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ORIGINAL ARTICLE

The Impact of Indoor Air Quality on Lung Function of the Orang Asli Residing Near Tasik Chini, Malaysia

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ABSTRAK

Kualiti udara dalaman boleh mempengaruhi kesihatan pernafasan penduduk di pelbagai lokasi, termasuklah Orang Asli yang tinggal di kawasan pedalaman. Kajian ini menerokai hubungan antara faktor kualiti udara dalaman dan fungsi paru-paru dalam kalangan populasi Orang Asli yang tinggal di Tasik Chini, Pahang, Malaysia. Semua responden yang memenuhi kriteria kemasukan telah terlibat dalam kajian ini. Soal selidik secara temuduga dan ujian spirometri telah dijalankan. Hasil kajian menunjukkan majoriti responden Orang Asli mempunyai Isipadu Ekspirasi Paksa dalam satu saat (FEV1) (69.2%) dan Kapasiti Vital Paksa (FVC) (82.9%) yang tidak normal. Sebaliknya, 75.8% responden menunjukkan Kadar Aliran Ekspirasi Puncak (PEFR) yang normal dan 99.1% responden mempunyai nisbah Isipadu Ekspirasi Paksa dalam satu saat dan Kapasiti Vital Paksa (FEV1/FVC) (%) yang normal. FEV1 ($r= 0.178$, $p=0.010$), FVC ($r = 0.164$, $p = 0.017$), dan PEFR ($r = 0.256$, $p < 0.001$) mempunyai hubungan yang positif dengan jenis perokok, manakala hanya FVC mempunyai hubungan yang positif dengan persekitaran rumah ($r = 0.166$, $p = 0.016$). Oleh itu, pihak berkuasa kesihatan harus melaksanakan aktiviti yang sesuai untuk melindungi Orang Asli daripada bahaya merokok dan pencemar udara dalaman yang lain.

Kata kunci: Fungsi paru-paru; kualiti udara dalaman; Malaysia; Orang Asli; Tasik Chini

ABSTRACT

Indoor air quality can influence the respiratory health of people in various locations, including the Orang Asli living in the remote rural area. This study explored the correlations between the indoor air quality factors and lung functions among the Orang Asli population living in Tasik Chini, Pahang, Malaysia. All respondents who fulfilled the

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inclusion criteria participated in this study. Interview-guided questionnaire and spirometry test were carried out. The study findings showed that most of the Orang Asli respondents had abnormal Forced Expiratory Volume in one second (FEV1) (69.2%) and Forced Vital Capacity (FVC) (82.9%). In contrast, 75.8% respondents showed a normal Peak Expiratory Flow Rate (PEFR) and 99.1% respondents had a normal ratio of Forced Expiratory Volume in one second and Forced Vital Capacity (FEV1/FVC) (%). FEV1 ($r = 0.178$, $p = 0.010$), FVC ($r = 0.164$, $p = 0.017$), and PEFR ($r = 0.256$, $p < 0.001$) were positively correlated with the type of smoker, while only FVC was positively correlated with the home environment ($r = 0.166$, $p = 0.016$). Thus, the health authority should carry out appropriate activities to protect the Orang Asli from the hazards of smoking and other types of indoor air pollutants.

Keywords: Indoor air quality; lung function; Malaysia; Orang Asli; Tasik Chini

INTRODUCTION

The World Health Organisation (WHO) reported that approximately 4.3 million people a year die because of household air pollution's exposure and over 3 million people reportedly passed away prematurely due to illness that attributed to indoor air pollution from cooking activities using solid fuel (WHO 2022). A high number of populations that count around 3 billion used open fire and simple stoves that use biomass fuel and coal for cooking and heating their house especially during winter period. Among these fatalities, 32% result from ischaemic heart disease, 21% from lower respiratory infections, 23% from stroke, 19% from chronic obstructive pulmonary disease (COPD), and 6% from lung cancer (World Health Organisation 2000).

Respiratory diseases have been linked to inadequate indoor air quality (IAQ) because the respiratory system serves as the primary pathway for the intake and spread of air pollutants. A study was done among the United Kingdom's non-smoker population showed that low birth weight, indoor air pollution (PM2.5 g/mm^3) and overweight are the factors associated with lung impairment. There were several studies that showed significant association between respiratory symptoms especially asthma related symptoms and indoor air pollutants that include volatile organic compounds (VOCs), chemical pollutants, wall painting, gas usage, heating and cooking using solid fuel such as wood or coal, and environmental tobacco smoke (ETS) exposure (Blanc et al. 2005; Jordan et al. 2011; Sarigiannis et al. 2011; Vardoulakis et al. 2020). Indoor air pollution exposure annually leads to 3.8 million premature deaths from non-communicable diseases including COPD, ischaemic heart disease, stroke and lung cancer (WHO 2016).

Lung Function

Lung function refers to the overall capacity and efficiency which the lungs take in oxygen from the air and expel carbon dioxide from the body. It includes several important parameters such as Lung Capacity (the total volume of air that the lungs can hold), Forced Vital Capacity (FVC) (the maximum amount of air that can be forcibly exhaled after taking a deep breath), Forced Expiratory Volume in one second (FEV1) (the volume of air exhaled during the first second of the FVC test, which indicates how quickly the lungs can be emptied) and Peak Expiratory Flow Rate (PEFR) (the maximum speed of exhalation, which can indicate the presence of airway obstruction). These parameters are measured using pulmonary function tests (PFTs) and are crucial indicators of respiratory health.

There are several determinants of lung function. Physiological determinants encompass factors such as age, gender, anthropometric measurements (weight and height) and ethnicity. Age impacts lung function, with lung volume increasing from birth through adulthood. The lungs typically mature between the ages of 20 to 25 years, with minimal changes in lung volume expected after a decade (Sharma & Goodwin 2006). The process of aging may cause gradual alterations in the lung volume and other lung functions after 35 years (Zeleznik 2003). These changes involved enhanced static lung compliance due to decreased alveolar elastic recoil, along with reduced chest wall compliance attributed to stiffening and increased outward recoil of the thoracic cage (Janssens 2005; Mittman et al. 1965). These alterations in lung and chest wall compliances collaborate to induce premature closure of small airways during forced exhalation, which elucidates the heightened residual lung volume observed in older individuals (Mittman et al. 1965).

There are several studies that showed that various ethnicities have different lung volumes. These variations were primarily due to the diverse anthropometric measurements observed across different ethnicities. For instance, individuals of European descent in the United States typically exhibit a higher trunk-to-leg ratio and greater lung volumes compared to individuals of African descent (Rossiter & Weill 1974). The Global Lung Initiative (GLI) has recommended spirometry prediction equations that consider ethnic differences that can be used globally (Quanjer et al. 2012).

Indoor Air Quality

IAQ pertains to the condition of air within and surrounding buildings and structures. Controlling the generation of typical indoor air pollutants is essential for minimising the risks of health related to indoor environments. Health impacts from indoor air pollutants can manifest as acute (short-term) or chronic (long-term) exposures (U.S. Environmental Protection Agency 2021).

Poor IAQ means that there is presence of higher concentrations of different indoor air pollutants that adversely affect the physical and psychological aspects of healthy indoor environment. Indoor air pollutants are categorised into several groups, including those from natural sources (such as radon), biological contaminants (like molds, mildews, fungi, bacteria, viruses, dust mites), combustion emissions (such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO2), respirable suspended particulates (RSP), and ETS), and pollutants from sources within the home (like asbestos, VOCs, lead, and formaldehyde) (IAQ Fact Sheet 2 8/2000).

Exposure to indoor air pollutants, whether single or repeated, can cause short-term health problems like eye, nose, and throat irritation, headaches, dizziness and fatigue, which are typically treatable and of temporary duration. Symptoms like asthma may exacerbate shortly after exposure to specific indoor air pollutants. Certain health issues such as respiratory diseases, heart diseases, and cancer may only become apparent following prolonged or repeated exposure to indoor air pollutants.

Household air pollution primarily stems from the combustion of fuels like wood, animal dung, charcoal, agricultural waste, and kerosene in open fires or inefficient stoves used within and around the household. Approximately 2.4 billion people globally depend primarily on harmful fuels for their cooking, heating, and lighting requirements. Exposure to indoor air pollution resulting from inefficient fuel combustion can result in health problems such as pneumonia in children, COPD, lung cancer, stroke and cardiovascular disease in adults (WHO 2022).

Orang Asli Population in Malaysia

Worldwide, there is an estimated 370 million indigenous people who are inhabitants of more than 70 countries (WHO 2013). There are various ethnics and different tribes of population who lives in different parts of Peninsular Malaysia that consist of Malays, Chinese, Indians and the indigenous people (Orang Asli) (Hood 2006; Lye 2001). The Malaysian Orang Asli represents about 12% of the 28.6 million Malaysian population (The International Work Group for Indigenous Affairs 2011). However, most Orang Asli (76.9%) were still categorised into the lowest group of poverty line. Approximately one third of them (35.2%) fall in the lowest poverty level compared to 1.4% at the national level (Department of Statistics Malaysia 2010). The average life expectancy of the Orang Asli is 53 years, significantly lower than the national average of 73 years (Rusaslina 2010).

The Orang Asli in Peninsular Malaysia constitute 0.6% of the total Malaysian population. They comprised of three large groups which are Senoi, Proto Malay (Aboriginal Malay), and Semang (Negrito), that covers 19 ethnicities (JHEOA 2002; Nicholas 2005) (Figure 1). Since 200 to 300 generations ago, the Orang Asli population had separated. The settlement pattern identified today is a result of this separation of Orang Asli in Peninsular Malaysia. According to Fix (1995), the category of Orang Asli as an ethnic group did not exist before 1960.

For administration purposes, the different Orang Asli ethnicities were classified according to their culture, geographical locations, language, and morphology. The Senoi ethnic is the biggest group, followed by Aboriginal Malay and Semang (Figure 2) (Ang et al. 2011; JHEOA 2010; Lim et al. 2010). The Negritos were the first ethnic group who resided in Southeast Asia. They were described as having a dark skin and curly hair, and they live as hunter-gatherers. It is different with the Aboriginal Malay who has a straight hair, epicanthal folds, and lighter skin color, and make their living as agricultural traders (Fix 1995; Nicholas 2006).

The Senoi has both the characteristics of previously discussed ethnicities. They make their living as both trader and hunter, and it is believed that this tribe

FIGURE 1: Category of ethnicities of Orang Asli in Malaysia (JHEOA 2006)

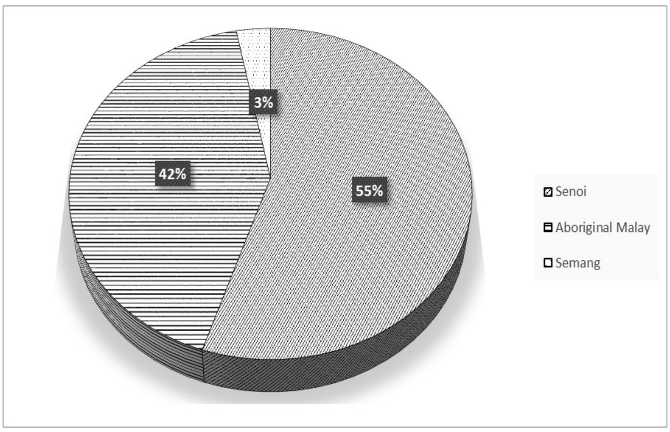

FIGURE 2: The distribution of Orang Asli based on ethnic groups in 2005 (JHEOA 2006)

were a mixture between Negrito and East Asian population. Thus, among their physical characteristics are wavy hair and having a broad range of skin color. The Orang Asli has varied occupations and lifestyle compared to other population. For example, the Orang Laut, Orang Selatar and Mah Meri work as fishermen and live close to the sea. The Temuan, Jakun and Semai people make out their living in agriculture and manage their own farm such as rubber, cocoa, and palm oil farms.

Orang Asli Population in Tasik Chini

Tasik Chini is located at the state of Pahang, West Malaysia. The majority of Orang Asli residing at Tasik Chini belong to the Jakun tribe, which falls under the Proto-Malay ethnicity. The Proto-Malay group comprises six ethnicities: Jakun or Orang Hulu, Temuan, Semelai, Orang Kuala, Orang Kanaq, and Orang Selatar. The Proto-Malay group is further categorised into three groups, including the Melayu Asli ethnic group, who speak Malay and wear traditional Malay attire (such as the Temuan); ethnicities blending cultural and linguistic aspects of Proto-Malay and Senoi; and ethnicities living near the coastal areas, they are mainly Muslims and speaks Sumatran dialects (Fix 1995).

The Jakun or Orang Hulu ethnic group primarily resides in the southern part of Pahang and the northern part of Johor (Figure 3). The Jakun speaking dialect has the same origin as the Austronesian language group such as Malay language. The differences among the Jakun ethnic group, including dialect variations, stem from their interactions with other communities, historical influences, and geographical locations. The Jakun are recognised as a communal society because they live closely together as extended family units in several villages around Tasik Chini. Their lifestyles included agriculture, horticulture and forest collectors. They are also involved in various activities such as fishing, farming, hunting, collecting forests resources and collecting herbs for their own personal use. Some of them are also working under different companies such as logging companies, plantations, and factories (TI-M & Coalition Partners 2012). Most of the Jakun population have no religion (animism) and still practice their ancestral rites and beliefs such as spirit of nature such as mountain, rivers, caves and others. They believed that any disaster that falls upon them and their family or villages are the result of breaching of nature rules (Masron et al. 2013).

FIGURE 3: The geographical placement of Orang Asli settlements in West Malaysia (Masron, Masami & Ismail 2013)

Indoor Air Quality and Orang Asli Population

For a large portion of Orang Asli population, solid fuels remain as significant source of energy for households' usage. Some of the solid fuels used are wood, charcoal, dung, coal, agricultural residues; and some may use kerosene stoves and lamps. It is because these types of fuels are easy to find and cheaper compared to modern fuel such as Liquefied Petroleum Gas (LPG). Cooking fuels among the Orang Asli in Malaysia traditionally include natural resources found in their environment. The choice of cooking fuel among the Orang Asli depends largely on availability, accessibility, and cultural practices. While traditional fuels like wood and charcoal remain prevalent, there is also some adaptation to modern energy sources which are feasible and appropriate.

Most Orang Asli who lived far from the urban area did not receive proper information and have poorer knowledge regarding the health risks and diseases that they might obtain from different types of indoor air pollutants such as from solid fuels. Therefore, the objective of this study was to explore the correlation between lung functions and the IAQ factors among the Orang Asli in Tasik Chini, Pahang. We hypothesised that there would be improved lung function with better IAQ.

MATERIALS AND METHODS

Study Location

This study was conducted in Orang Asli settlement in Tasik Chini, a place located at the state of Pahang, Malaysia. It is a freshwater lake situated near the town of Chini, about 100 kilometers south-west of Kuantan, the capital city of Pahang. Tasik Chini is the second largest natural lake in Malaysia and is known for its biodiversity. There are a total of five villages in which their occupants are the Orang Asli who live near the Tasik Chini. The major villages around Tasik Chini include Kampung Gumum (the main village), Kampung Chendahan, Kampung Tanjung Puput, Kampung Melai and Kampung Ulu Melai. The majority of residents from a total of 70 families who lived close to Tasik Chini were in Kampung Gumum with 39 families. The following villages are Kampung Ulu Gumum with 12 families, Kampung Melai with 3 families, Kampung Ulu Melai with 6 families, along with Kampung Cendahan and Kampung Tanjung Puput, each with 5 families (Ari Kurnia 2010).

Study Design

This is a cross-sectional study to determine the correlations between lung functions and IAQ factors. The correlations were measured between lung function parameters, namely FEV1, FVC, FEV1/FVC, and PEFR and the IAQ parameters, which are health status, smoke exposure, home environment, dust and type of smoker.

Data Collection

Data were collected using an interview-based questionnaire adapted from Jie et al. (2011), while the lung function test was carried out by a trained medical officer using the MicroDirect MicroGP Spirometer. The data collection methods were reported in detail by Mohd Razib et al. (2024).

Measurement of Lung Functions

The lung functions of the participants were assessed using a spirometer following the Advanced Trauma Life Support (ATLS) standard (Ali et al. 1993). Three measurements were recorded, they were FVC, FEV1 and PEFR. FVC represents the maximum amount of air expelled from the lungs after inhaling deeply. FEV1 represents the amount of air forcefully exhaled from the lungs during the initial second of exhalation. PEFR is the maximum flow rate generated during a forceful exhalation, starting from full inspiration. The measurements taken by the spirometry device were used to generate a pneumograph that helps to assess lung conditions. The volume of air breathed in and out during the test was compared to the average for individuals of similar age, height, sex and race. The spirometry results were used to categorise the patient's lung function into one of four classifications of ventilatory function: normal, obstructive, restrictive, or combined. The respondent was considered normal if FEV1 and FVC value was within the normal value, whereas it was considered abnormal if the result showed the respondent had obstructive, restrictive or combined results of spirometry. PEFR is a measure of how fast a person can exhale air from their lungs. It quantifies the maximum speed at which a person can forcefully blow air out of their lungs after taking a deep breath. PEFR is typically measured in liters per minute (L/min) and is used primarily in the assessment and monitoring of lung function, particularly in conditions such as asthma and COPD. PEFR can vary depending on factors such as age, height, sex, and overall lung health. It is often tracked over time to monitor changes in lung function and to assess the effectiveness of treatment interventions. PEFR measurements are typically obtained using a handheld device called a peak flow meter, which provides a numerical value indicating the maximum flow rate achieved during expiration.

Measurement of Indoor Air Quality Factors

Health status scores included previous medical treatment due to respiratory problems, history of childhood asthma and family history of asthma. The total minimum score for the health status factor was 10, while the total maximum score was 23. The higher the score, the better the health status (Table 1).

Smoke exposure scores included smoking habit and smoke exposure to ETS and woodstove. The total maximum smoke exposure score was 6, whereas the

TABLE 1: The studied variables and operational definitions

Item number	Variable	Operational definition
Dependent variable		
1	Forced expiratory volume in one second (FEV1)	Normal: 80% predicted normal; Obstructive: <80% predicted normal; Restrictive: <80% predicted normal; Combined: <80% predicted normal.
2	Forced vital capacity (FVC)	Normal: 80% predicted normal; Obstructive: <80% predicted normal (reduced but to a lesser extent than FEV1); Restrictive: <80% predicted normal; Combined: <80% predicted normal.
3	The proportion of the forced vital capacity exhaled in the first second (FEV1/FVC)	Normal: >0.7; Obstructive: <0.7; Restrictive: >0.7; Combined: <0.7.
4	Peak expiratory flow rate (PEFR)	Peak expiratory flow rate (PEFR) is the maximum flow rate (expressed in Liters per minute [L/min]) generated during a forceful exhalation, starting from full inspiration. Green zone: 80 to 100 percent of your usual or "normal" peak flow rate signaled all clear. Yellow zone: 50 to 80 percent of your usual or "normal" peak flow rate signaled caution. Red zone: Less than 50 percent of your usual or "normal" peak flow rate signaled a medical alert.

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Independent variables		
5	Age	Age was categorized into three groups (18-39, 40-59 and 60 years old) which represented young, middle and old age of the respondents.
6	Gender	Gender as stated in the identification card, either male or female.
7	Health status	Health status factors included previous medical treatment due to respiratory problem, history of childhood asthma and family history of asthma. The median score of health status was the numerical value separating the higher half of the health status score from the lower half. The exposure value was assigned for each source from the questionnaire. The sum of maximum exposure value for health status factor was 23 and the sum of minimum exposure value was 10. The score from 10 to 19 was considered as poor health status and the score from 20 to 23 was considered as good health status.
8	Smoke exposure	Smoke exposure factor included smoking habit and smoke exposure to environmental tobacco smoke (ETS) and woodstove. The median score of smoke exposure was the numerical value separating the higher half of the smoke exposure score from the lower half. The exposure value was assigned for each source from the questionnaire. The sum of maximum exposure value for health status factor was 6 and the sum of minimum exposure value was 14. The score from 6 to 9 was considered as more exposed and the score from 10 to 13 was considered as less exposed.
9	Home environmental	Home environmental factors included condition of the house, usage of woodstove in the house, ventilation, and presence of damp and mold area in the house. The median score of home environmental factor was the numerical value separating the higher half of the home environmental score from the lower half. The exposure value was assigned for each source from the questionnaire. The sum of maximum exposure value for home environmental factor was 30 and the sum of minimum exposure value was 18. The score from 18 to 23 was considered as poor home environment and the score from 24 to 30 was considered as good home environment.
10	Dust in the house	Dust in the house factor included presence of dust or pollen inside the house that can be obtained from long term usage of carpet and mattress, keeping pets with fur and feather in the house and bedroom, and dust acquired from outside the house when windows are opened. The median score of dust in the house factor is the numerical value separating the higher half of the dust in the house score from the lower half. The exposure value was assigned for each source from the questionnaire. The sum of maximum exposure value for dust in the house factor was 22 and the sum of minimum exposure value was 7. The score from 7 to 15 was considered as poor environment and the score from 16 to 22 was considered as good environment.
11	Type of smoker	a) Non-smoker: respondent who had never smoked for more than 6 months continuous period. b) Ex-smoker: respondent who had stopped smoking at least 1 year before this research was conducted. c) Current smoker: respondent wo had smoked at least 100 cigarettes (5 packs) in their lifetime and who smoked on daily basis within the time when this research was conducted (King et al. 2010).

total minimum smoke exposure score was 14. The higher the score, the lesser the exposure to smoke (Table 1).

Home environmental scores included condition of the house, usage of woodstove in the house, ventilation, and presence of damp and mold area in the house. The total minimum exposure score for the home environmental factor was 18, and the total maximum exposure score was 30. The higher the score, the better the home environment (Table 1).

Dust scores included presence of dust or pollen inside the house that can be obtained from long term usage of carpet and mattress, keeping pets with fur and feather in the house and bedroom, and dust acquired from outside the house when windows were opened. The total minimum exposure score for the dust in the house factor was 7, while the total maximum exposure score was 22. The higher the score, the better the environment (Table 1).

Type of smoker scores included the non-smoker which is respondent who had never smoked for more than 6 months continuous period (score 1); ex-smoker which is respondent who had stopped smoking at least 1 year before the data was collected (score 2); and current smoker was respondent who had smoked at least 100 cigarettes (5 packs) in their lifetime and who smoked on daily basis within the time when the data was collected (score 3). The higher the score, the more active the smoker (Table 1).

Table 1 showed the summary of the variables studied and their operational definitions (Mohd Razib et al. 2024).

Data analysis

There were two types of data analyses, the descriptive analysis and the bivariable analysis. The descriptive analysis was carried out to describe the demographic characteristics and the overall lung function status of the respondents, while the bivariable analysis was conducted to correlate the lung function status with the IAQ factors. Data were analysed using SPSS software version 23.0. The level of significance was determined at p value < 0.05 for a two-tailed analysis.

RESULTS

Background of Respondents

A total of 211 adult respondents aged 18 years old and above from five villages in Tasik Chini, Pahang participated in the study (Table 2). The detailed information about the demographic characteristics of the respondents was reported in Mohd Razib et al. (2024).

TABLE 2: Demographic characteristics of the respondents

Characteristics	Frequency (N = 211)	Percentage (%)
Age distribution (year)		
18-39	147	69.7
40-59	49	23.2
60 and above	15	7.1
Gender		
Male	105	49.8
Female	106	50.2
Ethnicity		
Jakun	199	94.3
Others	12	5.7

The Status of Lung Functions

Table 3 showed the status of lung functions (FEV1, FVC, FEV1/FVC and PEFR) of the Orang Asli in Tasik Chini. The majority of the respondents showed abnormal FEV1 (69.2%) and abnormal FVC (82.9%). Meanwhile, a total of 24.2% of the respondents showed an abnormal PEFR and only 0.9% respondents showed an abnormal FEV1/FVC ratio.

Lung Functions and Indoor Air Quality Factors

Table 4 illustrated the correlations between FEV1, FVC, FEV1/FVC ratio, PEFR and the scores of the IAQ factors. FEV1 represented the volume of air (measured in Liters) exhaled in the first second during forced exhalation following maximal inspiration. There was a significant positive weak correlation between FEV1 and type of smoker scores in which the higher the practice of smoking, the higher the FEV1.

FVC represents the entire volume of air exhaled during the forced expiratory volume (FEV) test. There was a significant positive weak correlation between FVC and home environment scores as well as type of smoker scores in which the better the home environment and the higher the practice of smoking, the higher the forced vital capacity.

The FEV1/FVC ratio is used to assess how effectively a person can expel air

TABLE 3: The status of lung functions among Orang Asli respondents (N=211)

Lung function parameters	Abnormal n (%)	Normal n (%)
FEV1	146 (69.2)	65 (30.8)
FVC	175 (82.9)	36 (17.1)
FEV1/ FVC	2 (0.9)	209 (99.1)
PEFR	51 (24.2)	160 (75.8)

FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: ratio of forced expiratory volume in one second to forced vital capacity; PEFR: peak expiratory flow rate. Normal FEV1 and FVC: ≥ 80% predicted; Normal FEV1/ FVC: >70%.

TABLE 4: FEV1, FVC, FEV1/FVC, PEFR and their correlations with indoor air quality factors among Orang Asli respondents (N=211)

Indoor air quality factors (score)	FEV1 (Liters)		FVC (Liters)		FEV1/FVC (%)		PEFR (Liters/min)	
	r	p value	r	p value	r	p value	r	p value
Health status	0.014	0.840	0.046	0.509	-0.046	0.503	0.081	0.239
Smoke exposure	0.058	0.399	0.067	0.332	0.047	0.500	-0.004	0.956
Home environment	0.129	0.061	0.166	0.016*	0.021	0.757	0.105	0.127
Dust	-0.093	0.177	-0.124	0.073	0.001	0.990	-0.086	0.213
Type of smoker	0.178	0.010*	0.164	0.017*	0.086	0.212	0.256	0.001*

Spearman's rank correlation, r: coefficient of correlation, *significant at p<0.05.

from their lungs relative to the total lung capacity. It is a key indicator in diagnosing and categorising various respiratory conditions, including obstructive and restrictive lung diseases. In this study, there was no significant correlation between the FEV1/FVC ratio and any of the IAQ factors.

PEFR measures the volume of air forcefully expelled from the lungs in a rapid exhalation, in which, it is an indicator of ventilation adequacy and airflow obstruction. There was a statistically significant weak positive correlation between PEFR and scores related to type of smoker, indicating that active smoking was associated with higher volumes of air forcefully expelled from the lungs.

DISCUSSION

Lung Functions

(i) Forced expiratory volume in one second

In this study, the majority of the Orang Asli respondents showed abnormal FEV1 (69.2%). FEV1 stands for forced expiratory volume in one second, which is a measure of how much air a person can forcefully exhale in one second during a PFT. An abnormal FEV1 typically indicates that the volume of air exhaled in the first second of the forced breath is either lower or higher than expected for a person of similar age, sex, height, and ethnicity. Low FEV1 (FEV1 < 80% of predicted) could indicate obstructive lung diseases such as asthma, COPD, or bronchiectasis, where the airways are narrowed or obstructed, making it difficult to exhale air. High FEV1 (FEV1 > 120% of predicted) might suggest restrictive lung diseases or conditions where the lung tissue is stiff or non-compliant, such as pulmonary fibrosis or sarcoidosis.

(ii) Forced vital capacity

In this study, most of the respondents showed abnormal FVC (82.9%). FVC stands for Forced Vital Capacity, which is the total amount of air that can be forcibly exhaled from the lungs after taking the deepest breath possible. An abnormal FVC indicates that the measured volume of air exhaled is either lower or higher than expected for a person of similar age, sex, height, and ethnicity. Low FVC (FVC < 80% of predicted) typically suggests a restrictive lung disease, where the lungs are unable to fully expand due to stiffness or restriction of the lung tissue. Examples include conditions like pulmonary fibrosis, interstitial lung disease or chest wall deformities. High FVC (FVC > 120% of predicted) can sometimes indicate that the test was performed incorrectly (for example, if the person did not exhale completely), but it can also occur in individuals with large lung volumes, such as tall individuals or athletes. It might also occur in certain obstructive lung diseases where the lungs are hyperinflated, such as severe asthma or COPD.

(iii) FEV1/FVC ratio

This study finding showed that almost all respondents (99.1%) had a normal FEV1/FVC ratio. The FEV1/FVC ratio, also known as the Tiffeneau-Pinelli index, is a measure used to assess airflow obstruction. It is calculated by dividing the FEV1 by the FVC. An abnormal FEV1/FVC ratio indicates a potential airflow obstruction, which can help to differentiate between obstructive and restrictive lung diseases. Typically, the FEV1/FVC ratio is about 70-80% in healthy adults. This means that about 70-80% of the FVC should be exhaled in the first second. Low FEV1/FVC ratio (FEV1/FVC < 70%) suggests airflow obstruction. Common causes include diseases like asthma, COPD, and bronchiectasis, where the airways are narrowed or obstructed, leading to difficulty exhaling air quickly. High FEV1/FVC ratio (FEV1/FVC > 80%) can indicate a restrictive pattern, where the lung volumes are reduced due to stiffness or restriction of the lung tissue. Conditions like pulmonary fibrosis, interstitial lung diseases, and chest wall deformities can lead to this pattern.

(iv) Peak expiratory flow rate

This study identified that majority of the respondents (75.8%) had a normal PEFR. PEFR is a measure of how fast a person can exhale air from the lungs during a forceful exhalation. An abnormal PEFR indicates that the measured flow rate is either lower or higher than expected for a person of similar age, sex, height and ethnicity. A low PEFR can indicate airflow limitation, often seen in conditions such as asthma, COPD or bronchitis. It can also be affected by conditions like severe allergies or lung infections. A high PEFR could indicate larger-than-normal airway diameter or high lung compliance, which may be seen in certain healthy individuals or athletes. However, it can also occur in conditions like hyperventilation syndrome or early stages of an asthma attack.

Lung Functions and Indoor Air Quality Factors

In the present study, there was a significant positive weak correlation between FEV1 and type of smoker scores ($r = 0.178$, $p = 0.010$) in which the higher the practice of smoking, the higher the FEV1. The higher FEV1 among the active smoking group could be influenced by the higher prevalence of smokers among the younger age group in which the majority of the Orang Asli respondents were within the age of 18-39 years old (69.7%) who probably showed a better lung function.

The study finding also showed a significant positive weak correlation between FVC and home environment scores ($r = 0.166$, $p = 0.016$) as well as type of smoker scores ($r = 0.164$, $p = 0.017$) in which the better the home environment and the higher the practice of smoking, the higher the FVC. The FVC result is in accordance with the better condition of the home environment such as less usage of woodstove in the house, good ventilation, and low presence of damp and mold area in the house. However, similar to FEV1 finding, the higher FVC among the active smoking group could be influenced by the higher prevalence of smokers among the younger age group who showed a better lung function.

In the present study, no correlation was observed between FEV1/FVC ratio and all the IAQ factors. However, there was a statistically significant weak positive correlation between PEFR and scores related to type of smoker ($r = 0.256$, $p = <0.001$), where active smoker showed a higher PEFR. Again, similar to the findings of FEV1 and FVC, the higher PEFR value among the actively smoking group may be attributed to the greater prevalence of smokers within the younger age population, where lung function tends to be more robust.

Indoor Air Pollutants and Its Sources

Indoor air pollutants can have lasting effects on human health and well-being. Early-life exposure to indoor air pollutants may disrupt lung development, with potential effects persisting into adulthood. Exposure to environmental hazards such as contaminated air at a young age may contribute to a long-term impact on health and productivity of human being (Currie & Almond 2011). Multiple studies on exposure to coal smoke have documented links between indoor air pollutants and conditions such as acute lower respiratory infections, COPD (WHO 2002), and lung cancer (Dabral & Bhatt 2012).

Biological Pollutants

Biological contaminants encompass bacteria, viruses, house dust, pollen, animal dander including cat saliva, mites and cockroaches. These pollutants develop due to occurrence of several conditions. Relative humidity is one of the sources in the development of biological pollutants. Thus, we must maintain relative humidity in optimal level to reduce these biological pollutants to grow. Dampness area or wet surfaces may become a source for growth of molds, mildews, bacteria and insects. Some of these biological pollutants have the potential to induce allergic reactions like hypersensitivity pneumonitis, allergic rhinitis, and asthma. Additionally, they can lead to infectious diseases such as influenza, measles and chickenpox, which are airborne illnesses. Other than that, molds and mildews produce toxin and cause the toxins related disease.

Exposure to biological pollutants can result in symptoms such as sneezing, watery eyes, coughing, breathing difficulties, dizziness, fatigue, fever and digestive issues. Repeated contact with a particular biological allergen can lead to increasingly severe allergic reactions if not treated. However, this reaction can occur either immediately upon encountering it again or after repeated exposures over time. Children, elderly individuals, and those with respiratory issues, allergies, or lung diseases are among the groups susceptible to biological agents in indoor air. Additional biological pollutants such as pet dander, mold, pollen, dust mites, and droppings or body parts of pests can trigger asthma and allergic reactions in certain individuals.

(i) Carbon monoxide

Carbon monoxide (CO) is a gas that is odourless, colourless and toxic. Its effects from exposure can vary among individuals depending on factors such as age, general health condition, and the level and length of exposure. Sources of carbon monoxide include unvented kerosene and gas space heaters, chimneys and furnaces with leaks, gas water heaters, wood stoves and fireplaces, gas stoves, generators, vehicle exhaust from enclosed garages, and tobacco smoke. These sources produce carbon monoxide through incomplete combustion and from poorly adjusted or maintained combustion devices such as boilers and furnaces.

Even at low concentrations, carbon monoxide (CO) can cause fatigue in healthy individuals and chest pain in those with heart disease. Moderate concentrations of CO may lead to symptoms such as angina, impaired vision and reduced brain function. Exposure to elevated levels of CO can lead to symptoms such as impaired vision, coordination difficulties, headaches, dizziness, confusion, nausea and symptoms resembling the flu. Symptoms typically improve upon leaving the contaminated environment, but in extreme cases, such exposure can lead to death. This sudden condition occurs because carboxyhemoglobin forms in the bloodstream, hindering the absorption of oxygen.

(ii) Nitrogen dioxide

The main sources of NOx in indoor environments are nitrogen dioxide (NO2) and nitric oxide (NO). These substances pose toxicity risks to humans, particularly NO2, which is extremely reactive, oxidising, and corrosive. NOs can also form from combustion processes involving unvented appliances (like gas stoves), improperly installed vented appliances, kerosene heaters, tobacco smoke and welding.

Irritant effect can influence the mucosa of the upper and lower respiratory tract (eyes, nose, throat, and respiratory tract). Pulmonary oedema and diffuse lung injury may develop due to exposure to very high dose of NO2. Extended exposure to elevated levels of NO2 can lead to acute or chronic bronchitis. Even minimal exposure to NO2 can increase bronchial reactivity in some people with asthma, decrease lung function in individuals with COPD, and raise the likelihood of respiratory infections, especially in young children.

An earlier study found that exposure to outdoor but not indoor, NO2 during the first year of life increased the risk of persistent cough (Esplugues et al. 2010). Conflicting results could be described as the difficulty to determine the amount of exposure, because it fluctuates and depending mainly on the season or the use of specific NO2 sources (for example peak concentrations occur during cooking or heating activities).

(iii) Indoor particulate matter

Particulate matter (PM) is a diverse combination of solid and/or liquid particles containing metals, organic compounds, sulfates, nitrates, ammonium and other ions suspended in the air (Adams et al. 2015). Previous studies have linked the composition of PM with respiratory diseases such as acute bronchitis, chronic bronchitis and asthma (Jones et al. 2015). These particles differ in size, shape and composition. Particles with diameters between 2.5 and 10 µm (PM2.5-10) are categorised as “coarse”; those less than 2.5 µm are categorised as “fine”; and those less than 0.1 µm are categorised as “ultrafine” particles (Liu et al. 2018). Particles of 10 µm in diameter or smaller require more attention because it can be inhaled. The significant health risk posed by PM is due to inhalable PM, which can enter the respiratory system and lead to negative health outcomes (Reiss et al. 2007). For instance, due to its lightness, PM2.5 tends to deposit more in the lungs compared to other particles, leading to prolonged retention in the respiratory tract (Hoffmann et al. 2007). Indoor levels of PM can surpass outdoor levels and exceed the National Ambient Air Quality Standards (NAAQS).

Because of technological advancements

and changes in lifestyle, more human activities such as indoor sports, cleaning and cooking are now carried out indoors. This trend contributes to higher levels of indoor PM (Lai et al. 2004). Studies on exposure have shown that indoor PM results in personal exposure, and indoor PM concentrations may surpass those found outdoors (Kim et al. 2015). Indoor PM consists of particles originating from outdoors that migrate indoors, as well as particles emitted from indoor sources. Indoor PM can originate from activities like smoking cigarettes, burning candles, using unvented space heaters or kerosene heaters and cooking.

Indoor PM levels can be influenced by several factors, including outdoor PM levels, infiltration, the type of ventilation and filtration systems in use, indoor sources, and the personal activities of occupants. Indoor PM levels would typically be the same as or lower than outdoor levels in the absence of smoking or other indoor particle sources. The main sources of indoor PM include specific activities such as sweeping, dusting, cooking, using laser-printing devices, burning candles or incense, fuel combustion for heating, secondary organic aerosols, smoking tobacco, and house design (Holmes et al. 2011; Waring 2014). Indoor PM is derived from outdoor sources as well, which encompass natural origins such as soil dust, sea salt, and forest fires, alongside human-made sources including emissions from transportation, combustion of oil, and coal burning in power plants (Adams et al. 2015; Karagulian et al. 2015). Improving the efficacy of assessing urban ambient air quality entails selecting suitable methods tailored to distinct geographic areas. Automated monitoring techniques for PM2.5 in ambient air quality encompass methods such as the β-ray method and micro-oscillatory balance method.

Evaluating the health impacts of indoor air PM exposure is essential due to people spending most of their time indoors, where pollutant levels can frequently exceed those found outdoors (Klepeis et al. 2001; Wallace 1996). Particles from outdoors can infiltrate indoor environments through ventilation and infiltration (Chen & Zhao 2011).

(iv) Second-hand tobacco smoke or environmental tobacco smoke

Second-hand tobacco smoke, also known as environmental tobacco smoke, comprises both the smoke produced by burning tobacco products (such as cigars, cigarettes, or pipes) and the smoke exhaled by smokers. Involuntary or passive smoking refers to exposure to second-hand smoke. Second-hand smoke contains more than 7,000 substances, some of which are known to cause cancer in humans or animals.

According to the Environmental Protection Agency (EPA), exposure to second-hand smoke may lead to lung cancer in non-smoking adults. In their 1992 Risk Assessment titled “Respiratory Health Effects of Passive Smoking,” the EPA concluded that ETS is associated with lung cancer in adults and classified ETS as a Group A carcinogen, known to be harmful to humans.

The smoke can permeate between rooms within a home and between units in apartment buildings. Households in buildings with smoke-free policies typically have lower levels of PM2.5 compared to those without such policies.

PM2.5 is commonly used as an indicator of air quality due to its smaller particle size. Exposure to elevated levels of fine particles in the air can have adverse health effects (Russo et al. 2014). In order to eliminate second-hand smoke from the indoor environment, smoking indoors must be prohibited. According to Pritsos & Muthumalageb (2015), second-hand smoke can be reduced but not eliminated by using ventilation and filtration techniques.

(v) Volatile organic compounds

VOC are gases released from specific solids or liquids. They encompass a range of chemicals that can contribute to short- and long-term health issues. Indoors VOC concentrations can be significantly higher (up to ten times) than outdoor levels. Household products commonly utilise organic chemicals and solvents such as paints, varnishes, wax, and fuel as ingredients. It is widely used for cleaning, disinfecting, cosmetic and degreasing. Organic compounds will be released to the environment once all of these products are used and stored.

According to the EPA's "Total Exposure Assessment Methodology (TEAM) Study," indoor levels of common organic pollutants are generally 2-5 times higher than outdoor levels, irrespective of whether the residence is situated in a rural or industrial area (Wallace et al. 1986). The TEAM studies indicated that individuals may experience elevated levels of pollutants when using products containing organic chemicals, as these levels can linger in the air even after the activity has ended. Exposure to VOCs can result in a range of health effects such as eye, nose, and throat irritation, headaches, coordination difficulties, nausea, and potential harm to the liver, kidneys, and central nervous system. Health effects that are caused by organic chemicals varied from no known health effect to a highly toxic effect.

CONCLUSION

The majority of the Orang Asli respondents in this study showed abnormal FEV1 (69.2%) and FVC (82.9%). A significant proportion of the respondents showed a normal PEFR (75.8%) and almost all (99.1%) had a normal FEV1/FVC ratio. FEV1, FVC and PEFR were positively correlated with the type of smoker, and only FVC was positively correlated with the home environment. The better lung function status among the active smoking group could be due to the larger proportion of active smokers among the younger age group (18-39 years old). Thus, the health authority should strengthen their tobacco control programme, effectively implement the existing laws and regulations, and promote a wide range of health education activities among Orang Asli community in Malaysia as to protect them from the hazards of active smoking and second-hand smoking. The health authority should also integrate health education and promotion to enhance Orang Asli's knowledge regarding indoor air pollutants and its impact, to reduce indoor air pollutants-related harmful behaviours, to promote them to adopt safe behaviours to reduce their exposure to indoor air pollutants, to prevent respiratory diseases resulting from indoor air pollutants and to improve their quality of life.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The authors received ethics approval from the Research and Ethics Committee of Universiti Kebangsaan Malaysia (UKM). Informed consent was obtained from all subjects and/or their legal guardian(s). All methods were carried out in accordance with the Declaration of Helsinki.

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AVAILABILITY OF DATA AND MATERIALS

All data generated or analysed during this study are included in this published article.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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AUTHORS' CONTRIBUTIONS

NFMR and ZMI wrote the manuscript. HI reviewed and edited the manuscript. NFMR, ZMI and HI contributed to the final manuscript. All authors reviewed the manuscript.

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