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Commuting on Public Transport: Health Risks and Responses

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Abstract

Rapid urbanization places a huge demand for infrastructure on busy city roads, exposing commuters to the health risks of atmospheric air pollutants. Traffic-related air pollution causes significant health burdens worldwide and enormous economic losses. Both short- and long-term exposures to atmospheric air pollutants cause a range of adverse health effects on people who commute. The short-term symptoms of exposure include coughing, shortness of breath, chest pain, and headaches. Long-term exposure is associated with cardiovascular, respiratory, and lung cancer mortality. Exposure to traffic-related air pollution also has detrimental effects on psychological and mental health. Although the use of proper respiratory protection may greatly reduce inhalation of microparticulate matter commonly found at high concentrations on busy roads, its use is not common in some communities. The adverse health risks associated with traffic-related air pollution can also be reduced through diet and lifestyle modifications, and these should be encouraged. A lack of environmental health literacy may result in the underutilization of preventive resources; therefore, fostering proper delivery of information may improve the health of commuters. Attention is drawn to the need for research tailored to individual societies or countries due to the influence of innumerable factors such as culture, religion, and climate, as well as policy and governance that contribute to diversity among health impacts and local community mitigation measures.

Keywords: health risks, mitigation responses, traffic-related pollution, commuters

1. Introduction

In recent decades, Asia has experienced rapid development of industrialization and urbanization, which has resulted in accelerated growth of many suburban cities surrounding large metropolitan areas. These suburbs are home to many who work in metropolitan areas, causing a tremendous number of suburban residents each day to commute to the city for work. As a consequence, urban areas are experiencing increasing automobile use, resulting in congestion and long hours of commuting. The increasing severity and duration of traffic congestion greatly intensify pollutant emissions and degrade air quality.

It is of tremendous concern that commuters are exposed to high concentrations of atmospheric pollutants, originating from both vehicular traffic and other urban, industrial, or environmental factors, during their transit. They are exposed during their daily commute while in vehicles, waiting for transportation and walking. Most commuters spend considerable time at bus stops and stations or walk on busy roads. It was reported commuters who travel by public transport may be exposed to up to eight times as much air pollution as those who drive to work [1].

1.1. Health impacts of air pollution

Most megacities in Asia are facing acute problems due to an increase in the ambient particulate matter (PM) and nitrogen dioxide (NO_2) concentrations as a result of rapid urbanization. In Shanghai, New Delhi, Mumbai, Guangzhou, Chongqing, Calcutta, Beijing and Bangkok, the ambient PM and NO_2 concentrations were reported to frequently violate World Health Organization (WHO) guidelines [2]. Worldwide, in most of the megacities, motorized road transport is categorized as one of the largest pollution sources. Motorized transport is responsible for 70% of environmental pollution and 40% of greenhouse gas emissions in European cities [3]. In the UK, automobile pollution sources frequently violate the national ambient air quality standards [4]. Likewise, on the Asian subcontinent, some rapidly developed countries, such as Singapore, Japan, and Hong Kong, are facing equally critical street-level air pollution problems due to an increase in the number of motorized vehicles [4].

Road vehicle emissions are one of the most important sources of human exposure to air pollution. Air pollution concentrations on roads are relatively high, and commuters face unavoidable exposure during commuting as they are near the source of emission. The deleterious effects of traffic-related atmospheric air pollution on health have been documented in many studies worldwide. Emissions from road traffic result in a complex mixture of harmful air pollutants. In many areas, vehicle emissions have become the dominant source of air pollutants, including carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOCs), hydrocarbons (HCs), nitrogen oxides (NO_x), and particulate matter of aerodynamic diameter $2.5 \mu\text{m}$ ($\text{PM}_{2.5}$) [5]. These toxic particles easily penetrate human airways. Inhaled $\text{PM}_{2.5}$ can reach the lung alveoli and induce local and systemic responses in the body, impacting cardiovascular and respiratory function [6]. Thus, traffic-related air pollution has been implicated in a range of illnesses related to respiratory diseases and cardiovascular complications. From a public health perspective, the health effects of air pollution are both chronic

(long term) and acute (short term). Breathing in high quantities of exhaust fumes can cause short-term irritation to the respiratory tract within a few minutes of exposure. Short-term inhalation of air pollutants may exacerbate ongoing irritation such as cough, mucous buildup, and inflamed airways. Although the acute, short-term effect is of the least concern to the general public, over time, long-term exposure eventually merges with the chronic effect. Of concern, prolonged exposure over many years places tremendous stress on the body and can be detrimental to human health.

Air pollution is now the world's largest environmental health risk [7]. In 2015, the WHO released a report stating that at least one in eight deaths worldwide is caused by air pollution. On a global scale, air pollution accounts for an estimated 9% of deaths due to lung cancer, 17% due to chronic obstructive pulmonary disease, more than 30% due to ischemic heart disease and stroke, and 9% due to respiratory infections [8]. It is estimated that approximately 80% of the world population lives in environments with pollution levels exceeding the air quality guideline (AQG) established by the WHO [9]. It is also a well-established fact that air pollution shortens life expectancy. The high level of particles in air pollution is related to lung cancer risk, cardiovascular disease, and mortality. In many countries in Asia, concentrations of ambient air pollutants exceed levels associated with increased risk of acute and chronic health problems. In particular, studies have shown that exposure to air pollution in traffic has been associated with chronic health effects, particularly cardiovascular and respiratory diseases [10–12]. Much evidence has also been found showing the high prevalence of respiratory disease symptoms and asthma exacerbation among those who reside near high-traffic roads [13, 14].

On the Asian continent, China, as one of the fastest developing countries, is battling the health impact associated with air pollution. Annual average $PM_{2.5}$ concentrations in Chinese megacities exceed the WHO's guideline of $10 \mu g/m^3$, and the corresponding black carbon (BC) concentrations are approximately $5 \mu g/m^3$ [15]. The primary sources of air pollution in China are industrial output, coal and biomass combustion, and traffic. Nevertheless, a recent report noted that emissions from heavy urban traffic are the main contributors to urban air pollution in China [16]. The 2010 Global Burden of Disease reported that exposure to air pollutants is the fourth leading health risk factor for Chinese people [17]. Likewise, air pollution in China is also associated with elevated rates of mortality whereby an estimated 350,000 to 500,000 premature deaths were reported to be linked to air pollution [18]. Similarly, in Jakarta, one of the most polluted cities in the world, air pollution was largely associated with motor vehicles, particularly emissions largely created by diesel vehicles [19].

1.2. Economic cost of health impacts of air pollution

Most countries globally and also those in Asia suffer enormous economic loss related to health effects of air pollution on the public. For instance, in China, the economic costs of the health impact of air pollution exceed expectations. It has been estimated that in 2005, China's direct welfare loss from mortalities associated with ozone (O_3) and PM exposure was US\$42 billion [20]. In Jakarta it was reported that the health cost of air pollution in 1999 reached US\$220 million [19]. Likewise, in other countries in Asia, Singapore reported a total economic cost of

US\$3662 million associated with the health impact of particulate air pollution [21]. In Malaysia, a remarkable increase in the hospital admission was noted during almost all haze episodes. In the recent 2013 haze, the cost of illness peaked at MYR410 million in Malaysia [22]. Of note, the cost of air pollution exceeds estimations. The economic impact of air pollution on human extends beyond health. It also has a tremendous impact on social and emotional well-being and daily activities of the affected community. Other important costs of the social effects of air pollution, such as loss of vegetation, and the resulting infertility of the surrounding land, loss of productivity, and decreased work efficiency have not been accounted for.

Considering the immense economic impact of air pollution, the affected communities, particularly the commuters who are regularly exposed to atmospheric air pollution, should be equipped with knowledge of the health impact of air pollution and preventive measures to reduce the health risks associated with exposure to air pollution. A concerted effort on the part of the public to practice mitigation measures is important in order to reduce the economic loss caused by the effects of air pollution.

1.3. Improving environmental health literacy

While effective policies to reduce traffic emissions at their sources are clearly preferable, the evidence supports the benefits of individual personal actions to reduce exposure and health risks associated with traffic emissions. It is well established that knowledge and positive attitudes enhance the population's interest in adopting healthy preventive behaviors. In the context of air pollution and the adverse health impact, environmental health literacy needs to be enhanced. Environmental health literacy is a measure of individual understanding of specific risks, which then leads to broader understanding, including strategies that empower people to reduce or eliminate environmental exposures that can harm their health [23]. Inadequate environmental health literacy, particularly regarding traffic-related air pollutants, may impair mitigation practices, thus leading to health impairment. This is because the level of an individual's awareness and concern has demonstrable effects on whether individuals are willing to carry out self-prevention of exposure to atmospheric air pollution during the daily commute. There was substantial evidence reporting individual- and community-level behavior change in response to environmental exposure and education about exposure [23]. The former is particularly true in Ningbo, where, despite experiencing a relatively low level of exposure to ambient pollution compared with other cities, residents showed a higher awareness about ambient air pollution and its adverse impact on health, which was due to previous episodes of heavy smog they experienced [24]. This implies the importance of experience in shaping health literacy and its implications for behavioral change.

Nevertheless, a review of the literature found that, in many megacities in China and India, as well as Malaysia, despite heightened air pollution, on the whole, there are still substantial important knowledge gaps among the population regarding causes, effects on health, and prevention practices that need considerable attention [25–27]. Efforts are needed from around rapidly developing cities in Asian regions affected by air pollution to set goal-bridging gaps and advance the population's knowledge about air pollutants and health outcomes and, most importantly, on pollution prevention practices that reduce or eliminate risks.

1.4. Community-level policy and practice in reducing traffic-related air pollution

Policy makers and urban planners at the national, city, and local levels of affected countries should make sustained efforts to combat traffic-related air pollution by effective implementation and enforcement of policies. Of immense importance, targets should be placed on reducing the most important source of atmospheric pollution in cities, which is motor vehicle-related emissions. In this regard, efforts should be made to promote environmentally sustainable transport and transport systems. Lowering emissions is one of the major means of improving local air quality, in addition to being the most frequent approach to coping with vehicular pollution. First and foremost, measures should be taken to improve or change the manner in which people get around as the most cost-effective means of reducing vehicle emissions [28]. These include restriction policies such as emission standards, mandatory vehicle inspections, technology and fuel improvement (electric vehicles, biofuels, and natural gas), restrictions on privately owned vehicles, integrated public transportation, rapid transit, and promotion of active transport such as proper bike and walking lanes [29–30]. The use of plug-in hybrid electric vehicles was also found to achieve greater outcomes in terms of pollutant reduction as well as reduce greenhouse gas [31]. Currently, the USA and China are the largest markets for plug-in hybrid electric vehicles, which are relatively less popular in the Southeast Asia region due to high cost, technical limitations of electric cars, and charging inconveniences [32]. There is a need for transport policies to encourage electric vehicle use with price incentives together with investment in more readily available recharging stations [32].

Active transportation (walking and bicycling) has been mentioned in many studies as the best way to reduce car congestion and lower vehicle emissions while also having important health co-benefits, in particular through increased physical activity [33]. Previous studies have quantified the health benefits of replacing car trips with active transportation trips in urban areas [34, 35]. However, considering the risk of exposure to environmental air pollutants and safety while on the road, the implementation of active transport should integrate a network of streets with bike lanes and pedestrian priority at intersections to make active transport trips convenient, pleasant, and safe [35]. Secondly, along with the promotion of active transport, urban planners and policy makers should have a low emission zone to minimize the risk of exposure to atmospheric pollution among active transport users. Heavy traffic coupled with high levels of traffic air pollution levels along active transport routes may pose a major obstacle to its use.

Another important solution to reducing atmospheric air pollution is absorbing existing pollution by increasing vegetation coverage. Numerous studies reported the capacity of urban trees and shrubs to serve as biological filters and mitigate air pollution [36]. Vegetation can serve as a sink for atmospheric particulate matter and is an interface that can absorb organic matter, chemicals, and heavy metals that adhere to particulate matter [37]. Therefore, urban landscape planning and management to increase vegetation and canopy areas along the sides of busy roads may effectively decrease traffic-related pollutants and benefit commuters.

In addition, there is a need to equip the air quality regulatory authorities with effective and efficient urban air quality management plans, primarily to help maintain urban air quality within the prescribed limits or standards. It has been reported that urban air quality

management within countries plays an important role in air quality monitoring and emission inventory [4]. However, this remains a challenge in many developing countries where urban air quality management plans are either in process of development or do not exist at all [4]. The ultimate role of urban air quality management planning is essentially to ensure that the impact of air pollution on the local population remains minimal [4]. It is therefore particularly important for local governments to develop effective air quality management plans for managing urban air pollution in a sustainable and effective long-term manner. Policy makers and urban planners should reinforce stringent air pollution control policies to reduce traffic emission of hazardous air, promote the use of active transport, and enhance green spaces in the cities. More importantly, stringent monitoring and supervision are needed to improve enforcement of traffic emission control. There is also a need for literacy policies and interventions to increase commuter literacy in air pollution and equip them with knowledge of effective pollution control strategies.

1.5. Best practices to reduce personal exposure

While national policies to reduce air pollution at the source are clearly more effective, it is well established that individual-level exposure prevention is effective in reducing exposure and health risks. Using a respiratory filter mask offers the most convenient way to reduce inhalation of pollutants. There is mounting evidence to suggest that the use of a respiratory filter mask is beneficial in minimizing the impact of atmospheric air pollution during rush hour traffic. A respiratory filter mask filters particulate matter out of the air and prevents it from entering the respiratory system. If commuting by public transport is inevitable, wearing a respiratory filter mask is the most effective way to reduce inhalation of particles and mitigate their negative health effects. A study showed that wearing even a simple inexpensive face mask has the potential to protect susceptible individuals and prevent cardiovascular events in cities with high concentrations of ambient air pollution and provides an alternative that may lead to reduced cardiovascular morbidity and mortality [38]. It has also been reported that reduction in symptoms and improvement in cardiovascular health were observed when patients with coronary heart disease were protected from exposure to particulate air pollution by the use of highly efficient face mask (e.g., N95 equivalent) [39]. Wearing a face mask was also found to be beneficial for people without cardiovascular health problems. Among healthy subjects, wearing a face mask appears to abrogate the adverse effects of air pollution on blood pressure and heart rate variability and to decrease cardiovascular risk [38].

Apart from face mask protection, a large body of evidence demonstrates that a healthy diet including fruits and vegetables and supplement intake may protect against the air pollution-induced health threat. Omega-3 polyunsaturated fatty acids (PUFAs) from fish oil were found to prevent the negative impact of $PM_{2.5}$ on heart rate variability [40] and protect against the deleterious cardiac and lipid effects induced by acute exposure to particulate matter [41]. In another study, health outcomes of $PM_{2.5}$, including heart rate variability, were modified by dietary intake of micronutrients (folate, vitamin B6 and B12, methionine) [42]. Antioxidant supplementation (vitamins E and C) was found to be helpful in reducing oxidative stress in the body associated with airborne contamination [43]. Thus, being in a polluted air environment, it is critical that commuters should have a healthy diet with adequate intake of essential

micronutrients to prevent the development of chronic diseases, particularly cardiovascular and pulmonary diseases. Increased intake of antioxidants, as well as other anti-inflammatory nutrients, is also important to reduce air pollution-induced oxidative stress and inflammation, particularly among those with cardiovascular disease, asthma, and other chronic inflammatory diseases [44]. Further, it has been suggested that, in addition to a healthy diet, drinking additional water can reduce throat irritation and help the kidneys flush out any absorbed toxins [45, 46].

As public transport commuters are exposed to pollution more than car commuters because they are in the open air during commuter waiting or walking along the road, carpooling as a way of transport may reduce the time spent outside the busy road. Of note, several barriers to carpooling have been reported. Inconveniences of sharing, sense of privacy, self-confidence, and self-gratification relating to driving “my own car” may serve as barriers to carpooling with privately owned vehicles [47]. To be functional, this system of transport should be promoted to elicit general awareness about private interests in carpooling to reduce health hazards, reduce traffic and pollution, and save costs. The current Uber and GrabCar concepts greatly reduce pollution and traffic congestion. Nevertheless, carpooling in Uber and GrabCar usually addresses the one person per vehicle problem with a two person per vehicle solution. It would be better if Uber and GrabCar extended to more than two persons per vehicle to fully maximize the concept of carpooling.

2. Physical and psychological health impacts on public transport commuters: evidence in Malaysia

In Malaysia, a swelling urban population and increased column of motorized traffic in cities have resulted in severe air pollution affecting the surrounding city environment as well as the health of people in the cities. The number of commuters and commute durations has increased substantially in recent decades. People in the city are spending long hours traveling to and from work. Most commuters are exposed to vehicle emission during transit (**Figure 1**). Considering that air pollution caused by traffic is the scourge of many modern cities worldwide and likewise in Malaysia, we conducted a study to examine the health impact of commuting and the mitigation measures practiced by public transport commuters. Presently, the understanding of the impact of air pollution from congestion on roads on the health of people in Malaysia who are exposed during their daily commute is very limited. Such a study is highly warranted and will be used to inform policy making related to traffic and air quality management and mitigation intervention in terms of health effects.

From June to October 2016, a total of 800 public transport commuters in urban cities in the heart of Selangor, Malaysia, were interviewed face to face. The commuters were approached at the Light Rail Transit train stations along the Kelana Jaya and Ampang lines in the state of Selangor, Malaysia. In the interview, self-reported adverse health effects (both physical health, 15 items, and psychological health, 7 items) associated with exposure to atmospheric air pollutants during the daily commute were queried. Self-reported control measures used by participants to mitigate their exposure to atmospheric air pollutants were also assessed.



Figure 1. Commuters exposed to vehicle emission during transit.

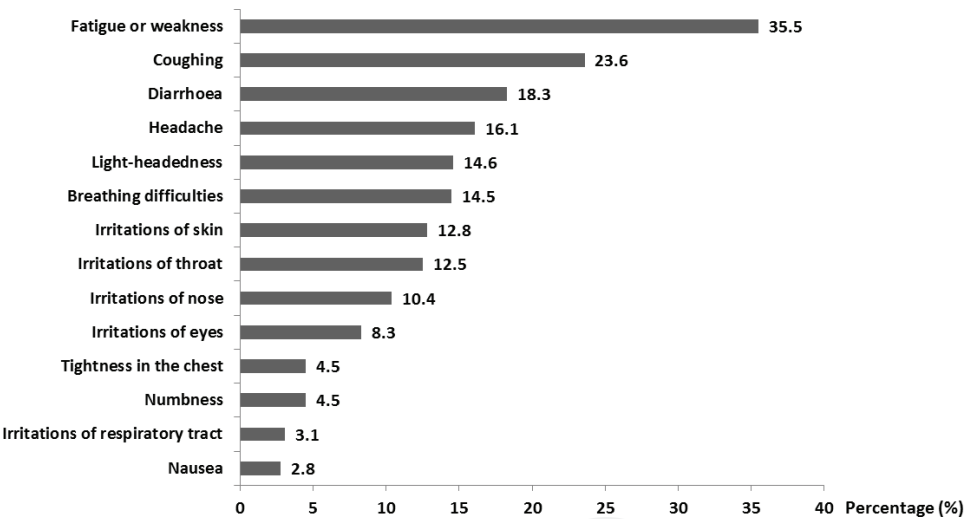


Figure 2. Proportion of adverse physical health effects experienced (%) during the daily commute.

The majority (56.5%) of respondents were aged 30 years and below (mean age, 30.8 years; standard deviation, 6.6; age range, 18–54 years). The ethnic and gender distribution of the study participants closely matched that of the general Malaysian population. A total of 41% of the study respondents spent more than 1 hour commuting by public transport daily. When the respondents were queried on adverse physical health effects they experienced from exposure to air pollution during their daily commute, as shown in **Figure 2**, the highest percentage reported physical fatigue or weakness (35.5%), followed by coughing (23.6%). A considerable proportion reported headache (16.1%), light-headedness (14.6%), and breathing difficulties (14.5%). Air pollution has a wide range of effects on human health. This study evidenced the experience of various physical health impacts commonly associated with exposure to atmospheric air pollutants by daily public transport users.

The physical effects of air pollution on human health has been studied and reported more than the psychological health impacts. However, the impact of air pollution on psychological health is equally prominent. In an animal model, exposure to exhaust emissions increased anxiety- and depression-like behavior and led to impaired memory in rats [48]. Few studies reported psychological health impacts in Western countries [49, 50]; however, psychological health impacts of being exposed to vehicular traffic-related pollutants have rarely been evident in the Asian region. In this study, as shown in **Figure 3**, the most common psychological impact associated with exposure to air pollution during the daily commute was stress (13.0%), followed by insomnia (5.0%) and feeling moody and anxious (3.6%). Depression was reported by 1.1% of respondents. Although the proportion of psychological health effects experienced are lower than that of physical health effects, mental and emotional well-being is essential to overall health. The proportions, although low, have significant clinical implications.

In this study females and the older age group reported higher levels of overall adverse physical and psychological health impacts. However, there were no differences in adverse health outcomes by income and educational levels. As the study is cross-sectional and cannot be used to infer causality, future longitudinal studies are needed to confirm the causal relationship between exposure to road traffic pollution and health impacts. Furthermore, this study recorded self-reported assessment of symptoms and thus was subject to self-reporting bias.

Figure 4 shows the proportion of control measures undertaken by respondents to reduce exposure to atmospheric pollutants during their daily commute. Despite exposure to atmospheric air pollutants during their daily commute, the vast majority of the study participants reported never or rarely practicing control measures to alleviate the adverse impact of air pollution during their daily commute. Relatively higher proportions reported practicing healthcare measures such as drinking more water and increasing their consumption of fruits and vegetables rather than using respiratory protection. On a positive note, consuming a healthy diet and drinking water may help to improve the body's immune system and alleviate the adverse impacts of air pollution [46]. Although face mask protection is widely used by many commuters in many cities worldwide and regarded as the most common and effective means of reducing inhalation of atmospheric air pollutants, the majority of the study

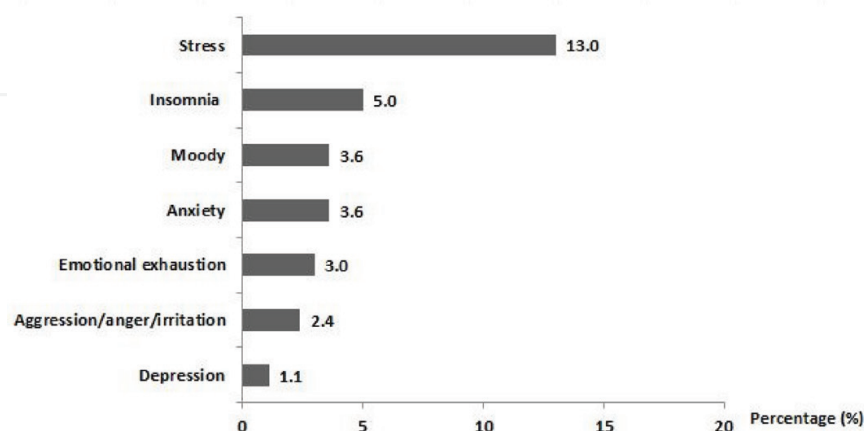


Figure 3. Proportion of the sample reporting adverse psychological health effects experienced during the daily commute.

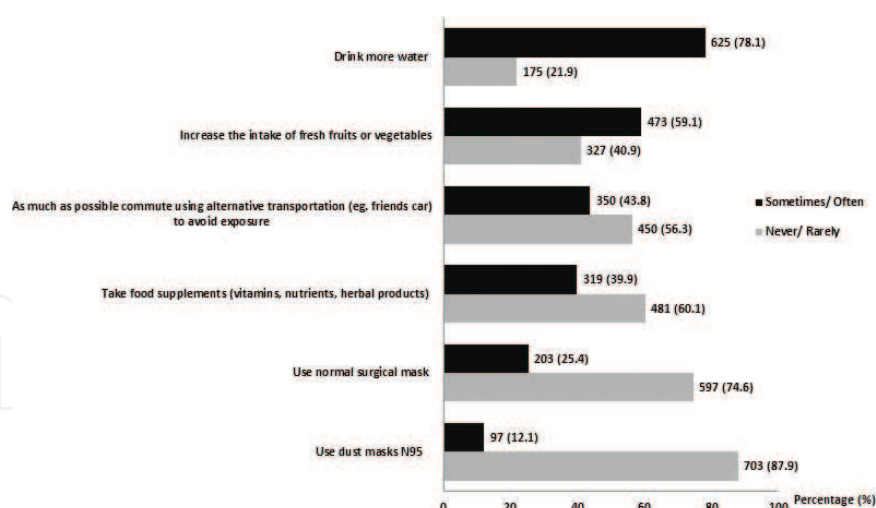


Figure 4. Proportion of respondents reporting the use of control measures during daily commuting.

respondents (74.6%, $n = 597$) reported never or rarely using a face mask. Face mask protection is not common among commuters in Malaysia and is rarely seen among the public, even on smoke-engulfed busy streets. Facial mask in Malaysia is inexpensive and readily available in most pharmacy outlets. There is a need to know if there is a feeling of embarrassment among the Malaysian public at being seen wearing a facial protection masks as face mask use in the community is not widespread (**Figure 5**), or reluctance to use a face mask is due to the perception of discomfort along with a feeling of difficulty breathing in hot and humid weather. In Japan, China, and Hong Kong, wearing a surgical mask is a social norm [51]. The use of a facial mask in tropical countries of Southeast Asia, such as Indonesia, India, and Malaysia, is relatively less common. If face mask usage becomes widespread and commonly seen, perhaps more people will be likely to use them. In this regard, more publicity is needed to encourage widespread use of face mask protection against atmospheric air pollutants in cities. Therefore, reluctance or barriers to the use of face masks during the daily commute or while on streets with polluted air are issues that need further investigation. The use of facial masks should be encouraged in Southeast Asian countries.

This study also found poor usage of N95 face protection. Although the use of simple surgical mask protection is recommended for commuters and has been found to have beneficial cardiovascular effects of reducing exposure to particulate air pollutants [38], the use of N95 face protection is more effective. Particles smaller than $2.5 \mu\text{m}$ are widespread in vehicle emissions and absorbed into the bloodstream, initiating the pro-inflammatory cascade, which leads to many adverse health effects. The N95 is a US government-certified mask that blocks 95% of particulate matter (PM) smaller than $2.5 \mu\text{m}$ —or even smaller, at $0.3 \mu\text{m}$. Emission of $\text{PM}_{2.5}$ from road vehicles is an important source of atmospheric air pollution in cities. Consequently, the levels of $\text{PM}_{2.5}$ near urban roadsides are consistently high [52]; therefore, the use of N95 will ideally offer better protection. In Malaysia, the prevalence of normal surgical mask use is low; therefore, enhancement of use of N95 may require extra effort. The public, especially daily commuters, should be made aware that wearing an N95 mask is more useful in avoiding the detrimental effects of ambient air pollutants [53] and is especially recommended for



Figure 5. Wearing a mask to reduce inhalation of air pollutant is not a common sight in Malaysia.

people with chronic respiratory disease [54]. In a separate report, we compared the use of a facial protection mask and an N95 mask among commuters in the event of severe haze, and increases in the use of both facial protection masks and N95 masks were reported [55]. Nevertheless, the proportion of the population that uses N95 masks is still low: only 66.0% of respondents reported using N95 masks while commuting during severe haze [55]. The haze phenomenon in Malaysia is often due to illegal burning of forests and peat and forest fires from neighboring countries. In the event of severe haze, respiratory protection is required when going outdoors and especially among commuters who are already exposed to vehicle emissions. While a face mask may be effective at filtering large particles, a face mask, by design, does not filter small particles in the air such as vehicle emissions and airborne particles. In contrast, an N95 is a respiratory protective device designed to achieve a close facial fit and is more efficient in the filtration of small particles. Therefore, using an N95 respirator which provides a good fit and high filtration should be highly recommended to public transport commuters.

The majority of respondents reported never or rarely trying to commute using alternative transportation as much as possible. These findings imply the considerable need to encourage as much as possible the use of alternative transit mode options while traveling around or to the city to work. Carpooling may help reduce contact with atmospheric air pollutions and

		Total physical and psychological health experience score during daily commute days		
		Score	Score	P value
		0–4	5–22	
		(n = 684)	(n = 116)	
Sociodemographic data				
Age group (years old)				
30 and below	452 (56.5)	387 (85.6)	65 (14.4)	0.389
31–40	265 (33.1)	230 (86.8)	35 (13.2)	
>40	83 (10.4)	67 (80.7)	16 (19.3)	
Gender				
Male	424 (53.0)	370 (87.3)	54 (12.7)	0.159
Female	376 (47.0)	314 (83.5)	62 (16.5)	
Marital status				
Single	414 (51.8)	356 (86.0)	58 (14.0)	0.689
Married	386 (48.3)	328 (85.0)	58 (15.0)	
Ethnicity				
Malay	388 (48.5)	332 (85.6)	56 (14.4)	0.636
Chinese	271 (33.9)	235 (86.7)	36 (13.3)	
Indian	138 (17.3)	115 (83.3)	23 (16.7)	
Others	3 (0.4)	2 (66.7)	1 (33.3)	
Highest education level				
Secondary level and below	146 (18.2)	124 (84.9)	22 (15.1)	0.796
Tertiary level	654 (81.8)	560 (85.6)	94 (14.4)	
Occupation				
Professional and managerial	419 (52.4)	358 (85.4)	61 (14.6)	0.951
Skilled/non-skilled worker	314 (40.6)	278 (85.5)	47 (14.5)	
Student	54 (6.8)	46 (85.2)	8 (14.8)	
Housewife	2 (0.2)	2 (100.0)	0 (0.0)	
Monthly income (MYR)				
5000 and below	651 (81.4)	559 (85.9)	36 (14.1)	0.826
>5000	149 (18.6)	125 (83.9)	56 (14.1)	
Other risks				
Chronic diseases				
Yes	51 (6.4)	40 (78.4)	92 (14.1)	0.521
No	749 (93.6)	644 (86.0)	24 (16.1)	

		Total physical and psychological health experience score during daily commute days		
		Score	Score	P value
		0–4	5–22	
		(n = 684)	(n = 116)	
Smoking status				
Yes	309 (38.6)	266 (86.1)	43 (13.9)	0.758
No	491 (61.4)	418 (85.1)	73 (14.9)	
Living near a highway				
Yes	292 (36.5)	255 (87.3)	37 (12.7)	0.297
No	508 (63.5)	429 (84.4)	79 (15.6)	
Duration spent commuting by public transport (hours)				
1 hour and below	472 (59.0)	412 (87.3)	60 (12.7)	0.102
>1 hour	328 (41.0)	272 (82.9)	56 (17.1)	
Control measures				
Total control measure score				
Score 0–8	440 (55.0)	371 (84.3)	69 (15.7)	0.314
Score 9–18	360 (45.0)	313 (86.9)	47 (13.1)	

Table 1. Factors associated with total physical and psychological health experience score (n = 800).

should be encouraged. As indicated above, carpooling by Uber and GrabCar that allow more than two persons per vehicle would reduce the chance of exposure while being out on the road or waiting at stops or stations while minimizing number of private cars on the road.

As shown in **Table 1**, further investigation of the association between control measures and overall physical and psychological health impacts found that respondents with lower use of control measures experience a higher total health impact. It was also found that those who spend longer commuting were more likely to report higher overall physical and psychological health impacts. However, none of the associations were statistically significant; therefore, further studies are needed to verify these associations. Of note, the absence of significant differences between control measures and health impact found in this study could also imply the need to enhance control measures among people who experience a higher health impact. Ideally those who experience a higher health impact should practice greater mitigation measures than those with lower health impacts. Consequently, our findings may imply that commuters in the city of Kuala Lumpur, in particular those who experience a higher health impact, should be encouraged to carry out greater mitigation practices against exposure to atmospheric air pollution during the daily commute. We also found higher health impact score among those with longer commuting duration, although the association is not statistically significant. Further studies are needed to confirm this finding. Of note, this is a cross-sectional study; therefore, the cause and effect relationship between control measures and health impact cannot be established.

3. Directions for future research

It is globally recognized that battling traffic congestion, spending a long time commuting, and exposure to atmospheric pollutants during the daily commute result in serious adverse effects on the health and general well-being of commuters. There is a paucity of epidemiological studies regarding the adverse health impacts of atmospheric air pollution, which is worsened by traffic-related air pollution in rapidly developing cities. Although commuting undeniably has a significant impact on public health outcomes, in the Asian region in particular, little empirical evidence has documented the adverse health effects associated with commuting. More research, especially in the form of longitudinal studies, is critically needed to provide insights into the population health impact of traffic-related air pollution in Asia, the world's most rapidly developing region.

Given the many factors such as vehicles, fuel type, topography, meteorological conditions, and a complex array of health determinants such as social, behavioral, and lifestyle factors that may influence the degree of atmospheric pollution and its subsequent impact on human health, emphasis is warranted across all countries on tailoring their health impact assessments according to the specific needs of the affected populations within cities. Measuring local specific health outcomes associated with using public transport would enable specific tailored monitoring and evaluation of and accountability for the health of the relevant population. Subsequently, action plans must be tailored to individual cities and countries at large.

Likewise, the assessment of mitigation practices must also be tailored to understanding barriers to carry out specialized prevention in order to determine target areas for education in the respective cities and countries. It is also important to assess how commuters in a specific area respond to the adverse effects of commuting to work and exposure to traffic pollutants daily. It is vital to assess the level of preventive measures carried out by commuters as well as the types of preventive measures undertaken and the barriers to their use. Such information varies among cities across Asia as well as in Western countries and may be influenced by various factors such as culture, religion, and climate, as well as policy and governance. Identifying the specific health impact of air pollution and level of mitigation measures taken provides an important basis for customized environmental governance by governments of the respective countries.

There is also a dire need to investigate ways to improve upon the measurement of ambient air quality, provide accurate air quality data, and effectively inform the public when ambient air quality is at a dangerous level. Coupled with that, publicly available air quality data can support communication efforts so that people can act to protect themselves against exposure. Furthermore, an informed public can also help to advocate for prevention initiatives such as a reduction in the use of private vehicles to decrease traffic volume during peak-period traffic. As the health effects of air pollution can be reduced via improved understanding and subsequent proper self-preventive measures, a study to identify knowledge gaps and barriers to reducing exposure to traffic-related air pollution during commuting should be carried out to identify intervention strategies, especially for the susceptible population of public transport commuters.

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Conflict of interest

The authors declare no conflict of interest.

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References

- [1] Rivas I, Kumar P, Hagen-Zanker A. Exposure to air pollutants during commuting in London: Are there inequalities among different socio-economic groups? *Environment International*. 2017;**101**:143-157
- [2] Baldasano JM, Valera E, Jimenez P. Air quality data from large cities. *The Science of the Total Environment*. 2003;**307**:141-165
- [3] Martin J. The European environment: State and outlook 2010: Synthesis. European Environment Agency. 2010:31-33
- [4] Gulia S, Nagendra SS, Khare M, Khanna I. Urban air quality management-a review. *Atmospheric Pollution Research*. 2015;**6**:286-304

- [5] Zhang K, Batterman S. Air pollution and health risks due to vehicle traffic. *The Science of the Total Environment*. 2013;**450**:307-316
- [6] Brook RD, Rajagopalan S, Pope CA, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation*. 2010;**121**:2331-2378
- [7] Cheng J. WHO: Air Pollution has Become the World's Largest Environmental Health Risk. Available from: http://health.huanqiu.com/health_news/2015-06/6581336.html?referer=huanqiu. [Accessed: 16-05-2018]
- [8] WHO. 7 million deaths annually linked to air pollution. *Central European Journal of Public Health*. 2014;**22**:53-59
- [9] Van Donkelaar A, Martin RV, Brauer M, Kahn R, Levy R, Verduzco C, Villeneuve PJ. Global estimates of ambient fine particulate matter concentrations from satellite-based aerosol optical depth: Development and application. *Environmental Health Perspectives*. 2010;**118**:847
- [10] Adar SD, Davey M, Sullivan JR, Compher M, Szpiro A, Liu LJ. Predicting airborne particle levels aboard Washington state school buses. *Atmospheric Environment*. 2008;**42**:7590-7599
- [11] McCreanor J, Cullinan P, Nieuwenhuijsen MJ, Stewart-Evans J, Malliarou E, Jarup L, Harrington R, Svartengren M, Han IK, Ohman-Strickland P, Chung KF. Respiratory effects of exposure to diesel traffic in persons with asthma. *The New England Journal of Medicine*. 2007;**357**:2348-2358
- [12] Peters A, Von Klot S, Heier M, Trentinaglia I, Hörmann A, Wichmann HE, Löwel H. Exposure to traffic and the onset of myocardial infarction. *The New England Journal of Medicine*. 2004;**351**:1721-1730
- [13] Shima M, Nitta Y, Adachi M. Traffic-related air pollution and respiratory symptoms in children living along trunk roads in Chiba prefecture, Japan. *Journal of Epidemiology*. 2003;**13**:108-119
- [14] Brauer M, Hoek G, Van Vliet P, Meliefste K, Fischer PH, Wijga A, Koopman LP, Neijens HJ, Gerritsen J, Kerkhof M, Heinrich J. Air pollution from traffic and the development of respiratory infections and asthmatic and allergic symptoms in children. *American Journal of Respiratory and Critical Care Medicine*. 2002;**166**:1092-1098
- [15] Ji D, Zhang J, He J, Wang X, Pang B, Liu Z, Wang L, Wang Y. Characteristics of atmospheric organic and elemental carbon aerosols in urban Beijing, China. *Atmospheric Environment*. 2016;**125**:293-306
- [16] Sun C, Luo Y, Li J. Urban traffic infrastructure investment and air pollution: Evidence from the 83 cities in China. *Journal of Cleaner Production*. 2018 Jan 20;**172**:488-496
- [17] Yang G, Wang Y, Zeng Y, Gao GF, Liang X, Zhou M, Wan X, Yu S, Jiang Y, Naghavi M, Vos T. Rapid health transition in China, 1990-2010: Findings from the global burden of disease study 2010. *The Lancet*. 2013;**381**:1987-2015

- [18] Chen Z, Wang JN, Ma GX, Zhang YS. China tackles the health effects of air pollution. *The Lancet*. 2013;**382**:1959-1960
- [19] Resosudarmo BP, Napitupulu L. Health and economic impact of air pollution in Jakarta. *The Economic Record*. 2004;**80**:65-66
- [20] Matus K, Nam KM, Selin NE, Lamsal LN, Reilly JM, Paltsev S. Health damages from air pollution in China. *Global Environmental Change*. 2012;**22**:55-66
- [21] Quah E, Boon TL. The economic cost of particulate air pollution on health in Singapore. *Journal of Asian Economics*. 2003;**14**:73-90
- [22] Abd Manan N, Abdul Manaf MR, Hod R. The Malaysia haze and its health economy impact. A literature review. *Malaysian Journal of Public Health Medicine*. 2018;**18**:1-9
- [23] Gray KM. From content knowledge to community change: A review of representations of environmental health literacy. *International Journal of Environmental Research and Public Health*. 2018;**15**:466
- [24] Qian X, Xu G, Li L, Shen Y, He T, Liang Y, Yang Z, Zhou WW, Xu J. Knowledge and perceptions of air pollution in Ningbo, China. *BMC Public Health*. 2016;**16**:1138
- [25] Liu X, Zhu H, Hu Y, Feng S, Chu Y, Wu Y, Wang C, Zhang Y, Yuan Z, Lu Y. Public's health risk awareness on urban air pollution in Chinese megacities: The cases of Shanghai, Wuhan and Nanchang. *International Journal of Environmental Research and Public Health*. 2016;**13**:845
- [26] Haque MS, Singh RB. Air pollution and human health in Kolkata, India: A case study. *Climate*. 2017;**5**:77
- [27] De Pretto L, Acreman S, Ashfold MJ, Mohankumar SK, Campos-Arceiz A. The link between knowledge, attitudes and practices in relation to atmospheric haze pollution in peninsular Malaysia. *PLoS One*. 2015;**10**:e0143655
- [28] Wright L, Fulton L. Climate change mitigation and transport in developing nations. *Transport Reviews*. 2005;**25**:691-717
- [29] Pojani D, Stead D. Sustainable urban transport in the developing world: Beyond megacities. *Sustainability*. 2015;**7**:7784-7805
- [30] Slovic AD, de Oliveira MA, Biehl J, Ribeiro H. How can urban policies improve air quality and help mitigate global climate change: A systematic mapping review. *Journal of Urban Health*. 2016;**93**:73-95
- [31] Kantor I, Fowler MW, Hajimiragha A, Elkamel A. Air quality and environmental impacts of alternative vehicle technologies in Ontario, Canada. *International Journal of Hydrogen Energy*. 2010;**35**:5145-5153
- [32] Delang CO, Cheng WT. Hong Kong people's attitudes towards electric cars. *International Journal of Electric and Hybrid Vehicles*. 2013;**5**:15-27
- [33] Macmillan A, Connor J, Witten K, Kearns R, Rees D, Woodward A. The societal costs and benefits of commuter bicycling: Simulating the effects of specific policies using system dynamics modeling. *Environmental Health Perspectives*. 2014;**122**:335-344

- [34] Rojas-Rueda D, De Nazelle A, Teixidó O, Nieuwenhuijsen MJ. Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: A health impact assessment study. *Environment International*. 2012;**49**:100-109
- [35] Rojas-Rueda D, De Nazelle A, Andersen ZJ, Braun-Fahrländer C, Bruha J, Bruhova-Foltynova H, Desqueyroux H, Praznocy C, Ragetti MS, Tainio M, Nieuwenhuijsen MJ. Health impacts of active transportation in Europe. *PLoS One*. 2016;**11**:e0149990
- [36] Brugge D, Patton AP, Bob A, Reisner E, Lowe L, Bright OJ, Durant JL, Newman J, Zamore W. Developing community-level policy and practice to reduce traffic-related air pollution exposure. *Environmental Justice*. 2015;**8**:95-104
- [37] Tallis M, Taylor G, Sinnett D, Freer-Smith P. Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*. 2011;**103**:129-138
- [38] Langrish JP, Mills NL, Chan JK, Leseman DL, Aitken RJ, Fokkens PH, Cassee FR, Li J, Donaldson K, Newby DE, Jiang L. Beneficial cardiovascular effects of reducing exposure to particulate air pollution with a simple facemask. *Particle and Fibre Toxicology*. 2009;**6**:8
- [39] Langrish JP, Li X, Wang S, Lee MM, Barnes GD, Miller MR, Cassee FR, Boon NA, Donaldson K, Li J, Li L. Reducing personal exposure to particulate air pollution improves cardiovascular health in patients with coronary heart disease. *Environmental Health Perspectives*. 2012;**120**:367
- [40] Romieu I, Téllez-Rojo MM, Lazo M, Manzano-Patiño A, Cortez-Lugo M, Julien P, Bélanger MC, Hernandez-Avila M, Holguin F. Omega-3 fatty acid prevents heart rate variability reductions associated with particulate matter. *American Journal of Respiratory and Critical Care Medicine*. 2005;**172**:1534-1540
- [41] Tong H, Rappold AG, Diaz-Sanchez D, Steck SE, Berntsen J, Cascio WE, Devlin RB, Samet JM. Omega-3 fatty acid supplementation appears to attenuate particulate air pollution-induced cardiac effects and lipid changes in healthy middle-aged adults. *Environmental Health Perspectives*. 2012;**120**:952
- [42] Baccarelli A, Cassano PA, Litonjua A, Park SK, Suh H, Sparrow D, Vokonas P, Schwartz J. Cardiac autonomic dysfunction: Effects from particulate air pollution and protection by dietary methyl nutrients and metabolic polymorphisms. *Circulation*. 2008;**117**:1802-1809
- [43] Possamai FP, Júnior SÁ, Parisotto EB, Moratelli AM, Inácio DB, Garlet TR, Dal-Pizzol F, Wilhelm Filho D. Antioxidant intervention compensates oxidative stress in blood of subjects exposed to emissions from a coal electric-power plant in South Brazil. *Environmental Toxicology and Pharmacology*. 2010;**30**:175-180
- [44] Péter S, Holguin F, Wood LG, Clougherty JE, Raederstorff D, Antal M, Weber P, Eggersdorfer M. Nutritional solutions to reduce risks of negative health impacts of air pollution. *Nutrients*. 2015;**7**:10398-10416

- [45] Cai DP, He YM. Daily lifestyles in the fog and haze weather. *Journal of Thoracic Disease*. 2016;**8**:E75
- [46] Rajper SA, Ullah S, Li Z. Exposure to air pollution and self-reported effects on Chinese students: A case study of 13 megacities. *PLoS One*. 2018;**13**:e0194364
- [47] Galizzi MM. The economics of car-pooling: A survey for Europe. In: Paper for the Workshop: Highways-Cost and Regulation in Europe. Bergamo, Italy: Università degli Studi di Bergamo; 2004
- [48] Salvi A, Patki G, Liu H, Salim S. Psychological impact of vehicle exhaust exposure: Insights from an animal model. *Scientific Reports*. 2017;**7**:8306
- [49] Shin J, Park JY, Choi J. Long-term exposure to ambient air pollutants and mental health status: A nationwide population-based cross-sectional study. *PLoS One*. 2018;**13**:e0195607
- [50] Sass V, Kravitz-Wirtz N, Karceski SM, Hajat A, Crowder K, Takeuchi D. The effects of air pollution on individual psychological distress. *Health & Place*. 2017;**48**:72-79
- [51] Wada K, Oka-Ezoe K, Smith DR. Wearing face masks in public during the influenza season may reflect other positive hygiene practices in Japan. *BMC Public Health*. 2012;**12**:1065
- [52] Ginzburg H, Liu X, Baker M, Shreeve R, Jayanty RK, Campbell D, Zielinska B. Monitoring study of the near-road PM_{2.5} concentrations in Maryland. *Journal of the Air & Waste Management Association*. 2015;**65**:1062-1071
- [53] Zhao P, Yu KP, Lin CC. Risk assessment of inhalation exposure to polycyclic aromatic hydrocarbons in Taiwanese workers at night markets. *International Archives of Occupational and Environmental Health*. 2011;**84**:231-237
- [54] Jiang XQ, Mei XD, Feng D. Air pollution and chronic airway diseases: What should people know and do? *Journal of Thoracic Disease*. 2016;**8**:E31
- [55] Wong LP, Alias H, Aghamohammadi N, Ghadimi A, Sulaiman NM. Control measures and health effects of air pollution: A survey among public transportation commuters in Malaysia. *Sustainability*. 2017;**9**:1616

