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THE CORRELATION BETWEEN LENGTH OF SERVICE, BODY MASS INDEX, AND FATIGUE WITH HANDGRIP STRENGTH AMONG RSS PRODUCTION WORKERS

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ABSTRACT

Handgrip strength is an important indicator of musculoskeletal health and overall body muscle strength. The production process of Ribbed Smoke Sheet (RSS) rubber at PTPN I Regional 3 Sukamangli is still dominated by manual handling. Objective: This study aimed to determine the correlation between working period, Body Mass Index (BMI), and fatigue with handgrip strength among RSS production workers. The research method was a quantitative analytic survey with a cross-sectional approach. The sampling technique used a saturated sample (census) with a total of 46 RSS production workers. Data analysis used the Spearman Rho correlation test. The univariate results showed that the respondents were dominated by males (91.3%), with an average age of 40 years, and predominantly had a junior high school education (47.8%). Most workers had a long working period >5 years (89.1%), a normal BMI (54.3%), moderate fatigue levels (34.8%), and handgrip strength in the good and moderate categories (28.3% each). The bivariate analysis indicated a significant correlation between working period and handgrip strength (p=0.004; r=-0.420), a significant correlation between BMI and handgrip strength (p=0.037; r=-0.308), and a very strong significant correlation between fatigue and handgrip strength (p=0.000; r=-0.745). Based on the findings, all three variables were significantly correlated with handgrip strength, with fatigue showing the most optimal negative correlation toward handgrip strength reduction.

Keywords: body mass index, fatigue, handgrip strength, working period

INTRODUCTION

Handgrip strength is an important indicator of a person's musculoskeletal and general health. Handgrip strength measurements are widely used in research and clinical practice because they are simple, reliable, and capable of reflecting overall muscle strength (Heidy, Tena Djuartina, 2019). Various factors are known to influence handgrip strength, including age, gender, body mass index (BMI), length of service, and work fatigue (Putrawan & Kuswardhani, 2021). Weaknesses in handgrip strength are still found in various populations. In South Korea, the prevalence of weak handgrip strength reached 6.3% in adults and increased to 17.5% in the age group 65 years and older (Lee, 2024). Research in Thailand also reported a high prevalence of weak handgrip strength in the elderly (Manjavong et al., 2022). This situation indicates that handgrip strength is an issue that requires attention because it is related to physical ability and work productivity. Long working hours can increase exposure to physical workloads, potentially reducing motor function and muscle strength (Syah et al., 2024). Furthermore, an abnormal BMI can affect the quality of muscle contractions due to an imbalance between fat and muscle (Suharni et al., 2025). Another contributing factor is work fatigue, which can lead to a decrease in the muscle's ability to generate maximum force(Kapan et al., 2025). Ribbed Smoke Sheet (RSS) production workers at PTPN I Regional 3 Sukamangli perform various manual handling activities such as lifting, moving, pushing, and manually carrying loads. These activities are performed over relatively long periods of time and can potentially increase the risk of fatigue and decreased muscle strength. Preliminary studies indicate that some workers have poor to moderate handgrip strength. Based on these

conditions, this study aims to analyze the relationship between work period, body mass index, and fatigue with handgrip strength in RSS production workers at PTPN I Regional 3 Sukamangli.

METHODS

This study employed a quantitative cross-sectional design and was conducted at the Ribbed Smoke Sheet (RSS) rubber production facility of PTPN I Regional 3 Sukamangli from December 2025 to April 2026. The study population consisted of all active. Using a total sampling technique, 46 workers were included in the study.

Data were collected using a Camry digital handgrip dynamometer to measure handgrip strength, a digital scale and microtoise to assess Body Mass Index (BMI), and the 30-item Industrial Fatigue Research Committee (IFRC) questionnaire to evaluate occupational fatigue. Length of service data were obtained from company records and verified through structured interviews. Data were analyzed using IBM SPSS Statistics version 25. Univariate analysis was performed to describe respondent characteristics and study variables, while Spearman's rho correlation test, a significance level of $\alpha = 0.05$.

RESULT AND DISCUSSION

Tabel 1
Univariate Analysis

Variabel	Frekuensi	(%)
(1)	(2)	(3)
Sex		
Male	42	91,3
Female	4	8,7
Education Level		
SD	8	17,4
SMP	22	47,8
SMA	16	34,8
Length of Service		
≤5 Year	5	10,9
>5 Year	41	89,1
IMT		
Underweight	7	15,2
Normal	25	54,3
Overweight	6	13
Obesity I	6	13
Obesity II	2	4,3
Fatigue		
Low	11	23,9
Medium	16	34,8
High	10	21,7
Very High	9	19,6
Handgrip Strengt		
Very Well	7	15,2
Good	13	28,3
Currently	9	19,6
Not Enough	13	28,3
Verry Little	4	8,7

Based on Table 1, the majority of respondents were male (91.3%). Regarding educational attainment, nearly half of the respondents had completed junior high school (47.8%), followed by senior high school (34.8%) and elementary school (17.4%). Most workers had a length of service of more than five years (89.1%). In terms of nutritional status, more than half of the respondents had a normal Body Mass Index (BMI) (54.3%), while 15.2% were underweight, 13.0% were overweight, 13.0% were classified as obesity class I, and 4.3% as obesity class II. Regarding occupational fatigue, moderate fatigue was the most common category (34.8%), followed by low fatigue (23.9%), high fatigue (21.7%), and very high fatigue (19.6%). Concerning handgrip strength, the largest proportions of workers were classified as having good and poor handgrip strength (28.3% each), followed by moderate handgrip strength (19.6%), excellent handgrip strength (15.2%), and very poor handgrip strength (8.7%).

Based on the research results, the gender characteristics are predominantly male. The majority of respondents were male, comprising 91.3% of the total respondents. Men have greater handgrip strength than women because they have more muscle tissue and testosterone, which contributes to muscle development (Wichelhaus et al., 2024). Furthermore, women also have approximately 60% greater muscle strength than men, making them more susceptible to fatigue during strenuous physical activity (Sitorus, 2022). The research results indicate that the majority of respondents were male, contributing to the achievement of higher handgrip strength. Therefore, gender is a factor influencing the physical capacity of workers, particularly in physical activities requiring muscle strength.

Based on the research results,have an average age of 40 years, with the lowest age being 24 and the highest being 54. Meanwhile, the highest age group was 41 years old. Muscle strength is at its peak in early adulthood, ranging from 25 to 35 years old, and then begins to decline gradually with age. This decline is caused by a reduction in muscle mass and neuromuscular capacity (Wichelhaus et al., 2018). The predominance of adults allows respondents to have fairly good grip strength. Therefore, in this study, the age of the respondents in this study supports maximum physical ability for activities, although the level of handgrip strength can also be influenced by the severity of the work.

Based on the research results, the education level is mostly secondary, accounting for 47.8% of the total respondents. Workers with higher education levels tend to have knowledge about safer work methods, tool usage, and adjusting rest periods, which can affect handgrip strength. This is in line with previous research, which states that education level influences an individual's ability to absorb information. A person's insight can be influenced by the educational path they have taken. The higher the education level, the broader the knowledge (Ariga, 2022), including matters related to handgrip strength and occupational safety. Although it does not directly impact physical fitness, education level can influence work methods.

Based on the research results, have long tenure, accounting for 89.1% of the total 46 workers. During the Ribbed Smoke Sheet manufacturing process, which largely still involves manual handling, workers engage in various physical activities such as lifting, moving, and processing raw materials repeatedly. These activities require continuous use of hand muscles, particularly when pulling, gripping, and pressing. Repeated and prolonged exposure to work can lead to the accumulation of muscle fatigue. Length of service indicates the length of time a person is exposed

to physical activity. The longer the working period, the higher the risk of fatigue due to accumulated workload (Suma'mur, 2014). Repeated muscle activity can also lead to the accumulation of lactic acid, which ultimately reduces muscle strength (Tarwaka et al., 2014).

Research shows that the majority have a normal Body Mass Index, namely 54.3% of a total of 46 workers. Work in the Ribbed Smoke Sheet production sector requires considerable physical activity. This activity requires sufficient energy and good physical condition to perform optimally. Body Mass Index (BMI) is a measurement used to evaluate an individual's nutritional status by comparing weight and height. Optimal nutritional status indicates a balance between calorie intake and body requirements (Kemenkes RI, 2025). BMI can indicate a person's physical readiness to carry out daily activities, especially those requiring energy. In the Ribbed Smoke Sheet production work environment, optimal physical condition supports workers in carrying out manual tasks that require energy (Suharni et al., 2025). Therefore, in this study, BMI reflects the physical response that supports the implementation of work tasks in the Ribbed Smoke Sheet production area.

Based on the research results, the majority experienced moderate fatigue, amounting to 34.8% of the total 46 workers. In the Ribbed Smoke Sheet manufacturing process, workers engage in heavy and repetitive activities. Fatigue is a condition in which the ability to work decreases due to continuous activity (Syah et al., 2024). Manual handling activities, such as repeatedly moving materials, can cause fatigue. The amount of work involved in Ribbed Smoke Sheet production is not fixed but is influenced by the quantity of raw materials obtained from the plantation. When the raw materials (latex) arrive, workers, particularly in the processing area, must process them immediately to prevent premature coagulation. This situation increases the workload during high harvests. A rotating work system with days off ensures that the Ribbed Smoke Sheet production process continues non-stop.

Based on research results, the majority have good and moderate hand grip strength, representing 28.3% of the 46 workers, respectively. Hand muscle use is predominant in Ribbed Smoke Sheet production. This activity is a crucial element and is performed continuously throughout the work period. All production, from processing, milling, smoking, and sorting, is still carried out manually. Hand grip strength is one indicator that can be used to assess a person's muscle strength, particularly in the arms and hands. Furthermore, hand grip strength also reflects a person's physical ability to carry out daily activities (Wichelhaus et al., 2018). In the Ribbed Smoke Sheet production environment, repeated hand use in various activities indicates that hand grip strength is a crucial factor in supporting smooth work flow. Furthermore, differences in raw material quantities from day to day indicate changes in work activity levels. When raw materials are produced in large quantities, the frequency of hand muscle use also increases.

Table 2
Distribution Responden of Age

N	Mean	Median	Mode	Minimun	Maximum
46	40,11	42,50	41	24	54

The results of the study on the age distribution that the average age (mean) of workers was 40 years old, indicating that this group was dominated by adults. The results also showed a median age of

42.5 years, and the mode or the highest age frequency was 41 years old. Meanwhile, the minimum (smallest) age of workers was 24 years old and the oldest age was 54 years old.

Bivariate Analysis

Tabel 3
Bivariate Analysis

Variable	Spearman's rho (r)	p-value
Length of Service	-0.420	0.004
BMI	-0.308	0.037
Fatigue	-0.745	<0.001

Table 3 shows that 31.7% of workers with a length of service exceeding five years were classified as having poor handgrip strength. Spearman's rho analysis revealed a statistically significant negative correlation between length of service and handgrip strength ($r = -0.420$, $p = 0.004$). The correlation coefficient indicates a moderate negative relationship, suggesting that workers with longer lengths of service tended to exhibit lower handgrip strength.

Regarding Body Mass Index (BMI), 56.5% of workers with a normal BMI demonstrated good handgrip strength. Spearman's rho analysis identified a statistically significant negative correlation between BMI and handgrip strength ($r = -0.308$, $p = 0.037$). The correlation coefficient indicates a weak negative relationship, suggesting that an increase in BMI was associated with a decrease in handgrip strength.In terms of fatigue, 58.3% of workers with low fatigue levels exhibited excellent handgrip strength. Spearman's rho analysis demonstrated a statistically significant negative correlation between fatigue and handgrip strength ($r = -0.745$, $p < 0.001$). The correlation coefficient indicates a strong negative relationship, suggesting that higher levels of fatigue were associated with lower handgrip strength. Among the variables examined, fatigue exhibited the strongest correlation with handgrip strength

Based on research conducted on 46 respondents working, it was found that the majority of new workers had handgrip strength classified as very good (60%) and good (40%). No workers fell into the moderate, poor, or very poor categories. On the other hand, among workers with longer tenure, handgrip strength varied more widely, with 9.8% falling into the very good category, 26.8% into the good category, 22.0% into the moderate category, 31.7% into the poor category, and 9.8% into the very poor category. The observed pattern indicates that as respondents' length of service increases, the decline in handgrip strength becomes more pronounced, marked by a predominance of grip strength among new workers, while among long-tenured workers, the poor category becomes the most prevalent. Bivariate analysis is a technique used to understand the relationship between the independent and dependent variables, namely tenure and handgrip strength. Using a significance level of 0.05 (α=0.05), the test results indicate a significance level (p-value) of less than 0.05, thus accepting the alternative hypothesis (Ha) and rejecting the null hypothesis (H0), indicating a significant relationship between tenure and handgrip strength. Conversely, if the significance value is greater than 0.05, Ha is rejected and H0 is accepted, indicating no significant relationship. The analysis using the Spearman's Rho correlation test showed a p-value of 0.004, indicating a significant relationship between tenure and handgrip strength. An r value of -0.420 indicates a moderate relationship, with a negative correlation indicating that longer tenure leads to a decline in workers' handgrip strength. This aligns with the theory proposed by Suma'mur that prolonged work, especially work requiring physical exertion, can lead to a decline in physical

abilities, including muscle strength (Suma'mur, 2014). Another theory also suggests that repetitive activities performed over a long period can lead to muscle fatigue and decreased muscle function due to overuse (Tarwaka et al., 2004). This condition is highly relevant to the characteristics of work in the Ribbed Smoke Sheet (RSS) production process, where all stages of the work are still dominated by manual handling. Workers perform various activities such as manually moving sheets, lifting wet sheets weighing 2.5–3.5 kg, arranging them on smoking racks, and lifting and moving balls weighing over 100 kg. These activities are repeated daily and last for quite long working hours, sometimes even exceeding 8 hours per day. Furthermore, the workload in the Ribbed Smoke Sheet production process is dynamic, depending on the amount of raw material (latex) received from the plantation. When raw materials are in large quantities, workers are required to work more intensively to prevent premature coagulation, thus increasing the frequency of physical activity. This condition causes workers with longer tenure to experience cumulative exposure to greater physical workloads than those with shorter tenure. The rotating work system also results in continuous production, limiting workers' physical recovery time. This can accelerate the onset of chronic fatigue, which leads to decreased muscle strength, particularly in the hand muscles, which are predominantly used for work. The results of this study also support previous research, which found that the longer a person's work experience, the greater the potential for decreased work ability due to chronic muscle fatigue (Morera et al., 2023). Therefore, in the context of manual, repetitive, and physically demanding RSS production work, length of service is a factor associated with decreased handgrip strength, with a tendency for decreased handgrip strength to increase with increasing length of service due to prolonged, sustained exposure to work.

The Relationship between Body Mass Index and Handgrip Strength it was found that workers with a normal Body Mass Index (BMI) mostly demonstrated good handgrip strength (56.5%) and excellent (30.4%), while a small proportion fell into the moderate category (13.0%). For workers with an underweight BMI, the distribution of handgrip strength consisted of 42.9% in the underweight category, 28.6% in the moderate category, and 28.6% in the very poor category. Meanwhile, workers with an overweight BMI mostly demonstrated handgrip strength in the underweight category (62.5%), followed by moderate (25%), and very poor (12.5%). In the group of workers classified as obese I BMI, handgrip strength was dominated by the underweight category (62.5%), with moderate (25%), and very poor (12.5%). Meanwhile, among workers with a BMI of Obesity II, all respondents (100%) were detected as having poor handgrip strength. The distribution above indicates that workers with a normal BMI tend to have better handgrip strength than those with an abnormal BMI. The Spearman correlation analysis showed a p-value of 0.037, indicating a significant relationship between BMI and handgrip strength. The correlation coefficient (r) of -0.308 indicates a weak relationship; the negative direction of the relationship indicates that the higher the BMI, the lower the worker's handgrip strength. A person's physical condition, including nutritional status, is one factor that can influence work ability. Good nutrition increases the body's strength for physical activity, including muscle use (Suma'mur, 2014). This reflects the nature of the work involved in the Ribbed Smoke Sheet manufacturing process, where each phase of the task still involves significant physical activity that requires significant energy. Workers engage in activities such as carrying wet rubber sheets, arranging them on smoking racks, and transporting large quantities of products, all of which require excellent physical condition. Furthermore, variations in workload, depending on the quantity of raw materials (latex), lead to increased energy requirements for workers, especially during high production volumes. Under these circumstances, workers with nutritional deficiencies, whether deficient or overweight, may

experience difficulties performing their duties, which can impact muscle performance, including handgrip strength. This phenomenon is also influenced by the physical workload characteristics of RSS production workers at PTPN I Regional 3 Sukamangli, which requires high mobility at work stations with dynamic break patterns. This mobility contributes to extensive physical activity in the workplace for an average of 8 hours per day, which is the standard formal working time for workers. These continuous high physical activity demands directly impact workers' daily energy expenditure, which in turn influences their weight stability and BMI. This relationship between physical intervention and physical activity aligns with previous research suggesting that physical activity plays a role in maintaining ideal body weight. High levels of physical activity are associated with preventing weight gain in adults, while low levels of physical activity can increase the prevalence of obesity (Fadila et al., 2024). Therefore, the dynamic physical activity associated with mobile work demands is an external factor influencing workers' BMI, which ultimately determines their muscle performance capacity and hand grip strength when handling rubber sheets. Beyond physical activity, the Body Mass Index (BMI) of the subjects in this study was also influenced by worker habits. This is primarily because most workers in RSS production are men who actively smoke at work. Theoretically, there is a relationship between smoking and weight change, as the nicotine content in cigarettes can reduce hunger and increase the body's overall metabolic rate. Previous research findings support this, stating that smoking is significantly associated with BMI, as compounds in cigarettes affect the central nervous system's regulation of energy intake (Sinurat, 2013). However, despite many workers having a smoking habit that should significantly reduce body weight, the descriptive data in this thesis shows that the majority of RSS production workers maintain an ideal or normal BMI. This phenomenon, where BMI remains within the normal range, can be explained by compensation resulting from the high physical activity and workload workers face during their approximately 8-hour workday. High energy sources from dynamic mobility activities can offset the metabolic effects of cigarette smoke exposure, thus maintaining workers' nutritional status and body weight. Stable BMI within this normal range ultimately contributes to efficient muscle contraction and supports workers' hand grip strength when handling RSS rubber materials. In the context of Ribbed Smoke Sheet production, which involves extensive manual, repetitive, and physically demanding work, Body Mass Index is related to hand grip strength. The relationship shows that grip strength tends to decrease with increasing BMI.

Correlation Between Fatigue and Handgrip Strength. It was found that workers with low fatigue levels had handgrip strength in the excellent category (58.3%), and good (41.7%). No workers fell into the moderate, poor, or very poor categories. Among workers with moderate fatigue levels, handgrip strength was categorized as moderate (45.5%) and good (54.5%). Conversely, among workers with high fatigue levels, the majority fell into the poor category (72.7%), and moderate (27.3%). Meanwhile, among workers with very high fatigue levels, handgrip strength was categorized as poor (41.7%), very poor (33.3%), good (16.7%), and moderate (8.3%). The distribution above shows a clear trend, where increasing levels of fatigue are associated with decreased handgrip strength. Analysis using the Spearman correlation test yielded a p-value of 0.000, indicating a significant relationship between fatigue and handgrip strength. A correlation coefficient (r) of -0.745 indicates a very strong relationship. The negative direction of the relationship indicates that the greater the worker's fatigue, the greater the decline in handgrip strength. This finding clearly demonstrates that fatigue has a significant impact on muscle performance, particularly in generating handgrip strength. Occupational fatigue is a condition in which the ability to work is reduced due to continuous activity. This occurs due to a mismatch

between workload and physical capacity, which ultimately reduces muscle performance(Suma'mur, 2014). Another theory also suggests that repetitive work activities without sufficient recovery time can accelerate muscle fatigue (Tarwaka et al., 2004). This condition aligns with the characteristics of work in the Ribbed Smoke Sheet (RSS) production process, where workers are required to perform continuous physical activity throughout the production cycle. Their duties not only involve lifting and moving materials but also require physical endurance to maintain consistent work from the processing stage to the final stage. Long working hours, sometimes exceeding eight hours a day, and a rotating work schedule with rest periods result in limited physical rest for workers. Coupled with a workload that varies depending on the amount of raw material, workers can experience sudden increases in work intensity, leading to fatigue. This aligns with previous research indicating that muscle fatigue can lead to a decrease in the ability to generate force. Low grip strength indicates muscle (Cotelez et al., 2016). Fatigue is a dominant factor affecting muscle performance, as fatigued muscles are unable to generate optimal force, including gripping. This is supported by other research, which states that work fatigue is strongly associated with decreased physical work capacity, especially in jobs involving manual activity and continuous muscle use (Morera et al., 2023). Thus, in the context of Ribbed Smoke Sheet production which has a high workload, long work duration, and continuous work system, fatigue is a dominant factor related to the decrease in hand grip strength, with a tendency for hand grip strength to decrease in line with the increasing level of fatigue. Fatigue control efforts can be achieved through engineering, with the provision of ergonomic work equipment crucial to reducing the high levels of fatigue experienced by RSS production workers. Given the heavy weight of rubber that must be moved manually, the risk of physical injury is high, as lifting loads exceeding 20 kg can potentially cause injuries, including lower back pain and musculoskeletal problems in operators (Mutia & Achiraeniwati, 2023). The use of trolleys necessary for transporting RSS from the smoking area to the sorting room is further strengthened by empirical evidence demonstrating the success of using similar transportation equipment in the rubber industry. Redesigning transportation equipment has been shown to reduce worker physical complaints, increase productivity by up to 116%, and reduce the frequency of work errors (human error) (Suryaningrat et al., 2020). Although occupational safety regulations do not specify a specific standard for the height of lifting equipment, the Ergonomic Factor Guidelines state that product design should accommodate the dimensions of the majority of the population; at least 90%-95% of users should be able to use the product safely (Kemnaker, 2018). Therefore, the tool proposed in this study is specifically a Two-Tier Manual Push Trolley with a Basket (Platform Hand Truck / Basket Trolley). The functional dimensions of this trolley were designed based on the anthropometric measurements of the Standing Elbow Height (SELH) of local workers, with a constant handle height between 100 cm and 110 cm (ISO-11228-2, 2007). The handle height, aligned with the standing elbow span of a relaxed Indonesian person, aims to ensure the worker's hand forms an ergonomic angle when shaking hands, thus avoiding excessive bending or unnatural shoulder shrugs when pushing rubber loads. In addition, the handle width is adjusted to the worker's Shoulder Width (LB), which is between 45 cm and 52 cm to provide stability in controlling direction, and is equipped with a paired wheel system consisting of four 5-6 inch hard rubber (polyurethane) wheels that use a combination of swivel wheels at the rear to facilitate turning and fixed wheels on the part (Suryaningrat et al., 2020). The design of the trolley sectional body is designed in two levels with a 30-40 cm high dividing wall to prevent the stack of RSS rubber sheets from slipping when moved on the factory floor, while also facilitating rubber arrangement without the need for too deep bending movements (awkward postures) that can cause lower back pain. The determination of the push point and the mechanical

specifications of this wheel are fully in accordance with the body mechanics limits set out in the ISO 11228-2 Standard, to ensure that the initial force and sustained force when pushing the trolley do not exceed the safe limits that can cause compression injuries to the lower spine (lumbar spine L4-L5/L5-S1) of workers (ISO-11228-2, 2007). With the technical specifications of this aid, physical fatigue due to excessive muscle exertion can be greatly reduced, so that the stability of the grip strength of workers' hands in RSS production is maintained optimally.

CONCLUSIONS

This study scientifically proves that working period, Body Mass Index (BMI), and occupational fatigue have a significant relationship with the handgrip strength Among the three factors, subjective occupational fatigue stands out as the primary determinant factor, exhibiting a very strong negative correlation (r = -0.745) due to neuromuscular functional capacity depletion and metabolic lactic acid loading within workers' muscle tissues. As a preventive measure to anticipate physical capacity degradation among workers and sustain factory operational productivity, the company management is highly recommended to introduce begin evaluating the introduction of mechanical lifting aids to minimize direct manual physical loading on workers.

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