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RESEARCH ARTICLE

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Associations between safety climate and safety management practices in the construction industry

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Background: Safety climate, a group-level measure of workers' perceptions regarding management's safety priorities, has been suggested as a key predictor of safety outcomes. However, its relationship with actual injury rates is inconsistent. We posit that safety climate may instead be a parallel outcome of workplace safety practices, rather than a determinant of workers' safety behaviors or outcomes.
Methods: Using a sample of 25 commercial construction companies in Colombia, selected by injury rate stratum (high, medium, low), we examined the relationship between workers' safety climate perceptions and safety management practices (SMPs) reported by safety officers.
Results: Workers' perceptions of safety climate were independent of their own company's implementation of SMPs, as measured here, and its injury rates. However, injury rates were negatively related to the implementation of SMPs.
Conclusions: Safety management practices may be more important than workers' perceptions of safety climate as direct predictors of injury rates.

KEYWORDS
injury prevention, management systems, safety outcomes, safety perceptions, safety predictors

1 | INTRODUCTION

Worldwide, workers in the construction industry disproportionately experience severe and fatal injuries as well as disabling illnesses.[1–5] Extensive research has addressed potential causes of work-related injuries in this complex and dynamic work environment, including lack of management commitment to safety, failures in hazard identification and control, improper or unsuitable protective equipment, and lack of worker participation.[6–9] Studies have compared organizations with high and low injury rates, identifying that gaps in management commitment, safety communication, hazard control, and training are less prevalent in higher risk companies.[10–13] Further, there is some evidence that safety practices such as the implementation of engineering controls, improved house-keeping, and worker training interventions are somewhat effective in preventing falls and other injuries in the construction sector.[14–16]

1.1 | Safety climate

The dynamic nature of the construction industry means that physical conditions, including safety hazards, need to be assessed on an ongoing basis to account for changes over time. An alternative strategy for research purposes is to use safety indicators able to summarize the overall hazardousness of a given site or company and effectively predict injury risk. Safety climate has emerged as a measure of workers' shared perceptions regarding the importance given to safety by management in comparison with other organizational priorities.[17–20] According to Zohar,[20] safety climate perceptions are part of the injury cause-effect pathway, affecting proximal injury factors such as safety behaviors and subsequent safety outcomes. It is suggested that through this construct, workers interpret organizational safety policies, procedures and practices, and that this interpretation subsequently is reflected in their safety behavior.[21]

In the last decades, safety climate has been suggested as a key factor for safety outcomes in different industries and environments.[22,23] However, its relationship with injury occurrence is inconsistent in the empirical literature.[19,22,24,25] Research has also explored safety climate ability to predict not only injury frequency, but also injury severity in a variety of occupational settings. This relationship is also inconclusive and particularly presents significant discrepancies in defining the outcome. For instance, for a short period (less than 3 months), safety climate predicted severe incidents such as ones that meet OSHA recordability guidelines but not permanently disabling or deadly.[26] In addition, a relationship between perception of safety climate and injury severity (referred to as functional limitations) was identified among injured construction workers.[27,28] Among truck drivers, employee safety climate perceptions predicted days away from work due to injury (an indicator of injury severity).[29]

Safety climate emphasizes the perceptions held by employees regarding the importance of safety in their organization,[30] while the implementation of specific management practices may be considered an actual manifestation of the management commitment to worker health and safety. Investigators vary in their operationalization of safety climate, but management commitment to, and involvement in safety is a consistent factor included in the majority of or all safety climate scales[31–34] as well as a recurring element reported in successful safety programs.[9,35–37] Despite differences in the dimensional structure of safety climate, its adoption as a leaning or leading indicator of workplace safety performance is gaining momentum among researchers and practitioners. Safety climate as a whole or its dimensions can be used as a reliable and valid indicator across industries not only as a benchmarking tool, but also to proactively identify areas needing improvement within an organization.[38]

1.2 | Safety management practices

Hazard recognition and control, safety training, allocation of resources for safety, promotion of safety committees, accident report and investigation, and workers' safety participation are all considered important elements of effective safety programs in the construction sector (ie, ref.[39–42]). Specific practices, such as hazard checklists, work permits, planned inspections, safety training, contractor's safety evaluation, and goal-setting, have also been recommended as important initiatives to reduce injuries and illnesses.[43–46]

Safety Management Practices (SMPs) here refer to a wide range of top or middle management initiatives implemented at any work site with the goal of mitigating hazards and achieving lower injury rates.[9,44] SMPs have been defined and promoted in many countries through voluntary and mandatory consensus standards, such as OSHA 18001:2007 (British Standards Institute), AS/NZS 4801:2001 (Australia and New Zealand Standards), Guidelines on Occupational Safety and Health Management Systems -ILO-OSH 2001- (International Labor Organization), OSHA Safety and Health Management Systems (United States), and the international standard Safety Management ISO 45001:2016. However, there is no consensus as to which specific management practices clearly lead to the preferred safety outcomes.

1.3 | Conceptual framework for this analysis

The safety climate concept holds that workers' safe/unsafe behaviors are formed on the basis of their interpretation of management implemented policies or practices, such as the formal or informal behavior-reward system. For example, a supervisor's response to work situations where complying with a safety procedure can delay deadlines would color worker perceptions.

Further, a connection between safety climate and injury rates mediated by safety behavior has been suggested in previous studies.[18,47] Indeed, Neal et al.[52] stated that in order to have any impact on safety performance, safety climate interventions must first produce changes in employee knowledge or motivation.

This conceptual model emphasizes individual factors as the main cause of work-related injuries and implicitly de-emphasizes the contribution of physical hazards and work organization. It also explicitly targets safety climate itself as an appropriate focus of an intervention effort. Although worker behavior can certainly be an element on the injury causal pathway, it is not necessarily a root rather than an immediate cause.[7,9] We posit instead that workers' safe/unsafe behaviors are influenced by the continuous interaction of the individual with his/her tasks, organization, and social environment. Thus, workers' behavior represents decisions based on individual factors (knowledge, perceptions, motivation), work environment conditions (tasks, workplace hazards, job decision latitude), organizational policies (subcontracting, work hours, risk control), and social conditions (job security, immigration status, socio-economic conditions).[49,50]

In contrast to the framework suggested by Zohar[20,51] and Neal et al.[48] we suggest that safety climate may be a parallel outcome rather than a direct predictor of worker's safety behavior (Fig. 1). More specifically, safety climate may represent an indicator capable of capturing the realities of the work environment, workers' experiences related to hazards and injury prevention efforts, and the organizational efforts needed to minimize hazards and worker exposure to those hazards. In the context of the construction industry, where project time pressures and budgetary constraints frequently underlie occupational safety and health management decisions, it is very important to be sure that we are targeting the true upstream determinants of work-related injuries.

This study examined the extent to which construction sites with high safety climate rating also had many SMPs implemented and/or lower injury rates. According to our model, we tested the hypothesis that worker's perceptions of safety climate can act as an indicator of the level of implementation of SMPs on construction sites. If this hypothesis is true, workers on construction sites with better overall implementation of SMPs should report both a report better safety climate and experience better safety performance outcomes (ie, lower injury rates).

2 | METHODS

2.1 | Study design and study population

The study was carried out with construction workers from a stratified sample of 25 commercial construction companies in Bogotá, Colombia. Selection criteria for participating companies included: 1) employing more than 20 construction personnel (no administrative employees); 2) being a workers' compensation company client for at least 1 year before

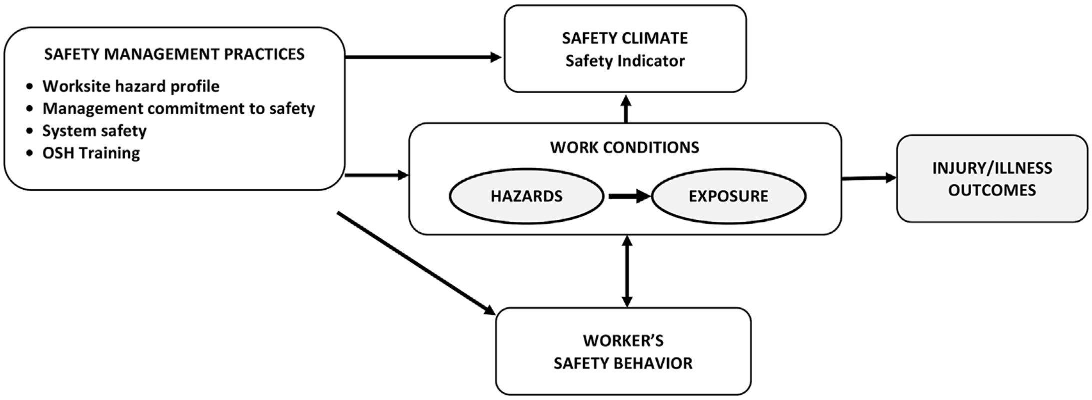

FIGURE 1 Proposed conceptual framework for the effect of safety management practices on work conditions and therefore on workers' perceptions of safety climate

the present study; and, 3) having construction projects in Bogotá and surrounding metropolitan area. The exclusion criteria included: 1) construction projects very close to completion (finishing stages) or in the preliminary stages (eg, field mobilization); and 2) when companies were owned by a construction holding group, only one company of that group could be selected to participate in the study.

Recruitment of construction companies was accomplished through a major private workers' compensation insurance company. The insurance company provided a database of construction company policy holders with information such as company name, contact information, number of workers, and injury rates for the three full years immediately preceding data collection (2010-2012).

Company burden of injuries was estimated through a 3-year injury rate, defined as the total number of claims per 100 workers. Based on this rate, potential participating companies were stratified into three groups (low, medium and high injury rates). The average injury rate for the entire construction sector in Colombia from 2010 to 2012 (8.5 injuries per 100 workers) was used to define the cut-off points for low, medium and high injury rate categories. Participating companies with a 3-year injury rate of less than 8.5 were classified in the "low" category, those twice the average (17.0) were classified as "high" and "medium" otherwise. Ten companies randomly selected from each group were invited to participate in the study and to nominate a single construction site for inclusion.

2.2 | Safety management practices assessment tool

Implementation of safety practices at the construction sites was evaluated using an assessment tool devised for this study. A list of desirable safety management practices was produced based on information from different sources such as management system audits (OHSAS 18000, ILO 2000), best safety practices reported in the literature, elements for successful safety programs, and special regulatory requirements (mandatory practices, fall prevention standards). The instrument consisted of 86 questions evaluating a total of 15 practices, sorted into four groups: 1) determining the construction site hazard profile; 2) promoting management commitment to safety; 3) improving system safety; and 4) occupational safety and health (OSH) training (Table 1).

The instrument assessed practices implemented in the construction sites, requiring a "yes" or "no" answer (Supplementary Appendix A). The SMPs index was measured as the percentage of "yes" responses over the total number of responses. Therefore, companies with higher percentages reported more SMPs in place.

Variables on the nature of the project such as expected duration, current stage, number of contractors, number of workers, and estimated project budget were collected for each construction site. Company records were reviewed with the site safety manager in order to verify scope and approach for safety practices such as use of a hazard identification matrix and risk assessment, specific safety programs, safety meeting minutes or worker's training reports.

2.3 | Safety climate survey

The Nordic Safety Climate Questionnaire (NOSACQ-50), a validated tool,[32] was used to assess workers' perceptions of safety climate at the organization and work-group levels. The questionnaire contains 50 items grouped into seven dimensions: 1) management safety priority, commitment, and competence; 2) management safety empowerment;

TABLE 1 Dimensions and elements of evaluated Safety Management Practices (SMPs)

Safety management practices (SMPs) domains	Practices
1. Construction site hazard profile (5 practices—32 items)	Hazard identification (4 items); hazard assessment (8 items); hazard prioritization (7 items); contractors participation in hazard identification and control (3 items); hazard control (10 items)
2. Management commitment to safety (5 practices—25 items)	Safety planning (4 items); safety responsibilities (5 items); safety committee (5 items); management participation (7 items); measuring safety performance (4 items)
3. System Safety (3 practices—17 items)	Goal setting (8 items); safety inspections (3 items); accident reporting and investigation (6 items)
4. OSH Training (2 practices—12 items)	Workers participation (4 items); training (8 items)

3) management safety justice; 4) workers' safety commitment; 5) workers' safety priority and risk non-acceptance; 6) peer safety communication, learning, and trust in co-workers' safety competence; and 7) workers' trust in the efficacy of system safety. Item responses are based on a 4-point Likert scale (strongly agree, agree, disagree, strongly disagree).

For this study, the background section from the original instrument was expanded from three demographic questions to 13 by adding questions related to experience in the construction industry, seniority, work-related injuries at the current and previous construction sites, and whether the participant was a safety committee member.

The NOSACQ-50 Spanish version was cross-checked for the first author to confirm that the constructs were translated accurately. In order to adapt the Spanish version to the Colombian work environment and construction terminology, the NOSACQ-50 Spanish version was discussed with two safety experts and with a group of ten safety professionals with broad experience in the construction sector. They were specifically asked to evaluate the language used throughout the questionnaire. Feedback was incorporated into the original Spanish version to reflect the appropriate terminology used at the Colombian construction worksites. NOSACQ-50 developers were consulted to verify that the proposed changes kept the original meaning of the construct.

2.4 | Company injury rates

Injury claims records from participating companies from January 2010 to December 2012 were provided by the workers' compensation insurance company. Thus, the 3-year injury rate used for stratified sampling (see above) was also used to examine the association between company SMPs and safety climate scores with injury burden.

2.5 | Data collection

Data from the safety climate survey and the SMPs assessment tool were collected using QuickTapSurvey,[54] an application created for collecting survey responses on tablets. Both the safety climate questionnaire and the safety practices instrument were created electronically and installed on the interviewer's tablet where responses were collected. The data were exported for subsequent analysis.

Data collection methods and protocols used in this study were reviewed and approved by the Institutional Review Board of the University of Massachusetts Lowell (12-131-PUN-XPD). All survey assistants were trained in human-subjects protection and the survey protocol. All respondents agreed to participate via oral informed consent according to the approved protocols. Participation was confidential with no personal identifiers collected or associated with survey and assessment tool responses; no monetary compensation was provided to participants.

2.6 | Safety management practices assessment tool

The SMPs assessment tool was administered once at each worksite between October 2012 and April 2013. Since safety managers and coordinators were directly dealing with the implementation of on-site practices and responsible for construction site safety compliance, they were chosen to provide information regarding safety practices on the site in question. SMPs that required verification (eg, hazard identification, accident investigations, contractor safety performance, training, safety responsibilities) were also contrasted by reviewing company documentation such as hazard identification matrix and risk assessment records, specific safety programs, safety meeting minutes, and workers' training reports. When there were inconsistencies with manager interview results, the SMP scores were changed to reflect actual level of implementation. Discrepancies regarding the level of implementation of SMPs occurred on three construction sites and specifically in practices related to hazard prioritization, safety planning, management participation, and workers participation.

The first author interviewed the site safety manager at each construction site. When the safety manager was not available, the safety coordinator was the person deemed most appropriate to answer the questionnaire. Only one respondent was interviewed per workplace. Interviews were conducted during work hours and lasted approximately 45-90 min each.

2.7 | Construction site safety climate

The survey took approximately 20-30 min, and was conducted as interviewer-administered during work hours from December 2012 to April 2013. Construction workers were randomly selected from the daily log and invited to respond to the survey. If the selected worker refused to take the survey, a new potential participant was randomly selected from the daily log form with the goal of surveying at least 10 construction workers per site. Workers with administrative responsibilities were not surveyed. Surveys were conducted by trained survey assistants who were safety and health specialists with broad experience in the construction industry.

2.8 | Data analysis

To summarize the extent of SMP implementation on each construction site, an index was used to express the percentage of practices reported by the interviewee. The SMP index was calculated for each of the four dimensions by dividing the number of "Yes" response items by the total number of items in each group, multiplied by 100. In addition, the arithmetic mean of the four dimension values was computed in order to obtain an overall index with each dimension weighted equally.

SMP indexes and injury rates were characterized at the company level, while data on perceptions of safety climate and demographic variables were collected at the individual level. Thus, two sets of analyses were performed. Associations between variables were examined at the company level ($n = 25$) and at the workers' level using the multi-level hierarchical data structure ($n = 256$). The intra-class correlation coefficient (ICC) was calculated to assess company-level aggregation of individual safety climate responses. The justification for safety climate scores aggregation at the company level relies on the safety climate conceptualization as a group-level variable.[55,56] ICC was 0.44, suggesting that individuals within each company reported safety climate in a moderately similar way; therefore, individual responses can be added to company level.[57,58]

For the company level analyses ($n = 25$), each company was assigned a safety climate score by averaging the individual safety climate scores from all workers who responded to the NOSACQ-50 questionnaire in that company. Non-parametric (Spearman) correlation coefficients were computed between SMP indexes and safety climate scores, as well as between SMP indexes and 3-year injury rate, and between safety climate scores and 3-year injury rate. Scatterplots were used to examine any non-linear patterns in the relationship between company safety climate and SMP scores.

Simple linear regression using generalized linear models was conducted with company SMP index as the independent variable and company safety climate score as the dependent variable. The main effect of each demographic control variable (average age, experience in the construction industry, seniority in the current construction company, and months in the current workplace) was also estimated.

Subsequently, Poisson regression was used to examine the associations between SMPs and safety climate scores with company injury rates. In order to conduct this analysis, the dependent variable was the company's total number of injuries during the 3-year-period (2010-2012). The natural logarithm of the total number of workers during the same period was the offset variable for regression models. Control variables again were average values of participants' age, experience, seniority, and months in the current workplace.

For the individual level analysis ($n = 256$), each participant was assigned their company SMP index and correlations between SMPs and individual safety climate scores were estimated using Spearman's correlation coefficient. Multilevel regression analysis was conducted using linear mixed models with two levels representing workers at level 1 and construction site (company) at level 2. Demographic variables were added to the model one at a time to estimate their main effect. All data were analyzed using the statistical software package SPSS 21.

3 | RESULTS

3.1 | Participating companies and individual respondents

A total of 30 randomly selected construction companies were invited and all accepted to participate in the study. However, due to the first author's own time limitations, only 25 construction sites were visited and included in the study. The stratified sample design based on a 3-year injury rate was preserved and the final sample comprised 9 companies in the low, 8 in the medium, and 8 in the high category. The assessment of SMPs was conducted in 25 commercial construction companies employing on average 103 employees (range 47-179). The respondents were safety managers, safety coordinators, and in one case, a worker in charge of safety at the construction site (Table 2). Almost half of the respondents reported having other responsibilities in addition to safety, such as managing workers' recreational activities (eg, monthly birthday celebrations), implementing wellness programs, or complying with the environmental management system (OHSAS 14000). They also conducted related administrative tasks such as daily verification that new workers had been enrolled in the workers' compensation system before entering the worksite, and that contractors had paid workers' compensation insurance premiums on time.

A total of 258 construction workers from the 25 companies were invited to respond to the NOSACQ-50 questionnaire. Only two workers (0.8%) from the same company refused to be surveyed because at the time of the interview they were performing a task that could not be paused. Respondents' mean age was 34.6 years. Twenty three percent stated having suffered work-related injuries in previous jobs, and 14% indicated having suffered injuries at the current construction site (Table 3).

3.2 | Safety management practices

The domain of practices *focused on improving management commitment to safety* resulted in the highest index among the 25 companies (most likely implemented), while practices to improve worker safety skills (*OSH training*) resulted in the lowest indexes (Table 4). *Safety responsibilities* which assessed assigning responsibilities to all organizational levels including supervisors, contractors and subcontractors, and safety officers, were most often reported to be in use. *Safety planning* and *management participation* were the least likely to be carried out.

Across all four dimensions, implementation of planning tools such as *goal setting*, *contractor participation*, and *worker participation* obtained the lowest indexes. The implementation of goal setting as a technique to establish measurable plans responding to hazard priorities, according to the project stage, was the practice less implemented in the construction sites studied. This low index skewed the results for the system safety domain.

TABLE 2 Demographic characteristics of Occupational Safety and Health (OSH) personnel responding to the SMPs assessment interview ($n = 25$)

					Education in safety and health		
Job title	*n*	Age (mean ± SD)	Experience in OSH (mean ± SD-years)	Years in current company (mean ± SD)	S&H specialist[a]	S&H technician[b]	Non-formal training
Safety manager	9	33 (±2.5)	7.5 (±4.2)	2.3 (±0.5)	8		1
Safety coordinator	15	30 (±5.0)	4.3 (±2.9)	1.5 (±0.8)	5	9	1
Safety officer (worker in charge)	1	55	2	15			1

[a]1-1.5 years of graduate studies in Occupational Safety and Health (OSH).
[b]2 years of undergraduate studies in Occupational Safety and Health (OSH).

TABLE 3 Construction workers demographic characteristics

	n		%	
Total participants	256			
Male	249		97.3%	
Work-related injuries on previous construction sites	58		22.7%	
Work-related injuries on current construction site	36		14.1%	
Current Safety and Health Committee member	33		12.9%	
	Mean	SD	Median	Range
Age (year)	34.4	10.3	32.0	18-64
Experience in construction (years)	8.5	7.8	6.0	0-49
Years in this company	3.1	4.3	2.0	0-30
Months in this construction site	7.2	7.0	6.0	1-36

3.3 | Safety climate

The average safety climate scores for each company ranged from 2.5 to 3.5 on a scale from 1 to 4. Among the seven safety climate dimensions, the lowest score was in the dimension of *workers' safety priority and risk non-acceptance*, while the highest mean score was for *workers' trust in the efficacy of the system safety* (Table 5).

At the company level, the overall SMPs index only weakly correlated with average safety climate scores ($r = 0.105$, $P = 0.619$). Otherwise, there were few correlations of SMPs index or its domains with overall safety climate scores or its dimensions (Table 6). The correlations between SMP index and two dimensions of safety climate, *management safety empowerment*, and *workers safety commitment* were moderate ($r = 0.30$, $P < 0.05$).

Three-year injury rate was not correlated with average safety climate score or any of its sub-scores. In contrast, 3-year injury rate was negatively associated with overall SMPs index ($r = -0.31$, $P < 0.01$) and with two of its four domains, SMPs focused on *construction site hazard profile* ($r = -0.33$, $P < 0.01$) and improving *system safety* ($r = -0.34$, $P < 0.01$).

At the workers' level ($n = 256$), safety climate score, and SMPs correlations were stronger than at the company level although not statistically significant. The SMPs focused on improving *system safety* was negatively correlated with 3-year injury rate ($r = -0.431$, $P < 0.01$).

TABLE 4 Safety management practices (SMPs) scores[a] in 25 participating construction companies in Colombia

SMPs domain	Practices	No. items	Mean (%)	Median (%)	SD (%)	Range (%)
1. Construction site hazard profile	Hazard identification	4	36	50	35	100
	Hazard assessment	8	50	50	22	63
	Hazard prioritization	7	20	13	20	63
	Contractors participation	3	12	13	12	38
	Hazard control	10	51	50	15	50
	Domain score	**32**	**41**	**44**	**16**	**59**
2. Management commitment to safety	Safety planning	4	45	50	39	100
	Safety responsibilities	5	76	72	12	28
	Safety committee	5	65	68	36	88
	Management participation	7	48	57	29	100
	Measuring safety performance	4	56	75	32	100
	Domain score	**25**	**58**	**56**	**20**	**72**
5. System safety	Goal setting	8	6	0	14	50
	Safety inspections	3	81	100	26	100
	Accident report and investigation	6	43	50	24	100
	Domain score	**17**	**32**	**35**	**14**	**53**
4. OSH training	Workers participation	4	23	25	30	100
	Training	8	30	25	11	38
	Domain score	**12**	**27**	**25**	**15**	**58**

[a]Each score is expressed as a percentage of the total number of practices assessed in each domain.

TABLE 5 Descriptive statistics of overall and dimension safety climate scores measured using the NOSACQ-50 safety climate questionnaire for 256 construction workers from 25 construction companies in Colombia

Safety climate dimensions	Mean	Std. deviation	Median	Interquartile range
Total safety climate score	2.8	0.30	2.8	0.29
1. Management safety priority	2.9	0.38	2.9	0.33
2. Management safety empowerment	2.5	0.43	2.5	0.43
3. Management safety justice	2.7	0.46	2.7	0.50
4. Workers' safety commitment	3.0	0.41	3.0	0.33
5. Workers' safety priority and risk non-acceptance	2.4	0.43	2.4	0.57
6. Safety communication	3.0	0.30	3.0	0.25
7. Workers Trust in the efficacy of safety systems	3.2	0.38	3.2	0.43

In the robust generalized linear regression model, SMPs index was not associated with company safety climate score, explaining only 1.4% of the variance in safety climate. In contrast, the overall SMPs index had a strong inverse relationship with 3-year injury rate ($P = 0.009$). When the SMPs sub-indexes were examined separately, neither management commitment nor worker's training were associated. The effect was concentrated in the domains of improving the hazard profile of the construction site and improving the system safety (Table 7).

At the individual level ($n = 256$), the SMP index was not significantly associated with safety climate scores in multilevel linear regression analyses (Table 8). Of note, being a member of the safety and health committee was associated with perceptions of safety climate as well as the time working in the current construction site. No other control variable showed a meaningful contribution to the model, and none of them changed the coefficient for the overall SMP index.

4 | DISCUSSION

The current study examined the relationships between SMPs index, safety climate scores, and injury rates. This study included 25 commercial construction companies covering 256 construction workers in Bogotá, Colombia. A safety practice score representing the percentage of recommended SMPs implemented was compared with individual perceptions of safety climate from construction workers on the same sites. Overall, workers' perceptions of safety climate from a given company were independent of that company's implementation of SMPs. Moreover, inconsistent with previous research, this study found no association between workers' perceptions of safety climate and company injury rate. However, results indicated that injury rates were negatively related to the implementation of SMPs, indicating that implementation of SMPs is the more important predictor of construction injury rate experience.

TABLE 6 Spearman rho correlations among safety management practices (SMP) scores, company safety climate score, and 3-year injury rates for Colombian construction companies ($n = 25$)

	Safety management practices and dimensions					
Safety climate and dimensions	Total safety management practices	Hazard profile	Management commitment	System safety	Training workers	3-year injury rate per 100 workers
Total safety climate	0.10	0.07	0.18	0.01	0.19	−0.13
Management safety priority	0.08	−0.02	0.22	0.01	0.21	−0.09
Management safety empowerment	0.30[b]	0.13	0.37	0.19	0.11	−0.19
Management safety justice	−0.03	0.06	0.05	−0.09	−0.06	−0.20
Workers' safety commitment	0.30[b]	0.22	0.34	0.25	0.35	−0.17
Workers safety priority	0.09	−0.05	0.25	−0.02	0.10	−0.17
Peer safety communication	−0.05	0.02	0.06	−0.02	0.03	0.02
Workers trust in efficacy of safety systems	0.00	0.05	0.09	−0.16	−0.17	0.14
3-year injury rate per 100 workers	−0.31[a]	−0.33[a]	−0.10	−0.34[a]	−0.11	–

[a]Correlation is significant at the 0.01 level (2-tailed).
[b]Correlation is significant at the 0.05 level (2-tailed).

TABLE 7 Effect of safety management practices (SMPs) on 3-year injury rate at the company level: Simple linear regression models of combined SMPs index and separate SMPs domains, for 25 Colombian construction companies

Independent variable	Unstandardized coefficient	SE	Wald chi-square	*P*
SMPs index	−0.435	0.166	−2.11	0.009
Hazard profile	−0.334	0.15	5.035	0.025
Management commitment to safety	−0.083	0.089	0.894	0.344
System safety	−0.433	0.19	5.22	0.022
Safety training	−0.069	0.371	0.204	0.652

Dependent variable: 3-year injury rate.

SMPs implemented in the workplace might be interpreted as the applied expression of manager's or supervisor's commitment to safety and would be expected to have a relationship with workers' perceptions of safety climate even if the top management played no role at all. Previous research has suggested positive associations between safety programs and practices with perceptions of safety climate.[30,59] In the healthcare sector, for example, safety climate was associated with employees' compliance with safe work practices, while training and administrative support for safety were identified as significant predictors of safety climate.[60,61]

Potential explanations for the independence between SMP index and safety climate scores may be found in the limitations of the data collection instrument, measurement error, and/or lack of statistical power. Alternatively, the observed independence between SMPs and safety climate may reflect a lack of true association. No significant correlations between workers' safety climate scores and contractor's safety program assessment scores were also reported in a previous study in commercial construction.[62] According to Zohar and Luria[53] workers gather their perceptions of safety priorities in the workplace during supervisor-worker interactions and through observations of supervisor's safety behavior. In this context, safety climate might reflect those safety practices carried out by middle or upper management in direct contact with workers, and not necessarily by other personnel who have little or no authority over, or direct relationship with workers, such as the safety officer. The SMPs assessment tool used in this study measured mainly those practices promoted at the management level but not necessarily implemented through site managers or supervisors. The lack of association identified in this study may accentuate the importance of the supervisor's involvement in the day-to-day aspects of safety in the construction sites, as a way to manifest the formal management commitment to safety. For example, a basic job safety analysis

TABLE 8 Linear regression analysis using company safety management practices (SMPs) index as a predictor of safety climate scores for 256 construction workers from 25 Colombian construction companies

Step	Predictors	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
	Safety management practices								
1	Intercept	2.74**	2.65**	2.73**	2.74**	2.77**	2.75**	2.75**	2.72**
	SMP index	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
		(0.16)	(0.18)	(0.17)	(0.18)	(0.09)	(0.16)	(0.15)	(0.15)
2	Age		0.003						
			(0.13)						
3	Years in the construction industry			0.002					
				(0.42)					
4	Years in the current company				0.005				
					(0.22)				
5	Months working in the current site					−0.007			
						(0.01)			
6	Injuries on current construction sites (Yes)						−0.024		
							(0.66)		
7	Injuries on previous construction sites (Yes)							−0.044	
								(0.33)	
8	Safety Committee Member (Yes)								0.012
									(0.03)

Estimated coefficients with *P* values in parenthesis.
$^{**}P < 0.0001$.

conducted by a field supervisor could be more effective in terms of transmitting the right message about the importance given to safety by the management than a highly technical job safety analysis elaborated only by the safety manager. Unlike this research, previous studies reporting the association between safety practices and safety climate have based their results on employees' self-reported compliance with safety practices, i.e. the outcome of safety behavior.

In addition, stating a company policy, procedure or practice by itself is not an effective way to influence worker's perceptions of safety climate. For a best practice to become a positive influence on safety climate perceptions, it must be consistently communicated, promoted, followed, and enforced by upper and middle management in the workplace.[48,51] At the construction site, most safety practices are introduced on-site by safety coordinators who often work in parallel, but independently or with limited collaboration from field supervisors and site managers. Although these SMPs are regularly communicated verbally to workers by the safety coordinator, they might not be reinforced by supervisors, contractors, or site managers. This could readily be seen by workers as a disconnection between safety requirements and daily practices.

Safety climate has been conceptualized for manufacturing industries which are typified by stable processes, hierarchical work organization, and clear layouts. However, the day-to-day nature of the building process presents a wide range of physical hazards, which can come simultaneously from many directions, multiple subcontractors and high turnover. This calls into question the assumption that human error is the primary cause of injuries; but rather than the worker's safety attitudes may reflect response to the working conditions.

While previous studies have reported an association between safety climate and injury rates, this study found that the reported work-related injuries were independent of the workers' perceptions of safety climate. The lack of association identified in this study may depend on the asynchronicity in measuring the two variables given that injury rates were collected from the 3 years preceding safety climate measurements. However, the three-year company rates are more stable than short-term rates would be on individual sites.

There was a strong protective relationship between SMPs and injury rates, suggesting that if SMPs could be improved, injury rates would decline. In other words, implementation of SMPs is more likely to benefit safety performance than trying to change workers' perceptions without efforts to reduce unsafe conditions in the workplace. It seems likely that employees' perceptions of safety climate reflect the level of general safety in an organization,[63] rather than playing a causal role in the pathway of injury occurrence. Thus, problems should be remediated at the point where they are caused, not where they manifest themselves downstream.

Safety committee participation was associated with higher individual safety climate scores. Safety committee composition is a legal requirement that dictates participation of equal number of management and employee representatives. Therefore, workers' representatives interact more often with management representatives through regular meetings (at least once per month), safety activities and safety trainings. Safety committee members may know directly about management efforts to improve safety and may be more likely to develop shared perceptions in line with the definition of safety climate as a group-level property. Seniority on site was also associated with safety climate scores, indicating that as group level variable, it is more likely to be developed consistently over a longer period.

4.1 | Strengths and limitations

This study presents certain limitations. First, the power of this study to examine the association between SMPs and safety climate (company-level analysis) was limited due to the small number of companies utilized (n = 25) and the limited number of workers surveyed on each site. Second, although the workers surveyed were randomly selected, assigning a company safety climate score based on a small group of workers may not be fully representative of the whole company. Third, limited observations were conducted to estimate the SMPs index, which narrow the opportunity to observe potential variability in how SMPs may have been applied across the different project stages. However, we observed 25 construction sites at different stages of the building process, so it is unlikely that there was a systematic bias by project stage that would alter the findings. Fourth, the SMPs' assessment tool designed for this study was intended to be comprehensive but was not previously validated. We could not ourselves assess potential measurement error. Finally, injury rates could also have some measurement error. They were based on the 3 years previous to this study while safety climate and SMPs corresponded to a single day. Further, injury rates were calculated with the number of workers as the denominators, because, information about employee hours worked daily or weekly was not available. Although participating companies nominated the construction site for inclusion in the study, it is unlikely that this introduced bias since most of the companies had no more than two active construction sites, which limited their ability to select a better-performing site. In any case, such differential selection could have shifted the overall distribution toward better safety performance but would not necessarily have biased the associations under study here. The findings from this study might reflect specific characteristics of the commercial construction sector thus may not be generalizable to the entire construction industry but can be used to expand knowledge and shape framework for future studies.

Despite these limitations, our study has several strengths. To the authors' knowledge, this is the first attempt to evaluate a different conceptual model of how safety climate may or may not function to prevent work-related injuries. Based on the original concept of safety climate as a leading indicator, our framework suggests that perceptions of safety climate are the result of implemented practices to reduce hazards and worker's exposure to hazards in the workplace, rather than a linear element into the injury causation pathway. Therefore, we suggest improving safety practices instead of efforts to modify safety climate directly. We used a multidimensional safety climate tool which had been validated in the construction industry. Additionally, this safety climate tool was piloted and modified in order to adapt it for the context of the construction industry in Colombia. Lastly, SMPs observations were based on reviewed evidence instead of self-report. This approach reduces the likelihood of safety managers varying their criteria for determining compliance with particular SMPs, or even having a vested interest in reporting what they believed to be appropriate practices, regardless of what was indeed being done.

5 | CONCLUSION

This study evaluated whether safety practices implemented by construction companies were associated with workers' perceptions of safety climate. Implementation of safety management practices is fundamental in pursuing the reduction of safety hazards in a workplace. However, their association with workers' general perceptions was surprisingly not strong or consistent in this study population. Perhaps managers overstated their practices or perhaps in the dynamic work environment on a construction site, workers are not in a position to observe some of the measures that safety staff take or in a position to try to reduce hazards.

As measured in this study, worker perceptions of safety climate were also independent of injury rates on the same construction sites. Our results were in line with a meta-analysis which revealed that safety climate is not a strong predictor of injuries.[22] Our results showed that practices implemented to control hazards in the workplace and prevent workers exposure to those hazards seemed to minimize the likelihood of injuries in the construction sites.

We encourage the evaluation of our framework to examine how workers develop their safety-related perceptions regarding the importance and priority given to safety by their organization. Our safety climate framework differs from those with emphasis on safety climate as an element of the injury causal pathway and we suggest safety climate as a parallel outcome. Further, we question the appropriateness of interventions directed solely at improving safety climate, rather than considering safety climate as an indicator. We suggest further analysis of this conceptual framework to test organizational practices as potential predictors of safety climate and other potential safety outcomes, recognizing the challenges in conducting adequately powered longitudinal analyses in the context of the construction industry.

AUTHORS' CONTRIBUTIONS

Marín L.S. designed the study, collected data, performed statistical analysis, and drafted the work. Lipscomb H. provided feedback on the study design, data analyses, critical review of the manuscript, and enhanced the methods and discussion sections. Cifuentes M. provided feedback on the study design, data analysis and critical review of the manuscript. Punnett L., contributed to the study design, provided critical review of the manuscript, and enhanced results and discussion sections. All authors gave final approval of the version to be published and agree to be accountable for all aspects of the work.

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ETHICS APPROVAL AND INFORMED CONSENT

Data collection methods and protocols used in this study were reviewed and approved by the Institutional Review Board of the University of Massachusetts Lowell (12-131-PUN-XPD). All survey assistants were trained in human-subjects protection and the survey protocol. All respondents agreed to participate via oral informed consent according to the approved protocols. Participation was confidential with no personal identifiers collected or associated with survey and assessment tool responses; no monetary compensation was provided to participants.

DISCLOSURE (AUTHORS)

The authors report no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven B. Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

None.

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