Comparative Analysis of Predictive Models of Pain Level from Work-Related Musculoskeletal Disorders among Sewing Machine Operators in the Garments Industry

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Abstract -*The Philippine garments industry has been experiencing a roller-coaster ride during the past decades, with much competition from its Asian neighbors, especially in the wake of the ASEAN 2015 Integration. One of the areas in the industry which can be looked into and possibly improved is the concern on Work-related Musculoskeletal Disorders (WMSDs). Literatures have shown that pain from WMSDs among sewing machine operators in this industry is very prevalent and its effects on the same operators have been very costly. After identifying the risk factors which may cause pain from WMSDs, this study generated three models which would predict the said pain level. These models were analyzed, compared and the best model was identified to make the most accurate prediction of pain level. This predictive model would be helpful for management of garment firms since first, the risk factors have been identified and hence can be used as bases for proposed improvements. Second, the prediction of each operator's pain level would allow management to assess better its employees in terms of their sewing capacity vis-à-vis the company's production plans.*

Keywords*: Ergonomic Interventions, Predictive Models, Risk Facts, Severity and Frequency of Pain, Work-related Musculoskeletal Disorders*

INTRODUCTION

The garments industry in the Philippines started in the 1950sas a backyard business for a lot of households. The industry slowly grew in the 1950s, especially due to the passage of the Embroidery Act (RA 3132) of 1961 where there was tax-free importation of textiles. The same industry further flourished in the 1970s when the country was given preferential treatment to export its garments and textiles to the United States, European Union and Canada through the Multi-Fabric Agreement (MFA) or more commonly known as the quota system. The industry then became export-oriented and grew to be the country's second biggest exporter, after the electronics industry.

Through the years, competition from the country's Asian neighbors has made the revenues and volumes of this Philippine industry travel a roller-coaster ride, more so after year 2005, when the MFA was phased out. In the meantime, another challenge looms in the horizon is the ASEAN Integration 2015, where trade and service barriers would be further liberalized among member countries.

With the competition becoming more tight in the industry, productivity initiatives should be carried out in order to find ways in making the said industry surpass its Asian neighbors.

One of the opportunities for improvement in the garments industry is in the area of Work-related Musculoskeletal Disorders (WMSDs).

The World Health Organization defined WMSDs [1]:

> *"as one that results from a number of factors, and where the work environment and the performance of the work contribute significantly, but in varying magnitude, to the causation of the disease. The term musculoskeletal disorder denotes health problems of the locomotor apparatus, i.e. muscles, tendons, the skeleton, cartilage, the vascular system, ligaments and nerves. Work-related musculoskeletal disorders (MSDs) include all musculoskeletal disorders that are*

induced or aggravated by work and the circumstances of its performance."

WMSDs are present in highly diversed work areas, from people who are sedentary to those who are highly mobile. Causes of WMSDs are also wide-ranging: individual risk factors such as age, weight, height, years of work experience, etc.; psycho-social risk factors such as relationships in the organization, demands and deadlines of the tasks, degree of difficulty of tasks, company policies, among others; physical risk factors, namely posture, duration of posture, force, repetition and other; and environmental risk factos such as sound level, temperature and illumination[2]-[8].

The costs of WMSDs are staggering. Data from the United States Occupational Safety and Health Administration (OSHA) and Bureua of Labor Statistics have shown these facts [9]:

- In the United States of America, around 130 million health care encounters, including emergencies and outpatient procedures, have been estimated annually.
- Between $45-$54 billion is lost annually due to productivity losses, loss wages and compensation costs.
- For Worker's Compensation costs for lost days, employers annually pay anywhere from $15-$20 billion
- The claims per injury for Worker's Compensation equal anywhere from $29,000-$32,000 per year
- Except for surgery, medical bills for the usual shoulder injury reach around $20,000 annually.

In view of the enormous costs of WMSDs and the impending tighter competition in the industry, this study, through the use of different statistical analyses, identified the factors causing pain from WMSDs. This identification process can therefore be a means for management of garment firms to look at these variables and make proposals to address the same in the hope of minimizing pain from WMSDs. In addition, the accurate prediction of the pain level of each sewing machine operator can make management assess better said operator's possible production capacity relative to his/her pain level experience.

OBJECTIVES

Given the significance of this study, the following research objectives are presented by this project: the first is to identify the risk factors which may cause pain from WMSDs among sewing machine operators in the garments industry. The second objective is to develop models which will predict "Pain Level" from WMSDs; and finally, this study aims to determine the most accurate model among those developed.

METHODS

This study followed a correlation/prediction-type process in order to achieve its objectives. From the Theoretical Framework below (Figure 1), risk factors possibly causing pain from WMSDs were initially identified. The different body parts of the operator affected by the said pain were then pinpointed. After which, the frequency and severity rates of the pain experienced by the operator were determined from the same operator's 13 body parts and then their combination(frequency and severity rates) was calculated, the result of which was the response variable termed as "Pain Level". After these steps, predictive models were developed, through the SPSS statistical software, analyzed and compared to determine which among the models generated was the most accurate in predicting "Pain Level".

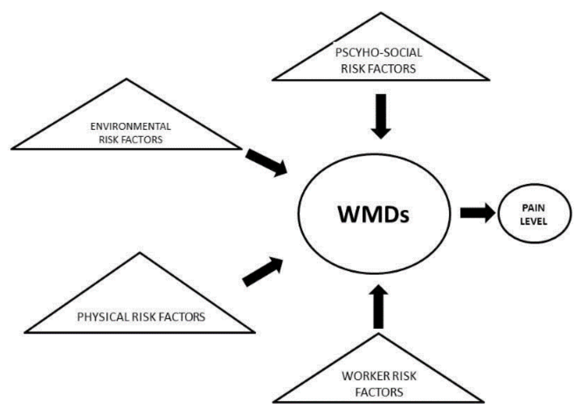

Figure 1. Theoretical Framework

Variables Under Consideration

Considering that Regression Analysis was utilized in this study, independent variables (IVs) or predictors or WMSD risk factors numbering 34 in this research and a dependent variable (DV) or response variable ("Pain Level" werecorrelated to be able to predict "Pain Level". Tables 1 and 2 showthese variables and their measurement details.

Table 1.Independent Variables

Risk Factor	Unit Of Measurement	Instrument Used For Measurement
I. Psychosocial Risk Factors	Rating: 1-Strong Agree; 2-Agree; 3-Disagree; 4-Strongly Disagree	Survey Questionnaire
II. Environmental Risk Factors		
a. Illumination	Lux or Foot-Candle	Lux Meter
b. WBGT	Celsius	Heat Stress WBGT; Meter
c. Sound level	Decibel	Sound Level Meter
III. Physical Risk Factors		
a. Posture and Force	Rapid Entire Body Assessment (REBA) Value	Work Sampling, REBA Employee Assessment Worksheet and REBA Tally Sheet per Operator
b. Duration of Awkward Posture	Percentage	Work Sampling and REBA Tally Sheet per Operator
c. Repetition	Rating: 1-no repetition, 4-highly repetitive	Survey Questionnaire
d. Vibration	Rating: 1-No vibration, 2-Low Vib., 3-Med. Vib., 4-High vibration	Survey Questionnaire
e. Personal Workplace Layout	Rating: 1-Strongly Agree, 2-Agree, 3-Disagree, 4-Strongly Disagree	Survey Questionnaire
f. Facility Layout	Rating: 1-Strongly Agree, 2-Agree, 3-Disagree, 4-Strongly Disagree	Survey Questionnaire
IV. Worker Risk Factors		
a. Gender	Male or Female	Survey Questionnaire
b. Age	Years	Survey Questionnaire
c. Weight	Kilos	Weighing Scale
d. Height	Centimeters	Steel Tape Measure
e. Ave. No. of Working Hours per day	Hours	Survey Questionnaire
f. Years of Work Experience	Years	Survey Questionnaire
g. Educational Background	Choice: 1-Elementary Grad., 2-High School Grad., 3-Vocational Grad., 4-College Grad.	Survey Questionnaire
h. Marital Status	Choice: 1-Single, 2-Married, 3-Divorced/Widowed,	Survey Questionnaire
i. No. of Children and Dependents	Numerical Value	Survey Questionnaire
j. No. of Other Jobs Providing Additional Income	Numerical Value	Survey Questionnaire
k. No. of Minutes of Physical Exercises/wk.	Minutes	Survey Questionnaire
l. No. of Minutes of Breaktime/day	Minutes	Survey Questionnaire
m. Type of Breaktime Preferred	Choice: 1-Short, frequent breaktimes, 2-long, seldom breaktimes	Survey Questionnaire
n. Degree of Difficulty of Sewing Task	Rating: 1-Very easy, 2-Easy, 3-Difficult, 4-Very Difficult	Survey Questionnaire
o. Monthly Salary	Peso Value	Survey Questionnaire

Table 2.Dependent Variable

Response Variable	Unit Of Measurment	Instrument
Frequency Rate (FR)	Rating: 1-No incidence, 4-High Frequency	Survey Questionnaire
Severity Rate (SR)	Rating: 1-No pain, 4 -Too painful	Survey Questionnaire
Combination of FR and SR (CFRSR) or "Pain Level"	Rating: 1/13 – Min. 16/208 - Maximum	Survey Questionnaire

For the whole body "Pain Level" of an operator, the value would be anywhere from 13 to 208. Since this is a wide range, a simple categorization has been made to easily denote the type of risk the operator is subjected to. Below is the risk factor table (Table 3):

Table 3. Risk Factor and Pain Level

Type Of Risk	Pain Level Range
No Risk	1-13
Low Risk	14-52
Medium Risk	53-117
High Risk	118-208

Sample Size

This study considered industrial sewing machine operators from the small and medium scale enterprises (SMEs) in Metro Manila [11] The SMEs were chosen since more than 99% of all industries in the country belong to this scale. From the study of Elder[12], a formula for computing sample sizes was utilized. Using a 95% confidence level and a 5% error, the minimum sample size computed was 73 respondents or operators.

Since this research has to do with work-related MSDs, this study had to segregate those operators with MSDs which are work-related from those with MSDs which are not work-related. A screener questionnaire was developed, with the assistance of medical practitioners and was used for this objective. Hence, to achieve the minimum number of respondents, a total of 123 respondents were given the survey and screener questionnaires. Out of this number, due to various reasons, 93 respondents were finally considered for this study.

Ethical Considerations

Permission was granted by company owners that this study be conducted in their facilities. Informed and signed consent was likewise taken from the respondents. Similarly, to avoid any potential conflict between management and respondents, since this study had survey questions sensitive to their relationship, no names were written on the survey form. A numbering system was made and only the researcher knows the identity of the respondent of the survey form.

Regression Analysis

Utilizing the Multiple Regression module in the SPSS statistical software, this research determined the significant IVs, the predictive model and its significance, to name a few. Three models were generated in this study and said models were compared to determine the most accurate predictive model.

RESULTS AND DISCUSSION

Using Regression Analyses, all thirty-four IVs, which have been determined by literature to bring about WMSDs, were subjected to Stepwise Regression to determine the significant IVs. Three models (Models 1, 2 and 3) were generated and each was evaluated to determine its predictive capability. The said three models and their evaluation process are discussed below.

Model 1

As one of the objectives of this study, significant IVs were identified for the first model, which has been denoted as Model 1. These significant variables are shown in the table below, Table 4, which came from the SPSS output.

Examination of Table 5, the Analysis of Variance (ANOVA) showed that the model is indeed significant, with its "Sig" less than 0.05, the maximum value allowed. However, interms of R-square value, it is only 30.2% (Table 6).This means that 30.2% of the variability in the response variable is due to the variability in the IVs. This value, though respectable, would need to be analyzed for further improvement.

Table 4. Coefficients for Model 1

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	24.000	6.113		3.926	.000
	Type Of Breaktime	11.700	4.322	.277	2.707	.008
2	(Constant)	7.795	8.664		.900	.371
	Type Of Breaktime	11.807	4.192	.280	2.817	.006
	Empowerment	6.397	2.494	.255	2.565	.012
3	(Constant)	20.746	10.243		2.025	.046
	Type Of Breaktime	11.092	4.110	.263	2.699	.008
	Empowerment	6.818	2.445	.272	2.788	.007
	Company Policies	-6.185	2.751	-.220	-2.248	.027
4	(Constant)	5.255	11.832		.444	.658
	Type Of Breaktime	10.341	4.010	.245	2.579	.012
	Empowerment	6.027	2.401	.240	2.510	.014
	Company Policies	-7.466	2.728	-.265	-2.737	.008
	Gender	11.769	4.849	.237	2.427	.017
5	(Constant)	-31.681	17.885		-1.771	.080
	Type Of Breaktime	10.236	3.871	.243	2.644	.010
	Empowerment	5.619	2.323	.224	2.419	.018
	Company Policies	-6.722	2.648	-.239	-2.539	.013
	Gender	15.467	4.880	.311	3.170	.002
	Degree Of Difficulty Of Sewing Tasks	13.788	5.137	.258	2.684	.009

Table 5. ANOVA for Model 1

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	2737.800	1	2737.800	7.327	.008[a]
	Residual	32881.800	88	373.657		
	Total	35619.600	89			
2	Regression	5048.883	2	2524.442	7.184	.001[b]
	Residual	30570.717	87	351.388		
	Total	35619.600	89			
3	Regression	6745.569	3	2248.523	6.697	.000[c]
	Residual	28874.031	86	335.745		
	Total	35619.600	89			
4	Regression	8616.843	4	2154.211	6.781	.000[d]
	Residual	27002.757	85	317.679		
	Total	35619.600	89			
5	Regression	10749.708	5	2149.942	7.262	.000[e]
	Residual	24869.892	84	296.070		
	Total	35619.600	89			

A. Predictors: (Constant), Type Of Breaktime
B. Predictors: (Constant), Type Of Breaktime, Empowerment
C. Predictors: (Constant), Type Of Breaktime, Empowerment, Company Policies
D. Predictors: (Constant), Type Of Breaktime, Empowerment, Company Policies, Gender
E. Predictors: (Constant), Type Of Breaktime, Empowerment, Company Policies, Gender, Degree Of Difficulty Of Sewing Tasks
F. Dependent Variable: Pain Level

Table 6. Model Summary for Model 1

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	.277[a]	.077	.066	19.330	.077	7.327	1
2	.376[b]	.142	.122	18.745	.065	6.577	1
3	.435[c]	.189	.161	18.323	.048	5.054	1
4	.492[d]	.242	.206	17.824	.053	5.890	1
5	.549[e]	.302	.260	17.207	.060	7.204	1

A. Predictors: (Constant), Type of Breaktime
B. Predictors: (Constant), Type of Breaktime, Empowerment
C. Predictors: (Constant), Type of Breaktime, Empowerment, Company Policies
D. Predictors: (Constant), Type of Breaktime, Empowerment, Company Policies, Gender
E. Predictors: (Constant), Type of Breaktime, Empowerment, Company Policies, Gender, Degree of Difficulty of Sewing Tasks
F. Dependent Variable: Pain Level

The predictive model for Model 1 is thus:

$$\hat{y}=-31.681+10.236x_{30}+15.467x_{15}+13.788x_{31}+5.619x_{6}-6.722x_{23}$$
(Equation1)

Where
$\hat{y}$ = Estimate of Pain Level from WMSD
x_{30} = Independent Variable,Type of Breaktime Preferred
x_{15} = Independent Variable,Gender
x_{31} = Independent Variable, Degree of Difficulty of Sewing Task
x_{6} = Independent Variable, Empowerment
x_{23} = Independent Variable, Company Policies

A measure to determine accuracy of a regression model for prediction is called the root mean square error (RMSE). This process calls for the determination of the error (difference between actual and predicted values) of each respondent, getting after which the variance of the summation of all errors and finally, obtaining the square root of the said variance. The lower the value of the RMSE, the more accurate the model is in predicting the estimated value. For model 1, RMSE is 16.46.

Model 2

Improvements in Model 1, in terms of accuracy and R-square, can be achieved by looking at the correlation of each significant IV and the DV. From the two figures below, the IVs "Empowerment" and "Company Policies" were better described through a quadratic relationship with the DV, "Pain Level". In this light, a new model, Model 2, was generated, whose coefficients are shown in Table 7.

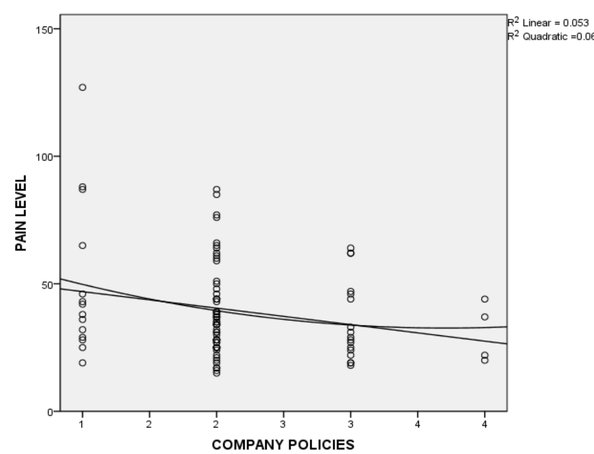

Figure 2. Scatter Plots of "Company Policies" and "Pain Level" with Quadratic Line

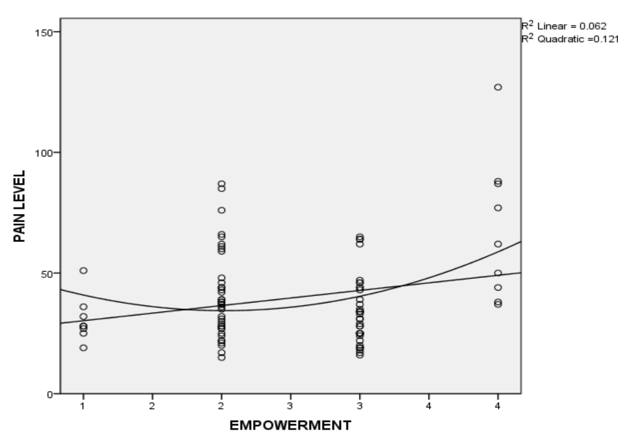

Figure 3. Scatter Plots of "Empowerment" and "Pain Level" with Quadratic Line

Table 7. Coefficients for Model 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-34.059	15.961		-2.134	.036
	empower_square	1.304	.437	.266	2.982	.004
	copol_square	-1.268	.543	-.214	-2.337	.022
	Degree of Difficulty Of Sewing Tasks	13.689	4.865	.261	2.814	.006
	Type of Breaktime	10.335	3.743	.246	2.761	.007
	Gender	15.263	4.743	.305	3.218	.002

a. Dependent Variable: PAINLEVEL

Thus, Table 7 shows the revised coefficients, which would then generate the new model, Model 2, whose predictive equation is as follows:

$$\hat{y} = -34.059 + 10.335x_{30} + 15.263x_{15} + 13.689x_{31} + 1.304x_6^2 - 1.268x_{23}^2 \qquad \text{(Equation2)}$$

Where:

$\hat{y}$ = Estimate of "Pain Level"from WMSD
x_{30} = Independent Variable,"Type of Breaktime Preferred"
x_{15} = Independent Variable,Gender
x_{31} = Independent Variable, Degree of Difficulty of Sewing Task
x_6= Independent Variable, Empowerment
x_{23} = Independent Variable, Company Policies

By looking at the SPSS output in Table 8 for Model 2, R-square had a slight increase, from 30.20% to 32.20%. Accuracy, through RMSE also improved to16.37.

Table 8. Model Summary for Model 2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.568[a]	.322	.283	16.838

a. Predictors: (Constant), Gender, "Type Of Breaktime", Empower_Square, Copol_Square, Degree of Difficulty of Sewing Tasks

Model 3

Further analyses were done to improve model fit and prediction accuracy by analyzing the outliers. Three tools used for this process were: Leverage, Cook's Distance and SPSS's automatic outliers' identification. After making use of these three tools, from a total of 93 respondents, 10 respondents were deemed to have undue influence on the model and thus were removed. Hence, for the third model, Model 3, only 83 respondents were utilized.

The equation is Model 3:

$$\hat{y}=36.817+12.540x_{30}+11.225x_{15}+14.640x_{31}+0.917x_6^2 \qquad \text{(Equation3)}$$

Where

$\hat{y}$ = Estimate of "Pain Level"from WMSD
x_{30} = Independent Variable,"Type of Breaktime Preferred"
x_{15} = Independent Variable,Gender
x_{31} = Independent Variable, Degree of Difficulty of Sewing Task
x_6 = Independent Variable, Empowerment

From Table 9 below, the rest of the IVs from Model 2 remained, except that "Company Policy" was deleted. Likewise, the "Sig" value in theANOVA table (Table 10)implies that the model is very significant in predicting "Pain Level".

Table 9. Coefficients for Model 3

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-36.817	14.200		-2.593	.011
Type of Breaktime Preferred	12.540	3.020	.386	4.152	.000
Gender	11.225	3.728	.297	3.011	.004
Degree of Difficulty of Sewing Task	14.640	4.505	.326	3.250	.002
Empowerment-_square	.917	.396	.222	2.317	.023

R =.568. R^2=.329, Adjusted R^2=.295; F=8.267, p=.000

Table 10. ANOVA for Model 3

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6334.322	4	1583.580	9.564	.000[b]
	Residual	12914.377	78	165.569		
	Total	19248.699	82			

a. Dependent Variable: PAIN LEVEL
b. Predictors: (Constant), empower_square, Type of Breaktime, Gender, Degree of Difficulty of Sewing Tasks

In terms of R-square, the model-fit improved further to 32.90% and for prediction accuracy, this model, Model 3, proved to be the most accurate among the three models since its RSME is 14.36.

Table 11. Model Summary for Model 3

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.574[a]	.329	.295	12.867

a. Predictors: (Constant), empower square, Type of Breakime, Gender, Degree of Difficulty of Sewing Tasks
b. Dependent Variable: PAIN LEVEL

Assumptions for Multiple Regression

To check if the last regression model, Model 3, satisfied the assumptions for regression models, the following tests were carried out:

1. Linearity between Observed and Predicted values of Pain Level
2. Homoscedasticity
3. Normality of Residuals
4. Normalityof Q-Q Plots
5. Multicollinearity

From the outputs of the software, all the above assumptions were satisfied.

CONCLUSION AND RECOMMENDATION

The following table compares the R-square and RMSE of the three models generated by this study:

Table 12. Comparison of Models

MODEL	R-SQUARE	RMSE
Model 1	30.20%	16.46
Model 2	32.20%	16.37
Model 3	32,90%	14.36

R-square, a measure which determines how the model fits the data, has been constantly increasing from Models 1 to 3, which can be seen on Table 12. Considering that a higher value for R-square would indicate a better fit for the model, this study concludes that Model 3 is the best among the three. However, since the Model 3 R-square value is still relatively small, future researchers may want to look for other significant IVs which can improve the fit of the model to the data.

RMSE values, from Table 12 as well, shows a decreasing trend in its values, from Models 1 to 3. Since RMSE is basically a measure of error between the actual and predicted pain levels, the lower its value, the more accurate is the model's prediction. Thus, for this study, Model 3 is the best predictive model.

With the choice of Model 3 as the most accurate and based on the said model's significant IVs, management of garment firms can now make action plans in the following areas on how to reduce from WMSDs:

- Gender – male sewing machine operators bring about lower pain levels.

- Type of Breaktime Preferred – short and frequent breaktimes [13], compared to long and seldom ones, cause lower pain levels among operators.
- Degree of Difficulty of Sewing Tasks – the more difficult the sewing tasks are, the higher the pain level the operators experience.
- Empowerment – the more empowered the operators are, the lower the pain level they experience.

Aside from identifying the significant IVs which can cause pain from WMSDs and making actions plans to address said IVs, the predicted "Pain Level" value of each operator will allow management to individually assess the operator's pain level (through Table 3) for corresponding corrective actions.

For Further Study

Though this study already considered more than thirty IVs, other literatures would signify that more risk factors can bring about pain due to WMSDs. Factors such as anthropometry and specific muscle movements may also bring about pain due to WMSDs. However, due to constraints in time and logistics, especially on the machine to be used to measure muscle movements, this study was not able to measure these variables. Thus, an important area for further study is the determination of other significant IVs, which may include the two mentioned, that would increase R-square/Adjusted R-square. Since the best R-square value is only around 33%, finding other significant IVs would create a more powerful predictive model.

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