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Demographic Factors and BMI on Declined Lung Function and Vitamin D Levels in Active Smokers

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Abstract

Cigarettes are one of the causes of health problems in the world. Smoking has been known to have a direct impact on reducing lung function. Smoking increases the risk of vitamin D deficiency. Vitamin D is a vital nutrient as a lung immunomodulator. Deficient levels will cause problems with lung health, especially in active smokers. This cross-sectional research using multivariate path analysis and the SEM-PLS method has three objectives. The direct influence of three independent variables, including obesity, smoking, and demographics. Regarding vitamin D status and lung function, analyzing the direct effect of vitamin D on lung function, and thirdly, analyzing the indirect one of the three independent variables on lung function through vitamin D levels. This research took time from October 2023 to January 2024 and involved 47 active smoker respondents whose vitamin D level status and lung function were measured. There was a significant direct effect of obesity level on vitamin D levels in the active smoker population ($p<0.05$;f-square=2.889). While demographic factors ($p>0.05$;f-square=0.030) and smoking frequency ($p>0.05$;f-square=0.003) did not have a direct significant effect. Demographic factors, obesity, and smoking frequency don't have significant direct effect on lung function in active smokers ($p>0.05$).

Introduction

Indonesia is one of the countries with the highest number of smokers in the world. Based on data from the 2021 Global Adult Tobacco Survey (GATS) released by the Ministry of Health of the Republic of Indonesia (KEMENKES RI), the smoking prevalence of the adult population in Indonesia reached 33.5% in 2021 with an addition of 8 million people over the last 10 years (CDC, 2021). Exposure to cigarette smoke can cause inflammation of the airways and accumulation of mucus in the lungs, resulting in symptoms of shortness of breath and accelerating the decline in lung function. It is often associated with the emergence of lung diseases such as lung cancer, chronic obstructive pulmonary disease (COPD), asthma, and tuberculosis (Chung *et al.*, 2023). Smokers experience decreased lung function compared to non-smokers, which can be measured using spirometry through a decrease in forced expiratory volume in 1 second (FEV1) values reaching >50 mL per year (Lorensia *et al.*, 2021). The higher the intensity of smoking, the lower the rate of decline in FEV1 and FVC. Greater than non-smokers.8 Further reduction in lung function due to smoking will have an impact on various lung health problems, such as COPD, including emphysema, chronic bronchitis, and asthma (Tian *et al.*, 2023).

Another mechanism that also plays a role in causing damage or decreased lung function is the involvement of levels of a vitamin in the body, namely vitamin D. Vitamin D has a protective mechanism for lung function

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through increasing the secretion of the antimicrobial peptide cathelicidin, decreasing chemokine production, inhibiting dendritic cell activation and changing cell activation. T. This cellular mechanism is vital for the response of the lung organ to the threat of infection and the development of allergic lung diseases such as asthma (Bishop *et al.*, 2020). A decrease in the production of the inactive form of vitamin D (25(OH)D) in lung epithelial cells is thought to be caused by exposure to smoke due to smoking activities (Lorensia *et al.*, 2024). A meta-analysis result by Yang *et al.* (2021) of 24 studies with 11,340 participants showed that levels of vitamin D in the inactive form 25(OH)D were lower in smokers than non-smokers (Yang *et al.*, 2021). In addition, the expression level of vitamin D receptors can also be influenced by exposure to cigarette smoke (Ahn *et al.*, 2021). A study by Ghosh *et al.* (2020) also stated that vitamin D deficiency plays a role in changes in lung structure and decreased lung function.

There are other influencing factors that can be part of the impact of decreased lung function besides smoking, namely, obesity. Individuals who are obese show reduced lung volume and capacity when compared to people of normal weight. Larger fat deposits in the abdominal area produce greater resistance to diaphragm contraction, thereby inhibiting respiratory ventilation mechanisms (Cao *et al.*, 2022). Based on the explanation above, several previous studies have been conducted that examined the effect of vitamin D on lung function. However, there have been no studies that have examined this by involving factors such as obesity levels, smoking, and demographics in Indonesia, which is one of the countries with the highest prevalence of smoking, accompanied by consequences in the form of increased death rates and lung disease sufferers due to smoking. Therefore, research will be carried out that will examine the influence of demographic factors, BMI, and smoking intensity, on the decline in lung function and vitamin D levels in active smokers. There is a study by Abi-Ayad *et al.* (2023) who measured smokers' vitamin D levels using blood plasma samples, found that vitamin D deficiency was associated with lower lung function conditions, lung function in this case FEV1, FVC, and FEV1/FVC measured using a spirometer experienced faster decrease in smoking subjects. It shows that adequate serum vitamin D levels are associated with a protective effect against the detrimental effects of smoking on lung function.

Method

This study used an observational clinical trial with a cross-sectional design where the data collection stage was carried out once at a time. The independent variables in this study were demographic factors, BMI, and smoking intensity. The dependent variable in this study was the lung function value (percentage of FEV1/FVC ratio). The mediating variable in this study was vitamin D levels. Demographic factors consist of age and education level. Age is a measure of the patient's length of life, which is calculated based on the patient's date of birth until they become a research respondent. Educational level is a measure of the respondent's level of education as evidenced by possession of the latest educational certificate. Body Mass Index, or BMI, is a value obtained from the mass and height of each sample individual. BMI can be calculated using a formula by dividing the individual's body weight in kilograms (kg) by the square of body height in meters squared (m^2) (Weir & Jan, 2023). Smoking intensity is the habit of smoking tobacco cigarettes. Smoker classification can be calculated using the Brinkman Index (IB)=number of cigarettes smoked per day x length of smoking (years) (Herath *et al.*, 2022). Lung function measurements using a handheld spirometer. The level of lung function impairment based on the percentage of the FEV1/FVC ratio is divided into 4 categories, namely normal-mild obstruction, moderate obstruction, severe obstruction, and very severe obstruction (Stanojevic, 2021).

The vitamin D levels that will be measured are the most abundant metabolite form in serum, namely 25(OH)D, 25(OH) levels reflect skin production of vitamin D3 and vitamin D (D2 and D3) from food, 25(OH) D has a half-life (The long t½) in the blood circulation is 3-4 weeks compared to the active vitamin D metabolite 1,25(OH)2D which only has a short t½ of around 4-6 hours (Tuckey *et al.*, 2019). Methods for observing vitamin

D levels (25(OH)D), which are the ELFA (Enzyme Linked Fluorescent Assay) method used is the VIDAS tool from bioMerieux. The type of specimen that can be used in testing can be serum or blood plasma. In this study, serum 25(OH)D levels were classified as deficient (<20 ng/mL), insufficiency (20-29 ng/mL), and normal (30-100 ng/mL) (Ahn *et al.*, 2021; Amrein *et al.*, 2020).

The population is active smokers located in the Mejoyo area, Rungkut District, Surabaya City. The accessible population is active smoking respondents in the Mejoyo 2 RT 6 Surabaya area who have filled out the questionnaire, can be found, and are not included in the exclusion criteria. The sample in this study was part of the affordable population who met the criterias: (1) aged 18-60 years; (2) didn't use vape; (3) no history of COVID-19 infection; (4) no history of diseases or conditions that can affect serum vitamin D levels; (5) not taking supplements containing vitamin D during the last 1 month before checking 25(OH)D levels; and (6) no history of diseases or conditions that can affect lung function. The minimum number of samples was calculated using the Slovin method. So the number of samples required in this research was 45 people. The sampling technique was purposive sampling.

The first meeting involved a recording of demographic data for the entire sample through a direct interview process with research respondents, and then continued with measuring height and weight. The researcher measured the height of the sample using a height measuring device with the Onemed brand type HT701 Wireless. Body weight measurements were carried out by researchers using a SPEEDS brand digital weight scale, type LX040-8 USB, which has a sensitivity of one digit after the comma. Lung function measurements were carried out by researchers who had received special training from clinicians using a Contec SP10 handheld spirometer to obtain FEV1 and FVC values. The lung function measurement procedure for each respondent was repeated 3 times. The results in milliliters (mL) are recorded to calculate the percentage of the FEV1/FVC ratio. Measurement of Vitamin D or 25(OH)D levels using the VIDAS® 25 OH Vitamin D TOTAL (VITD) tool with the ELFA technique carried out by a standardized laboratory in Surabaya.

The aim of carrying out multivariate analysis is to determine the magnitude of the influence between variables determined based on the P_{value} and $t_{statistic}$ value using the Structural Equation Modeling with Partial Least Squares (SEM-PLS) method with the help of the SmartPLS application. SEM-PLS is a powerful analysis method and is often referred to as soft modeling, because it eliminates the assumptions of Ordinary Least Square (OLS) regression such as data must be normally distributed in a multivariate manner and there is no problem of multicollinearity between independent variables, SEM-PLS can be used to testing weak theories and weak data (small samples and data normality problems). The analysis of the magnitude

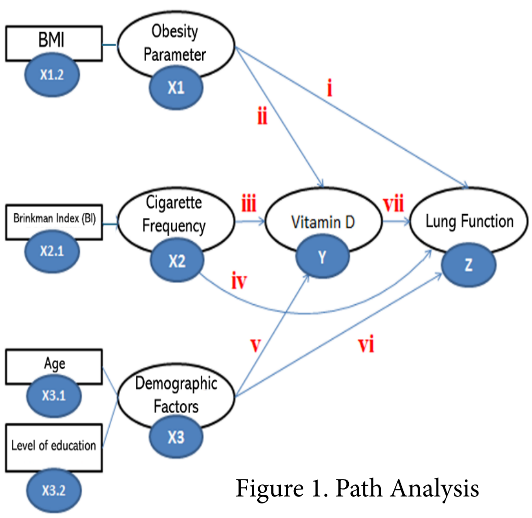


Figure 1. Path Analysis

Information :

i. Direct influence of obesity level on lung function
ii. Direct influence of obesity level on vitamin D levels
iii. Direct effect of smoking on vitamin D levels
iv. Direct effect of smoking on lung function
v. Direct influence of demographics on vitamin D levels
vi. Direct influence of demographics on lung function
vii. Direct influence of vitamin D levels on lung function

of the effect in this research will estimate the value of the P_{value} and also the value of the $t_{statistic}$. If the test results show a $P_{value}<0.05$ and a $t_{statistic} \geq t_{table}$ value, then the influence of the two variables is said to be significant. It comes along with the conclusion that there is an influence of the independent variable on the dependent variable of active smoking. However, if the $P_{value}>0.05$ and the $t_{statistic}<t_{table}$ value, then the influence of the two variables is said to be insignificant, with the conclusion that there is no influence of the independent variable on the dependent variable in active smokers. An overview of the path analysis model used in the research can be seen in **Figure 1**.

Result and Discussion

This research was conducted from October 2023 to March 2024, located in the Mejoyo 2 RT 6 Surabaya, Kalirungkut, East Surabaya. This research has received an ethical certificate number 232/KE/IX/2023 from the University of Surabaya. Based on the preliminary study, the affordable population was 54 smokers in the area, and 47 people were willing and met the research subject criteria. Most of the respondents were the largest early elderly, 23 respondents (48.93%). Based on BMI measurements, the normal BMI group was the largest, namely 29 respondents (61.70%). Based on the measurement of education level, the Secondary Education group was the largest, namely 20 respondents (42.55%). Based on smoking frequency, the moderate smoker group was the largest, namely 27 respondents (57.44%). Data on the distribution of respondents' characteristics can be seen in Table 1.

In this study, vitamin D (25(OH)D) levels were measured in 47 respondents using the ELFA method with the VIDAS® tool from Biomerieux. Based on the classification of vitamin D levels of the total respondents measured, the insufficiency group was the largest group with 23 respondents (48.93%). The results of the percentage value of the FEV1/FVC ratio, of the total respondents who were measured, the moderate obstruction group had the largest, namely 21 respondents (44.68%) (**Table 2**).

The implementation of multivariate statistical analysis in this research was carried out using a quantitative technical approach, where there were two analyzes used, namely descriptive analysis and hypothesis testing or statistical analysis using the Partial Least Square (PLS) method using the SmartPLS program. There are 5 (five) variables involved in this research, which include obesity levels, smoking, demographics, vitamin D, and lung function.

Table 1. Demographic Profile of Respondents

		Frequency (n=47)	Percentage (%)	x̄ ±SD
Age (years)	Late Adulthood (36-45)	10	21.27	51.20±6.43
	Early Seniors (46-55)	23	48..93	
	Late Seniors (56-60)	14	29.78	
Level of education	Basic Education (elementary school-junior high school)	19	40.42	
	Secondary Education (senior high school)	20	42.55	
	higher education	8	17.02	
BMI (kg/m²)	Normal (18.5-25.0)	29	61.70	
	Fat (Overweight) (25.1-27.0)	14	29.78	
	Obesity (>27)	4	8.51	
Brinkman Index (BI)	Light (<200)	14	29.78	
	Moderate (200-599)	27	57.44	
	High (>600)	6	12.76	

x̄ = average; SD= standard deviation
Source: Primary Data, 2024

Table 2. Distribution of Vitamin D and Lung Function Examination

		Frequency (n=47)	Percentage (%)	x̄ ±SD
Vitamin D Classification -25(OH) D Content (ng/mL)	Deficiency (<20)	15	31.91	23.52±8.75
	Insufficiency (20-29)	23	48.93	
	Normal (30-100)	9	19.14	
Lung Function Classification (FEV1/ FVC ratio) (%)	Normal-Mild Obstruction (≥ 80)	7	14.89	95.43±5.72
	Moderate Obstruction (50-79)	21	44.68	
	Severe Obstruction (30-49)	10	21.27	
	Very Severe Obstruction (<30)	9	19.14	

x̄ = average; SD= standard deviation
Source: Primary Data, 2024

The research model evaluation stage in PLS consists of measuring model evaluation and structural model evaluation. The measurement model in this research consists of a reflective measurement model for the variables Levels of Obesity, Smoking, Demography, Vitamin D, and Lung Function by examining loading factor values ≥0.50, composite reliability ≥0.60, and average variance extracted (AVE) ≥ 0.50. The level of obesity is measured by BMI **(X1.2)**, where the outer loading value is between 0.688-0.936, which shows that BMI is strongly correlated in explaining the obesity level variable. Every change in BMI on obesity levels has a more significant effect. The smoking variable is measured from the Brinkman index (IB) of smoking frequency **(X2.1),** where the outer loading value is between 0.243-0.996, which shows that IB is correlated in explaining the smoking variable. The level of reliability of the motivation variable is well accepted, with a composite reliability value (0.618)>0.60. Any change in smoking frequency on smoking activity has a more significant effect.

Demographic variables are measured by 2 (two) indicators, namely age **(X3.1)** and education level **(X3.2),** where the outer loading value is between 0.243-0.996, which shows that these two indicators correlate in explaining the obesity level variable. The level of reliability of the motivation variable is acceptable, even though the composite reliability value (0.406) is <0.60, but has an AVE value close to 5.0. Between the two measurement indicators, the validity of demographic variables appears to be more strongly reflected by the education level indicator **(X3.3).** It means that every change in age demographics has a more significant effect. The vitamin D variable is measured directly with 1 (one) indicator, namely the 25(OH)D level, where the outer loading value is 1,000, which shows that this indicator has a strong correlation in explaining the vitamin D variable. The level of reliability of the vitamin D variable is acceptable, with the composite reliability value (1,000)>0.60. The validity measurement of the vitamin D variable looks strong, as reflected by the 25(OH)D level indicator **(Y)**. The lung function variable is measured directly with 1 (one) indicator, namely the P_{value} of the percentage of the FEV1/FVC ratio, where the outer loading value is 1,000, which shows that this indicator has a strong correlation in explaining the lung function variable. The level of reliability of the vitamin D variable is acceptable, with a composite reliability value (1,000)>0.60. The validity measurement of lung function variables appears to be strong, as reflected by the percentage indicator of the FEV1/FVC ratio **(Z)**.

Structural model evaluation is a form of evaluation to determine the influence of various endogenous variables on exogenous ones by observing the R-square (R^2) value (coeffecient determination), if the R^2value=0.19 then the exogenous influence on the endogenous is weak,

Table 3. Evaluation Results of Reflective Measurement Model, Inner VIF Measurement

Variables	Measurement Item Code	Indicators	*Outer Loading*	*Composite Reliability*	AVE	VIF
Obesity Rate	X1.2	BMI	0.936	0.802	0.675	1.178
Cigarette Frequency	X2.1	Smoking Frequency	0.996	0.618	0.525	1.024
Demographics	X3.1	Age	0.137	0.406	0.485	1.007
	X3.2	Level of education	0.975			1.007
Vitamin D	Y	25(OH)D levels	1.000	1.000	1.000	1.000
Lung Function	Z	FEV1/FVC ratio	1.000	1.000	1.000	1.000

AVE=*average variance extracted; BMI=Body Mass Index;* FEV_1*=Forced Expiratory Volume in 1 second; VIF = Variance Inflated Facto*
Source: Primary Data, 2024

if the R^2value=0.33 the exogenous influence on the endogenous is moderate, if the R^2value=0.67 the exogenous influence on the endogenous is strong. Next, hypothesis testing is carried out to find out the significance of the influence of the observed research variables by observing the path coefficient value. The influence of the level of obesity, smoking, and demographics on vitamin D, with an R^2value of 0.782, means that the endogenous variable vitamin D is influenced by 78.2% by the exogenous variables the level of obesity, smoking, and demographics, while 21.8% is influenced by other factors outside the variable. It can be concluded that the influence of exogenous variables on endogenous variables is strong. The influence of the level of obesity, smoking, demographics, vitamin D on lung function with an R^2value of 0.190, meaning that the endogenous variable lung function is influenced by 19% by the exogenous variable the level of obesity, smoking, demographics, and vitamin D, while 81% is influenced by other factors in outside the variables studied. It can be concluded that the influence of exogenous variables on endogenous variables is weak.

Next, the evaluation of the structural model with path coefficients was carried out in three stages: The first stage, namely checking the absence of multicollinearity between variables and the inner VIF (Variance Inflated Factor). If the estimation results show an inner VIF value <5, then the level of multicollinearity between variables is low. All indicators have an inner VI value <5, so the estimates of all variables and indicators in SEM-PLS are not robust (not biased). The second stage, hypothesis testing, is carried out between variables by looking at the $t_{statistic}$ value and P_{value}. If the $t_{statistic}$ = calculation result is greater than the t_{table} (2.0166) and the P_{value} of the test results is <0.05, then there is a significant influence between the variables. The third stage, analysis of the results of the f-square value is carried out, namely the influence of variables at the structural level with the criteria f-square 0.02 ≤ no effect, 0.02 ≤ f-square ≤0.14 small effect, 0.15 ≤ f-square ≤ 0.35 has a medium effect, and >0.35 has a high effect. The patch coefficient assesses the magnitude of the direct influence of exogenous variables on endogenous variables; the magnitude of the influence ranges from -1 (negative influence) to +1 (positive influence).

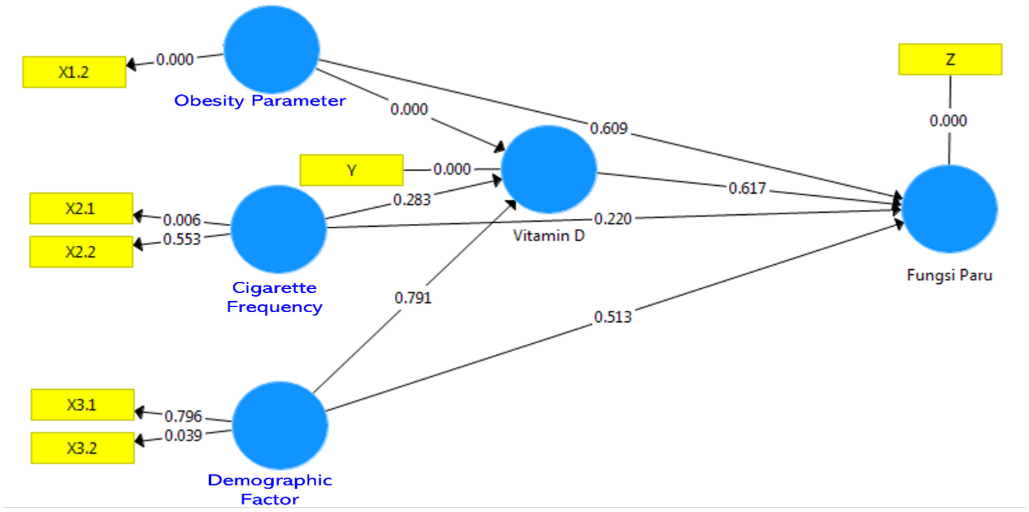
Hypothesis testing is not only direct observation between exogenous variables and endogenous variables, but also tested indirectly through mediating variables (vitamin D). The SEM-PLS model can also be useful as a predictor in developing strategies to improve health promotion related to the influence of obesity, smoking, and demographic factors on lung function and vitamin D levels directly, as well as on lung function indirectly through vitamin D levels in active smokers. Education provided in terms of increasing vitamin D (25(OH)D) levels is by reducing body weight through BMI indicators and reducing the frequency of smoking. It also applies to implementing education to improve lung function by improving or increasing vitamin D levels (Figure 2).

Body mass index (BMI) is the ratio of body weight to height squared. Most of the respondents had normal BMI values, namely 29 respondents (61.70%) and safe limit abdominal

Table 4. Structural Model Evaluation Results, consisting of Research Hypothesis Testing and Effect Size (f-square)

	Hypothesis	*Path coefficient*	$t_{statistic}$	P_{value}	*f-square*	Interpretations
Direct Hypothesis	Is there a direct effect of obesity level on vitamin D in active smokers?	0.908	9.497	0.000	2.889	There is a direct influence of the level of obesity on vitamin D levels in active smokers. The significant influence of the level of obesity on vitamin D has a high influence value.
	Is there a direct effect of the level of obesity on lung function in active smokers?	-0.090	1.076	0.283	0.030	There is no direct effect of the level of obesity on lung function in active smokers. The obesity level variable on vitamin D has a moderate influence value.
	Is there a direct effect of smoking on vitamin D in active smokers?	0.030	0.265	0.791	0.003	There is no direct effect of smoking on vitamin D in active smokers. The cigarette variable on vitamin D has a small influence value.
	Is there an effect of smoking on lung function in active smokers?	0.815	0.512	0.609	0.161	There is no direct effect of smoking on lung function in active smokers. The smoking variable on lung function has a small influence value.
	Is there a direct influence of demographics on vitamin D in active smokers?	-0.319	1.229	0.220	0.098	There is no direct influence of demographics on vitamin D in active smokers. Demographic variables on vitamin D have no influence.
	Is there a direct influence of demographics on lung function in active smokers?	0.122	0.654	0.513	0.016	There is no direct influence of demographics on lung function in active smokers. Demographic variables on lung function have no influence value.
	Is there a direct effect of vitamin D on lung function in active smokers?	-0.791	0.500	0.617	0.168	There is no direct effect of vitamin D on lung function in active smokers. The vitamin D variable on lung function has a moderate influence value.
Indirect Hypothesis	Is there an effect of obesity level on lung function through vitamin D levels in active smokers?	-	0.256	0.798	-	There is no influence of obesity level on lung function through vitamin D levels in active smokers. Vitamin D does not mediate the indirect relationship between obesity level and lung function.
	Is there an effect of smoking on lung function through vitamin D levels in active smokers?	-	1.087	0.277	-	There is no effect of smoking on lung function through vitamin D levels in active smokers. Vitamin D does not mediate the indirect relationship between smoking and lung function.
	Is there a demographic influence on lung function through vitamin D levels in active smokers?	-	0.454	0.650	-	There is no demographic influence on lung function through vitamin D levels in active smokers. Vitamin D did not mediate the indirect relationship between demographic variables and lung function.

Source: Primary Data, 2024



Source: Primary Data, 2024

Figure 2. SEM-PLS Model After Boostrapping with P_{value} = between Variables Based on SmartPLS analysis

circumference of 38 respondents (80.85%). It is supported by the results of research in Indonesia which analyzed the BMI picture and found that the majority of respondents had a normal BMI of 45%. 75 Another study in Indonesia which aimed to find out the factors related to the incidence of central obesity in adults found that there was a prevalence Central obesity with excessive abdominal circumference based on age 25-34 years (22.9%) and 35-44 years (33.5%), indicates that there are more respondents with abdominal circumference within safe limits. The results of this study found 4 respondents (8.51%) in the peripheral obesity category (BMI>27 kg/m^2) and 9 people (19.14%) with central obesity (abdominal circumference >90 cm). Based on the evaluation of the structural model (inner model) using SmartPLS version 3, there was a significant direct influence between the obesity level variable on vitamin D levels ($P_{value}<0.05$ and $t_{statistic}>t_{table}$) in active smokers. It is supported by a theory that states the relationship between obesity mechanisms in causing a decrease in vitamin D levels, including three mechanisms that can explain the relationship between deficiency in vitamin D levels in obese individuals. Individuals who are obese experience decreased exposure to sunlight compared to non-obese individuals (Mirza *et al*., 2022). The release of adiponectin from fatty tissues was inversely correlated with body weight and BMI suggesting a link between vitamin D deficiency and insulin resistance (Kauser *et al*., 2022).

The evaluation of the control model (inner model) found no direct significant influence between the obesity level variable on lung function (P_{value} >0.05 and $t_{statistic}<t_{table}$) in active smokers. 'These results have conclusions that are the opposite of several theories which state that obesity harms the lung organs, one of which is the development of OHS which is defined as a combination of obesity (BMI ≥30 kg/m^2), hypercapnia (arterial CO_2 ≥45 mmHg) and the presence of breathing disorders during sleep which causes alveolar hypoventilation (Masa *et al*., 2019; Palma *et al*., 2022). Research results that are not in accordance with theory or previous research can be caused by only a small portion of respondents being classified as obese, whereas based on lung function examinations also the majority of respondents (44.68%) included in the moderate obstruction category. Individuals who are obese show a decrease in lung volume and capacity when compared to people with a normal body weight, this is because in people with a normal BMI the diaphragm contracts to push the contents of the stomach down and forward without any obstacles from excess fat deposits, when Likewise, contraction of the external intercostal muscles (muscles that play a role in

the inspiration process) can push the ribs up and forward without resistance (Svartengren *et al*., 2020). Therefore, in this study, the majority of respondents had a normal BMI and the majority were in the obstruction category. moderate (27.65%), because the majority of respondents had breathing patterns that were not influenced by obesity.

Most of the smokers were moderate smokers (57.44%). Evaluation of the structural model (inner model) found that there was no direct significant influence between smoking variables on vitamin D levels (P_{value}>0.05 and $t_{statistic}$<t_{table}) in active smokers. Smoking, ultraviolet radiation, and age are considered important factors that contribute to the skin aging process in humans by increasing wrinkles on the skin surface. In addition, tobacco smoke can affect the expression level of vitamin D receptors. If the expression of vitamin D receptors increases, the physiological effects of vitamin D will be better, one of which is the effect on lung function (Yang *et al*., 2021). Most of the respondents fell into the moderate level with IB. Based on the evaluation of the inner control model using SmartPLS, it was found that there was no direct significant influence between smoking variables on lung function (P_{value}>0.05 and $t_{statistic}$<t_{table}) in active smokers. These results have conclusions that are the opposite of several theories, which state that cigarettes contain various dangerous substances and their pathophysiological mechanisms, which can disrupt lung function. Nicotine was found to be chemotactic for human neutrophils, neutrophils being the first cells recruited in the process of lung inflammation due to cigarette smoke, which ultimately causes airway obstruction (Ham *et al*., 2022). Cigarettes cause airway inflammation, which occurs more precisely in the bronchioles, causing lung remodeling. - The lungs lose their elasticity during the air exchange process, which then results in chronic obstructive airway limitations (Karnati *et al*., 2021). Inappropriate research results can be caused by other factors or variables that are not observed but can influence, among others, genetics, physical activity, food intake, knowledge, attitudes, and behavior, sun exposure, skin color, and air pollution.

Patient demographics, which include age and level of education, are one of the factors that have been widely studied and influence the reduction in vitamin D levels. Based on the evaluation of the structural model (inner model), the results found that there is no direct significant influence between demographic variables on vitamin D levels (P_{value}>0.05 and $t_{statistic}$<t_{table}) in active smokers. These results are aligned with the theory regarding demographic relationships, whether studied in terms of age or education level, which can influence vitamin D levels. In terms of age, physiologically an individual can experience a decrease in kidney function, resulting in reducing the production of the active metabolite 1,25(OH)D with increasing age, due to a decline in the activity of the kidney enzyme 1α-hydroxylase which converts 25(OH)D to 1,25(OH)D. Serum 1,25(OH)D levels are inversely proportional to serum creatinine levels and proportional to glomerular function rate (GFR). Aging is not only associated with a decrease in kidney function, but is also associated with a decrease in vitamin D production in the skin, in the form of a decline in the concentration of 7-dehydrocholesterol in the epidermis and a reduced response to UVB light exposure in elderly individuals compared to young adults, resulting in a decrease in the formation of previtamin D3 by 50% (Turner *et al*., 2022; Huish *et al*., 2021). The higher the level of education, the greater the knowledge and awareness of the importance of adequate vitamin D nutrition (Hamhoum & Aljefree, 2022). Therefore, this is a limitation of this research because there are several factors that were not observed but tend to influence vitamin D levels, including the influence of physical activity, knowledge and attitudes towards vitamin D, and genetics.

Age and education level are also considered factors that influence lung function. Based on the evaluation of the inner control model using SmartPLS, there was no direct significant influence between demographic variables on lung function (P_{value}>0.05 and $t_{statistic}$<t_{table}) in active smokers. These results have conclusions that are the opposite of several theories, which state that demographics, both in terms of age and level of education, can influence lung function, especially in active smokers. Other research results show that the older a person is, the lower the FEV1 value will be. In particular, the smaller the FVC value due to advanced age, the more significant the decrease in FEV1/FVC (Thomas *et al.*, 2019). It is different from the results of this study, where there was no influence of demographics on lung function. This result can be caused by factors that influence these two variables (demography and lung function), each of these two variables can be influenced by smoking factors and the level of obesity studied in this study to factors that were not examined in this study but can be contribute to changes in lung function such as physical activity, knowledge, attitudes and behavior, etc. as previously explained.

The largest number of respondents belonged to the vitamin D insufficiency and moderate obstruction group (25.53%). Based on the evaluation of the inner control model, it was found that there was no direct significant influence of the vitamin D variable on lung function (P_{value}>0.05 and $t_{statistic}$<t_{table}) in active smokers. These results have conclusions that are the opposite of several theories, which state that vitamin D can affect lung function, especially in active smokers. It is not aligned with previous theory and research, which states that there is an inverse relationship between vitamin D levels and lung function. Previous research by Ganji *et al.* (2020) involved 11,983 respondents aged ≥20 years. This study combines three NHANES data from 2007-2008, 2009–2010, and 2011–2012. The results of the study concluded that serum 25(OH)D levels were directly related to FVC and FEV1; in other words, serum 25(OH)D levels were associated with improved lung function values in healthy people, but not with the prevalence of asthma, emphysema, and chronic bronchitis. Other research also supports previous research, such as Wannamethee *et al.* (2021), who used a prospective cohort design involving 3575 male respondents (60-79 years), concluded that male respondents with COPD tend to experience vitamin D deficiency when compared to male respondents with normal lung function. In contrast to the results of this study, there was no effect of vitamin D on lung function. This result can be caused by factors that influence these two variables (vitamin D and lung function), each of these two variables can be influenced by obesity, smoking and demographic factors studied in this study to factors that were not studied such as genetics, physical activity, food intake, knowledge, attitudes and behavior, sun exposure, skin color, air pollution.

The results of the evaluation of the structural model (inner model) found that there was no influence of the level of obesity on lung function through vitamin D levels in active smokers. Therefore, vitamin D does not mediate the indirect relationship between obesity levels and lung function. This result could be caused by factors that influence these two variables (vitamin D and lung function), each of these three variables can be influenced by smoking and demographic factors studied in this study to factors not studied such as genetics, physical activity, food intake, knowledge, attitudes and behavior, sun exposure, skin color, air pollution and so on, as previously explained.

This research still has several limitations, including other factors that cannot be controlled such as genetic factors, physical activity, knowledge, attitudes and behavior, intensity of exposure to sunlight, use of sunscreen, air pollution, food intake cannot be controlled in this research so that it can influence the research results. Current knowledge finds that a lack of physical activity is an important risk factor for vitamin D deficiency. Various observational studies show that maintaining vitamin D nutritional status is related to physical activity/exercise habits, where the level of physical activity is significantly positively correlated with 25(OH)D levels (Song *et al.*, 2020; Lorensia *et al.*, 2022). Variations in sun exposure can cause vitamin D levels to fluctuate. Indoor activity may be a factor in these fluctuations and may cause a decrease in vitamin D levels. A systematic review and meta-analysis aimed at identifying whether physical activity or exercise indoors compared to outdoors has a significant effect on vitamin D levels through subgroup analysis and multivariate meta-regression (Bârsan *et al.*, 2023).

Conclusion

Obesity level factors (BMI) have a significant direct effect on vitamin D levels in active smokers. The demographic factors and smoking frequency do not have a direct significant effect on vitamin D in active smokers. Demographic factors, obesity level, and smoking frequency do not have a significant direct effect on lung function in active smokers. Vitamin D has no direct significant effect on lung function in active smokers. Demographic factors, obesity level, and smoking frequency do not have a significant effect on lung function via vitamin D in active smokers. Therefore, it is recommended to maintain body weight and lose weight, especially in obese populations, to reduce the incidence of vitamin D deficiency. So it is necessary to carry out further research on the influence of other factors on vitamin D levels and lung function, such as genetic factors, physical activity, knowledge and attitudes, and behavior, intensity of exposure to sunlight, use of sunscreen, air pollution, and food intake that were not observed in this study to develop theories about the influence of broader factors.

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