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Exploring Cyclists' Behavior, Traffic Safety Literacy, and Crash Occurrence in Latvia

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Abstract: While the role of safe riding behavior as a safety contributor for cyclists has been increasingly studied in recent years, there have been few studies analyzing cycling behavior in relation to crash-related outcomes. Indeed, to the best of our knowledge, this is the first time this issue has been addressed in the case of Latvia. **Aim:** The objective of this study was to assess the relationships among self-reported cyclists' behavior, traffic safety literacy, and their cycling crash involvement rates. **Method**: A total of 299 cyclists aged M = 32.8 from across Latvia participated in an online survey, which included questions regarding respondents' demographics, frequency of riding, cycling behaviors, and the number of crashes in the previous five years. The Cycling Behavior Questionnaire (CBQ) and the Cyclist Risk Perception and Regulation Scale (RPRS) were applied to assess cyclists' behavior patterns and traffic safety literacy. **Results:** According to the findings, it can be inferred that cyclists frequently engage in riding errors and traffic violations while cycling. Those who exhibit more anti-social behavior (such as traffic violations and riding errors) patterns are also more likely to be involved in road crashes. Conversely, cyclists with greater positive behavior rates more often also tend to possess better knowledge of traffic rules and exhibit a heightened risk perception, indicating a greater awareness of road traffic safety. **Conclusions:** This study underscores key age differences, with older individuals significantly less involved in riding crashes, exhibiting fewer driving errors and a higher level of risk perception, which serves as a relevant factor in road safety. At the practical level, these results stress the need to address both traffic safety literacy and protective cycling factors of cyclists, to improve overall road safety and promote active transport modes in Latvia.

Keywords: cycling; traffic safety; risk perception; behavior; crash occurrence

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1. Introduction

For many residents of Latvia, cycling to work is becoming increasingly popular each year, offering a range of benefits. This trend is not limited to working adults but also extends to students who are increasingly using bicycles as a mode of transport. Cycling is widely recognized for promoting physical activity, being environmentally friendly, contributing to sustainability, and being cost-effective, while also improving individuals' health [1]. Recent studies highlight the significance of ensuring sufficient and safe infrastructure as well as user-friendly environments in both smaller, middle, and larger urban areas to foster the sustained growth of cycling as a transportation mode and ensure its longevity in the mid and long term [2,3]. However, the safety of cyclists on Latvia's roads remains a significant concern, as in most countries around the world.

At a global level, and despite countless previous widespread actions (most of them predominantly infrastructural) conducted over the last two decades, the safety outcomes of cyclists remain considerably concerning. According to data compiled by the World Health Organization (WHO), approximately 41,000 cyclists die in road crashes annually. By 2030, the WHO aims to halve the number of minor cases [4]. However, it must be noted that,

in recent years, the decrease in the number of accidents has not been sufficiently positive. While there has been a reduction in cycling accidents, the pace and extent of this reduction have not met the expected or necessary levels to make a significant impact. According to statistics compiled by the Road Traffic Safety Directorate (CSDD) on accidents involving vulnerable road users in 2023, there were 503 registered injuries involving cyclists in Latvia, with 37 cyclists severely injured and 14 fatalities. Alarmingly, this represents an increase compared to previous years, particularly since 2021, indicating a growing safety challenge for cyclists on Latvian roads [5].

Overall, the existing literature seems to uniformly encourage researchers, policymakers, and practitioners to urgently address this issue and take action to ensure safer and more sustainable road mobility for cyclists. Indeed, this is one of the top priorities today if the current Sustainable Development Goals (SDGs), especially those related to more inclusive and sustainable cities, are considered [4]. Moreover, based on the existing body of applied research, the main causes of these crashes include, in addition to inadequate infrastructure issues, a range of behavioral factors: cycling under the influence of alcohol or other substances, disregarding road traffic regulations, engaging in distracting dynamics, often related to emerging technologies, and neglecting to wear protective helmets, which, while not preventing crashes, reduce their severity.

Overall, the high prevalence of all the aforementioned user behavior-related issues have made growingly evident unaddressed connections between infrastructure quality and cyclist behavior on the road, both of which significantly impact cycling safety outcomes [2]. Consequently, in recent years, researchers have shown an increasing interest in understanding the roles of both risky and protective cyclist behavior and how the increases or reductions in traffic crashes involving them contribute to promoting this sustainable but sometimes "feared" means of transport [6].

1.1. Cycling Safety-Related Discouragers, Challenges, and Behavioral Affairs

As aforementioned, an elevated crash risk (or a perception of it) associated with cycling as a mode of transportation might discourage people from using bicycles, especially on a regular basis [6,7]. Some studies highlight that, when comparing accident rates and outcomes between cyclists and car drivers, cyclists face a higher risk of fatality when involved in a crash [8,9]. Therefore, addressing crash-related perceptions, causes, and dynamics, as well as developing solutions to mitigate them, has been argued as a beneficial action to both enhance cyclists' safety on the roads and promote non-cyclists' engagement in active transportation means. However, it must be acknowledged that researchers still highlight a lack of empirical research on the most significant factors influencing self-governance for the promotion of cyclists' safety [10–12]. This includes not only infrastructure but also other influential factors.

Also, and as pointed out in systematic review papers such as Oja et al.'s [1], it is undeniable that cycling safety depends not only on external factors, such as infrastructure, but also on the behavior and actions of bicycle riders themselves, thus suggesting the need for developing further and better research to focus on variables directly influencing cyclists' behavior and the related aspects. This has led researchers to increasingly pay attention to the study of these factors and the association of various variables with the likelihood of road crashes involving cyclists. Recent studies show that a significant proportion of them are directly caused by risky or reckless behaviors performed by the users themselves [13,14].

A review of risky cycling behaviors among cyclists includes illegal the occupancy of vehicle lanes, speeding, running red lights, illegal carrying, and riding in the opposite direction [15]. It has been established that the behavior of road users is among the foremost factors posing a potential threat and serving as a predictor of road traffic accidents for cyclists [16]. Studies indicate that accidents on the road are often linked to negative and risky behaviors among cyclists, such as cycling in the opposite direction, disregarding road signs or signals, and distracted cycling [12,17].

In research, traffic safety literacy is often more emphasized and applied to car drivers, yet it holds equal importance among cyclists. In the context of this study, traffic safety literacy refers to cyclists' knowledge of traffic rules and their perception of risks. Chen et al. [18] highlight the significance of enhancing literacy to address traffic issues and note that much of the research on traffic literacy primarily investigates factors influencing traffic accidents and safety. For instance, in a recent study by Useche et al. [2] which compared the behavior and safety aspects of cyclists across urban environments of varying sizes, it was discovered that city size positively correlated with instances of traffic violations, cycling errors, and cycling crashes. This implies that, in cities with more extensive and complex infrastructure, cyclists' traffic safety literacy becomes an especially relevant factor in safety assessments.

Similarly, previous research conducted in other countries supports the role of knowing road rules and developing suitable risk perception as key safety-related factors. For instance, a recent study examining perceived risk levels among cyclists and motorists concludes that cyclists' perceived risk is closely linked to both errors of ignorance and the consequences of violations themselves. According to the findings, inattention was associated with the perceived risk level, while cyclist traffic violations were linked to a tendency towards risky behavior [19]. All in all, the results of previous studies support the critical significance of cyclists' traffic safety literacy in increasing their riding safety. From a theoretical point of view, this can be translated to the assumption that understanding and knowing traffic rules, as well as being aware of potential risks, may reduce the statistical likelihood of becoming involved in both cycling and non-cycling traffic crashes on top of strengthening cyclists' safety [16,20].

Nevertheless, there is still relatively little empirical research on cyclists' behavior and its relationship with safety in geographical areas such as the Baltic States [21]. In Latvia, safety considerations for cyclists receive insufficient attention and are not prioritized in road safety policies. Latvian researchers Kreicbergs et al. highlight in their study that Latvia remains one of the countries in the European Union with the highest number of road traffic fatalities per capita. By analyzing various aspects of road safety and recent statistical data, including those on cyclists, the above study identified several contributing factors to the high number of vulnerable road users among the deceased and seriously injured. These factors included issues related to road infrastructure, specific behavioral challenges among road users, and gaps in the regular collection of traffic data for safety analysis [22]. Unlike Kreicbergs's study, which primarily focused on statistical data and infrastructure-related causes, this research adopts a different methodological approach, concentrating on cyclist behavior through self-reported data to better understand behavioral patterns and their relationship with crash occurrences. At a practical level, identifying cyclists' behavior and its correlation with road traffic crashes could raise awareness among both cyclists and the public regarding the gravity of this issue.

1.2. Study Aim and Hypothesis

Bearing in mind the aforementioned considerations, the scarcity of similar empirical research in the region, and the possible contribution of a cycling safety-related case study in Latvia for both road safety practitioners and policymakers, this study aimed to assess the relationships among self-reported cyclist behavior, traffic safety literacy, and their cycling crash involvement rates.

As for what could be hypothesized on the basis of the existing literature, we expected to find significant relationships between risky cycling behaviors and safety outcomes self-reported by Latvian cyclists, as well as a lesser rate of safety-related cycling incidents among those bicycle riders with greater indexes of traffic safety literacy and positive cycling behaviors (*Hypothesis 1*). Moreover, based on the aforementioned theoretical insights provided by the preceding literature, this study added the directional hypothesis that traffic safety literacy would have a statistical effect on the actually reported (risky and protective) cycling behaviors of Latvian cyclists (*Hypothesis 2*).

2. Materials and Methods

2.1. Participants

This study, conducted across different regions of Latvia, involved a sample of 299 cyclists who filled out an online survey. The sample of this study consisted of cyclists between 18 and 76 years of age with a mean age of M = 32.80 (SD = 13.21) and a median age of 31, from the following Latvian cities: Riga (52.5%), Jurmala (4.3%), Jelgava (3.3%), Liepaja 3.3%), Ventspils (3.0%), Sigulda (2.7%), Ogre (2.7%), Valmiera (2.7%), and other cities (25.4%). Among the 299 participants, 124 identified as female (41.5%), 173 as male (57.9%), and 2 as non-binary (0.7%).

As for the participants' educational attainment features, the majority of the participants had higher education degrees (61.5%), while some had secondary school education (24.4%) and professional education levels (13.4%). Only 2 participants had a primary school education level or lower, representing 0.7% of the study sample. Regarding their current occupation, the majority of the research respondents reported being employed (47.2%) or students (35.5%). The remaining participants were self-employed (8.0%), unemployed (2.3%), retired (2.0%), householders (1.3%), or categorized as other (3.7%).

Regarding cycling intensity, the participants reported spending approximately M = 5.23 (SD = 5.48) hours per week cycling, with an average trip length of M = 61.84 (SD = 42.77) minutes. Based on the previous five years, 156 cyclists (52.2%) reported no accidents while riding a bicycle, while 142 participants (47.5%) indicated they had been involved in at least one crash. This analysis included various types of incidents, encompassing crashes involving only cyclists, those involving other vehicles, and incidents with stationary objects.

2.2. Data Collection Procedure

This study was conducted using a web-based questionnaire administered via Google Forms to a convenience (pseudo-probabilistic) sample of Latvian cyclists. The target population, as defined by the sampling strategy, consisted of cyclists aged 18 and over who regularly used bicycles for various purposes daily. Therefore, and regarding the inclusion criteria, every possible adult with basic literacy, able to respond to an e-form, and using a bicycle at least once a month (regardless of the motive(s) associated with it) was considered a possible research partaker, as long as they were willing to respond to the electronic survey upon receiving the invitation.

The data collection window covered a period of approximately 9 months, as data collection started in May 2023 and was concluded in February 2024. The survey was distributed through social media platforms (such as Facebook) and targeted emails to reach the specific research demographic. Participation in this study was voluntary, and the participants were assured of the anonymity of their data and their use solely for research purposes within the scope of this study. This study was conducted after receiving Ethics Committee approval (IRB HE0001291022).

2.3. Study Variable Measurement

Through the online survey, data were collected on respondents' demographic information, cycling habits, and frequency, as well as the number of traffic crashes experienced while cycling. Additionally, two questionnaires were included in the electronic survey: the Cycling Behavior Questionnaire [20] and the Cyclist Risk Perception and Regulation Scale [2,23].

The Cycling Behavior Questionnaire consists of questions that assess various aspects of cyclists' behavior on the road, such as the usage of helmets, interaction with other road users, compliance with traffic rules, and adherence to road signs and signals.

The Cyclist Risk Perception and Regulation Scale includes questions related to cyclists' perceived levels of risk in different cycling scenarios, strategies for risk avoidance, and regulatory behaviors such as speed adjustment and route selection.

2.3.1. The Cycling Behavior Questionnaire

Nowadays, the Cycling Behavior Questionnaire (CBQ) constitutes the most widely used tool to assess cyclists' behavior, focusing on self-reported risky and positive behaviors. Developed and cross-culturally validated by Useche et al. [20], the CBQ aims to explore the interrelationship between cyclists' behavior and its outcomes. The questionnaire consists of 29 items. The CBQ is structured into three scales: (1) traffic violations, (2) errors, and (3) positive behaviors. The traffic violation scale assesses deliberate risky behaviors, such as cycling against traffic flow or exceeding speed limits. The second factor, i.e., riding error scale, identifies unintentional behavior patterns that heighten the risk of accidents, such as failure to assess surrounding conditions, leading to potential crashes. Conversely, the positive behavior scale highlights safety-promoting habits like cycling under adverse conditions, helmet usage, and cautious approaching when crossing streets. Across all scales, respondents are required to rate each question on a 5-point scale, ranging from 1 (never) to 5 (almost always). The full version of the CBQ is available in the Appendix of its multi-national validation study [20].

At a practical level, the CBQ is increasingly being used in the latest scientific research addressing critical issues surrounding cyclist safety and strategies for its enhancement globally. Previous studies conducted on five continents have systematically shown that, apart from cross-cultural validity, the questionnaire has high reliability and internal consistency [2,20], as well as coherent relationships to similar questionnaires used in behavioral research for active transport users, including the Bicycle Rider Behavior Questionnaire (BRBQ) [24] or the Walking Behavior Questionnaire (WBQ) [10].

2.3.2. Cyclist Risk Perception and Regulation Scale (RPRS)

The Cyclist Risk Perception and Regulation Scale (RPRS) was employed to assess cyclists' perception and knowledge of traffic regulations. The scale was developed and constructed by Useche et al. [23], and it consists of twelve items distributed into two scales: (1) risk perception and (2) knowledge of traffic rules. The RPRS measures cyclists' perceived risk levels concerning common safety issues, such as their ability to identify road surface irregularities or potential obstacles along their route. Meanwhile, the knowledge of traffic rule scale evaluates cyclists' familiarity with essential traffic regulations, including the recognition of very basic road conventions. Respondents must rate each of the items on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree) [2,23]. Previous studies have consistently endorsed the RPRS's reliability and validity, underscoring its value in exploring the factors impacting cyclist safety concerns.

2.4. Mathematical Statistics

In the first step, data were carefully curated in order to check their quality, dismiss any potential duplicates, and calculate the study variables as advised in their original source validation studies or manuals. Subsequently, descriptive statistics were analyzed for all survey data, including results from the CBQ and RPRS.

In a further analysis, statistical methods were selected according to the research objectives. Namely, the internal consistency of the CBQ and RPRS was assessed using Cronbach's alpha coefficient, and the value of the coefficient is acceptable if it is 0.6 or higher. To explore correlations between respondents' demographics, weekly cycling duration, accident history, and questionnaire scales, bivariate Pearson's correlation tests were utilized.

Regarding multivariate analyses, two relevant tests were utilized to examine the study hypotheses: firstly, and regarding *Hypothesis 1*, a multivariate analysis of covariance (MANCOVA) was employed, with recent crash involvement (within the last five years) serving as a fixed factor. Apart from controlling for basic demographics such as age, gender, and education, the specific factors or sub-scales from the CBQ and RPRS were considered dependent variables, while age and average weekly cycling duration were included as covariates. Secondly, and as for *Hypothesis 2*, SEM (structural equation modeling)-based path analysis was used to estimate the statistical effects of traffic safety literacy (in this

study, it was understood as a compound of its measured related factors, i.e., risk perception and traffic rule knowledge) on self-reported risky (i.e., errors and violations) and positive cycling behaviors.

The full set of statistical analyses conducted with this study's data were carried out using the Statistical Package for Social Sciences (SPSS) software version 28.0, for the Windows operative system (Armonk, New York, NY, USA) and its extension for structural analyses (AMOS), version 28.0, for Windows operative systems.

3. Results

Table 1 summarizes the means and standard deviations of the CBQ and RPRS, collected from a sample of cyclists. The mean scores provide insight into the frequency of negative behavior patterns reported on the CBQ scales, which included traffic violations and riding errors. This means that lower scores indicated that negative behavior was reported less frequently. Higher scores on the CBQ scales for the positive behavior sub-scale and the RPRS questionnaire scales for knowledge of traffic rules and risk perception indicated a more positive outcome. Overall, the descriptive statistics suggest that Latvian cyclists' risky behavioral indicators were not particularly high, if compared to other countries in the region, included in previous multi-national studies using the CBQ [20].

Table 1. Descriptive statistics and internal consistency results of CBQ and RPRS (n = 299).

Factor	Descriptive Scores		Cronbach's Alpha (α)
	M	***SD***	
CBQ			
F1: Traffic violations	1.11	0.87	0.904
F2: Riding errors	0.75	0.75	0.965
F3: Positive behaviors	2.37	0.90	0.836
RPRS			
F1: Knowledge of traffic rules	3.16	0.66	0.780
F2: Risk perception	3.38	0.71	0.814

Notes: CBQ = Cycling Behavior Questionnaire; RPRS = Regulation and Perception of Risks Scale; M = arithmetic mean; and SD = standard deviation.

Moreover, the reliability analysis, carried out using Cronbach's alpha coefficients, showed high internal consistency indexes across all questionnaire scales, with coefficients ranging from 0.814 to 0.904, all of them over the commonly accepted cut-off point of $\alpha = 0.70$ in traffic psychology studies [25,26]. This indicated strong inner reliability and consistency in the measurement of constructs assessed by the CBQ and RPRS.

3.1. Traffic Violations

Upon closer examination of the CBQ items concerning specific activities carried out while cycling which may pose potential dangers according to respondents' analysis, it is worth pointing out that certain activities were practiced more frequently. The most typically reported cycling behavior patterns included the following activities: 71.24% of cyclists reported listening to music while cycling ($M = 1.83$; $SD = 1.51$); 68.56% reported talking on the phone or sending text messages while riding a bike ($M = 1.35$; $SD = 1.21$); and 68.56% of cyclists reported crossing what appears to be a clear crossing, even if the traffic light is red ($M = 1.34$; $SD = 1.22$).

It should be mentioned that a large part of the respondents self-reported their seldom engagement in potentially dangerous activities, such as cycling against the flow of traffic ($M = 1.03$; $SD = 1.11$; 57% of cyclists), handling potentially obstructive objects while riding a bicycle (food, packs, cigarettes, etc.) ($M = 1.12$; $SD = 1.15$; 63.54% of cyclists), and going at a higher speed than they should be going at ($M = 1.27$; $SD = 1.22$; 66.56% of cyclists).

Furthermore, other less reported risky behaviors included carrying passengers on the bicycle without it being adapted for such a purpose (M = 0.67; SD = 1.05; 43.48% of cyclists), cycling under the influence of alcohol and/or drugs or hallucinogens (M = 0.74; SD = 1.02; 47.16% of cyclists), zigzagging between (weaving in and out of) vehicles using a mixed lane (M = 0.88; SD = 1.16; 36.12% of cyclists), and having a dispute in speed or "race" with another cyclist or driver (M = 0.85; SD = 1.14; 45.15% of cyclists).

3.2. Riding Errors

Regarding non-deliberate risky road behaviors (i.e., errors) performed by Latvian cyclists, it was found that the most common road misbehavior of this nature consisted in failing to be aware of the road conditions and falling over bumps, holes, or obstacles present on the road (M = 1.02; SD = 0.99; 63.55% of cyclists), as well as braking very abruptly on slippery surfaces (something very expectable, given the weather conditions in the country; M = 0.87; SD = 0.97; 54.51% of cyclists) and not properly assessing the surrounding traffic situation, leading to failure in noticing another vehicle and causing it to brake sharply to avoid a collision (M = 0.83; SD = 0.88; 58.19% of participating cyclists).

3.3. Positive Behaviors

All items in the positive behavior scale of the CBQ received relatively similar ratings among the surveyed cyclists. However, upon closer analysis of positive behavioral expressions, it became evident that Latvian cyclists exhibited relatively low indicators concerning the consistent use of a helmet while riding (M = 1.61; SD = 1.51), with only 64.55% reporting regular helmet usage. Nevertheless, cyclists suggested positive actions that contribute to reducing the risk of injury and enhancing safety in various activities. These included the following: using designated bicycle paths (M = 2.79; SD = 1.17; 95.99%); keeping a safe distance from other cyclists or vehicles (M = 2.68; SD = 1.17; 94.98%); stopping and looking to both sides before crossing a corner or intersection (M = 2.67; SD = 1.25; 95.32%); selecting appropriate speeds (M = 2.59; SD = 1.21; 93.65%); avoiding cycling when feeling fatigued or ill (M = 2.17; SD = 1.25; 89.3%) and/or under adverse weather conditions (M = 2.07; SD = 1.27; 87.63%). These positive behaviors, despite variations in helmet usage, indicate a generally responsible approach to cycling safety among Latvian cyclists.

3.4. Traffic Safety Literacy

An analysis of the RPRS items provided valuable insights into cyclists' knowledge of traffic rules and their perception of risks. The results indicated a positive and satisfying level of understanding among the respondents regarding traffic signs and signals (M = 3.61; SD = 0.80), with 74% affirming their full familiarity with road signs and basic road rules (M = 3.61; SD = 0.80). Moreover, the questionnaire revealed reasonable knowledge of the bicycle safety regulations of one's city/town (M = 3.35; SD = 0.87), with 52.52% of cyclists indicating full familiarity. Additionally, a large part of respondents (59.19%) scored considerably high in their awareness of the potential consequences of being involved in a traffic accident, for example, with another vehicle (M = 3.34; SD = 0.94). While slightly lower, several indicators still reflected adequate levels of knowledge and awareness. Cyclists exhibited a moderate ability to identify areas prohibited for traffic or bicycle parking (M = 2.98; SD = 1.04; 40.8%). Furthermore, there was recognition that pedestrians should always have priority, even over cyclists (M = 2.65; SD = 1.22; 32.77%), and acknowledgment of the higher risks for one's safety while riding a bicycle compared to riding a motorized vehicle (M = 2.55; SD = 1.30; 33.78%).

Analyzing the perception of risks from a comparative approach to previous studies using the RPRS [16,23], it is noteworthy that the surveyed cyclists had a consistently high level of awareness regarding the various safety risks associated with riding a bicycle: 70.57% of respondents suggested high awareness of other vehicles that surround them on the road (M = 3.55; SD = 0.83), 62.87% acknowledged the impact that cycling under the influence of certain substances (alcohol, illegal and/or prescribed drugs) has on the ability

to ride well (M = 3.49; SD = 0.94), 71.91% realized that there are signaling and infrastructure problems that can affect their safety (M = 3.41; SD = 0.93), and 63.87% recognized the risks associated with using headphones and mobile phones while riding bicycle (M = 3.42; SD = 0.91). Additionally, 42.48% recognized that urban areas are especially risky, considering the number of vehicles and the complexity of the roads (M = 3.01; SD = 1.08).

3.5. Interrelationships Between Demographics, Crash Rates, and Cyclist Behavior

The Pearson correlation results in Table 2 show a significant relationship between the factors included in this analysis. The magnitude of a relationship in Pearson's correlation results can be considered weak (r > 0.1), moderate (r > 0.3), or strong (r > 0.5), in accordance with the standard suggestions provided by Cohen (1988), which can be applied in behavioral science [27]. According to the obtained results, it can be stated that there was a significant negative relationship between age and both traffic violations (r = −0.232, $p < 0.01$) and riding errors (r = −0.257, $p < 0.01$), suggesting that older participants were less likely to commit traffic violations or make riding errors while riding a bicycle. Age showed positive significant correlations with weekly cycling (r = 0.215, $p < 0.01$), positive behavior (r = 0.343, $p < 0.01$), knowledge of traffic rules (r = 0.115, $p < 0.05$), and risk perception (r = 0.213, $p < 0.01$), indicating that older cyclists tended to spend more time cycling weekly, exhibited more positive behaviors on the road, and had greater knowledge of traffic rules and perception of possible risk. No significant relationship was found between age and the total number of crashes.

Table 2. Pearson's correlation matrix between age, weekly time spent cycling, total crashes, CBQ, and RPRS.

	Factor	1	2	3	4	5	6	7	9
1	*Age*	1							
2	*Weekly cycling (min.)*	0.215 **	1						
3	*Traffic violations*	−0.232 **	−0.015	1					
4	*Riding errors*	−0.257 **	−0.024	0.646 **	1				
5	*Positive behaviors*	0.343 **	0.152 **	−0.139 *	−0.184 **	1			
6	*Knowledge of traffic rules*	0.115 *	0.117 *	−0.079	−0.183 **	0.177 **	1		
7	*Risk perception*	0.213 **	0.115 *	−0.111	−0.233 **	0.302 **	0.631 **	1	
8	*Self-reported cycling crashes (5 years)*	0.094	0.050	0.149 *	0.134 *	0.039	−0.031	0.027	1

Notes: ** Correlation is significant at the 0.01 level (2-tailed); * correlation is significant at the 0.05 level (2-tailed).

The weekly time spent cycling had positive significant relationships with positive behavior (r = 0.152, $p < 0.01$), knowledge of traffic rules (r = 0.117, $p < 0.05$), and risk perception (r = 0.115, $p < 0.05$). This suggests that cyclists who spend more time riding a bicycle each week tend to exhibit more positive behaviors, possess greater knowledge of traffic rules, and be more aware in terms of risk perception. Additionally, the traffic violation factor exhibited a negative significant relationship with positive behavior (r = −0.184, $p < 0.01$). In other words, this indicates that participants who committed fewer traffic violations tended to exhibit more positive behaviors while being on the road. There were also positive significant relationships between traffic violations and both riding errors (r = 0.646, $p < 0.01$) and crashes (r = 0.149, $p < 0.05$), suggesting that cyclists who tended to violate traffic laws more frequently also tended to make more riding errors and consequently experience more crashes.

Moreover, riding errors showed negative significant correlations with positive behavior (r = −0.184, $p < 0.01$), knowledge of traffic rules (r = −0.183, $p < 0.01$), and risk perception (r = −0.233, $p < 0.01$), meaning that cyclists with greater knowledge of traffic rules, higher risk perception, and more positive behaviors tended to make fewer riding errors. Additionally, positive behavior outcomes suggested strong and significant positive relationships with both knowledge of traffic rules (r = 0.177, $p < 0.01$) and risk perception (r= 0.302, $p < 0.01$), independently of any previously mentioned correlation. Finally, as for the traffic safety literacy factors, the self-reported level of knowledge of traffic rules

showed a significant positive correlation with risk perception (r = 0.631, $p < 0.01$), which indicated that cyclists with better knowledge of traffic rules also tended to have higher levels of perception of potential road risks.

3.6. Key Risk Factors and Safety Hazards Among Cyclist Groups

Table 3 represents the results of a multivariate analysis of covariance (MANCOVA) examining the relationship between crash occurrence and various factors related to cycling behavior. Before carrying out the MANCOVA, the required sample size was calculated using G*Power 3.1.9.6 software, with a 5% α-error level and 80% power (corresponding to a 20% β-error rate). The analysis indicated that a minimum of 134 cyclists were needed per group to ensure sufficient statistical power. Wilks's Lambda of the MANCOVA was 0.961 (F = 2.36, $p < 0.05$), indicating that the overall main effect of crash occurrence reached statistical significance. This suggests that crash occurrence was significantly influenced by the combined dependent variables. Among the 299 cyclists composing the study sample, 47.49% (n = 142) of them reported experiencing at least one crash in the previous five years, while the remaining 52.51% (n = 157) reported no crashes during the previous five years.

Table 3. Multivariate analysis of covariance (MANCOVA) of CBQ and RPRS and crash occurrence.

Factor	No Crashes (n = 157)	Crashes (n = 142)	F	η^2
Traffic violations	1 (0.88)	1.23 (0.84)	9.29 *	0.031
Riding errors	0.68 (0.73)	0.82 (0.76)	6.26 *	0.021
Positive behaviors	2.30 (0.95)	2.44 (0.84)	0.33	0.001
Knowledge of traffic rules	3.19 (0.72)	3.11 (0.60)	1.31	0.004
Risk perception	3.37 (0.75)	3.38 (0.67)	0.14	0.000

Notes: Wilks's Lambda = 0.961; F = 2.36; and $p < 0.05$. Age and weekly distance riding a bicycle are included as covariates. * Significant at the 0.05 level (2-tailed).

As for cycling safety outcomes, both risk-related factors, i.e., traffic violations (F = 9.29, $p < 0.05$) and riding errors (F = 6.26, $p < 0.05$), showed significant differences between the non-crashed and crashed groups of riders, suggesting that, as hypothesized, these behaviors may increase cyclists' likelihood of suffering road crashes. On the other hand, positive riding behaviors, knowledge of traffic rules, and risk perception did not show significant differences between the two groups, implying that these factors might not be as strongly associated with crash occurrence.

Figure 1 illustrates the cyclist safety aspects from this study's results and analysis. The scales of traffic violations (F = 9.29, $p < 0.05$) and riding errors (F = 6.26, $p < 0.05$) were found to have a statistically significant differences between the group of cyclist with and without crashes in the previous 5 years based on the MANCOVA analysis. This suggests that more frequent traffic violations and ridings errors impact the risk of road accidents involving cyclists. The results also included the scales of positive behaviors, knowledge of traffic rules, and risk perception. Although these scales did not show a direct and statistically significant impact on cyclist safety in the MANCOVA, there were statistically significant correlations between them, as indicated by the Pearson correlation results. These interrelationships reflect general cyclist behavior and have an indirect influence on road safety.

The above visualization emphasizes that traffic violations and riding errors are the primary factors that statistically differentiate cyclists who have experienced a crash from those who have not. Age significantly correlates with cyclist safety, as revealed by this study's findings. While older cyclists generally exhibit more positive behaviors on the road compared to younger cyclists, they tend to make more riding errors and commit more traffic violations, which are key contributors to crashes. Additionally, the interconnections between other factors contribute to a broader understanding of behaviors that can affect safety on the road.

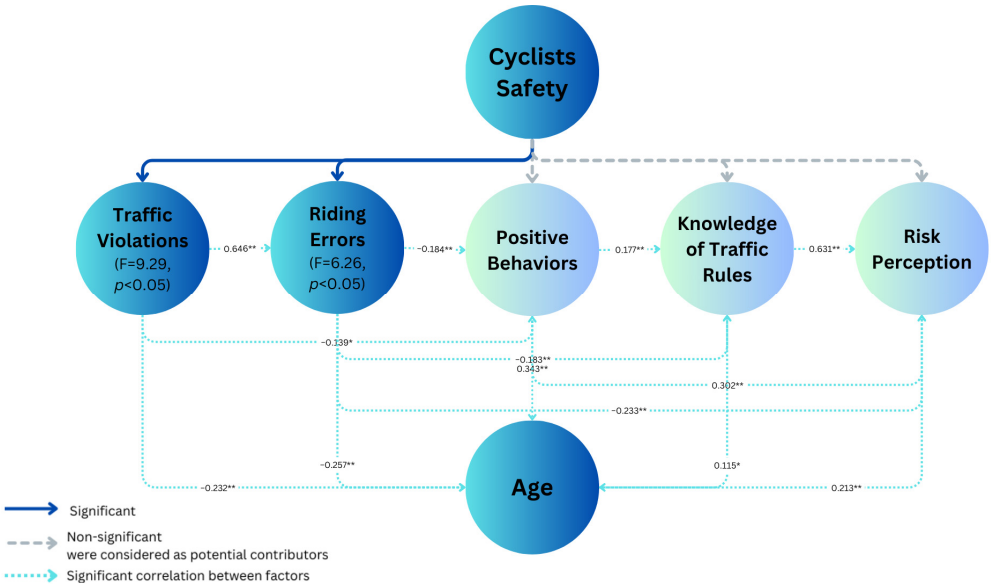

Figure 1. Visual representation of cyclist safety and crash risk: key findings. Notes: ** Correlation is significant at the 0.01 level (2-tailed); * correlation is significant at the 0.05 level (2-tailed) (as shown in Table 2).

3.7. Path Analysis

Before configuring the model, paths were defined based on theoretical grounds, using a confirmatory approach to ensure plausibility. The fit of the path models was assessed through several ordinal/incremental indexes, including the Normed Fit Index (NFI), the Incremental Fit Index (IFI), the Confirmatory Fit Index (CFI), and the Relative Fit Index (RFI), alongside their Root Mean Squared Errors of Approximation (RMSEAs). The cut-off criteria followed literature-based goodness-of-fit guidelines [28,29], with ordinal/incremental indexes expected to exceed 0.900, plus an RMSEA under 0.080, ensuring a satisfactory fit according to their theoretical path plausibility. Significance levels were differentiated at $p < 0.001$ (***), $p < 0.010$ (**), and $p < 0.050$ (*).

After configuring the model while controlling for age, gender, and city size and incorporating the theoretically driven covariances between the two predictors, the model fit statistics were as follows: $\chi^2 = 4.819$; $p < 0.001$; NFI (Delta 1) = 0.962; IFI (Delta 2) = 0.969; CFI = 0.966; RFI (rho 1) = 0.928; RMSEA = 0.073; and 90% CI [0.33–0.112]. Figure 2 illustrates the model, which was statistically significant and whose full set of coefficients is provided in Table 4, was retained based on its theoretical validity and overall good fit indexes, and it was bootstrapped for enhancing its statistical robustness [30].

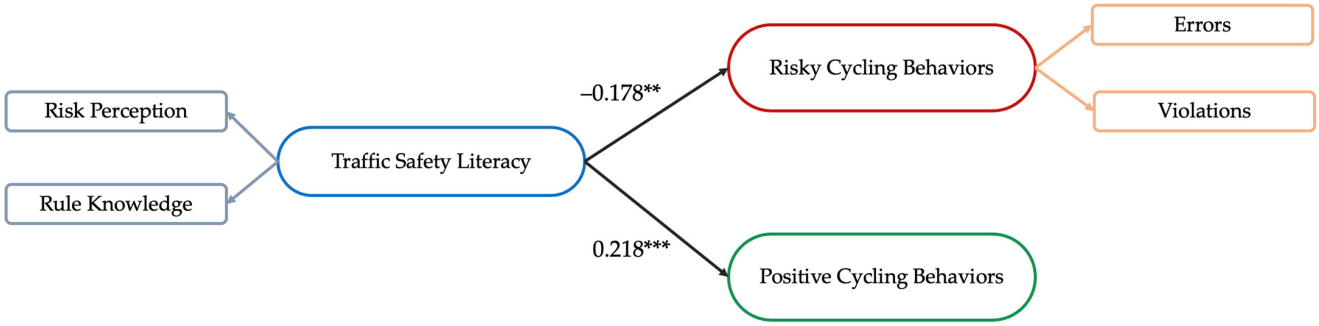

Figure 2. Traffic safety literacy as a predictor of self-reported cycling behaviors. Notes: ** Significant at the level $p < 0.010$; and *** significant at the level $p < 0.001$ (as shown in Table 4).

Table 4. Variables appended in the structural path model, estimates, significance levels, and confidence intervals (CI with lower and upper thresholds) at the 95% level for bootstrap bias-corrected coefficients.

Path			SPC [a]	S.E. [b]	C.R. [c]	*p* [d]	Bootstrap Bias-Corrected Values [e]				
							Est [f]	S.E. [b]	95% CI [g]		*p* [d]
Traffic safety literacy as a predictor of self-reported cycling behaviors											
Traffic Safety Literacy	→	Risky Behaviors	−0.178	0.067	−3.171	**	−0.178	0.070	−0.275	−0.060	*
Traffic Safety Literacy	→	Positive Behaviors	0.218	.084	4.019	***	0.218	0.085	0.112	0.323	*
Statistical controls											
Age	→	Risky Behaviors	−0.194	0.003	−3.330	***	−0.194	0.003	−0.302	-0.069	**
Age	→	Positive Behaviors	0.192	0.004	3.411	***	0.192	0.004	0.098	0.301	**
Education	→	Risky Behaviors	0.081	0.046	1.435	0.151	0.081	0.047	−0.057	0.176	0.303
Education	→	Positive Behaviors	0.079	0.058	1.450	0.147	0.079	0.053	−0.014	0.177	0.112
City Size	→	Risky Behaviors	−0.116	0.022	−2.055	**	−0.116	0.023	−0.221	0.013	0.059
City Size	→	Positive Behaviors	0.179	0.028	3.295	***	0.179	0.026	0.081	0.277	*

Notes: [a] SPC= standardized path coefficients (β-linear regression weights); [b] S.E.= standard error; [c] CP= critical ratio; [d] *p*-value: * significant at $p < 0.050$, ** significant at $p < 0.010$, and *** significant at $p < 0.001$; [e] bootstrapped model coefficients (bias-corrected); [f] bootstrapped model standardized estimates (bias-corrected); and [g] confidence interval at the 95% level (lower bound—left; upper bound—right).

Once the model paths were drawn and their effects were measured through a significant and theoretically coherent model with adequate goodness-of-fit indexes, it was found that traffic safety literacy had a direct, consistent, and significant effect on the self-reported behaviors of Latvian cyclists, as follows: On the one hand, the path between traffic safety literacy → risky cycling behaviors was negative and significant, with $\beta = -0.178$ and bootstrapped IC(95%) = [−0.275–−0.060]. On the other, the structural path drawn between traffic safety literacy → positive cycling behaviors was also positive/directionally coherent and significant, with $\beta = 0.218$ and bootstrapped IC(95%) = [0.112–0.323].

4. Discussion

This research analyzed the relationship between cyclists' behavior, traffic safety literacy, and self-reported crash involvement among Latvian cyclists. In the context of this study, the Cycling Behavior Questionnaire [20] was utilized to measure the risk-related behavioral patterns of cyclists, while the RPRS [23] was employed to evaluate cyclists' traffic safety literacy, measuring both risk perception and road rule knowledge, following a self-report approach. The approach to the analysis was chosen based on previous studies conducted in contexts of similar values [2,13].

4.1. Behavioral Correlates and Safety-Related Outcomes

Overall, the results of this study suggest significant correlations between self-reported cycling behavior, traffic safety literacy, and cyclist crashes, considering a time window of five years. From a bivariate approach, the data provided by this Latvian sample show significant positive behavioral patterns among cyclists, as well as cases where road traffic violations are committed intentionally, and errors are due to a lack of awareness or misjudgment of traffic situations.

Moreover, the findings show a correlation between the behavior of cyclists and the likelihood of traffic violations which are associated with crashes. Also, there is a significant positive correlation between traffic violations and riding errors ($p < 0.01$). This suggests that cyclists who commit more intentional traffic violations also make more riding errors, potentially endangering their safety on the road. Similar findings have been reported in studies conducted in other countries, even though, from a comparative point of view, the results obtained in this study indicate that the frequency with which the surveyed cyclists committed both deliberate (i.e., traffic violations) and non-deliberate (i.e., errors) actions was comparatively greater than the mean concerning other countries in the region, such as Finland (see [31]).

Building on further previous research, it is noteworthy that O'Hern et al.'s studies, conducted in Finland and Australia on cyclists' behavior and crash involvement, yielded similar results [14,31]. They concluded that cyclists who committed more traffic violations were, consistent with the findings of our initial study among the Latvian population, more prone to making additional errors on the road, indicating risky behaviors [14]. Similar results were found in research where traffic violations were associated with errors and multiple crashes [16,32]. According to our results, in Latvia, one of the most common and deliberate actions performed by cyclists while riding a bicycle is using a phone; 68% of the respondents admitted to regularly engaging in this action.

At a hands-on level, the potential consequences and dangers of such activities have attracted the attention of several researchers and road traffic context analyses [33]. For instance, De Angelis et al. conducted a separate study on smartphone use and crash risk among cyclists [34]. Their results provide insight into how smartphone use contributes to an increased likelihood of being involved in near-crashes and actual crashes. Another common and deliberate action is listening to music, as reported by 71% of the cyclists surveyed in our study. Stelling-Konczak et al. carried out a research proposing that not being able to hear traffic sounds may decrease cyclists' awareness of approaching vehicles and lead to unsafe situations which sometimes act as pre-crash scenarios [35].

4.2. Behavioral and Literacy-Related Predecessors of Crash Involvement History

Another important finding from this study is that cyclists with more frequent traffic violations also tend to uniformly show increased odds ratios of experiencing a crash compared to those with a self-reported lesser frequency of traffic violations while riding. Apart from endorsing the core study hypothesis, this aligns with the results of previous research experiences with similar findings. For instance, a study conducted by Rad et al. suggests that different behavioral patterns of cyclists may influence cycling outcomes [17]. The current study in Latvia observed significant levels of risky behavior among cyclists, which were significantly associated with their history of previous traffic crash involvement.

Also, except for variations in helmet usage, Latvian cyclists exhibited generally positive behaviors in aspects such as using designated bicycle paths, with stable trends in behaviors such as maintaining a safe distance from other cyclists or vehicles, practicing caution at intersections, selecting appropriate speeds, and avoiding cycling in unfavorable conditions, reflecting a responsible approach to cycling safety. Moreover, the negative correlations between traffic violations, risk perception, and positive habits or behaviors are coherent with those observed in other studies addressing protective habits in addition to merely risky riding behaviors [14,16].

This suggests that cyclists with enhanced knowledge of traffic regulations, heightened risk perception, and a proactive approach towards safety tend to make fewer riding errors, emphasizing the significance of promoting positive behaviors in cycling habits. Based on the results of Kummeneje and Rundmo's study, risk perception was a significant factor in shaping the positive behavioral perspectives of cyclists in Norway. Their study concluded that an individual's attitude, including their behavior, is directly influenced by their perception of risk. When this perception is low, it may manifest in cycling behaviors characterized by fewer positive attitudes towards road safety [36].

When evaluating cyclists' traffic knowledge and risk perception indicators, negative mutual relations between these factors and riding errors can be observed, indicating that, as these indicators increase, riding errors tend to coherently decrease. Likewise, these indicators also have a positive link to positive riding behaviors. These results are largely consistent with and support the findings of previous studies, such as Useche et al.'s study [2,23], where significant relationships were identified between involvement in reckless road behaviors, risk perception levels, and traffic knowledge, further endorsing the assumptions of our *Hypothesis 1*.

Regarding previous pieces of evidence supporting this finding, similar results were also found in the Australian study by O'Hern et al., where risky behavior indexes were pos-

itively and consistently correlated with negative crash-related outcomes [14]. In addition, some similar studies emphasize the need for increasing skills such as traffic knowledge, risk perception, and positive behavior on the road, underscoring the importance of promoting education and awareness among cyclists to foster safer and more responsible cycling practices [12,37].

One of the notable findings in the present study is the significant impact of cyclists' age on various factors, including weekly cycling intensity, traffic violations, riding errors, positive behavior, knowledge of traffic rules, and risk perception. This observation highlights a trend among Latvian cyclists, wherein individuals tend to exhibit greater caution and self-awareness as a function of age. In fact, it draws attention to the fact that age was the only consistently significant statistical control in the relationship between traffic literacy and both risky and positive self-reported cycling behaviors. From a theoretical standpoint, this study reveals that older cyclists show a tendency to engage in fewer traffic violations, consequently leading to a reduction in riding errors. While research emphasizes the prevalence of intentional traffic rule violations among cyclists, it suggests a decline in such risky behavior as individuals age [16,23].

For example, although it relates to a passive safety issue rather than modulating post-crash severity figures, older cyclists exhibited a higher frequency of helmet usage, similarly to that observed in previous studies conducted in other countries [17,38]. Moreover, older respondents demonstrated higher levels of positive behaviors, knowledge of traffic rules, and risk perception, indicating a more informed and responsible approach to cycling safety. This is essential for fostering a culture of road awareness and reducing the likelihood of accidents among cyclists of all ages.

4.3. Risky Behavior and Crash History: An Age-Based Perspective

The authors offer no explanation for the discrepancy between their results (age is associated with more crashes) and previous works. On the one hand, older cyclists tended to demonstrate more positive behaviors on the road, along with better knowledge of traffic rules and responsible cycling habits. On the other, they also experienced a higher number of crashes compared to the younger cyclists in the sample. Previous studies have identified several factors contributing to this paradox. For example, Engber et al. note that older cyclists have a higher risk of injury in traffic crashes due to mental impairment, unsuitable bicycle parameters, and an excessive sense of uncertainty on the road, leading to fall-provoking behaviors such as moving at excessively low speeds [39]. In other words, from a literature-based approach, it is hypothesized that older cyclists may increase their crash likelihood on the basis of a higher incidence of crash-causing riding errors (but not deliberate violations) than younger cyclists. This was observed in previous studies conducted in other countries, such as Useche et al. [12], using the same behavioral error/violation taxonomy as in the current study to compare safety outcomes of Latin American cyclists of different age groups.

Other research with common approaches and outcomes suggests that older cyclists are more likely to crash without motor vehicle involvement, despite reporting less frequent aberrant behaviors [37,40]. Additionally, Ayuso et al. indicate that physical fragility is a primary reason for crashes among older cyclists [41]. These findings suggest that older cyclists are not necessarily more dangerous on the road but are more vulnerable, at greater risk in traffic, and more likely to self-report cycling crashes. Nevertheless, this is just a theory-based assumption, as, in the current research, we did not address cyclists' riding skills or their subjective feelings of safety and confidence, which are important factors contributing to their overall crash risk. While positive cycling behaviors, such as maintaining safe speeds, controlling headway, and checking intersections, are generally assumed to enhance safety, this study did not find a strong correlation between these behaviors and crash risk. Older cyclists may be more prone to non-violation-related errors, such as low-speed falls or balance issues, which could explain their higher crash involvement despite exhibiting more positive cycling behaviors, as indicated by previous research.

4.4. Does Traffic Safety Literacy "Matter" for Cycling Behavior?

The second study hypothesis (see *Hypothesis 2*) posited that traffic safety literacy, understood in this study as a compound of road risk perception and road rule knowledge (our measured factors), might have a direct and significant effect on the actual cycling behavior of Latvian cyclists. While in this study the number of literacy-related variables remained limited, their directionality and statistical significance as predictors of behavioral outcomes of cyclists remained consistent with findings from previous research in this field. For instance, studies by Zavareh et al. [38] have shown that risk perception significantly impacts cyclists' compliance with traffic regulations and influences their overall safety behavior. Additionally, Useche et al. [20] found that both risk perception and traffic rule knowledge are critical predictors of cyclists' safety outcomes. Other research, such as that by McIlroy et al. [10] and Griffin et al. [19], has also emphasized the importance of traffic knowledge and perceived risk in influencing safer cycling behaviors.

At a practical level, these findings suggest that improving road safety literacy through targeted educational campaigns and training programs could effectively enhance cyclists' adherence to traffic rules, potentially reducing accident rates and risky behaviors among this population. Prior studies have shown that interventions focusing on improving knowledge of road safety can lead to measurable improvements in behavior, such as reduced risky maneuvers and greater use of protective equipment [36,38]. Moreover, integrating cycling-specific risk perception training has been linked to better decision making and hazard recognition among cyclists, as noted by reviews of the existing literature, such as that by Twisk et al. [42]. These practical strategies could contribute to more sustainable and safer cycling environments in urban settings, possibly making cycling a safer and more attractive transportation means in Latvia.

4.5. Limitations of This Study

While this study used validated research instruments and covered different regions of Latvia, there are some essential limitations that should be acknowledged, in order to make a fair interpretation of the study results. One of them is the relatively large age range of the sample, which ranged from 18 to 76 years. Age is often correlated with factors such as maturity, experience, level of education, state of health, and others. Given the highly covariant nature of this factor, it often acts as a confusing variable in road safety literature and may interfere with the accuracy of conclusions on research results if not properly controlled. In the case of this research, while age was included as a key covariant factor in both MANCOVA and SEM-based Path analyses, this issue should also be considered in qualitatively interpreting the study results.

Another limitation is that data collection occurred in an online environment, which did not afford full control over the veracity of respondents' answers and the validity of the data. It is important to note that participation was voluntary, and responses were anonymous, which helped mitigate this limitation. Also, some potential participant-based biases must be considered. Firstly, this study addressed road behavioral and safety-related topics, which can become sensitive for some participants and bias their self-reported outcomes. In addition, some common method biases, such as acquiescent responses and memory flaws, might affect the reliability of the results in some cases.

In addition to the previously mentioned limitations, it is important to consider the challenges associated with self-reported surveys studying selected variables. The behavioral patterns were evaluated using a self-reported measurement tool, which may have introduced common method variance and affected the reliability of the data. While the measuring instruments employed in this study are widely recognized for assessing the behavior patterns of cyclists, their limitations must be acknowledged when interpreting the results. However, it is essential to recognize that cyclist behavior is complex and multifaceted, making it difficult to measure accurately with other types of instruments; thus, surveys can be a more suitable approach in this context.

Furthermore, data collection spanned a period from May 2023 to February 2024. It is worth mentioning that the time of year during survey completion could have potentially influenced respondents' answers. For instance, during winter, when road surfaces are often covered with snow, the number of cyclists on the road tends to decrease compared to warmer seasons. Another shared important limitation to consider in this and other similar studies is not accounting for objective safety surrogate measures, such as traffic conflicts. These indicators could provide more concrete and quantifiable insights into cyclist safety by capturing near-miss incidents and other critical safety events, which would offer a more comprehensive understanding of the factors influencing cycling safety in this region.

Moving forward with the study of cyclists' road behavior, traffic safety literacy, and crash involvement in Latvia, it is critical for future research experiences to consider the aforementioned limitations, in order to apply improvements such as increasing the research sample, coverage, and number of variables measured to increase the explanatory potential of the research results, thus enhancing the robustness of the findings.

5. Conclusions

At a general level, the evidence obtained in this study suggests significant interrelationships between cyclists' behavior, traffic safety literacy, and crash occurrence among Latvian cyclists over the previous 5 years. As for specific issues, there are some findings worth mentioning, which can be found below.

When it comes to cyclists' demographics, it is noteworthy that older cyclists consistently demonstrated greater knowledge of traffic rules and a heightened perception of potential road risks. This may explain their inclination towards exhibiting more positive behaviors compared to younger individuals.

Regarding positive cycling behaviors, although no correlation was found between positive behavior and crashes, positive correlations were identified between total crashes in the previous 5 years and both traffic violations and riding errors. This suggests that the more cyclists engage in traffic violations and riding errors, the higher their likelihood of being involved in cycling crashes.

Latvia's road safety regulations may be influencing cyclist behavior due to inaccuracies or incompleteness in the existing laws. This is reflected in certain safety practices or behaviors and helmet usage. For example, this study reveals that, while 95.99% of Latvian cyclists reported regularly using designated bicycle paths, only 64.55% consistently wore helmets, despite the known benefits in injury prevention. This discrepancy highlights the lack of mandatory helmet laws for adults, which may contribute to lower helmet adoption rates.

Additionally, although cyclists demonstrated positive behaviors, only 33.78% of our participants fully recognized the higher risks associated with cycling compared to motorized vehicles, suggesting that safety education could be further improved.

As for the value of traffic safety literacy in improving cycling behaviors, path analyses revealed that it had direct, consistent, and significant, though differential, links to both risky and positive behaviors, thereby reinforcing the need to actively promote traffic safety literacy among the Latvian population.

Addressing this and other relevant cycling behavioral issues should be a key focus of future research, particularly at the national level. It is important to recognize and understand these behavioral patterns among Latvian cyclists and carefully evaluate the suitability of road infrastructure for cyclists, both in urban and rural environments.

Finally, although this study's analyses did not reveal a direct correlation between positive cycling behaviors and crash occurrences, the positive correlation found between traffic violations, driving errors, and crash rates is alarming. This finding highlights the importance of promoting safe cycling practices and enforcing traffic regulations. Future research should prioritize this critical factor.

Practical Implications of This Study

At a practical level, and based on both the results obtained through this study and the existing literature addressing similar populations of cyclists from other regions, it can be expected that promoting cyclists' risk perception (i.e., increasing their awareness of the potential risks and consequences of different cycling behaviors) could enhance both safety and positive behaviors among cyclists. In addition, promoting risk perception among Latvian cyclists is essential. To this end, targeted educational campaigns that have proven successful in other countries could be implemented. These initiatives may include interactive training sessions that highlight the dangers of cycling, as well as partnerships with local cycling organizations to foster a culture of safety among cyclists.

Additionally, the targeted relationships between cycling literacy and behavioral/safety outcomes suggest that, apart from aiming to reduce errors and violations on the road, addressing "positive" cycling habits could also contribute to a reduction in traffic violations and riding errors in the region, which is particularly relevant for strengthening the promotion of active and sustainable transportation methods in Latvia. To promote positive cycling habits, initiatives could include organized community cyclists that model safe cycling practices, educational workshops focusing on defensive riding techniques, and campaigns that encourage the use of appropriate safety gear, such as helmets and reflective clothing. In Latvia, for example, helmets are not mandatory for all cyclists, only for children under 16 years of age, highlighting a critical area for advocacy. Fostering a culture of mutual respect among all road users through awareness campaigns could help enhance cyclists' confidence and competence on the road.

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