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Personality traits, sensation seeking, and cycling safety outcomes: A multi-country study

Sergio A. Useche [a,*], Francisco Alonso [a], Isaac D. Castañeda [b], Boris Cendales [c], Arturo Cervantes [b], Tomas Echiburu [d], Mireia Faus [a], Zuleide O. Feitosa [e], Javier Gene-Morales [f], Victor Gonzalez [g], Mohd K.A. Ibrahim [h], Kira H. Janstrup [i], Rich C. McIlroy [j], Mette Møller [i], Mauricio Orozco-Fontalvo [k], Ksenia Shubenkova [l], Felix W. Siebert [i], Jose J. Soto [m], Amanda N. Stephens [n], Yonggang Wang [o], Elias S. Willberg [p], Philipp Wintersberger [q], Linus Zeuwts [r], Zarir H. Zulkipli [h], Steve O'Hern [s]

[a] Faculty of Psychology, University of Valencia, Spain
[b] Faculty of Health Sciences, Anahuac University, Mexico
[c] Pontificia Universidad Javeriana, Bogotá, Colombia
[d] University of Chile, Chile
[e] University of Brasília, Brazil
[f] University of Valencia, Spain
[g] Technological Institute of Santo Domingo (INTEC), Dominican Republic
[h] Malaysian Institute of Road Safety Research (MIROS), Malaysia
[i] Department of Technology, Management and Economics, Technical University of Denmark (DTU), Denmark
[j] Transportation Research Group, University of Southampton, United Kingdom
[k] CERIS – Technical Superior Institute, University of Lisbon, Portugal
[l] Kazan Federal University, Russia
[m] Universidad Tecnológica de Bolívar, Colombia
[n] Monash University Accident Research Centre (MUARC), Australia
[o] College of Transportation Engineering, Chang'an University, China
[p] Digital Geography Lab, Faculty of Science, University of Helsinki, Finland
[q] Technical University of Wien (TU Wien), Austria
[r] Ghent University, Belgium
[s] University of Leeds, United Kingdom

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ABSTRACT

Introduction: While the role of personality in shaping behavior and safety has been widely documented across domains, its study among cyclists has remained limited. Traditional trait-based approaches may also fall short in predicting real behaviors, which highlights the need to explore additional factors. *Aims:* This research examined associations between personality traits, cycling behaviors, and self-reported crashes, and tested the predictive role of sensation seeking (SS), an emerging construct in cycling safety, on risky and protective behaviors. *Methods:* A cross-sectional study was conducted with 5,778 cyclists from 17 countries (58% male, 41% female, 1% non-binary; M = 34 years). Participants completed an online questionnaire assessing personality, cycling behaviors, and self-reported crashes over five years. *Results:* Most personality traits showed significant associations with risky behaviors, but the strongest correlations involved SS. Path analyses indicated that high sensation seekers were more likely to engage in road conflicts. SS also covaried with risk perception, which predicted both

* Corresponding author.
E-mail addresses: sergio.useche@uv.es (S.A. Useche), francisco.alonso@uv.es (F. Alonso), isaac.castaneda@anahuac.mx (I.D. Castañeda), cendales.boris@javeriana.edu.co (B. Cendales), arturo.cervantes@anahuac.mx (A. Cervantes), tomas.echiburu@uc.cl (T. Echiburu), mireia.faus@uv.es (M. Faus), zld.feitosa@gmail.com (Z.O. Feitosa), javier.gene@uv.es (J. Gene-Morales), victor.gonzalez@intec.edu.do (V. Gonzalez), mkhairul@miros.gov.my (M.K.A. Ibrahim), kira.hyldekaer.janstrup@regionh.dk (K.H. Janstrup), r.mcilroy@soton.ac.uk (R.C. McIlroy), mette@dtu.dk (M. Møller), mauricio.orozco@tecnico.ulisboa.pt (M. Orozco-Fontalvo), ksenia.shubenkova@gmail.com (K. Shubenkova), felix@dtu.dk (F.W. Siebert), jsoto@utb.edu.co (J.J. Soto), amanda.stephens@monash.edu (A.N. Stephens), wangyg@chd.edu.cn (Y. Wang), elias.willberg@helsinki.fi (E.S. Willberg), philipp.wintersberger@tuwien.ac.at (P. Wintersberger), linus.zeuwts@ugent.be (L. Zeuwts), zarirhafiz@miros.gov.my (Z.H. Zulkipli), s.ohern@leeds.ac.uk (S. O'Hern).

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risky and protective behaviors. Cyclists reporting crashes scored higher on SS and openness, and lower on agreeableness. *Conclusion:* The findings suggest that personality traits are related to self-reported cycling safety outcomes, with SS showing the clearest links to risky behaviors, road conflicts, and crash involvement. The observed covariance between SS and risk perception also supports considering both factors jointly when examining cycling safety.

1. Introduction

Cycling is increasingly promoted as a healthy, efficient, and sustainable form of mobility. Yet safety risks remain a major concern for users, researchers, and policymakers (Schepers, 2013; Twisk, de Hair-Buijssen, & Otte, 2017). Crash risks are consistently cited as the main deterrent to cycling in different countries, ranking even above urban security and adverse weather (Kaplan et al., 2016; Useche et al., 2019). Globally, around 41,000 cyclists are estimated to die each year in traffic crashes, with several million suffering serious injuries (WHO, 2020). Beyond fatalities, the burden of lifelong disability among non-motorized users highlights the public health impact (Abrahams et al., 2021; European Commission, 2021).

Cycling casualties, much like other traffic crashes, result from multiple interacting factors. While vehicle and infrastructure aspects are relevant, behavioral issues have gained increasing attention (Mölenberg et al., 2019; Oviedo-Trespalacios et al., 2026; Useche et al., 2019a). Both deliberate violations and unintentional errors are considered reliable predictors of crash involvement (Hamann & Peek-Asa, 2017; NHTSA, 2018). Traditionally, demographic variables such as age, gender, and education have been used as predictors (Li et al., 2021; Wang et al., 2022). However, psychosocial factors are increasingly recognized as central for understanding cyclists' safety, including risk perception (Useche et al., 2019a), traffic rule knowledge (O'Hern et al., 2021), cycling anger (Stephens et al., 2020), and personality traits (Zheng et al., 2019).

1.1. Key gaps in personality and cycling safety research

Despite progress, the psychological study of cyclists remains underdeveloped compared to driver-focused research (Af Wåhlberg & Dorn, 2015). Studies have called for greater attention to the role of personality in cycling safety and its links to behavior and crash risk (O'Hern et al., 2020, 2025; Stelling-Konczak et al., 2017; Zheng et al., 2019). Three limitations stand out:

(a) Most studies are descriptive or correlational, often analyzing traits in isolation. This limits the explanatory scope of personality for predicting crashes (Sârbescu & Rusu, 2021; Dahlen & White, 2006). Personality is rarely studied together with risk perception, rule knowledge, or cycling patterns, despite their relevance (Wang et al., 2018; Zheng et al., 2019).
(b) Findings from driver-based research are frequently extrapolated to cyclists, although their behaviors and contexts differ markedly, reducing ecological validity and contributing to dissemination bias (Af Wåhlberg, Barraclough, & Freeman, 2015).
(c) Moreover, most tools used to assess traits in this context are generic (e.g., NEO-PI-R, BFI), which limits sensitivity to cycling-specific conditions. The literature highlights the need for adapted instruments that better measure behavioral expressions of personality in mobility (Kovaleva et al., 2013; Roberts et al., 2011; Useche, 2025; Zheng et al., 2019).

1.2. Personality traits and emerging constructs

Research typically adopts trait-based models, most prominently the Five Factor Model (FFM; McCrae & John, 1992), also known as OCEAN: openness (O; tendency to be creative, and open-minded), conscientiousness (C; linked with organization, responsibility, and hardworking), extraversion (E; related to outgoingness, sociability, and assertiveness), agreeableness (A; tendency to be cooperative, empathic, and helpful), and neuroticism (N; trend to experience negative emotions). In recent research, some of these traits have been associated with road behaviors, with evidence suggesting links to crash involvement (O'Hern et al., 2020; Zheng et al., 2019).

Beyond the FFM, sensation seeking (SS) has been increasingly studied as a key trait (Zuckerman, 1990, 1994). Defined as the tendency to pursue novel and intense experiences (Möller et al., 1998; Zuckerman, 1971, 1990), SS has been linked to risky behaviors across domains, from extreme sports to substance use (Herrera-Sánchez et al., 2025; Jonah, 1997; Lynne-Landsman et al., 2011; Mann et al., 2017). In road safety, its relevance has been recognized for decades (Jonah, 1997), and recent studies highlight its potential explanatory value in cycling risk-taking (Gamble & Walker, 2016; Poulos et al., 2015; Stelling-Konczak et al., 2017; Twisk et al., 2021).

However, empirical evidence on SS in cycling safety remains limited. Some findings suggest differences between recreational, sport, and utilitarian riders are not clear-cut (DuRoy, 2000; Kesenheimer et al., 2023; Poulos et al., 2015). What seems more consistent is that higher SS is associated with greater risk propensity, including faster riding and greater involvement in distractions and risky behaviors (Stelling-Konczak et al., 2017; Twisk et al., 2021; Useche, Traficante, Llamazares, & Marin, 2025).

1.3. The present study

This study applies the FFM (McCrae & John, 1992) along with SS to explore their joint contribution to cycling safety. While the FFM provides a robust and validated framework across cultures (McCrae, 2000; Vedel et al., 2021), SS represents a relevant but understudied trait in this context (DuRoy, 2000; Useche, Alonso, & O'Hern, 2025). Using a large multinational sample, we tested how these personality dimensions relate to cycling behaviors and self-reported crashes, with the aim of extending current evidence on the psychosocial correlates of cycling safety. Therefore, this study adds an SS measure to the typical Big Five trait framework to examine the roles of both traditional and emerging personality factors in cycling safety outcomes.

1.4. Objectives and hypotheses

This study had two objectives: (a) to examine the relationships among FFM traits, cycling behaviors, and self-reported cycling crashes in a multinational sample; and (b) to assess the predictive value of SS, an emerging construct in cycling safety, for risky and positive road behaviors.

Based on prior literature, we formulated four hypotheses:

Hypothesis 1. Risky behaviors (i.e., traffic violations and riding errors) would show significant bivariate associations with FFM traits, as well as with SS.

Hypothesis 2. SS would significantly predict cyclists' involvement in road conflicts, approached here through verbal and physical anger expressions toward other road users.

Hypothesis 3. SS and risk perception, although inversely covarying, would both act as direct predictors of risky and protective cycling behaviors.

Hypothesis 4. Scores on personality traits, specifically extraversion, neuroticism, and SS, would differ significantly between cyclists who reported crashes and those who did not over the past five years.

2. Methods

2.1. Participants

This cross-sectional study analyzed data provided by cyclists from 17 countries. A convenience, non-probabilistic sampling design was used, and participants completed an electronic survey. Potential respondents were contacted by e-mail invitations sent to approximately 13,000 individuals. Each invitation included a letter describing the project's scientific aim, voluntary nature, inclusion/exclusion criteria, and instructions for participation (i.e., completing an anonymous online questionnaire).

Eligibility criteria required participants to: (a) cycle more than once per month; (b) have basic literacy to understand the questionnaire; and (c) have access to a smartphone, tablet, or computer with an internet connection. To maximize coverage and compatibility across countries, the questionnaire was standardized in a web-based format adaptable to different devices and operating systems.

The response rate was estimated at 45%. From the original dataset, 230 incomplete responses (completion rate < 80%), six underage participants, and 14 duplicate MAC addresses were excluded. The final sample comprised 5,778 cyclists (M = 34.6 years, SD = 13.6; range = [16–82]). About 58% were male, 41% female, and 1% identified as non-binary.

In terms of safety outcomes, 39% reported at least one cycling crash in the past five years. The average number of self-reported crashes in this period was 0.75 (SD = 1.3), none of them fatal. Additional demographic and cycling-related characteristics are shown in Table 1.

Table 1
Descriptive data on the cycling patterns of the study sample.

Feature	Category	Frequency	Percentage
Cycling purpose(s)	For daily commuting	2,981	51.6%
	For sport/exercise or fitness	3,256	56.4%
	As part of their job	1,175	20.3%
	For making a short trip to a specific point in the city	3,962	68.6%
	For leisure ("go for a ride")	4,399	76.1%
Hours spent cycling in a week	<1 h	1,164	20.1%
	1–5 h	2,350	40.7%
	6–10 h	1,506	26.1%
	11–15 h	344	6%
	16–20 h	115	2%
	>20 h	95	1.6%
	Does not respond / NR	204	3.5%
Average length of the most common cycling trip	0–15 min	974	16.9%
	16–30 min	1,873	32.4%
	31–45 min	878	15.2%
	46–60 min	788	13.6%
	>60 min	1,000	17.4%
	Does not respond / NR	265	4.6%
Self-reported number of cycling crashes (last 5 years)	0	3,355	58.1%
	1	1,249	21.6%
	2	502	8.7%
	3	218	3.8%
	4	88	1.5%
	5 or more	157	2.7%
	Does not respond / NR	209	3.6%

2.2. Description of the questionnaire and study variables

The questionnaire used in this study consisted of four main sections. The scales, subscales, key indexes, and the translation–retranslation process are described below:

Section 1. Demographics and cycling-related variables. Participants reported demographic information including age, gender, country of residence, education, and occupation. Cycling-related questions addressed riding habits, such as average weekly hours of cycling and typical trip length. Respondents also self-reported cycling crashes (regardless of severity) experienced in the previous five years.

Section 2. Cycling behavior. Self-reported cycling behaviors were assessed with the validated Cycling Behavior Questionnaire (CBQ; Useche, Montoro, Cendales, & Tomas, 2018). The CBQ measures risky behaviors (errors and violations) as well as positive or protective riding behaviors.

It is a frequency-based Likert-type instrument composed of 29 items scored on a 5-point scale (0 = never, 4 = almost always). The three subscales are: Traffic Violations (8 items; CRI = 0.981; α = 0.768; ω = 0.770), Errors (15 items; CRI = 0.994; α = 0.914; ω = 0.913), and Positive Behaviors (6 items; CRI = 0.983; α = 0.785; ω = 0.782). Factor scores are calculated by averaging items 1–8 (violations), 9–23 (errors), and 24–29 (positive behaviors). Further psychometric properties, including reliability and validity evidence, are provided in Useche et al., 2019, 2022.

Section 3. Personality traits. Personality was assessed using two instruments:

Big Five Inventory – short version (BFI-S). This 15-item Likert-type scale was designed for large surveys (Gerlitz & Schupp, 2005; Lang, 2011). It measures openness (α = 0.631), conscientiousness (α = 0.602), extraversion (α = 0.665), agreeableness (α = 0.603), and neuroticism (α = 0.613), each with three items on a 7-point scale (1 = strongly disagree, 7 = strongly agree). Following Lang et al. (2011), negatively worded items (3, 6, 10, 14) were reverse coded. Trait scores were computed by averaging the corresponding three items: neuroticism (1–3), extraversion (4–6), openness (7–9), agreeableness (10–12), and conscientiousness (13–15).

Sensation Seeking in Cycling scale (SSC; Useche, 2025). This 13-item Likert-type scale evaluates the degree to which cyclists find gratification in behaviors or situations typical of cycling (e.g., riding at high speed). Responses range from 0 (never/hardly ever) to 4 (almost always/always). The SSC can be scored as a unidimensional measure (α = 0.757, ω = 0.760) or through two subscales: Risk assumptions/behavioral expressions (7 items; α = 0.914, ω = 0.913) and Attitudinal issues (6 items; α = 0.914, ω = 0.913). Subscale and total scores are obtained by averaging the respective items.

Section 4. Concurrent variables. Two additional constructs theoretically related to personality were included:

Risk perception. Measured with the 7-item Risk Perception subscale of the Risk Perception and Regulation Scale (RPRS; Useche et al., 2018). The full RPRS consists of 12 items assessing knowledge of traffic laws (F1: 5 items; α = 0.753, ω = 0.751) and risk perception (F2: 7 items; α = 0.757, ω = 0.760). Items are rated from 0 (no knowledge/risk perceived) to 4 (highest knowledge/risk perceived). For this study, only the risk perception subscale was used.

Cycling anger expressions. Evaluated using the Cycling Anger Expressions Questionnaire (CAX; Møller & Haustein, 2017). This 14-item instrument asks about aggressive responses in traffic over the past 12 months. For this study, we used two subscales: Physical aggression (items 1–3; α = 0.812, ω = 0.817) and Verbal aggression (items 4–9; α = 0.835, ω = 0.831). Each item is rated from 0 (never) to 4 (very often), and subscale scores are computed by averaging responses.

Translation process

To enhance clarity and comparability across countries, the questionnaire was translated into each region's main language(s) by research staff with experience in traffic psychology. A translation-retranslation procedure was applied, with back-translation into English reviewed and approved by senior researchers (all tenure-track or senior-level academics). This process aimed to preserve consistency and conceptual equivalence. The final set of languages used and the platforms for distribution are summarized in Table 2.

2.3. Ethics

The research protocol was reviewed and approved by the Ethics Committee at the University of Valencia (Spain), in accordance with the Declaration of Helsinki.

All participants read and electronically signed an informed consent form outlining the study procedures, participation dynamics, and ethical considerations prior to enrollment. No personally identifiable information was collected, and all responses were treated anonymously.

2.4. Data processing

After data curation, study variables were calculated according to the scoring procedures recommended in their original validation sources: the *Cycling Behavior Questionnaire* (CBQ; Useche et al., 2018, 2022), the *Risk Perception and Regulation Scale* (RPRS; Useche et al., 2018), the *Sensation Seeking in Cycling* scale (SSC; Useche, 2025; Useche et al., 2025a), the *Big Five Inventory – Short version* (BFI-S; Gerlitz & Schupp, 2005), and the *Cycling Anger Expressions Questionnaire* (CAX; Møller & Haustein, 2017). Cycling patterns and trip-related indicators were expressed in standard units (e.g., minutes/hours, days per week) to facilitate interpretation.

To test *Hypothesis 1,* correlations were used to analyze associations between personality traits, behavioral outcomes, and self-reported cycling crashes.

For *Hypotheses 2 and 3*, path analyses were conducted using models A and B. As recommended in questionnaire-based research to address multivariate non-normality and heteroscedasticity (Brown, 2015; Byrne, 2010), maximum likelihood bias-corrected (bootstrapped) estimations were performed with 2,000 bootstrap samples and 95% confidence intervals. Path directionality was theoretically defined, making the procedure confirmatory.

Model fit was evaluated using incremental indexes (NFI, RFI, CFI, TLI, IFI) and RMSEA. Following common cut-off criteria, values > 0.900 for incremental indexes and < 0.080 for RMSEA were considered acceptable, alongside theoretical plausibility (Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004; Miles & Shevlin, 2007). Statistical significance thresholds were set at $p < 0.001$, $p < 0.010$, and $p < 0.050$.

For *Hypothesis 4*, Welch's tests (robust t-based comparisons) were applied to compare group means (cyclists with vs. without crashes), as assumptions of multivariate normality and homogeneity of variances were not fully met and group sizes were unequal.

All descriptive and comparative analyses were conducted in IBM SPSS Statistics 28.0. Path analyses were performed in IBM SPSS AMOS 28.0.

Table 2
Basic questionnaire features in the 17 countries involved in the study.

Country	Participants	Language(s)	Platform
Austria	131	German	Google forms
Belgium	342	Dutch	Google forms
Brazil	226	Portuguese	Google forms
Chile	303	Spanish	Google forms
China	541	Chinese	Wenjuanxing
Colombia	603	Spanish	Google forms
Denmark	576	Danish	SurveyXact
Dominican Republic	386	Spanish	Google forms
Finland	213	Finnish	Google forms
Germany	458	German	Google forms
Malaysia	183	Malay	Google forms
Mexico	330	Spanish	Google forms
Poland	116	English & Polish	Google forms
Russia	374	Russian	Google forms
Slovakia	233	Slovak	Google forms
Spain	335	Spanish	Google forms
United Kingdom	428	English	Google forms

3. Results

3.1. Descriptive statistics and correlation analysis

Descriptive statistics for all measured variables are summarized in Table 3, grouped by variable blocks. Measurement scales are indicated in a footnote for interpretation. Overall, the six personality traits included in the FFM + SS framework showed average values compared with previous applications in the general population (see Lang et al., 2011).

Table 3 also reports the full set of bivariate correlations. Several statistically significant associations between personality factors and risky cycling behaviors were found, although some were small in magnitude. Traffic violations (i.e., deliberate risky behaviors) were positively associated with neuroticism (N; $\rho = 0.041$**, very small in magnitude) and Sensation Seeking (SS; $\rho = 0.475$**). In contrast, violations correlated negatively with conscientiousness (C; $\rho = -.130$**) and agreeableness (A; $\rho = -.139$**).

For riding errors (i.e., unintentional risky behaviors), significant positive correlations were found with neuroticism (N; $\rho = 0.156$**) and SS ($\rho = 0.441$**), while negative correlations appeared with openness (O; $\rho = -.122$**) and agreeableness (A; $\rho = -.209$**). Overall, the strongest bivariate associations involved SS, which also correlated positively with self-reported cycling crashes.

3.2. Path analysis

To test *Hypotheses 2 and 3*, two theoretically based path models were built.

Model A assessed the effect of SS on self-reported verbal and physical anger expressions toward other road users, considered in this study as an indicator of road conflict involvement. The model showed an adequate fit: $\chi^2 = 195.167$, $p < 0.001$; NFI = 0.961; RFI = 0.905; CFI = 0.961; TLI = 0.906; IFI = 0.961; RMSEA = 0.079, 90% CI [.055–.103].

Model B included SS and risk perception as covarying predictors of traffic violations, errors, and positive cycling behaviors. After modeling the covariance between the predictors, fit indices were: $\chi^2 = 35.990$, $p < 0.001$; NFI = 0.995; RFI = 0.947; CFI = 0.994; TLI = 0.948; IFI = 0.995; RMSEA = 0.078, 90% CI [.057–.101].

Both models were retained based on theoretical plausibility and acceptable fit indices. As described in the data analysis section, bias-corrected bootstrapping (2,000 samples) was applied to reduce estimation bias and Type I error risk. Standardized coefficients are presented in Table 4, with graphical representations in Figs. 1 and 2. Solid arrows indicate significant predictive relationships.

In *Model A* (Fig. 1), both paths (SS → verbal anger expressions; SS → physical anger expressions) were positive and significant at $p < 0.001$, indicating that SS strongly predicts both outcomes.

In *Model B* (Fig. 2), all six hypothesized paths were significant. On the one hand, higher risk perception predicted fewer violations ($\beta = -.136$) and errors ($\beta = -.218$), and more protective behaviors ($\beta = 0.448$). In contrast, higher SS predicted more violations ($\beta = 0.489$) and errors ($\beta = 0.354$), but fewer protective behaviors ($\beta = -.162$). On the other, risk perception and SS exerted opposite influences on behavior. Remarkably, the predictive effects of SS on risky behaviors were larger than those of risk perception, whereas the positive influence of risk perception on protective behaviors exceeded the negative effect of SS.

Table 3
Means, standard deviations, and bivariate correlation coefficients (ρ) between study variables, segmented according to their blocks.

	Variable	M[1]	SD[2]	1[a]	2[a]	3[a]	4[a]	5[a]	6[b]	7[b]	8[b]	9[b]	10[b]	11[b]	12[b]
	Personality traits														
1	Openness (O)	4.51	1.52	–-											
2	Conscientiousness (C)	4.74	1.12	0.469**	–-										
3	Extraversion (E)	4.11	1.32	0.256**	0.207**	–-									
4	Agreeableness (A)	4.80	1.09	0.434**	0.500**	0.168**	–-								
5	Neuroticism (N)	3.50	1.19	−0.019	−0.175**	−0.100**	−0.131**	–-							
6	Sensation Seeking (SS)	1.04	0.58	0.056**	−0.124**	0.043**	−0.089**	0.079**	–-						
	Theoretically-related variables														
7	Risk Perception	3.32	0.66	0.228**	0.312**	0.065**	0.234**	−0.085**	−0.113**	–-					
8	Verbal Anger Expressions	2.06	0.91	0.071**	−0.050**	0.067**	−0.182**	0.098**	0.319**	−0.021	–-				
9	Physical Anger Expressions	1.44	0.62	−0.132**	−0.249**	−0.034*	−0.289**	0.132**	0.404**	−0.278**	0.476**	–-			
	Cycling behavior and safety outcomes														
10	Traffic Violations	0.70	0.58	−0.019	−0.130**	0.021	−0.139**	0.041**	0.475**	−0.193**	0.258**	0.397**	–-		
11	Riding Errors	0.49	0.53	−0.122**	−0.208**	−0.027	−0.209**	0.156**	0.361**	−0.260**	0.232**	0.441**	0.640**	–-	
12	Positive Behaviors	2.97	0.83	0.176**	0.215**	0.027	0.224**	−0.048**	−0.149**	0.461**	−0.127**	−0.227**	−0.249**	−0.222**	–-
13	Cycling Crashes	0.75	1.30	0.008	−0.049**	−0.019	−0.098**	−0.030*	0.206**	−0.062**	0.199**	0.209**	0.296**	0.296**	−0.142**

Notes: ** Correlation is significant at $p < 0.001$ level (2-tailed); * Correlation is significant at $p < 0.050$ level (2-tailed); [1] M = Arithmetic mean; [2] SD= Standard deviation; [a] Scale = 1–7; [b] Scale = 0–4.

3.3. *Mean differences in personality traits: Crashed vs. non-crashed cyclists*

Hypothesis 4 proposed that cyclists who reported crashes in the past five years would differ in certain personality traits compared with those who did not. To test this, robust mean comparisons were conducted between cyclists with crashes (Group 1; n = 2,234) and without crashes (Group 2; n = 3,335). Results, including effect sizes (η^2, ω^2) and significance levels, are summarized in Table 5.

Three of the six traits examined showed significant group differences, partially supporting Hypothesis 4. Cyclists who reported crashes scored lower on agreeableness (A), and higher on openness (O) and SS. These trends are also illustrated in Fig. 3.

Regarding effect sizes, the smallest difference was observed in agreeableness. In contrast, differences in openness and SS showed stronger effects, with SS presenting the largest effect size among all traits analyzed.

4. Discussion

This study examined the relationships among personality traits, cycling behaviors, and self-reported crashes, and tested the predictive role of Sensation Seeking (SS) in risky and positive riding behaviors. Overall, the findings add meaningful insights to a still limited body of research addressing personality and safety among cyclists. To facilitate readability, the discussion is organized by hypotheses.

4.1. *Associations between personality traits and risky behavioral outcomes*

Hypothesis 1 proposed that certain personality traits, based on McCrae and John's (1992) Five Factor Model, would show significant bivariate associations with risky cycling behaviors. The data supported this assumption, in line with previous studies that have analyzed similar relationships in cyclist populations.

O'Hern et al. (2020) reported that conscientiousness and agreeableness were negatively associated with self-reported risky behaviors, including both violations and errors. The present results are largely consistent with those findings, although some differences emerged. For instance, in this study, neuroticism correlated positively with both errors and violations, whereas O'Hern et al. (2020) found a non-significant relationship with errors. Similarly, openness showed a significant negative correlation with errors here, while it was non-significant in the previous study.

These discrepancies may relate to differences in study contexts and sample characteristics. O'Hern et al. (2020) analyzed data from 615 Australian cyclists, whereas this study included 5,778 participants from 17 countries. The larger and more heterogeneous sample may have increased the statistical detection of weak correlations (Kaplan et al., 2014), so some significant bivariate associations should be interpreted cautiously. Cultural factors may also contribute, as suggested by Bleidorn et al. (2019) and Triandis and Suh (2002), who noted that inter-factor correlations (e.g., between agreeableness and conscientiousness) can vary across cultures due to stronger social norms and interpersonal harmony.

Across all traits, SS nevertheless remained the clearest and most consistent correlate of risky cycling behaviors and crash-related outcomes in this study, which is in line with previous work identifying this construct as a relevant psychological factor in cycling safety (Poulos et al., 2015; Zheng et al., 2019).

4.2. *Sensation Seeking, aggression, and road conflict involvement*

Consistent with *Hypothesis 2*, higher SS scores significantly predicted stronger self-reported verbal and physical anger expressions toward other road users. Accordingly, the literature supports that anger

Table 4
Variables included in the model, estimates, significance levels, and 95% confidence intervals for bootstrap bias-corrected values of the path models A and B.

Study variable			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]
Model A: Sensation Seeking as predictor of anger expressions											
Sensation Seeking	→	Verbal Anger Expressions	0.319	0.020	25.625	***	0.319	0.019	0.300	0.339	***
Sensation Seeking	→	Physical Anger Expressions	0.404	0.013	33.603	***	0.404	0.010	0.386	0.422	***
Model B: Risk perception and Sensation Seeking as predictors of cycling behaviors											
Sensation Seeking	→	Traffic Violations	0.489	0.011	43.324	***	0.489	0.010	0.472	0.506	***
Sensation Seeking	→	Errors	0.354	0.011	29.662	***	0.354	0.011	0.335	0.372	***
Sensation Seeking	→	Positive Behaviors	−0.162	0.017	−9.687	***	−0.113	0.015	−0.134	−0.096	***
Risk Perception	→	Traffic Violations	−0.136	0.010	−12.011	***	−0.136	0.009	−0.154	−0.118	***
Risk Perception	→	Errors	−0.218	0.009	−18.282	***	−0.218	0.008	−0.237	−0.198	***
Risk Perception	→	Positive Behaviors	0.448	0.015	38.399	***	0.448	0.015	0.431	0.465	***

Notes: [a] SPC= Standardized Path Coefficients (can be interpreted as β-linear regression weights); [b] S.E.= Standard Error; [c] CR= Critical Ratio; [d] p-value: *significant at the level $p < 0.050$; **significant at the level $p < 0.010$; ***significant at the level $p < 0.001$; [e] Bootstrapped (bias-corrected) model; [f] Bootstrapped (bias-corrected) model standardized estimates; [g] Confidence Interval at the level 95% (lower bound – left; upper bound – right).

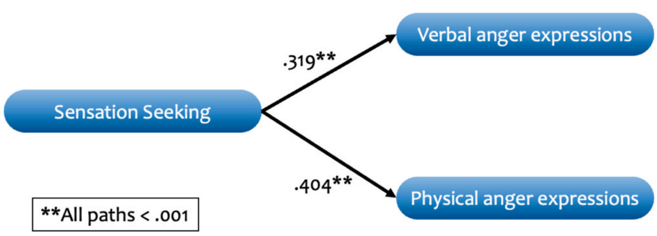

Fig. 1. Model A – Standardized parameter estimates. Solid lines represent significant paths, and ellipses represent latent variables. Note: All listed estimates in solid lines are significant (as shown in Table 4).

experiences and expressions are among the most common contributors to road conflicts involving cyclists and other two-wheelers (Møller & Haustein, 2017; Oehl, Brandenburg, & Huemer, 2019; Wood et al., 2009).

Previous research indicates that sensation seeking influences decision-making in both individual and social contexts (Gianfranchi et al., 2017). Studies focusing on cyclists have mainly reported correlational associations between higher SS and greater anger expression (Marín-Puchades et al., 2017; Zheng et al., 2019). The present results extend that evidence, showing consistent and significant relationships through both correlational and path analyses.

SS also showed the most consistent pattern of association with risky behaviors and crash-related outcomes across analyses. This pattern may be explained by the motivational tendency of high sensation seekers to pursue novel and stimulating experiences (Charnigo et al., 2013; Mann et al., 2017). Consequently, their greater impulsivity and sensitivity to

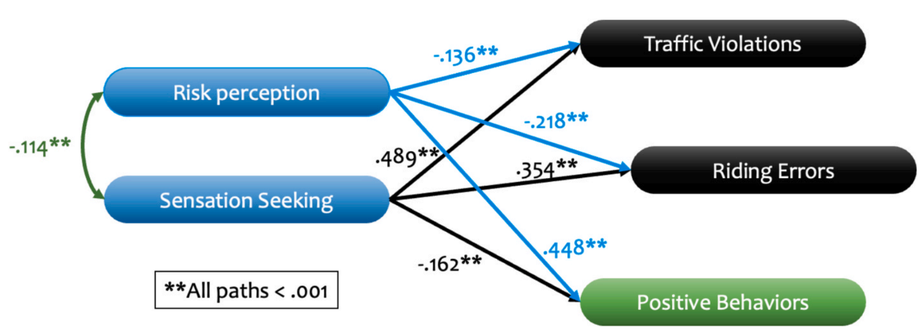

Fig. 2. Model B – Standardized parameter estimates. Solid lines represent significant paths, bi-directional arrows indicate variable covariances, and ellipses represent latent variables. Note: All listed estimates in solid lines are significant (as shown in Table 4).

Table 5
Welch's robust mean comparisons. Categorical factor: Cycling crash involvement in 5 years (dichotomized).

Variable	Group	M	SD	Statistic[a]	df1/df2[b]	η^2	ω^2	Sig.
Openness (O)	Non-crashed	4.43	1.55	26.021	1/4963.692	0.005	0.004	***
	Crashed	4.64	1.44					
Conscientiousness (C)	Non-crashed	4.73	1.15	0.599	1/4953.612	0.000	0.000	0.439
	Crashed	4.76	1.07					
Extraversion (E)	Non-crashed	4.12	1.31	0.182	1/4658.930	0.000	0.000	0.669
	Crashed	4.10	1.33					
Agreeableness (A)	Non-crashed	4.83	1.11	5.564	1/4728.070	0.001	0.001	*
	Crashed	4.76	1.05					
Neuroticism (N)	Non-crashed	3.50	1.18	0.139	1/4693.747	0.000	0.000	0.709
	Crashed	3.51	1.20					
Sensation Seeking (SS)	Non-crashed	0.96	0.55	165.667	1/4563.831	0.029	0.029	***
	Crashed	1.16	0.59					

Notes: [a]Asymptotically *F* distributed; [b]df = Degrees of freedom; *The difference is significant at the level < 0.050; η^2 = Eta-squared coefficient; ω^2= Omega-squared fixed-effect; ***The difference is significant at the level < 0.001.

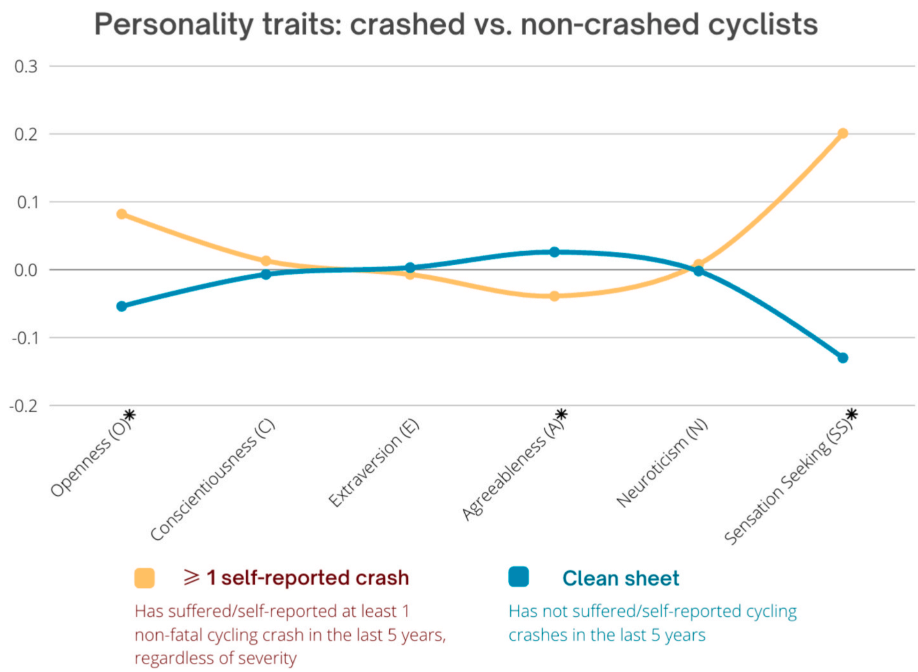

Fig. 3. Personality traits' mean differences between crashed (n = 2,234) and non-crashed cyclists (n = 3,335). *Notes:* Axis *Y* (left column) is graphically scaled in standard deviations to favor fair comparability; *Asterisks represent statistically significant differences.

external stimuli may be linked to higher risk-taking and frustration in traffic interactions, especially in contexts involving conflicts with other road users such as drivers or pedestrians (Møller & Haustein, 2017; Oehl, Brandenburg, & Huemer, 2019).

4.3. *Sensation seeking covariations: Risk perception and cycling behavioral outcomes*

Regarding *Hypothesis 3*, results from path Model B supported a negative covariance between SS and risk perception. Although this relationship has not been examined previously among cyclists, evidence from other contexts is consistent with this finding. Ulleberg and Rundmo (2003) observed similar patterns among young drivers, showing that both SS and low risk perception have been shown to be consistent contributors to deliberate risky driving. Likewise, MacPherson et al. (2010) and Hittner, Warner, and Swickert (2016) reported that individuals high in SS tend to perceive lower risks in potentially harmful situations.

In the current study, this negative and significant association was supported by both bivariate and path analyses, suggesting that risk perception may act as a mediating mechanism between SS and cycling behaviors. However, two methodological constraints prevented a mediation test. First, the lack of prior studies specifically examining this relationship limits its confirmatory basis (Marsh et al., 2014; Nasaescu et al., 2020; Useche et al., 2025b). Second, SS showed stronger predictive effects on risky behaviors than risk perception (as reflected in the β coefficients), making a formal mediation model statistically redundant.

This association aligns with previous evidence from Jonah (1997) and Zuckerman (1990), who proposed that high sensation seekers either underestimate or accept risk for the thrill it provides. Subsequent studies in other road user groups have supported this view (Dahlen & White, 2006; Gianfranchi et al., 2017).

4.4. *Personality traits and cycling crash involvement*

Hypothesis 4 anticipated significant mean differences in specific personality traits between cyclists who reported crashes and those who did not. Welch's test results supported this assumption: cyclists with crashes scored lower on agreeableness and higher on openness and SS.

These findings suggest that cyclists involved in crashes tend to be less agreeable, more open to experience, and higher in SS. This combination of traits may be theoretically meaningful. Individuals low in agreeableness often show reduced empathy and conflict management skills and are more prone to interpersonal disagreements (Laursen et al., 2002; Ode & Robinson, 2007). This aligns with the negative correlations found here between agreeableness and both verbal and physical anger expressions ($\rho = -.182^{**}$).

Cyclists higher in openness may experience greater risk exposure due to higher mobility and activity levels. Indeed, openness has been linked to healthier, more active lifestyles and greater use of alternative transport modes (Roos, Sprei, & Holmberg, 2022; Zolotareva et al., 2022). Openness and SS, while distinct constructs (Zuckerman, 1990), are often positively correlated (as also observed here), suggesting some shared underlying tendencies.

Finally, SS showed the largest group difference and effect size, supporting its role as the personality-related variable most consistently linked to behavioral and crash-related outcomes in this study. Although these results are theoretically coherent, they should be interpreted with caution, particularly because some associations observed in the broader correlational analysis were modest in magnitude.

4.5. *Limitations of the study and further research*

Although this study used a considerably sizeable and multi-country sample, some key limitations should be acknowledged.

First, despite its broad coverage, the study used a convenience, non-probabilistic sampling method based on participants' accessibility and willingness to participate rather than random selection. Therefore, the sample cannot be considered fully representative of the global cycling population. Previous large-scale studies have also noted this limitation, highlighting the potential influence of individual and cultural factors on mobility patterns and behaviors (Oviedo-Trespalacios et al., 2021). Increasing the participation of older cyclists in future research could also help clarify how age-related factors may covary with personality traits.

Second, although anonymity was ensured, the cross-sectional design remains susceptible to common method bias and self-report limitations such as recall errors (Af Wåhlberg & Dorn, 2015; Selaya et al., 2024; Vrij et al., 2025). While self-reports are standard tools for assessing personality and behavioral variables, complementary data sources or mixed-method approaches could help validate the information collected. Additionally, the sample composition leaves certain points unclear (e.g., how many of the 20.3% of job-related cyclists were delivery riders or bike messengers), which could influence the interpretation of some results (see Oviedo-Trespalacios et al., 2022; Useche et al., 2024, 2026).

Third, the crash indicator used (i.e., cycling crashes within the past five years) did not account for crash severity. Although the consequences of crashes can vary, severe cases are often linked to situational and contextual factors (Abrahams et al., 2021; Ruiz-Pérez & Becerra-Vargas, 2025). Moreover, the study did not differentiate crash typologies (e.g., single, bicycle–car, or bicycle–pedestrian collisions), despite evidence suggesting their distinct research relevance (Schepers, 2013). Future research could address these distinctions to better understand how SS relates to different crash types, severity levels, and contextual features.

Another relevant consideration is that personality traits are known to vary across time and social contexts. They are influenced by social change, age, and cultural values (Bleidorn et al., 2019). Consequently, the findings of this study likely reflect the current sociocultural context and may require reevaluation in future decades. This temporal variability may also explain slight differences in correlation magnitudes compared to earlier studies conducted in different settings (Aluja et al., 2003, 2005; Di Plinio, 2022; O'Hern et al., 2020).

Regarding future research directions, existing literature has already examined related aspects of cyclist safety, such as helmet use (Gamble & Walker, 2016), road conflicts (Gössling, 2022; Paschalidis et al., 2022), and pre-crash and crash involvement (Zheng et al., 2019). Adaptations of driving-related measures –e.g., the Driving Anger Scale (DAS; Deffenbacher, Oetting, & Lynch, 1994) and the Driving Anger Expression Inventory (DAX; Deffenbacher et al., 2002)– have proven useful in cycling contexts, as reflected in the Cycling Anger Scale (Oehl, Brandenburg, & Huemer, 2019) and the Cycling Anger Expression Inventory (CAX; Møller & Haustein, 2017). However, specific instruments designed to assess personality-related constructs in cyclists are still lacking.

Further research should examine these associations through longitudinal and cross-cultural designs (Zuckerman, 1994; Zuckerman et al., 1978). Since personality–behavior correlations may not operate in the same way across settings, future studies could also incorporate country-level moderators to assess whether sociocultural variation is associated with differences in the links between personality traits, cycling behaviors, and safety outcomes (Bleidorn et al., 2019; McCrae & Costa, 1997; Mõttus et al., 2006).

5. Conclusion

This research represents a pioneering multi-country examination of the relationships among personality traits, self-reported cycling behaviors, and cycling crashes. Based on the tested hypotheses and corresponding findings, the main conclusions can be summarized as follows:

Most personality traits from the FFM showed significant bivariate associations with risky cycling behaviors. Zuckerman's SS also correlated strongly with these outcomes and exhibited the highest effect magnitude among all traits examined.

Cyclists scoring high on SS reported greater involvement in both verbal and physical anger expressions toward other road users, interpreted here as indicators of road conflict.

SS consistently covaried with risk perception in explaining both risky and positive cycling behaviors. Considering the relative stability of personality traits, these findings suggest that related and potentially more malleable factors, such as risk perception, may be worth considering when designing interventions aimed at reducing risky cycling behaviors.

Regarding crash involvement, in addition to SS, two of the five FFM traits (i.e., openness and agreeableness) significantly differentiated cyclists who reported crashes from those who did not. Nonetheless, SS remained the trait showing the largest effect sizes and the most consistent crash-related pattern across analyses.

Overall, the findings suggest that personality is related to self-reported cycling safety outcomes, although not all observed associations were of the same magnitude. The most consistent pattern involved SS, which showed stronger links with risky cycling behaviors, road conflict variables, and crash-related differences than the remaining traits. In turn, the negative association between SS and risk perception supports considering both factors jointly when examining cycling safety outcomes.

CRediT authorship contribution statement

Sergio A. Useche: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francisco Alonso:** Writing – original draft, Validation, Investigation. **Isaac D. Castañeda:** Writing – original draft, Validation, Investigation. **Boris Cendales:** Writing – original draft, Validation, Investigation. **Arturo Cervantes:** Writing – original draft, Validation, Investigation. **Tomas Echiburu:** Writing – original draft, Validation, Investigation. **Mireia Faus:** Validation, Investigation. **Zuleide O. Feitosa:** Writing – original draft, Validation, Investigation. **Javier Gene-Morales:** Writing – original draft, Validation, Investigation. **Victor Gonzalez:** Writing – original draft, Validation, Investigation. **Mohd K. A. Ibrahim:** Writing – original draft, Validation, Investigation. **Kira H. Janstrup:** Writing – original draft, Validation, Investigation. **Rich C. McIlroy:** Writing – original draft, Validation, Investigation. **Mette Møller:** Writing – original draft, Validation, Investigation. **Mauricio Orozco-Fontalvo:** Writing – original draft, Validation, Investigation. **Ksenia Shubenkova:** Writing – original draft, Validation, Investigation. **Felix W. Siebert:** Writing – original draft, Validation, Investigation. **Jose J. Soto:** Writing – original draft, Validation, Investigation. **Amanda N. Stephens:** Writing – original draft, Validation, Investigation. **Yonggang Wang:** Writing – original draft, Validation, Investigation. **Elias S. Willberg:** Writing – original draft, Validation, Investigation. **Philipp Wintersberger:** Writing – original draft, Validation, Investigation. **Linus Zeuwts:** Writing – original draft, Validation, Investigation. **Zarir H. Zulkipli:** Writing – original draft, Validation, Investigation. **Steve O'Hern:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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