An Ergonomic Workstation Design for Apparel Manufacturing Workers in the Philippines

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Abstract

Latest data from the Philippine Statistics Authority shows that apparel production volume registered significant year-on-year growth rate index of 35.9% in the value of production (PSA, 2017). The local garments industry is picking up, leading export growth in the first four months of the year. Industry leaders said that the Philippine garments industry has bigger chances of growing faster. However, since the textile and apparel industry has been growing, this leads to dangerous occupational safety and health conditions for workers. Because of this, it became the research interest of authors to conduct an ergonomic workstation design for workers in apparel manufacturing company. Initially, the body discomfort experienced by workers in their current work setup were identified using Cornell Musculoskeletal Disorder Questionnaire (CMDQ). Then factors that affect the discomfort of workers were identified based on review of related literature, actual observation and interview from the respondents. 150 subjects were included in the study consisting of knitting, cutting and sewing operators. Factors that were considered in the study are age, BMI, duration of work hours, years of work experience, and other personal factors like smoking habits and alcohol intake. Afterwards, multiple regression analysis was used to identify significant factors affecting the body discomfort workers. Then, using the Rapid Upper Limb Assessment (RULA) the level of risk of workers were assessed based on their working posture. Finally, using the principles of anthropometry, an ergonomic workstation design was developed and were compared to present design of workstation to know if there is a mismatch and identify the gaps in the design.

Keywords
workstation design, ergonomics, apparel manufacturers

1. Introduction

Textile industry reportedly had the highest minimum wage among third-world countries in Asia and has remained competitive high-end market tier in the country (ECOP, 2016). The Department of Trade and Industry (DTI) attributed the growth mainly to Chinese apparel manufacturers that are setting up production in the Philippines because of labor inflation and other factors contributing to increasing costs of doing business in China, and to take advantage of the Philippines' highly skilled labor force.

Latest data from the Philippine Statistics Authority shows that apparel production volume registered significant year-on-year growth rate index of 35.9% increase in the value of production in 2017. The local garments industry is picking up, leading export growth in the first four months of the year. Industry leaders said that the Philippine garments industry has bigger chances of growing faster.

However, since the textile and apparel industry has been growing, this leads to dangerous occupational safety and health conditions for workers (Nossar, Johnstone and Quinlan, 2003). In a study examining the comparative dangers of contingent work in the clothing and manufacturing industries (Mayhew & Quinlan, 1999), contracted employees in the clothing industry had three times the number of occupational injuries as did contracted workers in the manufacturing sector. One possible explanation for this disparity in injury experience, is that garment workers are often paid by an incentive system that pushes them to work faster than their manufacturing counterparts, who are paid by the hour, and increases the risk for injury.

In another study conducted in four textile establishments in the Philippines, it showed that high concentration of cotton dust, high level of noise in the weaving areas, and toxic chemicals in bleaching, dyeing, printing and finishing processes. Also, women in the garment industry were found to be exposed to extreme heat, dust from textile fibers, and ergonomic hazards (OSHC, 2002).

Philippine garment workers are exposed to the physical demands and repetitive nature of industrial work, placing them at risk of different diseases and injuries. According to Philippine Industry Yearbook of 2013, the apparel manufacturing industry ranks second among highest in frequency rate of injuries and average days lost due to injuries. The work related injuries are estimated to be 35.82%, 13.79% 11.33% and 9.01% for musculoskeletal diseases, tuberculosis, occupational dermatitis, and occupational asthma respectively.

1.1. Objectives

Given this condition, it became the research interest of authors to conduct an ergonomic workstation design for apparel manufacturers in the Philippines. The study used ergonomic tools to create and design an ideal workplace for garment workers.

2. Methodology

This research had used the descriptive method to explain the data gathered and eventually determined the importance of the results that were obtained from the analysis to create and design an ideal workplace for garment workers following the conceptual framework as shown in Figure 1.

Initially the body discomfort and musculoskeletal disorders experienced by workers in their current work setup were identified using Cornell Musculoskeletal Disorder Questionnaire (CMDQ). It was developed by Dr. Alan Hedge and ergonomics graduate students at Cornell University. The questionnaires are based on previous published research studies of musculoskeletal discomfort among office workers (Hedge, 1999). The CMDQ is a 54-item questionnaire containing a body map diagram and questions about the prevalence of musculoskeletal ache, pain or discomfort in 18 regions of the body during the previous week. The questionnaires were filled in at the workplace.

To further analyze the data, personal factors that affect the body discomfort of workers were identified based on review of related literature (Gumasing & Sasot, 2019; Gumasing & Robielos, 2018; Gumasing & Pacheco, 2018) actual observation and interview from the respondents. 150 subjects were included in the study consisting of knitting, cutting and sewing operators. Factors that were considered in the study are age of the subjects, BMI, duration of work hours, years of work experience, and other personal factors like smoking habits and alcohol intake. The data for the personal were gathered through survey questionnaire. The subjects wrote the values of height and body weight themselves and the body mass index (kg/m2) was calculated.

Afterwards, multiple regression analysis was used to identify significant factors affecting the body discomfort workers. This was employed to identify the relationship of the predictors and how they affect the dependent variables identified in the study. Stepwise backward elimination procedure was also done to simplify the multiple regression equation formulated in the study. This technique was used to identify the true significant risk factors as predictors of the body discomfort of workers.

Then, using the Rapid Upper Limb Assessment (RULA) the level of risk of workers were assessed based on their working posture. The RULA was developed to rapidly evaluate the exposure of individual workers to ergonomic risk factors associated with upper extremity MSD. The RULA ergonomic assessment tool considers biomechanical and postural load requirements of job tasks/demands on the neck, trunk and upper extremities.

Finally, using the principles of anthropometry, an ergonomic workstation design was developed and were compared to present design of workstation to know if there is a mismatch and identify the gaps in the design.

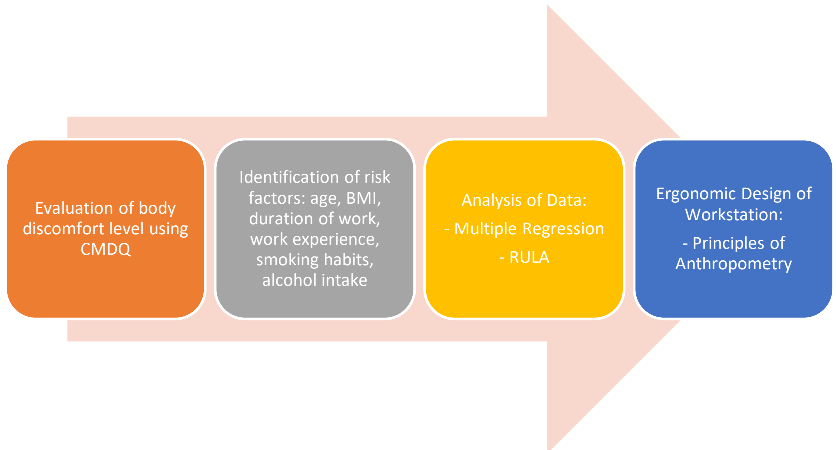

Figure 1. Methodology Framework

3. Results and Discussion

3.1. Result of CMDQ Scores

The researchers identified and evaluated the severity of work related musculoskeletal disorders experienced by the workers in three (3) different sections of the company namely knitting, cutting and sewing using CMDQ, the following results were obtained as shown in Table 1.

Table 1. Results of CMDQ

Body Parts	Knitting	Cutting	Sewing
Lower back	24.45%	15.43%	14.16%
Lower Leg	19.39%	14.39%	14.95%
Upper arm	15.74%	12.69%	13.69%
Neck	10.42%	11.51%	12.70%
Foot	10.30%	10.90%	11.34%
Shoulder	8.40%	9.86%	9.82%
Upper back	2.67%	8.21%	8.55%
Wrist	2.02%	4.84%	7.66%
Thigh	1.89%	4.48%	2.45%
Forearm	1.75%	4.26%	2.09%
Knee	1.57%	2.63%	1.54%
Hip/buttocks	1.42%	0.83%	1.09%

For the results of the study, the CMDQ scores of respondents have showed that for all the tasks, the body parts that have the highest prevalent body discomfort are lower back followed by lower leg, upper arm, neck and foot.

3.2. Result of Multiple Regression Analysis

Furthermore, the researchers intended to regard the following predictors such as age, body mass index, working hours per week, working experience, alcoholic intake and use of tobacco as contributing factors to aggravate the existence of work related musculoskeletal diseases experienced by garment workers. The result proved that strong predictors for body discomfort are BMI and years of working experience with p-value <0.01 while moderate predictors are smoking habit and alcohol intake with p-value <0.05 as shown in Table 2.

Table 2. Coefficient of Predictors of CMDQ

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	79.775	20.124		3.964	.000
	Age	-.712	.328	-.483	-2.171	.031
	BMI	.907	.224	.206	4.058	.000
	Working_hours_per_wek	-.370	.221	-.085	-1.673	.096
	Working_Experience	4.136	.808	1.140	5.121	.000
	Smoking_habit	1.546	.690	.116	2.243	.026
	Alcohol_intake	1.906	.803	.123	2.374	.019

a. Dependent Variable: CMDQ

3.3. Result of Rapid Upper Limb Assessment (RULA)

The Table 3 shows the result of work posture evaluation using RULA. Among all the tasks evaluated, it was identified that the following tasks below pose high risk for workers to develop upper limb disorders having RULA final score between 5-7. This means that the task must be investigated and changed immediately.

Table 3. Results of RULA

TYPE OF ACTIVITY	FINAL RULA SCORE
Putting of thread rolls in knitting machine	7
Putting of oil in roller / removing fabric	7
Cutting of cloth	6
Spreading of cloth	6
Sewing	5

3.4. Summary of Anthropometric Measurements

Using the anthropometric dimensions gathered from the respondents, the researchers were able to compute the minimum percentile, average percentile and maximum percentile as reference for workstation design. Shown on Table 4 are the samples of anthropometric measurements gathered from respondents.

Table 4. Sample anthropometric measurement from the respondents

Standing									
Male					Female				
Body Part	Mean	5th	Median	95th	Body Part	Mean	5th	Median	95th
overhead fingertip reach	210.02	192. 36	210. 50	227. 68	Elbow Height	98.96	90.04	98.00	107.87
					Chest Breadth	36.86	23.02	33.00	50.69
					Hip width	41.21	29.68	41.50	52.74

3.5. Ergonomic Design of Workstation

Since it was proved in the initial analysis that there is a risk of body discomfort on apparel manufacturing workers, it is justified that there is a need to redesign the current workstation of workers. The following are the design considerations.

A. Ergonomically Designed Roller Ladder for knitters (Figure 2)

- Step height is = step height of 5th female = 35.47.cm

- Total height of the ladder = (3 steps x 35.47 cm / step) + 60.78 cm (handle ht. of the ladder = knuckle height of 5th female) = 106.41+ 90.78 = 167.19cm
- Width of roller ladder = shoulder width standing 95th male = 50.54cm.
- Height of platform = knuckle height of 95th male standing = 80.24cm

Figure 2. Roller Ladder

B. Ergonomically Designed Chair with adjustable seat height for sewers and Cutters (Figure 3)

- Minimum seat height of the chair = 49.21cm (5th female popliteal height)
- Maximum seat Height of the chair = height of the cutting table (95th male elbow ht.) – 5th elbow ht. female = 115.21 cm - 14.47cm = 100.71cm.
- Seat width of the chair = 43.11cm (95th female hip breadth sitting)
- Seat depth = 38.05 cm (5th female buttock-popliteal length)
- Back rest width = 50.54cm (95th male shoulder width)
- Back rest height = 5th female shoulder ht. – 5th female hip ht. = 116.88 – 76.37 = 40.31cm
- Footrest height = 95th male popliteal height sitting – 5th female popliteal sitting = 49.21cm – 33.5 = 15.71cm from the ground

Figure 3. Adjustable chair

In consideration for both cutters and knitters, the height of the chair can be used when cutters needed to sit while working, that's why the researcher used the height of the cutting as a basis of the maximum height of the adjustment of the chair so the cutter can do their task when standing or sitting using the ergonomically designed chair.

C. Ergonomically Designed Cutting Table (Figure 4)

- Table height = 5th female elbow height standing = 89 cm
- Table Width = 48.9cm (standard size)
- Extension = 63.75cm – 53.52 = 10.23 cm

To accommodate the other cloth of sheet with a width of 63.75cm researcher designed the cutting with a table extension, based on final anthropometric measurement the 5th female thumb tip reach is = 53.52cm where it is considered the shortest and the width of the table is based on the said anthropometric part. Since the other width of the sheet of cloth which is 63.75cm is far more to 53.53cm, the researcher made an extension for the cutting.

Figure 4. Cutting table

D. Adjustable Height Sewing Table (Figure 5)

- Minimum height = 95th male popliteal height sitting + 95th male elbow sitting height = 49.27cm + 29.84cm = 79.11 cm
- Maximum height = 95th male standing elbow height = 115.12 cm
- Table length = 106cm (standard length)
- Table width = 5th female thumb tip reach = 53.52 cm

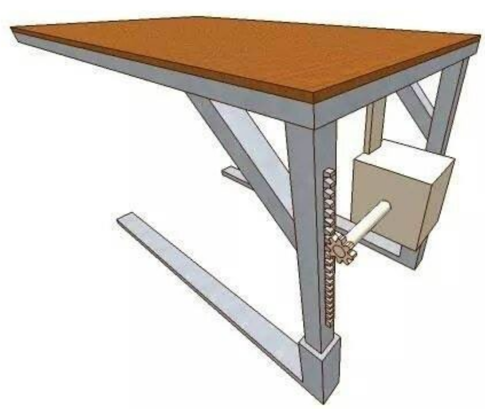

Figure 5. Sewing Table

3.6. Assessment of Existing Workstation Design

Then to determine if there is a mismatch or gap between the recommended design and present design of workstation, the researchers evaluated the current design to identify its effect on body discomfort of workers. The results are shown in Table 5 and 6.

Table 5. Evaluation of existing design of Tompkins knitting machine

Area	Gaps Identified	Supportive Findings
Height of Platform for Thread rolls	Too low (16 cm)	Severe Pain on Lower Back and Legs
Height of the roller of the knitter	Too high (192 cm)	Severe pain on the upper arm

Platform for knitting machine is improvised made to reduce the chances of thread rolls to get unclean while processing of knitting is ongoing. The height of the platform be likely to cause the knitters to lean forward, performing the task several times a day causes the lower back and legs of knitters to experience severe pain.

Table 6. Assessments on the existing height of the cutting table

Area	Gaps Identified	Supportive Findings
Height of the cutting table	Too low (86cm and 70 cm)	Severe Pain from the lower back, upper arm, and shoulder

Height of the cutting table: 5th female Elbow height standing = 89 cm. The existing height of the cutting table is evidently way too far from the anthropometric measurement; the low height of the existing table causes their arms and hand hanging for a long period of time. The assessment on the existing sewing table and chair is shown in Table 7.

Table 7. Assessment on the existing sewing table and chair

AREA	GAPS IDENTIFIED	SUPPORTIVE FINDINGS
Height of sewing machine	Too low	Pain on the neck, forearm and shoulder
Chair	No comfortable seat pad	Pain on hip/buttocks
	Too high	Pain on thigh and lower leg
	No backseat	Pain on the lower back

4. Conclusion

For the conclusion of the study, the following points were inferred in the analysis, first, based on the evaluation of MSD using CMDQ, the workers in knitting, cutting and sewing operations experience body discomfort on their lower back, lower leg, upper arm, neck and foot. Second, based on the result of regression analysis, it was proved that personal factors that significantly affect the prevalence of body discomfort of workers are BMI, years of working experience, smoking habits and alcohol intake. Additionally, the result of the RULA had proved that there are 5 different tasks that pose high risk of upper limb disorder for workers and these are putting of thread rolls in knitting machine, putting of oil in roller / removing fabric, cutting of cloth, spreading of cloth and sewing. Lastly, using the anthropometric data obtained from respondents, we were able to design an ergonomic workstation for workers. These workstation design where then compared to the existing design of workstation and determined that there is a mismatch or gap between the design that that is why the workers to experience body discomfort while performing their task.

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Biographies

Paul Jan V. Saguyod is a graduate of Bachelor of Science in Industrial Engineering and Engineering Management in Mapua Institute of Technology.

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Almarose C. Villapando has over 20 years of relevant working experience in various fields of Industrial Engineering including Methods and Systems Engineering, Work Measurement and Improvement, Compensation Administration, Operations Management, Productivity & Quality Management, and Value Engineering and Analysis. A Professor in the School of Industrial Engineering - Engineering Management of at Mapua University, Alma has likewise held key leadership positions at Shoemart Incorporated and VFL (Lee) Philippines. Alma obtained her Bachelor's degree in Industrial Engineering, and Master in Engineering Management (Magna Cum Laude) both from Mapua Institute of Technology. On the side, Alma is involved in a no. of consultancy works with various companies including construction, undergarments, logistics with engagement dealing with Process Review and Improvement, Compensation and Benefits, Productivity and Quality Improvement, to name a few. She is a certified Professional Industrial Engineer as conferred by the Philippine Institute of Industrial Engineers (PIIE)