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The hidden cost of your 'too fast food': stress-related factors and fatigue predict food delivery riders' occupational crashes

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ABSTRACT

Objectives. For several years, the so-called 'gig economy' has kept transforming urban transportation dynamics. However, the literature has often overlooked the demanding, stressful and safety-compromising conditions under which delivery riders carry out their occupational tasks. This research aimed to examine whether fatigue acts as a mediating mechanism in the complex relationships among job settings, stress-related psychosocial factors at work and the occurrence of occupational traffic crashes among two-wheeled food delivery riders. **Methods.** This cross-sectional study field-surveyed 248 food delivery riders operating across various platforms. Participants responded to a questionnaire on work features, psychosocial factors and occupational safety issues. The data underwent both descriptive analyses and structural equation modeling (SEM). **Results.** As hypothesized, the occupational (riding) crashes of food delivery riders can be largely explained through work-related fatigue, which exerts a full mediation between job settings, stress-related factors and riding safety outcomes. **Conclusions.** These results highlight fatigue as a significant yet overlooked threat in this occupation, emphasizing the need to connect stress-related conditions with safety incidents, a relationship not previously explored among delivery riders. Moreover, our findings stress the necessity for policies and interventions targeting stress and fatigue management to improve occupational health and road safety in the gig economy era.

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delivery riders; occupational crashes; stress; fatigue; psychosocial conditions; gig economy; safety risks

1. Introduction

One of the occupations that has experienced significant global growth in recent years is food delivery services. This surge can be attributed to various factors. Firstly, the rise of digitization and the increased accessibility to goods and services, characteristic of the 'connectivity era' [1]. Secondly, although home delivery services have been available for more than a decade, the demand sharply increased worldwide during the COVID-19 pandemic [2]. Notably, users find the 'contactless nature' of these platforms particularly attractive, a feature frequently emphasized in advertising strategies [3]. Lastly, the affordability of these services is a key factor for users. The commonly low or waived costs by platforms contribute to a favorable cost–benefit ratio, making the utilization of such services appealing [4].

In turn, food delivery jobs within the gig economy bring forth a series of 'collateral effects', the majority of which impact the workers' safety and welfare in both direct (e.g., occupational safety incidents) and indirect (e.g., mid-term and long-term health and lifestyle issues) ways. While these dynamics have been slightly addressed in empirical literature dealing with delivery riders, some early studies underscore different typical risks, negative outcomes and the need for prompt actions aimed at improving their job setting [3,5].

At this level, it is worth highlighting that this kind of job provides economic benefits only when carried out in large quantities and efficiently, establishing the logic of 'work under pressure' where time management is decisive, at all costs, to

guarantee economic benefits [6,7]. This partly explains why the objective occupational risks of this group can be considered higher than those of delivery people in other branches, such as mail, electronics or last-mile parcel delivery workers. However, even though their time frames are usually broader, these are still considered highly demanding jobs [1,7,8].

Moreover, some preliminary studies have outlined negative outcomes concerning safety-related practices among two-wheeled food delivery riders. In a recent Australian study conducted by Oviedo-Trespalacios et al. [9], it was found that using handheld devices, utilizing incorrect lanes and running red lights were relatively common practices among food delivery riders. Similarly, a study in Vietnam highlighted that, besides compromising self-care practices to prevent COVID-19, food delivery riders were prone to engaging in risky road behaviors, particularly under pressure situations [6]. Another study in Vietnam concluded that the nature of the job itself posed a risk, urging industry stakeholders to implement urgent measures to alleviate job strain [10]. Additionally, a study analyzing delivery riders' behavior in running red lights identified attitudes and the traffic environment as significant predictors [11].

As a whole, the work labor settings of food delivery riders have been consistently labeled as 'stressful', attributed to a set of documented job stressors. These include time pressure [12,13], long working/riding shifts [1,6], low rewards – both intrinsic and extrinsic [7,14] – and high levels of both physical and psychological demands [6,15]. Recent studies further suggest that this environment may contribute to an increased

likelihood of riding under states of considerable fatigue, posing risks to their riding performance and safety-related outcomes [9,16,17].

In the Global South, where employment and social conditions have compelled many to join and depend entirely on these jobs, there is limited literature studying their conditions and their impact on urban dynamics, let alone road safety issues. For instance, in Malaysia, official statistics show four fatalities, 55 serious injuries and 73 slight injuries from two food delivery companies in 3 months [7]. The Royal Malaysia Police reported 589 crashes related to these services between January and November 2021, and the Malaysian Society for Occupational Safety and Health stated that fatigue is causing three or four delivery rider crashes per week [18]. On the other hand, the Motorcycle Safety Institute from South Africa reported that at least 70 delivery riders died in that country during the year 2018, even though this figure could be even greater due to common data underreporting issues [19]. In Shanghai, 76 injuries and deaths were recorded, and in Nanjing, China 3000 crashes occurred in the first half of 2017 [20].

Regarding other countries, the available information is primarily derived from newspaper reports on specific cases, as official statistics are typically not public, often biased due to underreporting or simply non-existent. This is the case for Colombia, one of the Latin American countries facing significant employment-related challenges concerning workplace availability, stability, formal hiring and job security [21,22]. Conversely, the road safety panorama in the entire region has not shown improvement over the last few years, coinciding with a considerable increase in road fatality figures [23].

While this phenomenon is relatively common in countries of the Global South [24], it is crucial to highlight that numerous transport-related occupations report high turnover rates, precarious conditions and limited legal protections, especially for less-specialized tasks that do not necessarily require professionalization, tenure or advanced studies [21,25]. Another factor exacerbating this already challenging situation is the significant number of irregular migrants from border countries, most of whom arrive fleeing even more dire economic, political and social conditions [9,26].

Far from making any judgment about the connotations of migratory processes (which is not the role nor the intention of the authors), it is important to note that due to the substantial magnitude of the migratory flow, employability rates for most occupations have seen a dramatic decrease [9,27,28]. This phenomenon has compelled both migrant and local workers to gravitate toward occupations characterized by higher precarity in all terms, exacerbated by the unforeseen growth of the gig economy – an informal term used to describe casual employment through digital platforms [29].

1.1. Study aim and hypothesized model

The core aim of this research was to test whether fatigue serves as a mechanism mediating the multivariate relationships among job settings, stress-related psychosocial factors at work and self-reported occupational traffic crashes experienced by a sample of Colombian food delivery riders.

Previously, these relationships have been explored among various groups of commercial and professional transport-related workers [13,30–33]. However, to the best of our knowledge, the assessment of psychosocial work factors among food

delivery riders has never been empirically conducted in Colombia, as is the case in most Global South countries. This study serves as a valuable baseline contribution for informed policy formulation and the timely establishment of legislation to protect this highly vulnerable workforce.

Bearing in mind the literature-based insights presented in the literature review section, it was initially hypothesized that the need for recovery might mediate the relationships between job tenure, urban insecurity incidents, stress indicators and psychological distress, and, as an outcome, the self-reported number of crashes suffered while riding for work (delivery) reasons. Accordingly, the hypothesized model followed in this study is graphically presented in Figure 1.

2. Methods

2.1. Sample

The sample used for this study was collected from the full sample of 248 two-wheeled food delivery riders working in Bogotá, Colombia (the capital and largest city in the country) using conventional bicycles or motorcycles. The mean age of the sample was 29.05 (*SD* 8.04) years. Regarding riders' sex and bearing in mind the clear genderization of this occupation, 231 (93.1%) of the respondents were men while only 17 (6.9%) of participants were female riders. Regarding self-reported safety outcomes, the average number of occupational crashes suffered by the sample in the last 2 years was 0.34 (*M* 0.24 for motorcycle riders and *M* 0.37 for bike riders), with no significant differences between vehicle types ($F = 1.361$; $p = 0.245$). Further characteristics of the sample are presented in Table 1 in greater detail.

2.2. Procedure

The survey was conducted from September to November 2021 through face-to-face personal interviews in Bogotá, Colombia, administered by trained personnel. Information was collected using a computer-assisted personal interviewing (CAPI) system on tablets, with interviews recorded and geo-referenced to reduce both the interview duration and potential data recording errors. To be eligible for the study, participants had to meet the following inclusion criteria: being an active 'rider', working for at least one gig economy platform specializing in food delivery; being over 18 years old; and using a two-wheeled vehicle for these tasks (no potential participants were found carrying out this occupation in other types of vehicles or on foot).

For this study, population representativeness can be only partially assumed based on a non-probabilistic sampling method, given that: sampling took place following a snowball technique (i.e., a non-probability sampling method in which the subjects count on very specific features that are rather difficult to find using probabilistic methods); the number of workers in this sector is (still) undetermined; and although the number of participants was considerably high in terms of the difficulty of collecting information from a sample of these characteristics, it does not reach a 'prototypical' sample size, which normally exceeds 500 participants for more common occupations.

The average time needed to respond to each CAPI-assisted survey was about 20 min. To avoid potentially biased responses, before starting the survey it was emphasized that

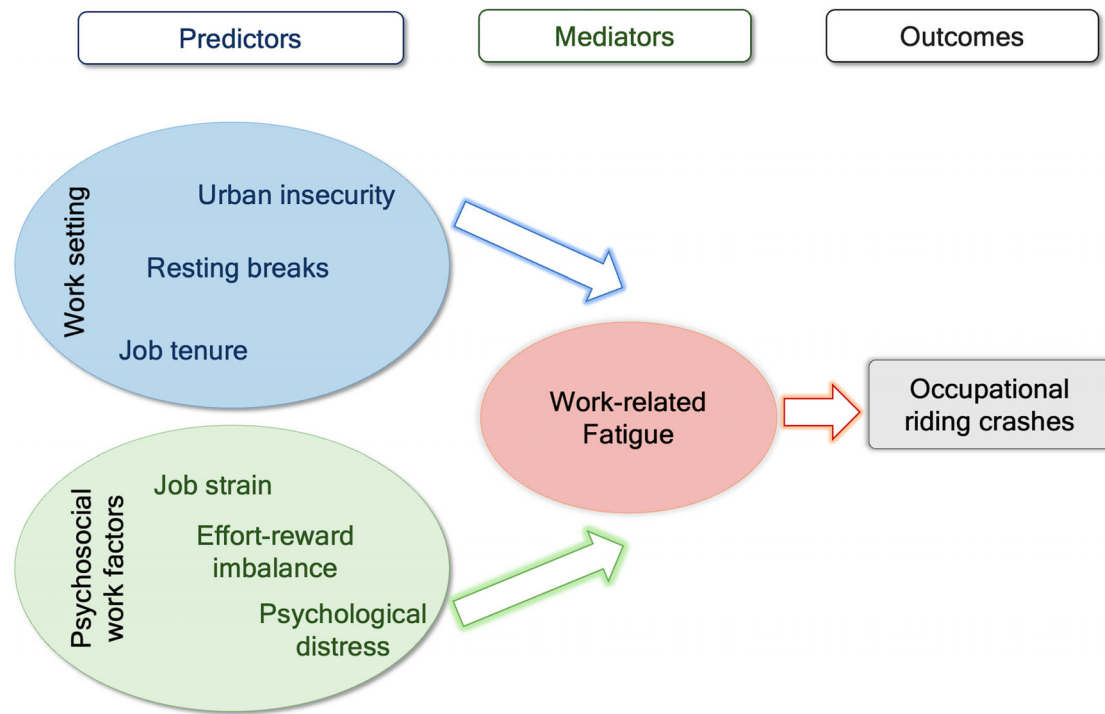


Figure 1. Hypothesized model of the study. Note: Variables are grouped in three blocks: predictors, mediators and outcomes. Ellipses represent inferred (latent) variables; rectangles represent observed variables.

Table 1. Socio-labor sample characteristics.

Variable	Label	Frequency	%
Educational level	Primary or lower	6	2.4
	Secondary	157	63.3
	Technical studies	38	15.3
	Graduate	44	17.7
	Postgraduate	3	1.2
Nationality	Colombian	57	23
	Other (i.e., Venezuelan)	182	77
Socioeconomic strata (household income) ^a	1 (very low)	26	10.6
	2 (low)	137	55.3
	3 (medium-low)	85	34.3
Monthly food delivery-based income	< 1 minimum wage	158	63.7
	1–2 minimum wages	89	35.9
	> 2 minimum wages	1	0.4
Vehicle used for work	Motorcycle	66	26.6
	Bicycle	182	73.4
Multi-platform work	One single platform	208	81.4
	More than one platform	40	19.6
Job tenure	< 1 year	113	45.6
	1–2 years	66	26.6
	2–3 years	39	15.7
	> 3 years	30	12.1

^aSocio-economic stratum is a standardized ordinal indicator used in Colombia to characterize individuals' household income level, ranging from 1 (very low) to 6 (very high).

the data would be exclusively used for statistical research purposes and that participation was anonymous. All participants signed informed consent before partaking in the study. Finally, the response rate was approximately 73%, considering that about 340 riders were initially (*in situ*) invited to participate in the research. Given that the surveys were applied while the riders were waiting for a new delivery service and did take considerable time to answer, as an incentive the raffle of a bicycle was held among the participants. However, 27% of surveys were incomplete as the riders left before finishing (mainly because they received a new assignment), and these were excluded from the analysis.

2.3. Questionnaire contents

The questionnaire was structured into three sections. The first section gathered information about individual socio-labor and demographic variables, such as age, gender, schooling, income level and occupational (work-related) features, as presented in Table 1. The second part of the survey addressed job stress, through two different – although complementary – models: Karasek's [34] demand–control approach and Siegrist's [35] effort–reward imbalance approach.

On the one hand, the 20-item job content questionnaire (JCQ), which is the instrument employed to assess job strain, was used under Karasek's [34] Job Demand-Control (JDC) approach. This questionnaire, in its Spanish version, was initially validated by Gómez [36], and subsequently psychometrically re-evaluated and re-adapted to transport workers by Useche et al. [37]. The JCQ is composed of a total of five sub-scales: F1, skill discretion ($\alpha = 0.633$); F2, decision authority ($\alpha = 0.725$); F3, psychological job demands ($\alpha = 0.886$); F4, supervisor and manager support ($\alpha = 0.983$); F5, coworker support ($\alpha = 0.966$). The job strain index, used as the model's

stress index, is calculated using the next algorithm: $(F3 \times 2) / (F1 + F2)$. Following a dichotomic approach, Job Strain (JS) coefficients larger than 1.0 suggest the occurrence of job strain. Given that it does not affect the calculation of the job strain index and the specificities of the job setting of delivery riders, social support subscales were not considered for the predictive modelling tasks.

On the other hand, the 10-item effort–reward imbalance inventory (ERI) was used to assess riders' effort–reward imbalance, the key index of Siegrist's [35] stress framework. This questionnaire has been previously validated in Spanish and widely used among transport workers [26,27]. Its two key sub-scales are as follows: F1, efforts ($\alpha = 0.759$) and rewards ($\alpha = 0.780$), assuming the ratio (i.e., imbalance) among both factors as a continuous stress indicator.

Work-related fatigue (also known in the literature as 'need for recovery') was assessed by means of the need for recovery (NFR) scale, developed by Sluiter et al. [38]. This self-report questionnaire has been also considerably used among transportation workforces [39,40], showing reasonably good psychometric results, and adequate test–retest reliability and sensitivity insights to test job-related fatigue among various (both specific and generic) conglomerates of workers [39,41]. The internal consistency of this 11-item dichotomous scale usually ranges between $\alpha = 0.678$, and $\alpha = 0.810$ [39,40].

The questionnaire also comprised the short 12-item version of Goldberg's [42] general health questionnaire (GHQ), the questions of which, ranging between 1 and 4, are commonly used to assess the presence and degree of several key symptoms of the global construct of psychological distress ($\alpha = 0.739$).

The last part of the questionnaire inquired into some specific questions related to occupational riding variables, such as current job tenure (measured as 'years working as a delivery rider'), type of vehicle driven at work (see Table 1), daily intensity of riding (hours), days driving a week, having (or not) resting breaks between services, security-related incidents suffered as a rider (i.e., thefts, theft attempts and/or aggressions of any nature) and road safety outcomes, defined for this study as the self-reported number of crashes suffered while on service in the last 2 years.

2.4. Data processing and modeling framework

After a careful data curation process, the study variables were scored. While descriptive demographic and socio-labor categories and numeric values were respectively calculated by means of frequency and central tendency mean-based procedures, latent variables (i.e., psychological distress, work-related fatigue and job stress indexes) were calculated on the basis of the own technical procedures used to score each instrument. For this case, all scales used counted on fixed scoring criteria.

Spearman's ρ bivariate correlation tests were used to assess potential measures of association between pairs of study variables and their significance, given their proven robustness over other similar techniques, including Pearson's (r) association coefficients when variables with an ordinal nature are measured [43,44].

Structural equation modeling (SEM) was used in this research to handle both latent variables and unobserved variables in consideration of potential endogeneity-related bias, thus helping control confounding and residual statistical

effects between correlated factors. Therefore, model estimators were calculated by controlling for age, gender and vehicle type. Further, Monte Carlo (parametric) bias-correcting procedures were used to test the data in absence of multivariate normality, an assumption that is considerably difficult to achieve in behavioral questionnaire-based studies [45,46]. The model was defined by:

$$\eta = \beta\eta + \Gamma\xi + \zeta, \quad (1)$$

where η = vector ($p \times 1$) of endogenous variables; ξ = vector ($q \times 1$) of latent independent variables; Γ = matrix ($p \times q$) of coefficients γ_{ij} that relate the latent independent variables to endogenous variables; β = matrix ($q \times p$) of coefficients that relate each endogenous variable to each other; ζ = vector ($q \times 1$) of errors, also known in specialized literature as 'disturbance terms'. They specify that endogenous variables cannot be perfectly predicted by structural equations, and a margin of error should be assumed [47].

In order to assess the fit of the model to the data, we used a literature-based predefined set of goodness-of-fit (GOF) criteria from different logics and families, i.e., χ^2 statistical test, CMIN/df (minimum discrepancy) ratio (adequate if < 5.0), root mean square error of approximation (RMSEA) (considered suitable if < 0.060) and the following ordinal indexes (optimal values > 0.900): comparative fit index (CFI), normed fit index (NFI) and incremental fit index (IFI), as suggested in specialized sources and by Marsh et al. [48].

The model fit was enhanced whenever possible by pondering the greatest and most parsimonious modification indexes. AMOS version 28.0 was used to carry out SEM, whereas IBM SPSS version 28.0 was used to perform descriptive statistical procedures.

2.5. Ethics

To perform this study, the Ethics Committee of the Research Institute on Traffic and Road Safety was consulted, granting that it responded to the general ethical principles and certified its accordance with the Declaration of Helsinki (IRB: HE0002190321).

Regarding the data collection process, participation was totally anonymous and voluntary. No financial rewards were offered to our study participants. All participants were adults (aged over 18 years) and gave their written consent before participating in the study after the research staff explained the research objectives and dynamics.

3. Results

Table 2 presents the descriptive analysis outcomes (i.e., means and standard deviations of the continuous study factors) and the bivariate correlations between pairs of them. Overall, this analysis allowed us to establish a set of significant and coherent associations between psychosocial work-related factors and self-reported work-traffic crashes. In summary, occupational traffic crashes were positively associated with urban security incidents, effort–reward imbalance (stress indicator), psychological distress and the need for recovery (or work-related fatigue) of delivery riders. There was, however, no significant correlation between job strain and self-reported crashes. The full set of bivariate correlations is presented in Table 2.

Table 2. Bivariate (Spearman's ρ) correlations among psychosocial work-related study variables.

Study variable	Mean (SD)	1	2	3	4	5	6
1 Job tenure (years)	1.94 (1.05)	–	–	–	–	–	–
2 Urban insecurity incidents	1.46 (0.79)	0.122	–	–	–	–	–
3 Effort–reward imbalance	1.07 (0.25)	–0.060	–0.114	–	–	–	–
4 Job strain	1.37 (0.28)	0.024	–0.025	0.112	–	–	–
5 Psychological distress	16.78 (3.75)	–0.034	0.121	0.142*	0.163*	–	–
6 Need for recovery	3.81 (2.47)	0.146*	0.141*	0.222**	0.098	0.190**	–
7 Work traffic crashes	0.35 (0.78)	0.084	0.227**	0.167**	0.091	0.182**	0.205**

*Correlation is significant at the 0.05 level (two-tailed).

**Correlation is significant at the 0.01 level (two-tailed).

Table 3. Variables included in the structural equation model, estimates and significance levels of the SEM paths to explain self-reported traffic crashes suffered by food delivery riders.

Path	SPC	SE	CR	p
Direct effects				
Vehicle ^a → Riding crashes	0.063	0.110	1.016	0.310
Job tenure → Riding crashes	0.051	0.046	0.831	0.406
Resting breaks → Riding crashes	–0.003	0.209	–0.043	0.966
Urban insecurity → Riding crashes	0.161	0.106	2.690	**
Effort–reward imbalance → Riding crashes	0.007	0.186	0.113	0.910
Job strain → Riding crashes	0.056	0.250	0.915	0.360
Psychological distress → Riding crashes	0.177	0.013	2.882	**
Fatigue → Riding crashes	0.170	0.047	2.637	**
Indirect effects				
Vehicle ^a → Fatigue	–0.204	0.149	–1.366	0.172
Job tenure → Fatigue	0.106	0.062	1.778	*
Resting breaks → Fatigue	–0.119	0.283	–2.043	*
Urban insecurity → Fatigue	0.082	0.144	1.377	0.168
Job strain → Fatigue	0.148	0.338	2.461	*
Effort–reward imbalance → Fatigue	0.192	0.248	3.200	**
Psychological distress → Fatigue	0.206	0.017	3.477	***

^aStatistical control – reference category: bicycle rider.

*Significant at the $p < 0.050$ level.

**Significant at the $p < 0.010$ level.

***Significant at the $p < 0.001$ level.

Note: CR = critical ratio; SEM = structural equation modeling; SPC = standardized path coefficients (can be interpreted as β -linear regression weights).

3.1. Structural equation modeling

With a strong foundation in the theoretical framework, which focuses on identifying multivariate relationships and mediating factors that can explain riders' safety outcomes, this study used SEM procedures. The core aim of this type of analysis is to explain a dependent variable (i.e., safety outcomes) in consideration of complex interactions and chain relationships among potential predictors. We used both work-related and psychosocial variables as potential predictors (independent variables).

The resulting structural equation model provides the following indexes: $\chi^2(6) = 8.689$, $p = 0.192$; $CMIN/df = 1.448$; $rmsea = 0.043$, $IC_{90\%} = [0.035, 0.051]$; $NFI = 0.937$; $CFI = 0.973$; $IFI = 0.979$. Overall, the GOF can be assumed as adequate, bearing in mind (apart from the theoretical plausibility of the model) the following fit metrics: $RMSEA \leq 0.060$, $CMIN/df < 5.0$ and all ordinal indexes (i.e., NFI , CFI and IFI) > 0.900 . This is consistent with the pre-defined reference values for GOF acceptability, adopted on a literature basis [30,48].

All standardized path coefficients (SPCs) (standardized parameter estimates) are presented in Table 3 and graphically shown in Figure 2. In this graph, the unidirectional arrows qualitatively specify the direction of each path or explanatory relationship between two variables included in the structural

equation model. In quantitative terms, this model shows that work-related traffic crashes can be explained by means of the interactions among the study variables but through mediated relationships. Therefore, it is based on both direct (see Figure 1) and indirect (see later) effects.

The SPCs (see Table 3 and values next to solid lines in Figure 2) of the model suggest positive associations among independent variables such as the two stress indexes used (ERI and JCQ), psychological distress and fatigue, in relation to the dependent factor, i.e., the self-reported number of work-related crashes suffered while riding. However, most of these relationships seem to be mediated by fatigue, making it necessary to differentiate between direct and indirect effects.

3.2. Direct and indirect structural effects

Regarding direct effects over self-reported occupational riding crashes, and apart from work-related fatigue whose SPC was $\beta = 0.170$ ($p < 0.010$), only two significant direct paths were found in the model, specifically from urban insecurity issues ($\beta = 0.161$; $p < 0.010$) and psychological distress (negative mental health indicator; $\beta = 0.177$; $p < 0.010$), as shown in Figures 2 and 3. However, neither JCQ nor ERI stress indicators,

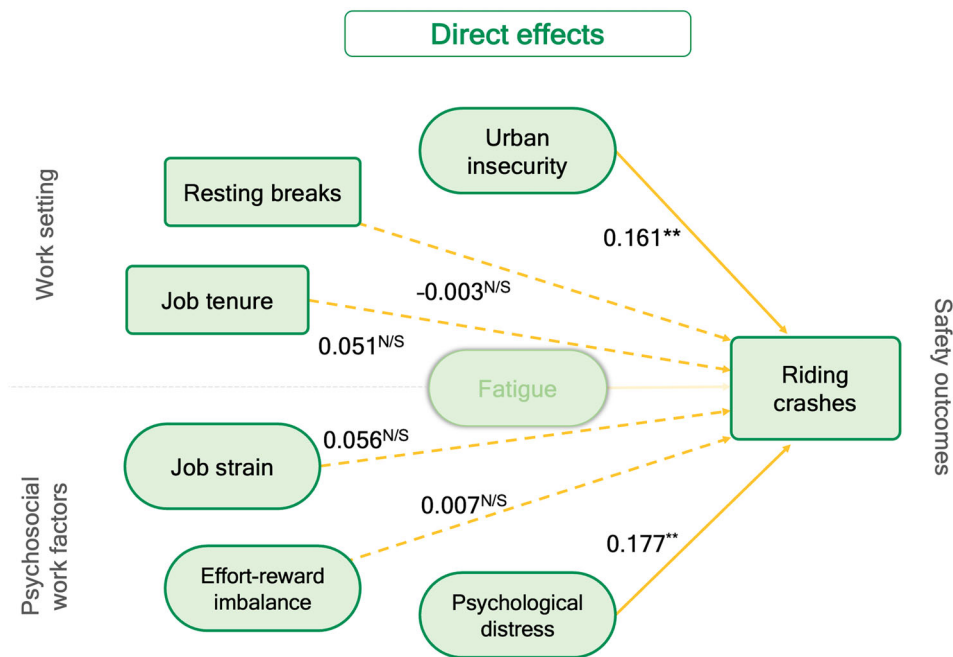


Figure 2. Direct effects – standardized parameter estimates. ** Significant at the $p < 0.010$ level. $^{N/S}$ Not significant. Note: Solid lines represent significant paths. All estimates listed for solid lines are significant (as presented in Table 2). Ellipses represent inferred (latent) variables; rectangles represent observed variables.

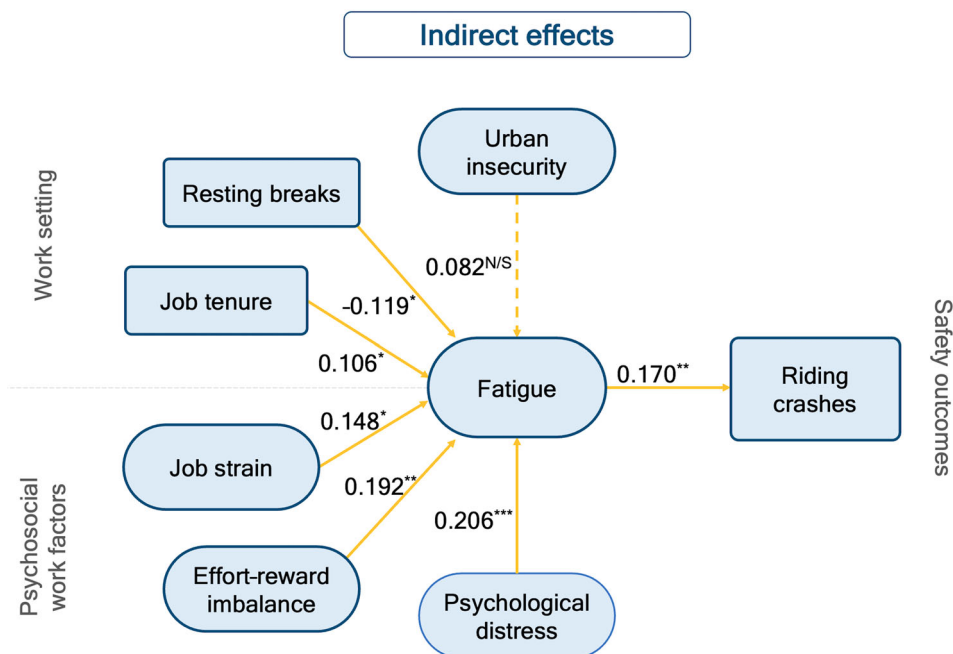


Figure 3. Indirect effects – standardized parameter estimates. * Significant at the $p < 0.050$ level. ** Significant at the $p < 0.010$ level. *** Significant at the $p < 0.001$ level. $^{N/S}$ Not significant. Note: Solid lines represent significant paths. All estimates listed for solid lines are significant (as presented in Table 2). Ellipses represent inferred (latent) variables; rectangles represent observed variables.

nor work settings such as resting breaks or job tenure, had a direct effect on safety outcomes.

However, five out of the six aforementioned variables (i.e., tenure, resting breaks, psychological distress, and the ERI and JCQ stress indicators) had a direct and significant predictive value for occupational fatigue. In this regard, and as for indirect effects (shown in detail in Figure 3), work-related fatigue (i.e., Sluiter's need for recovery) fully mediates the relationships between tenure, resting breaks, ERI and job strain indexes, and the dependent safety indicator (i.e., self-reported work riding crashes).

Also, work-related fatigue also exerts partial mediation between Goldberg's psychological distress indicator and

self-reported crashes, increasing its magnitude from $\beta = 0.170$ ($p < 0.010$) to $\beta = 0.206$ ($p < 0.010$). Said otherwise, and although psychological distress has a significant and positive direct path to occupational accidents (i.e., job-related riding crashes), its relationship seems more theoretically plausible and slightly statistically stronger through the mediation of the Sluiter's need for recovery (fatigue) index.

4. Discussion

The core aim of this study was to test whether fatigue mediates the multivariate relationships among job settings, stress-related psychosocial factors at work and occupational

traffic crashes suffered in a sample of Colombian food delivery riders. Overall, the study outcomes support the hypothesized assumption that fatigue plays a significant role in riders' safety and welfare-related outcomes. It is feasible to assert that occupational riding crashes experienced by food delivery riders can be statistically explained, to a certain extent, when considering stress-related factors, general mental health issues and work setting factors. While this aligns with the shared outcomes of most of the few previous studies in this regard [49,50], some key issues merit discussion to validate the present findings.

4.1. More than a 'chilly break': fatigue as a safety issue

While fatigue has been argued as a health impairer in several occupational studies conducted during the last few decades [38,40], its role as an occupational road safety impairer remains sparsely documented in the empirical literature. Most studies tend to analyze its relationship to job stress in a correlational manner [30,33,37]. Apart from identifying a positive and significant correlation between work-related fatigue (need for recovery) and self-reported occupational crashes ($r = 0.205$, significant at the $p < 0.010$ level), this study has revealed significant predictive paths from fatigue to crashes, as well as from stress to fatigue. This underscores the increased importance of fatigue management actions in delivery occupations.

At a theoretical level, evidence remains particularly scarce in the case of two-wheeled food delivery riders. Therefore, while the results of this study align theoretically and empirically with comparable findings, it is important to maintain a certain distance between this study and the findings derived from studies involving four-wheeled drivers. This cautionary approach is warranted, at least until the body of empirical knowledge allows for the replication of this evidence in new samples working under similar setting-related and psychosocial working conditions [31].

However, there are some relevant literature-based insights that merit discussion. Studies such as those by Nguyen-Phuoc et al. [10] and Christie and Ward [51] propose, with strong empirical support, that gig economy positions are likely to establish job dynamics based on a 'piece rate' instead of fixed salaries. In the case of food delivery riders, this dynamic may contribute to a greater propensity to self-report elevated fatigue indexes, frequently preceding occupational crashes. In this context, the mediating role of fatigue between stressful psychosocial work factors and traffic safety-related outcomes has been previously examined in the empirical literature among transport workers, particularly professional drivers of motorized vehicles [37,41,52].

Despite clear task-related differences among these occupations limiting the comparability of results, a noteworthy observation is that fatigue consistently appears to play a mediating role between psychosocial work factors, especially stress-related ones, and risky behaviors, crashes and near-misses [53,54]. This suggests a potential interaction with other factors related to delivery riders' work settings, regardless of vehicle type. This is supported by two key points: the structural equation model controlled for these differences; and the direct effect of these task-related differences on self-reported crash rates was statistically non-significant, maintaining coherent path directions for all types, among which stand out the positive predictive role of both fatigue and stress on occupational crashes.

4.2. An unhealthy work setting and other fatigue-related risk factors

In comparison with other studies addressing key safety impairers such as time pressure, psychosocial hazards and physical demands, our results reveal noteworthy findings. For example, in a recent study conducted in the UK, Christie and Ward [55] discovered that two-wheeled food deliverers are more likely to violate traffic laws when working under constant time pressure in addition to using app-based platforms. Similarly, Tran et al. [6] conducted a study in Ho Chi Minh City (Vietnam) and found that many delivery riders adopt risky riding behaviors due to job pressure, long working hours and financial commitments. In other words, job swiftness conditions are linked to the amount of economic rewards perceived.

Furthermore, the relationship between job settings and individual outcomes has been previously documented. Specifically, studies conducted in Asian countries with a high demand for (and growth of) food delivery rider services, such as Nguyen-Phuoc et al. [10] in Vietnam and Zheng et al. [13] in China, provide support for the association of lifestyle and riding behavioral outcomes, such as less rest, a higher frequency of engaging in risky riding behaviors and completing more daily orders to increase payment milestones, with a significant increase in crash involvement for delivery workers.

Turning our focus to road user groups undertaking long and recurring trips on two wheels, especially by bicycle, evidence from previous studies based on Latin American countries and their transportation challenges suggests that economic factors, convenience and access to opportunities in different spheres may exacerbate risky road behaviors and their subsequent crashes [56,57]. As a relevant example, a recent study addressing the case of frequent cyclists reinforced this notion, concluding that external risk factors could differentiate Latin American cyclists from other groups [58]. In most cases, the primary motivation for using bicycles in Latin American countries appears to be related to economic and convenience reasons. This stands in contrast to high-income countries where sustainability and health appear to be more common incentives among riders [59,60].

4.3. Practical insights and implications

At a practical level, the results of this study have two essential implications. Firstly, the already challenging work setting of delivery riders could be further exacerbated by technological issues (e.g., dependence on connected devices), environmental factors (e.g., urban insecurity) and psychosocial work factors (e.g., work stress and fatigue). Regarding the first aspect, handheld devices in this specific occupation constitute an almost indispensable tool for work, and there has been little progress in terms of ergonomics and behavior [61,62], particularly for two-wheeled users in 'connected occupations' [63–65].

Addressing these growing technological challenges and potential practices aimed at mitigating emerging threats, such as technologically induced distraction, stress and road conflicts, several literature insights offer potential solutions. Zheng et al. [13], e.g., argue that interventions addressing technological overcharging and improving the interaction with technology are needed for this type of workers, and it is also pointed that educational campaigns may also prove useful in reducing risky behaviors and improving compliance with traffic norms.

Additionally, Christie and Ward [51] suggest that the safety of delivery riders could be enhanced through improvements in payment sources (i.e., not fully dependent on the number of delivery services and their speed, but considering the full worked blocks) and improvements in the 'apps' through less distracting interfaces. Finally, other studies emphasize the need to strengthen protective legislation aimed at not leaving the health, safety and welfare of both riders and other road users in the hands of private operators (i.e., delivery app operating companies), framing it as a public health and safety matter [10,65].

5. Limitations of the study

Although this study had several strengths – such as following an evidence-based logic and having measured latent study variables by means of standardized/validated research instruments; having successfully achieved the essential statistical and theoretical assumptions (GOF criteria included) despite an 'enough but not optimal' sample size; and that the model had parsimony insights – it is worth acknowledging some basic shortcomings potentially affecting the study data, as well as the scope and interpretability.

First, regardless of the confidential treatment of participants' data, we cannot assure the non-interference of common method variance and biases (known in the literature as, respectively, CMV and CMBs). Precisely, and as this study dealt with considerably sensitive topics (e.g., work labor conditions, potentially negative personal experiences and health-related issues), specialized literature suggests the need for interpreting self-reported data with caution [66]. Further, and being unable to estimate the influence of participants' acquiescence or social desirability [47,67], we encourage our readers to interpret the current data considering both previous evidence and the technical rigor and bias-correction procedures used during the analysis phase.

Also, there might be several other factors not addressed in this research potentially influencing riders' safety outcomes, such as infrastructural adequacy, body mass index and vehicle-related issues. These issues, the same as the possibility of finding differential results in different city settings, sizes and transport dynamics, remain unexplored in this research [68]. Finally, and even though it practically affects all current empirical research, the latest COVID-related changes in terms of both transportation and work-related dynamics of riders must be considered for time-framing the results of this research [4,6,69].

6. Conclusions

This research empirically analyzed, for the first time, the multivariate relationships among work-related and psychosocial factors for job food delivery riders in Colombia, a low and middle-income country (LMIC) where limited attention has been given to the numerous risks faced by highly vulnerable workforces on a daily basis.

The SEM-based results suggest that riders' self-reported crash rates can be predicted through psychosocial and job setting and environmental factors. However, these relationships are primarily statistically mediated by work-related fatigue, emphasizing its crucial role in understanding a significant proportion of safety-related incidents in this occupation.

Furthermore, our results indicate that safety-related risks faced by two-wheeled delivery riders, many of whom are migrants in irregular situations, are exacerbated by various disparities, gaps and shortcomings in both workers' protection and infrastructural development. These findings underscore the importance of implementing additional safety policies and interventions aimed at mitigating both psychosocial and road safety risks for riders.

Concerning future research in the region, this article underscores the importance of prioritizing psychosocial working conditions as a focal point for policies that can contribute to enhancing the safety and health outcomes of food delivery riders. This aspect has often been overlooked in previous studies conducted in Global South countries. Additionally, a potentially complex set of issues not covered in this study includes the ever-present challenge of road distractions resulting from the high interaction between food delivery riders and handheld devices [9,10].

It is also noteworthy that current data suggest that many countries share with Colombia the disorganized growth of gig economy-based employment, coupled with 'several and severe' road safety issues among transportation-related workers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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