Journal of Health and Nutrition Research
Vol. 4, No. 3, 2025, pg. 1097-1108, https://doi.org/10.56303/jhnresearch.v4i3.533
Journal homepage: https://journalmpci.com/index.php/jhnr/index

e-ISSN: **2829-9760**

The Effect of Working Posture on Physical Fatigue Among Textile Workers with Age, Length of Service, and Body Mass Index as Covariates

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ORIGINAL ARTICLES

Submitted: 26 June 2025

Accepted: 20 July 2025

Keywords:
Working Posture, Physical Fatigue, Textile Workers

ABSTRACT

Physical fatigue among textile workers is caused by non-ergonomic working postures (e.g., prolonged standing) and personal characteristics such as age, length of service, and body mass index (BMI). The objective of the present investigation was to study the effect of working posture on physical fatigue after adjusting for the covariates of age, length of service, and BMI. An analytical cross-sectional study with a quantitative design was applied to 174 Surakarta workers selected by stratified random sampling. Work posture was categorized under standing and sitting, while physical fatigue was measured by the Subjective Self Rating Test (SSRT) questionnaire. ANCOVA via SPSS version 27 software was applied for the analysis, in which age, length of service, and BMI were employed as covariates. The findings indicated that the standing posture was strongly influenced positively on physical fatigue (Partial Eta Squared = 0.547, $p < 0.001$), and the effect size is large. Significant risk factors were also found to be age ($p = 0.012$) and BMI ($p = 0.035$), but the length of service was not significant ($p = 0.084$). The ANCOVA model also showed excellent predictability values of adjusted R 2 = 0.715, which implied that the model was able to explain 71.5 percent of the physical fatigue. These findings emphasize the importance of posture-based ergonomic interventions to prevent fatigue and improve occupational health in the textile industry.

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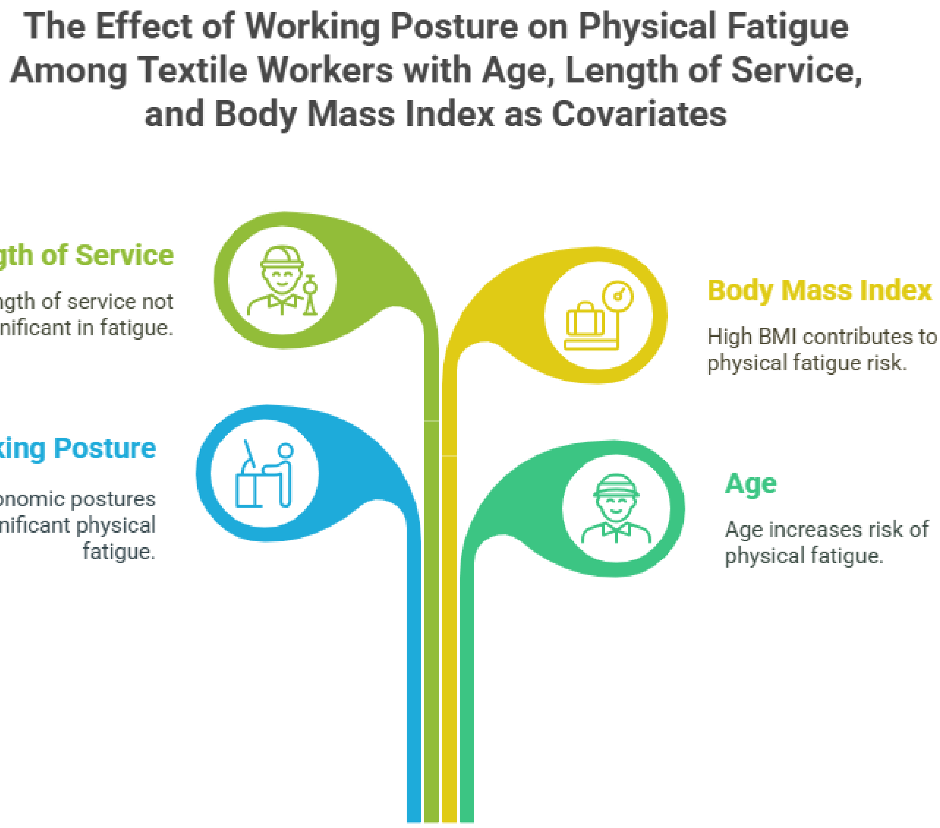
Key Messages:

- The working standing posture has been found to significantly contribute to physical tiredness among textile workers, even after adjusting for age, length of service, and body mass index..
- The ANCOVA model used had strong predictive power ($R^2 = 0.715$), which acknowledges the usefulness of multivariate statistical analysis in ergonomic studies.
- The findings provide the scientific basis for posture-based ergonomic interventions for reducing fatigue and enhancing productivity within the textile industry.

GRAPHICAL ABSTRACT



INTRODUCTION

Industrial hygiene is among the primary support pillars in the avoidance of occupational diseases, with attention paid to the detection, assessment, and control of environmental factors in the workplace that could impact employees' health (1). In the textile sector, workers are exposed to static and repetitive working conditions for long periods of time, and they are directly associated with physical workload and potential health issues, particularly physical fatigue (2–5). According to survey carried by the Zahra et al. in Indonesia, up to 60 percent of textile workers reached moderate to severe measures of physical fatigue at the end of their work shifts (6). This was a high level of exhaustion. Fatigue-related accidents that took place due to work-related means have been reported to make up around 36 percent of the cases in India (7), and up to 50 percent of the cases in others (8). Physical fatigue is a physiological response to overloading biomechanical stress, as evidenced by reduced work capacity and increased risk of workplace accidents (9–11).

One of the most important components of industrial hygiene that is normally overlooked is working posture. Static or extended sitting or standing has been shown to increase the level of muscle strain and decrease peripheral blood flow, thus accelerating physical fatigue development (12–14). Posture work studies have shown that workers who take static standing positions register a much higher rate of fatigue compared to workers who have varying postures (15–17). After all, however, it is not all that is accomplished in sitting position that is physically less demanding. Physical exhaustion may also be caused as a result of the build-up of muscle strain and diminished flow in the blood, especially to the lower body (18,19). Thus, on the one hand, this study concentrates on the aspects of comparing standing and sitting postures, but on the other hand, the existence of fatigue in a sedentary posture is also noted.

Physical fatigue has been found in some studies to be not only a function of working posture but also of individual aspects such as age, length of service, and body mass index (BMI) (20,21). Increased age has been associated with reduced physiological capacity and ability to recover from fatigue (22–24). Greater length of service can lead to greater cumulative exposure to biomechanical load,

https://doi.org/10.56303/jhnresearch.v4i3.533

and greater BMI contributes to static load to the musculoskeletal system (25). The majority of studies in the past however traced these variables independently. To give an example, one study conducted by Kondar et al. and Harahap et al. (26,27) examined only the age-related fatigue patterns among industrial workers, whereas another conducted by Safira et al. (28) used only the effects of BMI on occupational fatigue. The scattered results raise the necessity of a more coordinated analysis taking into consideration the possibility of confounding effects. In addition, these studies failed to look at the interaction that the variables may have together as well as the confusion one may impose to another. This analytical disparity has restricted the creation of a complete comprehension of the determinants of the physical fatigue. This research therefore tries to eliminate this limitation by examining the work posture and personal characteristics as a whole in a multivariate analysis.

The present study, therefore, attempts to analyze the effect of work posture on physical fatigue among textile workers with age, length of service, and BMI as confounding variables. The study is vital in addressing the knowledge gap in the literature about the relationship between work factors and physical fatigue through multivariate analytical research that acknowledges individual characteristics as a possible confounder. The conclusions of this study will probably provide a stronger scientific foundation for building data-driven ergonomic guidelines in the textile industry.

METHODS

Study Design

The study utilized an analytical cross-sectional design with a quantitative strategy. The design was selected to assess the correlation between working posture and physical fatigue among textile workers while controlling for confounders like age, length of service, and body mass index (BMI).

Study Location and Subjects

The study was undertaken at PT. Iskandar Indah Printing Textile in Surakarta, Central Java Province, Indonesia. This factory has production workers with various working postures (standing and sitting). The study population was all eligible workers at PT. Iskandar Indah Printing Textile included as follows: female workers, working for over one year, not ill or on sick leave, and willing to participate. The decision to focus on female workers was made because nearly 90% of the production work force are women and as a result the female workers tend to be the most dominant group in these settings. By investigating only one sex, we also decreased the gender-based physiologic variability that could potentially influence fatigue response, increasing the internal validity of the study. Exclusion criteria were those workers with a known history of musculoskeletal disorders prior to or during work in the factory. Although the study population consisted of current workers only, which may imply a 'healthy worker effect,' the factory's Human Resources Department indicated relatively stable employment with low turnover during the past 12 months. While not formally measured, this information provides preliminary support that healthy worker bias was minimal.

Sample Size Determination

The sample size needed was calculated a priori using the G*Power software version 3.1.9.7 for F test - ANCOVA: Fixed effects, main effects and interactions. Input parameters used were an effect size (f) of 0.25 (rated as "medium," in the lack of prior effect size data in similar research studies (29), significance level (α) of 0.05, and statistical power ($1 - \beta$) of 0.80. The study had two categories of postures (sitting and standing) and three covariates (age, service length, and BMI), and had numerator degrees of freedom as 2. The minimum required total number of subjects was 158 subjects, and this gave a resultant power of 0.802 and a critical F value of 3.055 (Figure 1). To account for any loss or distortion of data, the sample size was increased by 10%, i.e., 158 + 15.8 = 173.8, which was rounded up to 174 participants. Thus, there were 87 workers in each group: 87 workers in the standing group and 87 workers in the sitting group.

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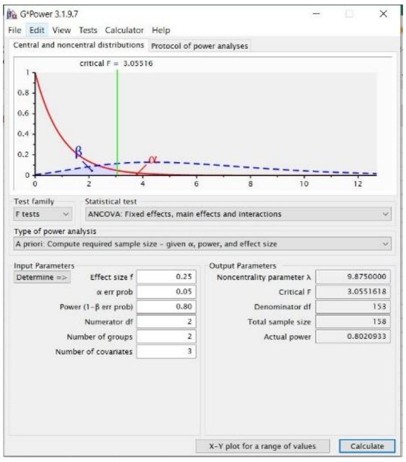

Figure 1. Calculation of Minimum Sample Size using G*Power

Sampling Technique

A total of 174 participants were selected by means of the stratified random sampling technique with the working posture type classification of standing and sitting. Randomization was performed within each stratum to select participants. Participants eligible for inclusion were selected from the employees of the production department who met inclusion and exclusion criteria and comprised 87 workers in the standing group and 87 workers in the sitting group.

Instruments and Data Collection

Working posture was categorized by direct observation and supervisor report: 1 = standing posture (Weaving Department), which involved mostly static standing with limited mobility around the loom; and 2 = sitting posture (Reed Drawing, Packing, and Sewing Departments), which involved prolonged sitting with minimal opportunities for posture change. Physical fatigue was assessed with the Subjective Self Rating Test (SSRT) of the Industrial Fatigue Research Committee (IFRC), Japan. The measure was validated and showed high item-total correlation coefficients (r = 0.453–0.723) of good construct validity, and Cronbach's α = 0.87 internal consistency reliability (30). The SSRT has 30 items, with 10 items for each of the declines in activity, motivation, and physical. Physical fatigue was measured using the 10 items of the physical decline domain in this study. Each item is measured on a 4-point Likert scale: 1 (never), 2 (rarely), 3 (often), and 4 (always). The total of all items was utilized to calculate the total fatigue score, from 10 to 40. An increased total fatigue score indicates more physical fatigue. The questionnaire attempts to quantify the subjective dimensions of physical fatigue experienced by workers performing their job tasks, particularly in textile work. Age and length of service data were obtained from the Human Resources Department, and BMI was approximated from actual height and weight measurements in the workplace using the formula: BMI = weight (kg) / height^2 (m^2).

Data Analysis

Data were analyzed using SPSS version 27. Kolmogorov–Smirnov test was used to check for normality of the standardized residuals. ANCOVA was the main statistical analysis used to find the effect of work posture on physical fatigue after adjusting for age, service, and BMI as covariates. A p-value of less than 0.05 was employed as the threshold for statistical significance.

Ethical Considerations

This study was accredited by the Health Research Ethics Committee of Dr. Moewardi General Hospital, Surakarta (Approval No: 932/IV/HREC/2024). Participants were provided information on the aims of the study, data confidentiality, and written informed consent prior to filling out the questionnaire and physical examination.

https://doi.org/10.56303/jhnresearch.v4i3.533

RESULTS

The demographic profile of the study sample, comprising employees of the textile sector, is presented in full in Table 1. Percentages and frequencies of categorical variables, along with means and standard deviations for numerical variables, are given to present a clear picture of the participants' profile.

Table 1. Demographic Characteristics of Textile Industry Workers (N=174)

Characteristic	Number of Workers	%
Working Posture		
Standing	87	50.0
Sitting	87	50.0
Physical Fatigue (points)	18.9 ± 3.8	-
Age (years)	42.9 ± 6.9	-
Length of Service (years)	11.7 ± 4.8	-
Body Mass Index (kg/m²)	25.1 ± 2.9	-

Next, Table 2 presents the mean and standard deviation of levels of physical fatigue for employees across major employee characteristics: working position (standing vs. sitting), and categories of age, length of service, and body mass index (BMI). These numbers present a preliminary view of group differences in levels of physical fatigue prior to follow-up inferential statistical analysis.

Table 2. Physical Fatigue by Worker Characteristics (N = 174)

Characteristic	Physical Fatigue (points)
Working Posture	
Standing	21.6 ± 2.3
Sitting	16.2 ± 3.1
Age (years)	
Above average	20.1 ± 3.6
Below average	17.7 ± 3.7
Length of Service (years)	
Above average	18.7 ± 3.7
Below average	19.1 ± 4.1
Body Mass Index (kg/m²)	
Above average	20.2 ± 3.6
Below average	17.6 ± 3.7

Conducting the ANCOVA, bivariate analysis using an Independent t-test (Table 3) showed that there was a significant difference in the level of physical fatigue between standing and sitting postures ($t(172) = 12.97$; $p < .001$). The standing group recorded a higher average physical fatigue (21.61 ± 2.32) than the sitting group (16.19 ± 3.13); MD = 5.42 (95 % CI: 4.60 – 6.25). The very large effect size is reflected in Cohen's d = 1.97.

Table 3. Comparison of Physical Fatigue Based on Working Posture

Working Posture	n	Mean (SD)	t (df)	p-value	Mean Diff.	95% CI (Lower–Upper)	Cohen's *d*
Standing	87	21.61 (2.32)	12.97	<0.001	5.42	4.60 – 6.25	1.97
Sitting	87	16.19 (3.13)	(172)				

Before executing the ANCOVA analysis, it is required that the residual normality assumption must be met. Table 4 provides the residual normality test results for the ANCOVA model using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Meeting this requirement is important to ensure the validity and reliability of the statistical conclusions derived from the analysis.

https://doi.org/10.56303/jhnresearch.v4i3.533

Table 4. Results of Residual Normality Tests for the ANCOVA Model

Normality Test	Test Statistic	df	p-value	Interpretation
Kolmogorov-Smirnov	0.044	174	0.200	Normal (p > 0.05)
Shapiro-Wilk	0.993	174	0.586	Normal (p > 0.05)

After confirming that statistical assumptions had been met, Table 5 reports Analysis of Covariance (ANCOVA) results, which examined the effect of working posture on physical fatigue while adjusting for age, length of service, and body mass index (BMI) as covariates. The table sums up the parameter estimates of the model, including F-values, p-values, and Partial Eta Squared, representing the statistical significance and effect sizes of all independent variables and covariates on physical fatigue.

Table 5. ANCOVA Model Estimates: Association of Working Posture, Age, Length of Service, and BMI with Physical Fatigue

Variabel	df	F	p-value	Partial Eta Squared	Keterangan Signifikansi
Age	1	56.761	< 0.001	0.251	Significant
Length of Service	1	1.776	0.184	0.010	Not significant
Body Mass Index	1	78.951	< 0.001	0.318	Significant
Working Posture	1	204.439	< 0.001	0.547	Significant
Total Model	4	106.057	< 0.001	R^2 = 0.715	Model significant

To further illustrate the effect of working posture on the level of physical fatigue, Figure 2 illustrates the adjusted estimated marginal means of physical fatigue by working posture (standing and sitting), with adjustment for age, lenth of service, and body mass index (BMI) as covariates. The analysis provides a visual representation of the contrast between the two groups of posture in differential physical fatigue, after statistical adjustment for other potential confounding variables.

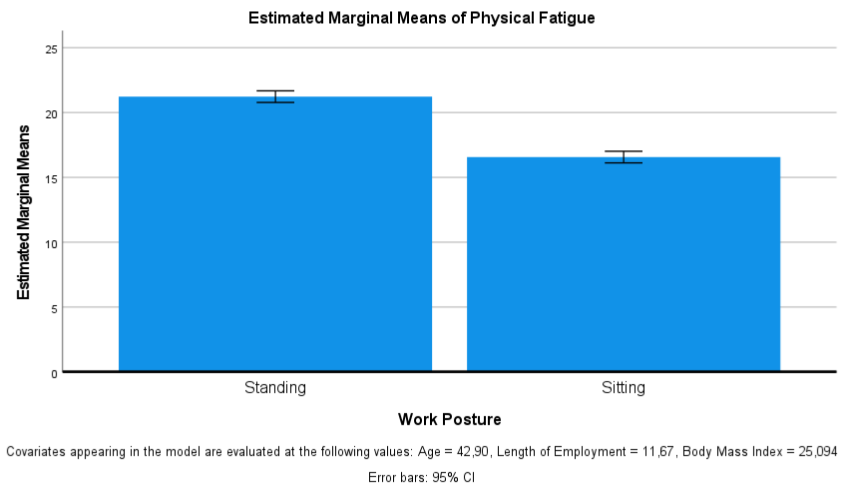

Figure 2. Estimated Marginal Means of Physical Fatigue by Working Posture, Adjusted for Covariates (Age, Length of Service, and Body Mass Index)

DISCUSSION

Working posture has a critical impact on physical fatigue, and workers spending most of their time standing experience greater levels of physical fatigue than those who sit (16). Physiologically, sustaining in a standing position promotes the elevated static demand of the postural muscles, particularly lower back,

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hamstrings, calves, and quadriceps to sustain the body stability and equilibrium during such works as body bending, reaching, or machine operation work in textile settings (31). This constant muscle contraction discourages local circulation, decreases oxygen and nutrient supply, increasing the rate of metabolic by-products like lactic acid especially in lower back and thighs to an extent that this may trigger muscle fatigue and discomfort feelings (32). Sitting, however, allows for more even weight distribution and more frequent periods of relaxation of postural muscles and therefore decelerates the rate of fatigue (33).

Older employees experience more physical fatigue compared to younger ones (34). Aging is a process of gradual decrease in physiological function, with the loss of muscle strength and mass (sarcopenia), decreased flexibility of connective tissue, and diminished efficiency of the cardiovascular and musculoskeletal systems. These changes result in a diminished fatigue threshold and longer recovery time following vigorous physical activity (35–37). That is, older workers require relatively more effort to perform the same amount of work as their young peers and become exhausted earlier (38,39).

Body Mass Index (BMI) also revealed significant correlation with physical fatigue. Those employees who have a higher BMI tend to experience worse physical fatigue compared to employees with lower BMI (40,41). Physiologically, overweight or obesity leads to more mechanical loading of the musculoskeletal and cardiorespiratory systems during exercise, e.g., occupational tasks (42,43). The increased body mass involves more energy expenditure with each movement and potentially more joint and muscle stress (43,44). Furthermore, excess body fat could lead to ongoing low-grade inflammation and metabolic dysregulation that indirectly results in the experience of fatigue (45,46).

Physiologically, length of service is said to be linked with physical exhaustion through the build-up effect of being involved in sitting or standing work over a long period that can lead to chronic exhaustion or fatigue on the body (13). In the present study, it is possible that the insignificant relationship between length of service and the physical fatigue is because not only the physiological reaction thought time, but also the Healthy Worker Survivor Effect (HWSE) may contribute to the result. The HWSE suggests that the employees who stay longer in the workforce are usually healthier, whereas those who grow tired or have more health issues exit the workforce creating a selection bias (47). However, unfortunately, the attrition rate data, direct health comparison of senior and junior workers were not attracted in this study. However, the results differ with some of the past researches that indicated that there was a positive strong correlation between length of service and fatigue (48). The discrepancy could be due to variation in job rotation practices, ergonomics interventions or due to the difference in physical task demands in study settings. In future studies, a more detailed one considering organizational and task specific variables would be merited.

Table 2 shows that the workers with standing working postures experienced much more physical fatigue (21.6 ± 2.3 points) than the workers in sitting postures (16.2 ± 3.1 points). This justifies that the prolonged standing posture is always associated with more static muscle load and energy consumption, which increases physical fatigue with time. This finding aligns with previous studies establishing that prolonged standing enhances the risk of muscle fatigue in the back, legs, and lower extremities (49). Furthermore, workers with above-average age recorded higher levels of fatigue (20.1 ± 3.6) compared to younger workers (17.7 ± 3.7). This result corroborates the hypothesis that age is a factor in heightened fatigue, as physical capacity and workload tolerance diminish with increasing age. However, for the length of service variable, it was found that workers with longer lengths of service actually had marginally lower fatigue levels (18.7 ± 3.7) compared with those with shorter lengths of service (19.1 ± 4.1). This result is contrary to our initial expectation but may be explained by the "healthy worker survivor effect," in which workers who remain employed after longer periods would, on average, have adapted more to the work or have a higher work capacity. In other words, people who are unable to cope with stressful working conditions are more likely to leave their jobs sooner. Body Mass Index (BMI) significantly affected fatigue as well. Workers with above-average BMI experienced more fatigue (20.2 ± 3.6) compared to those with lower BMI (17.6 ± 3.7). This observation is consistent with previous studies demonstrating that increased body weight increases biomechanical load, energy expenditure, and physical workload, thereby increasing exposure to fatigue—particularly in manual or repetitive work (42).

Normality testing of the residuals was done to confirm that the normally distributed residuals assumption in the ANCOVA model was fulfilled, which is one of the prerequisites for valid interpretation of

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the results of parametric tests. From Table 3, the p-value of the Kolmogorov–Smirnov test was 0.200, and the p-value of the Shapiro–Wilk test was 0.586. Both the values are above the significance level of 0.05 ($p > 0.05$), indicating there is insufficient evidence to reject the null hypothesis that the residuals are normally distributed. Therefore, it can be concluded that the residual normality assumption is valid in the ANCOVA model employed. This confirms the validity of the findings of analysis about the influence of work posture on physical fatigue, age-controlled, length of service-controlled, and body mass index (BMI)-controlled.

ANCOVA findings presented in Table 4 reveal that working posture, age, and body mass index statistically correlate with physical fatigue among textile factory workers. Of the four predictor variables used, working posture contributed the most to physical fatigue with a Partial Eta Squared of 0.547, which indicates a large effect size. This suggests that postural differences (standing vs. sitting) have significant effects on the level of physical fatigue, even after the control of age, length of service, and BMI. This is consistent with the results from previous research suggesting that workers performing tasks while standing registered more intense muscle fatigue compared to workers performing tasks while seated. Long standing position without movement is capable of increasing isometric muscle load and reducing peripheral blood flow, thereby causing systemic fatigue Moreover, the variable of substituting or switching age also exhibited a significant influence on fatigue ($F = 56.761$; $p < 0.001$; $\eta^2 = 0.251$). This is in line with the indication that an increase in age is accompanied by a reduction in physical work capacity and endurance. Older workers are more prone to cumulative fatigue since their metabolic efficacy is poor and they recover slower physiologically (50).

The Body Mass Index (BMI) variable played a significant role in work fatigue ($p < 0.001$) with a large effect size ($\eta^2 = 0.318$). This finding aligns with previous research findings showing that high BMI increases the mechanical load of the body, particularly when undertaking physical activities, thereby accelerating the onset of fatigue (51). Therefore, the nutritional state of workers—as measured by BMI—needs to be considered as a major factor when developing ergonomic interventions.

Conversely, length of service variable was not significant in correlating with fatigue ($p = 0.184$; $\eta^2 = 0.010$). This is because of the "healthy worker survivor effect," with individuals who work for longer being most likely to be those who are better physiological adapters or have greater work resilience. This finding also suggests that the length of service may not necessarily be associated with reduced fatigue because its effect could be moderated by other factors such as actual workload, ergonomic training, and nature of specific tasks performed (47). Overall, the ANCOVA model was extremely significant ($F = 106.057$; $p < 0.001$) with an R^2 value of 0.715, indicating that 71.5% of variance in physical fatigue was simultaneously explained by working posture, age, years of service, and BMI. This is a statistically strong and stable model.

In order to reinforce the connotations of our conclusions, several useful ergonomic measures are suggested to the textile factories. One of them is the introduction of sit-stand working positions to minimize static posture loading, frequent rotation of tasks (to limit risk of repetitive strain), and anti-fatigue mats when working in positions in which standing is required. As well, the staff can be educated on good body movements and micro-breaks during working hours to reduce muscle tiredness. Another considerations that should be done by the policy makers and the factory management is to incorporate the use of ergonomic risk assessment into their usual occupational health and safety protocol to minimize the overall effect of physical fatigue.

Though this study provides valuable insights on the effect of working posture on physical fatigue in textile workers, a few limitations must be mentioned. First, in the study, cross-sectional design was employed, which limits it to establish unrefutable causalities between working posture and physical fatigue; longitudinal design would be more appropriate in establishing causality. Second, physical fatigue data were also evaluated by self-report questionnaires, which, while widely used, are potentially prone to respondents' perception bias or social desirability bias. Third, although age, length of service, and BMI covariates were taken into account, other variables that may contribute to physical fatigue—e.g., work environment, mental workload, comorbid medical conditions, sleep patterns, or psychosocial variables—were neither measured nor controlled in the model. Such confounding causes can relate with the major study variables. As an example, psychosocial stressors, including a high job demand, time pressure, or a low decision-making autonomy, may possibly enhance the physical exhaustion of employees, particularly

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those people involved in a long-term standing operation. This may further exacerbate the physiological stress and in a way fasten the fatigue experience, more than could be attributed to the posture and/or the BMI. It is recommended that future research initiatives require that psychosocial dimensions be integrated into the framework of analysis guiding them so as to enable a more informed conceptualization of the multifactorial profile of occupational fatigue.

Furthermore, in order to overcome the effect of Healthy Worker Survivor Effect (HWSE) to the lesser extent, it is suggested that the future study should comprise a longitudinal cohort design. Monitoring the new workers in the long term will enable the researchers to determine the shift in the levels of fatigue over time and also determine which individuals will quit the job because of sickness or lack of adjustment. Inferences would be more valid in such a design, and it would make this question clearer: how the HWSE affects cross-sectional results in the research of occupational fatigue. Fourth, the study was conducted in a single industry (textile) and one workplace, which can limit the external validity of the findings to other industrial or worker groups.

Aside from these limitations, some sources of research bias can be reckoned with. The first is response bias due to self-reported data, in which employees may be motivated to respond with answers they perceive as being more socially acceptable or better rather than their actual states, particularly regarding physical fatigue. Although covariates were controlled, unmeasured confounding remains a source of bias as non-measured variables could also influence working posture and fatigue concurrently. Although biases were restricted in such a direction by stringent methodology, it is significant to identify the sources of bias for appropriate interpretation of results.

CONCLUSION

This study confirms that working posture, particularly standing position, has the highest level of physical fatigue among textile workers after adjusting for age, length of service, and body mass index (BMI). The age and the BMI were shown to increase the risk of fatigue, but not the service duration. The ANCOVA model with an R^2 of 0.715 shows that it is critical to practice certain posture-based ergonomic interventions in the textile industry. They are provision of sit-stand adjustable workstations, fixing anti-fatigue floor mat at standing stations, providing task rotation to reduce exposures to prolonged static postures, and education adopting the same in order to adopt good and proper posture and body mechanics in textile work. The interventions proposed are likely to substantially decrease the likelihood of the chronic physical fatigue and contribute to the sustainability of workers in the long run.

FUNDING

This research was funded by RKAT PTNBH Universitas Sebelas Maret for the 2025 Fiscal Year through the PENELITIAN FUNDAMENTAL (PF-UNS) research scheme, under the Research Assignment Agreement Number: 369/UN27.22/PT.01.03/2025. The funding was provided by Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Sebelas Maret.

ACKNOWLEDGMENTS

The authors express their appreciation for the cooperation of the management and all staff of PT. Iskandar Indah Printing Textile Surakarta to participate in this research. Additional thanks also go to the technical and administrative staff of the Bachelor Program of Occupational Health and Safety Applied, Vocational School, Universitas Sebelas Maret, for their technical support and arrangement during data collection.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

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