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AT-EAR NOISE LEVELS UNDER THE HELMET: A FIELD STUDY ON NOISE EXPOSURE OF YOUNG MOTORCYCLISTS

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ABSTRACT

At-ear noise exposure assessments of motorcyclists, with the function of speed, would be unsafe as on-road data acquisition has certain constraints including the operations and portability of appropriate instrument. Currently, there are no standardized protocols and methods for measuring the noise under motorcycle helmets. Furthermore, standard permissible noise emission levels for commuter motorcyclists are also not defined. Therefore, this study was aimed to investigate the motorcycle noise exposure assessments in realistic environment among young riders. A personal dosimeter was utilized to calculate the daily noise exposure level (L_{Aeq}, 8h) under three different standards including: OSHA-HC (Occupational Safety and Health Administration, Hearing Conservation), OSHA-PEL (Permissible Emission Level) and ACGIH/NIOSH (American Conference of Governmental Industrial Hygienists/ National Institute of Occupational Safety and Health). The study design consisted of noise assessment of riders (age range:19 to 25 years) at-ear under the open-face helmet in-realistic situation (main road to the motorway) motorcycling in dry weather conditions.

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Personal dosimeter results (*n*=52) revealed the average noise exposure level of 93.64 dBA, 92.51 dBA, 95.29 dBA for OSHA-HC, OSHA-PEL and ACGIH/NIOSH respectively. The mean Time-Weighted Average (TWA) was 76.82 dBA, 75.69 dBA, 85.16 dBA for OSHA-HC, OSHA-PEL and ACGIH/NIOSH respectively. Under the ACGIH and NIOSH standard, the TWA for motorcyclists is at hazardous limits, which requires further investigations associated with health effects on riders. Standardized methods and configurations should be set for assessing noise exposure related to the motorcycling.

Keywords: Motorcycle noise, Wind noise, Dosimeter, OSHA, ACGIH

INTRODUCTION

Motorcycles are recognized as a convenient form of transport as it causes less damage to the road surface, lessens traffic congestion and consumes less fuel than motorcars. Motorcycling carries obvious and some less obvious hazards, where noise exposure and its related health effects are one of the less obvious hazards (Binnington et al., 1993). Quieter machines have been developed by the manufacturers with increasingly faster motorcycles, but aeroacoustics noise stands more important for motorcycling and helmet design (Jordan et al., 2004). The unavoidable component associated with motorcycling is noise, which has been studied though numerous studies (Kennedy et al., 2014).

Since late 80's, it has been noted that motorcycle riders are exposed to noise levels above 90 d BA at 50 km/h (30 mph), which increases with increasing speed up to 105 dBA at 115 km/h (70 mph)(Jordan et al., 2004). Just over 20 years, noise has been recognized as hearing hazard due to motorcycling noise inside the helmet. Motorcyclists' noise exposure is unique and greatly influenced by the transmission through the helmet (Kennedy et al., 2014). Numerous studies investigated the noise sources, such as wind flow around the helmet, the sound of an engine and the combined windscreen generates interaction that sound at-ear to the rider (Carley et al., 2011; Jordan et al., 2004). The discrepancies between various motorcycling speeds and its associated noise exposure reported in previous studies were explained by Carley et al., (2011) as an external factor such as wind speed, engine, windscreen, helmet type and riding position.

In reported literature, a difference exists between sound pressure level with a function of riding speed (Kennedy et al., 2013). Numerous studies adopted varies measurement techniques under controlled study designs both for on-track and for wind-tunnel tests, while realistic situation assessments are scarce. The various instruments adopted for this purpose were: DAT (Digital Recording Tape) (Harvey et al., 2002; Ross, 1989; Kennedy et al., 2011;

Jordan et al., 2004), SLM (Sound Level Meter) (Carley et al., 2010; Jordan et al., 2004; Violini et al., 2015), DAQ system (Kennedy et al. 2011)(Kennedy et al. 2013) and multiple memory noise logging dosimeter (Binnington et al., 1993; McCombe et al., 1993).

Noise measurements inside a motorcycle helmet, while traveling at speeds of up to 120km/h, is not an easy task (Harvey et al., 2002). Measuring of sound level at various speeds would be unsafe and on-road data acquisition are problematic due to rider's safety along with portability of appropriate instrument. There are no standardized protocols and methods for measuring the noise under motorcycle helmets (Jordan et al., 2004), while the standard permissible noise emission level for commuter motorcyclists are also not defined.

Therefore, this study was aimed to investigate the realistic environment motorcycle riding noise exposure assessment among young riders through personal dosimeter and to calculate their daily noise exposure level (L_{Aeq}, 8h) under three standards: OSHA-HC (Occupational Safety and Health Administration, Hearing Conservation), OSHA-PEL (Permissible Emission Level) and ACGIH/NIOSH (American Conference of Governmental Industrial Hygienists/ National Institute of Occupational Safety and Health).

MATERIALS AND METHOD

Study population

A field study to assess motorcycling noise under helmet was carried out at Universiti Teknologi MARA, Puncak Alam campus, Malaysia. The participants were undergraduate students, aged between 19 to 25 years, who rode the motorcycle as primary means of transportation. Total participants recruited in the study were 52. Inclusion criteria set for the study consisted of participants exhibiting helmet-riding behavior and motorcycle capacity ranging from 100 cc to 150 cc. Study procedure and design was approved by Faculty's (Health Sciences) Internal Ethical Committee (600-FSK (PT.5/2)), Universiti Teknologi Mara, Malaysia.

INSTRUMENTS

At-ear noise exposure level of riders under the helmet during motorcycling was measured by pocket size dosimeter: 3M Noise Pro^{TM}, model: Noisepro DLX, Sound Pro Quest technology. Sound level calibrator, model: QUEST/Type was used for pre-calibration before each monitoring session. After the monitoring session, dosimeters were post-calibrated followed by the transfer of the data into the spreadsheet. Participant's personal use of motorcycles and helmets were compensated them with vouchers, which covered fuel consumption and participation incentive. All participants wore an open-face helmet with the visor closed as shown in Figure 1a. A structured questionnaire was used to obtain the general demographic information of the participants (age, semester and gender), data related to motorcycling (license no, motorcycle registration no, helmet type, motorcycle brand, engine capacity) and test day information (weather condition, test starting and ending time and date).

Instrument standardization

The dosimeter (shown in Figure 1b) used for assessment had simultaneously three virtual dosimeters settings, which were calibrated on occupational standards for possible comparison of noise exposure limits associated with motorcycling. Table 1 presents the three integrators in the instrument with configuration settings of logging interval of one minute, time-weighted slow and criterion time 8 hours. The virtual dosimeters first and second were based on the Occupational Safety and Health Administration (OSHA) criteria (Gilbertson and Vosburgh, 2015). The first virtual dosimeter was programmed to noise threshold of 80 dBA, criterion level of 90 dBA, and an exchange rate of 5 dB, which is based on OSHA-HC requirement. The second virtual dosimeter was programmed without noise threshold, criterion level of 90 dBA and exchange rate of 5 dB, based on OSHA -PEL. The third virtual dosimeter was based on ACGIH criteria, programmed with 80 dB threshold, 85 dBA criterion level and the exchange rate of 3 dB (Code of Federal Regulations Title, 29). Threshold defines the point where the measured decibel levels will not be included in the dosimeters noise level calculations. Below the threshold value, the decibel levels are replaced with a value of 0 dBA (Tingay and Robinson, 2014).

Table 1. Configuration of integrators

Integrators	1	2	3
Name	OSHA-HC	OSHA-PEL	ACGIH/NIOSH
Exchange Rate	5	5	3
Time Weighting	Slow	Slow	Slow
Frequency Weighting	dB(A)	dB(A)	dB(A)
Threshold	80	none	80
Criterion Time	8 hrs	8 hrs	8 hrs
Criterion Level	90	90	85

The motorcyclists normalized 8-hr time-weighted average (TWA) noise exposure was calculated using Equation I for OSHA-HC and OSHA-PEL virtual dosimeter. Equation II was used to calculate the third virtual dosimeter (ACGIH) which used 3db exchange rate (Gilbertson and Vosburgh 2015).

$$LOSHA,8h = LOSHA,T + 16.1Log(T/8) \qquad \text{(EQ-I)}$$

$$LA8hn = Leq,T + 10\,Log\,(T/8) \qquad \text{(EQ-II)}$$

In Equation I, $L_{OSHA,8h}$ is the normalized 8-hr TWA noise exposure and $L_{OSHA,\,T}$ is the average noise level (A-weighted) over the time T. In Equation II, L_{A8hn} stands for normalized 8-hr TWA noise exposure and Leq, T is the average noise level (A-weighted) exposed during the time period T.

Procedure

Testing route was UiTM, Faculty of Health Sciences bus station (D1) to UiTM Perdana (D2). Prior to the testing ride from D1 to D2 and return, participants filed the data questionnaire followed by the installation of dosimeter as shown in Figure 1c. The total distanced covered from D1-D2-D1 was approximately 40 km and 46 minutes.

Calibrated dosimeter (114 dBA) small microphone (Type 2) was placed near the entrance of the rider's ear canal, so as not to be in-contact with any other part of the ear. The microphone was attached to a clip to hold the wire to prevent movement, while a thin microphone cord attached to the dosimeter. A wire cord was drawn from the front of the rider and clipped at the front by placing the dosimeter instrument in the front basket of the motorcycle. The safety of the dosimeter was ensured by covering it with a front cover. The helmet was fixed and buckled tightly to avoid any displacement of wires and microphone.

The test road consisted of adjoining roads and highway (flat, asphalt road). The selection of this road was between the designated D1- D2 route to meet the purpose of assessing real-time exposure level encountered by the young riders on daily basis during their commute. Adjoining roads consisted of curves, road bumps, and traffic signals, while the highway was a straight road. The traffic flow is generally from low to medium, depending on the peak hours of the day such as morning 7-8 and 5-7pm. The timing of the test administration was flexible, depending on the availability of the participants. Riders own motorcycles were utilized, which were without windscreen and ranged from engine capacity of 100 cc to 150 cc. For the safety reasons, the speed could not be standardized for each kilometre travelled, therefore riders were instructed to follow the inscribed road speed. All test measurements were carried out in dry weather condition.

On their arrival, dosimeter data was saved as session number followed by turning it off and uninstallation of the instrument from the rider. Raw data was later transferred to computer software i.e. 3M Detection Management Software (DMS) to deliver the measurement of each session's report. Data measurement included: Start and stop time, device serial number, device model type, average A-weighted sound level (L_{Aeq}), the exchange rate at 5, dose (daily personal noise exposure), TWA (time-weighted average), SEL (sound exposure level).

Fig.1. Instruments used for field study: (a) Open-face helmet; (b) Dosimeter and calibrator; (c) Dosimeter installation on the rider

Statistical Analysis

Dosimeter software generated data was tabulated and logged on excel worksheet, and statistical analysis was conducted using Statistical Package for Social Sciences, IBM SPSS (Version 22 Inc., Chicago, IL). Descriptive data of session's duration, means and standard deviations and maximum and minimum noise level were computed through frequency chart. The experimental design consisted of standardized distance travelled but each rider completed in varied time duration. To normalize the effect of this time difference, 8-hourly time-weighted average (TWA) noise exposure level was calculated using EQ I and II. The descriptive statistics for the normalized 8-hr TWA noise exposure were calculated for all the three virtual dosimeters. The bar charts were plotted for average TWA noise level (dBA) against three standards.

RESULTS

Table 2 presents the descriptive results of the three virtual dosimeters based on three standard integrators. The average noise exposure (L_{avg}) for OSHA-HC was 93.64 d BA (*SD*=5.37) ranging from 87.2 to 106.9 d BA. The OSHA-PEL maximum noise exposure was 108.8 d BA and minimum 83.6 d BA with mean (L_{avg}) noise exposure of 92.51 d BA (*SD* = 6.18). The average noise exposure (L_{avg}) for ACGIH/NIOSH was 95.29 d BA (*SD* = 5.62) ranging from 88.8 to 109.8 d BA. The duration of ride ranged between 32 to 61 minutes with mean duration of 46.98 minutes (*SD* = 5.84). The 8-hour TWA normalized noise exposures for OSHA-HC, OSHA-PEL and ACGIH/NIOSH average was 76.82 d BA (*SD*=5.21; ranging:70.82 - 89.83), 75.69 d BA (*SD* = 6.03; ranging: 67.03 - 89.74), 85.16 d BA (*SD* = 5.53; ranging: 78.62-99.42) respectively. Figure 2 illustrates the comparisons between the three standards average noise exposure of the participants: (A) OSHA-HC, (B)OSHA-PEL, and (C) ACGIH/NIOSH.

Table 2. Descriptive analysis of average noise exposure and TWA[1] on three standards

Dosimeter Configuration	Mean (dBA)	SD	Range (dBA)
Lavg (OSHA HC)	93.64	5.37	106.9-87.2
Lavg (OSHA-PEL)	92.51	6.18	106.8-83.6
Lavg (ACGIH)	95.29	5.62	109.8-88.8
Duration of ride	46.98	5.84	60-32
8-hr TWA Normalized noise exposure			
(OSHA HC)	76.82	5.21	89.83-70.82
(OSHA-PEL)	75.69	6.03	89.74-67.03
(ACGIH)	85.16	5.53	99.42-78.62

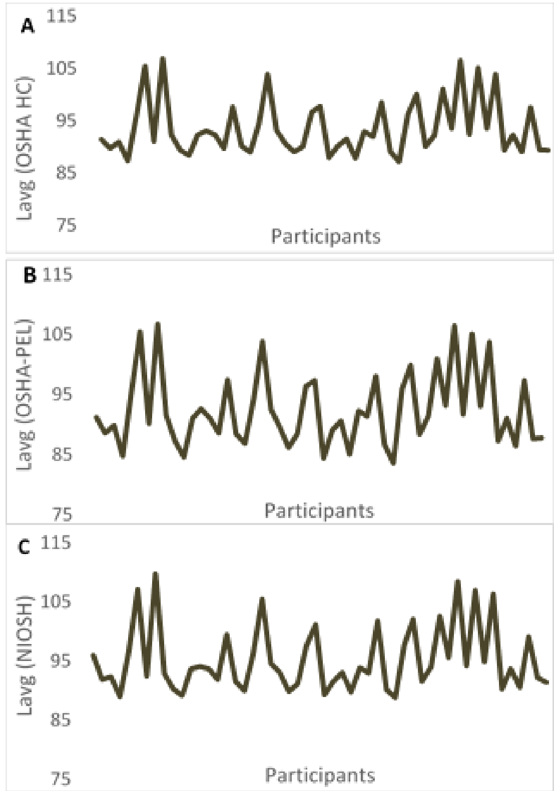

Fig.2. Average noise exposure level of participants on different standards: (A) OSHA-HC[2]; (B) OSHA-PEL[3]; (C) ACGIH[4]

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[1] TWA: Time-weighted average

[2] OSHA-HC: Occupational Safety and Health Administration-Hearing conversation.

[3] OSHA-PEL: Permissible Noise Exposure

[4] NIOSH: National Institute of Occupational Safety and Health

DISCUSSION

Motorcycling average at-ear noise exposure level of the rider under the open-face helmet in present study was determined to be above 90 dBA on simultaneously all three virtual dosimeters which is in accordance with previous studies reported (Kennedy et al., 2011) either on-track assessment (Carley et al., 2011) or through field study on mannequin road exposures (Kennedy et al., 2011). The average time taken by the riders (*n*=52) to complete the test ride was 46.98 minutes which is in accordance to the google map distance/time calculation, whereas the minimum time utilized was 32 minutes and maximum 60 minutes which can be attributed to the difference in riding behaviors of the riders. This study consisted of a large number of riders, which may reflect the average noise exposure experienced by motorcyclists through different styles of riding as it has been reported that varying riding position has different at-ear noise levels to the riders (Carley et al., 2011).

The other factors that influence the noise exposure are different types of helmets used by the riders, as reported by Ross, 1989 that open face helmets are less noisy with a difference of 7 dB compared to closed-face helmets. Participants in this study wore open-face helmets, but in case of closed-face helmets the exposure to noise would be much higher than 90 d BA.

It has been also investigated by (Carley et al., 2011) and (Kennedy et al., 2011), that there is a significant impact of the interaction of helmet with windscreen angle and location on sound pressure level as well as at-ear noise spectral content. In the current study, the windscreen was not attached to the participant's motorcycle.

The studied comparisons on three integrators showed different motorcycle noise exposure values for a range of different occupational noise exposure standards. The noise exposure in terms of the sound pressure, to which a rider during the ride would be exposed to, is the same for all the different integrators. But the average noise level (L_{avg}) differences between OSHA-HC (L_{avg}= 93.64 d BA), OSHA-PEL (L_{avg}= 92.51 d BA) and ACGIH/NIOSH (L_{avg}= 95.29 d BA) demonstrated clearly how a simple variance in the configuration of the integrators can produce significantly different outcomes. Such differences are attributed to the effects of the opposing threshold levels, exchange rates, and criterion levels, which combines to provide different results. The lowest level recorded was 83.6 dBA on OSHA-PEL and the highest level was recorded at 109.8 dBA on ACGIH/NIOSH standard. This emphasizes the need for establishing common and standardized measuring protocols for assessing motorcycle noise exposure levels. The 8-hour TWA average noise exposure above the permissible noise level was 85.16 dBA for ACGIH/NIOSH standard, which represents a hazardous level for young riders.

Previous studies related to motorcycle noise measurement did not quote the standards of the studied measurement, therefore, the present results cannot provide a cross analysis. Realistic situation based noise assessment has not been conducted with larger sample size, besides the study conducted by Ross, (1983), where he reported differences in sound levels at same speed while riding in town and motorway and on open roads, also motorcycling leads to increased noise exposure in closed-face helmet as compared to open-face helmet. Ross also reported that wet road exposes higher noise levels than dry roads as assessed by DAT method. All assessments in this study were conducted under dry weather conditions, but hypothetically it can be presumed that under wet weather conditions noise exposure levels would be greater than dry weather results.

Noise level above 80 dBA with continuous exposure over an extended period is referred as a quantifiable risk of hearing damage (McCombe et al., 1994). The temporary hearing threshold (THTS) is defined as a loss of hearing sensitivity after noise exposure. THTS recovery to hearing to pre-exposure level depends on the noise spectral content, age of the person (listener) and level of exposed noise (Quaranta et al., 1998). Periods of noise exposure cause the transition of THTS to a permanent hearing threshold shift (PHTS), which is defined as the characteristics of noise-induced hearing loss (NIHL). NIHL may occur from one off-loud noise exposure such as an explosion, but more commonly it is caused by repeated exposures to multiple noise doses or continuous loud sounds over a longer period of exposure time, such as wind noise during motorcycling. The riders noise exposure level is at sufficient level for developing THTS, but the relevant literature presents inadequate data which has focused merely on occupational rider's auditory assessment, whereas, young riders hearing status has never been investigated. High noise exposures can affect the hearing of such exposed population that can suffer in hearing sensitivity with the reduction of 30db or more (Kennedy et al., 2011) and possible distraction (Carley et al., 2010). The hearing ability acts as an early warning system and swiftly redirects our vision and this gazing shift is critical to assess the location, direction of travel and speed of approaching vehicles (Brown and Gordon, 2011).

In the literature little work is available on the nature and sources of noise exposed to riders and its effects other than hearing disabilities, particularly to occupational motorcyclists (Kennedy et al., 2011). It was shown that high to moderate noise levels hindered reaction times, impaired attention and reduced perceptual and behavioral response effectiveness (Brown and Gordon, 2011). It was reported that virtual stimulus paired with an auditory cue results in more accurate visual perception, increased the risk of accidents and increased level of stress (young riders)(Perroti et al., 1990; Ali et al., 2016; Ali et al., 2017).

The strength of the study is the larger sample size (participants) and real-time motorcycling noise exposure assessment on young riders, which has never been investigated. Secondly, it has provided the baseline of different standards for motorcycling noise exposure levels and TWA associated with it.

Limitation of this study was non-utilization of other equipment's such as aerometer and webcam digital recorder due to safety constraints for assessing the wind speed outside the helmet and the riders riding position.

CONCLUSION

Findings in this study show that the young motorcycle riders are exposed to noise above the permissible levels based on 8-hourly TWA ACGIH and NIOSH standard. The average noise exposure level ranged above 90 d BA under three integrators, which showed high noise exposure associated with motorcycling among young motorcyclists. The differences among different standards emphasize the need for established protocols and standards for assessing the noise exposure associated with motorcyclists. Further studies will embark the risk factors associated with high noise exposures to the rider's health.

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REFERENCES

Ali, A., Dom, N.C., Hussain, R.M. and Abdullah, M. (2017). Effect of motorcycling on salivary noise-induced cortisol among young motorcyclists. Environment-Behaviour Proceedings Journal, 2(6):269–277.

Ali, A., Karuppannan, S., Hussain, R.M., Rajan, S., Abdullah, M., Ikhwan, R. and Chinna, K. (2016). Epidemiological root cause analysis of noise and physio - psycho impacts related to motorcycle road accidents. Journal of Scientific Research and Development, 3(5), pp.150–156.

Binnington, J.D., Mccombe, A.W. and Harris, M. (1993). Warning signal detection and the acoustic environment of the motorcyclist Warning signal detection and the acoustic environment of the motorcyclist. British Journal of Audiology, 27(6): 415–422.

Brown, C.H. and Gordon, M.S. (2011). Motorcycle Helmet Noise and Active Noise Reduction. The Open Acoustics Journal, 4(2): 14–24.

Carley, M., Kennedy, J., Walker, I. and Holt, N. (2011). The experimental measurement of motorcycle noise. In Proceedings of Meetings on Acoustics 161ASA, 12(1): 040002.

Carley, M., Holt, N. and Walker, I. (2010). Noise mechanisms in motorcycle helmet noise. In Proceedings of Meetings on Acoustics 159ASA, 9(1): 040005.

Gilbertson, L.R. and Vosburgh, D.J. (2015). Patrol Officer Daily Noise Exposure. Journal of occupational and environmental hygiene, 12(10): 686-691.

Harvey, H.D., Hetherington, J.O., Woodside, A. and Jordan, C. (2002). Noise induced hearing loss in motorcyclists. Publication of: Association for European Transport.

Jordan, C., Hetherington, O., Woodside, A. and Harvey, H. (2004). Noise induced hearing loss in occupational motorcyclists. Journal of Environmental Health Research, 3(2): 70–77.

Kennedy, J., Carley, M., Walker, I. and Holt, N. (2013). On-road and wind-tunnel measurement of motorcycle helmet noise. The Journal of the Acoustical Society of America, 134(3): 2004-2010.

Kennedy, J., Holt, N., Carley, M. and Walker, I. (2011). Spectral filtering characteristics of a motorcycle helmet. In Proceedings of Meetings on Acoustics 161ASA, 12(1): 040001.

Kennedy, J., Holt, N., Carley, M. and Walker, I. (2014). The influence of the acoustic properties of motorcycle helmets on temporary hearing loss in motorcyclists. Acta Acustica united with Acustica, 100(6): 1129-1138.

McCombe, A.W., Binnington, J. and McCombe, T.S. (1993). Hearing protection for motorcyclists. Clinical Otolaryngology, 18(6): 465-469.

McCombe, A.W., Binnington, J. and Nash, D. (1994). Two solutions to the problem of noise exposure for motorcyclists. Occupational medicine, 44(5): 239-242.

Occupational Noise Exposure, Code of Federal Regulations Title 29, P. 1910. 9. subpart G.

Perrott, D.R., Saberi, K., Brown, K. and Strybel, T.Z. (1990). Auditory psychomotor coordination and visual search performance. Attention, Perception, & Psychophysics, 48(3): 214-226.

Quaranta, A., Portalatini, P. and Henderson, D. (1998). Temporary and permanent threshold shift: an overview. Scandinavian audiology. Supplementum, 48: 75-86.

Ross, B.C. (1989). Noise exposure of motorcyclists. Annals of Occupational Hygiene, 33(1): 123–127.

Tingay, J. and Robinson, D. (2014). A practical comparison of occupational noise standards. In INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 249(5): 2600-2607.

Violini, D.G., Peña, R.S.S. and Velis, A. (2015). Time-varying noise control in motorcycle helmets. Acoustical Science and Technology, 36(4): 333-335.

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