Microbial Air Quality in Mass Transport Buses and Work-Related Illness among Bus Drivers of Bangkok Mass Transit Authority[$]

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The air quality in mass transport buses, especially air-conditioned buses may affect bus drivers who work full time. Bus numbers 16, 63, 67 and 166 of the Seventh Bus Zone of Bangkok Mass Transit Authority were randomly selected to investigate for microbial air quality. Nine air-conditioned buses and 2-4 open-air buses for each number of the bus (36 air-conditioned buses and 12 open-air buses) were included. Five points of in-bus air samples in each studied bus were collected by using the Millipore Air Tester. Totally, 180 and 60 air samples collected from air-conditioned buses and open-air buses were cultured for bacterial and fungal counts. The bus drivers who drove the studied buses were interviewed towards histories of work-related illness while working. The results revealed that the mean $\pm$ SD of bacterial counts in the studied open-air buses ranged from 358.50 $\pm$ 146.66 CFU/m^3 to 506 $\pm$ 137.62 CFU/m^3; bus number 16 had the highest level. As well as the mean $\pm$ SD of fungal counts which ranged from 93.33 $\pm$ 44.83 CFU/m^3 to 302 $\pm$ 294.65 CFU/m^3; bus number 166 had the highest level. Whereas, the mean $\pm$ SD of bacterial counts in the studied air-conditioned buses ranged from 115.24 $\pm$ 136.01 CFU/m^3 to 244.69 $\pm$ 234.85 CFU/m^3; bus numbers 16 and 67 had the highest level. As well as the mean $\pm$ SD of fungal counts which ranged from 18.84 $\pm$ 39.42 CFU/m^3 to 96.13 $\pm$ 234.76 CFU/m^3; bus number 166 had the highest level. When 180 and 60 studied air samples were analyzed in detail, it was found that 33.33% of the air samples from open-air buses and 6.11% of air samples from air-conditioned buses had a high level of bacterial counts (> 500 CFU/m^3) while 6.67% of air samples from open-air buses and 2.78% of air samples from air-conditioned buses had a high level of fungal counts (> 500 CFU/m^3). Data from the history of work-related illnesses among the studied bus drivers showed that 91.67% of open-air bus drivers and 57.28% of air-conditioned bus drivers had symptoms of work-related illnesses, p = 0.0185.

***Keywords :** Microbial air quality, Mass transport buses, Work-related illness, Bus drivers*

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At present, many people in our society spend most of their lives indoors; house, school, office, theater, commercial center and are involved in a car or a bus. A previous study indicated that people spent approximately 90% of their time indoors and may spend most of their working hours in an office environment. The risk to health may be greater due to exposure to indoor air pollution than outdoors[1]. Indoor air quality is based on specific contaminants especially microbial agents, house dust mites, cockroaches and pollens. Many bio-aerosol related diseases are associated primarily with indoor environments, especially when ventilation is poor and can be a source of indoor pollution themselves by spreading microbiological contaminants that have

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multiplied in cooling towers, humidifiers, dehumidifiers, air conditioners, or the inside surfaces of ventilation duct work[2]. These provoke or contribute to symptoms, such as headache, fatigue, eye and/or nose and/or throat irritation and allergic reactions. Infectious illnesses, such as influenza, measles, chickenpox and severe acute respiratory syndrome (SARS) are transmitted by sneezing and/or coughing through the air[3-7]. In the United States, according to the Environmental Protection Agency Headquarters Building, one third of respondents reported that poor indoor air quality reduced their ability to work at least some of the time and approximately one fourth indicated that it caused them to stay home from work or leave early[8]. Anywhere that has poor indoor air quality has a potential affect on humans and society by either reducing quality of life or lost economic costs. In a city, humans spend most of the time travelling, especially in air-conditioned mass transport buses, where people crowd together in a limited area. Such situations may be sources of microbiological contaminants in indoor air and affects bus drivers directly. Bangkok is one of the largest cities in the world. There are approximately 10 million persons living and working each day. The traffic is busy on work days. Mass transport buses of the Bangkok Mass Transit Authority serve a large number of people. In conditions with heavy traffic and crowds of people in Bangkok, the air quality in mass transport buses, especially air-conditioned buses may affect the bus drivers who work full time. Therefore, the microbial air quality in mass transport buses should be assessed to develop an implementation plan to reduce the probability of risk to illness related to poor indoor air quality and to improve the working quality of life of bus drivers.

Material and Method

Study design and study buses

A cross-sectional study was conducted to assess microbial air quality in mass transport buses of the Bangkok Mass Transit Authority. The seventh Bangkok Mass Transit Bus Zone was selected for this study by voluntary participation. It consisted of 3 bus-stop zones. Bus numbers 16 and 67 were randomly selected from the first bus-stop zone (U-Srinarong), and bus numbers 63 and 166 were randomly selected from the second and third bus-stop zones (U-Khama and U-Thait, respectively). Nine air-conditioned buses for each number of bus and 3, 4, 3 and 2 open-air buses for bus numbers 16, 63, 67 and 166 depending on the total number of each bus number (the ratio was about 1:3) were included in the study. A total of 36 air-conditioned buses and 12 open-air buses were studied from November 2002 to February 2003. In addition, bus drivers who drove these studied buses were interviewed for some socio-demographic characteristics and histories of work-related illnesses while working (illness which presented while working and absences caused during work due to illness).

Air samples and methods of collection

In-bus air samples from 5 points from each studied bus including before starting at the bus station, the middle distance, the terminal station, the middle distance again and returning to bus station again were collected from 8.00 to12.00 am. A total of 180 air samples from the studied air-conditioned buses and 60 air samples from the studied open-air buses were collected to investigate the total bacterial count and fungal count. In addition, 9 out-door air samples were collected from the bus station (3 points), the middle distance (3 points), and the terminal station (3 points) of each bus. Air samples were collected and measured by using the Millipore Air Tester (M Air T). The microorganisms were impacted onto an agar surface in accordance with the USP reference method. The M Air T sieve has 967 holes to optimize colony distribution and reduce colony overlapping. The M Air T cassettes have a consistent filling level and flat surface, which helps ensure that samples are from the same volume of air during every test. At a constant air sample flow of 140 liters/min, air was collected for 250 liters. Inoculated agar plates were incubated at 37^o C, 3 days for bacterial count and at 25^o C, 5 days for fungal count. After incubation, the bacterial and fungal colonies were observed every day. Total colonies on the third day and the fifth day were counted and calculated by the formula as follows:

$$\text{Total count in the air sample (Colony Forming Unit or CFU/m}^3\text{)} = \frac{\text{Total colonies} \times 10^3}{250}$$

Interpretation of microbial counts in this study

The American Conference of Governmental Industrial Hygienist (ACGIH) Committee suggested that the presence of bacterial or fungal counts exceeding 500 CFU/m^3 in an office workplace was an indication of poor ventilation or over-crowding and in need of remedial action[9]. Therefore, the interpretation in the present study was as follows; if the bacterial count and/or fungal count were more than 500 CFU/m^3, it indicated poor ventilation or an unsanitary condition of in-bus air of the studied buses.

Data analysis

Descriptive statistics including percentage, mean, and standard deviation were used for describing the microbial air quality in the studied buses and prevalence of work-related illnesses among the bus drivers who drove the studied buses. The chi-square test was used for analyzing the difference of work-related illness prevalence between open-air bus drivers and air-conditioned bus drivers. The critical level of $\alpha = 0.05$ was used for statistical significance.

Result

General characteristics of studied buses

The studied buses included 36 air-conditioned buses and 12 open-air buses. The air-conditioned buses are orange-yellow in color, except bus number 166 which is blue. The studied air-conditioned buses have 2 doors, in the front and the middle of the buses, and the windows are closed. Although, there are 2 ventilation fans in each bus, they are usually closed. The other studied open-air buses are red-white and have 2 doors in the middle part. They have approximately 20 windows but no ventilation fan. In general, the open-air buses have good ventilation, except when it rains and the windows are closed. All the studied buses run through crowded communities. The traffic is busy all day, especially during the rush hours, but not on Sunday and public holidays. Only bus number 166 uses the expressway. Some information about the studied buses is shown in Table 1. All the bus drivers who drove the studied buses were male and aged 23-56 years. Mean of age was 41.57 years. Approximately 85% of them were married. About 60% finished primary education. Mean family income per month was 13,675.23 Baht.

Microbial air quality in the studied buses

In total, 180 air samples collected from the 36 air-conditioned buses and 60 air samples collected from the 12 open-air buses were analyzed and presented in the present study. The mean $\pm$ standard deviation of bacterial counts in the studied open-air buses ranged from 358.50 $\pm$ 146.66 CFU/m^3 to 506.01 $\pm$ 137.62 CFU/m^3 and that of fungal counts ranged from 93.33 $\pm$ 44.83 CFU/m^3 to 302.00 $\pm$ 294.65 CFU/m^3 depending on the studied bus number. Bus number 16 had the highest level of bacterial count with the mean $\pm$ standard deviation of 506.01 $\pm$ 137.62 CFU/m^3 and bus number 166 had the highest level of fungal count with the mean $\pm$ standard deviation of 302.00 $\pm$ 294.65 CFU/m^3. The means of bacterial and fungal counts of the studied air-conditioned buses were relatively lower than those of the studied open-air buses. The mean $\pm$ standard deviation of bacterial counts ranged from 115.24 $\pm$ 136.01 CFU/m^3 to 244.69 $\pm$ 234.85 CFU/m^3 and that of fungal counts ranged from 18.84 $\pm$ 39.42 CFU/m^3 to 96.13 $\pm$ 234.76 CFU/m^3 also depending on the studied bus number. Bus numbers 16 and 67 had relatively higher bacterial counts (242.02 $\pm$ 256.35 and 244.69 $\pm$ 234.85 CFU/m^3) than bus numbers 63 and 166 (177.05 $\pm$ 155.71 and 115.24 $\pm$ 136.01 CFU/m^3). Whereas, bus number 166 had a relatively higher fungal count (302.00 $\pm$ 294.65 CFU/m^3) than the others, details are shown in Table 2.

Table 1. Some characteristics of studied buses and the beginning/terminal stations

The bus number	Total buses	No. of studied	Some characteristics of studied buses	Beginning station Terminal station
Bus number 16				U-Srinarong
Open-air bus	8	3	red-white color, 2 doors, 20 windows, no ventilation fan	Surawong
Air-conditioned bus	25	9	orange-yellow color 2, doors, 2 ventilation fans	
Bus number 63				U-Khama
Open-air bus	11	4	red-white color, 2 doors, 20 windows, no ventilation fan	Victory monument
Air-conditioned bus	19	9	orange-yellow color 2, doors, 2 ventilation fans	
Bus number 67				Wat-samiannari
Open-air bus	9	3	red-white color, 2 doors, 20 windows, no ventilation fan	Chongnonsi
Air-conditioned bus	19	9	orange-yellow color 2, doors, 2 ventilation fans	
Bus number 166				Muangthongthani
Open-air bus	5	2	red-white color, 2 doors, 20 windows, no ventilation fan	Victory monument
Air-conditioned bus	29	9	blue color, 2 doors, 2 ventilation fans	

When the microbial air quality was described in detail by comparison with the level of guidelines of the American Conference of Governmental Industrial Hygienist (ACGIH), it was found that 33.33% of air samples collected from the studied open-air buses and 6.11% of air samples collected from the studied air-conditioned buses had bacterial counts more than the recommended level of ACGIH (> 500 CFU/m^3). Whereas, 6.67% of air samples collected from the studied open-air buses and 2.78% of air samples collected from the studied air-conditioned buses had fungal counts more than the recommended level of ACGIH (> 500 CFU/m^3). These air samples with the high levels of bacterial count and/or fungal count (> 500 CFU/m^3) were collected from 10 open-air buses (83.33% of the studied open-air buses) and 12 air-conditioned buses (33.33% of the studied air-conditioned buses) most of which were bus numbers 16, 67 and 166. These buses ran and passed busy traffic areas. Details are shown in Table 3.

Table 2. Mean and standard deviation of microbial counts in in-bus air samples by the number of studied buses

The bus number	Bacterial count (CFU/m^3)	Fungal count (CFU/m^3)
Bus number 16		
Open-air buses (n = 3 buses)	560.00±137.62*	209.33±215.52
Air-conditioned buses (n = 9 buses)	242.02±256.35	18.84±39.42
Out-door (n = 9 points)	463.43±309.58	63.71±26.19
Bus number 63		
Open-air buses (n = 4 buses)	358.50±146.66	99.50±46.73
Air-conditioned buses (n = 9 buses)	177.07±155.71	20.20±21.08
Out-door (n = 9 points)	530.86±340.56	59.67±30.99
Bus number 67		
Open-air buses (n = 3 buses)	482.00±129.57	93.33±44.83
Air-conditioned buses (n = 9 buses)	244.69±234.85	82.49±191.10
Out-door (n = 9 points)	588.26±278.16	60.29±45.88
Bus number 166		
Open-air buses (n = 2 buses)	452.00±353.26	302.00±294.65
Air-conditioned buses (n = 9 buses)	115.24±136.01	96.13±234.76
Out-door (n = 9 points)	277.43±121.93	97.71±73.08

* Mean of bacterial counts higher than the guideline level of American Conference of Governmental Industrial Hygienist (ACGIH) at the level of 500 CFU/m^3.

Remark: In-bus air samples from 5 points in each studied bus were collected for bacterial and fungal counts

History of work-related illness among studied bus drivers

Forty-eight bus drivers (12 open-air bus drivers and 36 air-conditioned bus drivers) answered the questionnaire which asked the history of work-related illness during work (illnesses which presented during work which caused absences from work). It was found that 91.67% of the studied open-air bus drivers and 52.78% of the studied air-conditioned bus drivers had a history of work-related illnesses including itching or irritated eyes, headache or dizziness, unusual tiredness or fatigue, pain or stiffness in the back, shoulder or neck, tension or irritability, and others. The prevalence of work-related illness in the open-air bus drivers was significantly

Table 3. Number and percentage of air samples with high microbial counts (> 500 CFU/m ^{3}) collected from 12 open-air buses and 36 air-conditioned buses

Air samples collected from each bus number	No. of air samples	No (%) of air samples with high microbial counts (> 500 CFU/m^3)			
		For bacteria		For fungi	
Bus number 16					
Open-air buses	15	7	46.67	2	13.33
Air-conditioned buses	45	3	6.67	0	0.00
Bus number 63					
Open-air buses	20	2	10.00	0	0.00
Air-conditioned buses	45	1	2.22	0	0.00
Bus number 67					
Open-air buses	15	5	33.33	0	0.00
Air-conditioned buses	45	6	13.33	2	4.44
Bus number 166					
Open-air buses	10	6	60.00	2	20.00
Air-conditioned buses	45	1	2.22	3	6.67
Total					
Open-air buses	60	20*	33.33	4*	6.67
Air-conditioned buses	180	11**	6.11	5**	2.78

* From 10/12 open-air buses (83.33% of studied open-air buses)

** From 12/36 air-conditioned buses (33.33% of studied air-conditioned buses)

Remarks: Most air samples with the high levels of bacterial count and/or fungal count (> 500 CFU /m ^{3}) were collected at the busy traffic areas or the areas which studied buses passed the hospitals higher than that of the air-conditioned bus drivers, p = 0.0185 (Table 4). Most bus drivers with a history of work-related illness (10 from 11 bus drivers of open-air buses and 12 from 19 bus drivers of air-conditioned buses) worked in the studied buses with air samples of high microbial counts (> 500 CFU/m^3). Details are shown in Table 4.

Discussion

Due to the different conditions of the traffic and the number of people in the bus in each cycle of the bus route, in-bus air samples from 5 points in each studied bus including before starting at the bus station, the middle distance, the terminal station, the middle distance again and the beginning bus station again were collected to cover the real situation of microbial air quality in each studied bus. The results of microbial air quality in the studied buses revealed that most studied buses had the means of bacterial and fungal counts lower than the guideline level of the American Conference of Governmental Industrial Hygienist (ACGIH) at the level of 500 CFU/m^3. However, 10 open-air buses (83.33% of the studied open-air buses) and 12 air-conditioned buses (33.33% of the studied air-conditioned buses) had at least 1 point of in-bus collected air sample with a high level of bacterial count and/or fungal count (> 500 CFU/m^3). The detection of the high level of bacterial and/or fungal counts was an indicator of over-crowding and/or inadequate air ventilation(9,10). Most air samples with a high level of bacterial and/or fungal counts were collected from bus numbers 16, 67, 166 which ran through crowded communities and busy traffic areas. A previous study showed that concentrations of dust were associated with bio-aerosol levels because the dust had many organisms for microbial growth(11). Another study revealed that human activities provided a major source of bio-aerosol in indoor air and persons residing in air-conditioned homes seemed to have a higher frequency of respiratory complaints than those living in naturally ventilated homes(12). Moreover, poor ventilation can contribute to the spread of respiratory infections for which people are the source, e.g. measles, influenza, chickenpox, and tuberculosis(3-6,13,14). Some biological contaminants trigger allergic reactions including hypersensitivity pneumonitis, allergic rhinitis and some types of asthma. The present study reported that the prevalence of work-related illness including itching or irritated eyes, headache or dizziness, unusual tiredness or fatigue, pain or stiffness in the back, shoulder or neck, tension or irritability, and others in the studied open-air bus drivers was significantly higher than that in the air-conditioned bus drivers (91.67% vs 52.78%, $p < 0.05$). This might be due to the higher microbial count exposure and/or higher concentration of dust and/or volatile organic compounds (VOCs) and/or other physical agents exposure, such as, the higher temperature, noise and others. Microbial concentration and volatile microbial products provoke or contribute to symptoms, such as, headache, fatigue, eye and/or nose and/or throat irritation(2,10). Chronic noise exposure induced the stress and constituted risk factors for cardiovascular disease(15). Moreover, gasoline vapor emissions and motor vehicle exhausts have been recognized as important sources of exposure of occupational group to VOCs which directly or indirectly affected health(16-18). Data of the high level of microbial counts in the studied buses and the history of work-related illness in the present

Table 4. History of work-related illness among studied bus drivers (open-air bus drivers = 12, air-conditioned bus drivers = 36)
(One can answer more than 1 item of illness)

Work-related illness*	No (%) of studied bus drivers with history of illness			
	Open-air bus (n=12)		Air-conditioned bus (n=36)	
Itching, irritated eyes	6	50.00	14	38.89
Stuffy, running nose, sinus congestion	4	33.33	6	16.67
Sneezing	4	33.33	10	27.78
Cough	3	25.00	8	22.22
Sore or dry throat	2	16.67	5	13.89
Chest tightness	1	8.33	0	0.00
Headache or dizziness	5	41.67	6	16.67
Tired, strained eyes	3	25.00	5	13.89
Unusual tiredness, fatigue	5	41.67	9	25.00
Pain or stiffness in back, shoulder or neck	6	50.00	14	38.89
Tension, irritability	3	25.00	2	5.56
Feeling depressed	2	16.67	0	0.00
Nausea or upset stomach	1	8.33	0	0.00
Dry or itching skin	1	8.33	2	5.56
Fever	0	0.00	0	0.00
Total	11	91.67[a]	19	52.78[b]

* Illness presented during working and reduced or to be absent after working each day
[a,b] Statistically significant difference by χ^2 test, p = 0.0185
[a,b] Most of them (10/11 of open-air bus drivers and 12/19 of air-conditioned bus drivers) drove buses with high microbial counts in air samples (> 500 CFU/m^3) at least 1 sample

study supported that the microbial air quality affected health and working life of workers or officers.

The Environmental Protection Agency (EPA), 1989 reported that improved indoor air quality could result in higher productivity and fewer lost work days[19]as well as the study of Wiids, 1989[20]. In the case of bus drivers who worked full time in buses, indoor air quality of air-conditioned buses might be related to the ventilation, the cleanness of the environment in the buses and the outdoor air quality. The intervention program for reducing the microbial concentration in the air of air-conditioned buses should emphasize the ventilation strategy, the cleaning program on in-bus environments (seats, curtains and on the floor) and air conditioners in the buses. The mechanical ventilation by an exhaust ventilation system in air-conditioned buses should be opened at least 3 times, before starting at the bus station, when the bus is over crowded and at the terminal station of every cycle. For open-air buses, a ceiling fan should be used for ventilating in-bus air and reducing the temperature in the area of the bus driver's seat. These recommended interventions will be considered in the Seventh Zone of Bangkok Mass Transit Authority Committee in the future. However, as the air quality in open-air buses might be related to the outdoor air quality, an intervention program should involve the traffic system more than the in-bus environment and the ventilation system in the bus.

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คุณภาพอากาศทางจุลินทรีย์ภายในรถโดยสารประจำทางและการเจ็บป่วยที่เกี่ยวข้องกับการทำงานในพนักงานขับรถโดยสารประจำทาง องค์การขนส่งมวลชนกรุงเทพ

พิพัฒน์ ลักษมีจรัลกุล, วิบูลย์ศรี สันธิโยธิน, เสาวลักษณ์ ลักษมีจรัลกุล, อรวรรณ แก้วบุญชู

คุณภาพอากาศภายในรถโดยสารประจำทาง อาจมีผลต่อพนักงานขับรถซึ่งต้องอยู่ในรถเป็นเวลานาน ๆ การศึกษานี้ได้สุ่มตัวอย่างรถโดยสารประจำทางสาย 16, 63, 67 และ 166 ของเขตการเดินรถที่ 7 องค์การขนส่งมวลชนกรุงเทพ เพื่อวิเคราะห์การปนเปื้อนจุลินทรีย์ในอากาศภายในรถ โดยเก็บตัวอย่างอากาศจากรถโดยสารปรับอากาศ สายละ 9 คัน (รวม 36 คัน) และรถธรรมดา สายละ 2 - 4 คัน (รวม 12 คัน) ในแต่ละคันเก็บตัวอย่างอากาศ 5 จุด ระหว่างที่รถวิ่งรับส่งผู้โดยสารด้วยเครื่อง Millipore Air Tester รวมจำนวนตัวอย่างอากาศภายในรถปรับอากาศ 180 ตัวอย่าง และรถธรรมดา 60 ตัวอย่าง นอกจากนี้ได้สัมภาษณ์พนักงานขับรถเกี่ยวกับประวัติการเจ็บป่วยด้วยอาการที่เกี่ยวข้องกับการทำงาน ผลการศึกษาพบว่าปริมาณเชื้อแบคทีเรียโดยเฉลี่ย $\pm$ ค่าเบี่ยงเบนมาตรฐานในตัวอย่างอากาศที่เก็บจากรถธรรมดาเท่ากับ 358.50 $\pm$ 146.66 CFU/m^3 ถึง 506 $\pm$ 137.62 CFU/m^3 โดยรถสาย 16 มีปริมาณสูงสุด เช่นเดียวกันปริมาณเชื้อราโดยเฉลี่ย $\pm$ ค่าเบี่ยงเบนมาตรฐาน เท่ากับ 93.33 $\pm$ 44.83 CFU/m^3 ถึง 302 $\pm$ 294.65 CFU/m^3 โดยรถสาย166 มีปริมาณสูงสุด ในขณะที่ปริมาณเชื้อแบคทีเรียโดยเฉลี่ย $\pm$ ค่าเบี่ยงเบนมาตรฐาน ในตัวอย่างอากาศที่เก็บจากรถปรับอากาศเท่ากับ 115.24 $\pm$ 136.01 CFU/m^3 ถึง 244.69 $\pm$ 234.85 CFU/m^3 โดยรถสาย 16 และ สาย 67 มีปริมาณสูงสุด เช่นเดียวกันปริมาณเชื้อราโดยเฉลี่ย $\pm$ ค่าเบี่ยงเบนมาตรฐาน เท่ากับ 18.84 $\pm$ 39.42 CFU/m^3 ถึง 96.13 $\pm$ 234.76 CFU/m^3 โดยสาย 166 มีปริมาณสูงสุด เมื่อวิเคราะห์โดยละเอียด พบว่าร้อยละ 33.33 ของจำนวนตัวอย่างอากาศที่เก็บจากรถธรรมดา และร้อยละ 6.11 ของจำนวนตัวอย่างอากาศที่เก็บจากรถปรับอากาศ มีการปนเปื้อนแบคทีเรียสูงกว่า 500 CFU/m^3 ในขณะที่ร้อยละ 6.67 และ 2.78 ของจำนวนตัวอย่างอากาศที่เก็บจากรถธรรมดา และรถปรับอากาศ มีการปนเปื้อนเชื้อราสูงกว่า 500 CFU/m^3 สำหรับอาการเจ็บป่วยที่เกี่ยวข้องกับการทำงานในพนักงานขับรถดังกล่าว พบว่า ร้อยละ 91.67 ของพนักงานขับรถธรรมดา และร้อยละ 57.28 ของพนักงานขับรถปรับอากาศมีอาการเจ็บป่วยที่เกี่ยวข้องกับการทำงาน (p = 0.0185)
