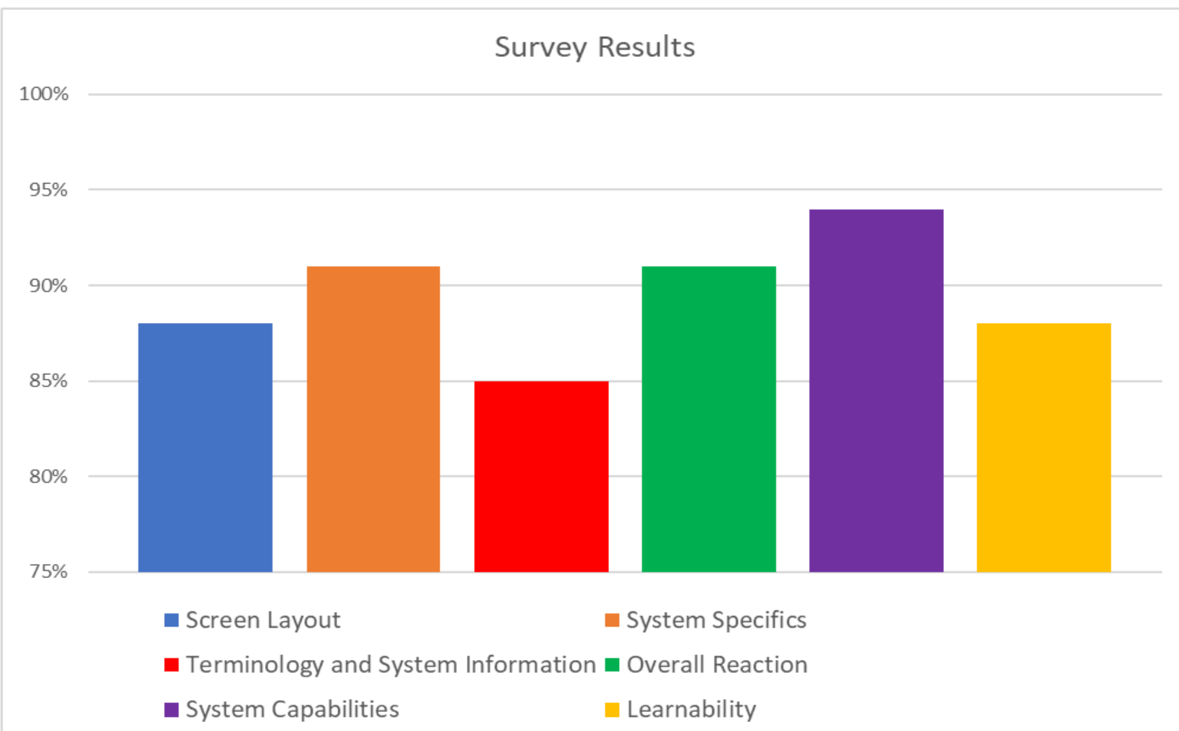


Figure 40: Survey Results

Each bar represents the average of each category within the survey. In the survey, these were explicitly evaluated:

- Overall Reaction of the User (Score: 91%)
- Screen Layout (Score: 88%)
- Terminology and System Information (Score: 85%)
- Learnability (Score: 88%)
- System Capabilities (Score: 94%)
- System Specifics (Score: 91%)

Each one of these categories had a few questions involving the specifics of each group to be thorough when assessing our product. The users liked the product because all areas of the product scored above 80% which was the benchmark for the rating. From the above graph, the product was easy to use and understand. IErgo successfully performed its function quickly, and the application provided a stimulating experience that did not waste the user's time. The client was also satisfied with the product, and we believe it provides an excellent foundation for future research.

5.3 Conclusion

IErgo is a framework which transformed a paper toolkit into a web application. It is a responsive application which quickly adapts to different screen sizes of a desktop, tablet or any mobile device without having to zoom or slide left and right. It is easy to use and understand, a fast application with a good user interface. It provides effective feedback, increases user experience, flow, usability, and interaction between users.

Based on the responses gotten from the users, the IErgo application provides better ease of use because it was built with the end users in minds. The web pages are fast and direct, the definitions and questionnaire pages help the users assess their risk with immediate feedback to the user. The color and font size of this application were carefully chosen, and the layout was carefully designed with an appealing interface. The users and client were also satisfied at the end of this research.

6. FUTURE WORK

6.1 Graphical Rating System

As a part of the next scope, we are developing the project in such a way that, we can rate the usability of a particular tool using data visualization techniques like Tableau, D3, etc.

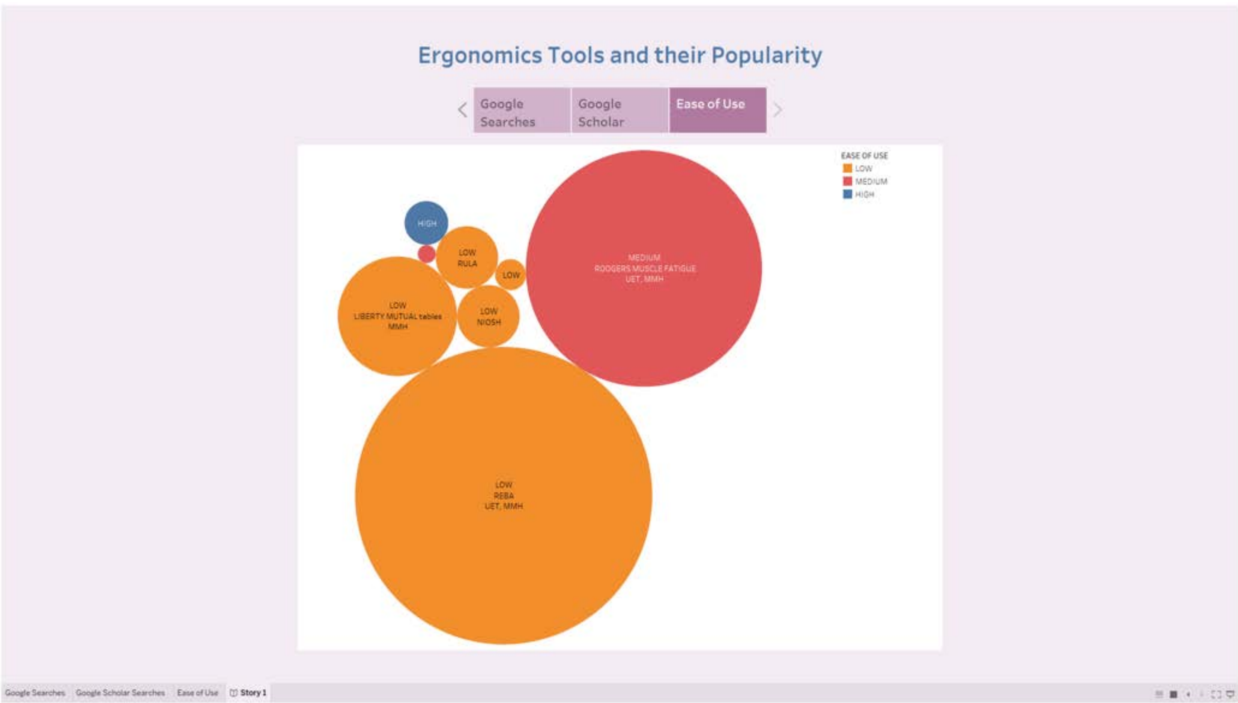


Figure 41: Data visualizations showing the ease of use

We believe this graphic will provide a lot of worth to IErgo for several reasons:

- It allows the user to know what tools are most popular and potentially the most helpful at a glance.
- It allows users to observe trends and to know what tools are falling or rising in popularity.
- It will allow users to discover newer and more useful tools.

6.2 Adding More Tools

As our ergonomics professors develop more tools, it would be valuable for those tools to be integrated into IErgo. This will provide more value to the product and can make IErgo more useful to industry professionals. The more functions and tools that IErgo delivers, the more significant appeal the software will have as a product.

A standard look and feel for each tool in IErgo was established which will help guide future groups when adding functionality. The views of IErgo are made with free, conventional technologies that are easy to use which include HTML, CSS, and Bootstrap. The application now uses jQuery and JavaScript to handle navigation. This is much simpler than the previous iterations of the software that required installation, an application server, and knowledge of development with jade files. Because of these changes, we believe future groups should have an easier time when developing future iterations of the IErgo software.

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