ORIGINAL ARTICLE

Wood Dust Exposure Toward FVC in Wood Furniture Craftsmen

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ABSTRACT

Introduction: This study examines the effects of wood dust exposure, serum IL-13 levels, and blood leukocyte counts on pulmonary function, particularly forced vital capacity (FVC) among furniture craftsmen in Ngawi Regency, considering IL-13's key role in asthma-related airway inflammation and remodeling. **Materials and Methods:** This cross-sectional study involved a total population of 35 respondents who met the inclusion criteria. The research utilized Structural Equation Modeling (SEM) via Smart PLS version 3.0 to explore the relationships between independent and dependent variables. Measurement of respirable dust concentration was conducted using High Volume Dust Sampler, IL-13 levels analyzed using ELISA from blood serum, and leukocyte counts measured in laboratory tests. Pulmonary function was evaluated with a spirometer, and symptoms questionnaire. **Results:** Results indicated that most participants were over 35 years old, with a work duration of more than five years. The highest wood dust concentration was found in the assembly area. All workers had abnormal IL-13 levels, which were indicated to be due to chronic exposure, while the majority of leukocyte levels were normal. A total of 11 workers demonstrated abnormal pulmonary function, categorized as mild to moderate restriction or obstruction. SEM analysis showed that dust exposure was significantly associated with FVC ($p = 0.001$), whereas IL-13 and leukocyte levels were not associated with FVC. **Conclusion:** Although all respondents had abnormal IL-13 levels, no significant association was found with FVC impairment, indicating other contributing factors. Regular pulmonary function examinations are necessary to prevent FVC impairment from wood dust exposure.
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Keywords: Wood Dust, Interleukin-13, Blood Leukocytes, FVC, Wood Furniture Craftmen

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INTRODUCTION

Inhaled wood dust exposure among workers, particularly in home-based furniture industries, can be a major cause of respiratory disorders because its fine particles (0.5–4 µm) can reach the alveoli and trigger chronic inflammatory reactions. (SNI 7325, 2009) [1, 2]. Environmental experts and public health professionals identify respirable dust with a size of less than 2.5 microns as a trigger for respiratory infections [3]. Certain irritant agents, such as dust, can lead to occupational diseases with both acute and chronic effects. Dust that settles in pulmonary tissue has the potential to cause pulmonary diseases. The incidence of work-related pulmonary disease is influenced by various factors, including the type of dust, concentration, duration of exposure, and dust particle size in the respiratory zone [4]. The common symptoms of work-related lung disease include cough, shortness of breath, chest pain, and abnormal breathing patterns. These symptoms may appear in individuals exposed to respirable dust, and it is essential to consult a doctor for accurate diagnosis[5]. According to data from the International Labour Organization (ILO) in 2018, there were 2.5 million cases of death associated with occupational diseases. Approximately 21% of those deaths were caused by disorders of the respiratory system [6–8]. Research from the Surveillance of Work-Related and Occupational Respiratory Disease (SWORD) conducted in the UK identified 3,300 new cases of work-related pulmonary diseases. In Indonesia, particularly among workers in home-based wood industries, there is a high likelihood of exposure to fine wood dust due to the lack of optimal use and awareness of proper personal protective equipment (PPE). Workers who are exposed to fine wood dust almost every day for prolonged periods are at high risk of developing pulmonary diseases and experiencing a decline in lung function [9]. In Ngawi Regency, wood furniture craftsmen are at high risk for pulmonary disease due to frequent exposure to wood dust during the production process.

Various studies have identified wood dust as a risk factor for occupational asthma. This review has highlighted that occupational exposure to wood dust in various wood industries remains a concern for both high- and low- and middle-income countries due to its association with respiratory symptoms, asthma, and decline in lung function [10]. One of the physiological test results that plays an important role in monitoring the progression of various respiratory disorders is the Forced Vital Capacity (FVC). FVC is defined as the vital capacity measured through forced expiration after maximum inspiration, and it can assist in diagnosing and identifying the causes of pulmonary diseases [11].

The Occupational Safety and Health Administration (OSHA) categorizes wood dust as a carcinogen in humans, based on research conducted in 1995 by the International Agency for Research on Cancer (IARC), which concluded that there is evidence of wood dust being carcinogenic to humans (A1) [12, 13]. This classification is based on studies indicating an increased risk of nasal cavity and paranasal sinus cancers associated with wood dust exposure. Wood dust can be generated through industrial mechanical processes such as cutting, sawing, and sanding. When airborne, wood dust can be inhaled and may settle in the respiratory organs, depending on particle diameter and shape, through mechanisms such as sedimentation, inertia, and diffusion. The threshold value indicates the level of a substance that elicits physiological reactions in humans. Several factors contribute to the emergence of airway disorders due to dust exposure, including particle size, shape, concentration, duration of exposure, and smoking habits. Individual factors such as smoking, work duration, and improper use of personal protective equipment (PPE) further exacerbate lung function impairment caused by wood dust exposure [1, 14, 15].

Additionally, individual factors encompass the mechanisms of pulmonary defense, as well as the anatomy and physiology of the airways. The selection of interleukin-13 (IL-13) as a focus in this study is justified by its role as a principal mediator in the inflammatory processes associated with asthma and pulmonary fibrosis [16]. Elevated levels of IL-13 are often correlated with prolonged exposure to dust, which can lead to damage in pulmonary tissue. Various studies indicate that IL-13 mediates the pathogenesis of asthma, airway hyperresponsiveness, mucus production, airway remodeling, and subepithelial fibrosis [17]. The synthesis of IL-13 by T-helper (Th) lymphocyte cells can stimulate collagen production independently of transforming growth factor-beta (TGF-β), leading to the proliferation and contraction of smooth muscle cells, which contributes to fibrosis [18]. Excessive IL-13 expression in the lungs has been shown to induce subepithelial airway fibrosis in mice even in the absence of other inflammatory stimuli [19]. Furthermore, IL-13 levels are elevated in cases of pulmonary fibrosis. However, studies examining the relationship between wood dust exposure, IL-13, and decreased lung function (FVC), particularly among home-based wood furniture industry workers in Indonesia, remain limited.

When assessing exposure in humans, it is crucial to consider factors such as the source of exposure, type of factory, duration of exposure, and exposure from additional sources [20]. Patterns of daily activities and potential confounding factors, including age, sex, smoking, allergen exposure, and the use of personal protective equipment (PPE) must also be taken into account [21].

One of the regions in Indonesia with the highest number of wood furniture craftsmen is Ngawi Regency, which records 133 home-based wood industries across 19 districts [22]. With the large number of home-based wood furniture industries, workers are essentially at high risk of inhaling respirable dust continuously. However, studies on respiratory conditions and lung function among workers in this area have not yet been conducted. An initial survey conducted in one home industry revealed that among approximately 160 workers, five frequently experienced cough and shortness of breath. These respiratory disorders are feared to be symptoms of pulmonary function impairment and pulmonary fibrosis. Based on the background and the outlined research problem, this study aims to analyze the effects of wood dust exposure, serum interleukin-13 (IL-13) levels, and blood leukocyte counts on pulmonary function, specifically forced vital capacity (FVC), among wood furniture craftsmen in Ngawi Regency. The results of this study are expected to provide insights into the health risks associated with wood dust exposure and serve as a basis for utilizing IL-13 as a biomarker of pulmonary function impairment.

MATERIALS AND METHODS

This study is an analytical observational research with a cross-sectional design aimed at determining the relationships between independent variables (wood dust exposure, serum IL-13 levels, and leukocyte counts) and the dependent variable, which is pulmonary function, among wood furniture craftsmen in Ngawi Regency. Measurements and observations were conducted simultaneously at a single point in time, specifically during field research activities in home-based wood furniture industries in Ngawi Regency, East Java. Data collection was carried out from March to June 2024.

Respirable dust concentrations were measured using the High Volume Dust Sampler (HVAS) method. IL-13 levels were analyzed using the Enzyme-Linked Immunosorbent Assay (ELISA), and leukocyte counts were determined through laboratory testing. IL-13 levels were categorized using a reference value of ≤3 pg/mL as the normal range, based on the median of the healthy control group reported by Joseph et al. (2004), in which control levels were approximately 3 pg/mL. Values >3 pg/mL were considered indicative of elevated IL-13 levels, suggesting potential chronic inflammation. Wood dust exposure among home industry workers across all areas was relatively uniform; therefore, it is likely that most workers had IL-13 levels above the established threshold. However, using this reference value ensured consistency in determining inflammatory status across the worker population analysis.

The study population consisted of all workers in home-based wood furniture industries, totaling 85 workers. This study employed a total population approach while considering inclusion criteria, namely workers who consented to participate and had no history of tuberculosis, asthma, allergies, or heart disease. Based on these criteria, 39 individuals were eligible to participate. However, only 35 workers were included in the final analysis due to data completeness considerations. The total population approach was chosen to comprehensively represent the impact of wood dust exposure on all workers at the study site.

Data analysis in this study used Structural Equation Modeling (SEM) with Smart PLS (Partial Least Square) version 3.0, as this method can still be applied with relatively small sample sizes (n=35) [23]. SEM-PLS can still be applied because this method does not rely on a normal distribution and focuses on parameter estimation as well as the relationships among variables; therefore, the analysis results remain valid and usable. SEM-PLS analysis was used to examine both direct and indirect relationships between independent and dependent variables simultaneously. Model feasibility tests such as Goodness of Fit and power analysis were not conducted because, in SEM-PLS, model suitability can already be assessed through the results of the outer and inner model values [24].

ETHICAL CLEARANCE

This study was approved by Research Ethics Committee, Universitas Airlangga Faculty of Dental Medicine Health Research Ethical Clearance Commission No. 0868/HRECC.FODM/VIII/2024.

RESULTS

The wood processing industry in Ngawi Regency, particularly in the teak root craft sector, involves three main stages: raw material preparation, production, and finishing. In the raw material preparation stage, teak roots are sorted by size and cut using chain saws and circular saws to make them manageable for further processing. During production, craftsmen use various tools, both manual and mechanical, for cutting, splitting, shaping, hole-making, assembly, leveling, gluing, puttying, and sanding to create the final products. The finishing stage involves applying a protective Mowilex polish to enhance the durability and appearance of the crafts. In the final stage, the product is coated with a finishing material or special varnish designed for wood. This protective layer enhances resistance to environmental factors and pests. Its composition contains several chemical substances that may release vapors, such as Volatile Organic Compounds (VOCs). Each step is designed to ensure high-quality, unique teak root products.

Individual Characteristics

The individual characteristics in this study include age and length of service. The individual characteristics are presented in each sub-chapter below.

Based on age classification, respondents are categorized into two groups: those under 35 years old and those aged 35 years and older. The analysis reveals that the ages of respondents range from a minimum of 18 years to a maximum of 81 years. The following section presents the age distribution of respondents within the production section of the home industry company located in Ngubalan Village, Pitu District, Ngawi Regency. Work duration was categorized into two groups: <5 years and ≥5 years.

Based on **Table I**, the data indicate that the majority of respondents were in the ≥35 years age group (66%). Meanwhile, most respondents had been working for ≥5 years (60%).

Table I: Distribution of Individual Characteristics in the Production Section of Home Industry Wood Furniture Companies in Ngubalan Village.

Variable	n	%
Age		
< 35 years	12	34
≥35 years	23	66
Work Duration		
< 5 year	14	40
≥ 5 year	21	60
Total	35	100

Results of Respirable Dust Measurement in the Home-Industry Wood Work Area of Ngawi Regency

In this study, exposure to respirable dust refers to particulate matter with a threshold limit value (TLV) of 5 mg/m^3, as outlined in the Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018. The measurement of respirable dust exposure was conducted using a personal dust sampler. The following sections present the results of these measurements for workers in the Wood Home Industry of Ngawi Regency.

Table II shows the levels of respirable dust measured from worker samples at various production sites engaged in activities such as assembling, sanding, and applying putty. Measurements were conducted over a duration of 6 to 8 hours and compared against the Threshold Limit Value (TLV) for respirable dust, as established by the Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018, which is set at 5 mg/m^3. The respirable dust levels are reported in milligrams per cubic meter (mg/m^3), with results ranging from 0.3916 - 3.2282 mg/m^3. All measured production sites had respirable dust levels below the Threshold Limit Value (TLV).

Table II: Respirable Dust Level Measurement Results

Location	Measured (mg/m^3)	Exposure Time	TLV of Respirable Dust (mg/m^3)
Production (Assemble)	0.3916	6 - 8 hours	5
Production (Assemble)	0.9016	6 - 8 hours	5
Production (Assemble)	0.5223	6 - 8 hours	5
Production (Sanding)	1.9266	6 - 8 hours	5
Production (Assemble)	1.3003	6 - 8 hours	5
Production (Assemble)	3.2282	6 - 8 hours	5
Production (Sanding)	2.1416	6 - 8 hours	5
Production (Drip Putty)	1.0789	6 - 8 hours	5

Total Dust Measurement Results in the Wood Work Area Home Industry of Ngawi Regency

Total dust content measurements were conducted by UPTK2 The recorded exposure duration of 6 to 8 hours typically reflects standard working hours, allowing for a direct correlation between measurement results and worker exposure during these periods. The following section outlines the results of total dust content measurements in various work areas.

Table III shows the results of total dust level measurements across various work areas in the production section of the home industry company located in Ngubalan Village, Pitu District, Ngawi Regency. The measurement results of total dust levels across all locations with an exposure duration of 6–8 hours were still below the TLV, which is <10 mg/m^3, in accordance with Regulation of Minister of Manpower of the Republic of Indonesia No. 5 of 2018 The measurement results show that all locations have total dust levels below the TLV.

Results of Interleukin-13 (IL-13) Level and Leukocyts Count Measurements of Home Industry Workers in Ngawi Regency

Measurements of interleukin-13 (IL-13) levels, conducted by UPTK2, were categorized as normal when the measurement results were ≤3 pg/mL, and values above this threshold were considered abnormal. Meanwhile, leukocyte levels among wood craftsmen were categorized into two groups: normal and abnormal. Based on **Table IV**, it can be seen that all 35 workers (100%) have abnormal interleukin-13 levels. This condition is likely due to the chronic and relatively homogeneous wood dust exposure experienced by all workers across the work areas. The increased IL-13 levels among all workers may represent a subclinical inflammatory response as an adaptive mechanism of the body to long-term respirable dust exposure. Meanwhile, most respondents had normal leukocyte levels, while a small proportion showed abnormal leukocyte counts.

Pulmonary Function (FVC) of Home Industry Workers in Ngawi Regency

The measurement of pulmonary function (FVC) among wood home industry workers in Ngawi Regency was conducted using a spirometry device by UPTK2 personnel. This assessment took place prior to the commencement of work. The results provide insight into the normalcy of the workers' pulmonary function, as summarized in the following table.

As shown in **Table V**, among the 35 respondents, the majority demonstrated normal lung function (FVC), while 31% exhibited abnormal pulmonary function, categorized as follows:

a. 4 workers with mild restrictive impairment,
b. 1 worker with moderate restrictive impairment,
c. 4 workers with mild obstructive impairment, and
d. 2 workers with combined mild restrictive and mild obstructive impairments.

Spirometry results also indicated that the mean FVC value among respondents with pulmonary impairment was 45.60%, while the lowest recorded FEV_1 value was 55.98%.

Description of Individual Characteristics and Overview of Serum IL-13 Levels and Leukocyte Counts in Relation to Pulmonary Function (FVC)

Based on **Table VI**, all respondents aged <35 years had normal pulmonary function. Among those aged ≥35 years, the proportion of respondents with normal FVC (52%) was not significantly different from those with abnormal FVC (48%). Furthermore, respondents who had worked for less than 5 years mostly exhibited normal pulmonary function, while among those with a work duration of ≥5 years, the majority also had normal pulmonary function, although 43% showed abnormal FVC values.

Table III: Total Dust Content Measurement Results

Location	Measured	Exposure Time (hours)	TLV of Dust Total (mg/m³)	Air Temp	RH (%)
Production Room 2 -Cutting section	0.8837	6 - 8	10	30.7	65.6
Production Room 1-Assembly section	1.1173	6 - 8	10	30.4	66.8
Production Room 1 -Cutting section	1,3724	6 - 8	10	30.5	65.8
Production Room 2 -Assembly section	2.3315	6 - 8 hours	10	30.3	64.5
Production Room 3	1.2361	6 - 8	10	32.4	52.7
Back Production Room -Sanding	2.5927	6 - 8	10	32.8	52.1
Back Production Room -Finishing Stand 1	0.7881	6 - 8	10	33	51.8
Animal Statue Production Room	0.9238	6 - 8	10	32.8	51.1
Production Room 5 - Finishing Stand 2	1.2441	6 - 8	10	32.7	53.4
Production Room 4	0.8536	6 - 8	10	32.1	53.2
Office Room	0.2042	6 - 8	10	28.1	68.0

Table IV: Distribution of IL-13 Levels, Leukocyte Level, and Pulmonary Function (FVC)of Respondents in the Production Section of Home Industry Wood Furniture Companies in Ngubalan Village.

Variable	n	%
IL-13 Level		
Normal (≤3 pg/mL)	0	0
Abnormal (>3 pg/mL)	35	100
Total	35	100
Leukocyte Level		
Normal	31	89
Abnormal	4	11
Total	35	100
Pulmonary Function (FVC)		
Normal	24	69
Abnormal	11	31
Total	35	100

Table V: Cross-Tabulation of Independent Variables and Pulmonary Function (FVC) Among Workers in Home Industry Production Units in Ngubalan Village

Variable	Pulmonary Function (FVC)				Total	
	Normal		Abnormal			
	n	%	n	%	n	%
Age						
<35 years	12	100	0	0	12	100
≥35 years	12	52	11	48	23	100
Work Duration						
<5 years	12	71	2	29	14	100
≥5 years	12	57	9	43	21	100
IL-13 Level						
Normal	0	0	0	0	0	0
Abnormal	24	69	11	31	35	100
Leukocyte Count						
Normal	23	74	8	26	31	100
Abnormal	1	25	3	75	4	100

In addition, **Table VI** indicates that most respondents with abnormal IL-13 levels had normal pulmonary function (FVC), whereas 31% exhibited abnormal function. Similarly, most respondents with normal leukocyte counts had normal pulmonary function, while those with abnormal leukocyte counts were predominantly found to have abnormal pulmonary function (FVC).

Table VI: Initial Inner Model Testing of the Effect of Wood Dust Exposure, Serum Interleukin-13 (IL-13) Levels and Blood Leukocyte Levels on Pulmonary Function (FVC) in Home Industry Company Workers in the Production Section in Ngubalan Village

Tested Indicators	Standard Deviation_(STDEV)	T-Statistics	P-Values
Dust Level→ Pulmonary Faal	0.114	3.426	0.001
Dust Level → Immune Response	0.246	0.520	0.603*
Individual Characteristics → Immune Response	0.348	0.414	0.679*
Immune Response → Pulmonary Faal	0.247	0.140	0.889*

Note: * Not significant; t ≥ 1.96; p ≤ 0.05 significant

Inner Model Analysis of the Effect of Wood Dust Exposure, Serum Interleukin-13 (IL-13) Levels and Blood Leukocyte Levels on Pulmonary Function (FVC)
Inner model analysis is carried out to test the significance of the influence of exogenous variables on endogenous variables. The test results are declared significant or influential if the p-value ≤ 0,05 or t-statistic ≥ 1.96. Significance testing can be seen in the path coefficients which are the results of testing direct effects and indirect effects can be seen in Specific Indirect Effects. The results of the model testing from the bootstrapping process can be seen in the following **Fig. 1.**

The analysis of the initial Inner Model test results in the image above can be explained in the following **Fig. 1**.

Fig. 1 presents the results of Structural Equation Modeling (SEM) analysis conducted using the SMART PLS (Partial Least Squares) program. The analysis revealed a very significant effect of dust levels on workers' pulmonary function FVC, with a p-value = 0.001 and t = 3.43. Although most dust level measurements were below the TLV, long-term and repeated exposure contributed to the decline in FVC. However, it was also noted that the latent variables of dust levels and individual characteristics yielded p-values greater than 0.05, indicating that these factors do not significantly influence the immune response.

Additionally, the latent variable representing the immune response also produced p-values = 0.889, suggesting that the immune response does not have a significant impact on pulmonary function. This finding can be attributed to the fact that IL-13 values were predominantly abnormal among the 35 workers (100%), Thus, there was no sufficient inter-individual variation to test its effect. In addition, only a small proportion (11%) of respondents showed abnormal leukocyte counts, resulting in limited leukocyte variation and a minimal contribution to the model.

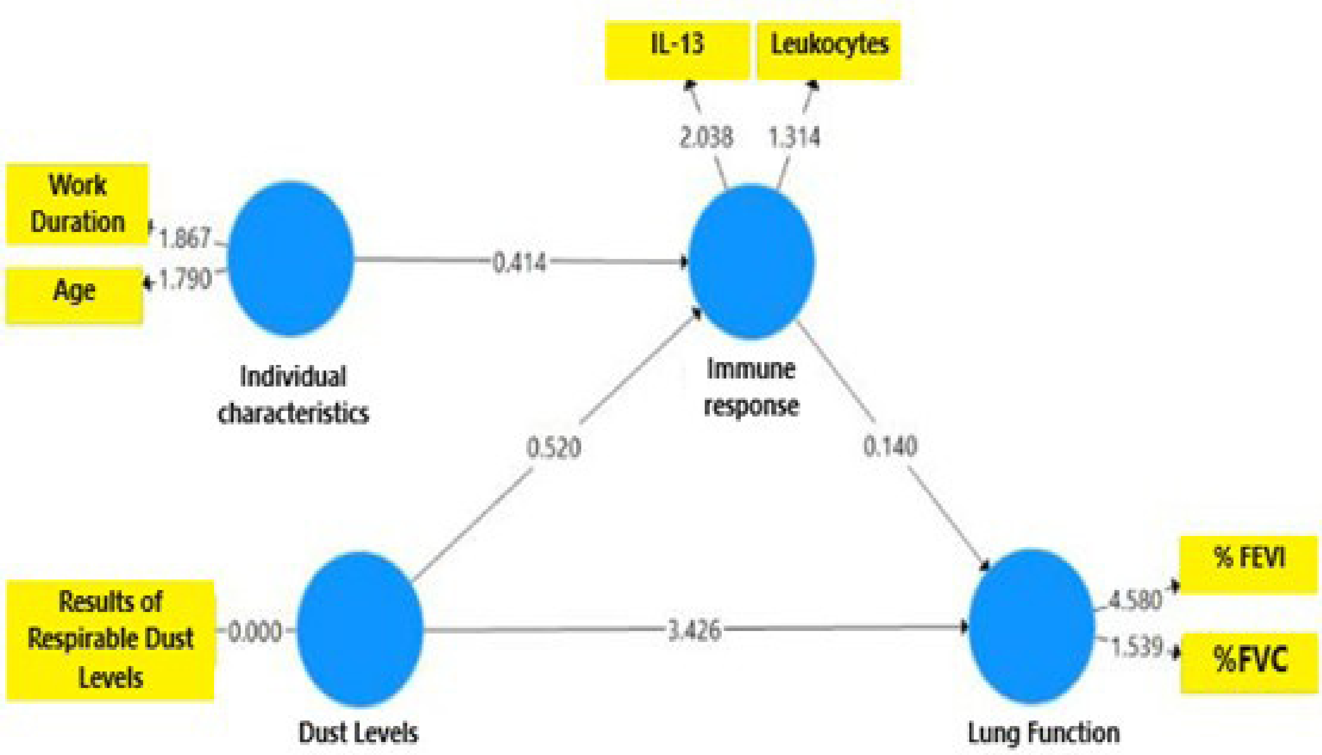

Fig. 1: Initial Inner Model Testing of the Effect of Wood Dust Exposure, Serum Interleukin-13 (IL-13) Levels and Blood Leukocyte Levels on Pulmonary Function (FVC) in Home Industry Company Workers in the Production Section in Ngubalan Village

There were also limitations in sample size and SEM output, so the model evaluation focused on interpreting the direction and significance of the pathways. Confounding factors such as smoking habits, use of personal protective equipment (PPE), and lifestyle were not analyzed multivariately, making the interpretation of dust exposure effects on pulmonary function partial.

DISCUSION

Overview of the Wood Processing Industry in the Wood Home Industry of Ngawi Regency

The process of crafting teak root products in the company is generally carried out in three stages: the raw material preparation stage, the production stage, and the finishing stage.

1. Raw Material Preparation Stage
2. The raw material preparation stage involves the selection and preparation of materials, specifically dhangkel or teak roots, before further cutting. The primary objective of this stage is to minimize machinery use and reduce the time required before the production process begins. Large raw materials refer to substantial dhangkel or teak roots that must be cut and split into smaller pieces using a chainsaw, followed by further cutting with a circular saw. This activity generates both coarse and fine wood dust as a result of repeated cutting.
3. Production Stage

At each stage of production, a significant amount of wood dust is generated. Workers are continuously exposed to this dust throughout the process. The production process of teak root crafts within the company encompasses several steps, including:

a. Process of Cutting and Splitting Raw Materials

This activity involves dividing and cutting the teak wood roots using both a chain saw and a circular saw machine into various parts.

b. Process of Forming Raw Materials

During this phase, the cutting and splitting processes may involve the use of a circular saw as well as hand tools such as a wooden hoe or peeler.

c. Process of Hole-Making

Creating these holes helps reduce assembly time. There are three methods for making holes: using a carpenter's chisel, employing a wooden hoe, or utilizing a drill machine.

d. Process of Assembly

The assembly process is the process of assembling raw materials for teak root crafts to be assembled or attached to their parts. The assembly process is also an activity of hooking and fastening.

e. Process of Leveling

The leveling process involves trimming or reducing the ends of teak root crafts to ensure they appear aesthetically pleasing and can stand upright. The manual cutting saw technique entails cutting or reducing unwanted parts of the teak root crafts with a manual cutting saw.

f. Process of Gluing and Puttying

The gluing and puttying process comprises a series of activities that apply glue and putty to specific sections of the teak root crafts when appropriate. The craftsmen utilize a combination of fox glue and sawdust as materials for these applications.

g. Process of Sanding Process

The sanding process involves smoothing the teak root crafts, ensuring that any necessary surfaces are refined to achieve a polished finish. Sanding can be conducted through three methods: using a grinder, utilizing a sanding machine, or sanding manually with sandpaper.

4. Finishing Stage

In the final stage, the product is coated with a finishing material or special varnish designed for wood. This protective layer enhances resistance to environmental factors and pests. The composition contains several chemical substances that may release vapors, such as Volatile Organic Compounds (VOCs).

The Characteristics of Individual Workers Home Industry Wood Furniture Ngawi Regency

The characteristics of individual workers in the wood furniture home industry can significantly influence their health, particularly their pulmonary function. Key factors include age and duration of employment.

Age of Worker

In this study, the age of workers is defined as the period from birth to the time of research. Based on the results obtained in the characteristics of individual workers, the results are obtained that the home industry wood furniture workers in Ngawi Regency are mostly found in the age category ≥ 35 years with a percentage of 69% so the dominant worker is included in the productive age. The productive age group is the most sought-after human resources by the company because workers who are included in this age have the potential to increase company productivity.

Period of Work

Long working hours pose potential hazards that can lead to long-term health risks (2). The period of work in this study is interpreted as the length of work from the beginning of work at the research location until the research was carried out in a matter of years. The dominance of the working period of Ngawi Regency Home Industry Workers is ≥ 5 years as much as 60%. The most-aged worker category is ≥ 35 years so the tenure of owned is also relatively long. Labour with a service period of > 5 years will experience pulmonary function impaired because dust particles are inhaled and have settled in the alveoli [25]. In addition, workers who are in a work environment with high particle levels for a long time will have a high risk of pulmonary obstruction disorders.

The Results of Dust Exposure Measurements and Their Correlation with Workers' Pulmonary Function (FVC) in the Wood Furniture Home Industry of Ngawi Regency

Dust is a solid particle measuring 0.1-50 μm or more.

Dust particles that can be seen by the eye are measuring >10 μm, while the size of <5 μm, can only be seen by the eye if there is a strong reflection of light from the dust particles. To see dust particles that are <10 μm (respirable dust), it must use a microscope. In this study, respiratory dust exposure was measured using personal dust samplers by UPTK2 officers across various work units, including assembly, sanding, and putty drip.

The results showed that all work units in the Wood Furniture Home Industry of Ngawi Regency complied with the respirable dust limit set by the Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018, which is 5 mg/m^3 with an exposure duration of 6–8 hours. The highest level of respiratory dust exposure was recorded at 3.2282 mg/m^3 in the assembly section, while the lowest was 0.3916 mg/m^3. Although the dust exposure was still below the permissible limit, which may contribute to pulmonary function disorders such as mild to moderate restrictive patterns [26].

This study also identified a significant correlation between dust concentration and pulmonary function (FVC) ($p = 0.001$). Consistent with these findings, a systematic review of industrial workers in Africa also reported that pulmonary function index (FVC) values were significantly lower among workers exposed to organic dust compared to those who were not exposed [27].

The Results of Measurement of Interleukin-13 (IL- 13) Workers in the Wood Furniture Home Industry of Ngawi Regency

IL-13 is a pleiotropic cytokine produced by the chromosome 5 gene in Q31 produced in significant amounts by Th2 cells. IL-13 has a mass of 13 KDA and is multiplied into a bond of 4 alpha helices namely A, B, C, and D. Various evidence shows that IL-13 is a mediator in the pathogenesis of asthma, hyperresponsive airways, mucus production, remodeling of airways, subepithelial fibrosis airway, asthma infection, allergic asthma, and respiration due to aspirin [16, 19].

Based on the study results, it was found that all workers had IL-13 levels greater than 3 pg/mL, indicating a chronic inflammatory response likely caused by long-term exposure to wood dust. The normal IL-13 threshold (≤3 pg/mL) was used as a pragmatic reference, based on the median value of the healthy control group reported by Joseph et al. (2004), in which the median IL-13 level was approximately 3 pg/mL. Meanwhile, IL-13 levels exceeding 6.6 pg/mL have been observed in patients with atopic asthma. [28]. This chronic increase in IL-13 levels may elevate workers' risk of developing various airway diseases, including asthma, airway remodeling, and fibrosis, all of which are associated with long-term inflammatory processes.[29].

The Results of the Measurement of the Number of Worker Leukocytes in the Wood Furniture Home Industry of Ngawi Regency

Leukocytes or white blood cells are an important component of the immune system that functions against infections and protects the body from foreign substances such as bacteria, viruses, and allergens. In wood furniture workers, the number of leukocytes can be influenced by various work environment factors, including exposure to wood dust, chemicals, and other air pollutants. Continuous proposal to these particles can trigger the body's immune response, which in turn affects the number of leukocytes in the blood.

Based on the results of the study conducted it was found that most workers still have a normal number of leukocytes or below 3 pg/ml. However, there are 4 workers who show the number of leukocytes above normal standards, which may indicate the body's response to irritation or excessive exposure to pollutants at work. These results indicate that although most workers have a significant immune system that is not significantly affected by the work environment, there are a small number of workers who may face an increased risk of health problems related to the immune system.

Pulmonary Function (FVC) Workers in the Wood Furniture Home Industry of Ngawi Regency

Wood Furniture Home industry workers in Ngawi Regency are workers who are at risk for pulmonary function disorders due to exposure to wood dust. The wood dust produced is not only limited to one work unit, but almost all work units produce significant amounts of dust, thereby increasing the risk of pulmonary function disorders for workers. Examination of pulmonary function is done using a Spirometer, which functions to measure pulmonary capacity and detect whether pulmonary function is in normal condition or there is a disruption, such as restriction (narrowing) and obstruction (blockage) of the respiratory tract.

Based on the Spirometry Examination of the Workers of Wood Furniture Home Industry of Ngawi Regency, out of 35 workers who were respondents there were 31% of workers experienced pulmonary physiology with a restrictive mild to moderate restrictive patterns and mild obstructive categories. These results indicate that exposure to constant wood dust can cause various types of pulmonary function disorders, both restrictive, which affects the capacity of the lungs to expand and obstructive, which complicates the flow of air in and out of the lungs. Although all work areas had dust exposure levels below the Threshold Limit Value (TLV), spirometry results still revealed several workers with impaired lung function. This finding indicates that even exposure below the TLV, when experienced continuously over a prolonged period, may lead to various types of pulmonary function disorders.

Analysis of the Effect of Individual Characteristics on Pulmonary Function (FVC)

Analysis of the Effect of Age on Pulmonary Function (FVC)

The sociodemographic factors of marble artisans, such as age, nutritional status, and work duration, significantly influence the occurrence of lung function disorders [30]. Age plays a particularly important role, as pulmonary function capacity tends to decrease naturally with advancing age due to physiological changes that affect the elasticity of lung tissue and the strength of respiratory muscles.

Several studies have shown that individuals over the age of 35 are more likely to exhibit abnormal pulmonary function. For instance, a study conducted in Surakarta reported that 55.3% of respondents aged over 40 years experienced decreased pulmonary function capacity. The data also demonstrated a significant relationship between age and vital lung capacity, with a p-value of 0.006, indicating a strong association between increasing age and reduced pulmonary function [31].

Other reviews have similarly confirmed that lung function declines progressively with age. Changes in FVC are estimated to decrease at a rate of approximately 14.1 mL per year in the youngest cohorts [32]. Pulmonary aging is a complex process characterized by cumulative damage resulting from structural and functional changes in the respiratory system. Immunosenescence, or the aging of the immune system, leads to increased production of pro-inflammatory cytokines, which accelerates the decline in lung function. Additionally, with age, the elasticity of lung tissue and alveoli diminishes, and respiratory muscle strength decreases, ultimately impairing gas exchange and overall respiratory performance [33].

Analysis of the Effect of Working Period on Pulmonary Function

Levels of dust exposure, including respirable dust and the duration of exposure in the workplace, also play a crucial role in affecting lung function among marble artisans [30]. In this study, workers with a work period of more than 5 years (38.1%) were more likely to exhibit abnormal pulmonary function compared to workers with less than 5 years of service (21.4%). Work duration has a significant influence on pulmonary function, as longer exposure increases the risk of pulmonary disorders.

A study conducted on stone-breaking workers in Bandar Lampung showed that workers with more than 10 years of service had a 21-fold higher risk of developing pulmonary function disorders compared to those with less than 10 years of service, with a very high level of significance ($p = 0.001$). This demonstrates a strong relationship between length of service and decreased pulmonary function [34].

The analysis indicates a strong positive relationship between working duration and impaired pulmonary function. This suggests that as the length of exposure to harmful dust in the work environment increases, Forced Vital Capacity (FVC) correspondingly decreases. Prolonged exposure to respirable dust particles can lead to chronic irritation and inflammation of the respiratory tract, potentially compromising lung elasticity and overall function [35, 36].

Other studies have reported similar findings. Among textile industry workers in Semarang Regency, a working period of more than five years was positively correlated with pulmonary function disorders ($p = 0.04$), with a prevalence ratio of 2, indicating that the likelihood of byssinosis doubles for workers with more than five years of service compared to those with less than five years. Similarly, a study on male textile workers in India reported that workers with ≥30 years of tenure had twice the risk of developing byssinosis compared to those with less than 30 years [37]. These findings reinforce the notion that longer work exposure in environments with industrial dust and pollutants increases the risk of reduced pulmonary function.

Overall, prolonged work periods increase both the frequency and duration of exposure to harmful particles, such as dust, fibers, and other pollutants, which can irritate and inflame the respiratory tract. If this chronic irritation persists over time, it can cause structural changes in lung tissue, reduce lung elasticity, and contribute to obstructive pulmonary diseases, such as byssinosis and chronic bronchitis, ultimately leading to a significant decline in pulmonary function.

Analysis of the Effect of Serum IL-13 Levels on Pulmonary Function (FVC)

Based on the results of this study, no significant relationship was identified between IL-13 levels and pulmonary function (FVC). This may be due to the homogeneity of IL-13 levels among all respondents (IL-13 > 3 pg/mL). Such homogeneity likely occurred because dust exposure concentrations were relatively similar across all work areas, combined with the limited sample size. Additionally, pulmonary function may be influenced by other more significant factors, such as age, work duration, nutritional status, exposure duration, and dust concentration [30].

These findings are consistent with previous studies reporting that Th2 cytokines, including IL-4, IL-5, IL-6, IL-8, IL-13, and IL-17 were not significantly correlated with pulmonary function test results, including FEV_1/FVC, MEF25, MEF50, and MEF75, with all p-values >0.05 [38]. Other research also found no significant correlation between IL-13 and pulmonary function parameters such as FEV_1, FVC, BDT, and DLCO [39].

Although no significant association was observed in this study, biologically, serum Interleukin-13 (IL-13) plays an important role in the inflammatory process and pulmonary fibrosis, which can affect pulmonary function, including FVC. IL-13 is a cytokine produced by Th2 cells that contributes to the regulation of immune responses and inflammation in the lungs. Elevated IL-13 levels are often associated with inflammatory conditions and pulmonary fibrosis, such as silicosis and asthma.

Research has shown that individuals with pulmonary fibrosis have increased IL-13 levels, contributing to pulmonary tissue damage and decreased lung function. This process involves the activation of alveolar macrophages and the release of proinflammatory cytokines, which induce tissue damage [40]. Other studies have indicated that IL-13 levels can be associated with decreased FVC in patients with certain pulmonary conditions [41]. For example, IL-13 levels were significantly higher in patients with idiopathic pulmonary fibrosis compared to patients with nonspecific interstitial pneumonia (249.0 ± 83.1 vs 137.7 ± 37.9 pg/mL, $p = 0.032$) and controls (249.0 ± 83.1 vs 49.0 ± 13.1 pg/mL, $p = 0.012$) [41]. High IL-13 levels can indicate ongoing inflammatory processes that interfere with normal pulmonary function, including reduced vital capacity.

Overall, IL-13 plays an important role in exacerbating pulmonary damage through inflammatory and fibrotic mechanisms, leading to decreased FVC. Therefore, serum IL-13 levels have potential as a biomarker for predicting progressive lung damage in patients with chronic pulmonary disease. Measuring increased IL-13 levels can provide insights into the degree of inflammation, although their effects on pulmonary function parameters are likely to become apparent only after long-term or higher-intensity exposure.

Consequently, further studies with larger sample sizes and different study designs are needed to identify the relationship between IL-13 and pulmonary function test parameters (FVC),as well as to evaluate the potential of IL-13 as a predictive biomarker for progressive lung damage in workers chronically exposed to wood dust.

Analysis of the Effect of the Number of Leukocytes on Pulmonary Function (FVC)

The leukocyte count, an indicator of the body's immune response, does not have a significant effect on pulmonary function (FVC). Several studies have indicated that leukocyte counts do not consistently correlate with pulmonary function. For instance, Alawiyah and Fachri (2020) reported no significant association between leukocyte counts and the severity of Chronic Obstructive Pulmonary Disease (COPD), with $p = 0.158$ [42]. Similarly, research on adult asthma patients showed that while blood eosinophils were associated with lower FEV_1 values, no significant decline in pulmonary function was observed over approximately 12 years [43]. Studies on workers in various industries also found no significant relationship between leukocyte counts and pulmonary function disorders. Although variations in leukocyte levels were observed, these did not correlate strongly with decreases in FVC, with analyses yielding insignificant p-values. This suggests that factors other than leukocyte counts may exert a greater influence on pulmonary function.

Rajanayagam et al. (2023) reported that eosinophil levels in mine workers could increase as an inflammatory response, accompanied by a decrease in FEV_1. However, other contributing factors, such as dust exposure, were not investigated [44]. Additionally, studies on pulp and aluminum factory workers identified an inverse correlation between leukocyte counts and forced vital capacity, independent of smoking habits [45].

Overall, although leukocytosis (an increased number of leukocytes) can indicate infection or inflammation, not all elevations directly relate to decreased pulmonary function. In some cases, factors such as age, smoking habits, and environmental exposures have a stronger impact on pulmonary function than leukocyte counts. For example, in patients with certain conditions like COVID-19, although leukocytosis is associated with pneumonia, not all patients with high leukocyte counts exhibit reduced FVC. This indicates that leukocytes, while markers of inflammation, are not always directly related to impaired pulmonary function.

Based on the findings of this study, dust exposure was significantly associated with pulmonary function, whereas IL-13 and leukocyte levels showed no significant relationship with FVC. This may be due to the relative homogeneity of the data and potential confounding factors that were not fully controlled. Other studies have indicated additional factors, such as cumulative cigarette smoking, which is associated with reduced pulmonary function [46, 47], and the use of personal protective equipment (PPE), which significantly influences pulmonary function among industrial workers [48]. Therefore, further research incorporating analyses that account for these confounding factors is necessary to better interpret the relationship between dust exposure, IL-13 levels, leukocyte counts, and pulmonary function. The limitations of this study include a relatively small sample size, which may affect the generalizability of the results. Additionally, the cross-sectional design limits the ability to establish causal relationships between dust exposure, IL-13 levels, and pulmonary function.

Nevertheless, the findings have important implications for worker health in the wood furniture industry. Although respirable dust exposure remains below threshold limits, long-term exposure can still significantly impact pulmonary function, especially when accompanied by elevated IL-13 levels. Therefore, it is recommended to increase the use of effective PPE, particularly highefficiency masks for fine dust. The effective use of personal protective equipment (PPE) depends not only on the availability of appropriate masks but also on enhancing perceived behavioral control through training and habituation that shape workers' perceptions that PPE use does not hinder their work. With a strong sense of control, workers are more likely to have consistent intentions to use PPE. [49]. In addition, Improvements in ventilation within production areas are also advised to reduce airborne dust concentrations. Routine monitoring of workers' pulmonary function is essential for early detection of pulmonary disorders and prevention of more severe conditions.

CONCLUSION

Based on the results of this study conducted on 35 home furniture industry workers, the following conclusions can be drawn: most respondents were aged ≥35 years with a work duration of ≥5 years. The highest dust concentration was measured at 3.2282 mg/m in the assembly area. All workers had abnormal IL-13 levels (>3 pg/mL), while the majority had normal leukocyte counts. Eleven respondents exhibited abnormal pulmonary function, categorized as mild to moderate restrictive and mild obstructive patterns.

Structural Equation Modeling (SEM) analysis showed that dust exposure had a significant effect on pulmonary function (FVC), whereas IL-13 and leukocyte levels had no significant influence. These findings indicate that chronic wood dust exposure can reduce pulmonary function (FVC), even though immune response markers did not show a significant relationship.

Therefore, occupational health and safety (OHS) measures are essential, including regular monitoring of pulmonary function and inflammatory biomarkers. Additionally, programs to improve compliance with the use of personal protective equipment (PPE) and dust control strategies in the workplace are needed to minimize exposure to respirable dust particles and prevent declines in pulmonary function.

CONFLICTS OF INTEREST

There is no conflict of interest in this study.

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