

Article

# Relationships between Body Mass Index and Self-Reported Motorcycle Crashes in Vietnam

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**Abstract:** The relationship between overweight, obesity, or body mass index (BMI) and crashes among drivers of passenger cars, vans, and trucks has been the focus of much research. However, little is understood about this relationship among motorcyclists, particularly motorcycle taxi drivers who tend to work long hours. Motorcycle taxis are an increasingly popular and important mode of travel in many cities, especially in South-East Asia, due partly to the rise of ride-hailing services. This paper assesses the body mass index (BMI) of motorcycle taxi drivers in Vietnam and its impacts on crashes among three types of drivers (traditional, ride-hailing, and hybrid). Data from a structured questionnaire survey of motorcycle taxi drivers conducted in Hanoi, Vietnam were used. Results show that 18.8% of motorcycle taxi drivers were overweight or obese whereas only 1.4% were underweight. Fulltime motorcycle taxi drivers were more likely to be overweight or obese. Results of random effect binary logistic regression show that overweight and obese motorcycle taxi drivers had significantly higher overall and injury crash risks, when compared to normal-weight motorcycle taxi drivers. Results also indicate that hybrid motorcycle taxi drivers had lower overall and injury crash risks when compared to traditional motorcycle taxi drivers.

**Keywords:** motorcycle; taxi; BMI; crash; overweight

## 1. Introduction

Obesity and overweight, which can be measured using the body mass index (BMI), is an increasing health issue in many countries [1]. Besides being a major risk factor in several non-communicable diseases, obesity can present substantial risks when performing complex tasks, such as driving that requires continuous attention and vigilance [2], due to associations with obstructive sleep apnea [3], excessive daytime sleepiness [4], and fatigue [5]. While the literature on the effects of overweight and obesity on riding a motorcycle has been scarce, there are a number of studies, often conducted in developed countries, reporting these effects in the context of driving a car or truck. For example, an association between increased crash risks and obesity was evident among professional truck drivers in the US [2]. Previous research also showed impacts of obesity on injury risks. In the US, it was reported that obese passenger car drivers had a significantly higher risk of fatalities when compared to non-obese drivers [6]. Another study of motor vehicle (passenger cars, light trucks, and vans) crashes in the US found that the risk of death increased substantially at both ends of the BMI distribution among male drivers [7]. In addition, among belted female drivers in the US (excluding motorcyclists), normal BMI was associated with the lowest risk of deaths [8].

As previous research tends to focus on the relationship between BMI/obesity and crashes among drivers of passenger cars, vans, and trucks, little is known about this relationship among motorcycle riders. Furthermore, mixed effects of obesity and overweight on motorcycle crash risks have been reported. A study focusing on older motorcycle riders in Taiwan found that obese older motorcycle riders had a lower risk of crashes compared to normal-weight riders [9]. A recent study focusing on crashes that were related to fatigue among motorcycle taxi drivers in Vietnam, however, showed an association between overweight and increased risks of fatigue-related crashes [10]. Different injury patterns and longer hospital stays were found among obese motorcycle riders when compared to normal-weight motorcycle riders in Taiwan [11]. Overall, existing evidence relating to the relationship between motorcycle riders' BMI and crashes has been scarce and remains inconclusive.

Riding a motorcycle is a different task compared to driving a car, truck, or van. Unlike drivers of passenger cars, trucks, and vans, motorcycle riders are directly exposed to weather conditions and must maintain the stability of their motorcycle constantly. Riding a motorcycle would be more physically demanding than driving a car. There is evidence that obesity and overweight can hinder physical functioning [12,13], and postural stability and balance [14,15]. These reduced physical abilities would be a contributor to the effects of overweight and obesity on occupational injuries reported in several studies [16,17]. It is worth noting that traffic-related occupational injuries were not explicitly considered in these studies. Yet, little is understood about the relationship between traffic injuries and BMIs among motorcyclists. Nevertheless, for motorcycle riders, obesity and overweight would impact crash risks due to the aforementioned associations with reduced physical abilities.

Motorcycle riders are vulnerable road users with an increasing frequency and severity of crashes in many developed and developing countries [18]. The share of motorcyclist road deaths is about 28% globally, and highest in South-East Asia with 43% [19]. Among the South-East Asian countries, Vietnam and Thailand have a significantly greater share of motorcyclist road deaths, with 60% and 74%, respectively [19–21]. Motorcyclist safety is significantly affected by risky riding behaviours, which were reported in various studies [18,22–25].

In many cities, particularly in South-East Asia, motorcycle taxis have become a popular means of travel given their inexpensive, flexible, and fast services [26,27]. The popularity of motorcycle taxis has been increasing substantially recently, following the emergence of ride-hailing services such as GrabBike. Previous studies have showed high prevalence of crashes among traditional motorcycle taxi drivers [28,29]. Recently, Truong and Nguyen [30] found that ride-hailing motorcycle taxi drivers tended to have a greater risk of involvement in a mobile phone-related crash. Wu and Loo [31] found a higher tendency to engage in risky riding behaviours among motorcycle taxi drivers when compared to non-occupational motorcycle riders.

As motorcycle taxi drivers often have prolonged working hours, the impacts of obesity and overweight on crash risks may potentially be significant. An understanding of associations between BMI and crashes among motorcycle taxi drivers will have important implications for the occupational health and safety of these taxi-riders as well as health and safety of the general road users. While occupational health and safety of professional drivers have been the subjects of a growing body of literature [2,31–34], there is a lack of research examining associations between BMI and crashes, particularly injury crashes, among motorcycle taxi drivers, as discussed above.

This paper aims to assess the body mass index (BMI) of motorcycle taxi drivers in Hanoi, Vietnam and examine its impacts on overall crashes and injury crashes. In addition to traditional motorcycle taxi drivers, two emerging types (ride-hailing and hybrid) are considered. The hybrid motorcycle taxi driver is a combination of the traditional and ride-hailing taxi driver.

In Vietnam, approximately 8100 people died on roads in 2018, in which approximately 7% occurred in Hanoi [35]. About 95% of above 40 million registered vehicles by 2013 in Vietnam were motorcycles [24]. Since motorcycles are the main means of travel, motorcyclists accounted for approximately 60% of road traffic deaths [20]. In Hanoi, the capital city of Vietnam, the traffic flow is dominated by motorcycles, i.e., more than eight out of ten vehicles are motorcycles [36]. Most

motorcycles have an engine size of less than 150cc. Motorcycle taxis are a popular form of transport in this city. It was estimated that in 2007, Hanoi had roughly between 50,000 and 100,000 motorcycle taxis [37], which is likely to be higher now due to the widespread development of ride-hailing services.

## 2. Materials and Methods

### 2.1. Data

Data were collected by a structured questionnaire survey conducted between January and March 2019 in Hanoi, Vietnam. The survey had a wider scope of exploring motorcycle taxi drivers' crash involvement and health conditions [30]. The focus of this paper is on BMI and its potential effects on crashes (including falls and other single vehicle crashes) among motorcycle taxi drivers. The research was approved by the La Trobe University Human Ethics Committee. No incentives were provided for motorcycle taxi drivers to complete the survey. This is an anonymous survey, and participation is strictly voluntary.

A team of four trained surveyors interviewed motorcycle taxi drivers in both inner- and outer-suburb locations in Hanoi, where motorcycle taxi activities were relatively high (e.g., universities, schools, shopping centres, hospitals, and bus interchanges). About 40% of all motorcycle taxi drivers who were approached by the interviewers agreed to participate in the survey. In total, 549 motorcycle taxi drivers completed the survey. Of the 549 survey respondents, 362 had at least 12 months of experience as a motorcycle taxi driver. Our analyses were therefore based on these 362 motorcycle taxi drivers because this study focused on the crash involvement in the last 12 months while riding a motorcycle taxi.

Each structured questionnaire interview took approximately 10–15 min to complete. Motorcycle taxi drivers' demographic information (e.g., age, gender, and experience of working as a taxi driver), weight, and height were recorded. Using self-reported weight and height, BMI was calculated and then using the World Health Organization (WHO) classifications [38], underweight, normal weight, and overweight (including obese) conditions were then determined. They were also asked if they operated as traditional, ride-hailing, or hybrid motorcycle taxi drivers. A hybrid motorcycle taxi driver operates as either a traditional or ride-hailing driver often at different times of day. Motorcycle taxi drivers were asked to indicate whether they worked fulltime and/or night shift. They were then asked to provide the average daily riding hour. Motorcycle taxi drivers were also asked to report their involvement in overall crashes (including falls and other single vehicle crashes) and in injury crashes while riding a motorcycle taxi in the last 12 months.

### 2.2. Analysis

A summary of key variables in this study is presented in Table 1. To determine if a variable was statistically associated with BMI categories, the one-way analysis of variance (ANOVA) was performed if the variable was continuous and the Fisher's exact test was utilised if the variable was categorical. It was particularly important to test whether BMI was associated with the fulltime status and daily riding hour, which would indicate the impact of motorcycle taxi drivers' work on overweight and obesity.

**Table 1.** Descriptive statistics by body mass index (BMI) category with results of ANOVA and Fisher's exact tests.

Variables	BMI Category			Overall N = 362	p-Value
	Under Weight (BMI < 18.5) n = 5	Normal Weight (18.5 ≤ BMI < 25) n = 289	Over Weight/Obese (BMI ≥ 25) n = 68		
<b>Continuous Variables</b>					
Age (year)	29 (3.46)	31.3 (9.15)	31.7 (8.13)	31.3 (8.91)	0.779
Taxi experience (year)	2.92 (1.37)	2.62 (2.24)	2.82 (2.07)	2.66 (2.2)	0.76
Daily riding hours	5.4 (2.41)	6.23 (2.32)	7.67 (2.37)	6.49 (2.39)	<0.001
Weight (kg)	48 (2.74)	63 (5.04)	73.9 (6.89)	64.8 (7.16)	<0.001
Height (cm)	164 (4.18)	168.1 (4.94)	166.8 (6.56)	167.8 (5.3)	0.049
BMI (kg/m <sup>2</sup> )	17.8 (0.5)	22.3 (1.38)	26.5 (1.43)	23.0 (2.24)	<0.001
<b>Categorical Variables</b>					
Gender					
Female	18.2 (n = 2)	63.6 (n = 7)	18.2 (n = 2)	3.0 (n = 11)	0.007
Male	0.9 (n = 3)	80.3 (n = 282)	18.8 (n = 66)	97.0 (n = 351)	
Fulltime worker					
No	1.0 (n = 2)	84.7 (n = 166)	14.3 (n = 28)	54.1 (n = 196)	0.038
Yes	1.8 (n = 3)	74.1 (n = 123)	24.1 (n = 40)	45.9 (n = 166)	
Night shift					
No	1.7 (n = 4)	81.5 (n = 189)	16.8 (n = 39)	64.1 (n = 232)	0.390
Yes	0.8 (n = 1)	76.9 (n = 100)	22.3 (n = 29)	35.9 (n = 130)	
Taxi type					
Traditional	0.0 (n = 0)	77.6 (n = 38)	22.4 (n = 11)	13.5 (n = 49)	0.849
Ride-hailing	1.6 (n = 4)	80.8 (n = 202)	17.6 (n = 44)	69.1 (n = 250)	
Hybrid	1.6 (n = 1)	77.8 (n = 49)	20.6 (n = 13)	17.4 (n = 63)	
Crash involvement					
No	1.2 (n = 3)	88.1 (n = 215)	10.7 (n = 26)	67.4 (n = 244)	<0.001
Yes	1.7 (n = 2)	62.7 (n = 74)	35.6 (n = 42)	32.6 (n = 118)	
Injury crash involvement					
No	1.4 (n = 4)	84.2 (n = 246)	14.4 (n = 42)	80.7 (n = 292)	<0.001
Yes	1.4 (n = 1)	61.4 (n = 43)	37.1 (n = 26)	19.3 (n = 70)	

Note: ANOVA was conducted for continuous variables and Fisher's exact tests were done for categorical variables. For continuous variables: mean and standard deviation (in parentheses) were reported. For categorical variables: row percentages reported for the three weight categories and column percentages reported for overall categories.

Two random effect binary logistic regression models were then used to assess the effects of BMI on overall crash involvement and injury crash involvement, controlling for various crash contributing factors. Since the response variable, crash involvement, is a binary variable, the logistic regression is a suitable modelling technique. While a range of variables were considered in this analysis, potential contributing factors, such as vehicle characteristics, traffic and road conditions, and risk-taking behaviours were missing in the survey data. To address the unobserved heterogeneity related to missing data, a random effect modelling approach was utilised in this study. The random effect binary logistic model can be described as follows:

$$\ln\left(\frac{P(Y_i = 1)}{1 - P(Y_i = 1)}\right) = X_i\beta + \omega_i, \quad (1)$$

where

$Y_i = 1$  if driver  $i$  was involved in a crash and 0 otherwise,

$P$  = probability of an event,

$X_i$  = vector of explanatory variables for driver  $i$ ,

$\beta$  = vector of coefficients to be estimated,

$\omega_i$  = random effect with mean zero and variance  $\sigma^2$ .

The random effect binary logistic regression is also known as the random intercept model. Akaike Information Criterion (AIC) was adopted to identify explanatory variables to be included in the final models. A better model is indicated by a lower AIC score. Multicollinearity was checked using the generalized variance inflation factor (GVIF). Statistical analysis was performed using R [39] and NLOGIT [40].

### 3. Results

#### 3.1. Descriptive Statistics

Motorcycle taxi drivers' characteristics and crash involvement are summarised in Table 1. Motorcycle taxi drivers aged were between 18 and 65 years old, with an average of 31.3 years. Approximately 79.8% of the taxi drivers ( $n = 289$ ) had a normal weight. Only 1.4% ( $n = 5$ ) were underweight, while 18.2% ( $n = 66$ ) were overweight and 0.6% ( $n = 2$ ) were obese. Since the number of obese riders was extremely small, it was combined with overweight riders in this study. The combined proportion of being overweight/obese was 18.8% ( $n = 68$ ). The average BMI was 23 kg/m<sup>2</sup>.

Although overweight/obese motorcycle taxi drivers were slightly older than normal-weight and underweight taxi drivers, the differences were not significant. Most motorcycle taxi drivers were male (around 97%). Female motorcycle taxi drivers ( $n = 11$ ) had a higher tendency to be underweight, which was confirmed by Fisher's exact test ( $p < 0.01$ ). Motorcycle taxi drivers had more than 2.6 years of working experience on average. There was no association between taxi experience and BMI categories.

About 45.9% of the motorcycle taxi drivers worked fulltime. Fulltime taxi drivers were more likely to be overweight/obese, compared to non-fulltime taxi drivers (24.1% versus 14.3%). This association was significant at  $p < 0.05$ . The average daily riding hour of fulltime motorcycle taxi drivers was approximately 8 h, which is higher compared to casual or part-time motorcycle taxi drivers with 5.2 h. Daily riding hours were strongly associated with increasing BMIs ( $p < 0.001$ ), which is in alignment with the effect of fulltime status.

There was no association between working night shift and BMI categories, although the proportion of being overweight/obese was slightly higher among those who worked night shift (22.3% versus 16.8%). Most motorcycle taxi drivers were ride-hailing taxi drivers (69.1%). The proportions of hybrid and traditional taxi drivers were 17.4% and 13.5%, respectively. The proportion of being overweight/obese was smaller among ride-hailing taxi drivers (17.6% versus 22.4% and 20.6%), which was however not significant.

About 32.6% of motorcycle taxi drivers reported crash involvement. The proportion of being overweight/obese among those who had been involved in a crash was substantially higher compared to that among those who had not (35.6% versus 10.7%). Approximately 19.3% of motorcycle taxi drivers reported injury crash involvement. Similarly, the proportion of being overweight/obese was significantly higher among those who had been involved in an injury crash compared to those who had not (37.1% versus 14.4%). Fisher's exact test confirmed that the associations between overall crash involvement/injury crash involvement and BMI categories were significant at  $p < 0.001$ .

#### 3.2. Random Effect Binary Logistic Models

Results of the final random effect binary logistic model for overall crash involvement are presented in Table 2. The crash involvement model was significant at  $p < 0.001$  (Chi-square = 61.48, degrees of freedom = 8). The random effect was also significant at  $p < 0.001$ . Results of the final random effect binary logistic model for injury crash involvement are presented in Table 3. Similarly, the injury crash involvement model was significant at  $p < 0.001$  (Chi-square = 41.12, degrees of freedom = 8). The random effect was also significant at  $p < 0.001$ . The significance of the random effects in both models indicated that unobserved heterogeneity in the data was controlled by the random effect binary logistic model. GVIF analysis indicated that there were no multicollinearity issues. It is noted that while the riding hour and taxi experience variables were not included in the final model based on AIC scores, the full time variable, an important exposure, was included.

**Table 2.** Results of random effect binary logistic model for overall crash involvement.

Variables	Estimate	Std. Error	p-Value	AOR	95% CI	
Age (years) **	0.062	0.022	0.004	1.064	1.019	1.110
Full time **	0.970	0.320	0.002	2.637	1.409	4.935
Night shift **	−0.919	0.295	0.002	0.399	0.224	0.711
Overweight/Obese ***	2.503	0.381	<0.001	12.219	5.787	25.800
Underweight	1.018	1.007	0.312	2.767	0.384	19.918
Taxi type (ref: Traditional)						
Ride-hailing	−0.392	0.463	0.396	0.675	0.273	1.672
Hybrid ***	−1.762	0.494	<0.001	0.172	0.065	0.452
Intercept ***	−3.245	0.956	<0.001			
Random effect (SD) ***	3.105	0.365	<0.001			
AIC	413.600					
Log likelihood (intercept only)	−228.525					
Log likelihood (full model)	−197.785					
Number of observations	362					

Note: \*, \*\* & \*\*\* denote statistically significant at 95%, 99%, and 99.9% confidence level. AOR = Adjusted Odds Ratio, CI = Confidence Interval, SD = standard deviation, Std. = standard.

**Table 3.** Results of random effect binary logistic model for injury crash involvement.

Variables	Estimate	Std. Error	p-Value	AOR	95% CI	
Age (years) *	0.069	0.030	0.022	1.072	1.010	1.137
Full time ***	2.569	0.582	<0.001	13.054	4.174	40.826
Night shift **	−1.332	0.462	0.004	0.264	0.107	0.653
Overweight/Obese ***	3.110	0.593	<0.001	22.422	7.016	71.654
Underweight	0.359	1.653	0.828	1.432	0.056	36.573
Taxi type (ref: Traditional)						
Ride-hailing	0.157	0.617	0.800	1.170	0.349	3.923
Hybrid *	−1.738	0.677	0.010	0.176	0.047	0.663
Intercept ***	−7.295	1.591	<0.001			
Random effect (SD) ***	5.546	0.836	<0.001			
AIC	332.400					
Log likelihood (intercept only)	−177.768					
Log likelihood (full model)	−157.210					
Number of observations	362					

Note: \*, \*\* & \*\*\* denote statistically significant at 95%, 99%, and 99.9% confidence level. AOR = Adjusted Odds Ratio, CI = Confidence Interval, SD = standard deviation, Std. = standard.

Age was significant in both models with positive coefficients. Every additional year of age among motorcycle taxi drivers was associated with a 6.4% increase in the odds of being involved in an overall crash and a 7.2% increase in the odds of being involved in an injury crash. Similarly, working fulltime was significant with positive coefficients in both models. Working fulltime would increase the odds of being involved in an overall crash by a factor of 2.6 and the odds of being in an injury crash by a factor of 13.1. However, working night shift was negatively associated with both overall and injury crash involvements. Working night shift would reduce the odds of being involved in an overall crash by a factor of 0.4 and in an injury crash by a factor of 0.26. Interestingly, the variable for hybrid motorcycle taxi drivers was significant in both models, with negative coefficients. When compared to traditional drivers, hybrid motorcycle taxi drivers were less likely to be involved in overall and injury crashes.

The underweight variable was not significant. However, the overweight/obese variable was significant in both models with positive coefficients. Compared to normal-weight motorcycle taxi drivers, the odds of being involved in an overall crash for overweight/obese taxi drivers was about 12.2 times higher. In addition, the odds of being involved in an injury crash for overweight/obese taxi drivers was about 22.4 times higher compared to normal-weight taxi drivers.

#### 4. Discussion

This paper accessed the body mass index (BMI) of 362 motorcycle taxi drivers in Hanoi, Vietnam and examined the influence of BMI on their crash involvement using the random effect binary logistic regression.

Results showed that 18.2% of the motorcycle taxi drivers were overweight and 0.6% were obese. In another study in Mexico, the percentages of overweight and obesity motorcycle taxi drivers were higher at 28.7% and 17%, respectively [41]. It is, however, noted that the proportions of overweight and obesity among adults aged above 20 in Vietnam were 12–13% and 1.5–1.7% respectively, which were much lower when compared to those among adults aged above 20 in Mexico [42]. The proportions of overweight and obesity among motorcycle taxi drivers in Hanoi were also lower than those among car taxi drivers in Thailand and Taiwan. It was reported that 53.9% of car taxi drivers in Thailand were obese [43], and 35% of car taxi drivers in Taiwan were overweight and 24% were obese [44]. This could be partly attributed to the higher prevalence of overweight and obesity among adults in Thailand and Taiwan when compared to Vietnam [42]. Furthermore, the lower proportions of overweight and obesity among motorcycle taxi drivers in Hanoi, when compared to car taxi drivers, could also be attributed to physical activities related to controlling and stabilising a motorcycle.

Results also indicated that female drivers were more likely to be underweight. This is interesting given that the prevalence of overweight/obese was similar between male and female adults in Vietnam [45]. It was found that fulltime drivers were more likely to be overweight/obese. In addition, longer riding hours were associated with increasing BMIs. These are important findings as they suggest that motorcycle taxi drivers' unhealthy work and lifestyle may contribute to overweight/obese issues.

Since the percentage of obesity was very small, it was combined with the overweight category in further analyses using the random effect logistic models. Results highlighted the effects of BMI and overweight on crashes, controlling for a range of factors (e.g., age, fulltime status, and motorcycle taxi type). Specifically, overweight and obese motorcycle taxi drivers had significantly greater overall crash and injury crash risks, when compared to normal-weight taxi drivers. The findings were in alignment with previous research, which showed associations between obesity/BMI and crashes among car and truck drivers [2,4,6]. Overweight and obesity would affect crash risks, particularly fatigue-related crash risks, due to associations with obstructive sleep apnea and fatigue [3,5]. Furthermore, motorcycle taxi drivers must constantly maintain the stability of their motorcycle while being directly exposed to weather conditions, which would be more challenging for overweight and obese motorcycle taxi drivers. This is because overweight and obesity could lead to declined physical functioning, and postural stability and balance [12,14,15], which may affect the ability to ride safely. Nevertheless, the mechanism that overweight and obesity would affect crash risks among motorcyclists by hindering physical functioning and postural stability should be further investigated in future work. Overall, this paper contributes to knowledge with an improved understanding of the effects of BMI and overweight on overall crashes and injury crashes among motorcycle taxi drivers.

It was found that working fulltime would increase the odds of being involved in overall crashes and injury crashes among motorcycle taxi drivers. This was expected considering that working fulltime increased crash exposure. Results also showed that older motorcycle taxi drivers had higher risks of being involved in overall and injury crashes. Increasing age may imply more experience but may also reflect reduced reaction times. It is worth noting that mixed effects of age on crashes among car taxi drivers have been reported in previous research [46,47]. Working night shift was associated with a lower likelihood of being involved in overall and injury crashes. Poor lighting conditions or increased

fatigue at night may increase crash risks [46,48]. However, it can be argued that motorcycle taxi drivers working night shift tended to deal with a much less stressful environment with fewer conflicts and lighter traffic flow. The impact of work-related stress on traffic safety outcomes was evident in previous research [34]. Furthermore, street lighting is generally adequate in Hanoi's urban areas. Results also indicated that hybrid motorcycle taxi drivers had lower overall and injury crash risks when comparing to traditional motorcycle taxi drivers. This is an interesting finding as hybrid motorcycle taxi drivers while optimising their operation by switching between traditional and ride-hailing types can also improve their safety.

The findings of this study have several important policy implications. Motorcycle taxi drivers should be made aware of the risks associated with BMIs through educational and publicity programs. The significant impacts of fulltime status and daily riding hours on BMIs suggest that restricted or at least recommended threshold for daily riding and working hours should be considered by the authorities. This is particularly important given the negative impacts of overweight and obesity on crash risks. While implementing limitations on working and riding hours among traditional motorcycle taxi drivers would be a challenge, the implementation among ride-hailing motorcycle taxi drivers would be facilitated by service providers who can monitor operations of ride-hailing taxi drivers. As motorcycle taxi drivers often carry a passenger, increased crash risks of taxi drivers imply reduced safety for passengers. Therefore, the risks associated with BMIs should be considered as part of wider health promotion programs to encourage healthy work and lifestyles among motorcycle taxi drivers. Given the growing popularity of motorcycle taxi services in many cities, it is also important to monitor the trends in BMIs as well as crash involvement in the motorcycle taxi driver population.

One of the limitations of this study is that as the analysis was based on self-reported data, common method bias (CMB) could potentially affect relationships between variables in the analysis [49]. Motorcycle taxi drivers' crashes, particularly injury crashes, may be under-reported due to social desirability response biases. Furthermore, motorcycle taxi drivers, seriously injured or killed, would be missed by the study. BMIs based on self-reported height and weight may be slightly underestimated given survey respondents would tend to report a slightly greater height and lower weight. It was not possible to account for potential impacts of the passenger's weight as the survey could not capture information about the passenger or whether there was a passenger at the time of a crash. There is a lack of information in the survey about vehicle characteristics (such as engine size), traffic and road environment (such as speed limit and road type), and risky riding behaviours (such as speeding and drink riding), which would affect crash involvement among motorcycle taxi drivers. Nevertheless, the effects of BMI were statistically assessed by random effect binary logistic models, controlling for a range of factors.

## 5. Conclusions

This paper has established associations between overweight and increased overall and injury crash risks among motorcycle taxi drivers. It also showed that fulltime motorcycle taxi drivers were more likely to be overweight, suggesting potential safety impacts of unhealthy work and lifestyle among fulltime motorcycle taxi drivers. Overall, this study showed that overweight and obesity present a growing safety problem among motorcycle taxi drivers, which in turns affects traffic safety in general, considering the popularity of motorcycle taxi services in many cities. Coordinated efforts should be made by authorities and ride-hailing service providers (e.g., GrabBike) to address this emerging safety problem.

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