An Ergonomic Intervention on Metal Fabrication Workstations to Minimize the Risk of Developing Work-related Musculoskeletal Disorders

Samantha Nicole C. Alanano, Hazel A. Caparas, Johna C. Ferolino, Juan Miguel A. Miranda, and Justine Ray V. Palattao
Industrial Engineering Department
Bulacan State University
City of Malolos, Bulacan, Philippines
samalanano13@gmail.com, hazel.caparas@bulsu.edu.ph, johnaferolino@gmail.com, juanmiguelalfonsomiranda@gmail.com, vilajustineray@gmail.com,

Abstract

A local manufacturing company engaged in the production of battery and metal fabrication for large kitchen equipment, small wares, steel doors, and the like for the said fast-food chains. The metal fabrication department is divided into two; the assembly line and the finishing line. With the variety of products being made, some workers have to work while standing up while others sit on the same chair during their 8-hour shift. Most of the tasks are being done manually requiring the workers to use different tools and equipment. Equipment such as soldering irons, hammers, grinders, and others are commonly used in the department. In this study, the researchers will assess the current workstations and identify areas that can be ergonomically improved for better work efficiency. Based on the exposure level and assessment, most workers will feel discomfort in the back, arms, and neck.

Keywords
Ergonomics, Metal Fabrication, Workplace Design, Work-related Musculoskeletal Disorders, Rapid Entire Body Assessment

1. Introduction

Ergonomics is defined as the practice of designing and arranging things and workplaces to optimize people's capacity, both for their productivity and for their health. It is used to reduce the occurrence of work-related musculoskeletal disorder that affects the workers' quality of work resulting in lesser productivity expectation and greater cost. By implementing ergonomic solutions, employees can be more comfortable and increase their efficiency in the workplace.

The globalization of the market is constantly changing, and companies need to focus on and adapt to reducing costs and profitability. This research study is important as cost reduction, and the improvement of productivity plays a big role in all manufacturing companies. Moreover, employee performance is an important factor that affects the productivity and quality of their work. Performances can be influenced by their working methods, and the working environment conditions.

The local company is engaged in battery manufacturing, particularly the battery used to provide power in a vehicle's starter; lead processing, plastic injection, tire retreading, real estate development and fast food chain operations. The study is focused in their Kitchen Metal Fabrication Department. They manufacture large kitchen equipment, small wares, steel doors and the like are being made. The area is divided with an assembly line and finishing line. Most of the task are being done manually requiring the workers to use different tools and equipment. Using Rapid Entire Body Assessment (REBA), Body Discomfort Chart (BDC), and Quick Exposure Check (QEC), the researchers assess the current workstation environment to obtain an interpretation that will be used as a basis for the workstation design proposal. The Metal Fabrication Department consists of assembly units for small kitchen ware, large kitchen ware, chairs and doors. The department also includes finishing, grinding and transforming activities.

In order to achieve a healthy workplace, one should consider giving importance to workers that will eventually fall into improvements in work. The main objective of the study is to develop an ergonomically designed workplace in Metal Fabrication Department in order to reduce the risk of developing work-related musculoskeletal disorders (WMSDs) that eventually lead to the improvement of workers well-being and overall system performance. In order to attain the main objective a sub objectives can be formulated over the course of the study:

- To identify problem areas and evaluate the risk level of develop WMSDs among workers in Metal Fabrication Department;
- To identify ergonomic risk factors, present in the work system of Metal Fabrication Department;
- To develop interventions in achieving an ergonomically designed workstation;
- To avoid discomfiture and pain on the affected body parts.

2. Literature Review

Today, with the dynamic nature of the environment, organizations and companies face several challenges. One of them is to satisfy employees in a constantly changing and evolving environment. A business must satisfy the need of its employees by providing good working conditions so as to increase efficiency, effectiveness, productivity, and commitment.

In a study conducted in 2014, the working environment has a positive impact on employee job satisfaction. Poor working conditions may restrict employees from expressing their abilities and realizing their full potential (Raziq & Maulabaksh, 2014). This study will be conducted to provide an ergonomically designed workstation for the production line. Appropriately designed workstation for the workers that will not only help reduce musculoskeletal risk but also increase job satisfaction

On the researcher's plant visits, the job done was observed as a static work. Static work is characterized by slow contraction, heavy load or long-lasting posture (Grandjean & Hunting, 1977). This issue is the cause of acute pain in statistically loaded muscles. Adjusting posture at an increased frequency throughout the workdays is a proposed strategy used to reduce discomfiture (Karwowski et al., 1944; Liao & Drury, 2000). Adjustments to posture can range from interventions as adjusting seating position, to more extreme interventions such as changing body postures or by increasing breaks (John et al., 2009). The researchers want to propose a workstation that will help prevent or eliminate workers' static awkward postures to decrease musculoskeletal risks.

Small kitchenware workers sit on their seats all day long, constantly moving their hands, arms, and neck to weld parts precisely. Sitting for long periods of time is associated with many health problems, including obesity, cardiovascular disease, abnormal metabolism, and the risk of lower back pain (Brown et al., 2003). The results of the physical discomfort chart show that the little cook will feel discomfiture in the lower back. Movements are encouraged to reduce the risks associated with prolonged seated work (Callaghan & Mcgill, 2001; Holmes et al., 2005).

In the large kitchen equipment, workers are also provided with chairs but tend to work while standing up due to the large sizes of products they need to accomplish. Standing is very common in the workplace and on the rise with the recent attention to the negative health impacts of sitting (Baddeley et al., 2016). Many others are now voluntary implementing standing as an alternative to sitting (Tissot et al., 2005; Alkhajah et al., 2012). For example, a survey of 4500 Australian workers revealed that 62% were involved with tasks that required standing in one place for prolonged periods (Safe Work Australia, 2011). While standing may be a better option than sitting down, the workers tend to bend and twist their backs causing them to have an awkward posture to reach parts of the kitchen equipment that needs to be welded.

According to (Van Hecke & Thijs, 2005), special attention needs to be paid to finishing operations such as polishing, polishing, and painting to obtain the best service life and service life from the manufacturer. This part of the manufacturing process can be called a quality label, and if done correctly, it can provide an excellent opportunity to prove the advantages of stainless steel. Carrying out hand finishing work requires temperature and pressure control. The worker's movement, pressure exerted, and peripheral speed of the abrasive as a combined effect contributes to the finished result.

With this kind of work, often times, workers feel discomfort in their arms and shoulders. Shoulder pain is frequently reported in both the general and the working population (Luime et al., 2004; Sterud et al., 2014). Mechanical workload, more specifically, working with hands above shoulder level is a risk factor for shoulder pain and discomfort (van der Windt et al., 2000; Mayer et al., 2012; van Rijn et al., 2010). Another study showed that the occurrence of specific diseases of the shoulder is related to the operation of the hand above the shoulder for less than 1 hour per day (van Rijn et al., 2010).

The study focuses on identifying ergonomic risk factors particularly on processes involved in the subject company's Metal Fabrication Department. Aside from this, the study also used Del Prado-Lu’s 2007 anthropometric study featuring Filipino manufacturers in the design’s measurement. While considering the work done by workers, the focus is on creating an ergonomic workplace.

3. Methods

Upon identifying the possible problem on each working station of different processes, the researchers first conducted an assessment, observe and be familiarized with the process and tasks in the area. After being familiarized with all the processes and tasks, the researchers then categorize which tools, equipment and worker must be in each of the working station. After identifying the important components of each working station, the researchers classified sufficient ergonomic assessment tools to be used on the workers in improving each work station. The researchers used ergonomic assessment tools that will support the study such as- REBA, QEC and BDC. In determining the necessary sampling size on the target population of the workers, the researchers decided to not use Slovin’s formula since there is only a few of a population. All the data that has been gathered through the three assessment tools are tabulated and consolidated to be able to assess and identify on what specific part of the work station must be ergonomically redesigned or improved. Figure 1 summarizes the methodology of the study together with the corresponding inputs and expected output for each stage.

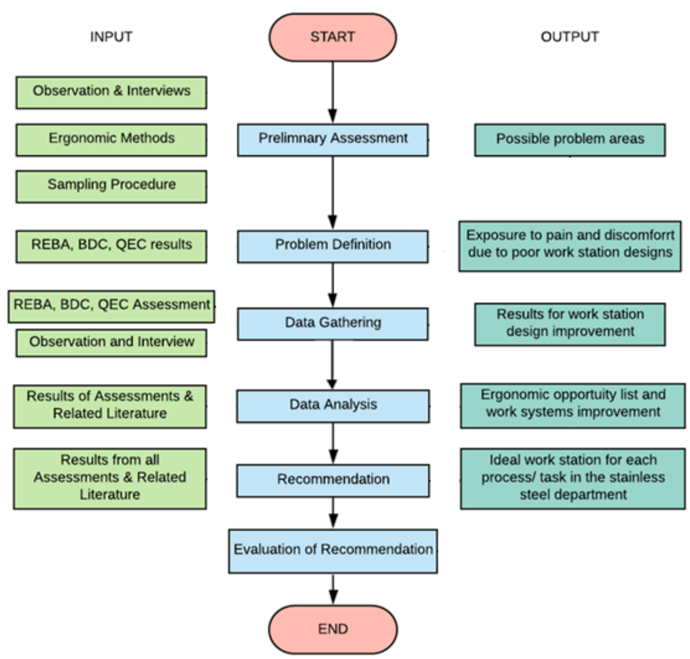

Figure 1. Methodological Framework

4. Data Collection

On the allotted day to conduct interviews and surveys in using ergonomic assessment tools, each researcher went to different processes/sections to use the time to observe and assess each task and worker. The researchers also observe the equipment and tools that the worker used in the task, the working pace of the workers as well as the surrounding of the work station, and other factors through observations and interviews that can possibly help to improve the work station design. The researchers use REBA, BDC, and QEC as ergonomic tools to evaluate each worker.

Rapid Entire Body Assessment (REBA) is a systematic process used to assess and evaluate the whole-body postural Musculoskeletal Disorder (MSD) and the risk associated with the job tasks. Researchers use it to evaluate required or selected body postures, forced movements, types of movements or movements, repetitions, and couplings. Using a REBA worksheet, the researchers assigned a score for the wrists, forearms, shoulders, elbows, neck, trunk, back, legs, and knees.

Another tool is the Quick Exposure Check (QEC), QEC includes thoughts from the evaluator and worker considering the back, shoulder, wrist/hand, neck, driving, vibration, workplace, and stress. A rapid exposure check can provide an exposure score of the body part and determine which ones need to be reduced. Researchers assess exposure and change in exposure to the main risk factors for work-related musculoskeletal risk factors (WMDs).

The last assessment tool is Body Discomfort Chart (BDC). The researchers used this tool to let the workers enumerate, which parts of their body have experienced uncomfortable and unnecessary pain. After identifying the part of the body where pain is felt, the workers should also choose what is the level of intensity of that pain. The level is ranging from one to five, one is the lowest and five is the highest intensity.

5. Results and Discussion

5.1 Rapid Entire Body Assessment (REBA) Results

The researcher used REBA for assessing the entire body of the workers. In order to analyze and validate the data gathered by the researcher. Figure 2 shows the percent distribution of workers based on obtained REBA results.

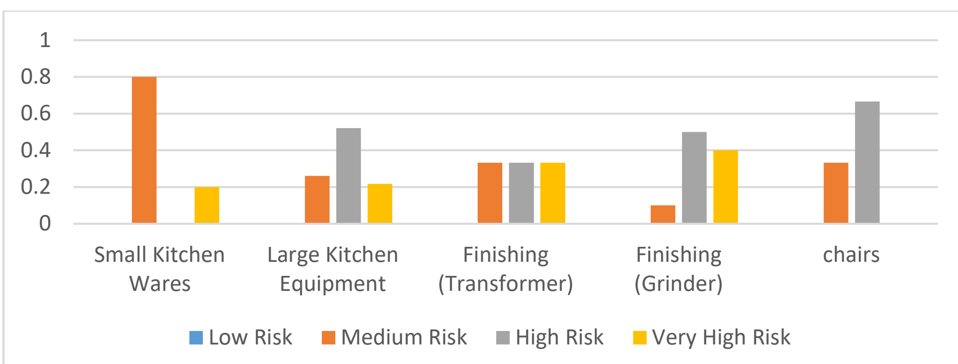

Figure 2. Distribution of Workers based on REBA Results

The researchers computed the average assessment score of 24 workers is 9.25. Also, it appears that 55%, 67%, 50%, 33% and 67% of Large Kitchen Assembly, Chair Assembly, Finishing, and Door Assembly workers got a score of 8-10, which applies to Level 4 or "High Risk". In this level implementing a change and redesigning is necessary. High risk is due to the different position of each body segment that is assessed through REBA. There is 20%, 17%, 40%, 33%, and 33% of workers in small and large kitchen ware assembly, finishing and door assembly, respectively, got scores of 11 above or "very high risk" which means that change should be implemented. The study uses the standard REBA scale indicated "1" with negligible risk, "2-3" with low risk and change may be needed, "4-7" with medium risk and further investigation and change is needed soon, "8-10" with high risk and there is a need to investigate and implement change and "11+" with very high risk and there is an immediate need to implement change. It appears that the total score exceeds the neutral position, implying that there is significant discomfiture experienced by the workers and implementation of change is needed.

5.2 Quick Exposure Checklist

The QEC results are interpreted using action levels with corresponding value with RULA scores. Table 1 shows the QEC exposure level ranges from acceptable having at most 40% QEC score up to the need to investigate and immediately change the work system having a QEC score of at least 70% exposure.

Table 1. QEC Final Score and Action Levels (Li and Buckle, 1999a)

Preliminary Action Levels for the QEC		
QEC Score (E) (percentage total)	Action	Equivalent RULA Score
≤ 40%	Acceptable	1-2
41 – 50%	Investigate further	3-4
51 – 70%	Investigate further and change soon	5-6
> 70%	Investigate and change immediately	7+

Quick exposure checklist shows that 50%, 25% and 62% of the workers go through high exposure on WMSDs in their backs, wrist/hand and neck. This means that further investigation is needed and change should be implemented soon. Figure 3 illustrates that female workers tend to have an abducted shoulder while working because when products are placed above the table the working height increases. When the small products are placed, the workers tend to add metal sheets to increase the height level of the working table. With this, the workers tend to bend their back causing them to have an awkward posture. Their necks are also bent forward most of the as they work.

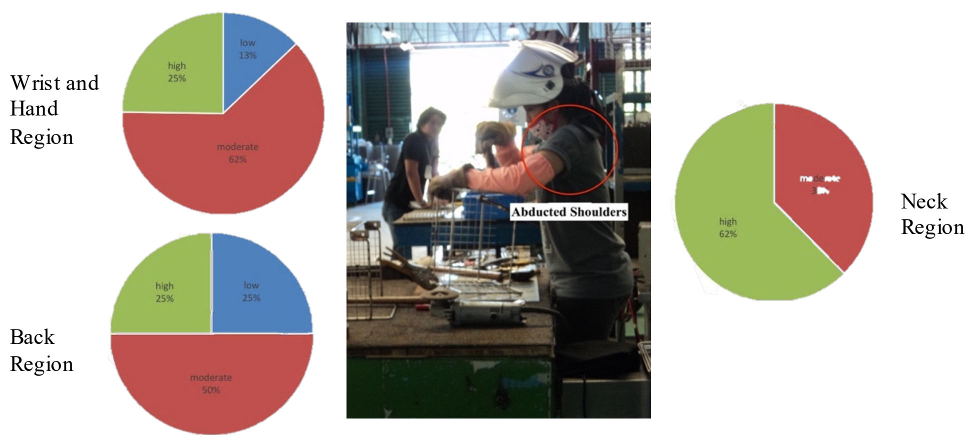

Figure 3. Current Small Ware Assembly Situation – Risk of Developing WMSDs

Quick exposure checklist results show that 17% and 67% of the workers are very highly exposed in WMSDs on their back and wrist/hand. This means that investigation and immediate change in the current workstation should be implemented. Figure 4 shows that workers assigned on the large sized products (i.e., cabinets, refrigerator, etc.) tend to bend their back up to almost 60 forward to solder or grind parts of the product. With this, the 17% and 67% of the workers are very high at risk on WMSDs.

Figure 5 shows the QEC results for finishing grinding task. In the graph, back and neck with 30% and 50% of the workers are very high at risk in their backs and neck. This means that investigation and immediate change in the current workstation should be implemented. Their neck is bended more than 45 degrees putting them in a very high risk. The workers also tend to work on improvised tables as medium to large sized products can be accommodated in their workstations.

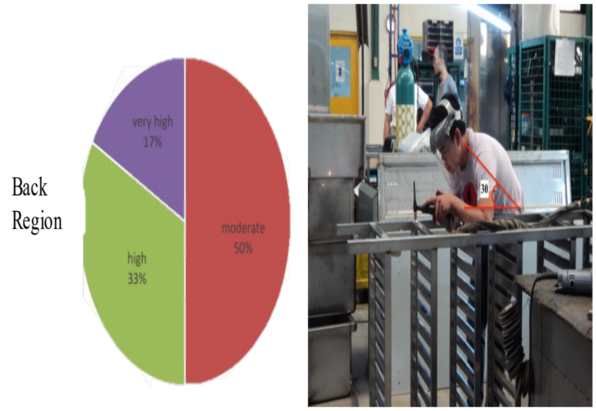

Figure 4. Current Large Kitchen Equipment Assembly and Situation – Risk of Developing WMSDs

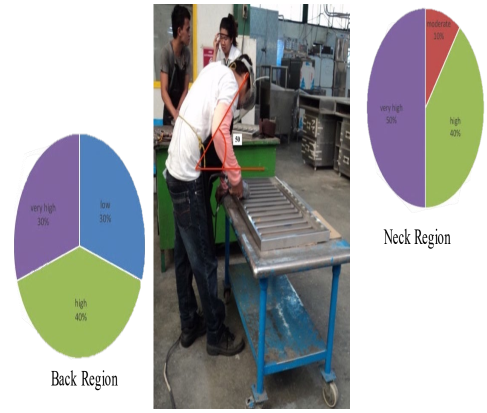

Figure 5. Current Finishing And Grinding Task Workstation – Risk of Developing WMSDs

Figure 6 illustrates the finishing transformer task indicating that 17% of the workers are at very high risk or exposure level to WMSDs. This means that investigation and immediate change in the current workstation should be implemented. In Figure 6, worker uses an improvised inclined working tale in erasing soldering marks. Causing them to raise their arms and twist their hands while working.

Figure 7 shows the QEC results for chair assembly task indicating that 83% of the workers are at very high risk in WMSDs exposure. This means that investigation and immediate change in the current workstation should be implemented. For the working table with jigs, workers tend to go around the table while soldering with bended necks. The workers use an improvised chair by their liking while working on the second table.

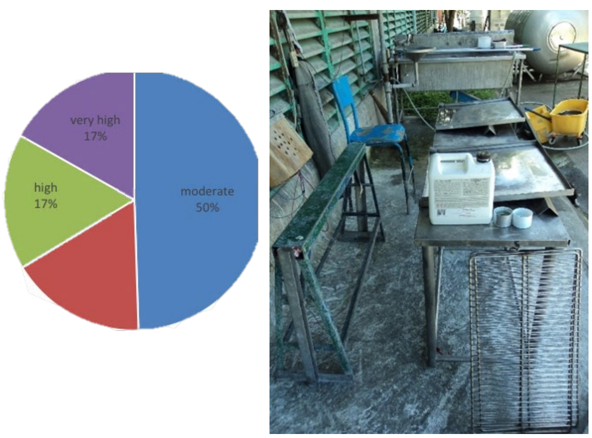

Figure 6. Current Soldering Workstation – Risk of Developing WMSDs

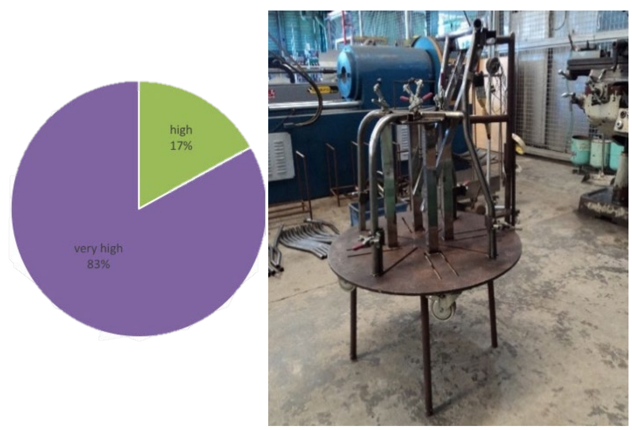

Figure 7. Current Chair Assembly Workstation – Overall Risk of Developing WMSDs

Figure 8 shows the QEC results for present door assembly indicating that 67% of the workers are highly exposed to WMSD risk. This means that investigation and immediate change in the current workstation should be implemented. In this workstation, workers are assigned to make metal doors for the restaurants commonly, 3 workers help each other to finish one door. As metal doors are big in sizes, the workers tend to bend their backs and neck to reach the middle parts of the door assembly.

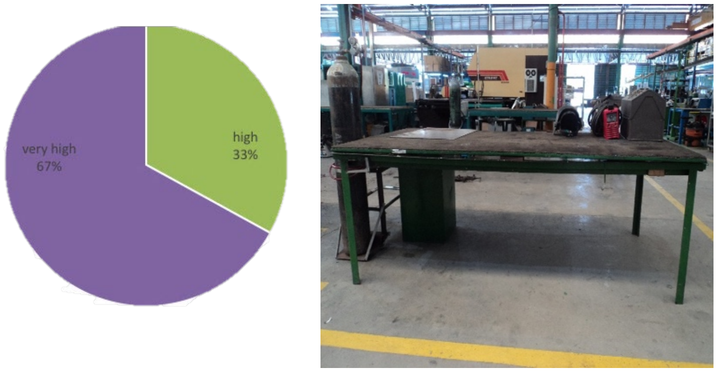

Figure 8. Current Door Assembly Workstation – Overall Risk of Developing WMSDs

5.3 Body Discomfort Chart Results using NIOSH Discomfort Scale

The study uses a Body Discomfort Chart to collect data pertaining to the level of perceived discomfort currently experienced by workers in metal fabrication section. Body discomfort for small kitchen ware assembly results show that 17% of the workers go through an intensity 5 of discomfort for more than 3 months and frequently experienced in their upper arm, right hand, and right and left upper back. BDC and QEC shows similarities of results with back and hands as the body segments, which high at risk and experiences discomfort. BDC for assembling large kitchen equipment show that 6% the workers experience discomfort in their feet with intensity level 5 for almost 3 months and a daily frequency. Standing while working without a support and inappropriate chair that is not put in use is one of the main factors why body discomfort in this body segment is experienced. Table 2 shows the discomfort rating scale adopted to evaluate the level of intensity, duration and frequency of occurrence of perceived discomfort among workers.

Table 2. Discomfort Rating Scales NIOSH

<table>
<tr><th colspan="6">Discomfort Rating Scales NIOSH</th></tr>
<tr><th>✔</th><th>Discomfort Duration</th><th colspan="2">Discomfort Frequency</th><th colspan="2">Discomfort Intensity</th></tr>
<tr><td>1</td><td>Less than 1 hour</td><td rowspan="2">1</td><td rowspan="2">Almost never (every 6 months)</td><td rowspan="2">1</td><td rowspan="2">No pain</td></tr>
<tr><td>2</td><td>1 to 24 hours</td></tr>
<tr><td>3</td><td>25 hours to 1 week</td><td rowspan="2">2</td><td rowspan="2">Rarely (every 2 to 3 months)</td><td rowspan="2">2</td><td rowspan="2">Mild</td></tr>
<tr><td>4</td><td>More than 1 to 2 weeks</td></tr>
<tr><td>5</td><td>More than 2 weeks to 1 month</td><td rowspan="2">3</td><td rowspan="2">Sometimes (once a month)</td><td rowspan="2">3</td><td rowspan="2">Moderate</td></tr>
<tr><td>6</td><td>More than 1 to 2 months</td></tr>
<tr><td>7</td><td>More than 3 months</td><td rowspan="2">4</td><td rowspan="2">Frequently (once a week)</td><td rowspan="2">4</td><td rowspan="2">Severe</td></tr>
<tr><td>8</td><td>Almost never (every 6 months)</td></tr>
<tr><td>9</td><td>Rarely (every 2 to 3 months)</td><td rowspan="2">5</td><td rowspan="2">Almost always (daily)</td><td rowspan="2">5</td><td rowspan="2">Worst pain ever in life</td></tr>
<tr><td>10</td><td>Sometimes (once a month)</td></tr>
<tr><td></td><td colspan="5">Source: Handbook of Human Factors and Ergonomics Method 2005</td></tr>
</table>

5.4 Application of Engineering Anthropometry

To compare and test the current workstations if they match with Filipino anthropometrics the researchers made tables for each line. Table 3 shows that the current workstation has mismatch with the anthropometric data of 1804 Filipino manufacturing workers conducted by Del Prado-Lu in year 2007.

Table 3. Anthropometric Measurements for Small Kitchen Ware Assembly

Requirement	Current Workstation (cm) Average	Anthropometric (cm)				Body Segment	Mismatch to 5th Female Percentile (cm)
		Male		Female			
		5th	95th	5th	95th		
Length	122.25	27	54.8	12	31	sitting grip strength	110.25
Width	108	27	55	12	31		96
Height	80	56	74	53	70.43	popliteal height + elbow height	27
Sitting Stool:							
Length	32.45	41	52	40	51	buttock popliteal length	7.55
Width	32	31	41	40	51	hip width	8
Height	42.65	39	47	31	42.45	popliteal height	11.65

After careful observation, the researchers found that when designing any workstation, it is necessary to decide as early as possible whether the operator should stand, sit, or have the opportunity to do both at the same time. The workstation can be designed to stand or sit. This allows users to periodically change their position and change their posture, which will help them prevent discomfort or long-term problems.

- The height of the work surface is vital and depends on the task being carried out. If the working surface is too low, the user will have to bend over to work; if the working surface is too high, the user will have to raise his arms, which will cause unnecessary pressure on the shoulders.
- The seat pan should not compress the buttocks or the thighs.
- The seat should suit the table's work surface height, the kitchenware size and layout, and the equipment used;
- The sitting stool should have a backrest.
- The size of the table or workstation should allow the workers to sit comfortably while having enough top surface space to ensure that all necessary equipment can be stored and used safely. If the table is not suitable, it will be difficult for them to work in a safe posture.
- Before creating a design, the tasks done and the equipment required should be considered with the intended user to ensure that there will be enough space for everything.
- Create an appropriate visual environment
- There should be enough space for the workers to access their workstation safely and conveniently to prevent interference between workstations.
- The temperature and ventilation of the indoor workplace should be maintained under comfortable working conditions.

5.5 Development of Ergonomic Improvements

The result of this study showed a strong discomfort in the left upper arm, right upper arm, hands and lower back of workers, discomfort experienced by the workers exist upon working on their assigned workstations, the aim of this chapter is to provide a solution in minimizing the discomforts by providing an ergonomically designed tool through the intervention of anthropometric measurements and ergonomic principles. Figure 9 illustrates the large kitchen equipment assembly to address the discomfort mostly experienced on their arms, wrists, back, and neck. Also, the recommended workstation helps in minimizing the workers' awkward position while working with abducted shoulders.

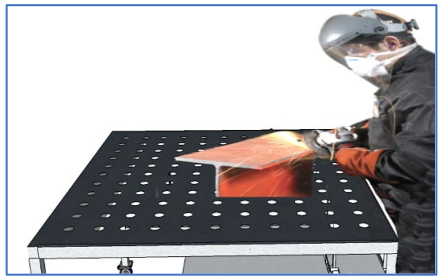

Figure 9. Recommended Large Kitchen Equipment Assembly

The current job assignments includes four (4) workers being assigned in doing the assembling task per operation or shift. Since the company is following an assembly line, where parts are added per table, the researchers decided to adjust the table height. It was divided into three (3) parts, small, medium, and large wares. For the small table, initial assembling of parts is done that is why the height proposed is appropriate as it gives the worker a clearer view of the task to be done. Only one table is assigned since initial parts take the least time to make. Two tables for medium wares is proposed since this is where it takes the longest to make. Figure 10 illustrates the recommended large kitchen equipment assembly workstations with different table height.

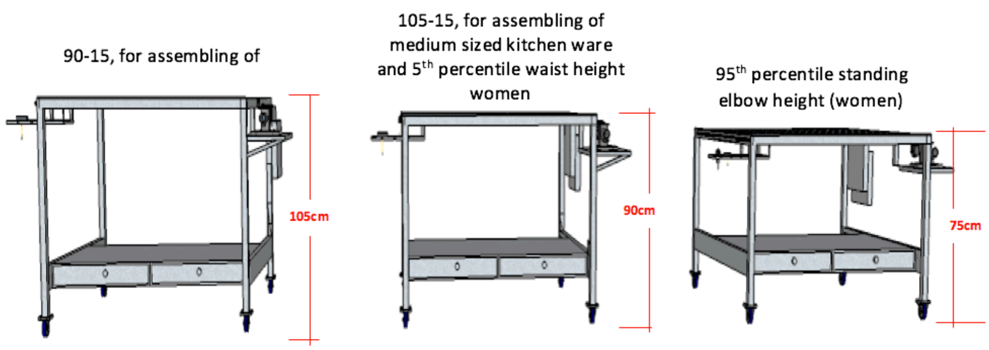

Figure 10. Proposed Large Kitchen Equipment Assembly Workstations (Front View)

The first table height is decreased as the product placed above increases size. This will maintain the workers posture as he doesn't need to raise his arms and hands while soldering. One table is assigned to large wares with larger height decrease. With this, workers do not have to bend to reach the lowest parts of the kitchen ware and need not to raise his arms and hands to reach the higher parts. This kind of tables would help the workers prevent the risk of musculoskeletal disorder.

Figure 11 shows that the researchers added holes on the working table with a diameter size of 2cm separated by 5cm spaces in between. This holes allow workers on the large kitchen equipment assembly line to clamp their kitchen equipment onto the table. This will prevent the kitchen equipment from moving while the workers finish the task whether it is grinding or putting pieces together. A bench clamp was also added and placed in a location where it will not cause accidents and where it can be easily used; on the right side and below the table surface.

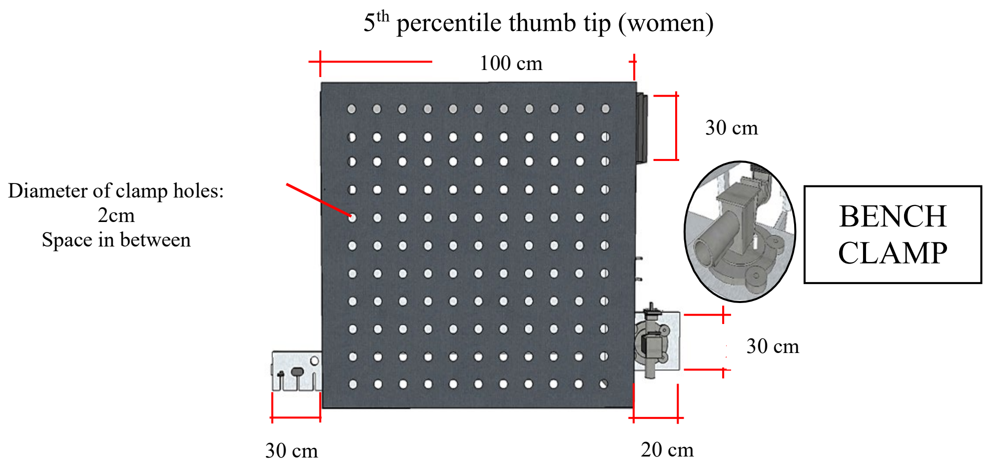

Figure 11. Proposed Large Kitchen Equipment Assembly Workstations (Top View)

The researchers also noticed the lack of space to place the tools used by the workers this is why they added a pull-out tool holder that is made according to the size of the tools. They also added hooks so that workers can hang the cords of their electric tools and prevent them from getting tangled. It was strategically placed after the bench clamp so that workers will not get caught on the hooks that may cause accidents while working. The workers also have two documents for recording purposes and was only placed above their tables. The researchers decided to give them a place to store these documents after the hook in order to give workers a free of obstructions working area. This will also help them organize the two types of document they have. At the end of the day, workers store their tools on a separate cabinet each which consumes additional space. That is why the researchers find a way to increase their working space and added drawers below the working table. The drawers were placed and pushed back allowing the workers to have enough leg room. Figure 12 illustrates the recommended components of the assembly workstations including the pull-out tool holder, hooks and locking caster.

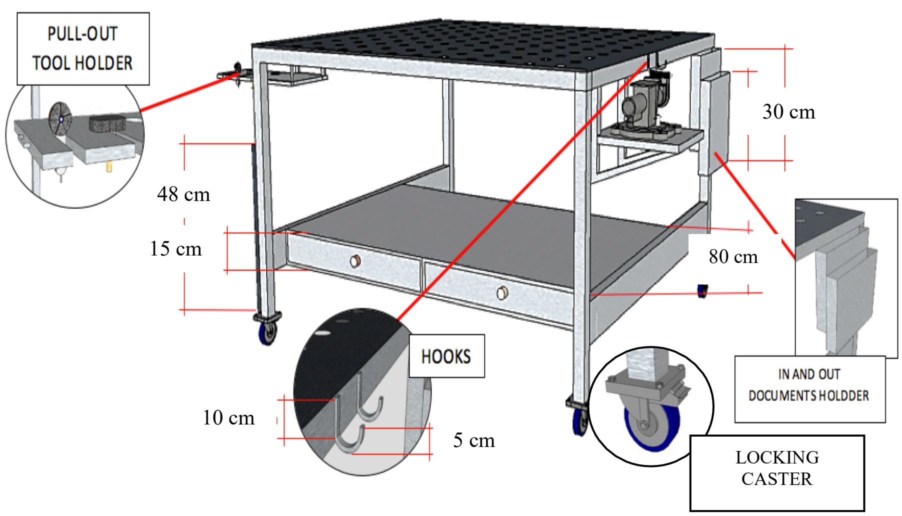

Figure 12. Proposed Large Kitchen Equipment Assembly Workstation Details

5.6 Evaluation of Ergonomic Improvements

The study evaluates the ergonomic interventions by comparing the present workstation designs and proposed assembly workstation designs. Table 4 summarizes the comparative assessment to emphasize the potential improvements from introducing modification on present assembly workstations.

Table 4. Comparative Assessment of Current and Proposed Workstations

Current	Proposed
Workers tend to work on the floor because of the large range of product sizes causing them to bend their backs or having an awkward posture	With the proposed 3 working heights the workers will now have a correct posture while working and can now use their working table to the fullest
Workers tend to stand while working since the table and stool heights varies	The table height matches the working height of 90% of the population. The table will also have an accompanying sit and stand stool since the workers also need strength while hammering.
Flat and carpeted table top	The proposed table features a rubber table top that can withstand the sparks emitted by the grinding machine and solder. The table top also features holes for clamping the kitchen ware in place.
Workers tend to solder an additional holder, shelves, cabinets etc. As they don't have a place to store their tools	Pull up tool box, hooks, and tool holders are safely placed and is made according to the sizes of the tools stored to prevent clutter.

6. Conclusion

After a detailed assessment, careful observation, and ergonomic testing, the researchers succeeded in achieving the objectives of this study. The researchers were able to evaluate and assess the level of musculoskeletal discomfort of the assembling and finishing workers using Rapid Entire Body Assessment (REBA), Body Discomfort Chart with NIOSH rating Scale (BDC), and Quick Exposure Checklist (QEC). With the help of the tools, the researchers found out that workers are at high risk in the development of Musculoskeletal Disorder. Based on the exposure level and assessment, most workers will feel discomfort in the back, arms, and neck. With this, the researchers redesigned their workstation to eliminate and prevent the risks of Musculoskeletal Disorder. The researchers managed to make recommendations to correct the posture of the workers to avoid musculoskeletal discomfort among the workers. In addition, the researchers hoped that this study will be used in the continual improvement of the working conditions not only in the metal fabrication department but in the whole company as well. Also, this research study is very important because cost reduction and productivity improvement are very important goals of all manufacturing companies.

References

Ajala, E.M., The Influence of Workplace Environment on Workers Welfare, Performance and Activity, *The African Symposium*, vol. 12, pp. 141-149, June 2012

Alkhajah TA, Reeves MM, et. al, Sit-stand workstations: a pilot intervention to reduce office sitting time, *Am J Prev Med*., vol. 43 (3), pp. 298-303, 2012

Briñol, P., Petty, R. E., et. al, Body posture effects on self-evaluation: A self-validation approach*, European Journal of Social Psychology,* vol. 39 (6), pp. 1053–1064, 2009

Brown, W., Miller, Y., and et. al, Sitting time and work patterns as indicators of overweight and obesity in Australian adults, *Int J Obes*, vol. 27, pp. 1340–1346, 2003

Callaghan, J. P., and Dunk, N. M., Examination of the flexion relaxation phenomenon in erector spinae muscles during short duration slumped sitting, *Clinical Biomechanics*, vol. 17 (5), pp. 353–360, 2002

Cramer, H., Mehling, W.E, et. al, Postural awareness and its relation to pain validation of an innovative instrument measuring awareness of body posture in patients with chronic pain, *Biomed Central Musculoskeletal Disorder*, March 2018

Das, B., and Sengupta A., Industrial Workstation Design: A systematic ergonomics approach, *Applied Ergonomics*, vol. 27. pp. 157-163, 1996

Gabriel, E. A. Baddeley, et. al, Spatial Point Patterns: Methodology and Applications with R, *Math Geosci*, vol. 49, pp. 815–817, 2017

Genaidy, A. M., and Karwowski, W., The effects of neutral posture deviations on perceived joint discomfort ratings in sitting and standing postures, *Ergonomics,* vol. 36 (7), pp. 785–792 , 1993

Grandjean, E., and Hünting, W., Ergonomics of Posture- Review of various problems of standing and sitting posture, *Applied Ergonomics*, vol. 8.3, pp. 135-140, Sept 1977

John, D., Bassett, D., et. al Effect of Using a Treadmill Workstation on Performance of Simulated Office Work Tasks, *Journal of Physical Activity and Health*, vol. 6 (5), pp. 617–624, 2009

Khan, M., and Pope-Ford, R., Improving and modifying the design of workstations within a manufacturing environment*, Bradley University*, 2015

Li, G., and Buckle, P., Quick Exposure Checklist (QEC) for the Assessment of Workplace Risks for Work-Related Musculoskeletal Disorders (WMSDs)*, Handbook of Human Factors and Ergonomics Methods*, 2005

Liao, M.-H., and Drury, C. GP, Posture, discomfort and performance in a VDT task*., Ergonomics,* vol. 43 (3), pp. 345–359, 2000

Luime, J.J., et al., Prevalence and incidence of shoulder pain in the general population; a systematic review, *Scand. J. Rheumatol*. vol. 33 (2), 2004

Raziq, A., and Maulabakhsh, R., Impact of Working Environment on Job Satisfaction*., Procedia Economics and Finance,* Vol. 23, pp. 717–725, 2015

Tissot, F., Messing, K., et. al, Studying the relationship between low back pain and working postures among those who stand and those who sit most of the working day*, Ergonomics,* vol. 52 (11), 2009

Van der Windt DA, Koes BW, et. al, Shoulder disorders in general practice: incidence, patient characteristics, and management. *Ann Rheum Dis*, vol. 54, pp. 959–964, 1995

Van Rijn RM, Huisstede BM, et. al., Associations between work-related factors and specific disorders of the shoulder--a systematic review of the literature*, Scand J Work Environ Health*., vol. 36 (3), pp. 189-201, May 2010

Biography

Samantha Nicole C. Alanano is an Industrial Engineering graduate. She earned B.S. in Industrial Engineering from Bulacan State University College of Engineering, Philippines. She competed in various research competitions during her college days. She is a Six Sigma Yellow Belt Professional and a Safety Officer 2. Her research interests include manufacturing, optimization, reliability, manufacturing, lean, and ergonomics.

Hazel A. Caparas is an ASEAN Engineer and a graduate of Master of Science in Industrial Engineering with specialization in Human Factors and Ergonomics at University of the Philippines – Diliman on June 2017. She conducted various studies focusing on Process Improvements and Human Factors and Ergonomics. Caparas is currently a College Instructor in a State University handling Industrial Engineering courses such as Human Factors and Ergonomics, Occupational Safety and Health and Facilities Planning and Design.

Johna Beth C. Ferolino is an Industrial Engineering graduate. Johna earned her BS in Industrial Engineering degree from Bulacan State University, Philippines. In college, she conducted research studies about time and motion, statistical quality control and ergonomics. Johna is a Lean Six Sigma Yellow Belt Professional.

Juan Miguel A. Miranda is an Industrial Engineer that grew up in Bulacan, Philippines. He pursued Bachelor of Science in Industrial Engineer in the respected Bulacan State University. He shows interest in various industrial engineering fields, this includes Ergonomics which showcased his critical thinking and analytical skills that soon led to winning a case study competition focusing on giving more accessibility to a small village for disabled residents. He also gives focus on other research interests such as Manufacturing and Feasibility study.

Justine Ray V. Palattao is an Industrial Engineering graduate. He earned his degree from Bulacan State University. He is a certified basic occupational safety and health officer and lean six sigma yellow belter. His research interests include manufacturing, optimization, and quality control.