REVIEW ARTICLE

Noise Exposure Among Motorcycle Riders: A Scoping Review

Ailin Razali, Roslila Rahman

Department of Otorhinolaryngology-Head and Neck Surgery (ORL-HNS), Ear and Hearing Clinic, Kulliyyah of Medicine, International Islamic University of Malaysia (IIUM), Bandar Indera Mahkota, Jalan Sultan Ahmad Shah, Kuantan, Malaysia

ABSTRACT

This scoping review aimed to determine the dosage of noise exposure among motorcycle riders and the sources contributing to a rider's noise exposure. A systematic search of several scientific databases was conducted from 1981 until 2021. Eligible articles were included into the defined criteria. The dosage of noise exposure, sources, and standardization method were extracted. A total of 37 studies were included. There was scarce publication regarding the exact level of noise exposure experienced by the riders. There was, however, abundant evidence on indirect sources of noise exposure for riders, which requires further critical analysis. The dosage of noise exposure among riders was significantly higher than the recommended level. Seven sources were determined to generate noise which could potentially affect the riders, presented in this paper along with their respective evidence.
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Keywords: Noise exposure, Motorcycle riders, Source of noise, Road traffic noise, Dosimeter

Corresponding Author:
Ailin binti Razali, PhD
Email: ailin@iium.edu.my
Tel: +609 570 4450

INTRODUCTION

Motorcycles have always been one of the popular modes of transportation due to their efficiency, affordability, and low maintenance. In 2022, economic growth is set to accelerate as the shifting post-pandemic recovery kicks off where an increase in the motorcycle demands globally is expected. Furthermore, Malaysia, as well as most developing countries worldwide have delegated the gig economy approaches especially in ride-hailing services (1). Mastercard (2) forecasted that global gig economy transactions will grow by USD455 billion by 2023, subsequently accelerating this segment of the economy.

Ride-hailing services are one of the most recognized in the gig economy. Ride-hailing services will most certainly intensify the utilization of motorcycles, hence increasing air and noise pollutants emitted from these vehicles. Goines and Hagler (3) stated that noise pollution has been the second major pollution that remains unaddressed and ignored, hence the inadequate study regarding the noise exposure and effects on a person's health, society, and lifestyle. Additionally, a motorcyclist's quality of life is specifically at stake, as these groups of people will be vulnerable to the detrimental effects of chronic exposure to hazardous noise due to the collective lack of awareness on this matter.

Adding to the fact that Occupational Safety and Health (Noise Exposure) Regulations 2019 has stated that no workers should be exposed to noise of more than 85 dBA for eight hours or equivalent, this scoping review aimed to establish the exact dosage of noise exposure among motorcycle riders during their daily working exposure, as well as the sources where the noise originated from.

METHODOLOGY

Literature search and article selection

This scoping review was conducted to determine the dosage of noise exposure among motorcycle riders, along with its sources of noise exposure. A systematic search was performed on the following electronic databases; SCOPUS, PubMed, and Science Direct during the past 45 years until 2022 written in the English language. We selected keywords based on the PICO method: 1. Population was defined as motorcycle(s), rider(s), and motorcyclist(s); 2. Intervention was defined as noise exposure, road traffic noise, and noise pollution; 3. Comparison was defined as train, transit, bicycle, and car 4. Outcome was defined as the level of exposure, and sources of noise exposure. The search strategy was designed using MeSH terms and keywords from related articles. Keywords related to population, intervention and comparison were used in the electronic database, and the related articles collected were then transferred to Mendeley Desktop (version 1.19.8).

Generally, road traffic noise was the main noise exposure faced by the riders. Several eligible articles regarding traffic noise will still be considered, even though it does not come directly from the motorcycle or have any direct effect on the riders. The same principle will be used for a few articles that discussed and commented on the sources of noise exposure for riders, either directly or indirectly.

Inclusion and Exclusion Criteria
Articles were determined eligible for inclusion if they discussed noise exposure among motorcycle riders, and whether it is related to occupational or non-occupational riders. Articles could be from Malaysia or worldwide; urban, developing areas, universities compound, community areas, and highways. Articles that discussed sources of noise exposure towards riders will also be included.

Articles were excluded if they were written in languages other than English. Articles that discussed noise exposure from transit trains, subways, or aircraft noise will be excluded. The same will be treated with articles that mentioned about the effect of noise on birds and fishes. Articles were excluded if the authors studied or commented on the health and social effect of noise exposure. Articles were also excluded if they solely report the noise exposure among the community, pedestrians (s), cyclists (s), and drivers of vehicles other than motorcycles.

Data Extraction
The screening process was conducted using the PRISMA extension for scoping reviews (Figure 1). Extracted data included article characteristics (year of publication, journal of publication, and country of origin), level of noise exposure (average dosage), and sources of noise exposure related to the purpose of the study.

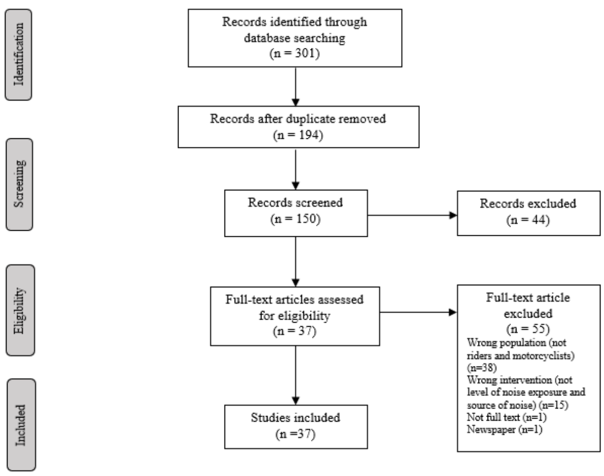

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for Scoping Reviews flow diagram of the search and study selection process.

RESULTS

Study Selection
Based on the initial search, 194 articles were identified after duplicates were removed. At the title and abstract screening stage, 44 articles were excluded. A total of 37 articles were screened as full text, and a further 55 articles were excluded for reasons outlined in Figure 1. Keywords for database searching have been strategized within Boolean Search Operator System, as stated in Table I, to maximize the comprehensive search for related articles. Special mention needs to be made with the use of "NOT" in the Boolean operator where it is used to limit the search by excluding a defining keyword. A difference was noted between different databases where Scopus database use "AND NOT" to exclude the keywords while PubMed and Science Direct used "NOT" to acquire the same objective.

Article Characteristics
The study identified 37 unique articles across 28 different journals, ranging from 1981 until 2021. The trend shows an upward trend in research in noise exposure.

Table I: Keyword selection by using Boolean Search operators in electronic databases

Keywords	Databases			Total Articles Searched
	PubMed	**Scopus**	**Science Direct**	
(motorcycle AND "noise exposure" NOT (train OR transit OR bicycle OR car OR fish OR bird)	10	16	38	64
(motorcyclist AND "noise exposure") NOT (train OR transit OR bicycle OR car OR fish OR bird)	3	5	8	16
(motorcyclist AND "noise exposure") NOT (train OR transit OR bicycle OR car OR fish OR bird)	2	6	11	19
(motorcycle AND "road traffic noise") NOT (train OR transit OR bicycle OR car OR fish OR bird)	3	24	17	44
(motorcyclist AND "road traffic noise") NOT (train OR transit OR bicycle OR car OR fish OR bird)	0	0	0	0
(riders AND "road traffic noise") NOT (train OR transit OR bicycle OR car OR fish OR bird)	0	0	2	2
(motorcycle AND "noise pollution") NOT (train OR transit OR bicycle OR car OR fish OR bird)	1	74	44	119
(motorcyclist AND "noise pollution") NOT (train OR transit OR bicycle OR car OR fish OR bird)	0	4	2	6
(riders AND "noise pollution") NOT (train OR transit OR bicycle OR car OR fish OR bird)	1	14	16	31
			Total Articles Selected	301

Dosage of Noise Exposure among Motorcycle Riders

Five articles extensively studied the daily dosage of noise exposure among motorcycle riders as outlined in Table II. Dosimeters, sound level meters, digital audio tapes and ArcGIS were used to investigate the noise exposure among riders for distances ranging from 4.8 km to 46 km according to the methodology of the study. The recorded period ranges from 34 minutes to 3 hours taken at various locations. The dosage of noise exposure was found to be lowest at 55.66 dBA and highest at 94.84 dBA.

Road Traffic Noise Exposure

Six articles were perused on the average traffic noise exposure that may affect riders, albeit without any one of them explicitly mentioning it in their studies. The studies were conducted using sound level meter to evaluate traffic noise measured on or alongside the road. Noise exposure dosage ranging from 72.00 dBA to 87.90 dBA was documented in public and highway roads, and urban areas, referring to Table III.

Source of Noise

As outlined in Figure 2, the articles included mostly stated the source of noise as categorized by the niche of study. Hence, seven sources of noise were identified that were related to motorcyclists or riders on the road. There was wind noise or turbulence around the helmet (19%), the vibroacoustic effect that comes from a motorcycle engine, exhaust and tires/ground interaction (17%), the speed of motorcycle (17%), the road and weather condition (8%), vehicular noises (12%), honking noises from other vehicles (8%), and types of helmets whether open face or full face (19%).

DISCUSSION

Dosage of Noise Exposure

This review revealed that the dosage of noise exposure experienced by riders was above 85.5 dBA, which was categorized as excessive noise as stated by the Occupational Safety and Health (Noise Exposure)

Table II: Noise dosage exposure among riders in five different locations.

Name of Author/ Year	Study Type	Devices Used	Condition of Study		Dosage of Noise Exposure
			Duration	**Distance**	
Ali 2020 (4)	26 samples Closed-circuit study track	Pocket size dosimeter (3M Noise ProTM, model: Noisepro DLX, Sound Pro Quest)	3 hours	4.8 km	88.00 dB
Ali 2018 (5)	52 samples Universities compound route assessment	Pocket size dosimeter (3M Noise ProTM, model: Noisepro DLX, Sound Pro Quest)	46 minutes	46 km	93.64 dB
Vlachokostas 2012 (6)	Urban city / public road assessment	Sound Level Meter, (Extech's HD 600)	34 minutes	8.4 km	85.50 dB
Harvey 2002 (7)	Exploratory study Public road assessment	Digital Audio Tape (DAT)	-	5 km	94.84 dB
Yang 2020 (8)	Public road assessment	ArcGIS	50 min	5 km	55.66 dB

Table III: Road traffic noise exposure in six different locations

Name of Author/ Year	Type of Study	Devices Used	Condition of study	Areas	Noise Exposure Dosage
Suthayana 2015 (9)	• Urban city road assessment	Sound Level Meter (Extech Model SDL600)	12 hours	Denpasar City, Bali, Indonesia	82.2 dB
Ingle 2005 (10)500 and 1000 Hz	• 54 samples (police traffic) • Major road junction	Noise Dosimeter	10 hours	Jalgaon City, India	87.9 dB
Chang 2011 (11)	• Main road assessment	Sound Level Meter (TES-1358, TES Electronic Corp)	8 hours	Taichung, Taiwan	> 75 dB
Mansourkhaki 2021 (12)	• Urban highway road assessment	Sound Level Meter (B & K 2240, ANSI Type 1)	8 hours	Tehran, Iran	75.37 dB
Hustim 2018 (13)	• 40 samples • Roadside assessment	Sound Level Meter	90 minutes	Makassar City, Indonesia	73 dB
Yusoff 2005 (14)	• Urban highway-road assessment	Noise dosimeter (Quest Technologies Model Q-400)	2 hours	Bandar Sunway, Kelana Jaya and Taman Megah., Petaling Jaya.	67 - 72 dB

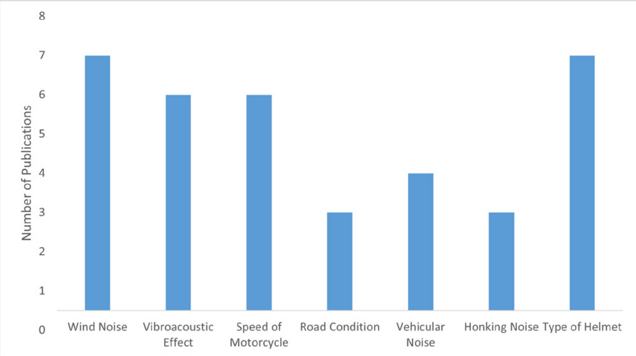

Figure 2: Sources of noise regarding the exposure among riders.

Regulations 2019. This dosage is also excessive when compared to the Environmental Noise Limits and Control 2019 enforced by the Department of Environment, Malaysia, which states that 60 dB to 65 dB is the limiting sound level (LAeq) from road traffic for high-density urban residential. Moreover, most of the studies were conducted for a relatively short period of time even though in reality most occupational riders spent more than three hours on the motorcycle during their daily occupational activities.

As the dosage of noise exposure range exceeds the safety law enforcement, these excessive noises implicated massive impact for the riders. According to Ali and colleagues (5), exposure to noise above 85 dBA contributed to the temporary dullness of hearing, while prolonged exposure will lead to permanent threshold shift and caused degeneration of nerve fibers which consequently increases the risk of noise-induced hearing loss (NIHL). Metabolic damage of cochlea will occur in relation to the continuance of exposure from noise between 85 dB to 140 dB, hence advanced NIHL is commonly correlated with chronic motorcycle exposure (5,15).

The lowest reading for noise dosage exposure was published by Yang et al. (8) as mentioned in Table II, where they investigated the noise exposure among delivery men in Wuhan, China. This low reading was recorded because the delivery men were noted to use silent electric motorcycle with driving speed not exceeding 30km/h. We have decided to include this study as we foresee the usage of silent electric motorcycle to be the norm rather than the exception in the near future.

Road traffic noise was also assessed and reviewed in this paper, as it has an indirect effect on motorcyclists. According to Table III, the road traffic noise exposure dosage ranges from 67 dBA to the highest of 87.9 dBA. Rylander & Dunt (16) stated that road traffic noise was contributed by the vehicle's engine, tires and air movement surrounding the vehicle, traffic flow, distance of the road, road surface, and speed of vehicles. Thus, these are the additional factors that we must consider in assessing noise exposure among riders as the road is their main mode of conduit.

In relation to the current economic situation, we predict that this noise exposure will continue to increase due to the demand of motorcycles for occupational purposes, and the feasibility it possesses for daily commutes. Therefore, the scarcity of study if remain unaddressed will further propagate this lack of awareness for safety, health, and social effect caused by noise exposure among riders.

Sources of Noise

Wind Noise or Turbulence Around Helmet

Wind noise or turbulence around the helmet is a major source of hazardous noise to a motorcyclist (4,7,9,16-18,30-31). It was recognized as a hearing hazard as noise flow in, and around the helmet is accountable for the hearing damage (28). A study by Harvey (7) stated that the flow of aerodynamic sources over the helmet caused the dominance of noise in the helmet. This data was correlated with a study conducted by Brown and colleagues (19) simplifies the wind noise inside helmets exceeding 100 dB without active noise reduction, with an increase in velocity and type of helmet. This conclusion was concurrent with a study from Ross (20) which stated that wind noise generated at the region of the head produced by turbulent air flow resulting from vehicles going at a velocity of 64.3 km/h is the main factor for noise exposure among motorcyclists.

Vibroacoustic Effects

Vibroacoustic effect is described as noise generated from the transport itself which includes the engines, exhaust, drive train, suspension, and tire interaction with road pavement among others. Engine noise radiates sound vibration originating from the creation of combustion pressure and excitement of the mechanical system, crank mechanism and valve train inside the vehicle engine system (21). The vibroacoustic effect does increase the discomfort level among motorcyclists in form of vibration and noise exposure as stated by Khamis et al. (22).

A study conducted by Figlus et al. (23) depicted that noise generated by exhaust was above 80 dB, and the highest exposure to vibration derived from handlebars to the upper limb of a motorcycle, which integrated noise of 78 dBA with increased acceleration by the vehicles. Furthermore, different muffler exhaust does distinguish the amount of noise produced by the vehicles (17). For example, a standard muffler produced sound at 101.7 dBA whereas a 'scorpion' muffler installed with a noise absorber attenuated the sound to 2.3 dBA. This study was in line with a study by Vlachokostas and colleagues (6) who mentioned that background motor noise adds up to 66 dB for idle speed conditions. Additionally, noise of the engine was a significant contributor for 1 to

3 kHz as a function of speed (29).

Speed of Motorcycle

Most of the study revealed that speed intensifies the noise exposure among riders towards unsafe level (4,8-9,18,32). The speed of motorcycle escalates the wind noise inside helmet, vibroacoustic effect, which is further amplified by conditions of the road. Ali and colleagues (5) concluded that the speed of the motorcycle has a linear correlation with the noise exposure among riders, with 88 dBA traveling at 80 km/h. Moreover, every 10 km/h speed increment will increase the noise up to 4 dB accordingly (7). In addition, motorcyclists will be exposed to at-ear level noise over 100 dB when bare-headed on a moderate acceleration of the vehicle, as corresponded by Van Moorhem et al (24). Hence, this source of noise has a quantifiable hazard of hearing damage to motorcyclists who are frequently exposed over an extensive period.

Road and Weather Condition

This scoping review also identified that road and weather conditions have a predominant influence on noise exposure among riders. The presence of water on road surfaces increases the sound pressure level with mean differences at 10.09 dB, 5.56 dB, and 4.26 dB with respect to light, middle-size, and heavy vehicles accordingly (18). This was in parallel to a study by Harvey et al. (7) that stated that wet roads tend to generate higher noise levels than dry roads around 4-5 dB, therefore greater noise exposure among riders in wet and rainy road conditions rather than dry and sunny weather situation (4,36-38).

Vehicular Noise

Vehicular noise is related to the volume of vehicles (33,38) and the type of vehicles on the road. Suthanaya stated that the increase of 100 motorcycles will amplify up to 0.3 dB of traffic noise in urban road areas (9). On the other hand, different noise levels emitted from vehicles also affect the vibroacoustic effect for the motorcyclist, which consequently increases their noise exposure. Figlus and colleagues (23) have illustrated in their study whereby trucks or lorries have higher vehicle noise emission, whilst car has compatible or even lesser noise emitted in comparison to the motorcycle. Moreover, heavy vehicles also acquired maximum noise level up to 86 dB, approximately (16). Roadside traffic noise will be accelerated with the increasing number of vehicles at any one time (25,39). Thus, this concluded that vehicular noise also has significant noise exposure for motorcyclists.

Honking Noise

Horns are principally purposed as a warning to other motorists for safety and to avoid collision. However, there are several countries or areas that substitute the use of horns as an expression of anger and culture. Hustim and colleagues assessed that the frequency of horn issued by motorcycles were 122 to 713 times per hour (13), throughout their study in Pettarani Road, Indonesia and predicted the LAeq calculation horn sound per day was 78.5 dB (34). Thus, this situation proves to be a source of noise for motorcyclists as honking increases the noise level from 0.5 to 13 dBA, similarly in a study conducted by Kalaiselvi and Ramachandraiah (26) in Chennai City, India. This result was in line with Chauhan et al. (27) where they demonstrated that a significant noise reduction up to 2.1 dBA was detected after the execution of 'No Horn Regulation' in Kathmandu.

Type of Helmet

A helmet is known to be the only safety equipment worn by motorcyclists. However, several types of helmets resulted in different amounts of noise perceived (7,8,19,24,28,35) by the rider. Two types of helmets were commonly used, which are open face and full-face helmet. Open face helmet is recognizable by the lack of chin bar, and it is held to the head by a chin strap. A full-face helmet has a fixed chin bar and the helmet can only be removed from the head as a whole structure. Ideal design for an acoustically engineered motorcycle helmet (19) could attenuate the noise from wind turbulence down to 26 dBA. Interestingly, full-face helmets were found to exhibit higher noise level than open face helmet (24), corresponding with a study by Ross (20) whereby 105 dBA and 98 dBA for full-face helmet and open face helmet were documented, respectively.

Limitation

Although this scoping review was conducted according to scoping review methodology, there were some limitations that are worth noted. Noise exposure was defined in terms of noise exposure, road traffic noise and noise pollution. Therefore, any article which uses only the term 'noise' will not be included as it is a broad definition that yielded more than 5000 initial searches. This could inevitably exclude several articles which could be of relevance to the review. Additionally, to minimize error during the phase of article review, at least three reviewers are expected to review and extract the paper according to the objective of the study, to ensure the reliability of the study. However, since there are only two authors involved, this is thus another limitation to this review.

CONCLUSION

In conclusion, the noise dosage exposure among riders was significantly higher than the recommended allowable daily noise dosage. Thus, future initiatives need to be determined as this could adversely affect the health of motorcyclists and the general population as well. This review also highlights the indirect contribution of other sources of noise towards motorcyclists and motorcycle riders.

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