Work-Related Musculoskeletal Risk Assessment among Structural Iron Workers in a Steel Company in the Philippines

Pauline Irish D. Jalac, John Paul E. Sison, John Michael Y. Fedilo, Romalyn L. Galingan, Ma. Teodora E. Gutierrez, Yoshiki B. Kurata
Department of Industrial Engineering
Technological Institute of the Philippines
Quezon City, Philippines
(paulinejalac@gmail.com, sisonjohnpaul90@yahoo.com.ph, johnmichaelfedilo011@gmail.com, rgalingan.ie@tip.edu.ph, dhorieg@gmail.com, yoshiki_kurata@yahoo.com)

Abstract

Steel is one of the most in demand product to be manufactured every year for it is the mainly used material in building infrastructures and households. Musculoskeletal Disorders and its discomforts is one of the reason why many company losses profits, for it affects the workers' joints, tendons, muscles, nerves, limb and back which results to decrease in productivity of the workers. Through observations, interviews, distribution of questionnaires and through the application of various statistical tools and software, data were gathered in order to find the main factors that contributes to MSDs and where do they experience discomforts. From the data gathered, it shows that 100% of the respondents experiences body discomforts in the lower back due to continuous operating of machines yields, various work postures and forced movements to the workers. Also, the data gathered shows that due to MSDs there is a 6.35% difference to the the expected output given by the company compared to the output produced the workers. The result of this paper aims decrease the 17.34% of the lower back discomfort and optimize the 6.60% decrease of outputs.

Keywords
Musculoskeletal Disorder, Physical workload and Risk Factor

1. Introduction

With an annual mortality rate of 1.2 million and annual years of healthy life loss of 1,518 per 100,000 people, the Philippines ranked fourth out of twenty-one in the annual mortality rate in Asia during the year 2013, resulting to annual years of healthy life lost of 24% since year 1990. [1] In years 2011 and 2013, the Philippines's most common type of occupational disease affecting workers is back pain which is accounted for 35.5% (30,374) and 31.6% (54,244) occurrences in both manufacturing and service industries, resulting for the number of musculoskeletal disorder cases to double from 85,483 in year 2011 to 171,787 cases in year 2013, yielding a 50.24%. [2] With the economic performance of the Philippines over the past years, from 5.1% in year 2011 to 7.2% in year 2013, the construction sector is one of the major contributor driven by demand for private residential, office buildings and infrastructure spending by the government, leading to an upswing in demand for steel products with a consumption growth of 61% from year 2010 up to 2013. [3] With this, the number of musculoskeletal disorders experienced by the manufacturing workers increases from 31,096 in year 2011 to 51,110 in year 2013, resulting to an increase of 39.16% in occupational disorders.[2]. In the subject company, the researchers were able to gather a 100% response rate of the workers who experience musculoskeletal discomfort; the response rate was gathered from the overall results of the questionnaire distributed by the researchers to the workers in the production area. The results showed 17.34% of the total workers experienced lower back discomfort. Furthermore, thirteen out of forty of the workers answered an average rating of eight out of ten from the questionnaire or 32.50%. Moreover, other body discomforts the workers experience are the neck, upper back, shoulder arms and legs with an overall cumulative frequency of

76.37%, this affects the overall capability of the worker to produce the expected number of outputs and it incurs an average decrease of 6.60%.

To solve the problem, the researchers considered the structural iron and steel worker's musculoskeletal disorders because it is considered as the biggest motivating factor to employers due to the costs associated with it. Moreover, musculoskeletal disorders are reflected as the costliest work-related injuries in the industry along with human costs. Also, it adds to the profit loss of the company that can eventually help the society at large. The researchers aim to minimize the occurrences of discomfort that the workers experience and determine the critical factors that contributes most to the bodily discomforts that result to the average decrease of 6.60% in actual outputs; this study will help to increase the worker's productivity and overall decrease the profit loss of the company.

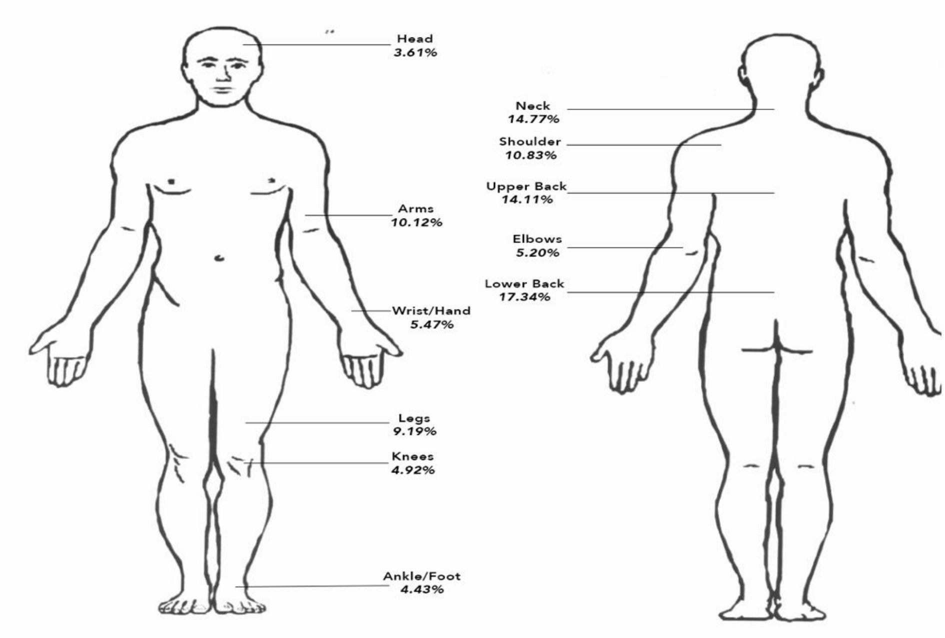

Figure 1. Discomforts in Various Body Parts

The figure above show the various body parts and discomforts of the iron and steel workers, wherein the workers directly experienced in the workplace. It shows the percentage of the occurring discomforts during the whole work schedule. It was determined that the most occurring discomfort was the lower back and it generated a percentage of 17.34%.

2. Review of Related Literature and Studies

Work-related musculoskeletal disorders or WMSD is a common disorder but continues to be a challenge to the health care professionals. WMSD disorders covers the back, upper limbs, and lower limbs and neck, if not properly or immediately addressed properly it can results to costly health check-up or aid. WMSD is a combination of different organizational factors as well as physical factors of the workers. It can often be amended when the factors are properly examined and attended. A health care professional plays an important role in ensuring that the workers are safe from WMSD. [4] The disorder can worsen due to the absence of overall awareness and lack of training on occupational safety and health (OSH), insufficient safety systems and deficiency of compliance with ergonomic standards. [5] In the year 1995, Philippines' MSDs was ranked as the fourth cause of compensation claims among other countries. [6] But during 2013, the annual mortality rate per 100,000 people is 1.2. Resulting to change in annual years of healthy life loss since 1990 to 24% and 20% of the healthy life loss per year is due to risk factors. [7] Musculoskeletal Disorders are those factors that can influence the muscles, tendons, supporting structures and nerves. These result to tissues tending to work harder than normal work. MSD may progress from mild to severe if not attended properly. In the early stage, it includes aching and tiredness while late stage includes aching, fatigue, inability to sleep and unable to perform easy task with a risk factors that includes repetitive, bending, heavy lifting and twisting, repeating an action too frequently such as, exerting too much force and uncomfortable working positions. [8] Physical workload or the amount of work a worker does from one task to another, is considered as one of the factor why the workers at a high risk of MSD. Workload is the relationship between the amount of mental processing ability and the amount required by the task. Another definition is that it is the physical and or mental requirements related with a task or combination of tasks. In other word, it is the capacity of the person to perform the expected work. Workload can be classified as physical and mental. Physical workload is the quantifiable portion of physical resources used when executing a given task and is affected by series of factors. The nature of work, training, motivation and environmental factors are the series of factors that affects the execution of the given task to a worker. [9] Work-related musculoskeletal disorders, known previously or commonly referred to as increasing trauma disorders or monotonous strain injuries, have lesser etiological implications. If not address appropriately, it can be extremely costly and will result to a physical factor (including awkward postures, force, and repetition) in organizational factors or workplace environmental (including insufficient breaks, variety of psychosocial workplace characteristics and an excessive work rates), When these factors are appropriately evaluated and attended WMSDs can often be remediated. [10]

Nunes and Bush stated that diseases that are related or aggravated by exerting too much force can affect the human's upper body's extremities, the lower limbs, and the lower back area is called Work-related Musculoskeletal Disorders or WMSD. It can be defined by the deficiencies of the human body structure such as joints, muscles, ligaments, tendons, bones, nerves, and the circulation of the blood system aggravated by the excessive work environment or work load. [11] When an employee experiences a throbbing painfulness while at work, this might decrease their productivity and resulting for them to do less quality of work. The prevalence rate for the three year period from 2013 up to 2016 in Britain, result to a rate of 1700 per 100,000 workers. In many developed nations, the number of workers are aging that they unintendedly suffer from WMSDs. [12] Even though there are numerous available jobs in the industry for the workers, those works are routinely lifting heavy objects, exposing themselves daily to vibration, perform routinely overhead work, working with a chronic flexion position of their neck, or repetitively performing forceful task. Over three million in the industries are having the highest rate of accidents that involves overexertion in repetitive motion and lifting overload objects that cause workers few day leave. With a high risk in the industries, the level of risk depends on the exposure of the workers in various works physically. [13] Steel factories is one of the key industries present in each country, the importance of these industries gradually increases in developing countries such as Iran. Employees in these companies are involved directly in the production process with physical activities, for instance, awkward postures and MMH are the most common of the physical activities. [14] One of the significant problems of the European Union caused by the disorders were associated cost and the company's productivity. The musculoskeletal disorders pathomechanisms affects the ligaments, tendons, muscle, circulation, muscle and pain perception are evaluated for the musculoskeletal disorders pathogenesis that affects the limbs and upper neck. Workplace intervention strategies for the reduction of both effect and exposure should focus within the organization and the individual worker's activity. [15 In the year 1996, various companies reported a total of 281,000 recurring trauma cases to the BLS. While in the year 1981 the number of reported cases were only at a total of 22,700, in the past decade the data were attuned in accordance to the changes with respect to the overall population of employees, it showed that such cases increased more than seven times. Statistical data from different industries show that roughly 10 out 100 workers experienced work-related MSDs from recurring trauma cases each year. The overall number of work-related lower back injuries happening each year was larger compared to the total number of upper limb disorders. Cases of back injuries were reported by industries to various hospitals and personal care facilities. [16]

The occurring rate of problems relating to musculoskeletal disorders, especially severe low back pain and common low back pain in a random sample of 1,773 of construction workers were considered; relationship between psychosocial and physical were analyzed. Results from the questionnaire answered by the workers showed that workload was measured by ten psychosocial indices and eight MMH indices and factor analyses. One year occurring rate of low back pain generated a percentage of 54% while the severe low back pain generated a percentage of 7%. Connection between heavy MMH differed with various factors such as age and can be deduced as an effect of a healthy worker. Relationship between kneeling and stooping were known to be as contributing factors to severe low back pain. The most noticeable of the psychosocial factors relating between low back pain and severe low back pain were psychic, psychosomatic and stress indices. [4] In general, in sound people, the aged pulmonary framework works well, and has not for the most part been observed to be the restricting element in practice execution. In practice utilizing small muscle gatherings, where muscle factor set the farthest point for physical work limit, age is not really the fundamental restricting element. In physical work errands requiring the dynamic utilization of substantial muscle gatherings, the more seasoned individuals would appear to be at a more noteworthy impediment in respect to youthful people. [17] As a rule the person's ability for strenuous work stays imperative regarding effective work execution. Most word related exercises are performed through human mediation. In such cases, a man's ability to perform mechanical work is controlled by his/her capacity to apply strong quality. The requests for human qualities to achieve physical exercises stay solid in spite of expanding robotization the idea of many errands and work circumstances requires the enrollment of muscle control. Various individual and undertaking factors impact human quality. The components that are especially vital are age, sexual orientation, act, achieve separation, arm and wrist introductions, speed of effort and span and recurrence of exertions. [18]

3. Methodology

The company is one of the leading manufacturers of iron and steel in the Philippines since 1973 and has numerous branches nationwide, it is affiliated with other knows companies and distributors such as Federal Hardware Store, Euro Tiles and PC Express. In order to determine the various problems and its factors occurring in the production area, observations were conducted by the researchers to the workers. During the observation process the researchers noticed the musculoskeletal discomforts that the workers experienced during the whole week of production, these musculoskeletal discomforts hinders and bottlenecks the production of the workers; decreasing their actual outputs from the expected outputs given by the management of the company. Moreover, to assess the observed problems, necessary data was gathered through interviews and distribution of questionnaires, a total of 40 questionnaires were distributed to the workers. Furthermore, the data that was gathered was to be utilized in statistical software such as Minitab. The main objective of the researchers is to determine the critical factors that affect not just the workers but the work itself. Also, to minimize the occurrences of the discomforts and illnesses experienced by the workers. Specifically, the researchers did normality testing and multiple regression. Also, the following statistical tools were used in order to determine whether the following data is sufficient, has positive and negative relationship and whether the independent variables are correlated and has significant effects on the dependent variables.

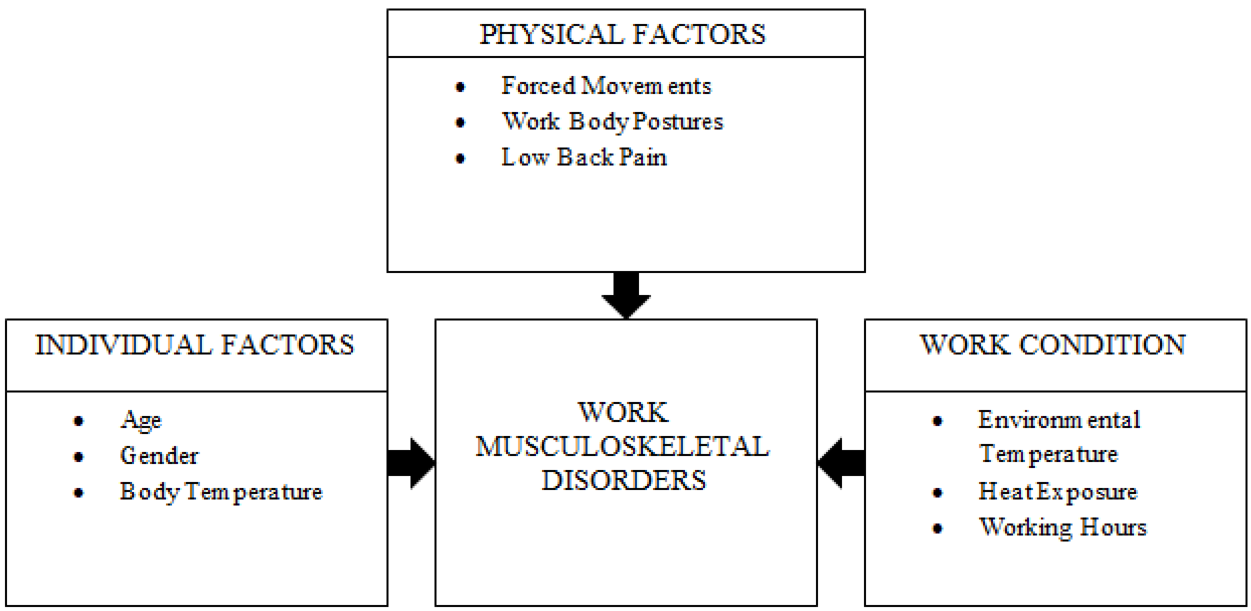

Figure 2. Conceptual Framework

A. *Physical Factor*

These are factors that can affect the physical structure of person on the working area. This can be categorized into how the person moves their body, handles, operates and maintain the various machines and tools present inside the company.

B. *Individual Factors*

These are factors that show the demographics present among the persons within a specific environment. This shows if the workers are fit to the work in accordance with their personal data records, records in which are known beforehand and can either be in controllable and an uncontrollable circumstance.

C. *Work Condition*

These are conditions present in the work environment, these conditions can affect the overall capabilities, movement and overall health and well-being of not only the workers but also the machines and tools that they are using for the whole work schedule.

3.1 Sample Size Determination

In order to determine the number of samples needed for the data gathering the researchers used Slovin's formula. The total number of workers in the production area has 44 structural iron and steel workers. The researchers gave 5% as a margin of error that can give 95% confidence level.

$$n = \frac{N}{1 + Ne^2} \qquad (1)$$

$$n = \frac{44}{1 + 44(0.05)^2}$$

$$n \cong 39.64 \; or \; 40 \; respondents$$

4. Results and Discussion

In this part it shows results and discussion of the gathered data, where researchers analyze the relevant data in musculoskeletal disorder of the workers through the use of statistical tools which is being utilized by the researchers to treat and analyze certain data.

Table 1. Descriptive Analysis of Respondents of Survey Results on the Steel Workers.

Age	Frequency	Percentage
30	2	5
31	1	2.5
32	3	7.5
33	3	7.5
34	14	35
35	4	10
36	6	15
37	3	7.5
38	4	10

Upon distribution of the questionnaires to the workers inside the production area, it was determined that the steel company has a majority of the age of their workers is ranged from 30 to 38 years old. Where 14 out of 40 respondents are of age 34 or 35% of the majority.

Table 2. Percentage and Frequency of the factor of MSD

Factors of MSD	Frequency	Percentage
Lower Back	317	32.5
Neck	270	27.5
Upper Back	258	27.5
Shoulder	198	37.5
Arms	185	40
Legs	168	40
Wrist/Hand	100	40
Elbow	95	55
Knees	90	37.5
Ankles/foot	81	37.5
Head	66	47.5

The table above shows that most of the workers experiences lower back pain, it has a frequency of 317 and has a percentage of 32.5%.

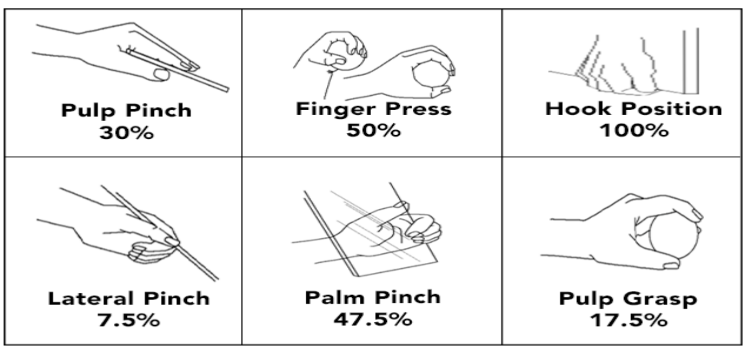

Figure 3. Force Movements

The figure above show the force movements of the workers, movements that were most occurring from the iron and steel worker in the production area and handling of machines include, pulp pinch, finger press, hook position lateral pinch, palm pinch and pulp grasp; wherein hook position is the most experienced by workers in the working area it generated a frequency of 40 that is equivalent to 100%.

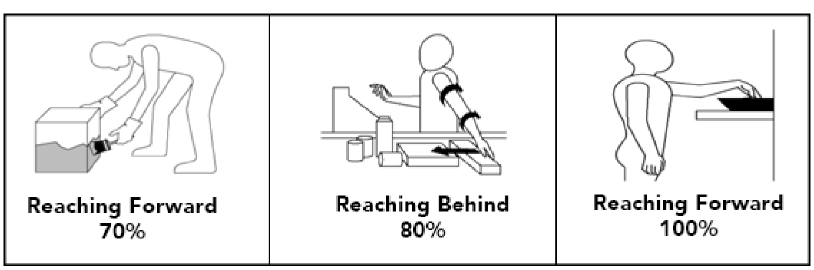

Figure 4. Work Postures

The figure above shows the work postures and movements of the worker in the production area. Such work posture include reaching forward and behind, results generated a frequency of 40 and is equivalent to 100%. The type of work posture they mainly do is reaching forward while standing.

Table 3. Descriptive Analysis of the Normality Test Used by Minitab

Factors	**Frequency**	**Mean**	**Standard Deviation**	**AD**	**P-Value**
Expected Output	40	62.79	0.8531	0.268	0.666
Actual Output	40	58.65	1.005	0.386	0.374

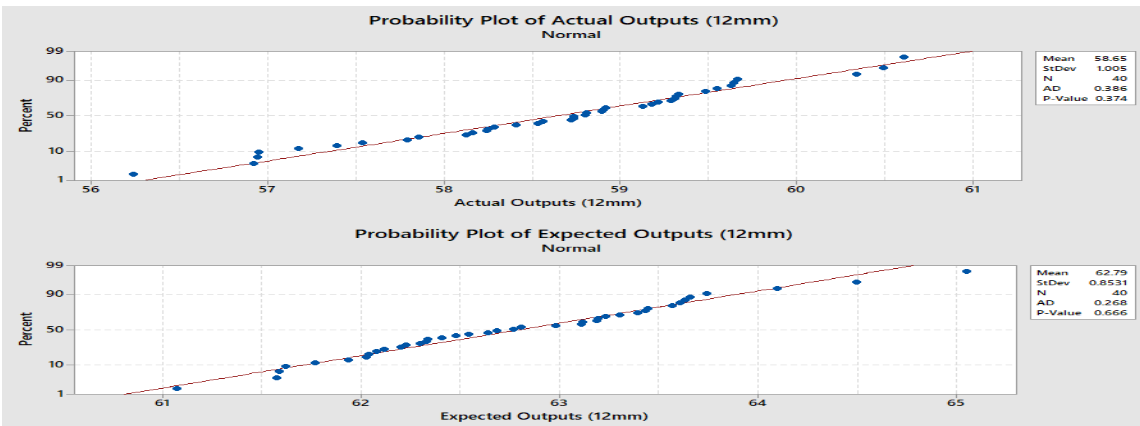

Figure 5. Probability Plot of Actual and Expected Output of a 12mm Steel rod

The Expected Output has a P-value of 0.666 while the Actual Output has a P-value of 0.374, this shows that the values are greater than alpha value of 0.05 that determines the normal distributed. Also, it follows a straight movement which indicates that it is normal and values and numbers of samples are sufficient. Moreover, the average number of expected output given by the management is at 62.79 or 63 pieces of steel rods while the iron and steel workers are currently capable of generating an average of 58.65 or 53 pieces of steel rods.

A. Expected Outputs

```
Analysis of Variance

Source                DF   Adj SS    Adj MS  F-Value  P-Value
Regression            20  15.4005   0.77002   100.94    0.000
  Physical Workload    1   2.6254   2.62536   344.16    0.000
  LowerBack            3   2.0468   0.68226    89.44    0.000
  Neck                 5   1.4259   0.28518    37.38    0.001
  Upper Back           4   1.0442   0.26104    34.22    0.001
  Shoulders            4   0.2590   0.06476     8.49    0.019
  Legs                 3   0.7767   0.25892    33.94    0.001
Error                  5   0.0381   0.00763
Total                 25  15.4386

Model Summary
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```
        S    R-sq  R-sq(adj)  R-sq(pred)
0.0873404  99.75%     98.76%           *
```

In the results above shows the expected output results that the significance variables that affect in the workers are physical workload, lower back, neck, upper back, shoulder and legs. It shows that R-sq(adj) of expected output value of 98.76%.

B. Actual Outputs

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Analysis of Variance

Source              DF  Adj SS   Adj MS  F-Value  P-Value
Regression           1   15.64  15.6427    27.93    0.000
  Physical Workload  1   15.64  15.6427    27.93    0.000
Error               37   20.72   0.5600
Total               38   36.36
```

```
Model Summary

       S    R-sq  R-sq(adj)  R-sq(pred)
0.748353  43.02%     41.48%      35.97%
```

In the results above shows the actual output results that the significance variables that affect in the workers is physical workload. It shows that R-sq(adj) of expected output value of 41.48% and has a value of 35.97% of R-sq(pred).

Table 4. Descriptive Analysis of Unstandardized Regression Weights of Steel Workers

Dependent Variables	Age	Facility Temperature	Body Temperature	Forced Movements	Work Posture	Exposure to Heat	Lower Back Pain	Total Estimation Value
Expected Outputs 12mm	0.016	-0.189	-0.006	0.377	0.094	0.075	0.138	0.505 or 50.5%
Actual Outputs 12mm	-0.099	0.062	0.041	0.204	0.532	0.006	0.118	0.456 or 45.6%

Table above show the results of results between the actual and the expected output under the unstandardized regression weights of steel works, where the expected output has a total estimation value of 50.5% while the actual output has a value of 45.6% in total estimation value.

Table 5. Descriptive Analysis of Standardized of Regression Weights of Steel Workers

Dependent Variables	Age	Facility Temperature	Body Temperature	Forced Movements	Work Posture	Exposure to Heat	Lower Back Pain	Total Estimation Value
Expected Outputs 12mm	0.037	-0.280	-0.008	0.222	0.055	0.103	0.171	0.58 or 58%
Actual Outputs 12mm	-0.191	0.075	0.043	0.097	0.0253	0.007	0.119	0.403 or 40.3%

The table above shows the data results of standardized of regression weights of steel workers in expected and actual outputs, where the expected output has a value of 58% in total estimates value while the actual output has a 40.3%.

Table 6. Descriptive Analysis of the Deference between Standardized and Unstandardized of Steel Workers

Dependent Variables	Percentage Difference Equation	Percent Difference
Expected Output 12mm	0.580-0.505/0.580	0.1293 or 12.93%
Actual Output 12mm	0.456-0.403/0.456	0.1162 or 11.62%

In Table 5 it shows the total estimates in expected output value of 0.580 or 58% while the total estimates of actual output value of 0.456 or 45.6% that are the unstandardized regression weights. In Table 6 it show the value of standardized regression weights in expected outputs of 0.58 or 58%, while the actual output value of 0.403 or 40.3 %. Furthermore, Table 7 shows the difference between the unstandardized and standardized; in expected output has a difference value of 0.1293 or 12.93% while the actual output has a difference value of 0.1162 or 11.62%. Which is the 12.93% of Expected Output is need to increase, 11.62% of actual output is need increase in production.

5. Recommendations

Based from the previously conducted Orebro Musculoskeletal Pain Questionnaire answered by the structural iron and steel workers, the lower back region of the body was the main factor that contributed to the pain that the workers experienced. The researchers proposed exercises and stretches in order to help the workers of the company in order to prevent the discomforts and illnesses relating to MSD's. Factors mostly related to the neck and shoulders and the rest of the upper body down to the lower part. Some of the recommended exercises include back/side stretch, middle/upper back stretch, back curl, standing stretch, and hip stretch; this is to minimize the MSDs of the workers in the company and to increase their capability to produce the expected outputs. The researchers also recommended the maintaining and controlling of the weight of the workers in line with the capability of the worker to the various work movements, postures and forced movements that they do. Furthermore, it helps to fit the job to the workers and their various tasks in the work area such as the operating of the machines, lifting of boxes, carrying of materials from one machine to the other and material handling of the assistance equipment present in the company. Having such inappropriate weight will hinder and bottleneck the process of finishing the outputs required by the company. Also, the researchers recommended a stricter implementation of PPE's this was recommended due to most of the workers in the production area do not wear the appropriate PPE and lastly, the researchers recommended to the company to place ventilation and cooling systems in the production area mainly because the area is naturally hot and the overall work schedule is operating continuously and it exposes the workers to excessive heat, this slows down the process and tasks due to exhaustion. To minimize physical workload the researchers recommends that on their eight working hours, adult's employee takes a recovering time-out of one and half hours in a working time that will have at least seven and half minutes in the morning and ten minutes in the afternoon.

6. Conclusions

Results from the questionnaires showed that 100% of the respondents experienced body discomforts and has decreased their productivity by not fully producing the desired outputs needed by the company. Results generated from the normality testing and multiple regressions indicated the critical factors that affected the expected outputs and actual outputs done by the workers; results from multiple regression generated the significant factors for expected outputs which were physical workload, lower back, neck, upper back, shoulder, and legs, while critical factor for the actual outputs was the physical workload. Moreover the 17.34% lower back pain and it decreased the outputs done by the company by 6.60%. Furthermore, the percent difference of the expected outputs from the actual outputs showed a negative relationship which indicates that in order to minimize the instances of experiencing discomfort the company will decrease the expected outputs by 12.93% to increase the actual outputs done by the workers by 11.62%. Moreover, to decrease the instances even further the researchers also recommended the proper exercises needed to prevent and minimize these illnesses; these include exercises for the upper body, neck and shoulders, chest, back, side and legs. The researchers also recommended to the workers to monitor their weight regularly, these ensures that the worker will be capable of handling the various tasks that can contribute to the MSD's and its health risks. Furthermore, this research can also serve as basis for future research by applying other ergonomic topics and tools such as Rapid Entire Body Movement (REBA), Rapid Upper Limb Assessment (RULA) and the NIOSH Lifting Index, these can aid as tools for determining specific movements of the different parts of the body and how it can affect the steel and iron workers. Manual Material Handling can also function as the proper tool for future research since material handling can also serve as a factor for experiencing MSD's.

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Biography

Pauline Irish D. Jalac is currently a fifth (5^{th}) year undergraduate student at Technological Institute of the Philippines – Quezon City, taking up Bachelor of Science in Industrial Engineering. At present, she is a member of Operations Research Society of the Philippines (ORSP) and an active member of Philippine Institute of Industrial Engineers- National Student Chapter (PIIE-NSC).

John Paul E. Sison is currently a fifth (5^{th}) year undergraduate student at Technological Institute of the Philippines – Quezon City, taking up Bachelor of Science in Industrial Engineering. At present, he is a member of Operations Research Society of the Philippines (ORSP) and an active member of Philippine Institute of Industrial Engineers- National Student Chapter (PIIE-NSC).

John Michael Y. Fedilo is currently a fourth (4^{th}) year undergraduate student at Technological Institute of the Philippines – Quezon City, taking up Bachelor of Science in Industrial Engineering. At present, he is a Student Federation Associate at Operations Research Society of the Philippines (ORSP) and an active member of Philippine Institute of Industrial Engineers- National Student Chapter (PIIE-NSC).

Romalyn L. Galingan is currently a fulltime lecturer at the Industrial Engineering department under the College of Engineeering and Architecture at the Technological Institute of the Philippines. Ms. Galingan holds a Bachelor of Science in Industrial Engineering from the same Institution. She has taught courses in Operations Research, Project Management, Feasibility Studies and Applied Statistics. Ms. Galingan also serves as an advisor for the Women in Engineering (Inhinyera) Advocacy of the institution which promotes gender equality in engineering.

Ma. Teodora E. Gutierrez an Assistant Professor IV in Industrial Engineering Department at Technological Institute of the Philippines, Quezon City. She is currently writing her dissertation to complete the Doctorate degree program in Industrial Engineering at De La Salle University. She finished her degrees in Master of Science in Industrial Engineering at the University of the Philippines, Diliman and Master in Business Administration at the Philippine School of Business Administration. Before joining TIP, she had experiences in various industrial companies involved in production planning and control and other Industrial Engineering works.

Yoshiki B. Kurata is a Certified Industrial Engineer (CIE) awarded by the Philippine Institute of Industrial Engineers (PIIE) and an Associate ASEAN Engineer (AAE) awarded by the ASEAN Federation of Engineering Organizations. Currently, he is an Assistant Professor in the Department of Industrial Engineering and a Professor of the Graduate School Program in the Technological Institute of the Philippines – Quezon City. He earned his B.S. in Industrial Engineering from the University of Santo Tomas, Manila, Philippines and Master of Science in Industrial Engineering from the University of the Philippines Diliman, Quezon City, Philippines. He has published several journal and conference papers in human factors and ergonomics, production optimization, operations research, and service system operations. His research interests include ergonomics, production systems, technopreneurship, and service science. At present, he is the president of the Philippine Institute of Industrial Engineers – Young Engineers Section (PIIE-YE).