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CYCLIST SAFETY: IDENTIFYING HIGH-RISK GROUPS THROUGH DATA ANALYSIS

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Abstract

Cycling has gained global popularity due to its health, environmental, and cost benefits; however, cyclist safety remains a significant concern. Understanding the factors contributing to risky cycling behaviours in Malaysia is therefore crucial for developing effective safety interventions. This study aimed to identify high-risk cyclist groups in Kuala Terengganu and Dungun, Terengganu, Malaysia, focusing on helmet non-use, reflective clothing non-use, and riding two abreast. A total of 2,205 cyclists were observed at eight locations over six days, revealing significant associations between behaviours and explanatory variables such as age, time of day, day of the week, speed, and road type, using a binary logistic regression model. Helmet non-use increased at speeds above 10 km/h, was less common among children and adolescents, and was less likely to occur during morning peak hours and on municipal roads. Non-use of reflective clothing increased during evening peak hours, was less common at speeds between 10 and 20 km/h and decreased on state roads. Riding two abreast was more common on weekdays and on state roads but less likely at speeds over 20 km/h and on municipal roads. The findings of this study may support the development of targeted interventions, including cyclist awareness programmes for specific groups, policy enforcement, promotion of safety gear, and other safety initiatives essential for improving cyclist safety.

Keywords: Cyclist Safety, Risky Cycling Behaviours, Helmet Non-Use, Reflective Cloth Non-Use, Riding Two Abreast

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INTRODUCTION

Every year, approximately 1.35 million lives are lost due to road crashes, making it the eighth leading cause of death worldwide, based on the report from the World Health Organisation (WHO, 2024). Pedestrians and cyclists account for 26% of fatalities, with low-income countries experiencing threefold higher death rates due to inadequate infrastructure and traffic growth (Barajas, 2018; Cahen, 2016; Lusk et al., 2019; Nantulya & Reich, 2003). In contrast, high-income regions typically have better safety provisions, leading to fewer collisions. Factors contributing to these crashes include distracted drivers, elderly bicyclists, careless operations, and riding in dark conditions (Das et al., 2023). These insights are essential for implementing strategies to reduce injury rates and improve cyclist safety both globally and in Malaysia.

Cycling has gained considerable popularity over recent decades, supported by growing awareness of its health benefits, environmental advantages, and potential to address urban mobility challenges. Many cities and countries have actively promoted cycling to enhance liveability and sustainability, contributing to a marked rise in cycling levels. Mason et al. (2015) reported that countries such as the Netherlands, Germany, and Denmark experienced significant growth in cycling due to environmental awareness and the promotion of healthier lifestyles. In South Tangerang City, Indonesia, Almassawa et al. (2024) found that expanding bicycle lane networks could encourage greater bicycle use and support the implementation of smart mobility initiatives. A survey conducted in Putrajaya, Malaysia revealed that almost all respondents' agreed cycling is a form of sustainable transport (Hashim et al., 2017). This global trend reflects the increasing recognition of cycling as a practical, eco-friendly, and health-conscious mode of transport. It also highlights the urgent need for improved cycling infrastructure and the introduction of comprehensive safety policies to address risky behaviours and protect the growing number of cyclists. In Malaysia, for instance, a study in Shah Alam, Selangor identified weaknesses in the bicycle path infrastructure and its lack of compliance with established guidelines (Abdullah et al., 2020).

Many factors have been identified that are related to risky cycling behaviours. For example, a study by Radun and Olivier (2018) in Finland revealed that many cyclists do not wear helmets despite their benefits in reducing head injuries. They identified factors influencing these health beliefs, sociodemographic characteristics, and risk-taking tendencies. Meanwhile, a study by Hounkpè Dos Santos et al. (2022) discovered that adolescents often skip helmets to seek peer approval. Similarly, Piatkowski and Marshall (2020) asserted that college students often do not wear helmets due to low health belief scores and perceived barriers. Engbers et al. (2018) reported that not wearing reflective clothing significantly increases crash risk, especially in low visibility conditions. Similarly, Wang et al. (2020) stated that only a small percentage of

adult cyclists consistently wear reflective jackets at night. Addressing these details is crucial for effective safety interventions and educational programmes. Moreover, Abdur et al. (2021) and Fraser and Meuleners (2020) reported that riding two abreast can enhance cyclist visibility and safety. Useche et al. (2024) posited that demographic factors like age, education level, and urban setting predict traffic rule violations among cyclists. Notably, young motorcyclists who seek excitement and exhibit aggressive attitudes tend to ride riskily. Although there are fewer studies on cyclists, these traits also likely apply to young cyclists, making them a high-risk group.

METHOD

Data Collection

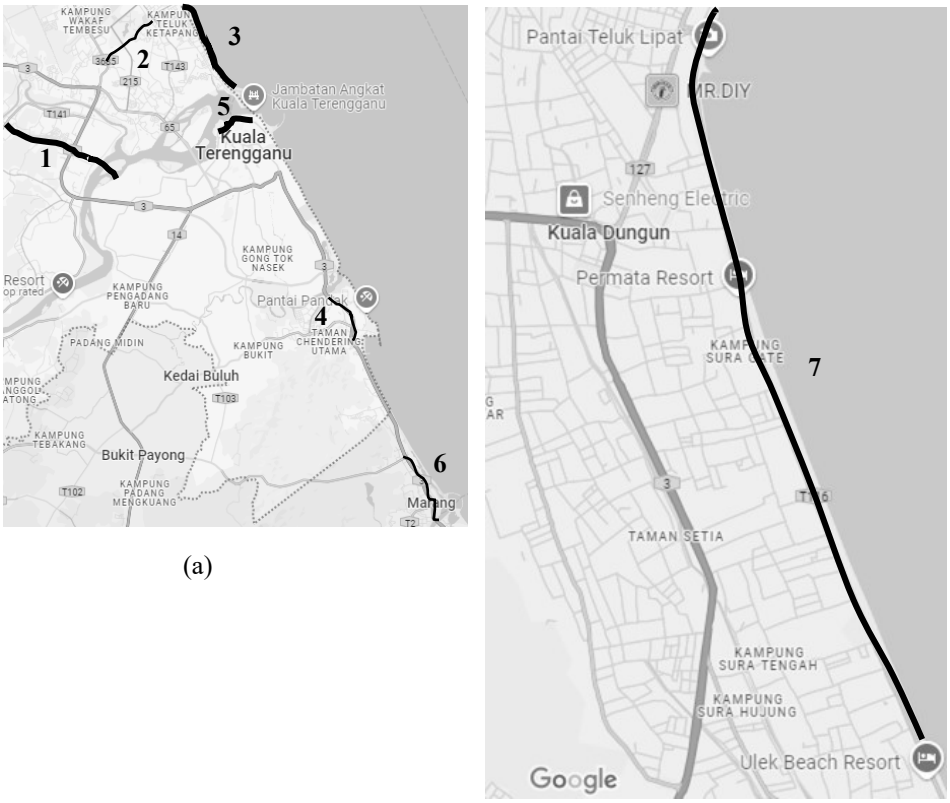
This research used a field observation survey conducted at seven road locations in Kuala Terengganu and Dungun, Terengganu, Malaysia, as displayed in Figure 1. Sites included two along (1) Kuala Terengganu Bypass Road, and one each on (2) Jalan Lapangan Terbang, (3) Jalan Pantai Teluk Ketapang, (4) Jalan Batu Buruk, (5) Jalan Balik Bukit, (6) Laluan Persekutuan 3, and (7) Jalan Pantai Sura in Dungun. The roads, classified as federal, state, and municipal, are managed by respective authorities. Observations were conducted from March 19th to March 22nd, 2021, during peak hours: 7:00-9:00 AM and 5:00-7:00 PM. To capture the effect of daily trends, this study was conducted on weekends (Friday and Saturday) and weekdays (Sunday to Thursday). It should be noted that Terengganu takes Friday and Saturday as their weekend. Clear weather was noted during the observations, and this variable was dropped from the further analysis of the same observations across days and times. Accordingly, seven research assistants have been appointed to collect data on risky behaviours, helmet, and reflective clothing non-use, and riding two abreast. They also recorded other information such as gender, age group, speed, bike type, time of the day, day of the week, and road type.

Data Analysis

In this study, three different binary logistic regression models related to the three risky riding behaviours (helmet non-use, reflective clothes non-use, and riding two abreast) were estimated using seven explanatory variables: gender, age, time of the day, day of the week, speed, type of bike, and type of road. Binary logistic regression allows for examining multiple variables within a complex model. This study reported all three logistic regression models. Notably, binary logistic regression has been used in this study to predict the probability of a binary outcome based on one or more predictor variables. It applies a logistic function to transform the output to a probability between 0 and 1. This technique is useful for classification tasks where the dependent variable has two possible outcomes. Eq. 1 represents the binary logistic regression employed in this study.

$$Z = \log (p/(1-p)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \epsilon \quad (1)$$

where Z is the logit (log-odds) of the probability p of the binary logistic regression, p is the probability of the event occurring, p/(1-p) represents the odds of the event occurring, and log (p/(1-p)) is the natural logarithm of the odds, also known as the logit. Meanwhile, β_0 is the intercept term, β_1, β_2, β_3… are the coefficients corresponding to the predictor variables (gender, age, time of day, day of week, speed, type of bike, and type of road) X_1, X_2, X_3, and ϵ is the error term.



(a) (b)

Figure 1: Location of observations in (a) Kuala Terengganu, and (b) Dungun, Terengganu, Malaysia
Source: Google Maps (2025)

RESULTS

Descriptive Analysis

Table 1 presents the distribution of risky behaviours among cyclists based on contextual and demographic factors. Helmet non-use was observed at similarly high rates among male (87.1%) and female (81.2%) cyclists. Across age groups, the highest percentage was recorded among adults (87.4%), followed by adolescents (68.7%) and children (68.5%). Helmet non-use was consistently prevalent during peak hours, with 87.7% recorded in the morning and 85.0% in the evening. Rates were also comparable between weekdays (86.3%) and weekends (86.7%). However, significant differences were observed based on cycling speed. Cyclists travelling below 10 km/h recorded a lower rate of helmet non-use (67.2%) compared to those riding at 10–20 km/h (90.0%) and above 20 km/h (97.6%). In terms of bicycle type, standard bicycles showed a slightly higher rate of helmet non-use (86.1%) compared to electric bicycles (83.3%). The most pronounced variation was noted across road types, with federal roads recording the highest rate (90.8%), followed by state roads (86.8%) and municipal roads (55.2%).

The analysis of reflective clothes non-use among cyclists reveals significant patterns across various demographic and situational factors. Notably, female cyclists are slightly more likely to not wear reflective clothes, with a non-use rate of 98.9% compared to 97.2% for male cyclists. Age-wise, adults exhibit a non-use rate of 97.4%, adolescents 97.0%, and children 100%, indicating consistent non-use among cyclists age groups. Reflective clothes non-use indicated 97.7% observed during evening peak hours and 97.2% during morning peak hours. Similarly, non-use rates are relatively stable between weekends (97.3%) and weekdays (97.5%). Cyclists travelling at higher speeds are associated with higher non-use rates, with those cycling above 20 km/h having a non-use rate of 95.3%, while cyclists between 10-20 km/h exhibit a rate of 97.8%. Cyclists on standard bikes exhibit a non-use rate of 97.4%, whereas none of the cyclists on electric bikes were observed without reflective clothing. However, non-use rates also vary by road type, with the highest non-use rate of 100% on municipal roads, 99.6% on state roads, and the lowest rate of 95.6% on federal roads.

Female cyclists (32.3%) are observed riding two abreast more frequently than their male counterparts (27.0%). Furthermore, children exhibit the highest rate of riding two abreast (33.3%), followed by adults (27.8%) and adolescents (23.5%). Interestingly, riding two abreast is more prevalent during the morning peak hour (29.1%) compared to the evening peak hour (26.5%). On weekends, there is a higher likelihood of cyclists riding two abreast (32.3%) compared to weekdays (23.3%). Additionally, the prevalence of riding two abreast decreases with increasing speed, with cyclists travelling below 10 km/h exhibiting the highest rate (39.6%). Notably, electric bikes demonstrate no

observation for riding two abreast, while standard bikes exhibit a moderate rate (28.0%). Furthermore, riding two abreast behaviour varies significantly across different types of roads, with state roads exhibiting the highest prevalence (58.5%), followed by federal roads (20.6%) and municipal roads (4.1%).

Table 1: Risky behaviours of cyclists by demographic and contextual factors

Variable	Helmet non-use		Reflective clothes		Riding two-abreast	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Gender						
Male	1,865(87.1)	249(12.9)	1,880(97.2)	54(2.8)	215(27.0)	581(73.0)
Female	220(81.2)	51(18.8)	268(98.9)	3(1.1)	41(32.3)	86(67.7)
Age						
Adult	1,822(87.4)	262(12.6)	2,029(97.4)	55(2.6)	243(27.8)	631(72.2)
Adolescent	46(68.7)	21(31.3)	65(97.0)	2(3.0)	8(23.5)	26(76.5)
Children	37(68.5)	17(31.5)	54(100.0)	0(0.0)	5(33.3)	10(66.7)
Time of the day						
Evening Peak-hour	888(85.0)	157(15.0)	1,021(97.7)	24(2.3)	131(26.5)	363(73.5)
Morning Peak-hour	1,017(87.7)	143(12.3)	1,127(97.2)	33(2.8)	125(29.1)	304(70.9)
Day of the week						
Weekend	851(86.7)	132(13.4)	956(97.3)	27(2.7)	131(32.3)	275(67.7)
Weekdays	1,054(86.3)	168(13.7)	1,192(97.5)	30(2.5)	392(3.3)	125(24.2)
Speed						
<10 km/h	299(67.2)	146(32.8)	434(97.5)	11(2.5)	61(39.6)	93(60.4)
10-20 km/h	1,316(90.0)	147(10.0)	1,431(97.8)	32(2.2)	176(29.9)	431(71.0)
>20 km/h	290(97.6)	7(2.4)	283(95.3)	14(4.7)	19(11.7)	143(88.3)
Type of bike						
Standard	1,875(86.1)	294(13.6)	2,112(97.4)	57(2.6)	256(28.0)	657(72.0)
Electric	30(83.3)	6(16.7)	36(100.0)	0(0.0)	0(0.0)	10(100)
Type of road						
Federal	1,105(90.8)	112(9.2)	1,163(95.6)	54(4.4)	140(20.6)	539(79.4)
State	699(86.8)	106(13.2)	802(99.6)	3(0.4)	114(58.5)	81(41.5)
Municipal	101(55.2)	82(448)	183(100.0)	0(0.0)	2(4.1)	47(95.9)

Source: Author's Calculation

Binary Logistic Regression

Table 2 presents the model fits examining the relationship between demographic and contextual factors across three risky cycling behaviours. Adolescents (OR = 0.323, 95% CI: 0.185–0.597) and children (OR = 0.251, 95% CI: 0.127–0.496) showed lower odds of helmet use compared to adults. Helmet non-use was also less likely in the morning (OR = 0.650, 95% CI: 0.516–0.923) than during the evening peak hour. Speeds of 10–20 km/h and above 20 km/h were associated with 3.2 times (95% CI: 2.428–4.327) and 16 times (95% CI: 7.207–34.987) higher odds of helmet non-use, respectively, compared to speeds below 10 km/h. Additionally, the odds of helmet non-use were significantly lower on municipal roads (OR = 0.193, 95% CI: 0.131–0.284) than on federal roads.

For reflective clothes non-use, significant odds in the morning were lower than in the evening *(OR = 0.545, 95% CI: 0.285-1.043)*, and for speed, the odds ratio was lower for speeds of 10-20 km/h compared to speeds less than 10 km/h *(OR = 0.467, 95% CI: 0.226-0.*968). Speeds more than 20 km/h demonstrated no significant association with reflective clothes non-use. State roads had a lower odds ratio (OR = 0.077, 95% CI: 0.024-0.250) than federal roads, while municipal roads revealed no significant association.

Only three significant variables were determined of seven for riding two abreast. Weekdays presented a higher odds ratio, with 2.4 times higher *(95% CI: 1.549-3.666)* than weekends. Regarding speed, speeds more than 20 km/h had a lower odds ratio than speeds less than 10 km/h *(OR = 0.197, 95% CI: 0.102-0.379)*. State roads had an odds ratio of 9.1 times higher *(95% CI: 5.962-13.804)* than federal roads, while municipal roads had a lower odds ratio *(OR = 0.208, 95% CI: 0.049-0.883)* than federal roads.

DISCUSSION

Out of seven explanatory factors selected for forward selection logistic regression, age, speed, type of road, and time of day were statistically significant for helmet non-use. Meanwhile, time of day, speed, and type of road were statistically significant for the non-use of reflective clothes. For riding two abreast, the day of the week, speed, and type of road were reported to be significant.

Table 2: The model estimation of the binary logistic regression for high-risk groups of cyclists

Variable	Reference	Helmet non-use			Reflective clothes non-use			Riding two-abreast		
		Odds Ratio	Confidence Interval (95%)	P-Value	Odds Ratio	Confidence Interval (95%)	P-Value	Odds Ratio	Confidence Interval (95%)	P-Value
Gender										
Female	Male	0.805	0.559-1.160	0.245	0.397	0.120-1.315	0.131	1.089	0.668-1.774	0.733
Age										
Adolescent	Adult	0.332	0.185-0.597	0.001***	1.122	0.251-5.010	0.88	0.900	0.376-2.151	0.812
Children		0.251	0.127-0.496	0.001***	0.000	0.000	0.997	0.521	0.162-0.521	0.272
Time of the day										
Morning Peak-hour	Evening Peak-hour	0.690	0.516-0.923	0.012*	0.545	0.285-1.043	0.067*	0.828	0.542-1.266	0.383
Day of the week										
Weekdays	Weekends	0.932	0.697-1.246	0.633	1.341	0.713-2.524	0.363	2.383	1.549-3.666	0.001***
Speed										
10-20 km/h	<10 km	3.241	2.428-4.327	0.001***	0.467	0.226-0.968	0.041*	0.986	0.617-1.575	0.954
>20 km/h		15.879	7.207-34.987	0.001***	1.112	0.470-2.634	0.809	0.197	0.102-0.379	0.001***
Type of bike										
Electric	Standard	0.466	0.185-1.175	0.105	0.000	0.000-0.000	0.998	0.000	0.000-0.000	0.999
Type of road										
State	Federal	0.847	0.624-1.150	0.288	0.077	0.024-0.250	0.001***	9.072	5.962-13.804	0.001***
Municipal		0.193	0.131-0.284	0.001***	0.000	0.000-0.000	0.995	0.208	0.049-0.883	0.033*

*significant at 0.05 level, **significant at 0.01 level, ***significant at 0.001 level

Source: Author's Calculation

Demography

Research into the cycling habits of different demographics has uncovered varying tendencies toward safety measures. This study observed that female and male cyclists often do not wear helmets at high rates. Notably, cultural norms and personal comfort may influence helmet use among female cyclists, especially in Islamic countries, with some studies asserting diverse perceptions of the necessity and benefits of helmets (Fallah, Hezaveh, & Nordfjærn, 2018; Ledesma et al., 2019; Valero-Mora et al., 2020). A study by Yuan et al. (2022) suggested that women are more aware of the practical benefits of helmets, potentially leading to higher usage rates compared to men. Interestingly, helmet usage appears more consistent among children and performance cyclists across genders (Hounkpè Dos Santos et al., 2022).

Research on cyclist safety reveals age-related patterns in helmet usage. Our finding indicates that adults wear helmets more consistently than adolescents and children, who often forgo helmets due to discomfort, overconfidence, or unawareness of regulations. Similarly, Piatkowski and Marshall (2020) discovered no evidence to support the common assumption that youth who wear helmets are more likely to engage in risk-taking behaviours. This current This study also observed that helmet use among children was less common in low-income areas, consistent with findings reported by Lajunen (2016) study. Lajunen (2016) further noted that children's helmet use was influenced by prevailing social norms.

The role of reflective clothing in preventing collisions is still debated. While reflective clothing may increase visibility, its impact on reducing crash risk is inconclusive (Wood et al., 2012). Some studies argue that reflective gear makes cyclists more noticeable to drivers, potentially reducing the likelihood of crashes during low-light conditions. However, others suggest that its effectiveness may be limited by factors such as driver awareness and road lighting. As such, research has proven that commuting cyclists are less likely to use reflective clothing compared to recreational cyclists and children, who often prioritise visibility for safety reasons (Pérez-Zuriaga et al., 2021). Despite mixed findings, promoting the use of reflective clothing remains a critical component of safety campaigns aimed at reducing cycling crashes.

Riding two abreast, where two cyclists ride side by side, has debated safety benefits. Some studies suggest that this practice can improve visibility, making it easier for drivers to see cyclists and potentially reducing crash risk. Research by Haworth et al. (2018) asserted that drivers give similar passing distances to male and female cyclists riding two abreast, suggesting that this practice does not disproportionately affect one gender. The systematic review conducted by Rubie et al. (2020) also supported this finding, suggesting that cyclist gender does not consistently influence lateral passing distances. Hence, drivers' perceptions and behaviours are key in determining passing distances.

Studies have emphasised that drivers who are also cyclists tend to give more space, likely due to a better understanding of cyclists' needs (Cubbin et al., 2024). Therefore, educating cyclists on when it is appropriate to ride two abreast can help improve safety and reduce risks.

Temporal Factors

Temporal factors significantly influenced risky cycling behaviours. Helmet non-use was more prevalent during morning peak hours and on weekends, suggesting that cyclists may feel rushed or perceive a reduced need for helmets during these periods. A similar trend was observed for the non-use of reflective clothing, which was more common during bright daylight hours when cyclists may underestimate the importance of visibility aids (Lahrmann et al., 2018). However, non-use of reflective wear poses safety risks during low visibility conditions (Vegas & Lin, 2019). The use of reflective wear also varies according to cycling patterns, with those riding in urban areas at night more likely to adopt such safety measures compared to those cycling during daylight. Miller et al. (2010) found no significant difference in reflective clothing use between weekdays and weekends, which is consistent with the findings of the present study.

This study found that riding two abreast was more common during weekends. No significant gender differences were observed. However, this finding contrasts with research by Babu and Anjaneyulu (2021), which highlighted those young male cyclists are generally more risk-prone, often engaging in behaviours such as riding two abreast. Such actions may result in traffic regulation violations and elevate the risk of road traffic crashes. The higher occurrence of this behaviour during weekdays may be linked to heightened stress and tension, potentially prompting cyclists to ride side by side for social or psychological comfort.

Speed and Type of Bike

The current study reported a significant association between risky behaviours and cycling speed. Helmet non-use was most prevalent at speeds over 20 km/h, particularly on federal roads, suggesting cyclists might underestimate head injury risks or find helmets uncomfortable at higher velocities. Fyhri et al. (2018) noted that experienced cyclists tend to ride faster without helmets, prioritising comfort over safety. Note that reflective clothing was generally used, but non-use increased at higher speeds, highlighting the need for better visibility aids to enhance safety. Cyclists travelling at 10-20 km/h were more likely to wear reflective clothing compared to those going below 10 km/h, underscoring the significance of visibility aids at moderate speeds. As such, Yan et al. (2018) reported that cyclists are less likely to ride side by side at speeds over 20 km/h due to safety, heavier traffic, and regulations. Moreover, research by Fu et al. (2017) demonstrated that cyclist speeds vary significantly, with a mean speed

estimation of 15.84 km/h. This indicates the need for targeted interventions to promote helmet and reflective clothing use, particularly among high-speed cyclists.

The type of bike does not influence the risky behaviours in this study. Standard bikes and electric present insignificant results in all three risky behaviours. Conversely, some research indicates that while the type of bike can impact risky behaviours, other factors such as rider demographics, psychological attributes, and situational contexts play more significant roles. A study by Rodon and Ragot-Court (2019) in Shanghai has suggested that electric bikes (e-bikes) often exhibit different risky behaviours compared to traditional bikes. The study also indicated that, due to their speed and power, e-bikes are more similar to motorised two-wheelers in terms of risky behaviours. Riders of e-bikes tend to engage in behaviours such as running red lights and riding on sidewalks more frequently than traditional cyclists. However, the type of bike alone does not fully account for these behaviours, as other factors like rider confidence and risk perception also play crucial roles (Wang et al., 2020b).

Type of Road

Road type was a significant factor in risky cycling behaviours. Helmet non-use was most common on federal roads, where higher speeds and traffic volumes might contribute to a false sense of security or urgency among cyclists. Conversely, reflective clothing non-use was less common on federal roads, possibly due to better lighting and infrastructure that improve overall visibility. Meanwhile, riding two abreast was more frequent on state roads, where traffic conditions might allow for more leisurely and social cycling. On municipal roads, narrower lanes and higher traffic density often necessitate single riding, resulting in lower incidences of helmet non-use and riding two abreast (Wang et al., 2020a; Lehmann et al., 2001). Accordingly, these findings highlight the impact of road conditions on cycling behaviours and safety practices, suggesting that the environment strongly influences cyclists' safety behaviours.

CONCLUSION

This study aimed to identify high-risk cyclist groups in Kuala Terengganu and Dungun, Terengganu, Malaysia, by examining three risky behaviours: helmet non-use, reflective clothing non-use, and riding two abreast. Field observations were conducted at seven locations over six days, capturing demographic and contextual data. Binary logistic regression analysis revealed significant associations between these behaviours and variables such as age, time of day, day of the week, speed, and road type. The results showed that helmet non-use was more common at speeds above 10 km/h, less frequent among children and adolescents, and less likely during morning peak hours and on municipal roads. Non-use of reflective clothing occurred more often during evening peak hours,

was less frequent at speeds between 10 and 20 km/h and declined on state roads. Riding two abreast was more prevalent on weekdays and state roads but less likely at speeds exceeding 20 km/h and on municipal roads. These findings highlight the need for targeted interventions such as cyclist awareness programmes, policy enforcement, promotion of safety gear, and other safety strategies to encourage safer cycling behaviour. The outcomes of this study offer valuable guidance for community planners, policymakers, researchers, and academicians, contributing to the advancement of sustainable transportation and the promotion of cyclist safety in Malaysia.

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ETHICAL STATEMENT

This study received approval from the Research Ethics Committee (REC) of Universiti Teknologi MARA (UiTM) under reference number REC/10/2024 (ST/MR/223).

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