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The Limited Predictive Power of Simple Demographic and Temporal Factors on WMSD Prevalence in Female Garment Workers: Implications for Ergonomic Design

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Abstract

Work-Related Musculoskeletal Disorders (WMSDs) are highly prevalent in the garment and apparel industry. This industry is characterized by highly repetitive tasks and sewing operation is recognized as the most challenging by the study cohort. Sewing operators are prone to discomfort in lower back and neck regions due to established risk factors such as unsafe posture, poor workstation design, and adverse demographic and temporal factors. This study aims to investigate the independent predictive power of demographic (Age, Height, Weight) and temporal factors (Work Experience, Daily Working Hours, Rest Between Work) on Neck Pain and Lower Back Pain (LBP) prevalence in a cohort of female sewing operators at a single facility. Data on symptom prevalence and associated factors were collected using the standardized Nordic Musculoskeletal Questionnaire (NMQ). A series of multivariate binary logistic regression models were trained to assess the predictive power of the grouped variables. Overall model fit was extremely low (ranging from 0.005 to 0.045) which indicates that the selected simple factors explain limited variance in WMSD outcomes. Age was the only consistent predictor across both outcomes. Age showed a positive association with LBP (cumulative risk) and a significant inverse association with Neck Pain (OR = 0.944, p = 0.034). The low explanatory power suggests that the primary determinants of WMSD risk in this population are unobserved factors such as specific postural constraints and the mismatch between anthropometric measures and workstation design. The inverse association of age with Neck Pain is indicative of a healthy worker effect (HWE), where less fit workers have left the highly demanding sewing task. Future research must incorporate objective ergonomic measures.

Keywords
Work related musculoskeletal disorders (WMSD), Garment Industry, Logistic Regression, Work Related Factors, Demographic Factors

1. Introduction
The ready-made garment (RMG) sector plays a vital role in global manufacturing. The sector is labor-intensive in Bangladesh and its neighboring developing countries. It poses significant occupational health risks to the workers. Among these, work-related musculoskeletal disorders (WMSDs) are the most prevalent. Sewing operators are affected most as they are engaged in repetitive tasks and static postures. Neck, lower back pain etc. are widespread and impact both worker well-being and operational productivity (Gebrye et al., 2025).

From literature it is evident that WMSDs are associated with factors such as age, gender, and work experience. Studies consistently point to awkward posture, repetition, and poor workstation design, as primary drivers of MSD risk (Parvin and Rafiquzzaman, 2024). While tools like RULA and REBA are used for ergonomic assessment, few studies have compared the predictive strength of demographic and work-related variables separately.

This study aims to assess if demographic and temporal variables alone can predict neck, lower back pain etc. among sewing workers using logistic regression. It is essential to consider Healthy Worker Effect to interpret the results for the case study. The objective is to prove the limited predictive power of temporal and demographic variables and incorporate anthropometric and work station variables for designing safe work station for the garment workers.

2. Literature Review
Work-related musculoskeletal disorders (WMSDs) are a major global occupational health concern in industries where repetitive tasks and static postures are common. They significantly contribute to worker disability and reduced productivity. Sectors like garment manufacturing show high prevalence rates of neck, shoulder, and back disorders due to biomechanical strain and poor ergonomic conditions (Punnett & Wegman, 2004; ISO, 2003), (Jain et al., 2023) A recent meta-analysis by Gebrye et al. (2025) reported a WMSD prevalence rate of 65.6% among garment workers and sewing operators are the most affected due to repetitive motion and poor ergonomic setup. Similarly, De Silva et al. (2025) observed that awkward postures and lack of dynamic movement significantly increase biomechanical stress during sewing operations. Nurhanisah et al. (2025), further emphasized that poor ergonomic design, repetitive tasks, and lack of structured breaks are consistent contributors to WMSDs across various sectors, particularly in developing economies.

Several demographic and work-related variables have association with WMSDs. Age is frequently linked to musculoskeletal symptoms due to degenerative changes and cumulative exposure over time (Kibria et al., 2023). Gender differences have also been reported and female workers generally shows higher susceptibility due to physiological and ergonomic mismatches in workstation design (Bizuneh & Kidanemariam, 2025). The ready-made garment (RMG) sector in Bangladesh is predominantly female-dominated. According to the International Labour Organization (2020), approximately 61.2% of RMG workers in Bangladesh are women. Work experience contributes to cumulative biomechanical stress, and longer exposure periods have been associated with higher MSD risk (Shakerian et al., 2023). Working hours per day is another critical factor, as prolonged static postures and repetitive movements without adequate rest increase physical strain (Wang et al., 2007). Numerous studies suggest that older workers or those with longer service durations are more susceptible to neck, back, and shoulder disorders due to prolonged biomechanical stress (Shakerian et al., 2023; Wang et al., 2007). However, this relationship is not always linear. Some research highlights a decline in reported discomfort with increased experience and the Healthy Worker Effect is considered to be responsible for it. It is the tendency of less healthy individuals to leave physically demanding jobs earlier which skews the results (McMichael, 1999).

Beltran Martinez et al. (2023) demonstrated that structured work-rest schedules significantly reduced muscle fatigue without compromising productivity. Similarly, Seidu et al. (2024) noted that inadequate break frequency was a recurring ergonomic risk factor in textile and garment factories.

Body Mass Index (BMI) is a widely recognized individual risk factor for WMSDs in relation to lower back pain and knee discomfort, which are often exacerbated by prolonged sitting or static postures. Excess body weight increases mechanical load on the spine and lower limbs which intensifies musculoskeletal strain during repetitive or seated tasks

(Das et al., 2023). Seife et al. (2025) further emphasized that overweight sewing operators in Ethiopian garment industries reported a higher prevalence of lumbar and knee pain especially when working in poorly adjusted seated workstations.

A variety of screening tools are employed to assess work-related musculoskeletal disorders (WMSDs). Gao et al. (2025) confirmed the efficacy of tools like RULA, REBA, and OWAS in identifying posture-related risks). Nordic Musculoskeletal Questionnaire (NMQ) stands out as a standardized, reliable instrument for evaluating the prevalence of discomfort across multiple body regions over a 12-month period. As noted by Barreto-Andrade et al. (2025), the NMQ is widely accepted for its simplicity, diagnostic value, and it is applicable across different work environments. The reviewed literature conclusively identifies MSDs as a prominent health risk among sewing workers and is influenced by workstation design, repetitive motions, static posture, and worker demographics. Statistical models have been developed to predict MSDs with demographic, temporal and anthropometric values. This study focuses solely on demographic and temporal values to predict the presence of WMSDs.

3. Methodology

This study utilized a cross-sectional design to investigate the associations between demographic and temporal work factors and to find out if temporal and demographic factors alone can predict the prevalence of Work-Related Musculoskeletal Disorders (WMSDs) among a cohort of female garment workers. The methodology was executed in three sequential phases: sample determination and research planning analyzing literature, data collection using Nordic Musculoskeletal Questionnaire (NMQ), and statistical modeling.

3.1. Study Population and Sample Size Determination

The research was confined to a single garment manufacturing facility with a documented finite population (N) of 3,000 workers. The focus was exclusively on female operators due to their overwhelming participation in sewing task. The required minimum sample size (n) was calculated using the Cochran formula for proportions with a Finite Population Correction (FPC) (Cochran 1977). Assuming a standard 95% Confidence Interval (Z=1.96), a maximum expected variability (p=0.5), and a desired 5% Margin of Error (e=0.05):

The required minimum sample size was determined to be approximate 341 participants. A total of 373 female operators were successfully recruited which reduced the Margin of Error to approximately 4.75% at the 95% Confidence Interval.

All procedures are conducted following the ethical principles outlined in the Declaration of Helsinki (World Medical Association 2013). Prior to participation, all subjects were provided with a detailed information sheet outlining the study's objectives, and voluntary nature. Informed verbal and written consent were obtained from every participant before data collection commenced. Anonymity was strictly maintained throughout the study by de-identifying the data.

3.2. Data Collection Instrument and Variable Definition

Musculoskeletal symptoms (WMSDs) were assessed using the standardized Nordic Musculoskeletal Questionnaire (NMQ) (Kuorinka et al. 1987). The NMQ is an established, nine-region checklist designed to measure the 12-month prevalence of pain or discomfort (Yes/No binary response) in the: Neck, Shoulder, Elbow, Wrist/Hand, Upper Back, Lower Back, Hip/Thigh, Knee, and Ankle/Feet.

As the NMQ is a categorical checklist of distinct anatomical regions rather than a psychometric scale items, Cronbach's Alpha was not calculated. The independent variables collected to test the predictive power of simple metrics. They were grouped as follows:

Demographic - Age (years), Height (ft), Weight (kg)
Work related - Work Experience (years), Daily Working Hours (hours), and Rest Between Work (hours).

3.3. Statistical Analysis Strategy and Subgroup Restriction

Initial data analysis revealed that the Sewing Operation was identified as the most challenging task by most of the participants. To focus on the highest-risk occupational group, the subsequent logistic regression analysis was applied on a subgroup of participants (n=255) (Table 1).

Table 1. Frequency of operations perceived as challenging by the operators

Operations Name	No. of participants found the operation challenging (count)
sewing	255
marking	44
checking quality	34
trimming	35
fabric cutting	5
total	373

The analysis of the nine NMQ body regions in the Sewing subgroup (n=255) showed that seven symptom categories had too few 'Yes' responses for stable statistical modeling.

Table 2. Prevalence of WMSD Symptoms in Sewing Subgroup (n=255)

Location	Number of Participants (Count)
Neck	73
Lower back	72
Knee	35
Upper back	20
Shoulder	18
Ankle /Feet	13
Elbow	10
Hips/Thighs	7
Finger	7
Total	255

To ensure model stability and maintain statistical power the inferential analysis was restricted to the two most frequently reported dependent variables: Lower Back Pain and Neck Pain.

Multivariate Logistic Regression was chosen as the primary inferential technique because the dependent variables (LBP and NP) are binary (Yes/No). The models were designed to test the independent predictive power of each factor type (demographic and work related). Prior to model construction, multicollinearity among predictors was assessed using the Variance Inflation Factor (VIF). All values for VIF falls below the critical threshold of 5 which is suitable for the regression analysis.

4. Result

4.1. Demographics

The participants who found Sewing as the most challenging operation have an average age of approximately 28.6 years, ranging their age from 18 to 55 years. The average height of participants is 5.07 ft (range: 4.1-5.6 ft), and the average weight is 55.05 kg (range: 41-78 kg). All 255 participants are identified as ‘Female’. Participants possess an

average of 2.75 years of work experience (range: 0.8-5 years), with the majority having 2 to 3 years of experience. The average daily working hour is 10.19 hours (range: 8-13 hours). The average rest period between work is approximately 1.14 hours (range: 0.25-3 hours) with half of the participants taking 1 hour or less rest.

4.2. Musculoskeletal disorders (MSDs)

The participants reported MSDs in different body regions like shoulder, lower and upper back, neck, wrist/ hand, hips, knee, and feet/ankle. They suffered pain mainly in the lower back and neck regions. Table 2 represents the frequency of MSDs according to the body regions and Table 3 shows the average demographic and work-related factors of participants who suffered lower back and neck pain. The findings of this study indicated that 28.63% and 28.24% of the participants respectively complained about discomfort in the lower back and neck regions. Moreover, knee pain also common among the participants (13.73%). However, very few of them reported hip and finger pain.

Table 3. Average demographic and work-related factors of participants who suffered Lower Back and Neck pain

Factor (Unit)	**Average for Participants Reporting Lower Back Pain (LBP)**	**Average for Participants Reporting Neck Pain**
Average Age (years)	30.46	27.01
Average Work Experience (years)	3.03	2.74
Average Daily Working Hours (hours)	10.13	10.3
Average Rest Between Work Hours (hours)	1.2	1.08

Multivariate Logistic Regression for Neck Pain

Three separate logistic regression models were constructed to investigate the association of different independent variables with the odds of reporting Neck Pain (NP):

1. Model 1 (Work Factors): This model (Work Experience, Rest Between Work, Daily Working Hours) was not statistically significant LLR p value = 0.759 with the lowest explanatory power Pseudo R^2 = 0.005
2. Model 2 (Demographic Factors): This model (Age, Height, Weight) was marginally non-significant LLR p value = 0.077, but identified Age as the only significant predictor.
3. Model 3 (Refined Final Model - Age Only): This model isolated the effect of the single significant predictor. It was found to be statistically significant in predicting the odds of Neck Pain LLR p value = 0.015, confirming that Age is the key independent demographic factor. The low explanatory power Pseudo R^2 = 0.024 persists which confirms the core hypothesis regarding the weakness of simple demographic factors in predicting NP in this subgroup.

The results for all predictors across the three models are presented in Table 4.

Table 4. Results for all predictors across the three models for neck pain

Model	**Predictor Variable**	**B (Log-Odds)**	**Odds Ratio**	**95% Confidence Interval (CI)**	**P-value**
Work Factors (Model 1)	Work Experience (year)	-0.0297	0.971	0.748 - 1.259	0.823
	Rest Between Work (hour)	-0.4358	0.647	0.278 - 1.504	0.311
	Daily Working Hour (hour)	0.0393	1.040	0.753 - 1.436	0.811
Demographic Factors (Model 2)	Age (year)	-0.0571	0.944	0.896 - 0.996	0.034
	Height (ft)	-0.2240	0.799	0.194 - 3.287	0.756
	Weight (kg)	-0.0207	0.980	0.933 - 1.028	0.400

Refined Final Model (Model 3 - Age Only)	Age (year)	-0.0611	0.941	0.892 - 0.991	0.021

Multivariate Logistic Regression for Lower Back Pain

Four separate logistic regression models were constructed to investigate the independent associations with the odds of reporting Lower Back Pain (LBP):

1. Model 1 (Demographic Factors): This model was found to be statistically significant LLR p value = 0.009, identifying Age as the only significant predictor among Age, Height, and Weight.
2. Model 2 (Work Factors): This model was not statistically significant LLR p value = 0.148, but identified Work Experience as a significant predictor when isolated from demographic factors.
3. Model 3 (Age and Work Experience): This model was constructed to test for confounding between the two previously significant variables. It was statistically significant LLR p value= 0.007 but confirmed that only Age maintained independent predictive power p= 0.016
4. Model 4 (Refined Final Model - Age Only): This model isolated the effect of the single independent predictor - Age.

Model 4 was found to be highly significant model for LBP with LLR p value= 0.003. The Pseudo R^2 of 0.033 persists, confirming that while Age is a reliable predictor. The majority (96.7%) of the risk variance is unexplained by simple demographic factors. The combined results for all predictors are presented in Table 5.

Table 5. Results for all predictors across the three models for lower back pain

Model	**Predictor Variable**	**B (Log-Odds)**	**Odds Ratio**	**95% Confidence Interval (CI)**	**P-value**
Model 1	Age (year)	0.0665	1.069	1.021 - 1.120	0.004
	Height (ft)	1.0614	2.890	0.758 - 11.021	0.120
	Weight (kg)	0.0136	1.014	0.969 - 1.061	0.560
Work Factors (Model 2)	Work Experience (year)	0.2791	1.322	1.018 - 1.716	0.036
	Rest Between Work (hour)	0.2456	1.278	0.611 - 2.678	0.515
	Daily Working Hour (hour)	-0.1497	0.861	0.636 - 1.165	0.333
Combined Refined Model (Model 3)	Age (year)	0.0566	1.058	1.010 - 1.108	0.016
	Work Experience (year)	0.1683	1.183	0.901 - 1.553	0.225
Refined Final Model (Model 4 - Age Only)	Age (year)	0.0649	1.067	1.021 - 1.115	0.004

5. Discussion

The primary objective of this study was to test the predictive limitations of demographic and temporal variables for Work-Related Musculoskeletal Disorders (WMSDs). The analysis provides statistical evidence that these factors are inadequate for prediction of risk in this population. The consistently low Pseudo R^2 values across all multivariate logistic regression models (ranging from 0.005 to 0.045) confirm that the variables included (Age, Height, Weight, and general work factors) fail to explain over 95% of the risk variance. This finding strongly suggests that work station design, anthropometric values and task related ergonomic, and biomechanical analysis is essential for predicting WMSDs in garment industry (Bizuneh & Kidanemariam, 2025),

The most robust finding in the LBP analysis was the significant positive association with Age. The final refined model (Model 4: Age Only) demonstrated that for every one-year increase in age, the probability of reporting LBP increased by 6.7% (OR = 1.067, p = 0.004). This result strongly supports that continuous exposure to physical and mechanical

loads over decades leads to age-related degenerative changes and makes older workers statistically more susceptible to LBP (Coenen et al., 2014).

In contrast to LBP, the analysis for Neck Pain revealed an inverse and statistically significant association with Age (Model 3: Age Only). The results show that for every one-year increase in age, the probability of reporting NP decreased by approximately 5.9% (OR = 0.941, p = 0.021).

This counter-intuitive finding suggests that in this population, younger workers are at a higher risk of NP. This inverse relationship is most likely explained by the Healthy Worker Effect, coupled with modern work behaviors:
Adaptation (Healthy Worker Effect): Older workers who remain employed may represent a healthier, more adapted subgroup who have self-selected out of the most demanding tasks or have developed effective coping mechanisms which may lead to a decreased reporting rate in the

This study has several limitations:

1. Its cross-sectional design prevents the determination of causality only establishing statistical association.
2. The reliance on self-reported pain may introduce recall bias.
3. The sample was restricted to only female workers, which significantly limits the generalizability of the findings to the broader industrial workforce.
4. The low Pseudo R^2 values underscore the limitation of using only general demographic and work factors.

The study did not include critical data on workstation dimensions, detailed anthropometry (e.g., sitting height, reach envelope), specific tasks performed (e.g., highly repetitive motions, force requirements), individual stress levels, and leisure-time physical activity. These unmeasured variables likely account for the majority of the unexplained risk.

6. Conclusion

The findings provide compelling evidence that Age is the single, independent demographic predictor for both LBP and NP, but with opposing effects. While older workers face a higher cumulative risk for LBP, younger workers appear to face NP more. The statistical failure to predict MSD with demographic and temporal models proves their limited predictive power. Integrating biomechanical variables (e.g., RULA scores, specific workstation dimensions, and required force) is essential to build a predictive model for actionable insights.

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