Ergonomic Risk Assessment of LPG Hose Handling Process at a Gantry Operation: A Basis for Administrative and Engineering Improvement

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Abstract

Liquified Petroleum Gas (LPG) is one of the longest-running fuel businesses in the Philippines, serving the needs of small and medium-sized enterprises. The import facility operates 24/7, ensuring the completion of loading and discharging operations. The gantry operators are involved in lifting the heavy LPG hoses and exerting forcefully with their hands to refill the flammable truck. It is necessary to assess them to determine their level of suffering, given the hours and days they consumed to accommodate the product's demands. Given these conditions, the paper aims to assess the current design of the gantry station to determine the factors that affect the discomfort of the operators. In this study, the current working conditions were assessed through interviews and observations with a total of ten (10) operators using the Workplace Ergonomic Risk Assessment, WISHA Caution/Hazard Zone Checklist, and Cornell Musculoskeletal Discomfort Questionnaires. Based on the results, both WERA and WISHA showed that risk was present, requiring further investigation due to the awkward postures. In CMDQ results, the body part of the wrist was the highest area of complaint (44.75%), which is the most important to address the pain suffered by the operators. The researchers determined that there is no significant relationship between ergonomics assessment and physical discomfort using Spearman rank correlations. Furthermore, a proposed action plan was created using the hierarchy of administrative (suggestions for administrative programs) and engineering controls of developed equipment that would hold the repositioned heavy hose to limit force exertion.

Keywords
CMDQ, ergonomic risk, LPG Hose Handling Process, WERA, WISHA

1. Introduction
In loading bays for truck carriers, LPG suction and discharge hoses have been used manually for many years, raising the risk of musculoskeletal disorders (MSDs) among workers. Even to this day, most LPG terminals in the Philippines handle LPG hoses manually with minimal automation. With little choice but to adhere to the handling practices specified by their operators are vulnerable to physical tiredness. These alarming conditions not only raise safety issues but also accelerate the deterioration of the operators' health and well-being. Manual Material Handling (MMH) is a significant source of worker repetitive, high-effort lifting is a major contributor to low back injuries. Before operators began their MMH-related jobs, it was underlined that companies and industries should assess the design of the workplace and come up with an ergonomically planned intervention for the operators' health and safety (Rossi et al. 2013).

According to Steinberg (2014), the relationship between Manual Handling Operations (MHO) at work and musculoskeletal disorders of the hands and forearms is well documented. It is typically defined as manual tasks that require manual skills, highly repeated sequences of hand and arm movement, and/or high levels of hand and arm force. MHO is characterized by repeated and static muscular and ligamentous tension. The strain placed on the body by these activities relies on the intensity of the required effort, the range of motion, as well as the duration and frequency of the motions. Other factors besides MHO may cause disorders, complaints, or pain in the hands and arms. There is evidence that various types of physical workload, such as the manual lifting of heavy loads and overhead work are risk factors for hand and forearm problems (Costa et al. 2015).

Management should make worker health and safety initiatives a top priority since they boost productivity and decrease costs. These health and safety initiatives should emphasize worker participation, ongoing monitoring, and wellness components overall. Workplace safety necessitates that safe working circumstances should not expose workers to a major risk of becoming unfit for work. Therefore, the goal of occupational health and safety is to provide the conditions, skills, and behaviors that enable the worker and his/her organization to perform their task successfully and in a manner that prevents them from being harmed.

The study was conducted in the company of Liquigaz LPG Terminal located in Sitio Bacungan Brgy. Castañas Sariaya, Quezon. In 2015, Liquigaz acquired an existing LPG import facility in Sariaya. This import facility was completed towards the end of 2017 with an upgraded total storage capacity of 12,500 metric tons. The terminal operates 24/7, ensuring the completion of discharging and loading operations. Over the years, the company continuously offers quality LPG products and services that cater to businesses that provide all their LPG needs, such as wholesale, commercial, industrial, and dealership businesses. In Sariaya, they offer wholesale business as the bulk LPG supplier in the market. The chosen part being studied is at the gantry of liquigaz LPG terminal, where operators can be found. The proposed solution is to improve the design of the existing gantry station by applying the concept of an LPG loading arm.

1.1 Objectives

This study aimed to assess the LPG hose handling of the gantry operators using ergonomic assessment tools evaluated the body posture and the manual operation state of the company. The paper initially intended to gather the existing process of loading and unloading in the gantry station. Thus, the researchers determined the risk factors of the work environment using WISHA Caution/Hazard Zone Checklist and Workplace Ergonomic Risk Assessment (WERA). The physical discomfort of the operators was recorded through interviews using the Cornell Musculoskeletal Discomfort Questionnaires (CMDQ). Based on the results of ergonomic assessment and physical discomfort, the researchers determined the relationship between the two variables. Furthermore, the data analysis was determined as the basis of the proposed action plan in terms of administrative and engineering controls.

2. Literature Review

According to Ma. Janice and Eidref (2020), they found out that awkward posture, material handling, repetition, force, mechanical compression, vibration, and temperature are all risk factors that could result in work-related musculoskeletal issues and pain. The evidence suggests that of these risk factors, force (forceful exertions), repetition, and uncomfortable postures, particularly when happening at high levels or in combination, are most frequently linked to the development of MSDs. A covered MSD may develop because of exposure to just one ergonomic risk factor. Even if a job task does not require the use of additional risk factors such as unpleasant postures or repetition, an MSD is likely to develop if it requires the application of this much physical force. But most frequently, a hazard is produced by a mix of ergonomic risk factors.

An increased chance of developing an MSD is associated with many risk factors, depending on the length, frequency, and/or degree of exposure to each. Therefore, it is important to consider how each ergonomic risk factor interacts with the others to produce or contribute to an MSD. This can only be done if the job hazard analysis and control approach include the identification of all ergonomic risk factors that might be present in a job. If they are not identified, employers were lack the knowledge necessary to identify the root cause of the covered MSD or comprehend which risk factors need to be decreased to minimize the MSD dangers completely or significantly.

According to Abad et al. (2016), doing repetitive motions like sitting for long periods while slouching, twisting, or pulling when carrying an object, and altering joints and discs relative to their natural condition are all causes of back discomfort. For a healthy body, remaining in one position for longer than 20 minutes is excessive. It becomes intolerable to sit for extended periods at a desk, in an office chair, or in a movie theatre for this reason. Back pain can result from standing still for extended periods, such as on a concrete floor during an assembly line. If the soft tissues are kept in the same position, they gradually become less flexible (muscles, ligaments, and tendons in the back).

As the stress increases, discomfort in the back and/or legs results. Frequent or repetitive straining to the limit of the range of motion or unpleasant, slanted positions might result in joint binds. Compared to tasks that require prolonged sitting in an office chair, occupations that often require repetitive motion might be rather painful. Work activities that involve lifting from the ground, lifting overhead, moving heavy objects, or applying rotational force or twisting when handling material can all cause back injuries. Carrying big loads carries a higher danger. If the job involves transporting huge or bulky goods, it's imperative to have the proper tools or employ assistance. When people are worn out from sitting in an office chair for hours on end, from a job, or insomnia, they move more awkwardly (Abad et al. 2016).

Ergonomics is unavoidable in industries, particularly in producing parts or large, heavy goods such as automotive tires. Large things must be lifted and moved manually during the production process. This could lead to negative repercussions or sickness. Musculoskeletal diseases can result in severe repercussions on the workforce's health (Kamal 2018). Muscles, joints, ligaments, nerves, bones, and local circulatory systems make up the body's structure (Agbor 2016). Musculoskeletal disorders are work-related diseases caused by assuming the same position for long periods, such as standing or sitting, reduced or no body movement, inadequate rest periods, lifting or moving heavy objects, and twisting, bending, or tilting any part of the body when assuming an awkward posture (Damaj et al. 2016). Depending on the duration and frequency of workload exposure, the symptoms and severity of musculoskeletal problems range from mild to acute pain.

Health hazards and risks are two of the most significant causes of uncertainty in the workplace, which in turn contributes to the fear of unexpected harm. This ambiguity might lead to a lack of self-confidence in one's ability to accomplish activities successfully and efficiently. A hazard is anything that can cause harm, damage, or have bad health impacts on people at their workplace, and risk is the possibility that someone was be injured because of a linked hazard. A mechanical arm made of steel pipes known as a marine loading arm, mechanical loading arm, or MLA connects an oil tanker, barge, or tankship to a cargo port. Marine loading arms are employed as an alternative to direct hose hookups, which is very helpful for larger ships because it transfers at higher loading and pressure rates. Using a loading arm rather than a hose can also result in more accessible, more ergonomic operation, a longer lifespan, and spilt products that are contained without polluting the environment. These machines can be hydraulically or manually operated. The marine loading arm is most frequently employed when loading and unloading practically any liquid or compressed gas from barges, ships, or tankers (Safe Harbor 2012).

3. Methods

3.1 Research Design

This study is an applied research method to find practical solutions for existing problems. The research was conducted using questionnaires, relevant literature, and data collection observations. The actual assessment of the gantry operators usually provides a natural knowledge of the situation. This directs how the acquired data were transformed into the desired output, which is the LPG loading arm. This study considered all graphical representations and recommendations to provide action plans using administrative and engineering controls.

3.2 Research Environment

The study was conducted at LPG Terminal Sariaya, Quezon, to determine the ergonomic risk assessment of gantry operators in hose equipment handling. The researchers determined this locale based on its availability and resources. Furthermore, the company offers wholesale business as the bulk LPG supplier in the market. The chosen part of the study is at the gantry station, where operators can be found that operate 24/7.

3.3 Data Gathering Procedures

The researchers conducted a preliminary data collection to identify the potential risks associated with postures. Furthermore, the assessment of workplace hazards and ergonomic risks were measured using WISHA Caution/Hazard Zone Checklist, Workplace Ergonomic Risk Assessment (WERA), and Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). Anthropometrics and dynamometry were used as basis for proper measurement of improved design.

3.4 Development of the Ergonomic LPG Loading Arm

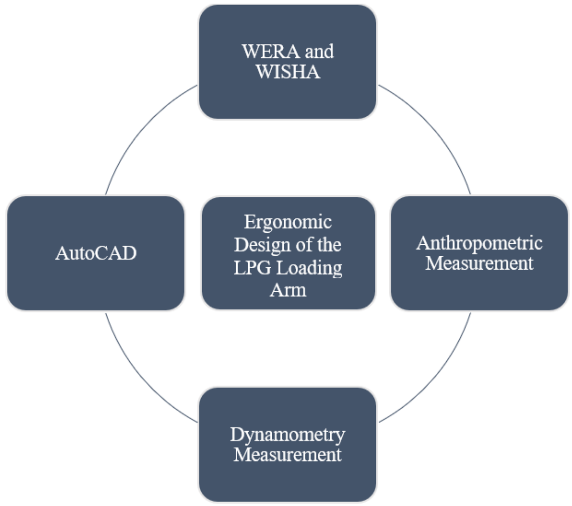

Figure 1. Block Diagram of the Ergonomic Design of the LPG Loading Arm

Fig 1 shows the IE tools and concepts were mainly used to provide an improved design of proposed solutions. The researchers used WERA and WISHA to assess the operator's postural risks and possible hazards that could occur during the process of loading/unloading procedures. The anthropometric measurement was used as basis for proper measurement of improved design. Furthermore, the researchers determined the dynamometry measurement of operators in terms of their isometric strength to grip the object. Lastly, the software of AutoCAD was used to properly visualize the proposed solution.

4. Results and Discussion

4.1 Existing Working Conditions

Figure 2. Existing Gantry Operator's Working Conditions

Fig 2 shows the existing working conditions at the LPG gantry station during their work hours, which puts them at significant risk of developing Work-Related Musculoskeletal Disorders (WMSDs).

4.1.1 Ergonomic Risk Assessment Associated with the Existing Working Conditions

Table 1. Summary of WERA Results

Assessment	Category	Mean Score	Remarks
WERA	Shoulder	4.6	task is need to further investigate, required change
	Wrist	3.5	
	Back	3.2	
	Neck	3.8	
	Leg	4.2	
	Forceful	4	
	Vibration	3.7	
	Contract Stress	4.5	
	Task Duration	4	
		35.5 (medium risk level)	

Table 1 presents the results of the workplace ergonomic risk assessment (WERA) conducted in this study. With a total risk level score of 35.5, there is a serious ergonomic risk in the workplace that requires further investigation and change. These findings have significant implications for workplace occupational health and safety, and steps should be taken to protect workers from pain and injuries related to their jobs.

Table 2. Summary of WISHA Caution/Hazard Zone Checklist Results

Body Part	Physical Risk Factor	Duration	Remarks
Awkward Posture			
Shoulder	Working with the hand(s) above the head or the elbow(s) above the shoulder(s)	More than 4 hours total per day	**Hazard**
Neck	Working with the neck bent more than 45º (without support or the ability to vary posture)	More than 4 hours total per day	**Hazard**
Back	Working with the back bent forward more than 45º (without support or the ability to vary posture)	More than 2 hours total per day	**Hazard**
Knees	Squatting	More than 2 hours total per day	Caution
High Hand Force - Pinch & Grasp			
Arms, Wrists, Hands	Wrists bent in flexion 30º or more, or in extension 45º or more, or in ulnar deviation 30º or more	More than 3 hours total per day	**Hazard**
Highly Repetitive Motion			
Necks, Shoulders, Elbows, Wrists, Hands	Using the same motion with little or no variation every few seconds (excluding keying activities)	More than 2 hours total per day	Caution
	Intensive keying	More than 4 hours total per day	**Hazard**
Repeated Impact			

Hands	Using the hand (heel/base of palm) as a hammer more than 10 times per hour	More than 2 hours total per day	Caution
Heavy, Frequent or Awkward Lifting			
Back and Shoulders	Lifting 55 or more pounds	More than 10 times per day	Caution

Table 2 shows the summary of the WISHA Caution/Hazard Zone Checklist. Five (5) hazards mean if one or more hazard boxes are checked, a work-related musculoskeletal disorder hazard exists, and further action is recommended.

4.1.2 Physical Discomfort Assessment Associated with the Existing Working Conditions

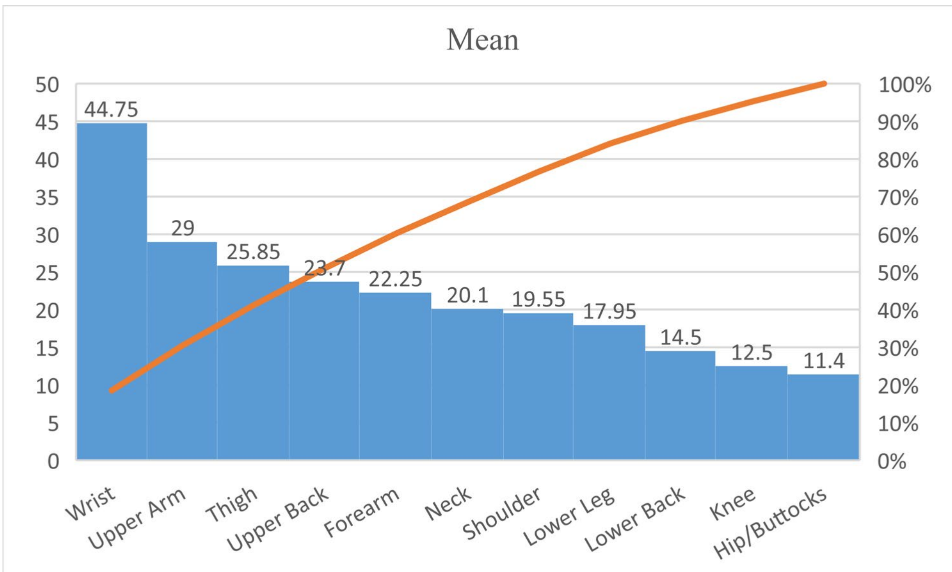

Figure 3. Summary of CMDQ Results

Fig 3 shows the different body parts to determine the level of suffering of the workers. Based on the result, the wrist part is the highest (44.75) among others due to the complaints of the workers that the heavy hose is not supported enough to lift it by the operator.

4.2 Results of Statistical Analysis

The researchers used the spearman rank-order correlation coefficient to measure the strength and direction of association that exists between two variables measured on at least an ordinal scale.

Table 3. Results of Spearman Rank-Order Correlation Analysis

Shoulder

			Ergonomic Assessment	Physical Discomfort
Spearman's rho	Ergonomic Assessment	Correlation Coefficient	1.000	-.265
		Sig. (2-tailed)	.	.460
		N	10	10
	Physical Discomfort	Correlation Coefficient	-.265	1.000
		Sig. (2-tailed)	.460	.
		N	10	10

Wrist

			Ergonomic Assessment	Physical Discomfort
Spearman's rho	Ergonomic Assessment	Correlation Coefficient	1.000	-.144
		Sig. (2-tailed)	.	.691
		N	10	10
	Physical Discomfort	Correlation Coefficient	-.144	1.000
		Sig. (2-tailed)	.691	.
		N	10	10

Back

			Ergonomic Assessment	Physical Discomfort
Spearman's rho	Ergonomic Assessment	Correlation Coefficient	1.000	.585
		Sig. (2-tailed)	.	.076
		N	10	10
	Physical Discomfort	Correlation Coefficient	.585	1.000
		Sig. (2-tailed)	.076	.
		N	10	10

Neck

			Ergonomic Assessment	Physical Discomfort
Spearman's rho	Ergonomic Assessment	Correlation Coefficient	1.000	.000
		Sig. (2-tailed)	.	1.000
		N	10	10
	Physical Discomfort	Correlation Coefficient	.000	1.000
		Sig. (2-tailed)	1.000	.
		N	10	10

Leg

			Ergonomic Assessment	Physical Discomfort
Spearman's rho	Ergonomic Assessment	Correlation Coefficient	1.000	.006
		Sig. (2-tailed)	.	.986
		N	10	10
	Physical Discomfort	Correlation Coefficient	.006	1.000
		Sig. (2-tailed)	.986	.
		N	10	10

Table 3 shows the test of the relationship between the two variables (ergonomic assessment and physical discomfort) of the shoulder, wrist, back, neck, and leg part. The body part of wrist, neck, and leg was no relationship between the two since the p>.005 as the p-value. However, the part of shoulder and back has relationship between the ergonomic assessment and physical discomfort. In shoulder part, there was a negative weak correlation between participants' ratings of ergonomic assessment and physical discomfort r_s (8) = -.265. However, there was a relationship between the two since the p<.005 as the p-value. While the back part, there was a positive strongly correlation between participants' ratings of ergonomic assessment and physical discomfort r_s (8) = .585. Then, there was a relationship between the two since p<.005 as the p-value. When the musculoskeletal conditions in terms of the shoulder and back are still present, physical discomfort would increase continuously.

4.3 Proposed Improvements

4.3.1 Operators' Anthropometric Measurements

Table 4. Summary of the Operators' Anthropometric Measurements

Dimension (cm, kg)	**Percentile**			**Standard Deviation**
	5^{th}	**50^{th} (Mean)**	**95^{th}**	
Height	159.8	170.7	181.6	6.6
Shoulder	26.6	40.6	54.6	8.5
Arm	22.1	28.0	33.9	3.6
Elbow to hand	34.4	36.9	39.4	1.5
Waist	20.0	31.4	42.8	6.9
Waist to heel	31.9	36.8	41.7	3.0
Knee to heel	47.8	51.1	54.4	2.0

The researchers used anthropometric measurements of the ten (10) operators from shoulder down to heel. The 5th, 50th, and 95th percentiles were incorporated in the operators' minimum and maximum dimensions. The measurements were used as basis of proper dimensions of proposed LPG loading arm.

4.3.2 Operators' Isometric Strength Using Dynamometer

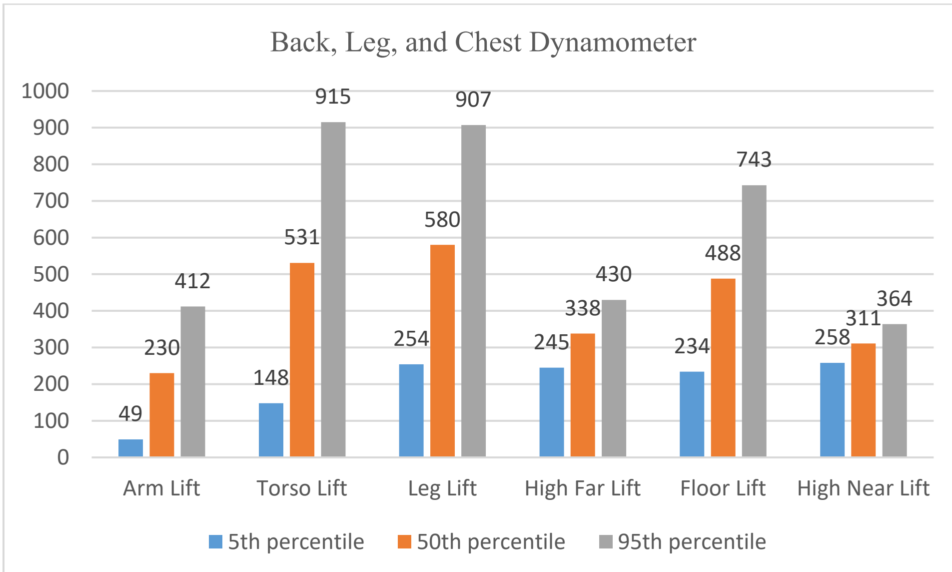

Figure 4. Isometric Strength of Operators

Fig 4 shows the back, leg, and chest muscle strength measurement, and the percentile of the result. The researchers determined the operator's strength as the basis for the proposed solution.

4.3.3 LPG Loading Arm Design

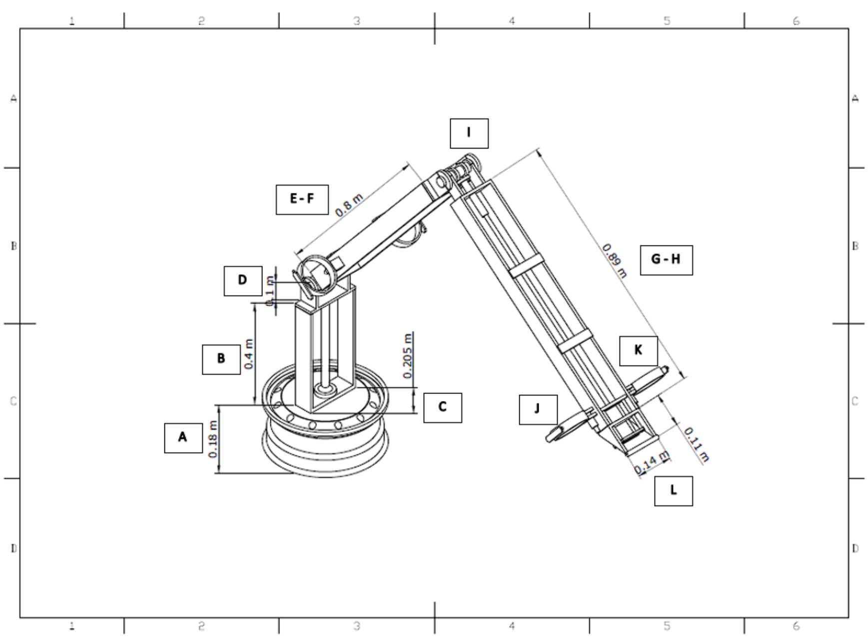

Figure 5. Proposed Ergonomic LPG Loading Arm

Table 5. Dimensions of the Ergonomic LPG Loading Arm

Legend	**Parts**	**Description**	**Actual Dimensions**	
			Inches	**Centimetre**
A	Base Plate Height	Height of the round base plate	7.09	18
B	Stand Column Height	Height of the stand column that rotates the loading arm	15.75	40
C	Stand Column Width	Width of the stand column that rotates the loading arm	8.07	20.5
D	Locking System Height	Height of the locking system that holds the inner and outer arm	3.94	10
E	Inner Arm Height	Height of the inner arm that lifts the outer arm	31.50	80
F	Inner Arm Width	Width of the inner that lifts the outer arm	7.09	18
G	Outer Arm Height	Height of the outer arm that supports the inner arm to lift the LPG hose	35.04	89
H	Outer Arm Width	Width of the outer arm that supports the inner arm to lift the LPG hose	5.51	14
I	Gear Diameter	Gear to rotate the inner and outer arm, upward or downward	3.64	9.24
J	Liquid Hose Holder Diameter	Diameter of liquid hose holder to support the lifting of LPG hose	4	10.16
K	Vapor Hose Holder Diameter	Diameter of vapour hose holder to support the lifting of LPG hose	3	7.62
L	Handle	The handle of the loading arm moves the outer arm upward or downward	5.51	14

4.3.4 Orthographic Projection

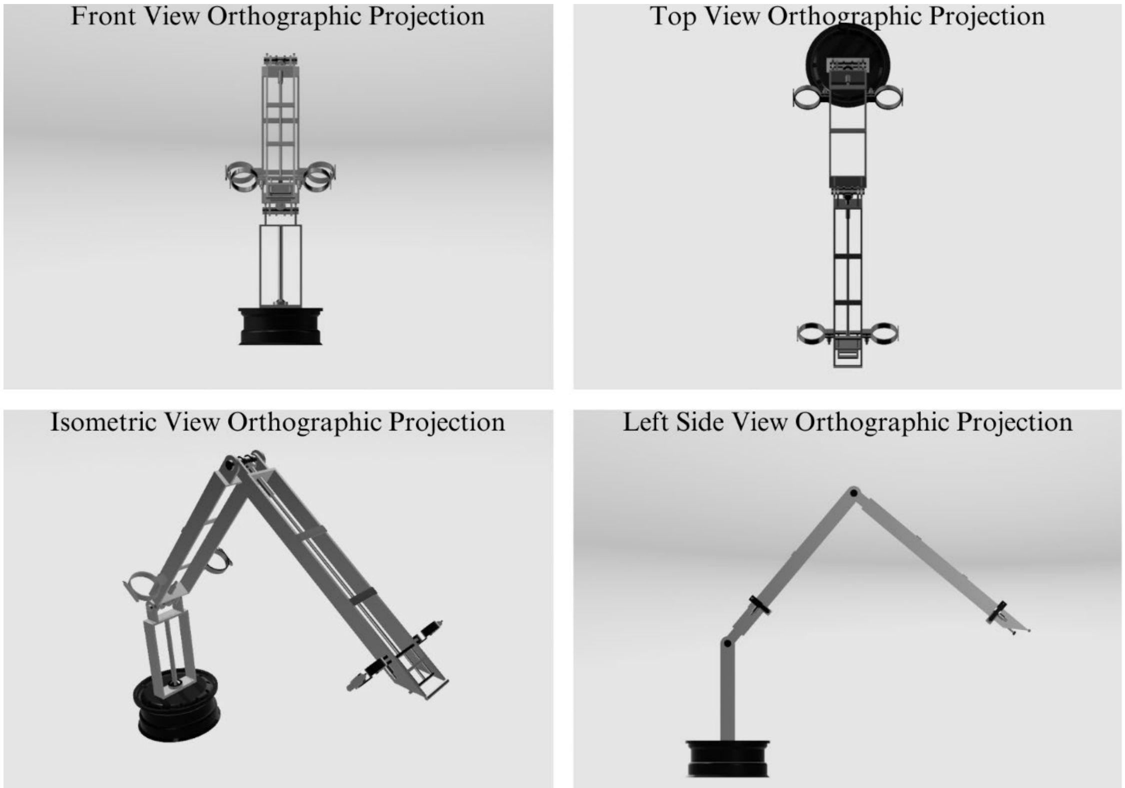

Figure 6. 3D All-View Orthographic Projections

Table 6. Proposed Ergonomic LPG Loading Arm Equipment Specifications

Components		Measurements (inch)	Characteristics	Considered Percentile
Height	Base Plate	7.09	Adjustable at 360 degrees	½ of 5th Percentile (Knee to heel)
	Stand Column	15.75	Fixed	5th Percentile (Knee to heel)
	Inner & Outer Arm	66.54	Fixed	50th Percentile (Height)
Width	Stand Column	8.07	Fixed	None
	Inner Arm	7.09	Fixed	None
	Outer Arm	5.51	Fixed	None

5. Conclusion

Based on the summary of the WISHA Caution/Hazard Zone Checklist, 5 hazards mean if one or more hazard boxes are checked, a work-related musculoskeletal disorder hazard exists, and further action is recommended. As a result of WERA, there is a serious ergonomic risk in the workplace that requires further investigation and requires change with a total mean of 35.5. These findings have significant implications for workplace occupational health and safety, and steps should be taken to protect workers from pain and injuries related to their jobs.

After the ergonomics assessment, the Cornell Musculoskeletal Discomfort Questionnaire was used to test its relationship with the previous assessment. The researchers used the spearman rank-order correlation coefficient to measure the strength and direction of association that exist between two variables measured on at least an ordinal scale. This test aims to assess the correlational relationship between ergonomic assessment and physical discomfort per body part such as the shoulder, wrist, back, neck and leg. Furthermore, the researchers created a proposed action plan using the hierarchy controls of administrative and engineering.

Administrative controls should be a change in work procedures such as written safety policies, rules, supervision, and training to reduce the severity of exposure to hazardous situations. First, the rotating gantry operators through various job tasks so that they do not develop repetitive motion. Second, prohibits operators from working with ionizing radiation once they have reached a predetermined level of exposure. Lastly, requiring them in hot environments to take a break in cool rest areas and provide fluids for rehydration.

Engineering controls must be implemented in a physical change to the workplace which eliminates the hazard on the job task. The researchers developed equipment that would hold the repositioned heavy hose to limit force exertion. Given the bad situations, the modified LPG loading arm is a good idea for workers to eliminate excessive leaning or reaching. A re-evaluation of the safety and health of the gantry operators in high-risk establishments must be conducted regularly, and to be conducted immediately following any changes in the manual operations.

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Biographies

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Mc Ronel P. Olivario is a graduating student from the Manuel S. Enverga University Foundation with a bachelor's degree in industrial engineering. During high school, he received a leadership award as President of the Supreme Student Government (SSG). Recently in college, he is an active member of the Philippine Institute of Industrial Engineers—Manuel S. Enverga Foundation Student Chapter. One of his research interests is human factors and ergonomics. During his college year, he also achieved a Certified Lean Six Sigma Yellow Belt with a gold award for excellence in digital projects and a spot on the Dean's List for two semesters.

Ramil Joshua L. Peñamante is a graduating industrial engineering student and an active member of the Philippine Institute of Industrial Engineers - Manuel S. Enverga Foundation Student Chapter. He has demonstrated his expertise in process improvement through his Lean Six Sigma Yellow Belt Certification and has earned notable accolades such as Excellence in Digital Project (Gold), Overall Performance Excellence (Silver), and Excellence in Proficiency Examination (Bronze).

Dr. James Louie Meneses is an experienced professor, consultant, industrial engineer, and researcher. He teaches industrial engineering courses, including research, operations management, operations research, feasibility studies, and ergonomics. As a consultant, he works in industrial engineering design, management, quality management systems, and data analysis. In his early professional life, he worked as a quality control engineer and management trainee in a manufacturing company. Currently, he is working as a full-time professor and a research coordinator at the Manuel S. Enverga University Foundation, Philippines. His role as a consultant is mainly related to the quality management system, quality, and system improvement. He works closely with researchers in data analysis, applying 1st- and 2nd-generation statistics (Structural Equation Modeling). His work as a researcher is mainly associated with using the lean six-sigma methodology, ergonomics design, and partial least square structural equation modeling (PLS-SEM). He holds a Doctor of Philosophy in Management from the Lyceum of the Philippines in Laguna and earned his master's in engineering majoring in industrial engineering at Adamson University. He presented his work in several research forums, where he was awarded best presenter and best research paper.

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