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Analysis of environmental ergonomic and individual characteristic factors to cloth mask production output in small-medium enterprises

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Abstract

Environmental ergonomics and individual characteristics factors play an important role in the productivity of workers. Environmental ergonomics must be designed to achieve ergonomic working conditions and production targets. A cloth mask manufacturer is one of the small and medium-sized enterprises (SMEs) that faces environmental ergonomics problems concerning achieving the production target. Therefore, this study's objective was to analyze the effect of the workplace environment and individual characteristic factors on cloth mask production output. Data were collected from 8 workers in a cloth mask production station. Furthermore, the correlation between these two factors to cloth mask production output was analyzed by multiple regression analysis. The research hypothesis stated cloth mask production output could be influenced by 6 predictors including lighting intensity and temperature for the workplace environment and age, height, weight, and work experience for individual characteristics. The result showed that lighting intensity, temperature, and age have a significant relationship partially to cloth mask production output. Meanwhile, a combination of all predictors predicted 41 percent of the cloth mask production output variation simultaneously while 59% by other causes. These results confirmed that workplace environment and individual characteristics factors influence the production output in SMEs.

Keywords: Individual characteristics factors, Lighting intensity, Multiple regression analysis, Production output, Temperature

1. Introduction

Indonesia is a member of the world's developing countries. As a result, numerous sectors in Indonesia have developed significantly. This trend may be found in both large-scale industries and small and medium-sized enterprises (SMEs). The Indonesian government has prioritized SMEs since recognizing their critical role as the backbone of the Indonesian economy, with SMEs accounting for 99.9 percent of all industries. They provide up to 61.07 percent of Indonesia's GDP and employ up to 97 percent of workers in the SME sector [1]. The increase in the number of SMEs has an impact on the increasing number of problems, one of which is related to productivity. A previous study has defined productivity as the performance criteria representing the size of the output generated from the number of inputs given [2]. Another study has revealed there is a relationship between productivity and workplace environment [3]. Temperature, humidity, light intensity, and noise are some of the environmental ergonomics factors that have been recognized as important for worker performance [3].

Another factor that affects labor productivity is the individual characteristic factor. Individual components that affect worker productivity include individual factors including age, gender, and working period [4]. Previous research revealed age, gender, daily working hours, and job experience have all been linked to musculoskeletal disorders (MSDs) in one or more upper body areas [5]. MSDs are one of the main causes of fatigue in workers. The greater risk of fatigue can have an impact on decreasing work productivity [4].

In Indonesia, one of the SMEs that encountered serious problems related to environmental ergonomic factors that are not in accordance with ergonomic standards and government regulations is the cloth mask manufacturing industry. The typical processes for this industry included the patterning process, cutting process, assembly process, and sewing process. The SME of cloth masks has working hours of 7 hours per day from 8 AM to 4 PM (local time) with an hour rest time from 12 to 1 PM (local time). The cloth mask production continues from Sunday until Saturday because the demand continues to increase.

Based on direct observation, the ambient temperature and illumination level are two factors to consider when defining the physical work environment on the SME of cloth mask manufacture. According to ergonomic standards and government regulations, these two factors must be carefully considered. From the data obtained, the temperature level of the cloth mask working conditions is 30.34 degree Celsius on average. Meanwhile, The Ministerial Regulation Number 5 of 2018 [6] stated that a comfortable temperature for workers to get optimum work productivity is in the range of 23 to 26 degree Celsius. The main cause of the high temperature in this room is due to the roof of the room is made of tin. Tin roofing has an excellent heat conductivity property. This makes the tin roof able to absorb and conduct the heat from the sun well into the interior room. The condition of the production room is made worse by the layout of goods that are piled up and untidy, and the lack of air ventilation and windows, causing the room temperature to be high.

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The SME in the cloth mask industry relies only on natural lighting from the sunlight through ventilation. When the weather is cloudy, the illumination intensity drops dramatically, causing the cloth mask manufacturing process to be disturbed. The maximum lighting level of 141 lux is located near a vent or light source, while the minimum one is 43 lux as it is located far from the light source and the average is 81.39 lux. Therefore, the lighting is not evenly distributed. The standard lighting intensity for the type of work involving small items that require a high level of accuracy (for example sewing brightly colored textiles) is 200 lux [6].

A stuffy and hot work environment and low lighting intensity might lead to fatal consequences for workers, such as causing the risk of work accidents and increasing stress for workers as the work environment is not up to standard [7]. This condition is suspected as the cause of low worker productivity in the cloth mask industry. This can be seen from the trend of not achieving the production target of cloth masks, which on average is only able to produce 30 masks out of 50 targeted masks. In the cloth mask sector, worker productivity plays a crucial role in determining wages. Therefore, this study aims to analyze the effect of environmental ergonomic and individual characteristic factors on worker productivity in small-medium enterprises. Furthermore, no previous research in Indonesia has developed mathematical equations for labor productivity based on work environment and individual characteristics. It became the motivation of the current study in addressing the critical issues faced by SMEs, specifically in the cloth mask manufacturing industry, related to environmental ergonomics and individual characteristics. The study significantly contributes to the understanding of the challenges faced by SMEs, particularly in the cloth mask manufacturing industry, and provides a basis for potential improvements in compliance, safety, productivity, and future research initiatives.

2. Materials and methods

2.1 Participants

This study is a cross-sectional study with a population of eight workers who routinely carried out cloth masks producing work. The participants must meet inclusion requirements, namely willing to become research respondents, have a minimum of 1-year work experience, be permanent workers at the SEM of cloth masks, and be in healthy condition. The respondents will be excluded from the study if they do not meet the requirements. The Human Ethics Committee of Universitas Ahmad Dahlan approved the study before it began. Before participating in the study, workers were required to read and sign a consent form.

2.2 Activity description

The workers were instructed to complete the cloth mask manufacturing work in a sitting position in the production workstation during working hours of 7 hours per day with an hour of rest time. The workers should finish a complete cloth mask production process consisting of a patterning process, cutting process, assembly process, and sewing process.

2.3 Data acquisition

In the current investigation, the factors analyzed are adjusted to the conditions of cloth mask workers. Firstly, the measurement of individual characteristic factors was conducted by direct interview. The data includes recent worker age, height, weight, and working period. Gender was not included as the analyzed factor because all workers are female. It is in line with what was done in a previous study where all respondents were male [8]. Second, environmental parameters are measured. Two work environment parameters were measured as light intensity and temperature of the cloth masks production workstation. Digital Lux Meter AS803 (Smart Sensor, China) is used to measure the lighting intensity and temperature parameters. Lighting intensity and temperature measurements were taken 5 times at 5 different points around the workers, which included 1 point near the worker's ear and 4 points around the workers within a radius of 1 m. Observations were carried out every hour starting 9 AM to 4 PM (local time).

2.4 Hypotheses

Based on the literature review, this study predicted a significant positive correlation between the predictor variables against the production output, either simultaneously or partially, on the cloth mask manufacturing process.

2.5 Statistical analyses

Descriptive statistics were applied for all dependent variables. Furthermore, multiple regression analyses were applied to assess predictor sets affecting the production output since the relationship between both variables met the test's assumptions. These include linear relationships, no multicollinearity, independence, homoscedasticity, and multivariate normality. The predictor variables were: (1) lighting intensity (in lux), (2) temperature (in degree celsius), (3) age (in years), (4) height (in centimeters), (5) weight (in kilograms), and (6) working period (in years). This predictor variable becomes the independent variable, while the dependent variable is the production output. All analyses were carried out using the IBM SPSS 26 software (IBM, New York, US) using a significance threshold of $p < 0.05$.

3. Results

3.1 Participants

The participant's demographic characteristics and descriptive statistics are shown in Table 1.

Table 1 The demographic characteristics and descriptive statistics of respondents (n = 8)

Characteristic	**N (%)**	***Mean* ± SD**
Sex		
• Male	0 (0%)	
• Female	8 (100%)	
Age (years)		29.00 ± 3.94
Height (cm)		156.75 ± 5.38
Weight (Kg)		56.88 ± 12.27
BMI (Kg/m^2)		23.01 ± 3.89
Year of work (years)		8.88 ± 2.85

All respondents (100%) were female ranging in age from 24 to 36 years (an average of 29.00 ± 3.94). The most prevalent responses (3 respondents; 38%) had a normal BMI. Respondents reported work experience ranging from 5 to 15 years (an average of 8.88 ± 2.85 years).

3.2 Lighting intensity

Among 56 measured data investigated, all data (100%) was below the standard lighting intensity, as shown in Figure 1. The mean lighting intensity was 81.39 ± 7.09 lux (63.86 lux minimum and 97.57 lux maximum).

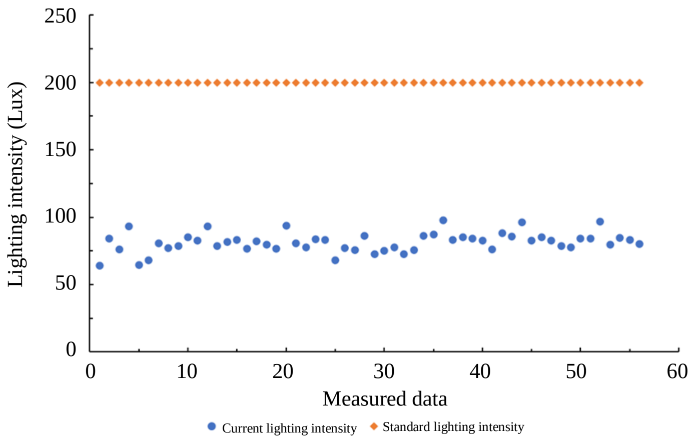

Figure 1 the lighting intensity of the SME of cloth mask manufacture

3.3 Temperature

Figure 2 showed 56 measured temperature data investigated. All data (100%) was outside the recommended temperature standard limits. The mean temperature was 30.34 ± 0.26-degree celsius (29.70 degrees celsius minimum and 30.93 degrees celsius maximum).

3.4 Production output

The production output of cloth masks with lighting and temperature conditions that do not meet the standards is always below the output target set by the company. The company's output target is 50 pcs of cloth masks per day while the achievement of cloth masks that can be produced by workers is an average of 30 pcs of cloth masks. The distribution of production output achievements during observation can be seen in Figure 3.

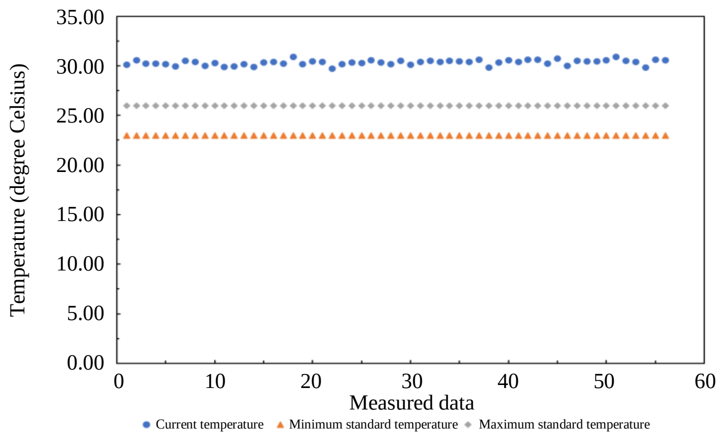

Figure 2 the temperature of the SME of cloth mask manufacture

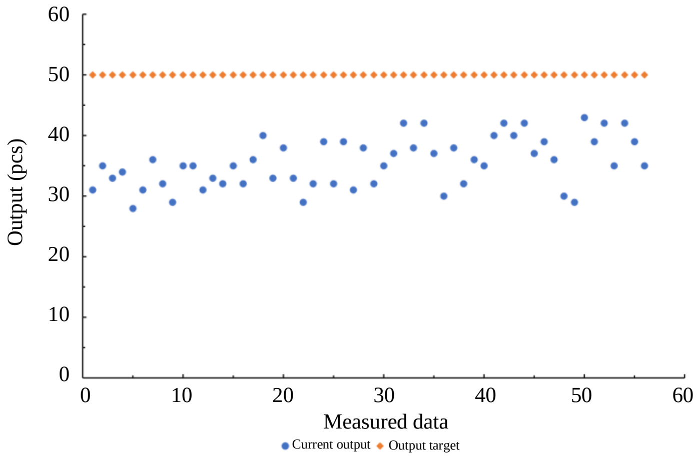

Figure 3 the production output of the workers

3.5 Predictors of production output

A multiple regression analysis was done to determine the relationship between the predictors and the dependent variable of cloth mask production output. The results revealed a simultaneously significant correlation ($p < 0.05$) between the predictors and the cloth mask manufacturing output, with a 41 percent variance during the combination of 6 variables that impact cloth mask production output. Table 2 showed a partially significant relationship ($p < 0.05$) between illumination intensity, temperature, and age to cloth mask manufacturing output. It was discovered that for every one-lux increase in light intensity, the output of cloth masks increased by 0.21 pcs. A positive correlation was also seen in temperature, with each one-degree Celsius rise increasing cloth mask fabrication productivity by 8.81 pcs. The production output will increase until it reaches the standard safe threshold limit both for illumination intensity and temperature [6]. The individual component also indicated that for every one-year rise in age, the output of cloth masks increased by 0.53 pcs.

Table 2 Multiple regression analysis models predicting production output through cloth mask manufacture

Variable	Regression Coefficients	T	Sig.
Constant	-241.38	-3.37	
Lighting intensity	0.21	2.19	0.03*
Temperature	8.81	4.04	<0.0001*
Age	0.53	2.11	0.04*
Height	-0.11	-0.90	0.37
Weight	-0.0001	0.00	1.00
Work period	-0.61	-1.61	0.11
F-value	5.72		<0.0001**
R square	0.41		

* Denoted a significant correlation partially. ** explained a significant difference concurrently.

4. Discussion

Small and medium-sized enterprises (SMEs) involve mental and physical requirements due to their nature. Material handling, sitting at workstations, incorrect postures, long-term sittings, locating small and large components, repetitive tasks, and so on are all risk factors that affect human mental and physical health. The relationship between the environment and humans is one of the most critical interactions in the work environment, alongside machine-human, system-human, and organization-human relationships, according to macro ergonomics [9, 10]. Making working environment factors such as noise, lighting, temperature stressors, ergonomics issues, and so on healthy and standard is critical for providing workers with health and enhancing their production output and performance.

The association between illumination level and worker production output in cloth mask production was investigated in this study. The results showed that the overall quantity of illumination intensity, including natural and artificial lighting, was less than national or international requirements (< 200 lux) during cloth mask fabrication operations. The findings of multiple regression analysis revealed a partially positive significant association between the impact of illumination and worker output. As a result, it is obvious that lighting amount has an impact on the worker production output of cloth mask fabrication and that changes in lighting amount have an effect on worker production output. In accordance with this, most studies have indicated increased productivity as a result of improved lighting conditions. A previous study found that light intensity had a strong correlation with textile workers' productivity in the weaving area ($p = 0.000$, $r = 0.629$) [11]. According to another study, the majority of office building workers were dissatisfied with the lighting quality in their workplace, and some respondents indicated that it had a substantial impact on their job efficiency, productivity, and well-being [12]. Although many studies stated that there was a significant relationship between lighting levels and increased worker productivity, this did not necessarily imply that the higher the lighting level, the higher the worker productivity. Previous research has found that too much light and dazzling in the workplace reduces worker performance and productivity. According to this study, the necessity for illumination would vary depending on the work the individual did and his age [13].

Multiple regression analysis revealed a partially significant association between the individual component of age and productivity. This result implied that productivity increased with age. An earlier study found that senior workers were more productive than younger workers [14]. This could be explained because worker productivity played an important role in determining workers' salaries in various SME sectors, including the cloth mask manufacturing industry. All workers in the cloth mask manufacturing industry were in the productive age range, which was 24-30 years. A study revealed that prime-age workers (30 – 49 years) earned higher salaries than the group of older workers (50 years and over) and young workers (16 – 29 years) [15]. However, previous studies have also reported that increasing age actually has an effect on reducing worker productivity. It stated that aging would decrease productivity in jobs that require problem thinking, learning, and speed, but in those that need experience and linguistic ability, productivity would decline marginally or not at all [16]. This adverse influence on aging may be explained by the introduction and rapid development of new technology [17]. Older workers have difficulty adapting to new modes of working, which reduces their output. Furthermore, they suffer from an aging knowledge reservoir, skill obsolescence [18], deteriorating cognitive ability (particularly by the age of 50, as previously studied [19]), and qualification depreciation [20].

The correlation between temperature factor and worker production output in cloth mask production was also investigated in this research. The results showed that the working environment temperature was outside the limits of national or international requirements (the range of 23 to 26 degree Celsius) during cloth mask fabrication operations. The findings of multiple regression analysis revealed a partially positive significant association between the impact of working environment temperature and worker output. These results were reinforced by research in China that reported findings that there has been an economic loss as a result of a decline in manufacturing labor productivity caused by the temperature of the surrounding work environment that did not meet the standards [21]. Humans are homeotherms, which means individuals try to keep an ideal internal (core) temperature (around 37 degrees Celsius). When the human body is put under heat stress, the thermoregulatory system will react by altering its condition in a manner that is compatible with keeping the core temperature to remain within the normal range. This body's reaction has implications for a person's health, pleasure, and productivity [22]. When the human body gets overheated or underheated, it responds in a manner compliant with keeping a generally constant core body temperature. The anterior hypothalamus controls the two primary systems for shedding heat when the body is subjected to thermal stress. The first response is vasodilation, in which the peripheral blood vessels widen and move blood, and therefore heat, to the body's surface, where it may be released to the external environment. Sweating and significant thermal loss by evaporation may happen when the core temperature continues to climb. Core temperature rises if these heat loss processes are insufficient to maintain thermal balance [23]. When the body is subjected to cold, the posterior hypothalamus controls the two primary systems for maintaining core temperature. The earliest response to cold is vasoconstriction, in which peripheral blood vessels contract and thereby restrict blood circulation to the body surface, reducing thermal loss. Shivering generates more heat if the body's core temperature continues to decline. If the body temperature continues to plummet, mental disorientation ensues, followed by unconsciousness and, finally, death due to ventricular "brillation" (heart failure) [23].

When heat is applied to the human body, the impacts on performance are determined by a variety of factors. Psychological aspects such as arousal and motivation, along with other elements that lead to individual variances, such as the level of acclimatization of the human to the environment, will be essential considerations. The mental performance will suffer as heat stress grows [24]. Performance degradation occurs not just at high ambient temperatures. Performance on vigilance tests may be impaired in mildly warm surroundings with soporific effects. Increased environmental stress can boost performance. Furthermore, as the pace of chemical processes in the body increases with temperature, so may a person's speed at both physical and mental activities [25]. The influences of cold on individual performance are frequently overlooked, despite the fact that they can be considerable. While cold has limited influence on mental function, it can raise arousal and boost performance in visual activities. Furthermore, in more extreme circumstances, cold can operate as a secondary task, increasing exertion and perhaps diminishing mental performance, and mental disorientation can ensue if the body core temperature decreases dramatically. The physiological responses to cold can be related to the impact of cold on manual performance. The major symptoms include a decrease in speed due to joint stiffness and sluggish muscle responsiveness, numbness, and a loss of strength. These responses impair manual dexterity and hence performance in many manual activities [26].

It is difficult to generate precise predictions regarding the influence of surroundings on performance at a given and real-world task. This is due to the fact that there are numerous factors that relate to certain jobs in various circumstances, and they cannot all be accounted for. Task analysis, on the other hand, may be used to determine task components. Research of comparable tasks or components of similar tasks can frequently give general information. A basic example is breaking down a work (or task) into mental and physical elements. Previous research may be used to deduce the influences of a particular setting on similar mental activities, and the same can be said for the physical task elements. Often, a meaningful general prediction may then be formed [27]. In the current study, a combination of all predictors predicted 41 percent of the variance in cloth mask fabrication output concurrently, whereas 59 percent was caused by other factors. Other predictors that may have an influence on workers' production output include poor office or workstation layout [28] and lack of work motivation [29, 30].

5. Conclusions

Lighting intensity, working environment temperature, and age had a significant effect partially on cloth mask production output. The results also revealed a simultaneous significant correlation between the predictors and the cloth mask manufacturing output, with a 41 percent variance during the combination of 6 variables that impact cloth mask production output. It can be concluded that 41 percent of productivity variation could be explained by all variables while 59 percent by other causes.

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