BY - NICK BENEVENTI 2022

MITIGATING INJURIES FOR COMMERCIAL PLUMBERS

by

Nick Beneventi

Submitted in partial fulfilment of the requirements for the degree of

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Supervisors: Catherine Chong and Sandro Zaccolo

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EXO GEAR for INJURY PREVENTION and WORKDAY SUPPORT

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Abstract

Commercial plumbers are susceptible to injuries from tasks endured during workdays. Injuries occur even with safety rules and regulations in place. With heavy lifting, repetitive movement, material transportation and machinery operation to list some, plumbers job tasks have high injury rates and health risks. Due to these job tasks being physically demanding, wear and strain on the the body is common. According to the Bureau of Labour Statistics, 37% of all days taken off include back pain and sprains as well as injuries to the muscles, tendons and ligaments. Longterm workers within the industry commonly experience muscular injuries that cause lifelong pain and discomfort. A fast efficient workflow is key within this field of work, safety and health sometimes gets pushed aside. How may we mitigate physical injuries for plumbers in a commercial setting? This thesis proposes a in depth study of tasks and job duties related to plumbers working on job sites. User research will be conducted involving interviews with knowledgeable people in the industry to give more insight towards current issues within user environment. A one to one scale human mock up will be used to evaluate ergonomics, provide user experience, convenience of use, enhancement of workers lifestyle's and provide a full bodied human interaction design. Providing possible user solutions towards injury prevention is

key. In depth research conducted will be used to ideally provide solutions to reduce physical injuries for Plumbers and enhance a safe work environment for all.

Acknowledgements

I would like to thank my professors for the great insight they provided during the whole process as well as my student faculty for all the support we have given each other over the years.

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CHAPTER 1
Problem Definiton

In this Chapter the problem definition will be further discovered locating the general problem. Rationale and significance will plan an investigation approach towards research, users, analysis and benefits. Background and history will investigate demographic, lifestyle and product trends.

1.1 Problem Definiton

This project proposes a solution towards injury prevention for commercial plumbers. Physical tasks that workers endure during a work shift can cause injuries that last in the longterm. Preventing these injuries early on is key. This project plans to enhance a safe work experience for workers while providing an efficient way of working. Creating a wearable device concept to protect workers that is easy to use, comfortable and user friendly is the intent.

1.2 Rationale and Significance

Key Information to be determined

Discovering certain tasks workers complete during a full work week needs to be determined. Research from user observation studies will help provide insight towards issues faced daily. Locating certain pain points and challenges workers face on a daily basis is needed to understand areas to work upon. Researching areas of the body that are commonly affected will help direct regions that aid is needed the most.

Key questions to be answered

What support can be most valuable to the user?

What injuries are most common?

What injuries are the main focus points?

What tasks are the most physically challenging?

What can be implemented to complete tasks more efficiently?

1.3 Background / History / Social Context

(2020). Applying For Workers' Compensation As An Injured Plumber In New York. Retrieved from https://banvillelaw.com/workers-compensation/hazardous-jobs/plumbing/.

Fig.1

Fig.12

Background

Commercial plumbers job tasks tend to be high risk when it comes to injuries. The image shown indicates common hazards, injuries and illnesses plumbers can face while on the job. Some injuries can put heavy amounts of wear on the body as well as putting plumbers out of work. According to the Bureau of Labour Statistics, 37% of all days taken off include back pain and sprains as well as injuries to the muscles, tendons and ligaments. (Haile, E., & Men, Y. (2007). Due to some major injuries, workers file for workers compensation to support themselves as they recover.

Social/Product Trends

Fig.2

(2017). What Do Plumbers Wear When Working? Retrieved from https://www.ra-heating-plumbing.co.uk/news/what-do-plumbers-wear.

Other than common personal protective equipment displayed in the image above, commercial plumbers are limited to what they wear on the job site. Social trends tend to lead experienced plumbers to disregard safety rules and work without proper equipment. Apprentices that come into the job site follow this behaviour and tend to not take proper safety rules and techniques seriously. This causes for injures to occur early on in the work stage that can have a long term impact on their life and career.

Chapter 2

2.1 - User Research

2.2 - Product Research of Existing Products

2.3 Summary of Chapter 2

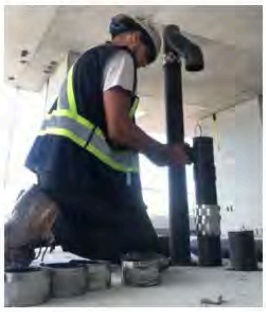
2.1 User Research

This chapter will display the research process and outcomes regarding different users, user observations, activity mapping and benchmarking of existing products.

2.1.1 - User Profile - Persona

Types of Users

Fig.3



User Primary - Younger Plumbing Worker (Apprentice) / Main Plumbing Workers

⊞

Fig.4

Secondary - Experienced/Long Term Plumbing Workers

Fig.5

Tertiary - Other Workers on-site

Tradesman

Maintenance

Delivery

Demographics

There is an estimate of around 350,000 plumbers in North America. Within those 350,000 people 91% are men while 9% are women. The average age of plumbers in the industry is around 42 years of age. The most dominant ethnicity being white followed by European and Hispanic. The average pay plumbers receive is an average of 60, 172 usd, the top percentage of plumbers earn around 90,000 usd. Most plumbers end up starting their own companies rather than working for a large corporation.

Demographics	
Gender	91% male
Age	42 years old
Ethnicity	69% white
Pay	60,172 usd
Average workers	350,000

Table 1 - Demographics

Persona Primary User - Younger Plumbing worker (Apprentice)

Fig.6

Name - Matt

Job - Commercial Plumber High-rise Buildings

Location - Toronto , ON

Year - Final Year apprentice (Year 5)

Age - 24

Shift hours - 8 hour shifts

Finishing Apprenticeship, experienced plumber but still early in the trade

Matt is a final year apprentice, about to transition to a licensed plumber next year. His wage is around 60,000 usd. He has been in the industry long enough to know all safety standards and rules, how things work and how to properly and efficiently complete commercial plumbing work. He is ready for the next big step in his career and is excited to get fully licensed.

User Behaviour

Matt is working with older experienced plumbers that tend to disregard safety standards and work comply leniently with most rules. Being in the industry for so long they tend to want to work the old fashioned way with as little protective equipment as possible. To be socially accepted/social peer pressure matt follows wearing just the right amount of personal protective equipment but nothing extra. He wants to create as many friends higher in the ranks, to help him progress as a plumber and learn as much as he can.

2.1.2 - Current User Practice - Tasks in a Day

A plumbers tasks are slightly different depending on the area of work being residential or commercial. In this case with commercial plumbers, they tend to do more physically challenging tasks due to the fast pace work environment. The tasks commonly included are transpiration of pipe, cutting pipe, measuring pipe, fitting pipe too high heights, reading blueprints and code, supervise apprentices, welding, waste disposal and using a vast amount of machinery and tools. New plumbers tend to get discouraged early on with how physical demand the job is.

2.1.3 - Activity Mapping

Fig.7

1. MATERIAL TRASPORTATION

- Material is dropped by a crane
- Plumbers transport this material to the areas needed

- Most plumbers lift the pipe/use carts

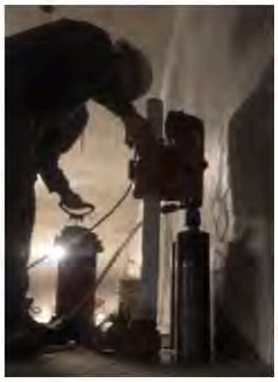


Fig.8

2. DRILLING

- Plumbers drill a hole to the below floor to feed pipe through
- Drilling sprays debris which can be harmful to breathe and harmful to the eyes

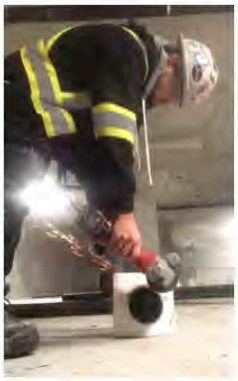


Fig.9

3. CUTTING

- Plumbers cut pipe at bad angles which causes strain on the body
- Plumbers measure and cut the pipe according to length needed

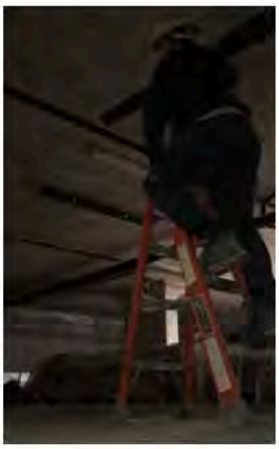


Fig.10

Fig.11

4.TRANSPORTING PIPE UP LADDER

- Plumbers carry heavy pipe up a ladder
- Placing the pipe in metal rings to hold

5. SECURING PIPE TO CEILING

- Plumbers fully push the pipe through metal rings
- Once fitment looks right they secure the metal rings around the pipe to hold it in place

Fig.12

7. ADJUSTMENT AND ALIGNMENT OF PIPE

- Pipe is aligned perfectly
- Pipe is inspected once complete and adjusted again if needed

2.1.4 - User Observation - Human Factors of Existing Products

Fig.13

Taking a look at existing products in the wearable section of a commercial plumbers inventory. A recent addition and or new product in the market is wearable exo components. This product displays the ergonomics needed for a worker to work comfortably in this equipment all day long. The product is always in contact with the body making ergonomics very important. The product allows the user to admit less energy towards lifting an object. It also puts less strain on the muscles creating a reduction in pain felt at the end of a work day but lacks in a other parts of the body where support is needed.

2.1.5 - User Observation - Safety and Health

In the construction industry safety and health is always regulated and pushed upon but not many seem to follow. Equipment is always recommended but not all workers choose to follow this one hundred percent. With that said, the number of injuries these workers could face increases dramatically. This is where opportunity is formed.

2.2 - User Observation - Safety and Healt

The objectives of this sub chapter is to analyze current products on the market to see the benefits and features they give to the user. In the commercial plumbing field a lot of equipment is used wether that be protective equipment or tools to make tasks/workday easier. The ability to complete this study will help see challenges and pain points that current benchmarked products are not solving well or at all. This will open up opportunity for a possible direction.

2.2.1 - Benchmarking - Benefits and Features

Benchmarking Products						
						
1	2	3	4	5	6	7
3M Ultimate FX Full Face piece Respirator	Husky Gel-Foam Soft Cap Work Knee Pads	Milwaukee Tool Large Winter Performance Work Gloves	Pipe Stand Fold-A-Jack VHead	Sumner 2412 Contractor Lift 12' Lift 450 Lb Capacity	Reed HPC Series Guillotine Pipe Cutters	DEWALT Industrial Footwear Torque Mid *CSA approved*
BENEFITS						
- Prevent toxins/ chemicals from entering the body - Face protection (injury prevention) - Wide visibility when working - Clear voice transparency through mask	- Enables comfort when working - Longterm injury prevention - Provides grip to work surface - Adjustability for the user through various straps	- All day comfort through memory foam - Secure fit and adjustability - Grips to multiple surfaces - Ease when handling small objects	- Frame allows for heavy loads - Adjustability for different pipe diameters - Takes weight and body strain off user - Easy movability	- Easy maneuverability while product is on - Reduction of weight and strain on the body - Adjustability, to get product at a certain height	- Improves safety of task for user - Hand tools not required (injury prevention) - Safe distance for user - Adjustability for every form of pipe - One person usable	- Waterproof allows feet to be kept dry - Steel toe (injury prevention) - Reduces stress on the ankle - Durable long lasting work boot (many uses) - Slip and fall prevention - Proper support

Table 2 - Benchmarking

Above are current benchmarked products and their benefits. There is products from different categories, from personal protective equipment to lift devices and wearables each serving their own purpose.

Benchmarking Products						
						
1	2	3	4	5	6	7
3M Ultimate FX Full Face piece Respirator	Husky Gel-Foam Soft Cap Work Knee Pads	Milwaukee Tool Large Winter Performance Work Gloves	Pipe Stand Fold-A-Jack VHead	Sumner 2412 Contractor Lift 12' Lift 450 Lb Capacity	Reed HPC Series Guillotine Pipe Cutters	DEWALT Industrial Footwear Torque Mid *CSA approved*
			FEATURES			
- Full silicone face piece - Large Lens - Passive speaking diaphragm - Scotch guard protection Paint - Chemical Protection filters - Compatible 3M respirator assemblies	- Tough, nylon molded shell - Gel and memory foam protection - Wide neoprene comfort strap - Comfortable kneeling - Hook and loop closure - Impact protection	- Smart swipe fingertips, knuckles and palms - Built-in terry cloth sweat wipe - Breathable lining - Reenforced thumb seam - Hook and loop closure for a secure fit	- Durable construction - Heavy duty v-head - Portable and compact - Great stability legs - 2500 lbs capacity - 28in-52in height adjustment - 1/8-12" pipe adjustment	- Improved lifting capacity up to 400 lb - one piece construction - Extremely portable design - One man operation - Fits most vans and suv's - Lightweight material	- Non stick coated blade - Chip resistant - Taper blade - From holding stand - Durable metal frame	- Pro comfort shank - Steel toe - Steel plate - Electrical hazard protection - Oil and slip resistant - Pro comfort insole with ergonomic arch support

Table 3 - Benchmarking Features

Above are current benchmarked products and their features. There is a wide range selection as each piece of equipment has different attributes to support the user in a different ways. These products will be analyzed further in the report to determine the benefits they give the each user depending on the task they are used for.

2.2.2 - Benchmarking - Functionality

The products that were chosen for benchmarking are based on prevention/support methods for tasks plumbers endured. Each product has benefits to help the user throughout the work day and protect them from harm. The functionality of each product is different, some tackling physical strain when transporting, some tackling and preventing common injuries that can occur and some tackling respiratory safety during tasks that cause debris and fumes. Incorporating things each of these products do well ad innovating on that will allow for possible design directions

Table 4 - Benchmarking Functionality

2.2.3 - Benchmarking - Aesthetics and Semantic Profile

Aesthetics

The aesthetics of current products found on the market tend to look rigid, tough and durable. They are styled in a way to make the user and or future buyer believe in the brand and the utility the product is advertised to have. Products tend to match each other and resemble a family of products. Each brand has their unique colour combination. Lighter and vibrant colours tend to be used to stand out from the competition. In a job site environment people are able to establish the brand of equipment just based on the colour itself. This information will be used to provide specific styling cues and attributes towards future concepts.

This image is an example of a toolkit a plumbing apprentice would have. The colours in the products all resemble each other and branding can easily be identified by other plumbers or tradesman in the industry.

Fig.14

(n.d.). My first year plumbing apprentice toolkit. Retrieved from https://www.reddit.com/r/Tools/comments/byiyrj/my_first_year_plumbing_apprentice_toolkit_aus/.

Semantics

Products in the industry tend to show their cost value based on various factors such as aesthetic presence, colour, size and texture. The products that cost the most tend to be as aesthetically pleasing as possible. This engages the user to feel like its a good purchase based on appearance alone. It also gives social recognition between peers that can notice the brand based on design aspects the companies use. Although expensive equipment may have the best aesthetic looks they may not be the best quality wise for the price. When looking at workers tend to lean towards the most durable option, displaying that within the design of the product may persuade the buyer to gravitate towards it. Knowing this, Exo was designed to be as durable looking as possible as well as providing unique colour scheme ideas to fit the current market trends.

Fig.15

(2021). Who makes the best tools in 2021. Retrieved from https://www.protoolreviews.com/who-makes-the-best-tools/.

2.2.4 - Benchmarking - Materials and Manufacturing

Materials

In the industry current product use different materials base on usage aspects. Hand tools and machinery tend to use chrome vanadium steel with a mix of TBE (Thermoplastics) with their plastic parts. When it comes to wearable safety equipment such as a hard hat high-density polyethylene is used, gloves tend to use polyurethane coatings and vest and padded equipment tend to use polyester and nylon. These materials provide strength to protect the user and materials are specifically chosen to make sure that's always the case at the highest level of use.

Manufacturing

Casting metal into moulds for metal parts are used for high end machinery and hand tools. Casting is a very common methods of creating these products. Injection moulding is very common for plastic parts in the construction industry, this is where parts are two parts are moulded and constructed tighter to form one part in the end. An example of this would be a hand tool such as a drill where both pieces are connected around the drill body. When it comes to efficiency of manufacturing and or the eco friendly aspect of these products some may be poor, and opportunity is there to achieve better.

2.2.5 - Benchmarking - Sustainability of Existing Products

With sustainability aspects it all comes down to the certain materials used base on the the product being displayed. When it comes to metal parts they can be broken down and recycled to make new ones. With plastic parts and metal combined it's harder to break down to recycle. As well as the batteries used in most tools and machinery there is not a know initiative to have all these batteries recycled properly after a tool end its life cycle.

2.3 Summary of Chapter 2

Chapter 2 allowed for informative insights to be gathered on topics such as different user profiles, user observations, product benchmarking and the comparison between them. Focusing and analyzing this data into what the user needs the most to benefit their daily work lifestyle is needed. Determining which tasks have the most challenges for the user and locating support methods for each is key..

Chapter 3

Chapter 3

Bringing the research information from chapter 1-2 together and conducting an analysis on the collected data found is the goal of this chapter. Results found in this chapter will help guide directions for the future design.

3.1 - Analysis needs

Focusing on the needs of plumbers will help target areas to work upon. The largest need for plumbers is a safe work environment or a way to reduce themselves from injuries. There are many routes plumbers can take to protect themselves but analyzing the highest need points have to be determined.

3.1.1- Needs/Benefits Not Met by Current Products

Products on the market have many equipment components that can help prevent from common injuries such as cuts, lacerations, bruises and required equipment that prevent plumbers from more serious cases such as a hard hat protecting a workers head from falling material for example. They also have products for making tasks a bit easier for a plumber. A major area they lack in is protecting workers against long term injuries. More areas not met by current products is displayed below.

Needs	Benefits Not Met/Improvements
Long term injury Prevention	- Plumbers face physical body strain on a daily basis - Must be looking out for the future health of customers
Posture Control	- Plumbers work in different areas, angles and positions throughout the day - Benefits that can reduce bad posture is important
Comfort	- The unit and or product must be comfortable enough for a user to withstand a full workday with ease - Having an item that the user forgets is even on is key
Aesthetically Pleasing & Safe	- Having an item that does its job correctly but is also standing out from other products on the market is needed - Must cater towards all safety needs

Table 5 - Needs/Benefits Not Met by Current Products

3.1.2 - Latent Needs

Plumbers need to realize the long term consequences of not taking safety seriously early on. Making sure the work environment is safe and the equipment used provides proper safety prevention to the user is needed for the future. Injuries that occur early on can be a burden to a plumber in the long run, a small injury can make that area susceptible to frequent pain or even a bigger injury that can occur down the line. One major injury can cause a plumber to not be able to work again.

3.1.3 - Categorization of Needs

Latent Needs	Immediate Needs	Wants and Wishes
- Mitigate injury areas early on to reduce long term / future injuries from occurring - Improve bad posture points - Reduction of physical strain on the body	- Increase overall safety during high physical tasks - Improve lifting and transportation methods - Combat pain from frequent repetitive movements	- Reduction in pain after work - Reduce risk of injuries - Work more efficiently - Ability to feel safe in the work field

Table 6 - Categorization of Needs

The chart above displays the categorization of latent needs, immediate needs and want and wishes of a commercial plumber. These needs are a good base for narrowing down possible design directions.

3.2 - Analysis

The data collected from the user observation activity map in 2.1.3 helped determine key areas where improvements are needed. The data was analyzed, major pain points, challenges and thoughts of the user were collected and listed below.

3.2.1 - Journey Mapping

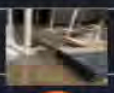
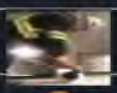
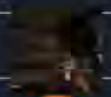
	Preparation and set up	Task 1	Task 2	Task 3	Task 4	Completion
User Goals	Material Transportation	Drilling	Cutting pipe to length	Transporting pipe up ladder	Pipe secured / fitted	Adjustments and alignment of pipe
User Actions	Lifting heavy pipe	Certain stance for drilling	Using saw to cut pipe	Lift Heavy material	Securing pipe	Look for pipe that needs tightening
	Transport long distances	Arched Back while drilling	Bad posture while cutting	Stepping up ladder with weight	Fitted pipe in metal rings	Adjust alignment to fit
User Thoughts	What a struggle to transport all this	Heavy vibration, debris flying	Don't want to get cut / injured	How heavy is this pipe	Constantly moving ladder to positions	Will this pipe connect properly
	A pain moving, heavy material	Don't want to get hurt . mess up	Free blade is dangerous	Wish i had someone to help me	Hopefully the pipe doesn't fall	Glad I'm finished
Storyboard						
User Experience	😡	😐	😐	😡	😡	😐😀
Problems and challenges	Physical strain on the body, heavy material	Bad posture, lots of debris	Free blade can cause injuries	Pipe can be too heavy and exceed 100 lbs	Pipe may not be secured properly, tough angles	Making sure everything is fit properly
Ideas / Takeaways	Improve transport methods	Improve eye and body protection	Improve safety equipment and cutting methods	Efficient way to get pipe to high heights	Improve positions / posture	

Table 7 - User Journey Map

User Observation Connection

The data represented in this chart is based on the user observation study from chapter 2. The chart is a collection of data based on the users thoughts, goals, actions. Insights on problems and challenges the user had while performing these tasks were noted. Possible takeaways and ideas were formed based on the information collected. This information helps form perusable design directions as it shows pains the user is having while completing certain tasks and which areas these occur in. The users emotions for each task represents the level of challenge and most difficult tasks they are enduring.

3.2.2 User Experience

	😠	😐	😐	😠	😠	😐😀
	Preparation and set up	Task 1	Task 2	Task 3	Task 4	Completion
User Goals	Material Transportation	Drilling	Pipe Cutting/ measurement	Transporting Pipe to Ceiling	Pipe Secured and fitted	Adjustments and alignment
Problems / Challenges	Physical strain, heavy material	Bad posture, heavy debris caused	Free blade can cause injuries	Pipe can be too heavy for one person, over 100 lbs	Pipe may not be secured properly , can fall	Hard to tell if everything is secured properly
	Heavy material to carry	Eyewear is very much needed	User can be cut / injured	Physically difficult task	Bad posture is caused by certain angles	
Ideas / Takeaways	Improve transport methods	Improve eye and body protection	Improve Safety Equipment and cutting methods	Efficient way to get pipe to high heights	Improve positions / posture	Improve way of getting to heights, improve vision

Table 8 - User Experience

Out of all the tasks the plumber has gone through, material transportation, transportation of pipes towards the ceiling level and securing/adjustment of pipe is where the major problems are. Lifting heavy material such as heavy pipe puts physical strain on the body and takes a lot of effort. Having to transport pipe within a large commercial building can take a lot of effort and energy. Some pipe can exceed 100 pounds plus which can be too heavy for one person, with nobody around plumbers tend to give it a go anyway risking their safety and a possible injury to get the job completed. Constantly repeating the process can really wear down the body. The last task that discouraged the user was adjustment and fitment of the pipe. Getting into various positions and angles while completing the job can allow for bad posture habits. Some ideas stated for possible design directions include improved transport methods, improved safety equipment relating to areas taking on high strain points and improving posture.

Fig.16

(n.d.). Common Plumbing Pipe Materials. Retrieved from https://www.shamrockplumbing.net/2016/03/common-

Fig.17

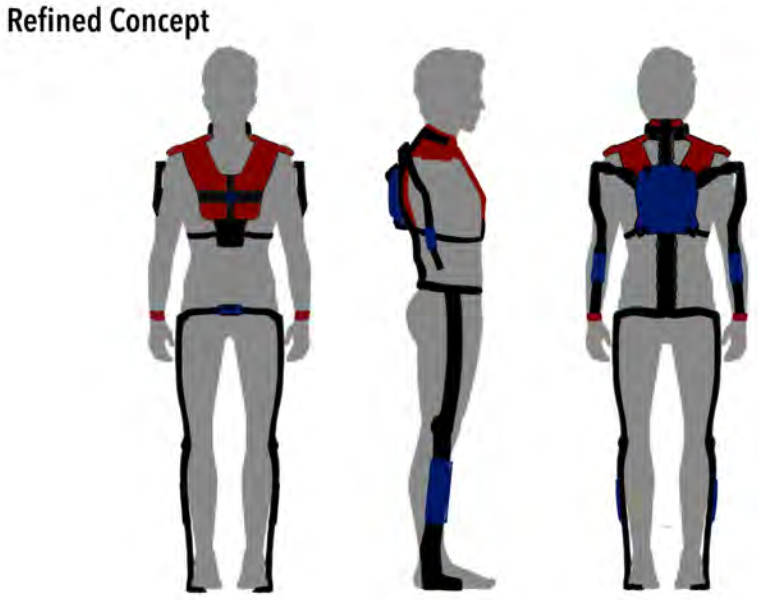
(n.d.). Retrieved from https://www.istockphoto.com/search/2/image?phrase=union+plumber.

3.3 - Analysis Human Factors Literature Review

To determine certain measurements needed a 1:1 model was built. Using the The Measure of Man and Women-Human Factors in Design by Henry Dreyfuss Associates (Tilley, 2002), Anthropometric Survey of US personnel : Summary Statistics Interim Report (Gordon, Claire, C 1988) and Anthropometric detailed data tables - multisite.eos.ncsu.edu. (n.d.). As references.

Methodology

A 95th percentile male was used in testing to locate sizing issues and to test form and fitment of the 1:1 model. Adjustable components were integrated in the model to allow for fitment within most user groups without having multiple size variations. A 5th percentile female was not used in the testing process but information gathered helped determine possible issues that certain user group may have.



Refined Concept Sketch

Fig.18

3.3.1 - Product Schematic / Configuration Diagram

Diagram of 95th Percentile Man

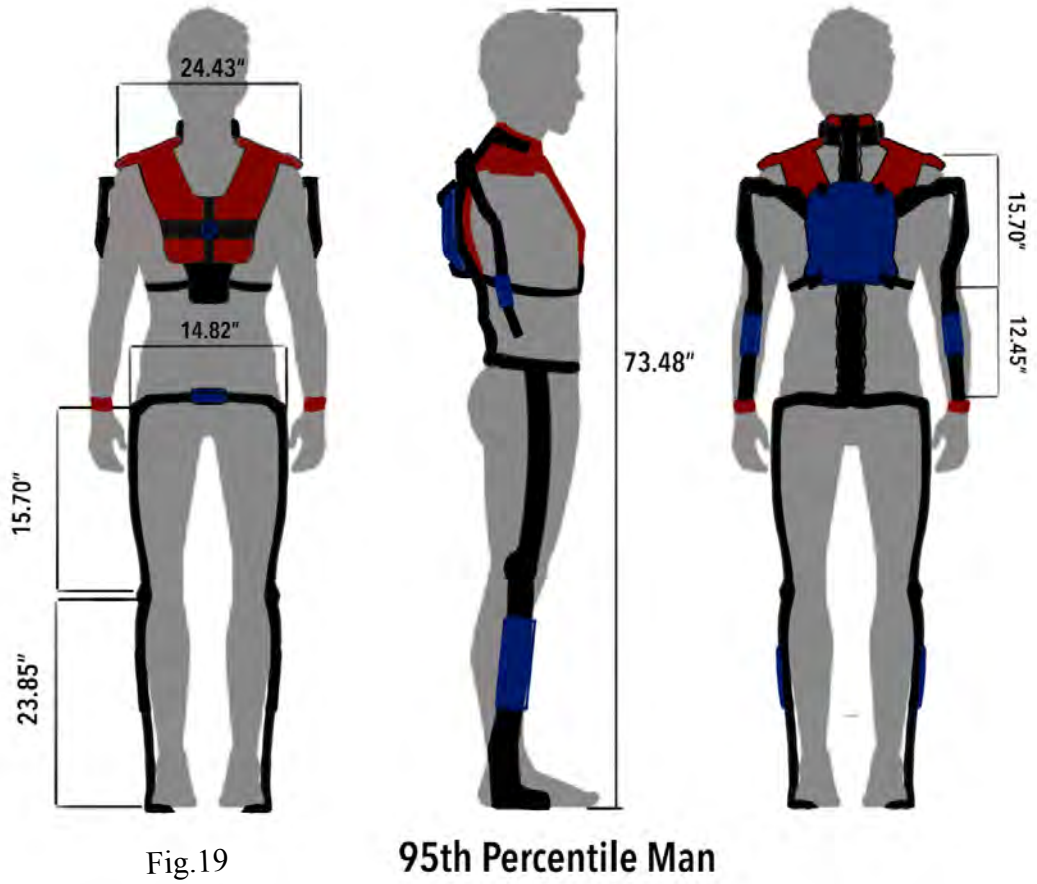


Fig.19

Drawn Sketch of Male / Components

Diagram of 95th Percentile Woman

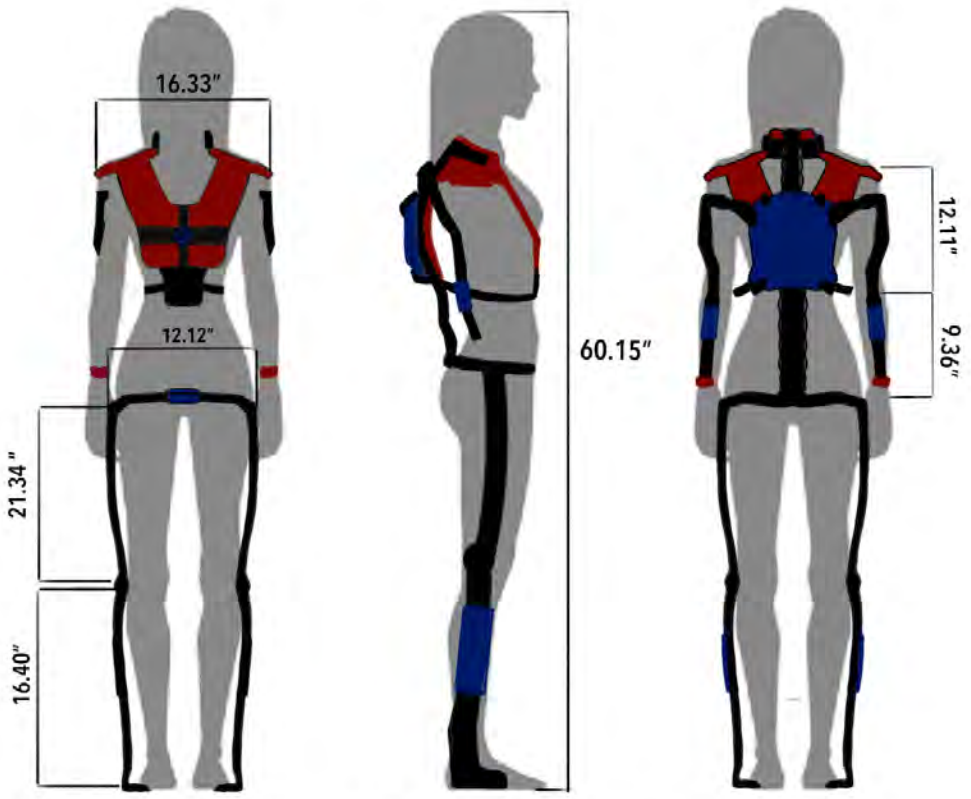
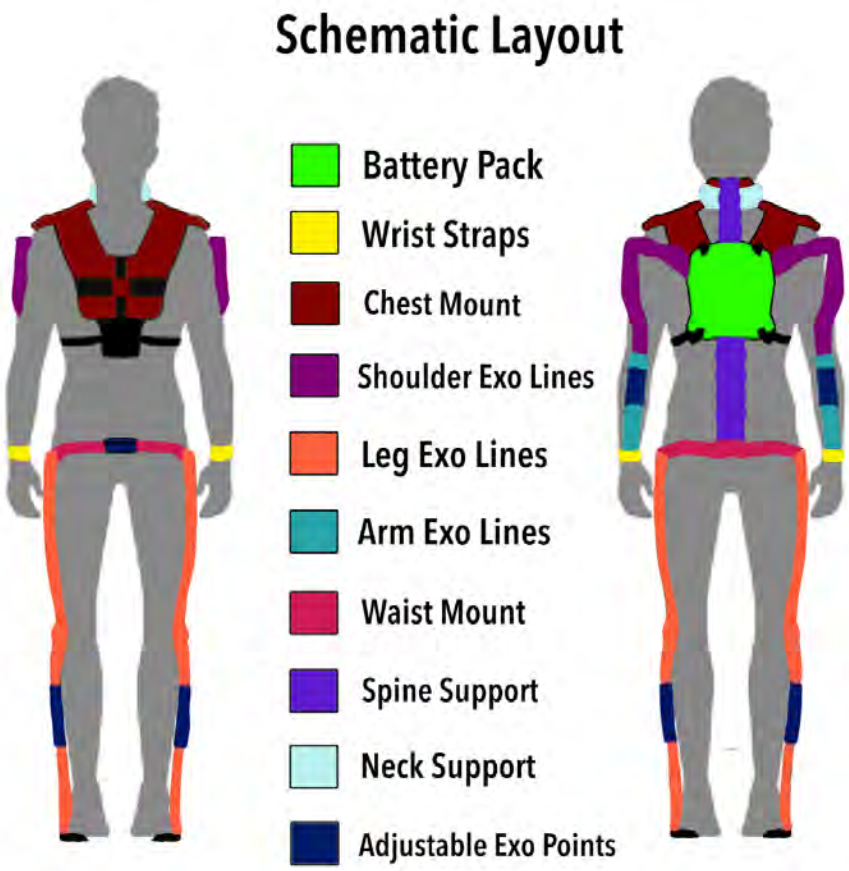


Fig.20

Drawn Sketch of woman and Components

Schematic Layout Diagram

Fig.21



Drawn Sketch of Components

A schematic diagram is used to display all the key components within the concept. Each part is colour coated for an easy display of information. The schematic layout is based off the progress from the fall semester. The concept will be developed further.

3.3.2 - Ergonomic -1:1 Human Scale Study

Fig.22

Front and Back View of 1:1 Model

Fig.23

Side and Back View of 1:1 Model

3.3.2 - 1:1 Human Scale Study

Study Objective

The objective of this study was to find and analyze ergonomic areas too in the end collect data that will ensure plumbers will feel most comfortable when working. The ability to create a 1:1 mock up model allows for this data to be collected.

Limitations

The 1:1 model was used to determine proper form and fitment. A main goal is for the user to feel comfortable while working long hours. After conducting movements tests, the chest mount was odd fitting and wouldn't be able to fit lower percentile groups. Adjustability in the arm and leg exo lines allowed for extensions in length for higher percentile groups. Adjustability in the shoulder exo lines will be considered as it may be too wide for smaller percentile groups. Waist support was able to be adjusted to a wide range of lengths. Adjustability in the neck support will be taken into consideration. Form around the sides of the neck were good. Dimensions from references were used in the making of the 1:1 model.

Using the model to feel problem areas helped find future adjustment points. Some areas that were planned to fit had comfort issues that need to be addressed as well as adjustability points that could be added. Some major considerations that will be addressed are that the adjustability in certain features not yet used may help the smaller percentile ranges feel more confortahbe wearing the suit for an extended period of time. A removable neck support system will be considered to allow better comfort and optional use if the user does not need it at a certain point of the workday.

Summary

This study revealed very informative data that will be considered in the refinement of future concepts and designs. The comfort of the user was the main goal for this study the ability for the user to work long hours in this equipment is key. Adjustability points to fit all users is important and data collect in that aspect will be applied in the future. With the problems faced throughout this study and addressing them, the future refinement will be able to be more ergonomic and will improve the users work experience .

3.4 - Aesthetics and Semantics

Products in the industry tend to have a rigid durable approach to them. A styling theme that makes the product look like its very well fit for the task even before it is used. All products resemble one another by having the same colour association throughout their whole brand.

Fig.24

(n.d.). Best Pipe Wrench of 2020. Retrieved from https://righttorisesuperpac.org/best-pipe-wrench/.

Products in a brand family have the same colour so the user and people around are distinctly able to tell what brand that is from.The most popular colours in the trades industry are red, yellow blue and black. These colours allow for the product to bee seen from far distances and really gets the attention of people.

The tool should have the attributes of :

Durability Toughness Rigid Trustworthy

Some of these attributes are what designers in the industry base their concepts on. Some customers don’t have time or the opportunity to be able to test the product before buying. It has to fit a certain target market that is willing to buy the item before major use. The product gains the belief of the customer based off of its styling cues and attributes listed above.

3.5 - Sustainability - Safety & Health

Health

The Exo unit is planned to aid in mitigating injuries for commercial plumbers. As this is the focus of the project, it may also improve the long term and short term health of the user. Reducing strain on the body that will allow for muscle health to be improved and not damaged over time. Also combating posture issues faced within the work field will help the user reduce pains they may have been experiencing as some examples. Overtime exo units have been helping people in the medical sector with recovering from injuries such as paralysis and other conditions that may affect the movement of the body. As the national institute for health and care excellence stated “The technology described in this briefing is the Ekso GT robotic exoskeleton. It is a motorized orthosis device for use in rehabilitation activities for people who have weak or paralyzed legs and sufficient arm strength to use crutches” NICE. (n.d.).

Safety

Safety is a key initiative when it comes to the exo unit. Mitigating injuries for commercial plumbers is the focus and the goal. Creating a unit that is safe to use and keeping the user that is working the unit safe is whats most important. To achieve this many areas were researched to figure out the most common injury points within commercial plumbers and combat them. Materials used within the unit will be chosen to keep the suit durable when completing certain tasks. The suits goal is providing the user with consistent results throughout an entire workaday to mitigate harm, injuries and pain and keep themselves safe at all times.

3.6 - Sustainability - Innovation Opportunity

The goal for an exo unit is to be efficient in every aspect of the design. Analysis of different sectors of the design process was researched. When it comes to materials, manufacturing and usage all these sectors are planned to be as efficient as possible. When it comes to materials carbon fibre is planned to be used as it has the highest strength per weight ratio allowing it to be easier to manufacture in some areas and the weight of the product will be significantly less as if another material would be used. This allows for the user to get the same amount of strength and durability as if it were metal but replacing it with carbon fibre will help in efficiently as the battery power needed will be reduced due to the decrease in weight of the material. Manufacturing the unit is planned to be efficient too, as new carbon manufacturing methods and technologies are introduced to the market. One method to manufacture carbon fibre parts is with the new technology via a solar powered algae based carbon fixation process as stated in this article “Carbon fibers, if generated from anthropogenic CO2 via algae-based carbon fixation and subsequent energy and cost-efficient carbonization, would be a sustainable CO2 sink” (ACS Publications, (n.d.). This will provide a cost efficient energy saving alternative to the standard process. As many batteries may be produced to power the units, consideration in joining the “Call2Recylce" initiative to provide a recycling solution for all batteries at the end of their lifecycle will be looked towards.

3.7 - Design Brief

The Goal : Design a system to mitigate physical injuries for plumbers in the commercial work field, the purpose is prevent long term injuries from occurring early on and ease the work experience for users already affected. The design must be comfortable enough to last an entire workday.

Needs Statements

The worker needs to protect themselves/body because they want to reduce injuries when working

The worker needs to find out why they feel pain after work because they want to feel better

The worker needs to keep safe/take precautions while working because long term injuries may occur in the future

The worker needs to find out how to reduce risk of injury when working because not knowing gives them worry/anxiety

The worker needs to find out ways to complete certain tasks more efficiently because they want to save time, get more done and make work easier

Chapter 4

4.6 - Design Resolution

4.7 - Cad Development

4.8 - Physical Model Fabrication

Chapter 4

Where the design came to be will be analyzed in this chapter. Showcasing initial thoughts/ brainstorming, ideas, concepts and design development and refinement.

4.1.1- Aesthetics Approach & Semantic Profile

With Exo, the task is to create an easy to use, comfortable and well rounded product for the user in hopes to mitigate injuries for commercial plumbers. Benchmarked products in the trades worker sector such as tool kits, personal protective equipment and material transportation devices gave insight into the themes products in the industry follow. Research from these products showed that people in the industry likes a product that has styling cues related to quality, social presence and durability. Having a well styled product that can display durability to the user just based on looks is the main theme seen throughout benchmarked products in the market. Workers in this target demographic want a product that will last a long time, enhance their work experience and a product that will stand out on the job site gaining social recognition. For the Exo unit styling cues of bright colours to signify each interactive component was chosen, the bright colour choices add to the value of social recognition. Most brands seen throughout the industry are recognized just based off their colour for example people recognize Dewalt based on the bright yellow colour theme throughout each product. With the outside product housing workers want them to “feel” right in your hands and look great (Nasvik, J, n.d.). Having a product look durable adds trust into the performance of the product, having a great feel and sense of quality gives the user faith in the longevity of the product. These important factors were used

into designing the Exo as a tough build to fit the target demographic was key. Having a futuristic look towards the Exo was also needed to fit the time range the product is meant to be in. As new technology will be implemented in the suit design features were developed further in the future than benchmarked products on todays market.

Fig.25

4.1.2 - Mind Mapping

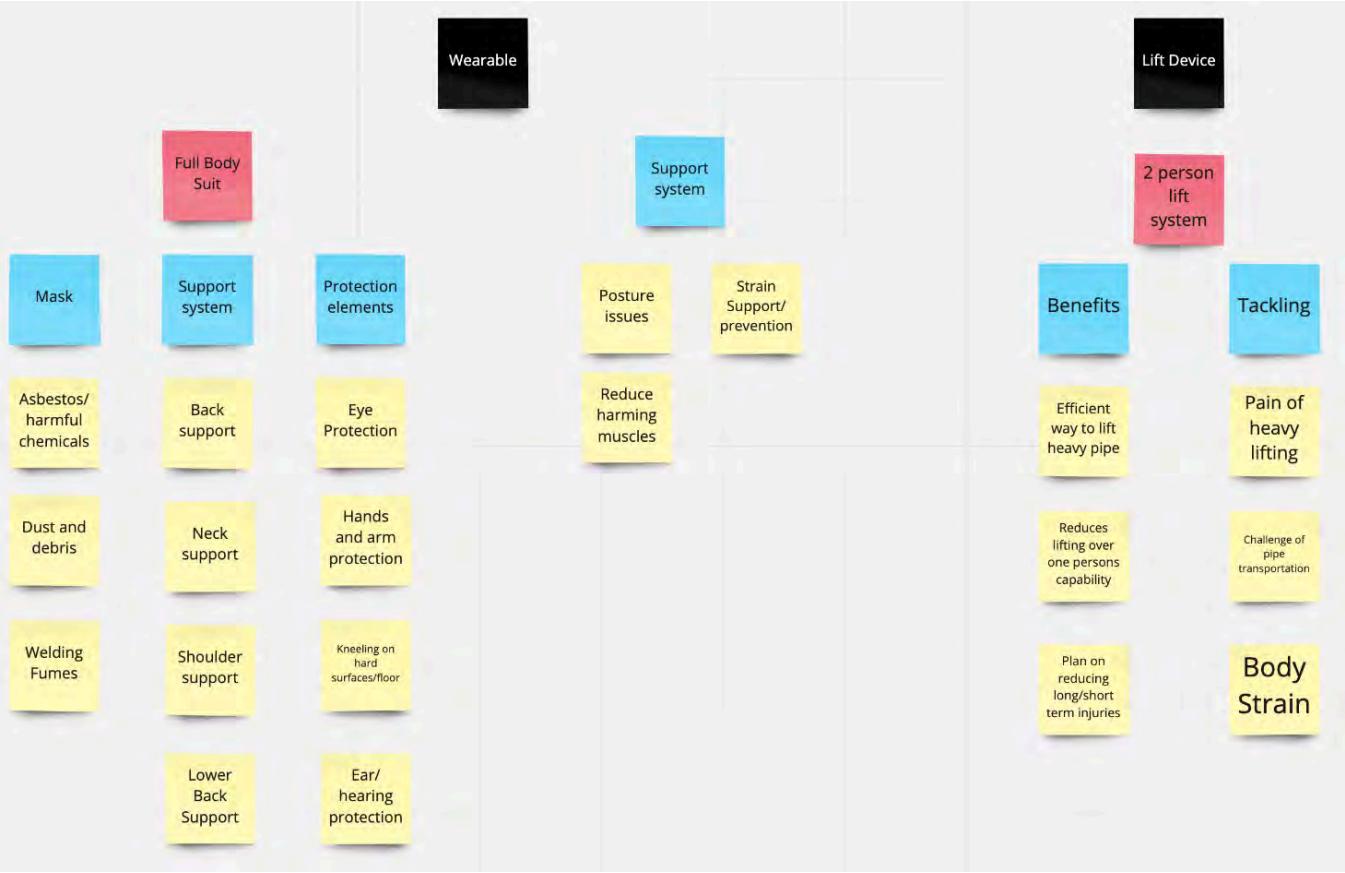
Pain points and Challenges of current commercial plumbers were researched and noted below. Using the data found within different research methods helped aid the brainstorming / mind mapping process shown next.

Fig.26

4.1.2 - Mind Mapping - Cont

With initial ideas filtered through, possible design directions have been brainstormed using insights and research discovered. Main challenges and pain points have been taken into account and possible concepts are brainstormed. Ideas displayed are to be addressed in future concept iterations.

Fig.27



4.1.3 - Ideation Sketches

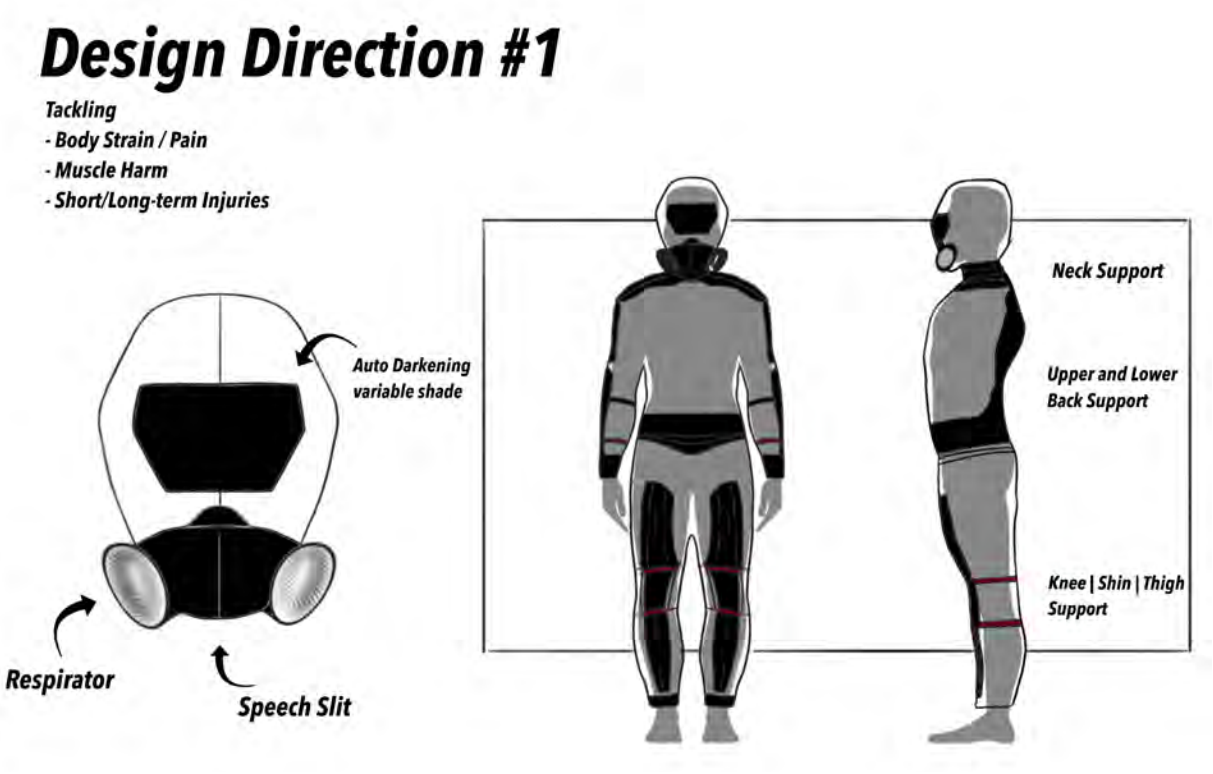
With initial ideas filtered through, possible design directions have been brainstormed using insights and research. Main issues are being noted and possible concepts are brainstormed, to be addressed in future concept iterations

4.2 - Concepts Exploration

With initial ideas filtered through, possible design directions have been brainstormed using insights and research. Main issues are being noted and possible concepts are brainstormed, to be addressed in future concept iterations

4.2.1 - Concept 1

Fig.28



Concept 1 is designed to tackle body strain pain, muscle harm and short too long term injuries. Pain points intended to be reduced by providing neck support, leg/knee support as well as support for the upper and lower back. The mask addition aims to prevent fume inhalation plumbers endure white welding in rooms and areas with little airflow.

Fig 4.2.2 - Concept 2

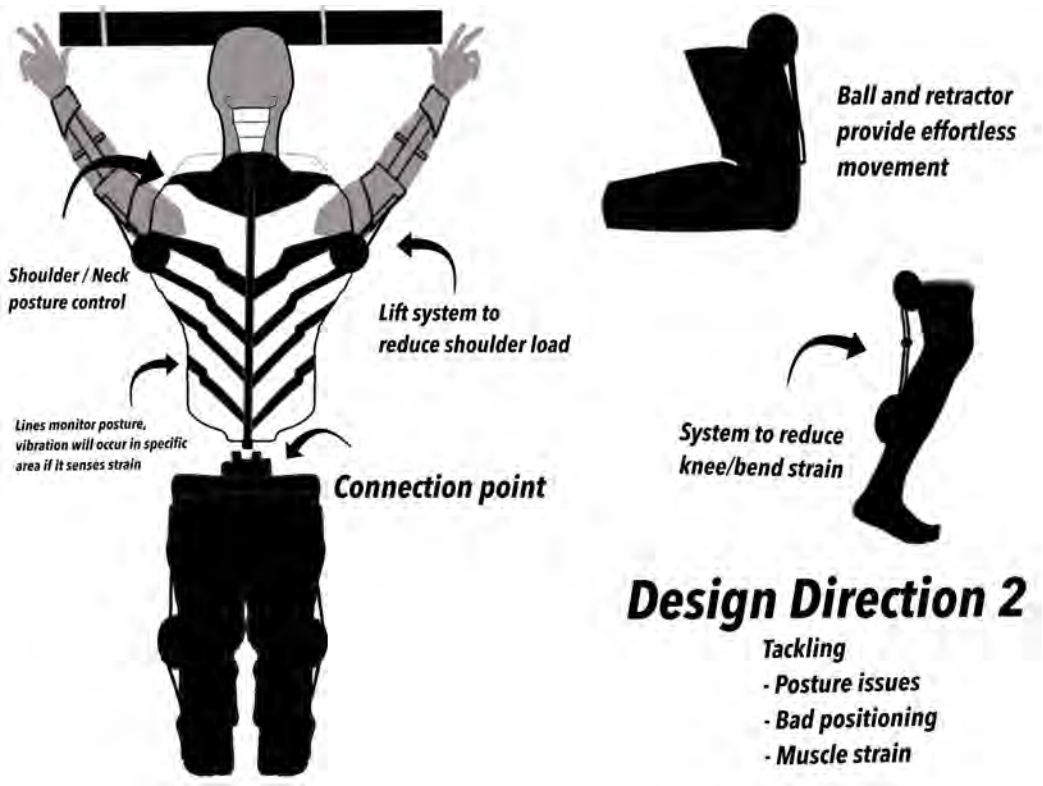


Fig.29

Concept 2 is designed to tackle pain points and challenges related to posture/ bad positioning and muscle strain. Lift systems, posture monitor sensors and movements assists are added to provide support to plumbers while enduring physically demanding tasks.

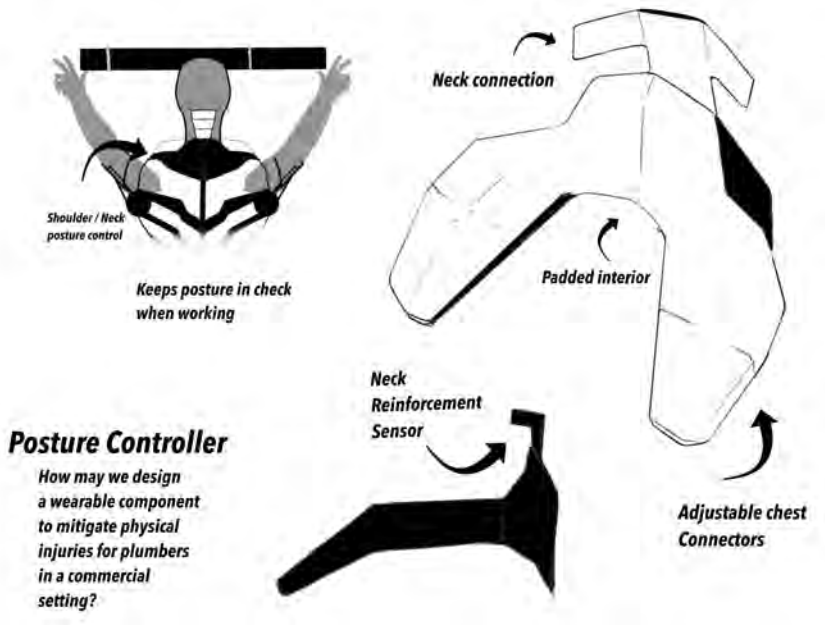


Fig.30

Fig 4.2.3 - Concept 3

Concept 3 is designed to assist plumbers in the task of lifting pipe. Plumbers decide to lift pipe by themselves at times running the risk of major injuries as pipe can exceed the 100lbs range. Pipe may have to be carried towards ceiling height which is hard on the body with the excessive weight pipe can range up too. Creating a two person lift device system plans to tackle this issue.

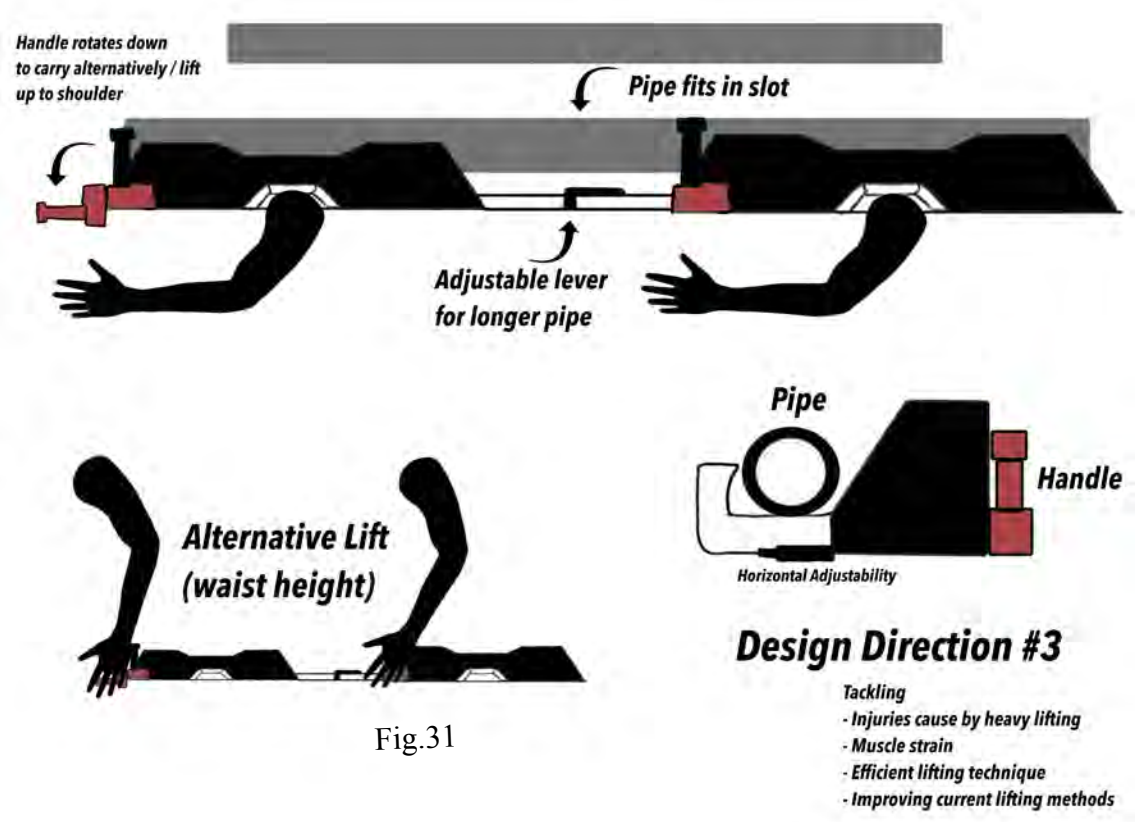


Fig.31

4.3 - Concept Strategy

With 3 initial concepts produced, two were selected to be continued and refined further. Many challenges faced was mostly due to bad posture and muscle strain during tasks throughout the workday which was the main focus in these iterations.

4.3.1 - Concept 1

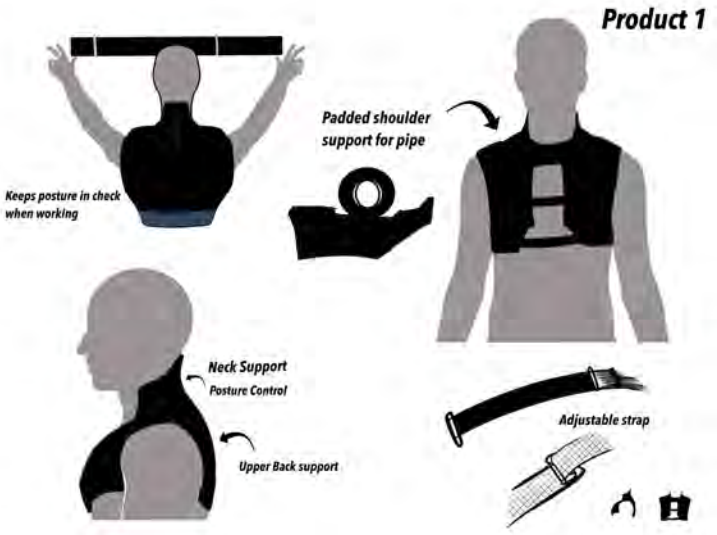


Fig.32

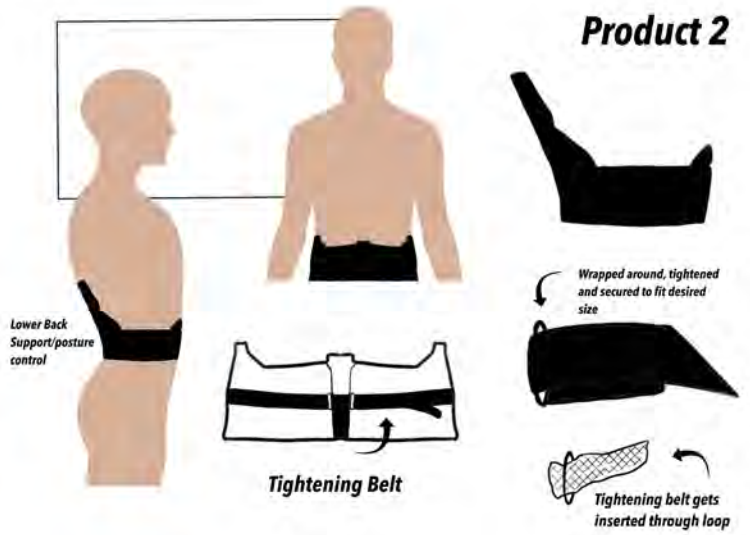


Fig.33

Concept 1 had a main priority of handling bad posture points that are frequently faced as well as parts of the body that consistently are affected. Support modules of the upper body and back area are seen above to tackle pains from heavy lifting of pipe and bad position during certain tasks.

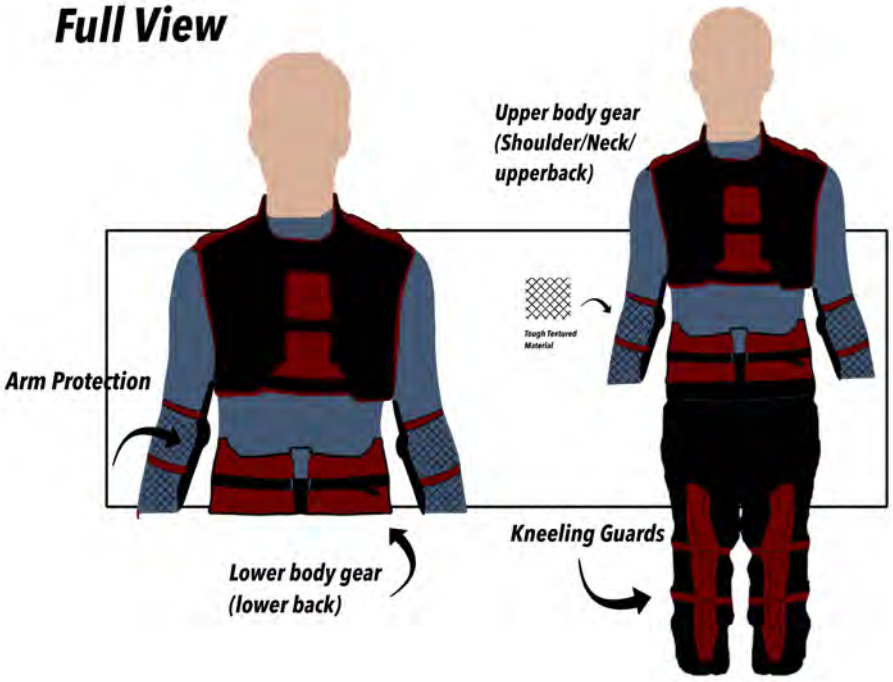


Fig.34

Adding new gear of kneeling guards and arm protection, in combination with the current gear allowed for full body support.

A 5th percentile woman and 95th percentile man are used for a full range of workers to use the equipment.

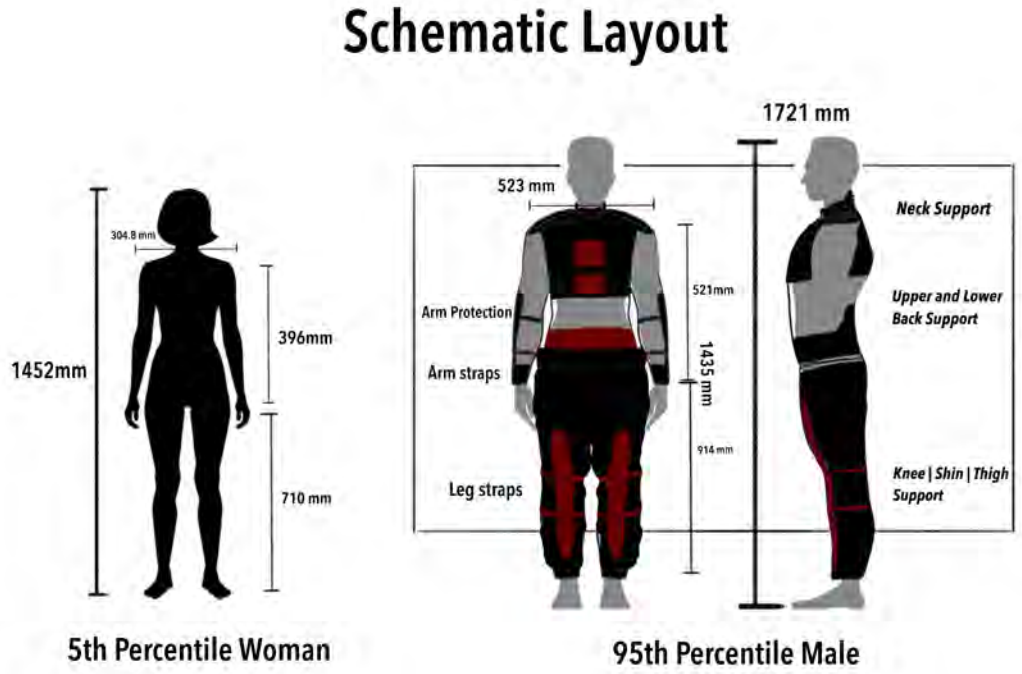


Fig.35

4.3.2 - Concept 2

Concept 2 has a main priority of reducing muscle strain and pain from repetitive movements during a workday. Providing assistance and support for the task of heavy lifting materials was also a goal.

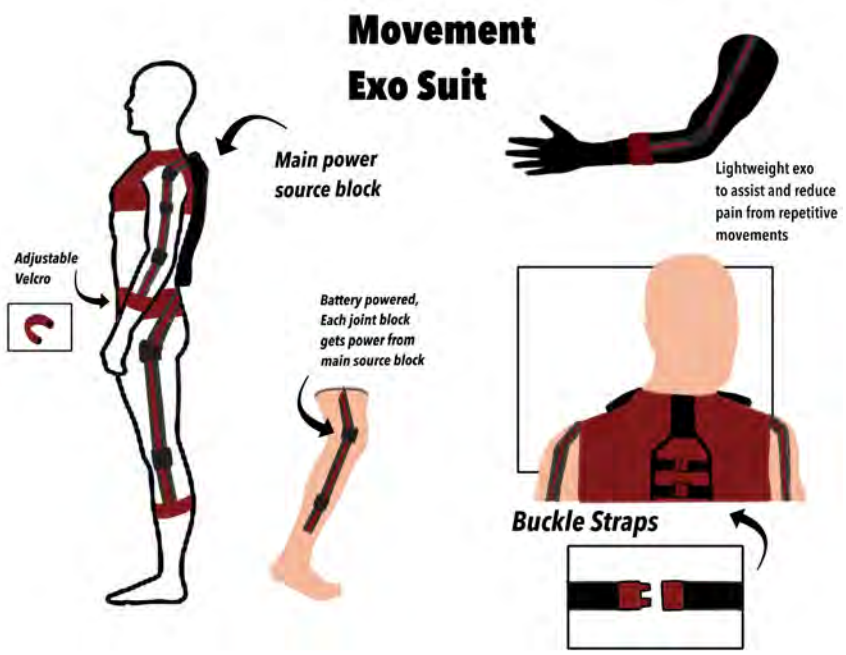


Fig.36

To achieve this a movement Exo suit is used and attached to the plumber. Providing battery operated power support to each body part.

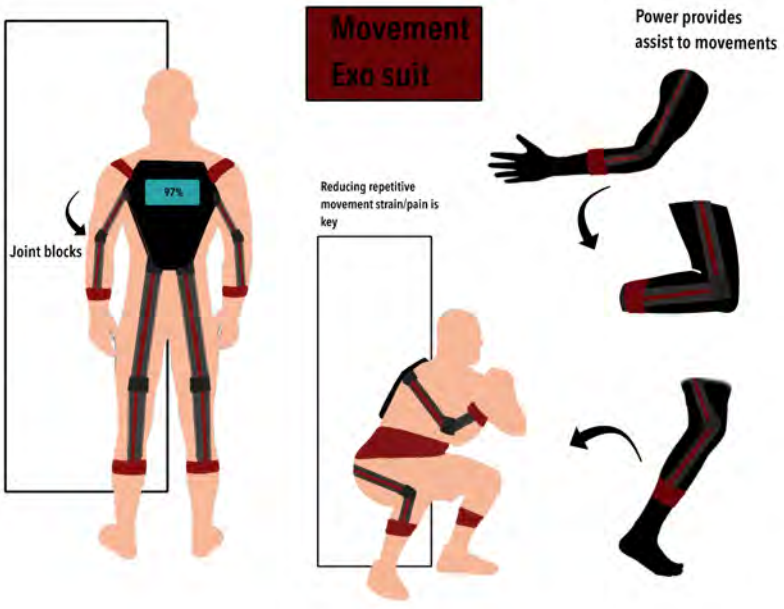


Fig.37

4.4 - Concept Refinement and Validation

Based on the two concepts displayed in 4.3, one was selected to develop and move forward with.

The Exo movement suit underwent design refinement and adjustments.

4.4.1- Design Refinement

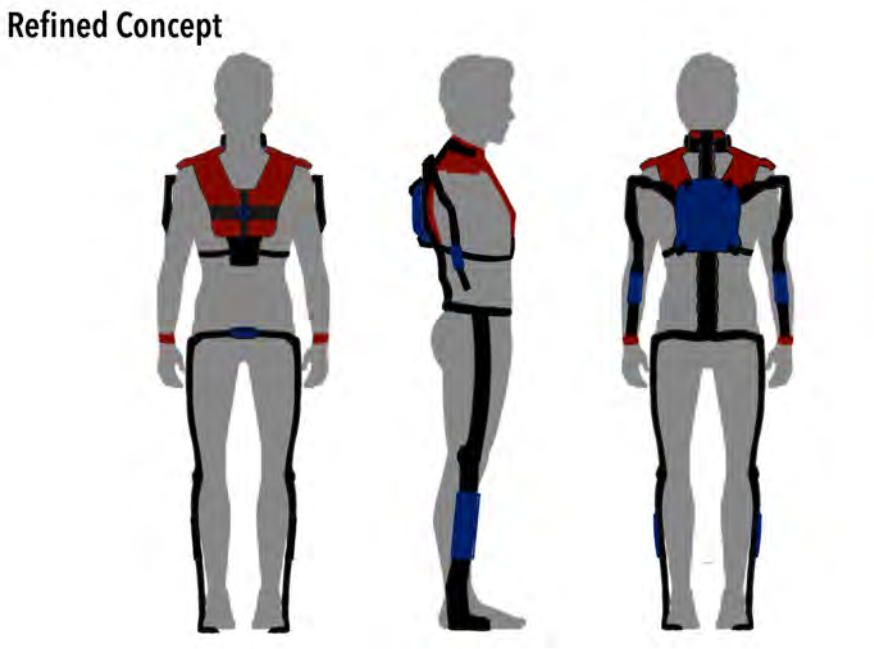
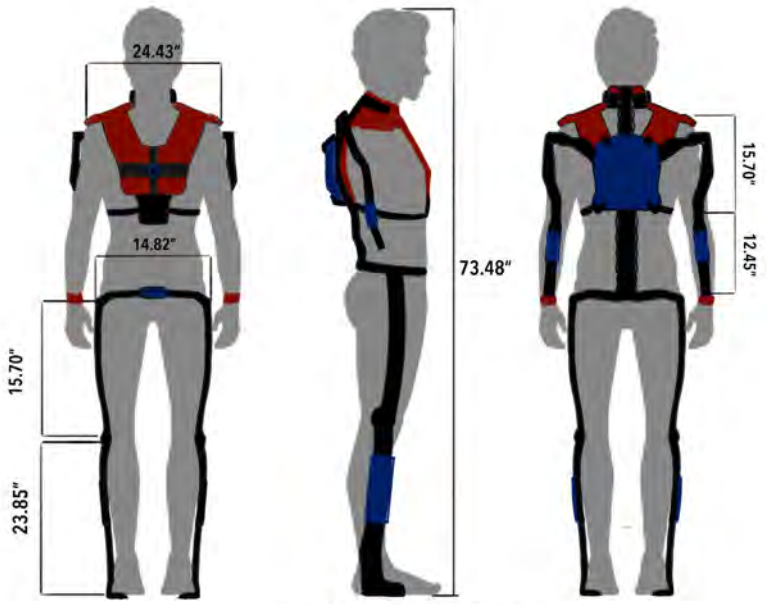


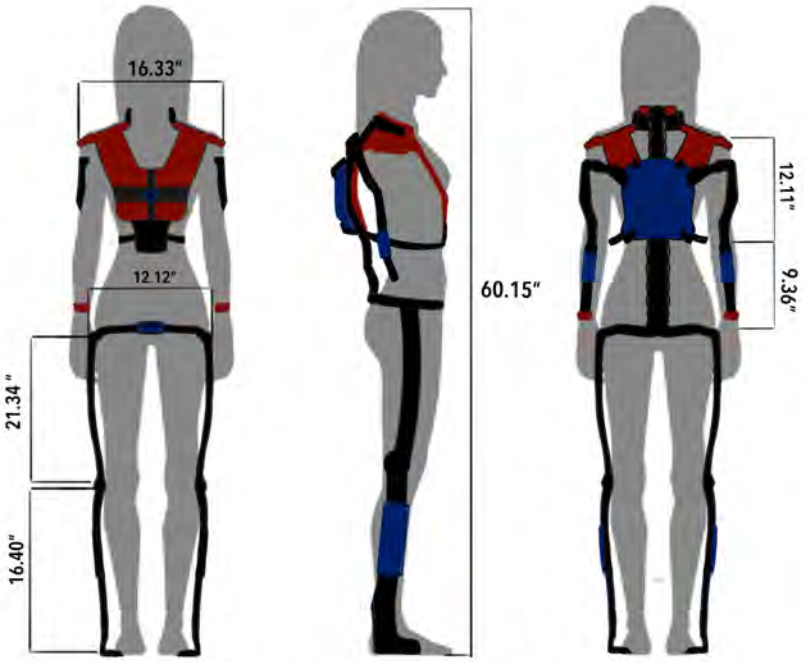
Fig.38

Fig.39



95th Percentile Man

Fig.40



5th Percentile Woman

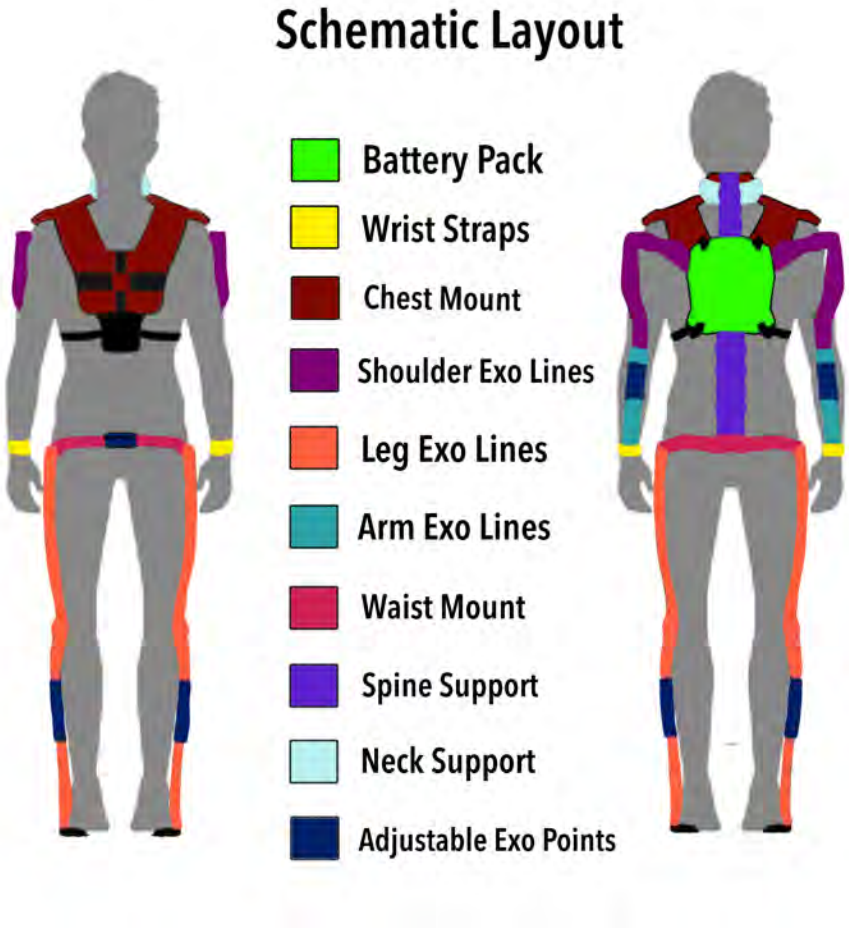
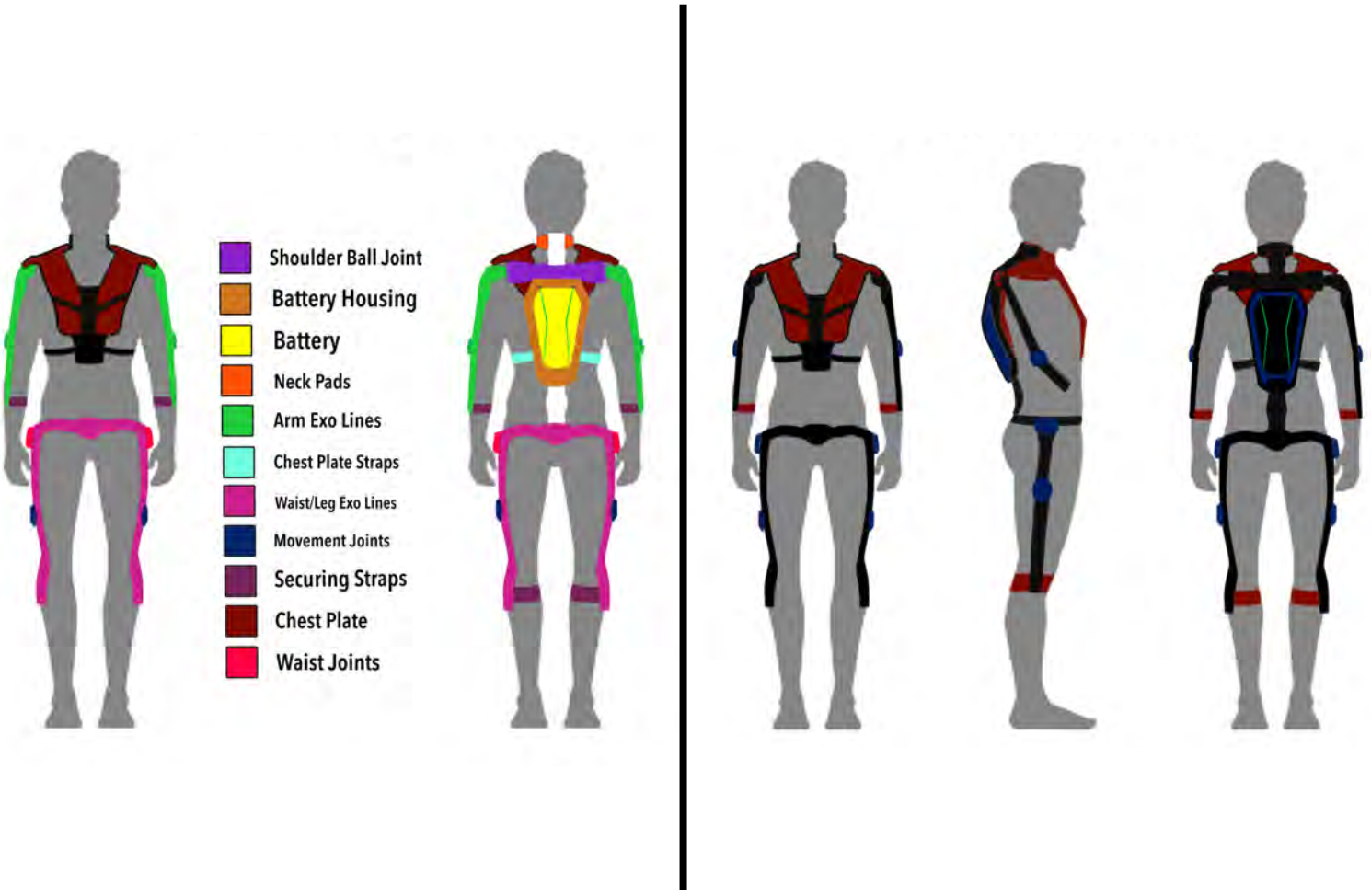

Schematic Layout
Battery Pack
Wrist Straps
Chest Mount
Shoulder Exo Lines
Leg Exo Lines
Arm Exo Lines
Waist Mount
Spine Support
Neck Support
Adjustable Exo Points

Fig.41

4.5 - Concept Realization

4.5.1 - Design Finalization -1

Fig.42



4.6 - Design Resolution

After all the concepts and refinements the design was tweaked in regards to aesthetics to make it more unique and add a durable look to the unit. Minor shifts in component placement were also introduced to provide better ergonomics and range of motion to the user. Lastly the design motors and mechanisms changed to allow for an efficiently smooth operation when using the product, this allows for no parts to come in contact with each other.

These design changes allowed for an overall resolved possible solution for mitigating injuries commercial plumbers. One goal was to achieve a wearable product that will last the worker an entire day without losing the factor of comfort. These changes helped bring this to life.

4.7 - Cad Development

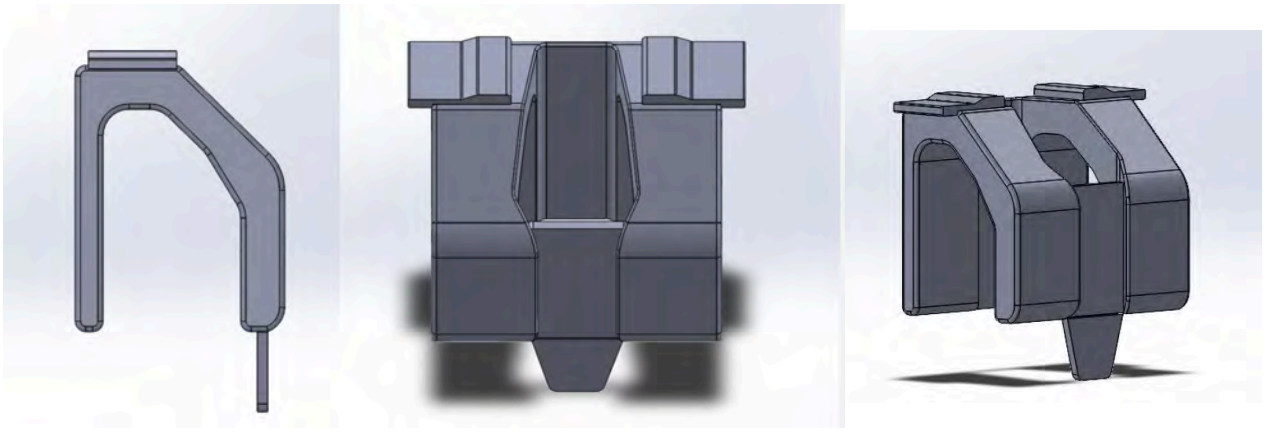


Fig.43

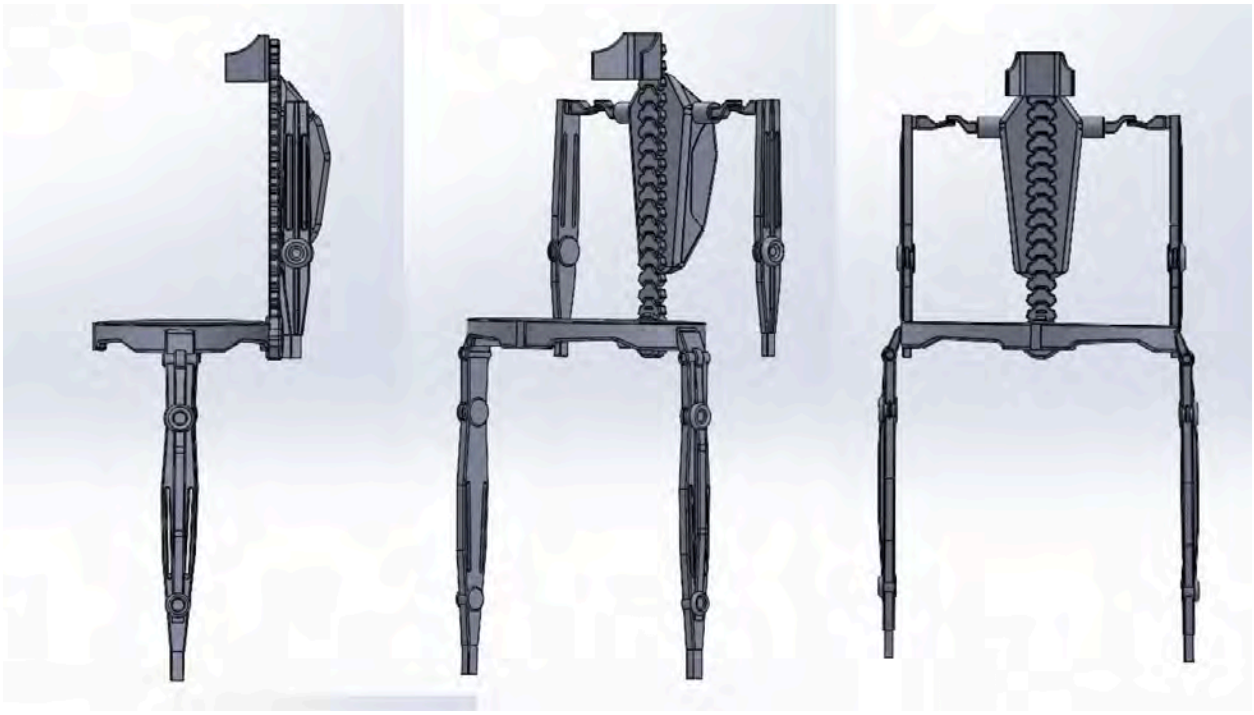


Fig.44

Fig.45

Progressing from sketches into the cad process was the hardest part. Knowing where to start and deciding a plan of constructing your planned design is a challenge. Once the first parts were constructed the rest of the design flowed freely allowing me to progress rather quickly. Along the way issues arose which is common to happen using the program but all the problems ironed out and were cleared in the end result. The final result of the cad model was tweaked which will appear further in the reading, as some measurements and areas needed to be refined just a tad more to get ready for the 3d printing stage.

4.7 - Physical Model Fabrication

Fig.46

At this stage the files were sent off to the prying company to be manufactured. A couple parts failed and measurements had to be tweaked a tiny amount to fit the 1/6 model that the parts are attaching onto. The final result of the print process is shown above as all parts were to spec and ready for the painting process.

Chapter 5

5.1 Summary

Exo X is an exo suit unit devoted to helping with mitigation surrounding injuries of commercial plumbers in order to prevent long term injuries from occurring early on where apprentice workers are at most risk.

Explanation

Commercial plumbers are susceptible to injuries from tasks endured during workdays. Injuries occur even with safety rules and regulations in place. With heavy lifting, repetitive movement, material transportation and machinery operation to list some, plumbers job tasks have high injury rates and health risks. Due to these job tasks being physically demanding, wear and strain on the the body is common. According to the Bureau of Labour Statistics, 37% of all days taken off include back pain and sprains as well as injuries to the muscles, tendons and ligaments. Long Term workers within the industry commonly experience muscular injuries that cause lifelong pain and discomfort. A fast efficient workflow is key within this field of work, safety and health sometimes gets pushed aside. How may we mitigate physical injuries for plumbers in a commercial setting? Preventing these injuries early on is key. Exo X plans to enhance a safe work experience for workers while providing an efficient way of working.

5.2 Design Criteria Met

5.2.1 Full Bodied Interaction Design

Exo X is designed with the user in mind. The main goals of the product are for the user to experience a new efficient way of working. Important user factors pursued within the product include ease of use, comfort and simple usability. Ease of use was considered as the user gets on the job site Exo X is intended to be a fast install as delaying this process would get workers to not want to use the product as frustration will overtake them. The process to equip Exo X is simple, there is six attachment points in the product, one on each arm, one on each leg, the Exo belt and lastly the chest plate. All of these components are adjustable to fit most percentile groups. Comfort was also in mind. Having components like neck support and a Exo spine allows the user to feel in good posture. Usability is the last major thing that was considered. The product is very easy to use. The computer system within the product helps guide the user into proper motion providing power to where the user applies the movement using its motor systems.

5.2.2 Materials, Processes and Technology

Materials for Exo X is extremely important. Having a lightweight, comfortable and durable unit is the main focus. This is because workers will be using the product throughout an entire workday and need to feel comfortable all shift long. The current use of materials found in benchmarked products and other exo suit units all depends on whether the suit is powered or meant to be a passive mechanical unit. A company by the name of “Ekso Bionics” an exo suit technologies company and developer stated that “Every exoskeleton suits is different. Some are

made from rigid materials such as carbon fibre or metal, while others are made from soft and elastic parts" (Bionics, E, 2022). The materials used are also dependent on the utilization of the suit as seen in the graph below in (fig.1). Some exo suits can be used for outdoor physical activities such as usage in the military that need to be more durable for certain tasks, while some may be used in the medical field to combat certain issues such as paralysis or other conditions and need to be more free moving. In each case different materials may work better than others depending on its use. Overall early exo units used to use aluminum and steel for the main frame as it was easy to manufacture and not too costly. Later in development popular materials of newer exo units transitioned to materials that are durable and light in weight. This was to increase the efficiency within the unit and provide a higher strength per weight ratio. Materials that fit into this category are carbon fibre for the weight reduction and durability and fibreglass for its light weight and strength. Materials used for padding, straps and fitment components are mainly nylon, cell foam/polyethylene sponge as well as neoprene (polychloroprene) a synthetic rubber material. For some outer components high density polyethylene plastics may be used over the foam for protection.

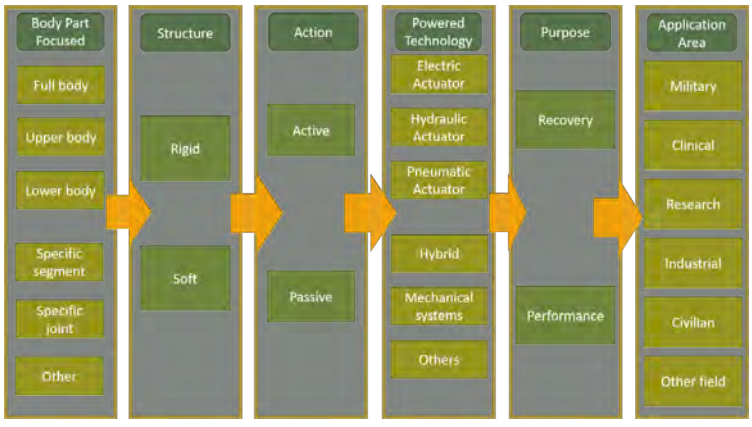


Fig 47 - Exo unit Graph displaying different use cases

5.2.3 - Implementation - Feasibility and Viability

Part	Material	Manufacturing	Cost
Exo Arms	Carbon fibre	Compression Moulding	$200
Exo Legs	Carbon fibre	Compression Moulding	$200
Exo Spine	Elastic Fiber	Industrial Crafting	$75
Exo Chest Plate	Polyethylene	Industrial Sewing	$100
Exo Battery	Lithium Ion	Supplied	$140
Exo Battery Housing	Polypropylene	Injection Moulding	$40
Exo Belt	Thermoformable Foam/ Polychloroprene	Industrial Crafting	$50
Exo Neck Support	Thermoformable Foam	Blowing Agent Process	$25
Exo Motors	Stainless Steel	Metal Injection Moulding	$150
Exo Padding	Thermoformable Foam	Blowing Agent Process	$30
			Total : $1010

Table 9 - Bill of Materials

Although the end total of the unit is on the more expensive side. Quality materials are needed to make a unit related to the aspects covered earlier in the reading. This product is not only intended for the future but will be put through a ton of use during its lifetime as well as being mostly reusable after the life cycle of the product is over.

5.3 - Final Cad Rendering

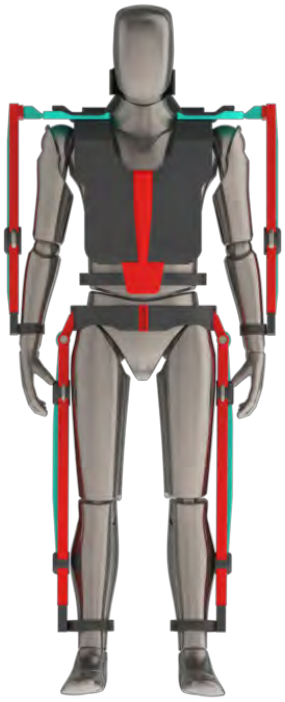


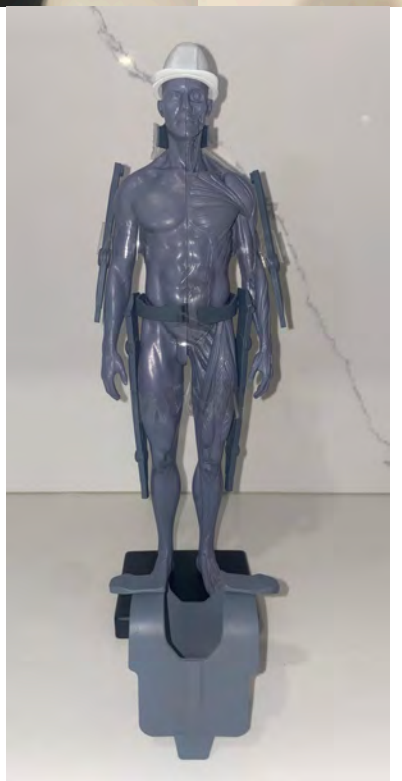
Fig.48

Fig. 49

Fig.50

5.4 - Physical Model

Fig. 51



5.5 - Technical Drawing

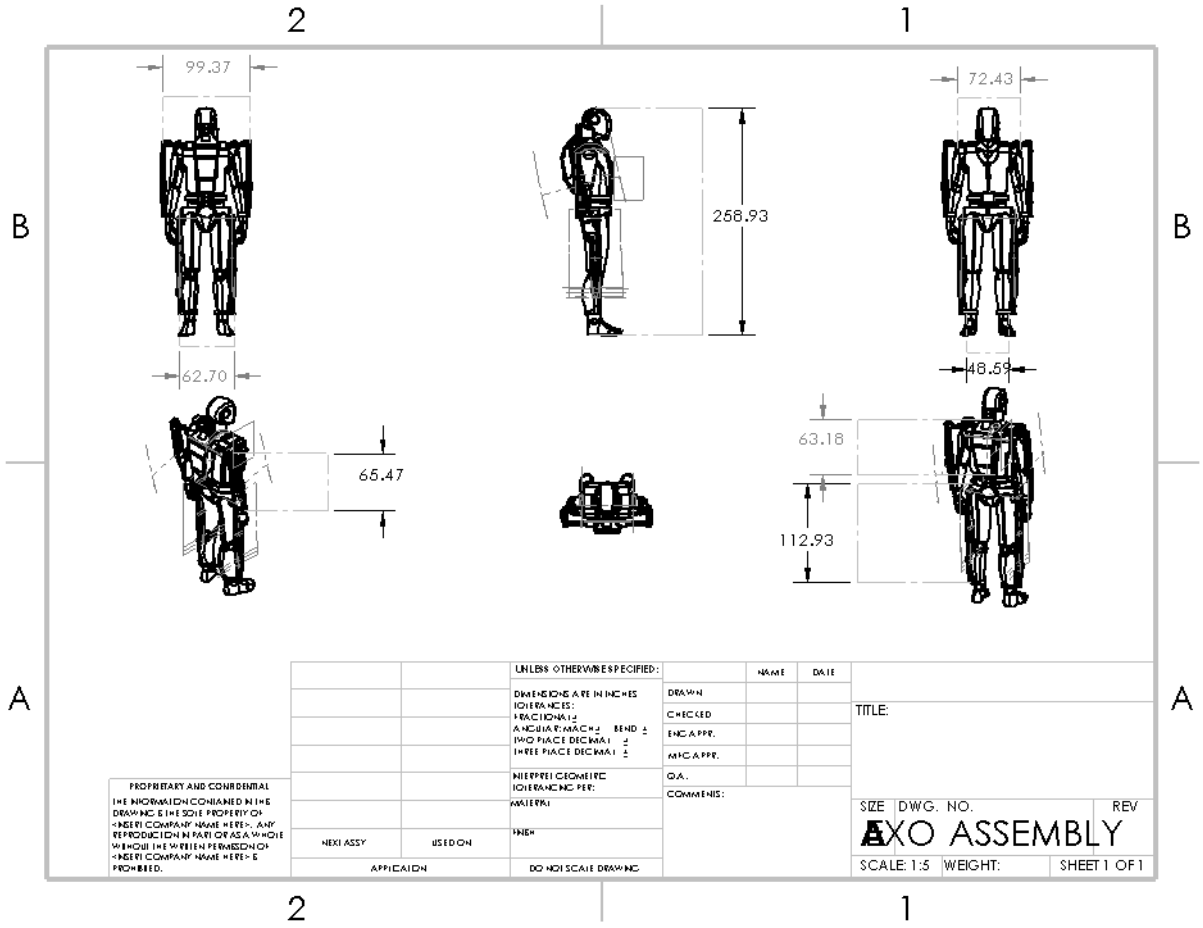


Fig - 52

5.6 - Sustainability

Exo X considers sustainability with respect to minimal impact disposal, efficient lifecycle, the use of responsible materials and applying a battery/carbon fibre recycle initiative program. This is achieved as most materials used for Exo x such as the main carbon fibre components as well as the battery packs are able to be recycled due to the carbon and battery initiative. This initiative will help create a eco friendly life cycle towards the product as well as making little parts as possible go to waste. Each part is able to be swapped out which makes the unit reliable for the long term. Once a unit is produced it should get a ton of work years before it's time to be replaced for a new one.

Chapter 6

Conclusion

Exo X is a exo unit system intending to mitigate injuries for commercial plumbers, as well as preventing these injuries at an early enough state so long term injuries don't occur. Exo X also caters to older people who suffer with these injuries on a daily basis. Exo X has a strong drive to be integrated in the commercial plumbing industry.

Fig - 53

References

Anthropometric detailed data tables - multisite.eos.ncsu.edu. (n.d.). Retrieved December 6, 2021, from https://multisite.eos.ncsu.edu/www-ergocenter-ncsu-edu/wp-content/uploads/sites/18/2016/06/Anthropometric-Detailed-Data-Tables.pdf.

2020). Applying For Workers' Compensation As An Injured Plumber In New York. Retrieved from https://banvillelaw.com/workers-compensation/hazardous-jobs/plumbing/.

Bionics, E. (2022, January 31). What is an Exoskeleton Suit? Ekso Bionics. Retrieved February 8, 2022, from https://eksobionics.com/about-us/

Bet You Didn’t Know These Interesting Plumbing Facts. (n.d.). Retrieved from https://bfplumbingbayarea.com/blog/bet-you-didnt-know-these-plumbing-facts/.

Best Pipe Wrench of 2020. Retrieved from https://righttorisesuperpac.org/best-pipe-wrench/.

Conexpoconagg. (n.d.). Sustainable technology on Construction Equipment. conexpoconagg. Retrieved February 8, 2022, from https://www.conexpoconagg.com/news/sustainable-technology-on-construction-equipment

Common Plumbing Pipe Materials. Retrieved from https://www.shamrockplumbing.net/2016/03/common-plumbing-pipe-materials/.

Energy-efficient carbon fiber production with concentrated solar power: Process design and techno-economic analysis. ACS Publications. (n.d.). Retrieved February 8, 2022, from https://pubs.acs.org/doi/10.1021/acs.iecr.7b04841

Exo-O1 Overhead Exoskeleton. Overhead Exoskeleton - Hilti Canada. Retrieved April 21, 2022, from https://www.hilti.ca/c/CLS_EXOSKELETON_HUMAN_AUGMENTATION/CLS_UPPERBODY_EXOSKELETON/CLS_SUB_UPPERBODY_EXOSKELETON/r11987306

Guardian, J. (2021, July 28). Exoskeletons: Five manufacturing applications. Manufacturing AUTOMATION. Retrieved February 8, 2022, from https://www.automationmag.com/9609-exoskeletons-five-manufacturing-applications/#

Ianpoultney. (2018, January 25). Exoskeleton. Camera Revolution. Retrieved April 21, 2022, from https://camerarevolution.com/equipment/exoskeleton

Javier A. de la Tejera, Bustamante-Bello, R., Ramirez-Mendoza, R. A., & Izquierdo-Reyes, J. (2021, December 1). Systematic Review of Exoskeletons towards a General Categorization Model Proposal. Applied Sciences. Retrieved February 8, 2022, from https://doaj.org/article/5b4aca79a50e45e0b2d436a71d084a76

Kerns, J. (2015, January 8). The rise of the exoskeletons | machine design. Machine Design. Retrieved February 8, 2022, from https://www.machinedesign.com/mechanical-motion-systems/article/21831817/the-rise-of-the-exoskeletons

Milwaukee Electric Tool: Leading the way in sustainability: Call2recycle: United States. Call2Recycle. (2013, June 3). Retrieved February 8, 2022, from https://www.call2recycle.org/milwaukee-electric-tool-leading-the-way-in-sustainability/#:~:text=The%20company%20has%20also%20proven,with%20the%20Call2Recycle%20Licensee%20Seal.

My first year plumbing apprentice toolkit. Retrieved from https://www.reddit.com/r/Tools/comments/byiyrj/my_first_year_plumbing_apprentice_toolkit_aus/.

Overview: Ekso exoskeleton for rehabilitation in people with neurological weakness or paralysis: Advice. NICE. (n.d.). Retrieved February 8, 2022, from https://www.nice.org.uk/advice/mib93

Repairs And Maintenance. (n.d.). Retrieved from http://danmacplumbing.com/services/commercial-plumbing-services/repairs-and-maintenance/.

Tilta armor-man 2.0 exoskeleton - v mount arm-T02-v camera stabilizer & gimbals - vistek canada product detail. Vistek. (n.d.). Retrieved April 21, 2022, from https://www.vistek.ca/store/428150/tilta-armorman-20-exoskeleton-v-mount

Waehrer, G. M., Dong, X. S., Miller, T., Haile, E., & Men, Y. (2007). Costs of occupational injuries in construction in the united states. Accident Analysis and Prevention

(2017). What Do Plumbers Wear When Working? Retrieved from https://www.ra-heating-plumbing.co.uk/news/what-do-plumbers-wear.

Who makes the best tools in 2021. Retrieved from https://www.protoolreviews.com/who-makes-the-best-tools/.

APENDICIES

A - Discovery

Report 1 Preliminary Information Search

The objective of report 1 is to conduct a quick gathering of information, know as preliminary research. Preliminary research will be directed towards injuries in the pluming and construction industry. Using scholarly articles and online searches such as Google Scholar this will be performed.

Scope/Background:

In the construction industry an importance is people/worker safety, making sure all workers arrive and leave well and safe is ideal, providing a consistently safe workplace for all. Many workers in the construction industry have constant pains and consistently get injured within the field. Even with procedures and rules in place the fast pace and heavy workload takes a toll on the body. Finding a way to reduce and combat this is key.

Needs statement : Construction workers (plumbers) need a unique solution to reduce injuries in the workplace.

How is this need being addressed currently?

Currently, construction workers have on site safety inspectors and safety influencers inspecting and making sure the the job site is a safe workplace to work in. Rules and procedures are also set in place to avoid injuries. Wearable equipment is also used to protect workers based on certain tasks they are

preforming. Many solutions provided do have their flaws in different aspects, and some common injuries get overlooked until it becomes a bigger problem long term.

Key Article 1

Method :

A ideal article for this topic was researched and choose to use for the preliminary research report. The information from the chosen article was copied and red highlights indicates superior information found.

- Search Engine : Humber Library Discover Peer Review
- Key Words : Plumbing injuries

Findings

Citation :

Kinn, S. , Khuder, S. , Bisesi, M. & Woolley, S. (2000). Evaluation of Safety Orientation and Training Programs for Reducing Injuries in the Plumbing and Pipefitting Industry. *Journal of Occupational and Environmental Medicine, 42* (12), 1142-1147.

Key Content: Copied Below :

Abstract

Construction workers are at increased risk for fatal and non-fatal injuries. This study examined the effectiveness of employee orientation and training in reducing injuries among plumbers and pipefitters. We searched the Occupational Safety and Health Administration's "recordable" injury data and "documentable" safety and training records for six plumbing and pipefitting employers in northwestern Ohio. During the period 1996 to 1998, 133 injuries were recorded with the duration of 2,541,432 working hours. The most common types of injuries were cuts, lacerations, and abrasions. The majority of injuries resulted from workers being struck by objects. The injury rate was significantly higher for small companies and longer working hours. No difference was

found between traveling and local workers. Seventy-five percent of workers received safety orientations on injury prevention. Among workers who received safety orientations, only 3.4% experienced injuries, compared with 11.1% of workers without orientations. Safety orientations were associated with a significant reduction in injuries (odds ratio, 0.23; 95% confidence interval, 0.15 to 0.35). Proper safety orientation and training could reduce the risks for occupational injuries in construction workers.

Introduction

Safety and health education and training are important elements of programs targeting the causes and frequency of work-related injuries and illnesses. Workers in construction in general, and in plumbing and pipefitting in particular, are at increased risk as they perform tasks with a high risk for injuries. In 1997, the plumbing and pipefitting industry in the United States had an average employment of 793,600 workers and experienced 84,000 injuries.
1 The average cost of an injury in the construction industry was between $781 and $935 per person in direct costs.
2 The indirect costs ranged from 2 to 20 times the direct costs.
3 Therefore, in 1997 the total losses in the plumbing and pipefitting industry were estimated to range between 216 million and 1.51 billion dollars.
Although safety education and training in the construction industry are intended to reduce the severity and number of accidents, the effectiveness of this preventive treatment in the construction industry has not been documented. Currently, there are no published studies evaluating the effectiveness of safety training in the plumbing and pipefitting industry even though it has the highest incident rates among the construction industry as a whole. In this study, we examined the effectiveness of a safety education and training program in reducing injuries within the plumbing and pipefitting industry of northwestern Ohio.

Discussion/Conclusion

This study examined the association between OSHA-recordable injury data and “documentable” safety and health training/education records available for six plumbing and pipefitting employers in northwestern Ohio. The findings showed that the incidence rate for injuries during the study

period was 10.5 cases per 200,000 working hours. This rate is slightly lower than the national rate (11.3%) for plumbers and pipefitters.

The majority of injuries sustained by plumbers and pipefitters were cuts, lacerations, and abrasions (40.6%), and eye abrasion constituted 15.8% of the total injuries. This finding is inconsistent with that reported by the Bureau of Labor Statistics for 1997.

1 In this report the majority of injuries were sprains and strains, and only 9.6% of the injuries were classified as cuts or lacerations. Our finding, though, is supported by another study 7 conducted with plumbers and pipefitters, which indicates an association with the type of work being performed. Plumbing and pipefitting work is typically overhead work involving cutting, grinding, welding, and material handling.

The results of the study show that 57.9% of the injured workers did not have the appropriate safety education and training level. This is most likely attributed to the nomadic working environment. Workers are constantly moving from one worksite to the next without receiving updated safety education and training. Employers may hire a worker for only 2 or 3 days, thus making safety education and training economically impractical. They rely on past safety education and training and do not educate and train workers who work on job sites for short periods. If the workers have not received the appropriate documentable safety education and training before the start of the short-term job, they most likely will not receive it afterward.

Company size was significantly associated with injuries. Smaller companies experienced a higher percentage of injuries in comparison with larger companies. This finding is consistent with other reports in the literature

8,9 and can be explained by the typically longer hours of work in small companies compared with larger ones.

No statistical difference was observed between the occurrence of injuries in the local workers and the traveling workers, which is easily explained by union training practices. Unions have basic safety education and training requirements that are standard throughout the nation, which

provides all union workers with the same general safety background. In addition, 74.9% of all workers received job-site and company orientation that addressed the safety issues present at that specific job site. This essentially evened the safety awareness levels for the entire study group. Because local and traveling workers perform the same type of work and assume a comparative safety awareness level, our finding of no significant difference between these groups is not surprising. There are no other known studies that distinguish between local and traveling workers, so this finding could not be corroborated through a literature review.

In this study, we found that safety education and training in the form of safety orientation was significantly associated with lower injuries in plumbers and pipefitters. Safety orientation was associated with a 77% reduction in injuries (odds ratio, 0.23; confidence interval, 0.15 to 0.35). This is a new finding for the construction industry. We searched the literature for studies comparable with ours that evaluated the effectiveness of safety orientation in reducing injuries in construction workers but were unable to locate any. Johnston et al

10 reported that workplace safety education and training is not commonplace. Rivera and Thompson

11 reported that there are few data to support the effectiveness of current programs to decrease fall-related injuries in the construction industry. McKenzie et al

12 reported that an orientation program aimed at informing plant supervisors and engineers of risk factors underlying chronic trauma disorders and how to control them reduced OSHA-reportable injury rates for repetitive motion disorders from 2.2 cases per 200,000 work hours to 0.53 cases per 200,000 work hours.

Safety orientation is scheduled training on the company safety and health rules and procedures, the job-site hazards present, and the controls in place to eliminate or reduce the hazards (engineering and administrative controls and personal protective equipment). If workers receive safety orientation and are aware of existing hazards on the job site, they should be better prepared to work around those hazards and use the proper tools and equipment to ensure their safety and health. In addition, if those workers who receive safety orientation are aware of the

company rules and procedures implemented to eliminate or reduce existing hazards, and if the rules and procedures are enforced, the hazards are less likely to result in an injury. Ringen et al

13 reported that many hazardous exposures in the construction industry result from inadequate access to information, measurement technology, and personal protective equipment. Thus, it is expected that proper orientation will lead to a decreased injury rate. Mishra and Strait

14 indicated that effective orientation leads to cost savings for an organization and is a key to lasting and productive results.

The major limitation of this study is the inability to evaluate the effectiveness of particular safety education and training programs on the specific injury. This is because of the retrospective nature of the study and because documentation for particular safety education and training was not available for a specific injury. For example, for an injury involving the use of a ladder, it was easy to determine whether the injured worker was trained in ladder safety, but it would be impractical to do this for other workers. What would be needed is a prospective cohort study in which workers with documented training on a particular task are followed for a specified time and the number of injuries associated with that particular task are documented. Because the data were not structured to determine the length of employment before an injury, we were unable to assess the full impact of orientation training. Another limitation is the lack of information about the individual workers, such as age, gender, and personal characteristics (eg, personality or risk-taking behavior). Despite these limitations, our study is among the first to report on the effectiveness of safety orientation in reducing injuries in construction workers.

In summary, the findings of this study provide some evidence of the effectiveness of employee safety orientation on injuries among plumbers and pipefitters. Further studies are needed to prospectively evaluate the effect of specific safety education and training on injuries in construction workers.

Summary Statements

1. Workers in construction in general, and in plumbing and pipefitting in particular, are at increased risk as they perform tasks with a high risk for injuries.

2. The most common types of injuries were cuts, lacerations, and abrasions. The majority of injuries resulted from workers being struck by objects. The injury rate was significantly higher for small companies and longer working hours.

3. Although safety education and training in the construction industry are intended to reduce the severity and number of accidents, the effectiveness of this preventive treatment in the construction industry has not been documented.

4. Reported that many hazardous exposures in the construction industry result from inadequate access to information, measurement technology, and personal protective equipment.

5. The results of the study show that 57.9% of the injured workers did not have the appropriate safety education and training level.

Key Article 2

Method :

A ideal article for this topic was researched and choose to use for the preliminary research report. The information from the chosen article was copied and red highlights indicates superior information found.

- Search Engine : Humber Library Discover Peer Review
- Key Words : Common Construction Injuries

Findings

Citation :

Waehrer, G. M., Dong, X. S., Miller, T., Haile, E., & Men, Y. (2007). Costs of occupational injuries in construction in the united states. *Accident Analysis and Prevention, 39*(6), 1258-1266. https://doi.org/10.1016/j.aap.2007.03.012

Key Content: Copied Below :

Abstract

This paper presents costs of fatal and nonfatal injuries for the construction industry using 2002 national incidence data from the Bureau of Labor Statistics and a comprehensive cost model that includes direct medical costs, indirect losses in wage and household productivity, as well as an estimate of the quality of life costs due to injury. Costs are presented at the three-digit industry level, by worker characteristics, and by detailed source and event of injury. The total costs of fatal and nonfatal injuries in the construction industry were estimated at $11.5 billion in 2002, 15% of the costs for all private industry. The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002. Five industries accounted for over half the industry's total fatal and nonfatal injury costs. They were miscellaneous special trade contractors (SIC 179), followed by plumbing, heating and air-conditioning (SIC 171), electrical work (SIC 173), heavy construction except highway (SIC 162), and residential building construction (SIC 152), each with over $1 billion in costs.

Introduction

Construction is one of the most dangerous industries in the United States. Despite efforts to reduce the risk of occupational injuries and illnesses in construction, the industry continues to account for a disproportionate share of work-related injuries and illnesses in the United States. In 2004, construction workers were 7.7% of the U.S. workforce (BLS, 2005a), but suffered 22.2% (1278) of the nation's 5764 reported work-related deaths (BLS, 2005b). In addition, there were

more than 150,000 nonfatal injuries and illnesses with days away in construction this year. The rate was 71% higher than that for all industry as a whole (BLS, 2005c).

In spite of the high risk of fatal and nonfatal workplace injuries, there are few estimates of the costs associated with occupational injuries in the construction industry. Most of these are limited to workers' compensation costs and many are specific to a particular geographic area. Cost estimates would combine the frequency and severity of injuries into one measure that can be used to highlight the problem areas in the industry and define the case for safety interventions. Economic evaluations of such interventions would benefit from estimates of the costs associated with occupational injuries. Cost estimates based on individual data on work-related injuries in construction, would reflect the particular patterns of injury, their associated events and sources specific to the construction industry. Given the changes in injury risk as jobs proceed through different stages of the construction process, detailed job- and event-specific costs of injury will be especially useful for the construction industry.

In this paper, we will present costs of fatal and nonfatal injuries for the construction industry at the three-digit industry level using incidence data from the Bureau of Labor Statistics' (BLS) Survey of Occupational Injuries and Illnesses and Census of Fatal Occupational Injuries and cost estimates based on an existing cost model for occupational injuries (Miller et al., 2002, Leigh et al., 2004, Leigh et al., 2006, Waehrer et al., 2005, Waehrer et al., 2004). For nonfatal injuries involving days away from work (DFW), the BLS data allow us to break down construction industry costs for injuries involving days away from work by detailed source and event of injury, as well as by worker characteristics like age, race/ethnicity, and tenure in their current job. Where relevant, we will present analogous costs for all private industry allowing us to gauge the relative severity of injuries in the construction industry. By presenting costs in terms of productivity lost, medical expenses, household disruption, and impairment to one's quality of life, our work enables readers to compare the impact of different injuries along several different dimensions.

Conclusion

This paper presents a comprehensive estimate of the societal costs of occupational injury in the construction industry including both direct medical costs, indirect losses in wage, and household productivity, as well as an estimate of the quality of life costs due to injury. The total costs of fatal and nonfatal injuries in the construction industry were estimated at $11.5 billion in 2002, a disproportionately high 15% of the costs for all industries. The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002.

Because of the comprehensive accounting of costs in our model, the cost estimates presented here are higher than those based on workers' compensation data, which range from an average of $7500 for all construction injury types in construction to $10,000 for workers in the Oregon workers' compensation system (CPWR, 2002, Horwitz and McCall, 2004). The average per-fatality cost of $4 million in construction is also higher than the recent NIOSH estimate of $864,000 which did not include quality of life losses (NIOSH, 2006). Subtracting quality of life costs from our estimate results in a more similar cost per fatality of approximately $1 million. Our results show that falls and overexertion result in the highest costs of DFW injuries in construction. This is not surprising—these two events dominate the incidence of injuries in the industry. Falls to a lower level and repetitive motion were two injury events that ranked highly when looking at both total costs and per-case costs of DFW injuries.

We examined the sensitivity of our estimates to key parameters. If the estimated number of injuries was one standard error from the estimated mean, total costs would vary by 2.5%. If the Consumer Price Index-Medical Care was used as the medical cost inflator, costs would decline by 0.65%. If the value of lost quality of life varied by one standard deviation from its estimated mean (about 29% of its value), costs would shift by 16%.

A comparison of our estimates of injury costs in construction with estimates from Leigh et al. (2004) using the same cost model shows that the total costs of injury remained relatively stable from 1993 to 2002 reflecting the secular decline in occupational injuries over this period. For example, in 1993, heavy construction, except highway, was estimated to cost $1.12 billion in lost wages, household productivity, medical costs and quality of life losses. In 2002, total costs for

this sector increased only marginally to $1.2 billion suggesting that the 30% reduction in the incidence of occupational injuries for this sector has largely offset increases in medical costs and wages over the 9 years.

As stated earlier, our cost estimates for detailed construction industries combine 2002 estimates of injury incidence with 1993 per-case costs that are inflated to 2002 dollars. Thus, we assume that the composition of construction injuries within each industry remains stable between 1993 and 2002. A simple comparison of the injury distribution between the 2 years reveals that this is a reasonable assumption. Back sprains and other injuries to the muscles, tendons, or ligaments account for approximately 37% of the construction days-away cases in both years. Similarly, fractures and dislocations account for a stable 12% of these cases for both years.

One drawback to our estimates of long-term losses is the lack of information on the actual disability status of each injured worker in the Annual Survey. However, assuming that the cases in the Annual Survey are a fair reflection of permanent disability cases, conditional on diagnosis, our methods will still provide reasonable estimates of the average productivity losses by various categories.

Our estimates of work losses capture the loss to injured workers but ignore any employment opportunities that arise because the injured are no longer able to work. We also put a zero dollar value on productivity losses among persons with restricted (light duty) work. This is a conservative assumption because persons working on restricted or light duty are probably not producing as much as they would be if they were working at their usual job. Our calculation of medical costs also ignores the effect of construction injuries on the time that less serious injuries spend waiting for treatment in emergency departments.

Occupational diseases, many of which are not apparent until years after exposure, are likely to be underestimated in our data. The Annual Survey is also limited by excluding federal, state, and local government workers, workers on farms with fewer than 11 employees, and the self-employed. This is especially a problem for the construction workers, 24% of whom are self-employed (CPWR, 2002). Inspite of these data limitations, this study provides a comprehensive estimate of construction injury costs and a detailed breakdown by source and event. These

estimates will allow for better-grounded cost-benefit analyses of preventive interventions aimed at reducing occupational hazards.

Summary Statements

1. Back sprains and other injuries to the muscles, tendons, or ligaments account for approximately 37% of the construction days-away cases in both years. Similarly, fractures and dislocations account for a stable 12% of these cases for both years.

2. The total costs of fatal and nonfatal injuries in the construction industry were estimated at $11.5 billion in 2002, a disproportionately high 15% of the costs for all industries.

3. The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002. Five industries accounted for over half the industry's total fatal and nonfatal injury costs..

4. Our estimates of work losses capture the loss to injured workers but ignore any employment opportunities that arise because the injured are no longer able to work.

5. Our results show that falls and overexertion result in the highest costs of DFW injuries in construction.

6. Occupational diseases, many of which are not apparent until years after exposure

Citations

Kinn, S. , Khuder, S. , Bisesi, M. & Woolley, S. (2000). Evaluation of Safety Orientation and Training Programs for Reducing Injuries in the Plumbing and Pipefitting Industry. *Journal of Occupational and Environmental Medicine, 42* (12), 1142-1147.

Waehrer, G. M., Dong, X. S., Miller, T., Haile, E., & Men, Y. (2007). Costs of occupational injuries in construction in the united states. *Accident Analysis and Prevention, 39*(6), 1258-1266. https://doi.org/10.1016/j.aap.2007.03.012

C - Product Research

Benchmarking Products

1	2	3	4	5	6	7
3M Ultimate FX Full Face piece Respirator	Husky Gel-Foam Soft Cap Work Knee Pads	Milwaukee Tool Large Winter Performance Work Gloves	Pipe Stand Fold-A-Jack VHead	Sumner 2412 Contractor Lift 12' Lift 450 Lb Capacity	Reed HPC Series Guillotine Pipe Cutters	DEWALT Industrial Footwear Torque Mid *CSA approved*
BENEFITS						
- Prevent toxins/ chemicals from entering the body - Face protection (injury prevention) - Wide visibility when working - Clear voice transparency through mask	- Enables comfort when working - Longterm injury prevention - Provides grip to work surface - Adjustability for the user through various straps	- All day comfort through memory foam - Secure fit and adjustability - Grips to multiple surfaces - Ease when handling small objects	- Frame allows for heavy loads - Adjustability for different pipe diameters - Takes weight and body strain off user - Easy movability	- Easy maneuverability while product is on - Reduction of weight and strain on the body - Adjustability, to get product at a certain height	- Improves safety of task for user - Hand tools not required (injury prevention) - Safe distance for user - Adjustability for every form of pipe - One person usable	- Waterproof allows feet to be kept dry - Steel toe (injury prevention) - Reduces stress on the ankle - Durable long lasting work boot (many uses) - Slip and fall prevention - Proper support

Benchmarking Products

1	2	3	4	5	6	7
3M Ultimate FX Full Face piece Respirator	Husky Gel-Foam Soft Cap Work Knee Pads	Milwaukee Tool Large Winter Performance Work Gloves	Pipe Stand Fold-A-Jack VHead	Sumner 2412 Contractor Lift 12' Lift 450 Lb Capacity	Reed HPC Series Guillotine Pipe Cutters	DEWALT Industrial Footwear Torque Mid *CSA approved*
FEATURES						
- Full silicone face piece - Large Lens - Passive speaking diaphragm - Scotch guard protection Paint - Chemical Protection filters - Compatible 3M respirator assemblies	- Tough, nylon molded shell - Gel and memory foam protection - Wide neoprene comfort strap - Comfortable kneeling - Hook and loop closure - Impact protection	- Smart swipe fingertips, knuckles and palms - Built-in terry cloth sweat wipe - Breathable lining - Reenforced thumb seam - Hook and loop closure for a secure fit	- Durable construction - Heavy duty v-head - Portable and compact - Great stability legs - 2500 lbs capacity - 28in-52in height adjustment - 1/8-12" pipe adjustment	- Improved lifting capacity up to 400 lb - one piece construction - Extremely portable design - One man operation - Fits most vans and suv's - Lightweight material	- Non stick coated blade - Chip resistant - Taper blade - From holding stand - Durable metal frame	- Pro comfort shank - Steel toe - Steel plate - Electrical hazard protection - Oil and slip resistant - Pro comfort insole with ergonomic arch support

D - Results Analysis

Needs Statements

The worker needs to protect themselves/body because they want to reduce injuries when working

The worker needs to find out why they feel pain after work because they want to feel better

The worker needs to keep safe/take precautions while working because long term injuries may occur in the future

The worker needs to find out how to reduce risk of injury when working because not knowing gives them worry/anxiety

The worker needs to find out ways to complete certain tasks more efficiently because they want to save time, get more done and make work easier

Insight Statements

Increase of Injuries in the work field tend to occur due to :

- Lack of protective equipment worn / used

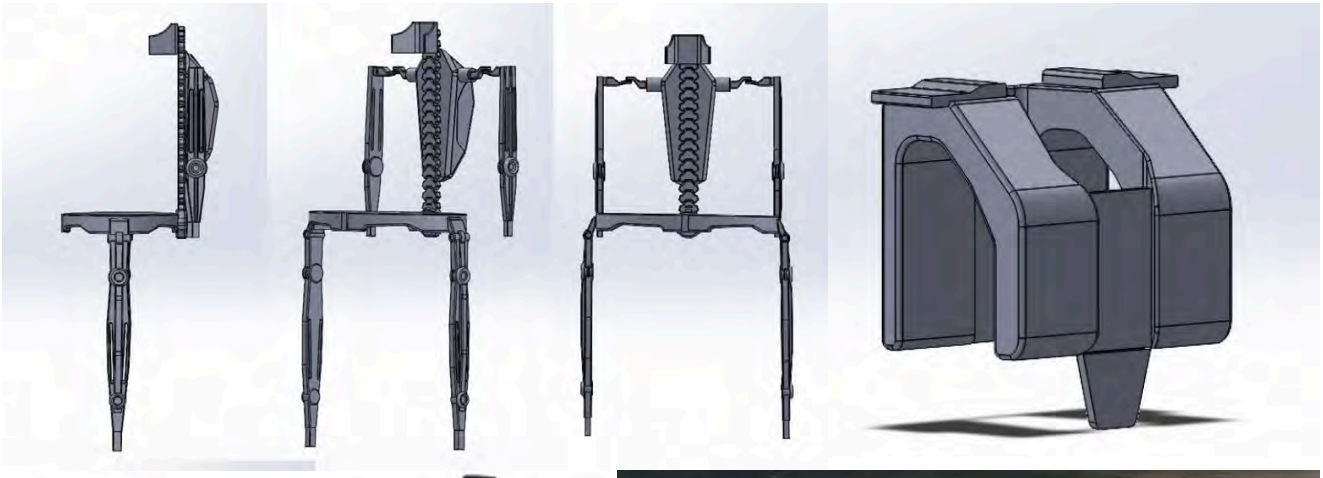
- Prevention methods for injuries long term

- Physical strain on the body during certain tasks

- Bad posture while working

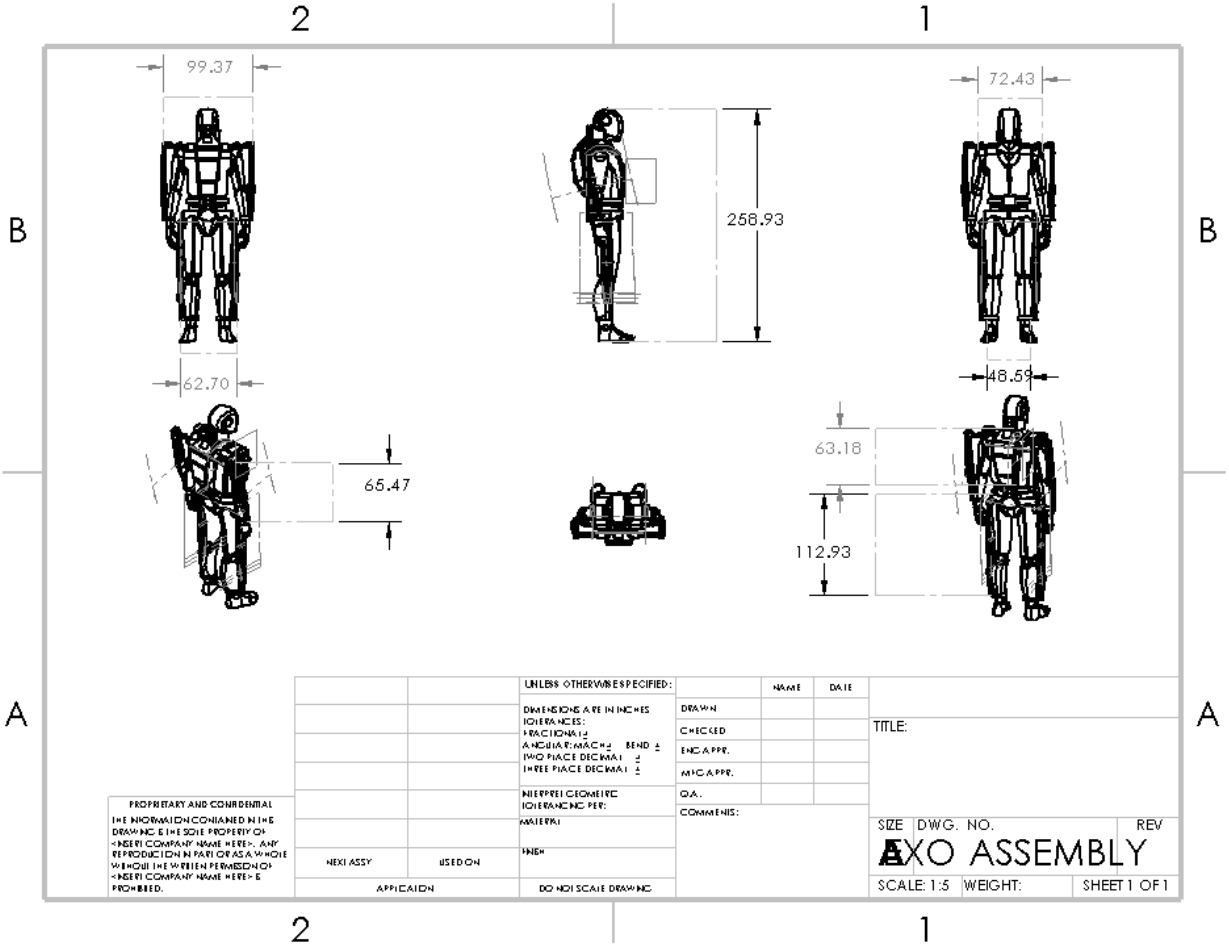
- Repetitive movements throughout the day

E - Cad Development



F - Physical Model Photos

G - Technical Drawings



H - Bill of Materials

Part	Material	Manufacturing	Cost
Exo Arms	Carbon fibre	Compression Moulding	$200
Exo Legs	Carbon fibre	Compression Moulding	$200
Exo Spine	Elastic Fiber	Industrial Crafting	$75
Exo Chest Plate	Polyethylene	Industrial Sewing	$100
Exo Battery	Lithium Ion	Supplied	$140
Exo Battery Housing	Polypropylene	Injection Moulding	$40
Exo Belt	Thermoformable Foam/ Polychloroprene	Industrial Crafting	$50
Exo Neck Support	Thermoformable Foam	Blowing Agent Process	$25
Exo Motors	Stainless Steel	Metal Injection Moulding	$150
Exo Padding	Thermoformable Foam	Blowing Agent Process	$30
			Total : $1010

I - Sustainability

Exo X considers sustainability with respect to minimal impact disposal, efficient lifecycle, the use of responsible materials and applying a battery/carbon fibre recycle initiative program. This is achieved as most materials used for Exo x such as the main carbon fibre components as well as the battery packs are able to be recycled due to the carbon and battery initiative. This initiative will help create a eco friendly life cycle towards the product as well as making little parts as possible go to waste. Each part is able to be swapped out which makes the unit reliable for the long term. Once a unit is produced it should get a ton of work years before it's time to be replaced for a new one.

J - Approval Forms

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2022
Catherine Chong / Sandro Zaccolo

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Nick Beneventi
Topic / Thesis Title:	**MITIGATING INJURIES FOR COMMERCIAL PLUMBERS**

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	X	**CAD Design and Development Phase**
Comment:	- Initial CAD started reasonably as of week #6/February 15th, continue with detailing and refinement. - No review in week #7 or week #8, unsure about development progress - as of week #8/March 8th. - Advised completion latest by week #9 (March 17th).	

Design is reviewed and approved to proceed for the following:	X	**Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comment:	- Cannot approve of model fabrication until CAD development at 90% completion of all components > advised completion latest by week #9 (March 17th). - Once CAD is completed, can move forward to model fabrication from week #10 onward.	

Instructor Signature(s):	
Date:	22nd March, 2022

Chong, Kappen, Thomson, Zaccolo

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Nick Beneventi

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

n01236494

Date of Issue: **28 September, 2021**

Research Plan

Research Sources

- Scholarly articles within the humber library portal
- Youtube channels such as Roger Wakefield (#! Plumbing channel on youtube)
- Potential and confirmed advisors to help gain in depth research and further my design directions
- Journals and blogs getting community insight

Research Methods

Potential research methods include :

- Surveys

Once set up allows for quick distribution and access to a large sample size of answers

- Interviews

Smaller sample size but allows or in-depth open ended questions to be asked giving the participant to elaborate on answers

- Participant observation

Seeing the problems first hand, allowing myself to observe a day within the industry and see where main/common problems reside

- Questionnaire / Questions asked

Providing a set of particular questions to get answers to key points needed to further your research. Having good questions allows for ease/efficiency when research is conducted.

Interview and Survey based questions

Interview sample questions :

What are some common issues within the workplace?

What challenges do you face on a daily basis?

What tasks do you complete at work?

What injuries are common in the field?

What equipment do you use?

Any pain felt at or after work?

Is the work environment safe?

Etc…

Survey Based Questions

What is your age?

How long have you been working in the industry?

What is your job title?

What job tasks are you responsible for?

What is the most common injuries occurring in the industry?

Is common injuries or muscular injuries more of a pain?

Do long term workers endure/speak on muscular pain frequently?

Would safety equipment/posture protection be beneficial?

Etc…

Research Schedule

Week	Format
Week 8 Reading week Oct 23-31	Finalize research methods / Begin securing advisors
Week 9 Oct 31st-Nov 6th	Schedule/Meet with advisors to help with idea generation / research methods
Week 10 Nov 7th-13th	Continue meeting to help with concepts exploration / research methods
Week 11 Nov 14th-20th	Narrowing down design directions/concepts and getting feedback if this would be beneficial

Advisor initiatives

Advisor Engagement	Confirmed / Unconfirmed	Value
Close friend in the industry (commercial plumber on a job site) Year 4 Apprentice	**Confirmed**	**4 year experience in the industry - No long term experience but enough to narrow design direction**
Local Family Friend Plumber (Long term Plumber) Many years of experience	**Unconfirmed - Very likely / Almost certain**	**Long Term Worker in the industry - Knowledge and Experience**
Other friends / locals in the Industry	**Unconfirmed - Likely**	**More information / Support to topic / Ability for surveys**
Local Companies within my area	**Unconfirmed**	**Long Term experience and Short term experience - many users to gain info on**

Upcoming weeks

Week 1 - Contact each potential advisor to see which will be available / engage in the study
- Interview with Close friend
- Finalize Research methods

Week 2 - Distribute surveys to people in the industry / gain information to help with idea generation
- Potentially meet/ plan to meet with Local family friend Plumber

Week 3 - If secured continue meeting, gaining research to develop concepts
- Deliver specific research method chosen to long term plumbers (Local companies in the area)

Conclusion

Having a bunch of potential advisors allows for many opportunities to be secured. This will help get a large sample size for surveys. When it comes to interviews having people close to me who will be consistent will give me ease of access to information that I need to further my process and concepts coming up. Each advisor listed here provides a certain value to my research, securing as many as I can or getting them to help me in different ways will help a ton. Whether it be in person surveys or interviews each peers here can help execute and further my research.

K - Advisor Form

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 /4502
SENIOR LEVEL THESIS ONE & THESIS TWO

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How may we mitigate injuries for commercial plumbers?
Investigator: Nick Beneventi / Nickbeneventi@outlook.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, Mattew Rigato *(First Name/Last Name)*, have carefully read the Information Letter for the project « Mitigating injuries for commercial plumbers, led by Nick Beneventi. A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact Nick Beneventi at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☒	☐
Review	I give consent for review by the Professor	☒	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principle investigator /researcher, Nick Beneventi and Prof. Catherine Chong or Prof. Sandro Zaccolo may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or Nick Beneventi / Nickbeneventi@outlook.com.

Verification of having read the Informed Consent Form:

☒ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Mattew Rigato	MR	2021-11-17
Participant's Name	Participant's Signature	Date