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Assessing the Self-Report Instruments of Younger Versus Older Riders Involved in Near-Miss Motorcycle Incidents

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Abstract

Road accidents pose severe and pervasive consequences, especially in low- and middle-income countries (LMICs), where both the population and fatal accidents among youth and the elderly are steadily increasing. Therefore, this study aims to develop a model for risky behavior in near-miss incidents among motorcycle riders in Thailand. It intends to compare models between younger and older riders utilizing structural equation modeling (SEM) with a multi-group approach. The data were examined employing modified instruments derived from the Motorcycle Rider Behavior Questionnaire (MRBQ). Samples depicting risky riding behavior were obtained from both younger and older rider groups. Parameter invariance testing revealed differences between the two groups. Control errors notably emerged as the predominant factor contributing to near-miss incidents for both age groups. Speeding was identified as the primary concern for the younger group, while adverse weather conditions were deemed crucial for the older group. Based on this study, policy recommendations endorse the creation of targeted training programs for novice riders, emphasizing adherence to legal speed limits and the adoption of safe riding practices. Additionally, the study underscores the importance of preparing riders, especially those in the older age group, for adverse weather conditions.

Keywords: PTW Rider; Low- and Middle-Income Countries (LMICs); Road Traffic Safety; Age Difference; Multi-group SEM.

1. Introduction

Annually, the global toll of fatalities resulting from road accidents stands at approximately 1.35 million, as documented by the World Health Organization [1]. In conjunction with this, a significant demographic number of between 20 and 50 million individuals experience incapacitating injuries or disabilities due to these incidents. Notably, vulnerable road users, encompassing pedestrians, cyclists, and motorcyclists, are disproportionately implicated in nearly 50% of these occurrences. This predilection for vulnerability is particularly pronounced within nations characterized by modest to intermediate economic indicators, a classification delineated by the World Health Organization [1]. Furthermore, prevailing projections, as posited by Inada et al. [2], portend a sustained increase in these figures. An especially noteworthy facet is the disproportionate impact on the age group spanning from 5 to 29 years, which comprises children and young adults, as underscored by the World Health Organization. Thailand's motorcycle fatality rate holds the global second position and leads within the Asian region, a classification supported by the World Health Organization [1].

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Remarkably, the nation boasts a cumulative registration tally of 21 million motorcycles, representing a substantial 70% portion of the entire vehicular landscape, as evidenced by the Department of Land Transport [3]. The allure of motorcycles can be attributed to their inherent advantages, including convenience, swiftness, fuel efficiency, and cost-effectiveness. However, it is noteworthy that these very attributes contribute to the cultivation of risky driving behaviors, a proposition expounded by Lin et al. [4]. This propensity for imprudent driving practices significantly contributes to the prevalence of injuries and fatalities stemming from accidents. Drawing attention to the situation in developing countries, Fitzpatrick and O'Neill [5] reveal a confluence of factors that accentuate the heightened vulnerability within these regions. Specifically, such countries often exhibit deficient road user training, diminished adherence to traffic regulations, and inadequacies in both road infrastructure and healthcare systems. These deficiencies collectively culminate in elevated rates of injuries and fatalities among their populace.

The ThaiRoads Foundation's report in 2022 highlights that in the year 2021, Thailand confronted a notable fatality rate attributed to motorcycle-related incidents, accounting for approximately 51% of the overall fatalities resulting from road accidents. In-depth analysis of motorcycle accidents further discloses that nearly 50% of these occurrences trace their origins to perceptual lapses among motorcycle riders during the assessment of situations. It is of significance that individuals aged between 15 and 24 years, constituting the adolescent and young adult cohort, exhibit the highest incidence of motorcycle accidents. The principal underlying cause of these incidents predominantly revolves around errors linked to motorcycle control, particularly the mastery of braking techniques for speed moderation and halting. This factor prominently features in 90% of motorcycle accident cases involving riders, irrespective of their possession of a valid driver's license. The acquisition of motorcycle riding skills is frequently influenced by peers, family members, or self-initiated practice, commonly excluding the incorporation of safe driving skills [6].

2. Literature Review

2.1. Younger and Older Rider

A study conducted by the OECD contends that adolescent drivers lack full preparedness in terms of physical and cognitive development. Notably, the prefrontal cortex, often recognized as the "executive function" of the brain governing decision-making, impulse regulation, and reasoning, remains inadequately matured until the age of 25 [7]. Adolescent drivers, who are commonly identified as high-risk candidates for road accidents, confront limitations stemming from their limited driving experience and an increasing inclination toward risky behaviors [8]. Adolescents are substantially more susceptible to severe road accidents compared to adults, often exhibiting a threefold higher propensity [9]. Moreover, the incidence of road traffic crashes per million miles driven is shown to be up to six times greater for adolescents when compared with adults [10]. It is imperative to underscore that adolescent riders are inherently predisposed to an escalated accident risk, primarily due to their status as novice drivers with limited experiential exposure. This vulnerability is compounded by their underdeveloped physical, cognitive, and brain maturation, which compromises their aptitude for proficient motorcycle operation.

Since the beginning of 2020, the COVID-19 pandemic has had a discernible impact on reduced road usage among the population. Despite an overall decrease in the occurrence of road accidents, there has been a troubling trend of significantly increased severity in injuries resulting from these accidents [6]. Notably, "motorcycles" persist as the predominant high-risk vehicle category, contributing to fatalities arising from road accidents. This fact is vividly portrayed in Figure 1, mirroring the pattern delineated in Figure 2. These graphical representations underscore that the "working-age group" remains more susceptible to fatalities compared to other age cohorts, with a consistent upward trajectory. An intriguing observation pertains to the "elderly population," specifically individuals aged 50 to 60 years and above. This demographic constitutes an additional vulnerable group that necessitates vigilant attention, as the ascending trend in fatality rates over the past five years is approaching levels almost on par with those of the youth and working-age groups [6]. This phenomenon is intricately tied to Thailand's progression into an "aged society," as those aged 60 years and older currently comprise 10% of the population. Projections indicate that the elderly population will escalate to 28%, ushering Thailand into the realm of a "super-aged society" within the next decade [11]. It is imperative to note that Thailand is not the sole contender grappling with the complexities of an aging society.

Lower and middle-income countries (LMICs) are predicted to encompass two-thirds of their populations with elderly individuals by 2050 [12]. As a result, the elderly population grapples with a spectrum of issues and requirements, encompassing age-related visual impairments, chronic ailments, and risky behaviors. Of paramount importance, elderly individuals who sustain injuries in road accidents endure more severe ramifications than their younger counterparts. This often necessitates intensive medical care, extended convalescence periods, and heightened possibilities of complications [5]. The elderly are doubly susceptible to succumbing in road accidents compared to the youth [13, 14], largely attributed to their diminished physical resilience, thereby elevating the risk of fatality [15]. The process of driving mandates faculties such as attention, memory, problem-solving skills, and information processing, all of which tend to wane with advancing age. These cognitive impairments, frequently linked with conditions like Alzheimer's disease and dementia, are more prevalent among the elderly. Common categories of errors committed by elderly drivers encompass pedal misapplications, lane positioning errors, collisions, running red lights, and exceeding speed limits [16]. These errors have significant repercussions on other road users, consequently augmenting the hazards of morbidity and mortality for passengers across diverse modes of transportation [17]. This study acknowledges the importance of road accidents, particularly concerning youth and adolescents, who bear a significant role in a country's future development. Furthermore, the globally increasing elderly population is a matter of concern.

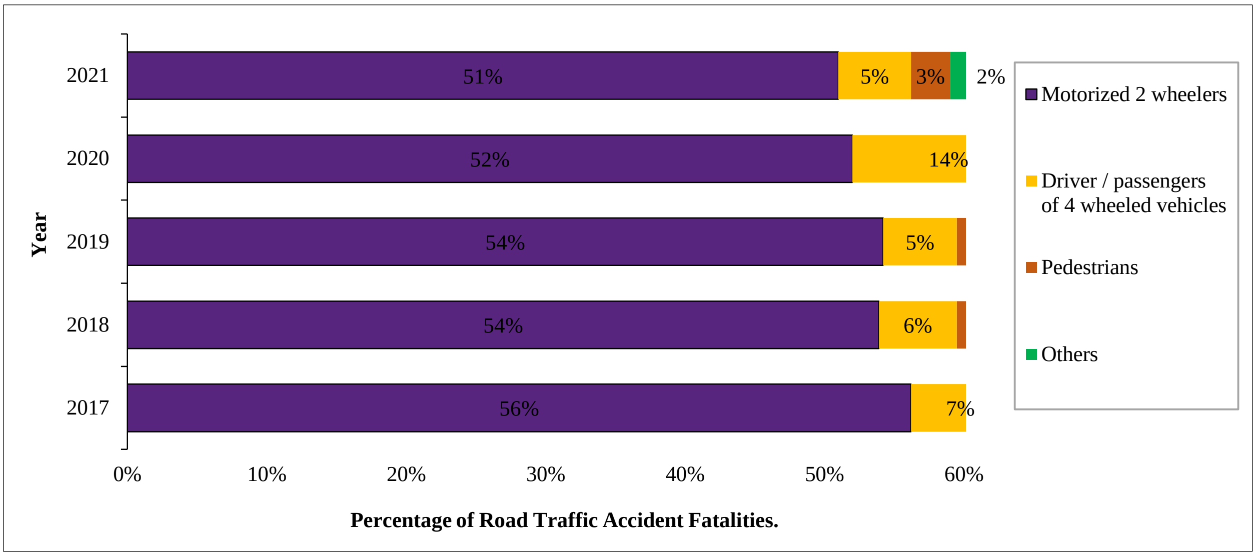


Figure 1. The Proportion of Road Traffic Accident Fatalities in Thailand, 2017–2021, Segmented by vehicle type [6]

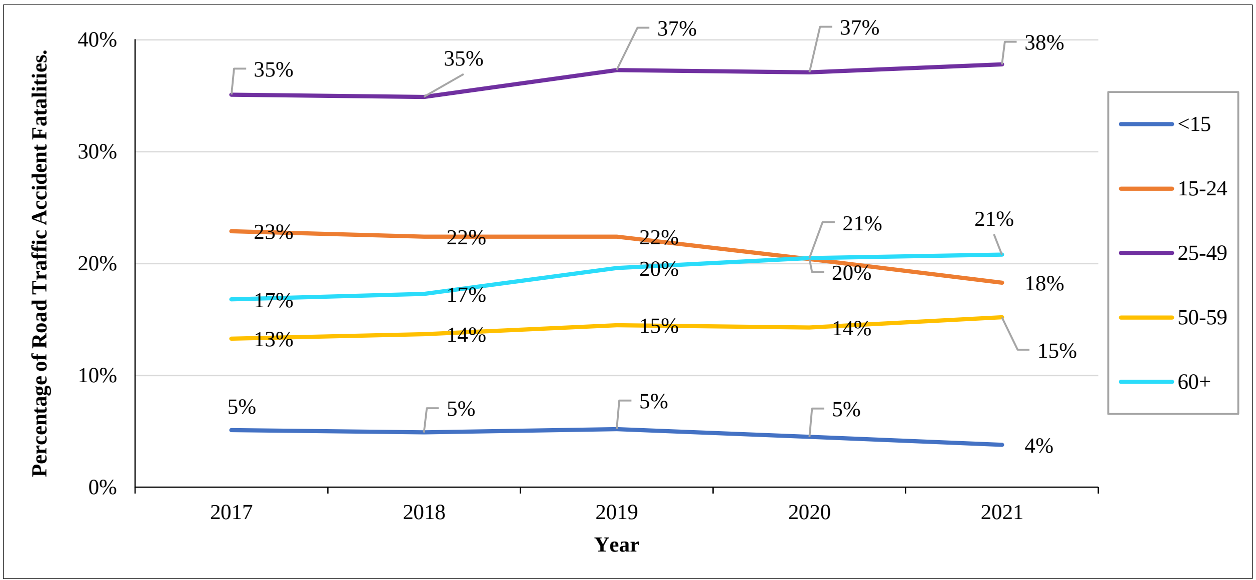


Figure 2. The Proportion of Road Traffic Accident Fatalities in Thailand, 2017–2021, Segmented by age groups [6]

2.2. The Importance of a Near-Miss Incident

A crucial aspect emphasized in this study concerning accident prevention is the notion of near-miss incidents, or near-crashes. These events involve scenarios in which collisions or accidents are narrowly avoided [18–20]. Importantly, research indicates that near-miss incidents can serve as proxies for real accidents [21–23]. Wright and Van der Schaaf [24] imply a fundamental assumption for utilizing minor incidents as a foundation for accident prevention measures: the common cause hypothesis, positing that the causal pathways of near misses resemble those of actual accidents leading to injuries and damages. As a result, the inclusion of near-miss incidents has been incorporated as additional information alongside police-reported crashes to identify areas prone to accidents within road networks and develop safety measures and strategies [25]. The origin of the near-miss incident concept traces back to Jehring & Heinrich's (1941) research in industrial safety, which scrutinized over 75,000 incident reports [26]. This discovery engendered Heinrich's law, Heinrich's Accident Triangle, or Heinrich's Safety Pyramid, depicted in Figure 3. The paramount objective of Heinrich's Safety Pyramid is to broaden the base of the triangle for identifying leading indicators and analyzing risk behaviors, unsafe conditions, unsafe acts, and near misses to forestall first aid, injuries, illnesses, and fatalities. Safety performance indicators are classified into leading and lagging indicators. Lagging indicators might not effectively reflect the severity of hazards, event intensity, or event causation reduction. Conversely, leading indicators involve evaluating processes, activities, and conditions that assess safety efficacy and forecast future outcomes [27]. The significance of near-miss incidents in road safety lies in their capacity to predict behavior patterns or physical attributes of roads that could lead to injuries or fatalities [28]. Additionally, near-misses can serve as advanced warning signals for events or behaviors that could potentially lead to accidents (collisions) [29]. Importantly, near-misses occur more frequently than actual collisions [19]. Furthermore, the enhancement of risk factors associated with near-misses can substantially curtail or prevent actual collisions or severe events [30].

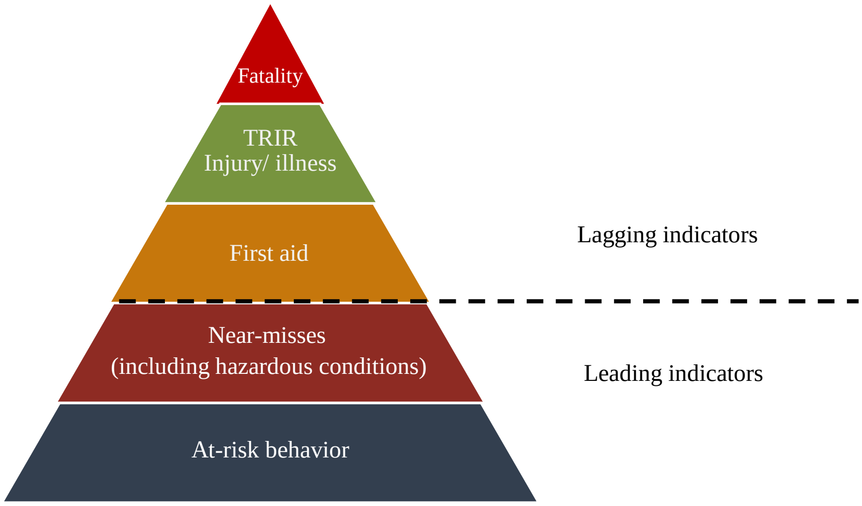


Figure 3. Heinrich's Accident Triangle or Heinrich's Safety Pyramid [27]

2.3. Measuring Rider Behavior with Self-Report: The Motorcycle Rider Behavior Questionnaire (MRBQ)

In prior research, self-reports have been utilized as a means to quantify driving style and driver behavior. The original iteration of the Motorcycle Rider Behavior Questionnaire (MRBQ) was crafted by Elliott et al. [31] and adapted from the Manchester Driver Behavior Questionnaire (DBQ), formulated by Reason et al. [32]. The MRBQ encompasses a wide array of facets, spanning from errors and violations to the use of safety gear while riding. Elliott et al. [31] embarked on a study aimed at constructing a survey instrument capable of assessing the behavior of motorcycle riders. This endeavor sought to determine which factors linked to specific behavior patterns could serve as predictors of the likelihood of collisions. The Motorcycle Rider Behavior Questionnaire (MRBQ), comprising 43 items, was employed for this purpose. It incorporates five distinct categories: traffic errors, control errors, speed violations, stunts performance, and use of safety equipment. Within these categories, traffic errors delineate inadvertent errors, while safety equipment pertains to the rider's actions, mechanisms, and protective elements. Stunts involve purposeful maneuvers that engender heightened risks for motorcyclists, while speed violations comprise intentional acts with utilitarian motivations. Control errors encompass both conscious and subconscious mishandling of the motorcycle. Several research investigations have adjusted variables within their questionnaires. This adaptation is driven by disparities in physical attributes and traffic regulations among countries, which give rise to divergent driving behaviors. As a result, the questionnaire's content must be suitably attuned to the motorcycle behavior inherent in each nation. Table 1 provides a comprehensive global overview of studies pertaining to the MRBQ tool. It encompasses investigations conducted in both low- and middle-income countries as well as high-income countries. The table serves to delineate the evidence, sample characteristics, and analytical methodologies employed in these studies.

Table 1. Literature Review Summary: Motorcycle Rider Behavior Questionnaire (MRBQ)

Country (author)	Compare the rider's age	Sample Type	Sample Size	Items	Factor structure	Factor analysis method
			High-income countries			
United Kingdom [31]	No	General Rider Population	8,666	43	5- factors (traffic errors, speed violations, stunts, safety equipment, and control errors)	Principle component analysis with varimax rotation
Netherland [33]	No	Young moped riders	146	43	3-factors (errors, lapses, and violation)	Exploratory and confirmatory factor analysis
Australia [34]	No	Australian novice riders	1,305	43	4-factors (errors, speed violation, stunts, and protective gear)	Confirmatory factor analysis and principal axis factoring
Slovenia [35]	No	General Rider Population	205	43 + 11	7- factors (safety equipment, errors, stunts, helmet, clothing, speed violations, and alcohol)	Exploratory and second-order confirmatory factor analysis
Australia [36]	No	General rider population	470	29	5- factors (traffic errors, speed violations, stunts, protective gear, and control errors)	Principal axis factoring

Low- and middle-income countries						
Iran [37]	No	General rider population	518	48	6- factors (traffic errors, speed violations, stunts, safety violations, traffic violations, and control errors)	Principle component analysis with varimax rotation
Turkey [38]	No	General Rider Population	451	43	5- factors (traffic errors, speed violations, stunts, safety equipment, and control errors)	Principle component analysis
Nigeria [39]	No	Commercial Motorcycle Riders	500	40	4- factors (Control/Safety, Stunts, Errors, Speeding/Impatience)	Principle component analysis
Vietnam [40]	No	General rider population	2,254	43	4- factors (traffic errors, speed and alcohol-related violations, safety equipment, and control errors)	Confirmatory factor analysis and principal axis factoring
Thailand [41]	No	General rider population	1,516	38	4- factors (traffic errors, stunts, safety equipment, and control errors)	Exploratory and second-order confirmatory factor analysis
India [42]	No	General rider population	392	32	4-factors (traffic errors, stunts, speed violations, and control errors)	Exploratory factor analysis
India [43]	No	Young Motorcycle Riders	300	43	5- factors (traffic errors, violations, stunts, safety equipment, and control errors)	Exploratory factor analysis
Colombia [44]	No	Motorcycle taxi riders	438	45	5- factors (stunts, speed violations, traffic errors, control errors, and safety)	Exploratory factor analysis
Thailand [45]	No	General Rider Population (Compare the rider's zone)	2002	17	3- factors (violation, safety equipment, and control errors)	Exploratory and confirmatory factor analysis
Thailand (This study)	Yes	Young and Older Motorcycle Riders	855	19	3- factors (traffic violation, safety equipment, and control errors)	Exploratory and confirmatory factor analysis

The Motorcycle Rider Behavior Questionnaire (MRBQ) comprises a series of inquiries designed to elicit information about riders' conduct, attitudes, and encounters pertaining to near-miss incidents. The following features are commonly incorporated in the MRBQ to assess near-miss risk behaviors:

(1) *Scenario-Based Questions:* The MRBQ employs hypothetical or real-life scenarios, illustrating situations where a near-miss incident might transpire. Participants are then prompted to respond to these scenarios, offering insights into their potential behavior in comparable situations.

(2) *Frequency of Near-Miss Experiences:* Questions within the questionnaire may address the frequency of near-miss experiences encountered by riders within a specific timeframe. This aids researchers in comprehending how frequently riders confront situations with the potential for accidents.

(3) *Behavioral Responses:* Riders are queried about their reactions and responses during or after a near-miss incident. This encompasses inquiries about evasive actions taken, alterations in speed, utilization of protective gear, or other behaviors aimed at averting a collision.

(4) *Perceived Causes:* Participants may be prompted to pinpoint factors they believe contributed to the occurrence of near-miss incidents. This involves an assessment of their perception of external elements (e.g., road conditions, weather) and internal factors (e.g., rider's behavior, skills).

(5) *Attitudes and Risk Perception:* Questions may delve into riders' attitudes regarding risk, their perception of the likelihood of being involved in a near-miss incident, and the extent of their concern about such occurrences.

The MRBQ serves as a valuable instrument for researchers, providing a comprehensive understanding of the cognitive and behavioral aspects of riders in situations leading to near-miss incidents. The gathered responses contribute to the identification of patterns and risk factors and the development of targeted interventions and safety measures to mitigate the occurrence of near-miss incidents among motorcycle riders. The research conducted in Thailand by Hantanong et al. [45] highlighted the substantial impact of risky motorcycle riding behaviors on the frequency of near-miss incidents, both in urban and rural settings. The study identified three primary risk factors contributing to these incidents. (1) Control Errors: This unintentional factor is linked to the management of motorcycle control, particularly in situations involving speed adjustment, negotiating curves, riding on slippery surfaces, and adverse weather conditions. (2) Violations: This category encompasses variables associated with high-risk behaviors, including speeding, reckless driving, mobile phone use, and driving under the influence of alcohol while operating a motorcycle. (3) Safety Equipment: This factor is associated with the usage of safety equipment, specifically the adherence to wearing helmets and the utilization of motorcycle headlights. The study underscores the pivotal role of these risk factors in influencing the occurrence of near-miss incidents. Understanding these factors enables the development of targeted interventions and safety measures aimed at addressing specific aspects of motorcycle rider behavior, ultimately reducing the likelihood of near-miss accidents.

Drawing insights from a study conducted in India [42], it was revealed that control errors exhibit a significant correlation with an elevated likelihood of near-miss incidents. Additionally, the study underscored a noteworthy correlation between the frequency of control errors and age categories. This finding substantiates the fundamental null hypothesis pertaining to control error factors among the younger and older groups in the current investigation.

Hypothesis$_{1a}$ (H_{1a}): Control errors exert an adverse impact on the occurrence of near-miss incidents among younger riders.

Hypothesis$_{1b}$ (H_{1b}): Control errors exert an adverse impact on the occurrence of near-miss incidents among older riders.

Research conducted in various countries, including the UK [31], Colombia [44], Vietnam [40], and India [42], has consistently indicated that traffic errors are strongly associated with risky driving behavior and play a pivotal role in contributing to accidents. Studies from Australia have further corroborated these findings by establishing a clear link between errors and speeding in both accidents [46] and near-miss incidents [36] .Additionally, the occurrence of stunts has also been identified as a contributing factor in these incidents [36, 38] .These conclusions align harmoniously with the core null hypothesis, which pertains to the influence of traffic violation factors within the younger and older groups investigated in the present study.

Hypothesis$_{2a}$ (H_{2a}): Traffic violations exert an adverse impact on the occurrence of near-miss incidents among younger riders.

Hypothesis$_{2b}$ (H_{2b}): Traffic violations exert an adverse impact on the occurrence of near-miss incidents among older riders.

Regarding the aspect of safety equipment, it is regarded as a safety-conscious driving behavior [34, 35]. The research conducted by Sakashita et al. [34] pointed out that the use of safety equipment does not exhibit a significant association with either the risk of actual crashes or near-miss incidents. This observation corresponds with the central null hypothesis concerning the safety equipment factors within the younger and older groups under investigation in this present study.

Hypothesis$_{3a}$ (H_{3a}): Safety equipment exerts an adverse impact on the occurrence of near-miss incidents among younger riders.

Hypothesis$_{3b}$ (H_{3b}): Safety equipment exerts an adverse impact on the occurrence of near-miss incidents among older riders

2.4. Purpose and Contributions

Based on previous studies, Table 1 presents a succinct summary of the existing literature on the Motorcycle Rider Behavior Questionnaire (MRBQ), delving into risk-behavior factors across both high-income and low- and middle-income countries. The majority of studies predominantly concentrated on scrutinizing driving behavior within the general rider population. A notable exception is the research conducted by Jomnonkwao et al. [45], which specifically delved into evaluating risky behaviors contributing to near-miss accidents. The research investigates riding conduct in both urban and rural regions of Thailand, which is a developing nation. However, as noted earlier in Section 2.1, this emphasizes the importance of taking into account the hazardous conduct of both younger and older riders. Therefore, the aims of this study encompass the development of a risk behavior model concerning near-miss incidents among Thailand's motorcycle riders. The methodology employs MRBQ and involves a comparison between two distinct cohorts: young riders and elderly riders. The pivotal contributions of this research primarily center on the identification of risk behavior factors that precipitate near-miss incidents while juxtaposing these factors across the two divergent groups characterized by significant differences in physical and psychological attributes. Considering that near-miss incidents represent potential events that have yet to materialize but can nevertheless be harnessed, their study serves as a proactive approach to forestall potentially hazardous situations from escalating into full-fledged accidents.

The comprehension of the underlying causes driving unsafe scenarios and their proactive mitigation serves as a pivotal measure to preclude the occurrence of loss of life and property damage, thereby emerging as a consequential proactive strategy in accident prevention and consequently fostering genuine safety. This paradigm can also augment the efficacy of police-reported crash data, empowering pertinent authorities to precisely refine, strategize, and rectify issues within the domain of road safety. Thailand, classified as a developing nation with middle-income status and notable motorcycle utilization, records alarmingly high accident rates on a global scale. Notably, statistical data underscores a marked prevalence of motorcycle accidents involving both the younger and older demographics, with an observable upward trajectory. Therefore, the exploration of near-miss incidents emerges as a fresh and captivating subject of inquiry, endowing a focused comprehension capable of tackling road safety issues and implementing proactive measures to reduce the occurrence of accidents, consequently leading to reductions in both injuries and fatalities. Furthermore, the elevation of safety considerations concerning life and property assumes paramount importance for both the local community and broader society. The elevation of safety standards within society, including the establishment of sustainable communities, would manifest through the creation of a secure milieu, ultimately contributing to an enriched quality of life.

In this study, we undertake a comparison of risk behaviors associated with near-miss incidents among motorcycle riders, with a specific emphasis on the distinctions between young and elderly riders. In this context, the classification "younger" encompasses individuals aged 30 years or below [47], while "older" pertains to those aged 60 years and above [48, 49]. The primary null hypothesis is formulated as follows:

Hypothesis$_0$ (H_0). There is no difference in invariance between younger and older riders' behaviors.

3. Methods

3.1. Research Methods

The original MRBQ questionnaire underwent modifications based on the research conducted by Elliott et al. [31], with comprehensive particulars elucidated in Table 1. These adaptations encompassed both the removal and addition of questions to intricately align with the specific driving contexts characteristic of each respective country. Within the ambit of this study, the original interrogative items underwent refinements guided by the discerning input and recommendations provided by experts specializing in the design of survey questions. Subsequent to this meticulous refinement process, a preliminary pilot test was meticulously executed prior to embarking on the primary phase of data collection. It is crucial to emphasize that the study meticulously followed the ethical principles of experiments involving humans, as stipulated by the Ethical Committee (EC), prior to progressing further. The survey instrument was systematically administered to motorcycle riders across the entirety of the nation. Rigorous scrutiny was directed towards the assessment of data distribution normality, followed by subjecting the dataset to a rigorous exploratory factor analysis (EFA). The outcome of this analytical endeavor revealed the emergence of three distinct factors: control errors, traffic violations, and safety equipment. These identified factors subsequently underwent a confirmatory factor analysis (CFA) aimed at meticulously gauging the precision of measurement inherent within the latent structure within the overarching framework of structural equation modeling (SEM). Furthermore, factors exerting influence on occurrences of near-miss incidents within both the adolescent and elderly demographic cohorts were subjected to a comprehensive examination and comparative analysis using the sophisticated approach of multi-group SEM, as visually depicted in Figure 4.

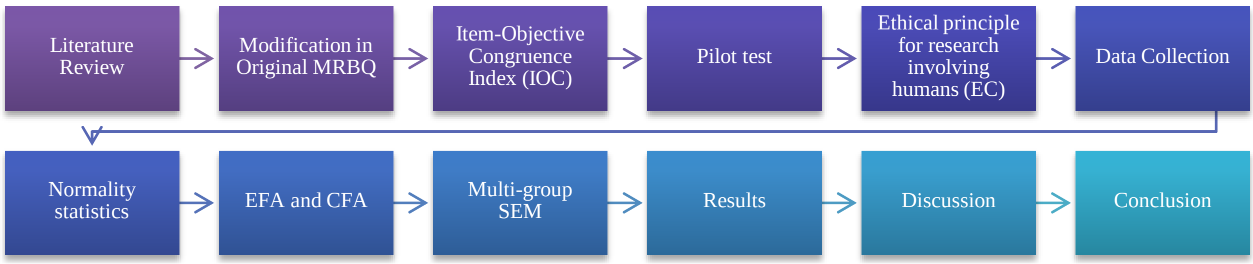


Figure 4. Research procedures

3.2. Questionnaire Construction

3.2.1. General Information

Previous research has illuminated the considerable impact of demographic factors and riding experience on distinguishing various cohorts of riders. A wealth of studies underscore that adolescents, owing to their limited driving experience, tend to manifest the highest degree of risky driving behaviors. Their nascent experience often translates into engagement in perilous actions, such as exceeding speed limits and operating vehicles while under the influence. Immediate impulses frequently overshadow their cognizance of potential repercussions [50]. This phenomenon is particularly pronounced among student riders in comparison to their non-student counterparts due to the disparate lifestyles that contribute to behavioral disparities. Adolescents, being both youthful and positioned within a high-risk category concerning driving conduct and traffic incidents, evince an elevated propensity for engaging in unsafe driving practices [51]. The discourse on riding experience is yet another recurrent theme of significance in the literature. It is closely linked with an augmented likelihood of risky driving conduct and traffic accidents. Novice drivers generally exhibit diminished driving proficiency, thereby engendering more precarious driving scenarios and an increased probability of accidents [52]. Conversely, less-seasoned drivers might struggle to anticipate concealed hazards and exhibit an enhanced proclivity for frequent errors due to a misguided allocation of attention [53]. Although age and driving experience often correlate, they embody distinct concepts. While young individuals might possess substantial driving experience, particularly if they engage frequently in motorcycle riding, the variance in driving experience between older and younger drivers can lead to judicious and more considered driving choices among the former, attributed to their heightened physical and mental maturity [54]. Furthermore, even within the category of elderly drivers, the presence of risky behaviors is observable. A tendency to be involved in collisions on high-speed roadways and in rural areas is evident. While the proportion of elderly motorcycle riders tends to rise, their driving acumen typically diminishes over time [5].

3.2.2. Utilization of the Questionnaire

The present research, the utilization of the MRBQ (Motorcycle Rider Behavior Questionnaire) was modified for application in the Thai context, where extremely dangerous riding behavior occurs. This contrasts with higher-income or developed countries, where riding behaviors are molded by distinct contextual elements encompassing geographical topography, traffic regulations, cultural norms, and divergent belief systems. Consequently, adjustments were made to the questionnaire items to effectively capture the riding behavior of motorcyclists in the Thai setting. The questionnaire encompassed a total of 19 items, of which 13 were drawn from previous research while the remaining 6 were refined and incorporated anew. The initial inquiries were focused on elements related to speed and control of the vehicle. However, the supplementary questions revolved around practices such as cell phone usage, drinking alcohol, failure to wear a helmet, donning reflective clothing, and the activation of headlights during daylight hours. This methodological technique is consistent with similar research undertaken in India and Iran [37, 42], which also undertook adaptations and augmentations to questionnaires, notably in relation to helmet usage. Remarkably, the current study broadened its focus to encompass behaviors such as cell phone engagement while riding and use of alcohol during festive periods [6], thereby aligning more closely with the riding habits characteristic of Thailand. To evaluate rider behavior, the research will adopt a questionnaire-based assessment employing a Likert scale. Responses will be categorized across five levels, signifying: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), and 5 (always).

3.3. Data Collection

In the data collection phase, the researchers aimed to achieve nationwide representation by distributing the sample across all regions of Thailand. Data gathering encompassed six regions, each with a designated number of provinces: Central (6 provinces), Eastern (5 provinces), Northeastern (6 provinces), Northern (7 provinces), Western (5 provinces), and Southern (5 provinces), totaling 34 provinces, as illustrated in Figure 5. The selection of provinces was guided by the evaluation outcomes of the Human Achievement Index (HAI), a composite index gauging provincial-level human development. This index incorporates eight sub-indices, computed to establish proportions and stratified into four quartiles (Q1 = provinces with the highest human development index, up to Q4 = provinces with the lowest human development index). Subsequently, the proportions were determined based on the cumulative registered motorcycle population and the age distribution of the youth and elderly populations in the selected provinces. The sample size, amounting to 815 datasets, was determined through the principles of structural equation modeling analysis. Guided by the recommendation that the sample size for maximum likelihood estimation should be at least 10 times the number of observed variables [55], the research collected a total of 815 samples, comprising 475 from the younger demographic and 340 from the older demographic, as detailed in Table 2, which presents the number of samples collected for each region categorized into younger and older groups. The research adopted a stratified sampling approach, randomly choosing individuals who have lived in the designated locations for at least a year, possessing the capability to ride motorcycles, and having their motorcycles registered with the Department of Land Transport.

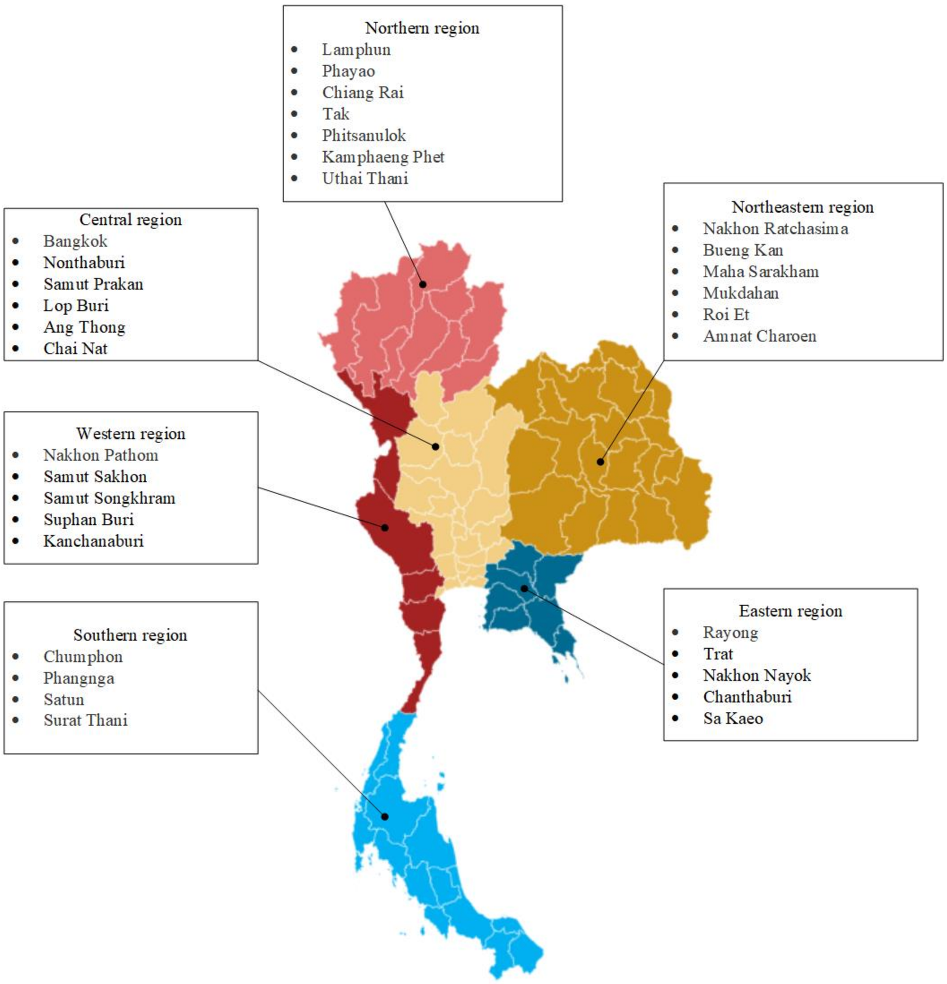


Figure 5. Map depicting the provinces selected for collecting questionnaire data from motorcycle riders in Thailand

Table 2. The collected and compiled sample sizes for each region were categorized into younger and older groups

Regions	Younger	Older
Western	72	53
North-eastern	74	49
Southern	68	47
Central	94	63
Eastern	70	56
Northern	97	72
Total	**475**	**340**

The individual's characteristics are outlined in Table 3 and classified into two distinct groups according to their responses to the questionnaire: (1) younger respondents (n = 475) with an average age of 24.4 years, and (2) older respondents (n = 340) with an average age of 66.2 years. It was noted that the sample attributes of both groups showed considerable similarity. To elaborate, a significant portion were unmarried and held bachelor's degrees. The mean personal monthly income for the younger group was below 18,000 Baht, whereas for the older group, it ranged between 18,000 and 25,000 Baht. The mean household monthly income primarily fell within the bracket of 30,001 to 50,000 Baht. A noteworthy observation is that more than half of the participants lacked a valid motorcycle driver's license, frequently utilizing motorcycles for commuting to educational institutions or workplaces. The average riding speed predominantly remained below 80 km/hr. It is pertinent to highlight that over 90% of the participants had a clean record with no reported traffic violations within the past three years, while nearly 80% had encountered near-miss incidents. However, over 90% had not experienced any accidents in the preceding year.

Table 3. Sample characteristics

Variable name	Category	Younger (n=475)	Older (n=340)
		% (n)	% (n)
Gender	Male	49.7% (236)	46.5% (158)
	Female	50.3% (239)	53.5% (182)
Age	Mean	24.4	66.2
Marital status	Single	77.7% (369)	41.5% (141)
	Married	22.1% (105)	40.6% (138)
	Divorce	0.2% (1)	17.9% (61)
Education level	Diploma	38.1% (181)	39.71% (135)
	Bachelor's degree	60% (285)	55.3% (188)
	Postgraduate or PhD	1.9% (9)	5% (17)
Individual income (THB/month)	18,000 or less	51.6% (245)	26.18% (89)
	18,001 to 25,000	29.7% (141)	37.95% (129)
	25,001 or more	18.5% (89)	35.89% (122)
Household income (THB/month)	30,000 or less	22.7% (109)	18.53% (63)
	30,001 to 50,000	37.4% (179)	32.36% (110)
	50,001 to 70,000	21.9% (105)	27.95% (95)
	70,001 or more	17.1% (82)	21.18% (72)
Household members	1 to 2	32% (152)	33.53% (114)
	3 to 4	54.8% (260)	54.71% (186)
	5 or more	13.3% (63)	11.77% (40)
Occupation	Student	30.9% (147)	-
	Civil servant/state enterprise employee	2.7% (13)	1.8% (6)
	Private companies	34.5% (164)	29.1% (99)
	Personal business/trading owner	14.7% (70)	40.3% (137)
	Agriculturist	4.8% (23)	10.3% (35)
	Contractors	12% (57)	14.4% (49)
	Housewife	0.2% (1)	4.1% (14)

Holding License	Yes	41.9% (199)	39.7% (135)
	No	58.1% (276)	60.3% (205)
Riding experience (years)	5 or less	5.8% (28)	-
	6 to 10	38.7% (184)	-
	11 to 20	55.4% (263)	0.59% (2)
	21 to 30	-	2.65% (9)
	31 or more	-	96.77% (329)
Average hours riding per week	5 or less	32.4% (154)	56.48% (192)
	6 to 10	38.4% (183)	39.71% (135)
	11 or more	28.9% (138)	3.83% (13)
Average weekly kilometers	50 km or less	15.8% (75)	29.12% (99)
	51 to 100	30.3% (144)	41.48% (141)
	101 to 200	29% (138)	26.77% (91)
	201 or more	24.7% (118)	2.65% (9)
Frequency of motorcycle riding	Once a week	33.9% (161)	36.8% (125)
	Several times per week	29.7% (141)	31.2% (106)
	Everyday	36.4% (173)	32.1% (109)
Purpose for riding	Only for work or study	58.9% (280)	48.5% (165)
	Only for recreation	20.4% (97)	20.6% (70)
	Shopping	20.6% (98)	30.6% (104)
	Other	-	0.3% (1)
Average speed (km/hr)	Less than or equal 80	59.9% (285)	92.36% (314)
	More than 80	40% (190)	7.65% (26)
Motorcycle-specific traffic violations within the last three years	Yes	5.9% (28)	4.1% (14)
	No	94.1% (447)	95.9% (326)
Traffic violations across all types of vehicles within the last three years	Yes	8.2% (39)	8.2% (28)
	No	91.8% (436)	91.8% (312)
Near miss (part 12 months)	None	22.3% (106)	22.6% (77)
	1 to 2	47% (223)	48.9% (89)
	3 or more	30.7% (146)	28.6% (77)
Accident (part 12 months)	None	93.3% (443)	96.5% (328)
	1 or more	6.7% (32)	3.5% (12)

Based on Table 4, showing the category of near-miss occurrence, the near-miss occurrences can be divided into three main categories: skidding, nearly losing control of the motorcycle, and using brakes in reaction to interactions with other vehicles or pedestrians. The examination uncovered that both the younger and older cohorts experienced the highest frequency of the "swerving or braking in response to another road user" type of near-miss accident, accounting for more than 50% in each group. The main contributing factors to this type of incident were abrupt lane changes and sudden cuts in front by other vehicles, necessitating sudden braking.

Table 4. Category of near-miss occurrence

Category of near-miss	Cause of the near-miss	Younger (n=475)	Older (n=340)
		% (n)	% (n)
Skid	By rain or water.	7.3% (27)	5.71% (15)
	By mud, wet leaves, and animal manure.	0.9% (3)	0.39% (1)
	By oil spillage on the road.	1.9% (7)	2.67% (7)
	By slippery or loose road surfaces (e.g., paint or worn asphalt), loose gravel.	2.5% (9)	3.43% (9)
	By road objects (e.g., clothing, plastic bags, or debris).	3.8% (14)	1.91% (5)
	Total	**16.3% (60)**	**14.11% (37)**

Near loss of control	By evasion (preceding vehicle moving slowly or abruptly applying brakes).	8.4% (31)	6.85% (18)
	By a tire puncture.	0.3% (1)	-
	By mechanical failure.	0.3% (1)	0.39% (1)
	By traveling too fast for the conditions.	3.6% (13)	4.19% (11)
	By potholes or grooves in the road.	9.8% (36)	10.27% (27)
	By flying objects (e.g., insects, birds, paper).	1.4% (5)	1.15% (3)
	By tiredness or inattention (lack of focus).	0.9% (3)	1.53% (4)
	Total	**24.4% (90)**	**24.38% (64)**
Swerving or braking in response to another road user	Overtaking from behind.	12.2% (45)	10.65% (28)
	Coming towards you in your lane.	9.5% (35)	9.13% (24)
	Another car turns right, cutting you off.	12.5% (46)	12.17% (32)
	Turning into your path from a side road, private driveway, or opposite direction.	7.6% (28)	6.09% (16)
	Cutting you off at a junction.	3.6% (13)	9.13% (24)
	Cutting you off while performing a U-turn.	7.9% (29)	7.61% (20)
	Cyclist riding into your path.	-	0.39% (1)
	Pedestrian walking into your path.	0.3% (1)	-
	Animal(s) walking into your path.	5.7% (21)	6.09% (16)
	Total	**59% (218)**	**61.26% (161)**
Any additional form of near-miss encounter.		0.6% (2)	0.39% (1)
Overall		**100% (370)**	**100% (298)**

3.4. Methods

The present research employs a theoretical approach grounded in structural equation modeling (SEM) to analyze the factors influencing near-miss incidents among motorcycle riders, particularly focusing on the differences between younger and older age groups. SEM is a statistical technique that combines factor analysis and multiple regression to examine the complex relationships between observed and latent variables. The research commences by formulating hypotheses concerning control errors, traffic violations, and safety equipment. These hypotheses are then tested using SEM, allowing for the examination of direct and indirect relationships between the variables. Factor analysis is utilized to assess the measurement model, examining the relationships between observed variables and their underlying latent constructs, such as control errors, traffic violations, and safety equipment. This helps in identifying the key factors contributing to near-miss incidents within each age group. The study also employs multi-group SEM to test for invariance between younger and older groups, allowing for the investigation of age-specific differences in the structural relationships between variables. This approach enables a nuanced understanding of how the factors influencing near-miss incidents may vary across different age demographics. Moreover, the research integrates statistical analyses, such as mean, standard deviation, skewness, and kurtosis, to provide a comprehensive overview of the data's distribution characteristics. Descriptive statistics contribute to the interpretation of factor loadings and model fit, offering insights into the reliability and validity of the measurement model. The specifics of the statistical framework are outlined in the following manner:

3.4.1. Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) is a very popular statistical tool that is used throughout the social sciences. It has proven useful for reducing the dimensionality of a set of variables [56]. This research has integrated diverse assessment indicators, validated through the MRBQ. However, owing to differences in physical characteristics and traffic laws across countries, distinct riding behaviors are present. The questionnaire consisted of 19 indicators, with 14 derived from prior research and an additional 5 adjusted and incorporated. Given further deliberation, aspects pertaining to cell phone usage, alcohol drinking, failure to wear a helmet, wearing reflective clothing, and activating headlights during daylight hours were incorporated for additional scrutiny. Subsequently, an EFA was utilized to restructure the indicators pertaining to motorcycle riding behavior, marking its second application in this study.

3.4.2. Confirmatory Factor Analysis (CFA)

It is utilized when one wants to determine the number of factors needed to explain the relationships between variables and what these factors represent. It helps identify latent variables and their interpretations, typically after analytic rotation. On the other hand, confirmatory factor analysis starts by defining latent variables based on theory or prior knowledge and then constructs observable variables to measure these latent variables [57].

3.4.3. Multi-Group Analysis

This method is a widely utilized approach for conducting group comparisons. It encompasses a range of advanced techniques that researchers typically employ when they intend to investigate variations among categorical variables. [58]. In this study, a comparison was undertaken between young and older motorcycle riders. During the second phase, cross-validation was employed to evaluate measurement models and scrutinize various parameters, encompassing the number of constructs, indicator factor loadings, means, and covariances. For the evaluation, goodness of fit like differences in chi-square ($\Delta\chi^2$) and differences in degrees of freedom (Δ-DF) were utilized [59]. The results obtained will reveal whether there are statistically significant differences in the model's parameters between young and older motorcycle riders.

3.4.4. Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) is a complex statistical technique used to estimate the effect of observable factors on a variable that cannot be directly observed. Structural Equation Models (SEM) have two components: the measurement component and the structural component. The measurement component defines latent constructs that reflect study concepts with multiple indicators [60].

3.4.5. Goodness of Fit

The research assessed the structural validity of the model by examining statistical values to gauge the extent to which the model aligns with empirical data. The evaluation criteria were as follows:

i. The chi-square to the degrees of freedom ratio (χ^2/df) should not exceed 3 [61], or 5 for more complex models [62].

ii. The standardized root mean residual (SRMR) should be below 0.08 [62].

iii. The Root Mean Square Error of Approximation (RMSEA) should be below 0.07 [63].

iv. The comparative fit index (CFI) is deemed acceptable if it equals or exceeds 0.90 [62].

v. The Tucker-Lewis Index (TLI) is considered satisfactory if it is 0.80 or higher [64, 65].

These criteria were utilized to determine whether the model effectively aligns with empirical data and possesses structural validity.

4. Results

4.1. Descriptive Statistics

The computed descriptive statistics (see Table 5). The dataset will provide descriptive statistics for the younger cohort, encompassing mean values [1.580–4.490], standard deviation (SD) [0.639–1.025], skewness [-1.466–0.936], and kurtosis [-1.329–1.922]. Correspondingly, the older group's statistics encompass mean values [1.660–4.460], standard deviation (SD) [0.647–1.017], skewness [-1.483–0.744], and kurtosis [-1.326–2.556]. This suggests that the MRBQ variable data conforms to a normal distribution, aligning with the guidelines provided by Kline [61], which stipulate that skewness values should not surpass 3, and kurtosis values should not exceed 10.

Table 5. Descriptive statistics

	Questionnaire	Younger (N = 475)				Older (N = 340)			
		Mean	SD	SK	KU	Mean	SD	SK	KU
ER1	Experience challenges in maintaining control of the motorcycle when riding at high speeds.	1.640	0.653	0.538	-0.680	1.730	0.702	0.638	0.301
ER2	The roadway becomes slippery in rainy conditions, leading to abrupt braking.	1.730	0.698	0.681	0.259	1.720	0.741	0.712	-0.110
ER3	Experience difficulty in staying within the lane while negotiating a turn.	1.580	0.639	0.643	-0.569	1.660	0.647	0.455	-0.698
ER4	Encounter issues with visor or goggles fogging up.	1.650	0.714	0.936	0.667	1.660	0.720	0.744	-0.205
VI1	Exceed the speed limit on a residential road.	1.780	0.793	0.415	-1.293	1.800	0.796	0.380	-1.326
VI2	Exceed the speed limit on a country/rural road.	1.750	0.766	0.469	-1.158	1.770	0.760	0.405	-1.167
VI3	Overtaking in an overtaking-prohibited area.	1.760	0.760	0.441	-1.150	1.700	0.744	0.555	-1.009
VI4	Disregard the speed limit late at night or in the early hours of the morning.	1.810	0.814	0.450	-0.967	1.710	0.786	0.551	-1.174
VI5	Attempt to overtake someone that you had not noticed to be signaling a right turn.	1.760	0.777	0.441	-1.218	1.710	0.767	0.536	-1.113
VI6	When a car abruptly enters your vehicle's path or hinders your progress, you accelerate and swiftly overtake it while applying sudden braking.	1.790	0.801	0.407	-1.329	1.710	0.794	0.563	-1.195
VI7	You will blow your horn or close behind when the car in front drives slowly.	1.760	0.800	0.450	-1.300	1.720	0.789	0.546	-1.189

VI8	During your ride, you consult maps (either on paper or on a smartphone).	2.000	0.675	-0.005	-0.797	2.000	0.716	0.000	-1.044
VI9	You engage with the internet (Facebook, Instagram, Line, and YouTube) on your phone while riding.	2.040	0.726	0.065	-0.762	2.050	0.727	0.058	-0.751
VI10	Ride when you suspect you might be over the legal limit for alcohol.	1.980	0.702	0.023	-0.967	1.970	0.738	0.051	-1.157
VI11	Significant celebrations like New Year, Songkran, or social events, you partake in alcohol consumption and frequently operate a motorcycle.	2.040	0.752	0.143	-0.712	2.040	0.736	0.123	-0.689
EQ1	Fail to use a helmet while riding a motorcycle.	4.330	0.874	-1.392	1.589	4.290	0.903	-1.310	1.317
EQ2	Wear a helmet on a motorcycle, but neglect to secure the chin strap.	4.210	1.025	-1.466	1.721	4.140	1.017	-1.279	1.162
EQ3	Neglect to activate daytime headlights on your motorcycle.	4.320	0.870	-1.204	0.873	4.190	0.971	-1.158	0.794
EQ4	Wear riding boots?	4.490	0.676	-1.302	1.922	4.460	0.726	-1.483	2.556

Note: SK = Skewness, KU = Kurtosis and SD = standard deviation

4.2. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) Results

The results of the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are presented in Table 6 for younger and Table 7 for older, respectively. These tables include variables for the measurement model, Cronbach's α, factor loading of EFA, factor loading of CFA, error variance, CR, and AVE value. Based on the conducted factor analysis for both the younger and older groups, the extracted components from the exploratory factor analysis (EFA) could be categorized into three distinct groups. The elements were derived through the application of the principal component analysis (PCA) method with the varimax rotation technique. The factor loading values set the threshold criterion for considering values greater than 0.3 [66, 67]. Furthermore, Hair et al. [59] recommended that the Kaiser-Meyer-Olkin (KMO) value be accepted if it exceeds 0.5. Values falling between 0.5 and 0.7 indicate a mediocre level of suitability, while values ranging from 0.7 to 0.8 signify good suitability. To evaluate the reliability of the measurement indicators, Cronbach's α was employed, with values exceeding 0.6 being deemed acceptable [68].

Table 6. EFA and CFA for Younger. N = 475, KMO = 0.897

Measurement Model	EFA		CFA					
	Communalities	Factor loading	Factor loading	Z	p-Value	Error	Composite reliability (CR)	Average variance extracted (AVE)
Control error (Cronbach's α = 0.672)							0.678	0.348
ER1	0.498	0.678	0.657	16.287	<0.001**	0.568		
ER2	0.410	0.628	0.480	10.396	<0.001**	0.769		
ER3	0.516	0.707	0.637	15.729	<0.001**	0.594		
ER4	0.522	0.697	0.571	13.136	<0.001**	0.674		
Traffic violation (Cronbach's α = 0.877)							0.875	0.406
VI1	0.672	0.740	0.813	42.802	<0.001**	0.339		
VI2	0.607	0.719	0.765	34.501	<0.001**	0.415		
VI3	0.554	0.701	0.681	24.807	<0.001**	0.536		
VI4	0.558	0.706	0.711	27.748	<0.001**	0.495		
VI5	0.618	0.761	0.729	29.563	<0.001**	0.468		
VI6	0.577	0.712	0.737	30.729	<0.001**	0.457		
VI7	0.584	0.732	0.709	27.243	<0.001**	0.498		
VI8	0.385	0.472	0.430	10.747	<0.001**	0.815		
VI9	0.293	0.502	0.376	8.971	<0.001**	0.858		
VI10	0.385	0.529	0.452	11.525	<0.001**	0.796		
VI11	0.338	0.543	0.376	8.952	<0.001**	0.859		
Safety equipment (Cronbach's α = 0.772)							0.777	0.480
EQ1	0.672	0.798	0.764	28.358	<0.001**	0.417		
EQ2	0.685	0.778	0.795	30.281	<0.001**	0.368		
EQ3	0.675	0.807	0.741	26.192	<0.001**	0.451		
EQ4	0.365	0.583	0.394	9.013	<0.001**	0.845		

$\chi 2/df$ = 356.741/147= 2.427, RMSEA = 0.055 (0.048 - 0.062), CFI = 0.932, TLI = 0.921, SRMR = 0.064

Note: ** The level of significance at 0.001

Table 7. EFA and CFA for Older. N = 340, KMO = 0.874

Measurement Model	EFA		CFA					
	Communalities	Factor loading	Factor loading	Z	p-Value	Error	Composite reliability (CR)	Average variance extracted (AVE)
Control error (Cronbach's α = 0.695)							0.701	0.373
ER1	0.413	0.630	0.535	10.543	<0.001**	0.714		
ER2	0.508	0.709	0.588	11.860	<0.001**	0.655		
ER3	0.451	0.668	0.569	11.318	<0.001**	0.676		
ER4	0.598	0.771	0.732	15.990	<0.001**	0.465		
Traffic violation (Cronbach's α = 0.881)							0.878	0.405
VI1	0.621	0.763	0.768	29.181	<0.001**	0.411		
VI2	0.538	0.704	0.703	22.596	<0.001**	0.505		
VI3	0.440	0.649	0.635	17.738	<0.001**	0.596		
VI4	0.610	0.760	0.750	27.257	<0.001**	0.437		
VI5	0.576	0.723	0.705	22.642	<0.001**	0.504		
VI6	0.559	0.725	0.720	24.171	<0.001**	0.481		
VI7	0.602	0.760	0.739	26.020	<0.001**	0.453		
VI8	0.425	0.504	0.451	9.727	<0.001**	0.797		
VI9	0.338	0.545	0.433	9.161	<0.001**	0.812		
VI10	0.433	0.553	0.494	11.149	<0.001**	0.756		
VI11	0.456	0.574	0.452	9.721	<0.001**	0.796		
Safety equipment (Cronbach's α = 0. 773)							0.776	0.475
EQ1	0.582	0.737	0.656	17.168	<0.001**	0.570		
EQ2	0.675	0.786	0.768	22.959	<0.001**	0.410		
EQ3	0.719	0.831	0.825	26.964	<0.001**	0.319		
EQ4	0.406	0.635	0.447	9.049	<0.001**	0.801		

χ^2/df = 290.799/145= 2.005, RMSEA = 0.054 (0.045 - 0.063), CFI = 0.933, TLI = 0.921, SRMR = 0.063

Note: ** The level of significance at 0.001.

Table 6 reveals that, for the younger group, the KMO value is 0.897. The factor loadings for EFA are as follows: control errors (ER) [0.628–0.707], traffic violations (VI) [0.472–0.761], and safety equipment (SE) [0.583–0.807]. Additionally, the factor loadings for CFA are Control Error (ER) [0.480–0.657], Traffic Violation (VI) [0.376–0.813], and Safety Equipment (SE) [0.394–0.795]. Moving on to Table 7, for the older group, the KMO value is 0.874. The factor loadings for EFA are as follows: control errors (ER) [0.630–0.771], traffic violations (VI) [0.504–0.763], and safety equipment (SE) [0.635–0.831]. Additionally, the factor loadings for CFA are Control Error (ER) [0.535–0.732], Traffic Violation (VI) [0.433–0.768], and Safety Equipment (SE) [0.447–0.825].

Additionally, the outcomes illustrate both the younger model presented in Table 6 and the older model presented in Table 7. It was determined that the χ^2/df ratio [62], RMSEA]62, 63], TLI [64, 65], and SRMR [64, 65] all demonstrated a favorable fit with the empirical data, reaching a satisfactory level of agreement. For the purpose of evaluating convergent validity, the composite reliability (CR) and average variance extracted (AVE) values for both the younger model (Table 6) and the older model (Table 7) are below 0.5, while the composite reliability (CR) values surpass the threshold of 0.6. According to Lam [69], it is acceptable if the CR value is greater than 0.6, even when the AVE value does not exceed 0.5.

4.3. Multi-Group Analysis Results

In testing Hypothesis$_0$, multi-group structural equation modeling (SEM) was employed to assess invariance between the younger and older groups. The analysis outcomes are detailed in Table 8, providing insights into the model fit, statistical parameters, and multi-group analysis. The results are structured into four sub-models for a comprehensive evaluation. The initial grouping, referred to as the individual group, encompasses Model 1: Younger and Model 2: Older. This segment presents the goodness of fit for both models, elucidating their overall explanatory capacity. The subsequent grouping, labeled Measurement of Invariance, includes Model 3: Simultaneous. This model represents an analysis where path coefficients are not constrained to be equal between groups. It serves as a multi-group measurement model analysis, allowing parameters to be freely estimated across groups. Finally, Model 4 involves an analysis with constrained path coefficients set to be equal between groups. This model aims to test the stability of standardized path coefficients when constrained to be equal. Both sets of models 3 and 4 exhibited commendable fit and alignment with the predefined criteria for evaluation. The comparison between model 3 and model 4 yielded a Chi-square value of 55.193 with degrees of freedom (df) equal to 38 at a significance level (p-value) below 0.05. This signifies the existence of noteworthy parameter disparities within the risk behavior model of motorcycle riders when comparing the younger and older groups. This empirical evidence highlights the variance in risk behavior tendencies between these distinct age cohorts.

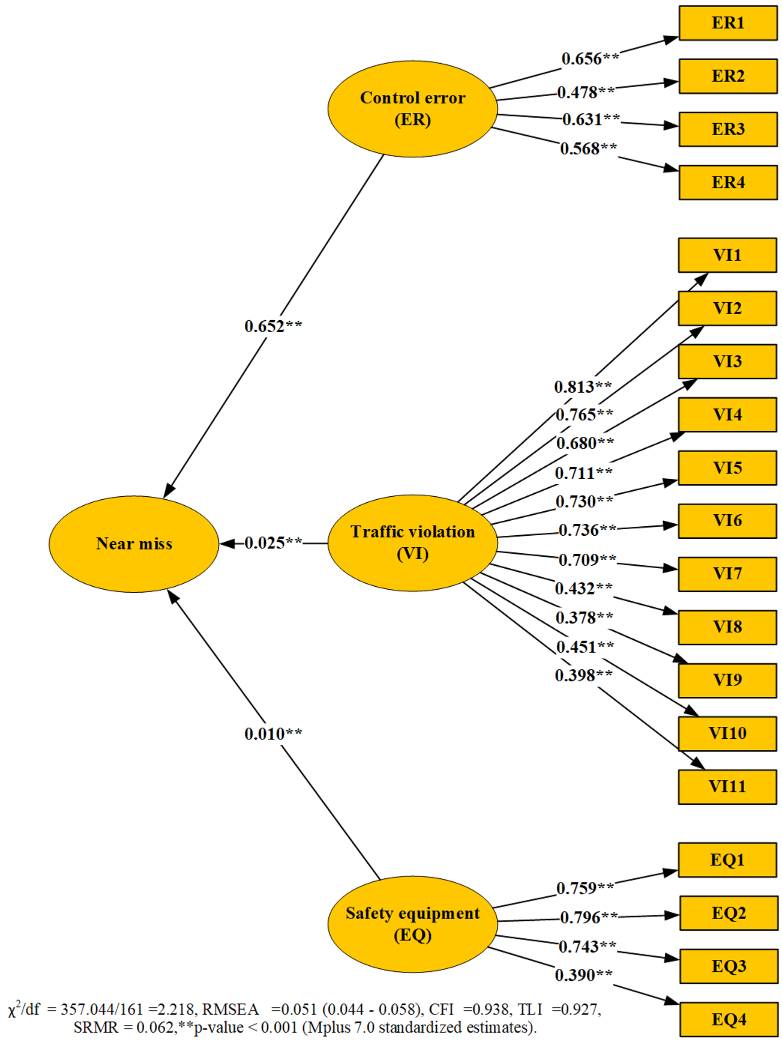
Table 8. Multi-group analysis

Model	χ^2	df	χ^2/df	RMSEA	CFI	TLI	SRMR	Delta- χ^2	Delta-df	*p*-Value
Individual Group										
Model 1: Younger (n=475)	357.044	161	2.218	0.051	0.938	0.927	0.062			
Model 2: Older (n=340)	282.888	158	1.790	0.048	0.943	0.932	0.068			
Measurement of Invariance										
Model 3: Simultaneous	732.599	326	2.247	0.055	0.924	0.912	0.064			
Model 4: Factor loading, intercept, and structural path held equal groups	787.792	364	2.164	0.053	0.921	0.918	0.070	55.193	38	<0.05*

Note: ** The level of significance at 0.05

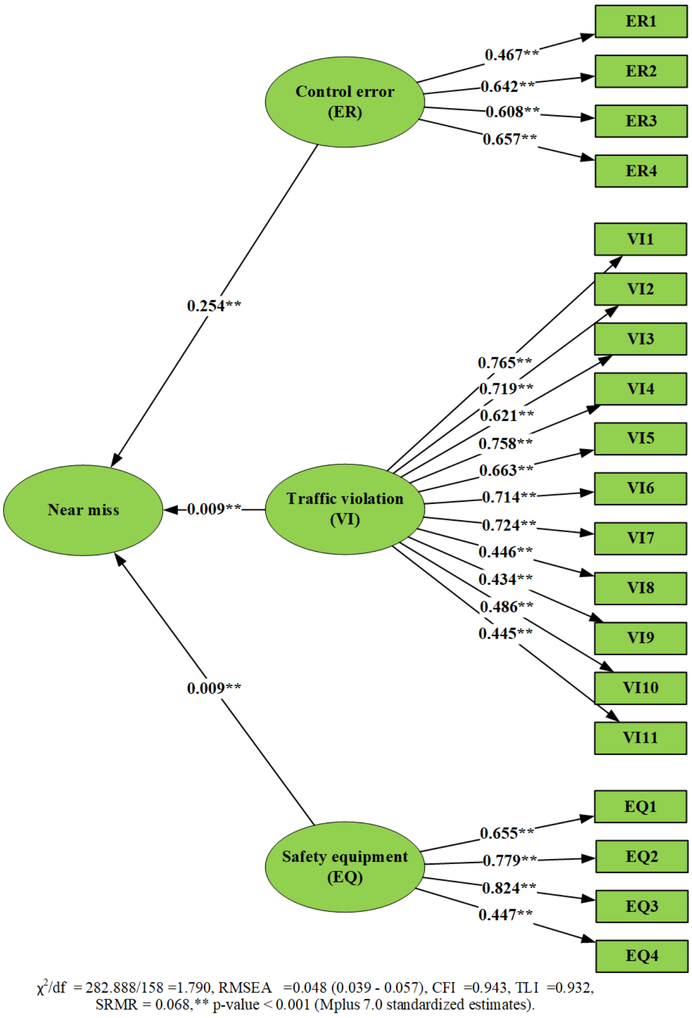
4.4. Structural Equation Modeling (SEM) Results

The outcomes yield statistical values indicating a well-fitted model for both Model 1 and Model 2, as illustrated in Figures 6 and 7. These models demonstrate a good fit with the observed data. Table 9 provides the parameter estimates of the measurement model for the younger and older groups. Within this table, 19 observed indicators (ER1-ER4, VI1-VI11, and EQ1-EQ4) and three latent indicators (control error, traffic violation, and safety equipment) are considered. The table presents standardized coefficients, standard errors (S.E.), Z values, p-values, and R^2 for each variable. Notably, the standardized coefficients for observed variables surpass 0.30 in both the younger and older groups. Additionally, the results of the structural equation modeling (SEM) for both the younger and older groups are delineated in Table 10. This table unveils the factors influencing the occurrence of near-miss incidents in both groups, encompassing three key factors.



Hypothesis$_{1a}$ (H_{1a}): Control errors exert an adverse impact on the occurrence of near-miss incidents among younger riders.
Hypothesis$_{2a}$ (H_{2a}): Traffic violations exert an adverse impact on the occurrence of near-miss incidents among younger riders.
Hypothesis$_{3a}$ (H_{3a}): Safety equipment exerts an adverse impact on the occurrence of near-miss incidents among younger riders.

Figure 6. Application of structural equation modeling to analyze near-miss incidents in motorcycle riding among younger riders



Hypothesis$_{1b}$ (H_{1b}): Control errors exert an adverse impact on the occurrence of near-miss incidents among older riders.
Hypothesis$_{2b}$ (H_{2b}): Traffic violations exert an adverse impact on the occurrence of near-miss incidents among older riders.
Hypothesis$_{3b}$ (H_{3b}): Safety equipment exerts an adverse impact on the occurrence of near-miss incidents among older riders.

Figure 7. Application of structural equation modeling to analyze near-miss incidents in motorcycle riding among older riders

Table 9. Measurement model

Variable	Younger					Older				
	Standardized coefficients	**S.E.**	**Z**	***p*-Value**	**R^2**	**Standardized coefficients**	**S.E.**	**Z**	***p*-Value**	**R^2**
Control error by										
ER1	0.656	0.041	15.979	<0.001**	0.430	0.467	0.060	7.788	<0.001**	0.218
ER2	0.478	0.046	10.305	<0.001**	0.228	0.642	0.051	12.646	<0.001**	0.412
ER3	0.631	0.041	15.526	<0.001**	0.398	0.608	0.051	11.986	<0.001**	0.370
ER4	0.568	0.044	12.875	<0.001**	0.323	0.657	0.052	12.704	<0.001**	0.431
Traffic violation by										
VI1	0.813	0.019	42.942	<0.001**	0.661	0.765	0.027	27.858	<0.001**	0.586
VI2	0.765	0.022	34.676	<0.001**	0.585	0.719	0.031	23.453	<0.001**	0.517
VI3	0.680	0.027	24.759	<0.001**	0.462	0.621	0.038	16.319	<0.001**	0.385
VI4	0.711	0.026	27.803	<0.001**	0.505	0.758	0.028	27.447	<0.001**	0.575
VI5	0.730	0.025	29.680	<0.001**	0.533	0.663	0.035	18.706	<0.001**	0.440
VI6	0.736	0.024	30.668	<0.001**	0.541	0.714	0.031	23.187	<0.001**	0.509
VI7	0.709	0.026	27.321	<0.001**	0.502	0.724	0.030	23.853	<0.001**	0.524
VI8	0.432	0.040	10.824	<0.001**	0.187	0.446	0.047	9.422	<0.001**	0.199
VI9	0.378	0.042	9.039	<0.001**	0.143	0.434	0.048	9.083	<0.001**	0.188
VI10	0.451	0.039	11.509	<0.001**	0.203	0.486	0.045	10.724	<0.001**	0.236
VI11	0.398	0.041	9.727	<0.001**	0.158	0.445	0.047	9.394	<0.001**	0.198

Safety equipment by										
EQ1	0.759	0.027	27.931	<0.001**	0.576	0.655	0.038	17.197	<0.001**	0.429
EQ2	0.796	0.026	30.251	<0.001**	0.634	0.779	0.032	24.157	<0.001**	0.607
EQ3	0.743	0.028	26.309	<0.001**	0.552	0.824	0.031	26.884	<0.001**	0.679
EQ4	0.390	0.044	8.888	<0.001**	0.152	0.447	0.049	9.075	<0.001**	0.200

Note: ** The level of significance at 0.001

Table 10. Structural model

		Younger				Older			
	Hypothesis	**Standardized coefficients**	**Standard Error**	***p*-Value**	**Result**	**Standardized coefficients**	**Standard Error**	***p*-Value**	**Result**
1	Control error → Near miss	0.652	0.055	<0.001**	Supported	0.254	0.037	<0.001**	Supported
2	Traffic violation → Near miss	0.025	0.001	<0.001**	Supported	0.009	0.001	<0.001**	Supported
3	Safety Equipment →Near miss	0.010	0.000	<0.001**	Supported	0.009	0.001	<0.001**	Supported

Note: ** The level of significance at 0.001

The structural equation modeling (SEM) analysis results for the younger group, depicted in Figure 6 and discussed in Hypothesis$_{1a}$ (H$_{1a}$), reveal that control errors exert an adverse impact on the occurrence of near-miss incidents among younger riders. The statistical results strongly support this hypothesis ($\beta = 0.652$, $p < 0.001$). Similarly, Hypothesis$_{2a}$ (H$_{2a}$) suggests that traffic violations exert an adverse impact on the occurrence of near-miss incidents among younger riders, and the analysis confirms this hypothesis ($\beta = 0.025$, $p < 0.001$). Additionally, Hypothesis$_{3a}$ (H$_{3a}$) posits that safety equipment exerts an adverse impact on the occurrence of near-miss incidents among younger riders, and the results provide substantial support for this hypothesis as well ($\beta = 0.010$, $p < 0.001$). These outcomes are visually represented in Figure 6 and summarized in Table 10. Turning to the SEM analysis results for the older group (Figure 7), Hypothesis$_{1b}$ (H$_{1b}$) suggests that control errors exert an adverse impact on the occurrence of near-miss incidents among older riders, and the results significantly support this hypothesis ($\beta = 0.254$, $p < 0.001$). Following this, Hypothesis$_{2b}$ (H$_{2b}$) proposes that traffic violations exert an adverse impact on the occurrence of near-miss incidents among older riders, and the analysis affirms this hypothesis ($\beta = 0.009$, $p < 0.001$). Finally, in Hypothesis$_{3b}$ (H$_{3b}$), the analysis indicates that safety equipment exerts an adverse impact on the occurrence of near-miss incidents among older riders, with the results providing robust support for this hypothesis as well ($\beta = 0.009$, $p < 0.001$). These findings are visually represented in Figure 7 and detailed in Table 10.

The results of the individual model analysis indicate that all 19 indicators in younger and older groups exhibited strong relationships. Concerning the structural model, control error emerged as the factor with the most significant factor loading values. In the younger model, the coefficient was 0.652 with a significance level of 0.001, while in the older model, the coefficient was 0.254 with a significance level of 0.001. In contrast, traffic violations and safety equipment displayed the lowest factor loading values, both with coefficient values < 0.01 and a significance level of 0.001 in both models.

Upon investigating specific indicators within the measurement model, certain indicators displayed low factor loading values (e.g., VI8, VI9, VI10, VI11, and EQ4). This illustrates that the causal relationships between latent variables and observable indicators are considerably weaker. The observed outcome could potentially be attributed to alterations in contextual factors that exert an influence on motorcycle operating patterns within the specific setting of Thailand. These contextual adjustments could lead to deviations from the established theoretical framework. However, it is important to note that the measurement model retained its congruence with previous discoveries garnered through the utilization of CFA. This congruence was evident, as all indicators exhibited notable statistical significance. It is noteworthy to mention that prior scholarly investigations have also deemed factor loading values surpassing the threshold of 0.20 to be satisfactory and acceptable within this context [41, 70].

5. Discussion

In this section, the discussion focuses on the outcomes of both the measurement model and the structural model. The measurement model involves an assessment of the indicators related to motorcycle rider behavior along with preliminary insights. Regarding the structural model, an analysis and interpretation of the results pertaining to the association between the MRBQ measurement model and its influence on near misses are presented for both the younger and older groups. Furthermore, a comparative analysis is performed between these two population groups.

5.1. The Factor Structure of the MRBQ

5.1.1. Control Errors (ER) Factor

In this investigation, the control error factor comprises a set of four indicators. Within this group, ER2 (the roadway becomes slippery in rainy conditions, leading to abrupt braking) and ER4 (encounter issues with visors or goggles fogging up) are classified as non-intentional factors. Conversely, ER1 (experience challenges in maintaining control of the motorcycle when riding at high speeds) and ER3 (experience difficulty in staying within the lane while negotiating a turn) are behaviors linked to speed control, which could lead to lapses in attention and a lack of vigilance. The outcomes of this study mirror prior research, where all four indicators are categorized under the Control Errors factor [31, 42].

5.1.2. Traffic Violations (VI) Factor

Speeding is acknowledged as a pivotal factor contributing to accidents and is also a notable public health concern. Engaging in excessive speeding (driving beyond the prescribed speed limit) or inappropriate speeding (driving within the limits but excessively fast for the traffic conditions) presents hazards by decreasing the time available for reacting to prevent accidents and amplifying the impact in the event of a collision [71]. Within the identified indicators, VI1 (exceed the speed limit on a residential road),' VI2 (exceed the speed limit on a country or rural road),' and VI4 (disregard the speed limit late at night or in the early hours of the morning) were formerly classified under speed violations. However, VI5, 'Attempt to overtake someone that you had not noticed to be signaling a right turn, was categorized under traffic errors in the study conducted by Elliott et al. [31]. Furthermore, VI3 (overtaking in an overtaking-prohibited area) was delineated as a traffic error in the research by Uttra et al. [41] in Thailand.

Subsequently, aggressive riding behavior is considered an intentional action and poses risks not only to the rider but also to others, impacting both their psychological well-being and physical safety. This behavior is acknowledged as provocative and holds relevance in the context of this study. Indicators VI6 (when a car abruptly enters your vehicle's path or hinders your progress, you accelerate and swiftly overtake it while applying sudden braking) and VI7 (you will blow your horn or close behind when the car in front drives slowly) align with the aggressive violations category, previously established in the Driver Behavior Questionnaire [72]. This category demonstrates a significant association with an increased likelihood of motorcycle accidents, particularly severe crashes resulting in fatalities [73].

When considering the use of mobile phones while operating a motorcycle, it is regarded as distracting behavior. Many countries have implemented laws prohibiting the use of handheld phones and texting while riding, a regulation often referred to as the cell phone handheld use and text messaging while riding ban. Thailand is among these countries, having established traffic regulations addressing mobile phone usage while riding. This prohibition stems from the understanding that riding while engaging with a mobile phone poses the risk of diverting attention and leading to distracted riding. Data compiled by The National Highway Traffic Safety Administration [74] underscores the gravity of this issue by linking texting while riding to numerous fatalities. The act of reading and composing messages introduces visual, manual, and cognitive distractions, contributing to diminished attentiveness and compromised control of the vehicle. This diversion of the driver's focus from the road heightens the likelihood of accidents [75]. In the context of this study, the indicators VI8 (during your ride, you consult maps (either on paper or on a smartphone)) and VI9 (you engage with the internet (Facebook, Instagram, Line, and YouTube) on your phone while riding) on your phone while riding) represent metrics associated with mobile phone use while riding and fall within the category of traffic violations (VI). These findings align with research conducted in Mexico and Vietnam, revealing that the usage of mobile phones while riding is prevalent across various age groups of motorcycle riders [76]. Moreover, in Vietnam, the utilization of mobile phones while riding is particularly pronounced among adolescent motorcycle riders [77]. This trend has also been identified in India, where mobile phone usage while riding has surged [78].

Riding under the influence of alcohol poses a significant societal concern due to its substantial contribution to the rise in road accidents. Numerous countries still struggle with the issue of motorcycle riders operating vehicles while intoxicated. This problem is evident in several countries, including Cambodia [79], Ghana [80], the USA [81], Taiwan [82], Italy [83], and the Nordic countries [84]. It is widely recognized that alcohol has a detrimental effect on riding abilities, impacting areas such as postural control, decision-making, attention, alertness, peripheral vision, contrast sensitivity, responsiveness to external stimuli, and psychomotor coordination and cognition [85]. In the context of this study, indicators VI10 (ride when you suspect you might be over the legal limit for alcohol) and VI11 (significant celebrations like New Year, Songkran, or social events, you partake in alcohol consumption and frequently operate a motorcycle) are categorized as traffic violations (VI). Accident statistics in Thailand highlight alcohol consumption while riding as a leading cause of road fatalities, particularly during significant festivals like New Year and Songkran [86]. Consequently, campaigns advocating against "don't drink and drive" have been released, accompanied by rigorous law enforcement measures spanning multiple years. The 11 indicators featured in this study are integrated into the traffic violation (VI) measurement model, representing risk factors that could potentially result in near misses.

5.1.3. Safety Equipment (EQ) Factor

The Safety Equipment (EQ) factor pertains to the utilization of safety gear, encompassing helmet usage and the activation of daytime headlights on motorcycles. The inquiries comprise EQ1 (fail to use a helmet while riding a motorcycle) and EQ2 (wear a helmet on a motorcycle, but neglect to secure the chin strap). In prior investigations conducted in Iran [37], these elements were classified under the safety violation and control error categories. A study by Zamani-Alavijeh et al. [87] revealed that more than 67% of Iranian motorcycle riders rode without helmets. Similarly, countries such as Ghana and Jamaica have reported limited adoption of helmets among motorcycle riders [88, 89].

Shifting the focus, the query EQ3 (do not use daytime headlights on your motorcycle) and the question EQ4 (do you wear riding boots?) were formerly associated with the safety factor [31, 34]. Research illustrates that the use of daytime running lights (DRL) during daylight hours can substantially diminish the likelihood of accidents [90]. Numerous countries have even enforced legal mandates regarding the use of DRL, leading to a potential reduction of motorcycle collision risks ranging from 4% to 20% [91]. Studies have indicated that the adoption of DRL can lower fatalities by 24.6%, casualties in multiple daytime crashes by 20%, and multiple daytime crashes by 12.4% [92], attributed to augmented vehicle visibility (as per the lighting contrast theory) [93].

5.2. Comparing Factors Influencing Near Miss Incidents between Younger and Older Individuals

Based on the outcomes of the multi-group analysis model investigating risky behaviors among motorcycle riders and comparing the younger and older age groups, significant distinctions have been identified. The key findings regarding significant differences between younger and older rider groups in terms of factor loadings, intercepts, and structural pathways are crucial for understanding near-miss incidents among different age groups. The SEM analysis indicated that control errors exerted a more pronounced negative impact on near-misses among younger individuals ($\beta = 0.652$) in contrast to older individuals ($\beta = 0.254$). Traffic violations had a slightly stronger negative effect on near-misses for younger individuals ($\beta = 0.025$) compared to older individuals ($\beta = 0.009$). Safety equipment exhibited a comparable adverse influence on near-misses for both younger ($\beta = 0.010$) and older individuals ($\beta = 0.009$). These distinctions underscore the variability in the contributions of control errors, traffic violations, and safety equipment usage to near-miss incidents across diverse age groups. Younger riders seem to be more influenced by control errors. Understanding these nuances can inform targeted interventions and safety measures tailored to specific age demographics, ultimately contributing to the reduction of near-miss incidents.

As a result, the formulation of distinct models to address risky conduct among motorcycle riders became imperative. Research has underscored the contributing elements to risky riding behaviors within both cohorts. Younger riders commonly possess less riding experience relative to their older counterparts, and there is a perception of deficient safe riding skills among them [6]. Novice drivers, particularly, exhibit an insufficiency in experience and lack comprehensive physical, cognitive, and psychological development, encompassing essential attributes like critical thinking, impulse control, and decision-making proficiencies crucial for adept motorcycle riding [7]. Furthermore, the physiological and cognitive responsiveness of older riders may be diminished, consequently impacting driving competencies tied to vigilance, memory, problem-solving, and information processing [16]. Moreover, an elevated susceptibility to health-related concerns [5] could potentially compromise the driving capacities of the elderly population.

In light of the outcomes derived from the structural model, a notable distinction emerged between two distinct cohorts. Notably, the factor loading coefficients attributed to the control error construct provided the most important influence on the occurrence of near-miss events within both model frameworks. This outcome corroborates findings documented in a parallel investigation conducted in India, where a noteworthy correlation was established between control errors and an escalated susceptibility to near-miss incidents. Furthermore, the research underscored a discernible linkage between the frequency of control errors and specific age demographics [42, 94].

In assessing the key indicators among the younger cohort, two factors emerged with substantial influence: ER1 (experience challenges in maintaining control of the motorcycle when riding at high speeds) and ER3 (experience difficulty in staying within the lane while negotiating a turn). Notably, younger riders typically exhibit significantly higher rates of errors in bike control. This trend is particularly prevalent among adolescents and students, who fall into the category of novice riders. Their limited experience, unfamiliarity with bike control and balance, and diminished alertness due to factors like adrenaline rushes contribute to this phenomenon. When coupled with their lack of experience and occasional disregard for traffic regulations, certain young drivers become more predisposed to risk-taking behaviors such as speeding [95], ultimately culminating in accidents that carry the potential for injuries or fatalities [96].

In Taiwan, the government has integrated the Road Safety Class (RSC) into the rider's licensing process. The RSC involves the presentation of motorcycle accident videos followed by safety-oriented lectures. Its overarching goal is to mitigate road accidents and traffic infractions among novice riders. Results indicate that the RSC yields a temporary reduction in violation incidents by approximately 12%–17% and contributes to an 11% decrease in frequency. Similarly, Australia has embraced a comparable approach by implementing training programs for novice motorcycle riders. These programs encompass three phases: pre-learner (motorcycle permit assessment), learner (check ride), and pre-license (motorcycle licence assessment). The insertion of an intermediate course between the learner permit and license phases serves to extend the novice license duration. Each course mandates on-the-road training and/or assessment components. This initiative has demonstrated its efficacy in ameliorating motorcycle collision concerns among novice riders [46].

A study of significance was also conducted in Vietnam, revealing that the formulation of secure riding guidelines for young riders can effectively reduce their involvement in perilous traffic scenarios. Developed through questionnaire surveys, these guidelines contribute to reshaping adolescents' riding behaviors and attitudes, fostering their ability to recognize, avoid, and navigate risks within demanding traffic situations [97].

In evaluating the older group, it was observed that the factor loading values for the control error construct also exhibited the highest impact on near-miss incidents. Nevertheless, the magnitude of these factor loading values was not as pronounced as that observed in the younger group. Upon closer examination of the specific indicators, it became apparent that the most substantial loading weights were associated with ER4 (encounter issues with visor or goggles fogging up) and ER2 (the roadway becomes slippery in rainy conditions, leading to abrupt braking). These elements are classified as non-intentional factors and relate to challenges such as impaired visibility due to fog or smoke, as well as treacherous road conditions caused by rain-induced slipperiness. These environmental circumstances accentuate the vulnerability to accidents. The studies carried out in China confirmed a significant correlation between collisions with vehicles and particulate matter (PM) [98].

Additionally, inclement weather conditions exacerbate the challenge by rendering road surfaces even more precarious. This corresponds with Nguyen et al. [99], who assert that motorcycling in conditions characterized by wind, dust, or rain heightens the susceptibility to errors. This effect is compounded among older riders, who, despite possessing extensive riding experience, may confront physical limitations due to the aging process. These challenges impact attention, memory, problem-solving, and information processing capabilities [16], consequently amplifying the frequency of control errors and, consequently, elevating the accident risk [42]. The present study shares similarities with the research conducted by Jomnonkwao et al. [45], where risk behavior factors in motorcycle riding significantly contributed to near-miss incidents, with control errors being the most influential. These control errors encompass issues related to managing the motorcycle's speed, negotiating curves, driving on slippery surfaces, and navigating unfavorable weather conditions. These findings resonate with the outcomes of the current study. Additionally, another study by Jomnonkwao et al. [100] identified factors leading to near-miss incidents, encompassing road factors (e.g., road surface, number of traffic lanes, speed limit), environmental factors (e.g., driving at night), and driver factors (e.g., using a phone while driving).

Therefore, control errors, recognized as the most influential factor effecting near-miss incidents, pertain to unintentional mistakes or misjudgments made by motorcycle riders in managing their vehicles. The manifestation of control errors encompasses various critical aspects:

- *Speed Management:* Riders may misjudge appropriate speeds for different road conditions, leading to situations where they are unable to effectively control their motorcycles.
- *Curve Negotiation:* Errors in navigating curves can result in instability, loss of control, and potential near-miss incidents, particularly when riders fail to adjust their speed and positioning adequately.
- *Handling on Slippery Surfaces:* Difficulty in managing the motorcycle on slippery or uneven surfaces can contribute to control errors, making riders more susceptible to near-miss situations.
- *Adverse Weather Conditions:* Poor weather conditions, such as rain or strong winds, can exacerbate control errors, affecting riders' ability to maintain control of their motorcycles.

Understanding how these control errors manifest is crucial for developing targeted training and awareness programs. For younger riders, emphasis could be placed on improving judgment related to speed management and curve negotiation. Older riders might benefit from training that focuses on enhancing skills in handling motorcycles on slippery surfaces and in adverse weather conditions. Additionally, promoting general awareness about the impact of environmental factors on control errors can contribute to overall rider safety for both age groups.

6. Conclusions

The aim of this study is to construct a model for understanding near-miss risk behaviors using data gathered from the Motorcycle Rider Behavior Questionnaire (MRBQ) to compare two distinct groups: younger and older riders. The analysis focuses on three factors—control error, traffic violations, and safety equipment—and evaluates their influence on near-miss. The investigation centers on riding behaviors within countries characterized by medium to low income, where road user training is limited and compliance with traffic regulations is lower. The study employs Thailand as a representative sample for questionnaire responses. The collected samples originate from six diverse regions across the country, comprising a total of 815 participants, including 475 younger riders and 340 older riders.

The study's emphasis on speeding as a significant concern, particularly among novice or younger riders, suggests several recommendations for rider's license training and measures to promote safe riding practices:

- *Incorporate speed management training into licensing programs:* Integrate specific modules on speed management into driver's license training programs, emphasizing the importance of adjusting speeds according to road conditions and surroundings. Include practical scenarios and simulations that allow riders to experience the consequences of inappropriate speeds.
- *Target Novice and Younger Riders:* Develop specialized training initiatives aimed at novice and younger riders, acknowledging their higher susceptibility to speed-related issues. Emphasize the risks associated with speeding through interactive and engaging educational materials.

- *Promote defensive riding techniques:* Integrate defensive riding techniques into training programs, teaching riders how to anticipate and respond to potential hazards on the road. Highlight the role of defensive riding in preventing near-miss incidents and enhancing overall safety.
- *Use advanced training technologies:* Incorporate advanced training technologies, such as virtual reality (VR) simulations, to provide realistic scenarios that emphasize the consequences of speeding. Utilize technology to assess and improve riders' decision-making skills related to speed management.
- *Collaborate with riding schools and instructors:* Collaborate with riding schools and instructors to ensure the consistent and effective delivery of speed management training. Encourage riding schools to adopt best practices in teaching speed awareness and control.
- *Community awareness campaigns:* Launch community-wide awareness campaigns targeting both riders and the general public to emphasize the dangers of speeding. Use various media channels to disseminate information, including social media, posters, and community events.
- *Regular Refresher Courses:* Implement periodic refresher courses for licensed riders to reinforce safe riding practices and update them on any changes in speed regulations or road conditions. Offer incentives for riders who voluntarily participate in refresher training.

By integrating these recommendations into driver's license training and broader awareness campaigns, authorities can address the specific challenges related to speeding among younger riders and enhance overall motorcycle safety.

When considering the older age group, it is evident that the primary issue revolves around adverse weather conditions that are unfavorable for riding. To address visibility-related challenges during adverse weather conditions, especially for older riders who may face heightened risks, policies and recommendations can focus on the following strategies:

- *Educational Campaigns:* Launch targeted educational campaigns emphasizing the impact of adverse weather on visibility and the specific challenges faced by older riders. Provide information on how adverse weather conditions affect visibility, road conditions, and the importance of adjusting riding behaviors accordingly.
- *Incorporate weather awareness into training programs:* Integrate weather-specific modules into rider training programs, with a focus on teaching riders, especially older ones, how to adapt to various weather conditions. Emphasize safe riding practices during rain, fog, and other adverse weather scenarios.
- *Enhanced Licensing Requirements:* Consider implementing enhanced licensing requirements for older riders, including additional training or testing related to riding in adverse weather conditions. Encourage ongoing education and skill development for older riders through refresher courses.
- *Promote the Use of Protective Gear:* Encourage the use of high-visibility protective gear, such as reflective clothing and helmets with visibility-enhancing features, to improve older riders' visibility to other road users. Provide information on the effectiveness of such gear in adverse weather conditions.
- *Weather-Responsive Road Signage:* Implement dynamic road signage that adjusts to weather conditions, providing real-time information to riders about potential hazards and recommended speeds. Include specific signage that warns about reduced visibility and encourages cautious riding.
- *Public Transportation Options:* Promote public transportation options during severe weather conditions, offering older riders an alternative to riding in adverse weather. Provide information on accessible and rider-friendly public transportation services.
- *Community Workshops and Seminars:* Conduct workshops and seminars in local communities to raise awareness about the challenges of riding in adverse weather, especially for older riders. Facilitate discussions on strategies for mitigating risks and enhancing safety.

By implementing these policies and recommendations, authorities can address the unique challenges older riders face in adverse weather conditions and promote safer riding practices. Additionally, collaboration between government agencies, rider organizations, and other stakeholders is essential to ensuring a comprehensive and effective approach.

While the feasibility of road safety recommendations may be impacted by resource constraints in regions characterized by medium to low income, strategic adaptations, community involvement, and collaboration with external partners can contribute to the successful implementation of these measures. Tailoring initiatives to the specific context and addressing local challenges will be crucial for the effectiveness of road safety efforts in such regions. It's essential to recognize the limitations posed by being a lower- to medium-income country in certain geographic regions. However, by adopting a strategic and localized approach, these challenges can be addressed to enhance road safety. This may involve partnerships with international organizations, leveraging technology for cost-effective solutions, and fostering community engagement to ensure that road safety measures are culturally relevant and well-received.

In summary, while the financial limitations in medium- to low-income regions present challenges, proactive and context-specific strategies can enhance the feasibility and effectiveness of road safety recommendations. The key lies in adapting initiatives to the unique circumstances of each region, considering local resources, and fostering collaboration for sustainable outcomes.

6.1. Limitations and Further Research

While this investigation focuses on motorcycle riders, it is essential to carry out further research on the prevalence of near-miss incidents involving trucks and interactions between smaller and larger vehicles, like motorcycles and trucks. This becomes particularly critical in swiftly developing industrial zones with significant truck traffic. In such industrial areas, the risk of not detecting smaller vehicles, especially at intersections or junctions, is elevated, thereby increasing the likelihood of accidents.

7. Declarations

7.1. Author Contributions

Conceptualization, N.H. and S.J.; methodology, N.H.; software, V.R.; validation, C.S., T.C., and N.H.; formal analysis, N.H.; investigation, S.J.; resources, T.C.; data curation, N.H.; writing—original draft preparation, N.H.; writing—review and editing, S.J.; visualization, S.J.; supervision, S.J.; project administration, V.R.; funding acquisition, S.J. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available in the article.

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7.4. Institutional Review Board Statement

The study was conducted following the ethical guidelines outlined in the Helsinki Declaration and received approval from the Suranaree University of Technology Ethics Committee (COA No. 24/2563).

7.5. Conflicts of Interest

The authors declare no conflict of interest.

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