



Individual Characteristics and Particulate Matter Exposure Associated with Lung Function Impairment Among Online Taxi-bike Drivers in Medan City

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Abstract

Impaired lung function contributes to a range of major health problems, including poor respiratory health and chronic lung disease. Online taxi-bike drivers are a vulnerable group of workers exposed to air pollutants, such as particulate matter (PM), thereby risking lung function impairment. This study aims to determine the association between individual characteristics and PM exposure with lung function impairment among online taxi-bike drivers in Medan City. The sample size in this cross-sectional study was

138 online taxi-bike drivers in Medan City who were selected by accidental sampling. Data analysis using simple logistic regression test. The results showed that the prevalence of lung function impairment among online taxi-bike drivers in Medan City was 26.8%. Age ($p=0.001$), BMI ($p=0.006$), years of work ($p=0.002$), length of work ($p=0.032$), smoking ($p=0.006$), and inhaled PM₁₀ intake ≥ 0.0048 mg/kg/day on maximum PM₁₀ concentration ($40.10 \mu\text{g}/\text{m}^3$) ($p=0.045$) are associated with lung function impairment, while the behavior of using masks as personal protective equipment ($p=0.332$) and inhaled PM₁₀ intake ≥ 0.0028 mg/kg/day on minimum PM₁₀ concentration ($23.20 \mu\text{g}/\text{m}^3$) ($p=0.464$) are not significantly associated with lung function impairment among online taxi-bike drivers in Medan City. The local government is expected to conduct regular vehicle emission tests as well as preserve green open spaces to reduce air pollution in Medan City, and facilitate education for online taxi-bike drivers to maintain and improve lung health and seek medical attention when experiencing respiratory symptoms. Online taxi-bike drivers are also advised to continue using good quality masks and wearing them properly while working.

Keywords: Individual characteristics, Lung function impairment, Online taxi-bike driver, Particulate matter

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Introduction

Lung function impairment, characterized by decreased forced expiratory volume in one second (FEV1) and/or forced vital capacity (FVC), contributes significantly to several major health problems, including poor respiratory health and chronic lung diseases, such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer, cardiovascular and cerebrovascular events and all-cause premature mortality (Ullah et al., 2024). The prevalence of COPD, a disease characterized by progressive decline in lung function, is estimated at 10.3% globally, and is the fourth leading cause of death worldwide, accounting for up to 3.5 million deaths in 2021 (5% of overall deaths) (WHO, 2024b). COPD is estimated to cause around 3 million deaths annually worldwide, of which about 90% occur in individuals aged less than 70 years in low- to middle-income countries (GOLD, 2024). Global Burden Disease data shows that Indonesia is one of the 10 countries with the most COPD cases, contributing up to 65.1% of COPD cases globally in 2019 (Adeloye et al., 2022). Patients with COPD in Indonesia were also estimated to increase from 2020, from 4.9 million cases to more than 5 million cases in 2021 (IHME, 2024). Other than that, studies report that impaired lung function is significantly associated with metabolic syndrome or a large number of cardiometabolic risk factors (Lin et al., 2021). Individuals with abnormal lung function were also found to be more prone to various respiratory symptoms such as coughing or phlegm, shortness of breath, and chest pain compared to individuals with normal lung function (Liu & Kalhan, 2021).

Lung function impairment is influenced by various factors, including socio-demographics, genetic factors, lifestyle, and environmental factors. Studies have found that age, gender, weight, height, and smoking habits explain a large proportion of the variation in lung function measurements. Other factors such as occupation, income, obesity, physical activity, and the presence of comorbidities (e.g., diabetes, muscular or hormonal disorders) have also been reported to affect lung function (McHugh et al., 2020). Environmental factors, especially air pollution, are associated with lung health at all ages, and not only affect lung growth, but also contribute significantly to lung function decline and impairment. Air pollutants are one of the environmental risk factors that have become a major problem for health, especially with the rapid progress of industrialization nowadays (Liu & Kalhan, 2021).

Different types of air pollutants identified by the WHO include nitrogen dioxide (NO₂), particulate matter (PM), sulfur dioxide (SO₂), and ozone (O₃). Particulate matter consists of microscopic particles with various diameter sizes that determine PM deposition in the human body (Li et al., 2024). PM₁₀, which is 10 µm or smaller in diameter, when inhaled can be deposited in the larger respiratory tract, up to the lungs, causing various respiratory disorders, while PM_{2.5}, which has a diameter of ≤2.5 µm, can penetrate the alveolar-capillary barrier and enter the



bloodstream, adversely affecting lung function and various other organs in the human body. Most of these particles are formed in the atmosphere as a result of complex reactions of chemicals such as SO₂ and NO₂, which are pollutants generated from power plants, industries, and motor vehicle exhaust emissions (EPA, 2024). Indonesia is the country with the worst air pollution ranking 14th worldwide in 2023, with an air quality index value of 105 units, thus falling into the unhealthy category, especially for sensitive groups such as children and the elderly (IQAir, 2023). Meanwhile, Medan City is one of the largest cities in Indonesia that has a moderate level of air pollution, but is included as the worst air polluted city in North Sumatra Province, with an air quality index value of 60 units in August 2024 and ambient air concentrations for the PM₁₀ parameter reaching 18.7 µg/m³, which is classified as unhealthy (IQAir, 2024).

One workgroup that also has the risk of exposure to air pollutants, including PM and vehicle emissions for a long time is online taxi-bike drivers. Online taxi-bike drivers are a new type of work that emerges along with technological developments, which provides motorcycle driver booking services through online-based applications that serve pick-ups from and deliveries to the desired location point of consumers. Although it has a flexible work system, online taxi-bike drivers have targets that must be achieved to pursue points or bonuses so they often have to work more than 8 hours a day driving on the road (Farida, 2020). Therefore, they will be more often and longer exposed to air pollutants. A survey conducted in Bekasi City, Indonesia found that around 15.2% of online taxi-bike drivers interviewed had lung function impairment and suffered from respiratory symptoms such as coughing (17.2%) and shortness of breath (6.1%) (Damayanti et al., 2019). Samana et al. (2024) in their research also found that as many as 28% of online motorbike taxi drivers in Bangkok, Thailand and other adjacent provinces had impaired lung function, with symptoms of chronic bronchitis (12%) and acute bronchitis (7.3%).

The results of a preliminary survey conducted on 20 online taxi-bike drivers in Medan City showed that most drivers were reporting respiratory symptoms such as coughing with phlegm (62%) and tightness in the chest area (56%), but had never been diagnosed with lung disease or other respiratory disorders and had never been examined to detect lung function impairment. Based on the issues identified, researchers are interested in investigating lung function impairment among online taxi-bike drivers in Medan City as well as individual factors and particulate matter exposure associated with lung function impairment among online taxi-bike drivers in Medan City.

Methods

This type of research is observational analytic using cross-sectional design. The study population was all online taxi-bike drivers in Medan City. The sample size was calculated using the Lemeshow formula (1990) to determine the minimum sample size from an unknown



population, at an error rate of 5%, thus obtaining a sample size of 138 online taxi-bike drivers. Accidental sampling is used, where ojek drivers who are coincidentally encountered at several shelter locations (base) and meet the criteria can be selected as research samples. The sample inclusion criteria in this study are online taxi-bike drivers aged >30 years and have been actively working as online taxi-bike drivers for at least three years, while the exclusion criteria are online taxi-bike drivers who are under medical care or taking drugs, and those with a history of pulmonary disease.

The independent variables in this study were age, body mass index (BMI), years of work, length of work, smoking behavior, personal protective equipment (PPE) use behavior, and inhaled PM10 intake. Meanwhile, the dependent variable was lung function impairment. The variables of age, years of work, length of work, smoking behavior and the use of PPE (masks) were known through interviews using a questionnaire. Body mass index (in kg/m²) is the result of dividing body weight (kg) and the square of height (m²). Body weight was measured using a calibrated scale, while height was measured using a microtoise. PM10 inhalation intake (in units of mg/kg/day) was calculated using the exposure analysis formula as follows (Dirjen P2PL, 2012):

$$\text{Intake} = \frac{C \times R \times tE \times fE \times Dt}{Wb \times Tavg}$$

Concentration (C) is the concentration of PM10 in the air (mg/m³), rate (R) is the inhalation rate (m³/hour) which in adults is about 0.83 m³/hour, time of exposure (tE) is the duration of exposure in hours/day, frequency of exposure (fE) is the frequency of exposure in days/year, duration time (Dt) is the duration of exposure in years, weight of body (Wb) is the body weight in kg, dan time average (Tavg) is the average time period for non-carcinogen effects (365 days/year). Based on the air quality monitoring data of Medan City obtained using the Air Quality Monitoring System (AQMS) tool for 24 hours at three monitoring locations, which are Gajah Mada Park Station, Rusunawa Kayu Putih Station, and Brida Office Station, it was found that the highest PM10 dust level at each location was 30.20 µg/m³, 40.10 µg/m³, and 31.40 µg/m³, while the lowest levels at each location were 23.20 µg/m³, 30.40 µg/m³, and 23.20 µg/m³, giving a maximum concentration (C) of PM10 in Medan City of 40.10 µg/m³ and a minimum of 23.20 µg/m³. For the maximum level of PM10, which is 40.10 µg/m³, inhalation intakes were measured based on the variables of length of exposure, frequency and duration of exposure, and body weight of each online taxi-bike driver using the formula to obtain the range of inhalation intakes for the maximum level of PM10 of 0.0029–0.0069 mg/kg/day with a median value of 0.0048 mg/kg/day. Meanwhile, for the minimum level of PM10, which is 23.20 µg/m³, inhalation intakes were also measured using the formula for each online taxi-bike driver, resulting in a range of inhalation intakes for the minimum level of PM10 of 0.0017–0.0040 mg/kg/day with a median value of



0.0028 mg/kg/day. Furthermore, the inhalation intake of online taxi-bike drivers at the maximum concentration of PM10 in the air is categorized into ≥ 0.0048 mg/kg/day and < 0.0048 mg/kg/day, while the inhalation intake of online taxi-bike drivers at the minimum concentration of PM10 in the air is categorized into ≥ 0.0028 mg/kg/day and < 0.0028 mg/kg/day.

Measurement of lung function variables was conducted with the help of health workers using spirometry equipment with repeated examinations for three times. Lung function was assessed using forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) parameters. FVC aims to determine the maximum amount of air that can be exhaled after inhaling as deeply as possible through expiration as quickly and forcefully as possible, while FEV1 aims to determine the amount of air that can be forcibly expired in the first second. The FEV1 value is automatically determined from the FVC value in the first second. Normal lung function is further defined as $FEV1/FVC \geq 70\%$ and $FVC \geq 80\%$ (Lin et al., 2021). The categorization of lung function abnormalities in this study did not distinguish between restrictive (lung expansion impairment), obstructive (expiratory impairment due to airway narrowing or blockage), or combination.

The collected data were then analyzed through univariate and bivariate analysis. Univariate analysis was used to determine the frequency distribution of respondents based on the research variables. Meanwhile, bivariate analysis aims to determine the relationship between each independent variable (age, BMI, years of work, length of work, smoking behavior, PPE use, and PM10 inhalation intake) with the dependent variable (lung function impairment in online taxi-bike drivers in Medan City) using simple logistic regression test at 95% confidence level or significantly associated if the $p\text{-value} < 0.05$.

Results

Based on the results of data collection from 138 online taxi-bike drivers in Medan City, the following research results are obtained:

Table 1. Frequency Distribution of Respondents Based on Individual Characteristics and Lung Function Impairment

Variables	n(=138)	% (=100)
Age		
30–40 years	93	67.4
≥ 40 years	45	32.6
BMI		
Underweight or normal weight ($BMI \leq 25$ kg/m ²)	48	34.8
Overweight and obese ($BMI > 25$ kg/m ²)	90	65.2
Years of work		



<5 years	56	40.6
≥5 years	82	59.4
Length of work		
≤8 hours/day	23	16.7
>8 hours/day	115	83.3
Smoking behavior		
Not smoking	29	21.0
Smoking	109	79.0
Personal protective equipment (masks) use behavior		
Always	128	92.8
Sometimes	10	7.2
Lung function		
Abnormal	37	26.8
Normal	101	73.2

The frequency distribution of respondents based on individual characteristics as seen in Table 1 shows that the majority of online taxi-bike drivers in this study are 30–40 years old (67.4%) and belong to the overweight and obese category based on their BMI which is $>25 \text{ kg/m}^2$ (65.2%). Most respondents have been actively working as online taxi-bike drivers for 5 years or more (59.4%) and work for more than 8 hours per day (83.3%). The majority of online taxi-bike drivers also have smoking habits (79%); meanwhile, based on PPE use behavior, most respondents always use masks when driving (92.8%). Based on the results of lung function examination, most online taxi-bike drivers who became research respondents had normal lung function (73.2%), and only 26.8% had abnormal lung function.

Table 2. Overview of PM10 Inhalation Intake in Online Taxi-bike Drivers in Medan City

PM10 Inhalation Intake	N	Mean (mg/kg/day)	SD (mg/kg/day)	Median (mg/kg/day)	Min (mg/kg/day)	Max (mg/kg/day)
Maximum concentration (40.10 $\mu\text{g/m}^3$)	138	0,0047	0,0009	0.0048	0,0029	0,0069
Minimum concentration (23.20 $\mu\text{g/m}^3$)	138	0,0027	0,0005	0.0028	0,0017	0,0040

As seen in Table 2 above, at the maximum concentration (40.10 $\mu\text{g/m}^3$) of PM10 in the air, inhalation intake of online taxi-bike drivers in Medan City is in the range of 0.0029–0.0069 mg/kg/day with an average of 0.0047 (± 0.0009) mg/kg/day, while at the minimum concentration



of PM10 ($23.20 \mu\text{g}/\text{m}^3$) in the air, inhalation intake of online taxi-bike drivers in Medan City ranges from 0.0017–0.0040 mg/kg/day with an average inhalation intake of $0.0027 (\pm 0.0005)$ mg/kg/day.

Table 3. Results of Bivariate Analysis

Independen variables	Lung function				Total		p-value
	Abnormal		Normal		n(=138)	%	
	n	%	n	%			
Age							
≥40 years	34	75.6	11	24.4	45	100	0.001
30–40 years	3	3.2	90	96.8	93	100	
BMI							
Overweight and obese	32	35.6	58	64.4	90	100	0.006
Underweight or normal weight	5	10.4	43	89.6	48	100	
Years of work							
≥5 years	30	36.6	52	63.4	82	100	0.002
<5 years	7	12.5	49	87.5	56	100	
Length of work							
>8 hours/day	35	30.4	80	69.6	115	100	0.032
≤8 hours/day	2	8.7	21	91.3	23	100	
Smoking behavior							
Smoking	35	32.1	74	67.9	109	100	0.006
Not smoking	2	6.9	27	93.1	29	100	
PPE (masks) use behavior							
Sometimes	4	40.0	6	60.0	10	100	0.332
Always	33	25.8	95	74.2	128	100	
Inhalation intake for maximum PM10 concentration (40.10 µg/m³)							
≥0,0048 mg/kg/day	15	21.1	56	78.9	71	100	0.045
<0,0048 mg/kg/day	21	31.3	46	68.7	67	100	
Inhalation intake for minimum PM10 concentration (23.20 µg/m³)							
≥0,0028 mg/kg/day	20	27.4	53	72.6	73	100	0.464
<0,0028 mg/kg/day	17	26.2	48	73.8	65	100	

The information in Table 3 shows that out of 45 online taxi-bike drivers aged 40 years and older, the majority (75.6%) have abnormal lung function, while out of a total of 93 drivers aged 30–40 years, most (96.8%) have normal lung function. The results of bivariate analysis showed a p-value of 0.001 which means that there is an association between age and lung function impairment among online taxi-bike drivers in Medan City. Based on BMI, online taxi-bike drivers



included in the overweight and obese category are more prevalent (35.6%) to have abnormal lung function, compared to drivers who are underweight or normal (10.4%). Through bivariate analysis, a p -value of 0.006 is obtained, indicating that BMI is associated with lung function impairment.

The results showed that there are more online taxi-bike drivers with a working period of 5 years or more (36.6%) who have impaired lung function compared to drivers who work for less than 5 years (12.5%). Similarly, more drivers who work for more than 8 hours/day have abnormal lung function (30.4%) compared to online taxi-bike drivers who work for ≤ 8 hours/day (8.7%). The results of bivariate analysis show that years of work and length of work are significantly associated with lung function impairment among online taxi-bike drivers in Medan City with p -values of 0.002 and 0.032, respectively. Furthermore, among online taxi-bike drivers who have smoking behavior, more have impaired lung function (32.1%) compared to those who do not smoke (6.9%). Through the results of bivariate analysis obtained a p -value of 0.006 which means that there is an association between smoking behavior with lung function impairment among online taxi-bike drivers. Meanwhile, out of 128 drivers who always use masks as PPE, there are 25.8% of online taxi-bike drivers who have abnormal lung function. The results showed that PPE use behavior was not significantly associated with lung function impairment among online taxi-bike drivers in Medan City with a p -value of 0.332.

Based on the inhaled intake at the maximum PM10 concentration ($40.10 \mu\text{g}/\text{m}^3$), there were 71 online taxi-bike drivers with inhaled intake of $\geq 0.0048 \text{ mg}/\text{kg}/\text{day}$, of which 21.1% had abnormal lung function. For the minimum PM10 concentration in Medan City ($23.20 \mu\text{g}/\text{m}^3$), there are 73 online taxi-bike drivers with inhalation intakes of $\geq 0.0028 \text{ mg}/\text{kg}/\text{day}$, of which 27.4% have impaired lung function. The results of bivariate analysis show that there is a significant association between the maximum concentration of PM10 ($40.10 \mu\text{g}/\text{m}^3$) or PM10 inhaled intake $\geq 0.0048 \text{ mg}/\text{kg}/\text{day}$ with impaired lung function in online taxi-bike drivers in Medan City ($p=0.045$), while the minimum concentration of PM10 ($23.20 \mu\text{g}/\text{m}^3$) or PM10 inhaled intake $\geq 0.0028 \text{ mg}/\text{kg}/\text{day}$ is not associated with impaired lung function in online taxi-bike drivers ($p=0.464$).

Discussion

Association of Individual Characteristics with Lung Function Impairment Among Online Taxi-bike Drivers in Medan City

The results of this study showed that age is significantly associated with lung function impairment among online taxi-bike drivers in Medan City ($p=0.001$). The majority of online taxi-bike drivers aged 40 years and older have abnormal lung function (75.6%), whereas most drivers aged 30–40 years have normal lung function (96.8%). This is consistent with research conducted by Damayanti et al. (2019) which found that there was a significant relationship between age and FVC ($p=0.001$) and FEV1 ($p=0.039$) values among online taxi-bike drivers in Bekasi City, Indonesia, where a decrease in FVC and FEV1 values was more common in drivers aged 40 years



and older. Another study conducted by Samana et al. (2024) also mentioned that age is one of the factors that increase the risk of impaired lung function ($p < 0.001$), besides smoking and inhaled dust concentration. Aging is one of the main factors that significantly affects lung function. Lung maturity is reached at around 20–25 years old, and thereafter lung function progressively declines due to decreased chest wall elasticity, loss of lung tissue elasticity, and weakened respiratory muscles. This makes older individuals more susceptible to respiratory symptoms compared to younger individuals. Therefore, FVC and FEV1 parameters will generally decrease gradually with age. FEV1 in particular decreases by about 20 ml/year in the age of 25–39 years and reaches a decline of 35 ml/year after the age of 65 years (S. J. Cho & Stout-Delgado, 2020). Meanwhile, an average decrease of about 20–25 ml of FVC occurs after the age of 40 years. Gas exchange will also tend to decrease with age, especially after the age of 40 years, due to reduced alveolar surface area and decreased blood flow in pulmonary capillaries which can cause respiratory symptoms such as breathing difficulties due to decreased lung diffusion capacity (H. E. Cho, 2023). According to the American Lung Association (2024), the risk of lung function decline that contributes to the development of COPD is greater in individuals aged 40 years and older and increases with age, compared to individuals aged less than 40 years.

Not only age, BMI is also reported to affect lung function. The results of this study showed that BMI was significantly associated with lung function impairment among online taxi-bike drivers in Medan City ($p = 0.006$), where more lung function impairment (35.6%) was found in overweight and obese online taxi-bike drivers ($BMI > 25 \text{ kg/m}^2$) compared to underweight or normal weight drivers (10.4%). McHugh et al. (2020) in their research also found that there is a relationship between BMI with FEV1 value and FEV1/FVC ratio ($p = 0.012$). This is also in line with research conducted by Alamsyah et al. (2022) which revealed that BMI is the most dominant factor affecting lung function abnormalities ($p = 0.003$). The relationship between BMI and lung function has been described previously in various literatures, but the results are inconsistent. Some studies have found that overweight younger adults experience a significantly greater decline in lung function over the next 10 years compared to individuals with a normal BMI. The higher the BMI, the more the lung capacity is reported to decline. Expiratory flow, in particular, will decrease as BMI increases (Barroso et al., 2018). One potential explanation for this finding is that excess fat in obese individuals may create mechanical pressure that causes the diaphragm to push toward the chest cavity, reducing airflow, especially during expiration. Being overweight or obese is also associated with low physical activity which can indirectly affect lung function and overall health (Warkentin et al., 2019). On the other hand, there are studies that suggest both overweight and obesity are protective factors for lung function, and conversely report the risk of decreased lung function in individuals with low BMI. Some of these findings report that poor exercise ability and muscle function in underweight individuals are contributing factors to lung function impairment (Tang et al., 2024).



The results of this study also show that years of work ($p=0.002$) and length of work ($p=0.032$) are significantly associated with lung function impairment among online taxi-bike drivers in Medan City. Abnormal lung function is found more in online taxi-bike drivers with a working period of five years or more (36.6%) compared to drivers who have worked for less than five years (12.5%) and who have a working time of more than 8 hours/day (30.4%) compared to drivers who work for ≤ 8 hours / day (8.7%). This is similar to the study by Samana et al. (2024) who found that there was an association between length of service ($p<0.001$) and impaired lung function among online motorbike taxi drivers in Bangkok, Thailand and other adjacent provinces. The results showed that the decline in FVC and FEV1/FVC values was more common in online motorbike taxi drivers with a working period of more than 10 years compared to drivers who worked for less than five years. Simatupang et al. (2022) in their research also mentioned that online taxi-bike drivers who work more than 9 hours/day have a greater risk of experiencing impaired lung function and various adverse respiratory symptoms. Online taxi-bike drivers have a risk of direct exposure to more air pollution when driving on motorbikes compared to drivers of other closed modes of transport, such as taxis, or trains. According to the formula for analysing exposure to pollutants in inhalable air media, the length of exposure (time of exposure/tE) in hours/day and the duration of exposure in years (Dt) is directly proportional to the intake of pollutants into the individual's body (Dirjen P2PL, 2012). In other words, the longer the working time per day and the longer the working period of online ojek drivers, the higher their exposure to various pollutants in the air, such as NO₂, SO₂, PM, and O₃ (ozone). More frequent exposure with prolonged duration can certainly increase the likelihood of various health risks, including lung function impairment (Simatupang et al., 2022).

In addition to physiological aging, several other factors can accelerate the decline in lung function in adulthood, including smoking behaviour, air pollution, and the presence of other respiratory disorders or conditions (Agusti & Faner, 2019). This study shows that smoking behaviour is significantly associated with lung function impairment among online taxi-bike drivers in Medan City ($p=0.006$), where abnormal lung function is more common among drivers who have a habit of smoking (32.1%), compared to those who do not smoke (6.9%). The results of this study are in line with research by Samana et al. (2024) who also found that there is an association between smoking behaviour and decreased lung function in online motorbike taxi drivers in Bangkok, Thailand and other adjacent provinces. The number of cigarettes per day was negatively correlated with percent predicted FEV1 ($r = -0.1270$; $p=0.019$) and FEV1/FVC ($r = -0.1159$; $p=0.032$), indicating that drivers who smoked large amounts of cigarettes tended to have smaller FEV1 and FEV1/FVC values or worse lung function decline. Monica et al. (2021) in their research also showed that smoking behaviour was significantly associated with lung function in online motorbike taxi drivers in the DKI Jakarta, Indonesia ($p=0.001$), where drivers who were moderate smokers mostly (54.5%) experienced impaired lung function characterized by complaints of dyspnea. Another study conducted by Ramadhan & Hartono (2020) also suggested that online taxi-bike drivers with heavy smoking had a 3.5 times greater risk ($p=0.032$) of experiencing COPD characterized by progressive decline in lung function, compared to drivers who were light smokers.



Smoking is a well-established risk factor for chronic lung disease and is also strongly associated with a greater and more rapid risk of lung function decline. Smokers have a higher prevalence of respiratory symptoms and lung function abnormalities, more severe annual FEV1 decline, and greater mortality from COPD compared to non-smoking individuals (GOLD, 2024). This is because cigarettes contain various harmful substances, such as nicotine, tar, and carbon monoxide, as well as free radicals which, when exposed for a long period of time, can accumulate and cause chronic inflammation of the airways and damage to the alveolus which ultimately results in decreased lung function (Agusti & Faner, 2019).

Time and frequency of exposure to air pollutants can be controlled by using masks as personal protective equipment. Research conducted by Soeroso et al. (2020) suggested that the use of masks, including surgical masks ($p=0.002$), carbon masks ($p<0.001$), and N95 masks ($p<0.001$) proved effective in reducing exposure to air pollution as indicated by a decrease in the average level of carbon monoxide inhaled after wearing it for 8 hours. Cherrie et al. (2018) in their study also reported that the use of masks can effectively protect against urban air pollution, especially masks that have filter materials that can protect against small pollutant particles. However, the results of this study showed that there was no significant association between the use of PPE (masks) with lung function impairment among online taxi-bike drivers in Medan City ($p=0.332$). This is in line with research by Roffana et al. (2023) who found that the use of masks during work was not significantly associated with lung health in online taxi-bike drivers in Denpasar City, Indonesia ($p=0.000$). Research conducted by Damayanti et al. (2019) also showed that the use of personal protective equipment was not associated with obstructive ($p=0.450$), nor restrictive ($p=0.290$) lung function impairment in online motorbike taxi drivers in Bekasi City, Indonesia. Ramadhan & Hartono (2020) in their study also reported that PPE use behaviour was not associated with the risk of chronic lung disease with decreased lung function, specifically COPD, among online taxi-bike drivers in Bogor City and Depok City, Indonesia ($p=0.254$). In this study, most (92.8%) online taxi-bike drivers in Medan City always use masks as personal protective equipment when driving while working, but among drivers who use masks, there are still quite a lot (25.8%) who have abnormal lung function. This can be caused by the quality and type of masks used that are not able to filter fine pollutant particles such as PM10 or improper use of masks. High intensity of exposure to pollutants accompanied by long-term exposure duration is also another factor that can weaken PPE protection. In addition, the presence of other more dominant risk factors such as age, smoking, medical history and so on can also more significantly affect lung function impairment despite PPE use.

Association of Particulate Matter (PM) Exposure with Lung Function Impairment Among Online Taxi-bike Drivers in Medan City

Air pollution, which commonly consists of particulate matter (PM), ozone, NO₂ or SO₂, and other pollutants, is a major risk factor for lung function decline in non-smoking individuals. Even in areas with low levels of ambient air pollution, chronic exposure to PM_{2.5} and nitrogen dioxide can significantly inhibit lung development and maturity in children, accelerate lung



function decline in adults, and increase the risk of COPD, particularly in individuals with pre-existing risk factors (GOLD, 2024). PM₁₀, one of the air pollution particles that is 10 µm or smaller in diameter, can be inhaled and deposited in the respiratory tract or deeper into the lungs, putting it at risk of causing various respiratory disorders and in long-term exposure can lead to decreased lung function. The average concentration of PM₁₀ recommended by WHO should not exceed 45 µg/m³ in 24 hours to prevent adverse health effects (WHO, 2024a).

Based on air quality monitoring data of Medan City obtained using Air Quality Monitoring System (AQMS) for 24 hours at three monitoring locations including Gajah Mada Park Station, Rusunawa Kayu Putih Station, and Bida Office Station, the highest PM₁₀ dust concentration in Medan City is 40.10 µg/m³ and the minimum is 23.20 µg/m³. Based on the calculation of the amount of PM₁₀ inhaled intake at maximum and minimum concentrations by entering all variables of inhalation rate, duration of exposure, frequency of exposure, duration of exposure, and body weight of online taxi-bike drivers into the formula, the median maximum and minimum intake values are 0.0048 mg/kg/day and 0.0028 mg/kg/day, respectively. The results of the analysis show that there is a significant relationship between the inhaled intake of PM₁₀ ≥0.0048 mg/kg/day (on maximum concentration of PM₁₀ (40.10 µg/m³)) and lung function impairment among online taxi-bike drivers in Medan City ($p=0.045$), while the inhaled intake of PM₁₀ ≥0.0028 mg/kg/day (on minimum concentration of PM₁₀ (23.20 µg/m³)) is not associated with lung function impairment among online taxi-bike drivers ($p=0.464$). This indicates that the greater the concentration of PM₁₀ in the air, the longer and more frequent the exposure, the greater the value of PM₁₀ inhaled intake that can cause a decrease in lung function among online taxi-bike drivers. The results of this study are consistent with research by Arphorn et al. (2018) which found that lung function impairment characterized by low FEV₁/FVC values in online motorbike taxi drivers in Bangkok, Thailand, was associated with long-term exposure to PM₁₀ with concentrations ≥50µg/m³ ($p<0,001$). Samana et al. (2023) in their study also showed that exposure to PM₁₀ with average concentrations ranging from 11–70 µg/m³ for 24 hours was negatively associated with the percentage of FVC in online motorbike taxi drivers in Bangkok, Thailand and other adjacent provinces ($p<0.05$). This means that the higher the concentration of inhaled pollutants, the lower the lung function as seen from the FVC value. Another study conducted by Samana et al. (2024) in other provinces in Thailand suggested that although there was no significant correlation between the average concentration of respirable PM₁₀ and abnormalities in lung function parameters in online motorbike taxi drivers, the results showed that in Pathum Thani Province, which has the highest average concentration of PM₁₀ among the six provinces studied, online motorbike taxi drivers who experience lung function abnormalities were found the most (37.8%), which indicates that there is an association between the average concentration of PM₁₀ and lung function abnormalities.



Conclusion and Recommendation

The prevalence of impaired lung function among online taxi-bike drivers in Medan City is 26.8%. The results showed that age, BMI, years of work, length of work, smoking behaviour and inhaled intake of PM10 ≥ 0.0048 mg/kg/day on maximum concentration of PM10 ($40.10 \mu\text{g}/\text{m}^3$) were associated with lung function impairment, while the behaviour of using masks as personal protective equipment and inhaled intake of PM10 ≥ 0.0028 mg/kg/day on minimum concentration of PM10 ($23.20 \mu\text{g}/\text{m}^3$) were not significantly associated with lung function impairment among online taxi-bike drivers in Medan City.

Researchers recommend that online taxi-bike drivers in Medan City who have impaired lung function or have other symptoms of respiratory problems should undergo an examination to get treatment. Online taxi-bike drivers are also expected to continue to use masks with efficient quality as personal protective equipment while working, and use them properly and consistently. For the local government of Medan City, the researcher suggests that regular vehicle emission tests be conducted as well as maintaining and preserving green open spaces as an effort to reduce air pollution in Medan City. The Medan City Government is also expected to facilitate education about health, especially about lung health to online taxi-bike drivers in Medan City so that they can maintain and improve lung health and their overall health independently.

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