Fatigue Assessment with Swedish Occupational Fatigue Inventory (SOFI) and Blink Rate in Garment Manufacturing

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**Abstract.** The garment industry in Indonesia is highly labor-intensive, often exposing workers to demanding tasks and non-ergonomic conditions that may result in both physical and mental fatigue. This study aims to provide a comprehensive assessment of worker fatigue by integrating the Swedish Occupational Fatigue Index (SOFI) as a subjective measure of physical fatigue and Eye Blink Rate (EBR) as an objective indicator of mental fatigue. A total of 36 workers from four production divisions—sewing, embroidery, cutting, and pressing—participated in the study. SOFI questionnaires were administered at the end of work shifts, while EBR was recorded before and after workload exposure and analyzed using a paired-sample t-test.The results showed that all divisions experienced moderate levels of physical fatigue, with the sewing division recording the highest mean score (3.74), particularly in the dimension of physical discomfort. Blink rate analysis indicated significant decreases in the sewing and embroidery divisions (p < 0.05), reflecting elevated mental workload and cognitive fatigue, while cutting and pressing divisions showed no significant changes. These findings demonstrate that sewing workers are the most vulnerable to dual fatigue burdens due to repetitive tasks, prolonged concentration, and unfavorable environmental conditions. This study contributes to the literature by integrating subjective and objective fatigue measures, offering a more holistic approach compared to single-dimensional assessments. Practically, the results underscore the importance of ergonomic interventions, improved environmental conditions, task rotation, and stress management programs to reduce fatigue and enhance productivity. The findings provide valuable insights for occupational health practices in labor-intensive industries, particularly within developing economies.

**Keywords:** Physical Fatigue, Mental Fatigue, SOFI, Blink Rate, Garment Manufacturing, Ergonomics

# introduction

The garment industry plays a vital role in the Indonesian economy, driven by the increasing demand for clothing as one of the basic human needs [1]. Its competitiveness depends not only on technology and market orientation but also on human resources, whose professionalism and work commitment determine productivity and product quality ([2]. However, workers in this sector are frequently exposed to high workloads, repetitive tasks, and non-ergonomic postures, which may lead to both physical and mental fatigue, ultimately reducing efficiency and well-being [3]

Physical fatigue commonly occurs in labor-intensive industries where workers are required to perform prolonged repetitive movements, sustain awkward postures, or work in environments with excessive heat and limited ventilation [4]. Prolonged exposure to such conditions increases musculoskeletal discomfort, decreases endurance, and elevates the risk of occupational injury [5]. At the same time, mental workload arises when job demands exceed workers’ cognitive capacity, causing concentration lapses, psychological stress, and decreased motivation [6]. The imbalance between workload and worker capacity not only impairs performance but may also increase long-term health risks such as anxiety and burnout [7].

In screen-printing garment production, tasks such as sewing, embroidery, pressing, and fabric cutting are performed manually, often under strict deadlines and demanding quality standards. These conditions expose workers to various sources of fatigue. Sewing and embroidery, for example, involve sustained concentration and precision, which may result in mental fatigue, while repetitive movements and constrained postures contribute to physical strain. In addition, hot room temperatures from pressing machines and inadequate lighting further aggravate fatigue symptoms, highlighting the importance of ergonomic evaluation in this sector [8].

Previous studies have investigated fatigue assessment using either subjective approaches such as the Swedish Occupational Fatigue Index (SOFI) or objective methods such as Cognitive Workload and Eye Tracking [9, 10]. While these studies provide useful insights, most research tends to focus on a single dimension of fatigue—either physical or mental—without capturing their combined effects on workers’ performance and well-being. This creates a research gap in developing a more holistic understanding of fatigue in labor-intensive industries.

To address this gap, the present study integrates the Swedish Occupational Fatigue Index (SOFI) as a subjective measure of physical fatigue with the Eye Blink Rate as an objective indicator of mental fatigue. This combination allows for a more comprehensive assessment of workers’ conditions by capturing both physiological and psychological aspects of fatigue. The study focuses on workers in an Indonesian garment screen-printing company, providing new empirical evidence from a labor-intensive sector where ergonomic improvements remain limited. By identifying divisions most affected by fatigue and proposing targeted interventions, this research aims to contribute practical recommendations for improving workplace ergonomics, enhancing worker well-being, and supporting sustainable productivity in the manufacturing sector.

# Literature Review

Fatigue has long been recognized as a multidimensional construct encompassing both physical and mental aspects, with significant implications for occupational health and productivity. Various tools have been developed to measure fatigue, yet their application often remains fragmented, focusing only on one dimension at a time.

## Physical Fatigue Assessment.

The Swedish Occupational Fatigue Index (SOFI) is one of the most widely applied tools for assessing subjective fatigue in industrial settings. Previous studies demonstrated its reliability in identifying symptoms such as lack of energy, physical exertion, and musculoskeletal discomfort across different sectors, including manufacturing [11], mining [12] and food processing [13]. These studies highlight the relevance of SOFI in capturing workers’ perceptions of fatigue; however, they are inherently subjective and may not fully represent the cognitive dimension of fatigue.

## Mental Fatigue Assessment.

Workload can be measured in several ways, including subjective measures, performance measures, and physiological measures. Accordingly, there are a number of physiological measures, such as electrocardiogram (ECG) measures, eye movement measures, electroencephalogram (EEG) measures, respiration measures, and electromyogram (EMG) measure[14, 15]. Among these, Eye Blink Rate has emerged as a promising physiological indicator of cognitive fatigue. Studies in electronics and automotive industries found that reduced blink frequency is strongly correlated with increased workload and attentional demand [9, 16]. This method provides a real-time, non-intrusive measure of mental fatigue, offering advantages over purely self-reported metrics. Yet, applications of Eye Blink Rate in labor-intensive sectors such as garment manufacturing remain limited, indicating the need for further exploration in such contexts.

Most prior studies have either applied SOFI for subjective assessment of physical fatigue or Blink Rate for objective evaluation of mental workload[17]. As a result, the relationship between physical fatigue and mental workload remains underexplored[18]. This gap underscores the need for research designs that combine subjective and objective indicators to provide a more comprehensive understanding of worker fatigue and its implications for mental health. Although these approaches provide valuable insights, few studies have integrated both SOFI and Blink Rate to capture the interplay between physical and mental fatigue[19]. This is a critical gap, as physical exertion and mental load often occur simultaneously in labor-intensive workplaces, potentially reinforcing each other’s impact on worker performance and well-being.

# METHODS

## Research Design

This study employed a quantitative research design to assess both physical and mental fatigue among workers in a screen-printing garment company in Indonesia. Physical fatigue was measured using the Swedish Occupational Fatigue Index (SOFI), while mental fatigue was assessed using the Eye Blink Rate (EBR). The integration of these two approaches allows for a comprehensive evaluation by combining subjective and objective indicators of worker fatigue. The study involved all 36 workers employed in the company, distributed across four production divisions: sewing (24 workers), embroidery (5 workers), fabric cutting (3 workers), and pressing (4 workers). Since the workforce was relatively small, a total population sampling approach was adopted to ensure representation of all divisions.

## Swedish Occupational Fatigue Index (SOFI)

SOFI was used to capture workers’ subjective perception of physical fatigue. The instrument consists of 25 items grouped into five dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness [20]. Each item is rated on a 7-point Likert scale ranging from 0 (“not at all”) to 6 (“very much”), with higher scores indicating greater fatigue. The average score of each dimension was calculated, followed by the total average score, and interpreted using the fatigue classification :

* <1.13 = Low fatigue
* 1.13–4.87 = Moderate fatigue
* 4.87 = High fatigue

The SOFI method was developed by considering several question indicators, where each indicator has 5 questions. The five dimensions are sleepiness, physical discomfort, lack of motivation, lack of energy, and physical exertion. Each dimension is described and forms 25 questions. Each subject is asked to provide a subjective assessment of their condition on a scale of 0 to 6. A scale of 0 means not felt while a scale of 6 means very felt. This is done to find out which questions have the highest level, ratings with submaximal levels are ranked. The questions in this questionnaire are asked 10 minutes at the end of the work period or when the condition is most tired at work [20].

**Table 1.** Dimensions of the Swedish Occupational Fatigue Index (SOFI) Questionnaire

|  |  |  |
| --- | --- | --- |
| **No** | **Dimensions** | **Assessment Items** |
| 1. | Lack of Energy | Overworked  Worn Out  Exhausted  Spent  Drained |
| 2. | Physycal Exertion | Sweaty  Breathing Heavily  Palpilations  Warm  Out of Breath |
| 3. | Physycal Discomfort | Tense Muscles  Stiff Joints  Numbness  Hurting  Arching |
| 4. | Lack of Motivation | Uninterested  Passive  Listless  Indifferent  Lack of Concern |
| 5. | Sleepiness | Sleepy  Falling A sllep  Drowsy  Yawning  Lazy |

Source : [21]

The steps used to manage the SOFI method after the results of each dimension are known are as follows:

1. Calculate the average of each dimension

*Average score for each dimension* (1)

1. Calculating the Total Average

*Total average score* (2)

1. Interpretation of score values

After the calculation is done on the data processing using the SOFI method, the next step is to analyze the data that has been processed with the aim of seeing and understanding the fatigue groups experienced by workers. The following are the categories of work fatigue assessment in the SOFI method which can be seen in Table 2 Classification of SOFI Method Fatigue Ratings below.

**Tabel 2.** SOFI Method Fatigue Rating Classification

|  |  |  |
| --- | --- | --- |
| **No** | **Value Rating** | **Fatigue Category** |
| 1 | <1,13 | Low |
| 2 | 1,13-4,87 | Medium |
| 3 | >4,87 | High |

Source: [21]

## Eye Blink Rate

Mental workload can be measured using various methods, one of which is through an approach known as Objective Mental Workload Measurement. This approach utilizes quantitative data to obtain information about workload. One way to measure mental workload is by assessing eye blink duration, which can provide an indication of the level of workload experienced by an individual. Individuals who are facing heavy workloads and fatigue generally show longer eye blink durations, while those working with lighter loads tend to have relatively faster blink durations[22]. In this method, a person's blink rate is observed while they are performing tasks that require a high level of concentration. Blinking is an important mechanism for maintaining eye moisture and health. Mental fatigue will be measured using the blink rate, which is the frequency of eye blinks as an indicator of the level of concentration and mental fatigue[23]. During tasks that require high concentration, the frequency of eye blinks will be monitored using an eye blink recording device. The data obtained will be analyzed to evaluate the relationship between blink rate and mental fatigue. Video collection to analyze mental workload through the blink rate method is carried out using a video camera device. The video recording process is carried out when the subject is carrying out production activities, to ensure that the blink rate measurement reflects actual working conditions. The video is recorded with a duration of between five and ten minutes. There are two data processing steps in the Blink Rate method, namely:

To calculate the number of eye blinks per minute, the process is carried out manually by analyzing the videos that have been recorded during data collection. However, this manual calculation method has a drawback, namely that it can give rise to the potential for human error in calculating it. Therefore, to minimize the possibility of such errors, the study involved two people to count eye blinks in the video simultaneously. Any differences in results between the two observers were corrected by recalculating to ensure data accuracy. With a normal eye blink standard ranging from 12 to 15 blinks per minute at rest or without heavy mental workload, an eye blink frequency exceeding 20 blinks per minute can indicate mental fatigue. A significant increase in blink frequency, especially if it reaches more than 25 blinks per minute or exceeds 75 blinks per 5 minutes, often indicates that workers are experiencing cognitive fatigue or stress, which can affect concentration and work performance in workers[24].

After obtaining the number of eye blinks per minute from the population of respondents, the next step is to calculate the frequency of eye blinks using the formula listed below. The addition of this step can help reduce potential errors and ensure that the data obtained is representative.

(3)

In this study, the Paired Sample t-test was applied, the Paired Sample t-test is one of the comparative hypothesis testing methods that compares two data. The purpose of using the Paired Sample t-test is to evaluate the impact of treatment on the same sample group measured at two different times, namely before doing the work and after doing the work. With the hypothesis tested in this study are as follows:

* Null Hypothesis (H₀): There is no significant difference in the level of physical and mental fatigue of workers before and after doing the work.
* Alternative Hypothesis (H₁): There is a significant difference in the level of physical and mental fatigue of workers before and after doing the work.

The research procedure followed three main stages:

1. Data Collection – Workers completed the SOFI questionnaire at the end of their work shift, while blink rate recordings were taken before and after workload exposure.
2. Data Processing – SOFI responses were averaged by dimension and compared across divisions. Blink rate data were extracted from video recordings and tabulated.
3. Data Analysis – SOFI scores were classified into fatigue categories, and paired-sample t-tests were conducted on blink rate data to test the null hypothesis that no significant differences exist before and after workload exposure.

# RESULTS

## Fatigue Levels in Production Departments (SOFI Results)

The data analysis was conducted to evaluate the level of physical fatigue among workers across different production divisions. Using the Swedish Occupational Fatigue Index (SOFI), workers’ perceptions of fatigue were systematically assessed through five dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness. This approach provides a comprehensive view of how fatigue manifests in various tasks within the garment production process, where differences in workload intensity, task characteristics, and environmental factors are expected to influence the results. The analysis aimed to identify which divisions are most affected by fatigue, thereby offering insights into the specific ergonomic challenges faced by workers. Table 3 presents the average fatigue scores across the four production divisions. All divisions were classified in the moderate fatigue category, with sewing workers reporting the highest mean score (3.74), followed by embroidery (3.10), pressing (2.51), and cutting (2.28).

**Tabel 3.** Average Score of Each Production Section

|  |  |  |  |
| --- | --- | --- | --- |
| **Rank** | **Section** | **Average score** | **Fatigue level category** |
| 1 | Sewing | 3,740 | Medium |
| 2 | Embroidery | 3,096 | Medium |
| 3 | Pressing | 2,510 | Medium |
| 4 | Cutting | 2,280 | Medium |

Table 3 highlights the dominant fatigue dimensions experienced in each production division. The results show that physical discomfort was the most prominent dimension in both the cutting and sewing divisions, with average scores of 3.267 (28.65%) and 4.725 (25.27%), respectively. This indicates that workers in these divisions are highly exposed to musculoskeletal strain caused by repetitive movements, prolonged static postures, and non-ergonomic workstation design. The sewing division, in particular, exhibited the highest level of physical discomfort, reinforcing its vulnerability to musculoskeletal disorders.

In contrast, workers in the embroidery division reported sleepiness as the ultimate fatigue dimension, with an average score of 3.920 (25.32%). This suggests that embroidery tasks, which require sustained attention and precision over extended periods, contribute to monotony and reduced alertness, thereby increasing the risk of cognitive strain and reduced concentration. Meanwhile, the pressing division showed lack of energy as the primary fatigue dimension, with an average score of 3.000 (23.90%). This reflects the physical demands of operating pressing equipment under hot environmental conditions, which deplete workers’ stamina and endurance during their shifts.

These findings confirm that although all divisions fall within the moderate fatigue category, the nature of dominant fatigue differs according to task characteristics: physical discomfort dominates in movement-intensive tasks (cutting and sewing), sleepiness in monotonous tasks (embroidery), and lack of energy in heat-exposed tasks (pressing). This emphasizes the need for division-specific ergonomic interventions tailored to the unique demands of each production stage.

**Table 4.** Recapitulation of Highest Fatigue Levels

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Section** | **Ultimate Dimension** | **Average Score** | **Presentase** | **Fatigue Level Category** |
| Cutting | Physycal Discomfort | 3,267 | 28,65% | Medium |
| Embroidery | Sleepiness | 3,920 | 25,32% | Medium |
| Pressing | Lack of Energy | 3,000 | 23,90% | Medium |
| Sewing | Physycal Discomfort | 4,725 | 25,27% | Medium |

These findings are consistent with Shah, Amjad [25] who emphasized that prolonged repetitive movements and awkward postures contribute significantly to musculoskeletal complaints in manufacturing workers. Similarly, Boonruksa, Maturachon [26] highlighted that poor ventilation and excessive heat amplify fatigue symptoms, which were also observed in this study due to the presence of pressing machines and limited workspace.

## Mental Fatigue Assessment (Eye Blink Rate)

**Table 5.** Paired Sample T-test Results Recapitulation

|  |  |  |  |
| --- | --- | --- | --- |
| **Section** | **Sig.(2-tailed)** | **Information** | **Fatigue Level Category** |
| Cutting | 0,074 | >0,05 | There is no significant difference |
| Embroidery | 0,000 | <0,05 | There are significant differences |
| Pressing | 0,122 | >0,05 | There is no significant difference |
| Sewing | 0,000 | <0,05 | There are significant differences |

The analysis of blink frequency (Table 5) revealed significant differences in two divisions: embroidery (p = 0.000) and sewing (p = 0.000). In contrast, the cutting (p = 0.074) and pressing (p = 0.122) divisions did not show statistically significant changes in blink rate, with averages remaining close to the normal baseline. This suggests that tasks in these divisions, although physically demanding, may not exert the same cognitive burden as sewing and embroidery.

The results of the Blink Rate analysis show changes in eye blink frequency before and after the workload. In the cutting section, the average eye blink rate before and after the workload was 16 and 14 blinks per minute, with no significant changes. In the embroidery section, eye blinks dropped from 18 to 13 blinks per minute, showing a significant decrease. In the pressing section, eye blinks dropped from 18 to 16 blinks per minute, with no significant changes. In the sewing section, eye blinks dropped from 12 to 7 blinks per minute, with a significant decrease.

Workers in the fabric cutting and pressing sections did not show mental workload, while workers in the embroidery and sewing sections showed significant mental fatigue. Increased eye blinking frequency reflects high levels of mental fatigue associated with stress and physical fatigue, such as discomfort and excessive exertion. Mental fatigue is influenced by factors such as work pressure, monotonous loads, and poor environmental conditions, such as noise and inadequate lighting, which interfere with concentration and cause stress, affecting workers' performance and well-being.

The results of the comparison of eye blink frequency before and after the workload in the cutting and pressing divisions show no significant changes. In the cutting division, the eye blink frequency before the workload was 51% and after 49%, as well as in the pressing division. The Paired Sample T-Test statistical test produced a p value (Sig. (2-tailed)) of 0.074 for cutting and 0.122 for pressing, both of which are greater than α = 0.05, so there is no statistical evidence to support a significant difference in eye blink frequency before and after the workload.

The results of the comparison of eye blink frequency before and after workload in the Embroidery and Sewing divisions showed a significant decrease. In Embroidery, the eye blink frequency decreased from 61% to 39%, and in Sewing from 70% to 30%. The statistical test produced a p value (Sig. (2-tailed)) of 0.000, which is less than 0.05, so the alternative hypothesis (H1) is accepted. This indicates a significant difference between the eye blink frequency before and after workload, which reflects the impact of workload on worker performance and comfort.

These results align with Rosenfield, Jahan [9] and Biondi, Saberi [16] who reported that decreased blink frequency is strongly associated with increased cognitive demand and sustained concentration. The findings also reinforce Basar and Duzcu [27], who found that monotonous, detail-oriented tasks heighten mental fatigue, particularly when combined with unfavorable environmental conditions.

## Integrated Findings

When comparing both methods, a clear pattern emerges: sewing workers experience the highest levels of both physical and mental fatigue, followed by embroidery workers. These findings highlight the dual burden faced by workers who must maintain precision under physically strenuous conditions. Conversely, cutting and pressing divisions primarily exhibit moderate physical fatigue without significant mental strain.

This dual-method approach provides a more holistic perspective than studies focusing solely on one fatigue dimension. While SOFI captures self-reported discomfort, the blink rate method objectively identifies changes in cognitive load. By integrating both, this study demonstrates that subjective perceptions of fatigue are reinforced by physiological indicators, strengthening the validity of the results.

## Implications for Workplace Ergonomics

The findings underscore the urgent need for ergonomic interventions in the garment industry to address both physical and mental fatigue experienced by workers. Improvements in the **work environment**, such as better ventilation, reduced heat exposure, and adequate lighting, are essential to create more comfortable and sustainable working conditions [28]. In addition, optimizing **task design through job rotation or the introduction of micro-breaks** is particularly important for sewing and embroidery activities, which are repetitive and monotonous, in order to minimize musculoskeletal strain and maintain concentration levels [29].

The provision of **ergonomic equipment**, including adjustable seating, well-designed workstations, and supportive tools, can further reduce physical discomfort and prevent the onset of musculoskeletal disorders [30]. Beyond physical aspects, interventions should also include **mental health programs** such as training on stress management and coping strategies, which enable workers to better manage prolonged attention demands and reduce the risk of burnout [31].Taken together, these recommendations highlight the importance of a comprehensive ergonomic approach that simultaneously targets environmental, task-related, equipment-based, and psychological factors to improve worker well-being and productivity.

## Theoretical and Practical Contributions

This study advances the literature by demonstrating the value of integrating subjective (SOFI) and objective (Blink Rate) fatigue measures, which has been rarely applied in labor-intensive industries. The findings confirm that physical and mental fatigue are not isolated phenomena but interact dynamically, particularly in precision-based tasks. Practically, the results provide actionable insights for small- and medium-sized garment enterprises in developing economies, where ergonomic improvements are often overlooked.

# CONCLUSION

This study assessed physical and mental fatigue among garment workers in Indonesia by integrating the Swedish Occupational Fatigue Index (SOFI) and Eye Blink Rate (EBR). The findings revealed that the sewing division experienced the highest level of fatigue, both physically and mentally, primarily due to non-ergonomic postures, repetitive movements, and hot working conditions. The embroidery division also showed a significant decline in blink frequency, indicating elevated cognitive demand. In contrast, cutting and pressing divisions reported only moderate physical fatigue with no significant evidence of mental strain. The integration of SOFI and EBR proved effective in capturing the dual dimensions of fatigue—subjective perceptions of physical exhaustion and objective indicators of cognitive load. This dual-method approach contributes to the literature by addressing the limitations of single-dimensional assessments and offering a more holistic understanding of fatigue in labor-intensive industries.

From a practical standpoint, the results highlight the urgency of ergonomic interventions, including workstation redesign, improved ventilation and lighting, task rotation, and stress management programs. Implementing these measures can enhance worker well-being, reduce fatigue-related risks, and improve productivity in garment manufacturing. Future research should expand this approach to larger and more diverse samples across different manufacturing sectors, incorporate longitudinal designs to capture fatigue trends over time, and integrate additional physiological indicators such as heart rate variability or pupil dilation. Such efforts will strengthen the evidence base for fatigue management and support sustainable labor practices in developing economies.

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