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Original Article

Assessing safety culture and stress-related disorders among chemical laboratory workers in Sri Lanka: A cross-sectional study

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ABSTRACT

Introduction: Understanding the impact of safety culture on mental health is crucial for designing effective interventions. This study examines the relationship between safety culture and stress-related disorders (SRDs) among chemical laboratory workers across Sri Lanka's academic, industrial, and government sectors.

Methods: In a cross-sectional study 267 laboratory workers completed the Laboratory Safety Culture Survey and the General Health Questionnaire (GHQ-12) in English via email, with recruitment and data collection conducted between March 14 and July 14, 2024. The survey assessed key safety culture components, including attitudes, perceptions, laboratory practices, and safety opinions. Pearson correlation and multiple linear regression analyses were used to explore the relationships between these factors and mental health outcomes.

Results: SRDs were prevalent in 36.3% of participants, with many exceeding the GHQ threshold for mental health concerns. Sociodemographic factors, including education, job role, and chemical handling experience, significantly influenced mental health outcomes. Strong negative correlations were found between SRDs and safety culture subscales, specifically attitudes, perceptions, and safety opinions. Enhanced perceptions of safety culture and positive safety opinions were linked to potential reductions in SRDs by 32.4% and 52.1%, respectively. Longer chemical handling durations emerged as a significant predictor of SRDs. Multiple regression confirmed that a positive safety culture reduces SRD risk, while prolonged chemical exposure increases vulnerability. Industry workers reported higher SRD levels than the academic and government sectors.

Conclusion: Enhancing safety culture, improving mental health support, and balancing safety with productivity are crucial for reducing SRDs and ensuring the well-being of chemical laboratory workers across sectors in Sri Lanka.

Keywords: Chemical Laboratory, Safety Culture, Sri Lankan Employees, Stress-Related Disorders.

Introduction

Chemical laboratories are high-risk environments where personnel are exposed to hazards related to the handling of dangerous chemicals and complex procedures. Establishing a strong safety culture is essential to minimizing these risks and protecting the health of laboratory workers.[1] The International Nuclear Safety Group (INSAG) and the Occupational Safety and Health Administration (OSHA) emphasize that prioritizing safety and proactively mitigating hazards are crucial to an effective safety culture. OSHA's laboratory standard (29 CFR 1910.1450) has significantly improved safety awareness and accountability in industrial, governmental, and academic laboratories.[2]

Comprehensive safety practices extend beyond the safe handling of materials and include risk assessments and planning for emergency scenarios.[3] These protocols are legally mandated and follow a hierarchy of controls: isolation, engineering measures, administrative procedures, and personal protective equipment (PPE).[4–7] Proper adherence to these controls is vital, as lapses can lead to SRDs, including anxiety, PTSD, and stress-induced physical illnesses.[8]

Laboratory workers often experience heightened professional stress due to competitive environments and exposure to hazardous substances, which can negatively affect both physical and mental health.[9] This underscores the importance of integrating mental health into safety practices. The World Health Organization (WHO) and the International Labour Organization (ILO) emphasize the connection between employment conditions and well-being, particularly in regions like South-East Asia, including Sri Lanka, where mental health resources are limited.[10]

This cross-sectional study addresses the gap in research concerning the relationship between safety culture and SRDs among chemical laboratory workers in Sri Lanka. It hypothesizes a significant correlation between SRDs and safety culture, suggesting that weaker safety cultures, characterized by inadequate safety attitudes, poor laboratory practices, and negative safety perceptions, are associated with higher SRDs. The study aims to examine differences in safety culture perceptions and safety compliance behaviors across researchers in academic, government, and industry laboratories. It also seeks to assess the impact of safety culture on SRDs and identify key predictors. Ultimately, the research aims to propose strategies for strengthening safety culture and improving the well-being of laboratory workers in Sri Lanka.

Methods

This cross-sectional survey was conducted in Sri Lanka to evaluate safety culture and its association with SRDs among chemical laboratory workers. Participants were recruited from diverse sectors, including academic, government, and industry laboratories, to ensure broad representation of the chemical laboratory workforce. The study included personnel working in research and development, quality control, environmental, and analytical laboratories. Data collection occurred from March 14, 2024, to July 14, 2024, through email invitations containing a link to an English-language online questionnaire.

The target population consisted of full-time chemical laboratory employees aged 18 years or older who were actively engaged in laboratory activities during the study period. Exclusion criteria included part-time employees, individuals under 18, and those not directly involved in laboratory work. The sample size was calculated using G*Power software, employing a linear multiple regression model to examine the association between safety culture and SRDs. Assuming a medium effect size (Cohen's $f^2 = 0.15$), a significance level (alpha) of 0.05, and a power of 0.95, the minimum required sample size was 250. To account for potential non-responses or incomplete data, the target sample size was adjusted to 267.[11]

The survey comprised two main sections. The first section captured sociodemographic information, including gender, age, education, marital status, employment status, laboratory role, household income, years of laboratory experience, and average time spent handling chemicals. These variables provided contextual insights into how participant characteristics influence safety culture perceptions and SRDs. The second section assessed safety culture and mental health outcomes.

Safety culture was evaluated using a modified version of the 2012 "Laboratory Safety Attitudes and Practices" survey, developed by the University of California Center for Laboratory Safety, BioRAFT, and the Nature Publishing Group. This validated instrument, approved by the UCLA Institutional Review Board, assessed laboratory safety attitudes and practices across three subcategories: attitudes and perceptions (6 questions), laboratory practices (14 questions), and safety opinions (7 questions). Responses were measured on Likert scales with two, three, four, or five points and standardized to a 0–100 scale for comparability. The original survey demonstrated strong reliability (Cronbach's alpha > 0.80), and in this study, it achieved a Cronbach's alpha of 0.87, confirming its suitability for Sri Lankan chemical laboratory workers.[12]

Mental health outcomes related to SRDs were assessed using the 12-item GHQ-12, a validated screening tool for psychological distress. The GHQ-12 consists of six positively and six negatively worded items scored on a four-point scale (0 to 3), with a maximum score of 36 indicating greater psychological distress.[13] The tool has demonstrated high reliability in prior studies (Cronbach's alpha > 0.85) and achieved a Cronbach's alpha of 0.89 in this study.[14] Before the main study, field testing was conducted to ensure the cultural relevance and clarity of both tools, with adjustments made based on participant feedback.

Data analysis was performed using IBM SPSS Statistics, version 29.0. Descriptive statistics, including means and standard deviations, were used to summarize the data. Pearson correlation tests, two-sample t-tests, and ANOVA were used to identify significant relationships and group differences in SRDs, safety attitudes, and practices. Additionally, multiple linear regression analysis was used to estimate the likelihood of SRDs, considering safety culture and sociodemographic factors. These analyses provided a comprehensive framework for exploring the relationship between safety culture and mental health outcomes in chemical laboratory settings.

Ethical approval was obtained from the Institutional Review Board (IRB) at Inje University, South Korea (File No. 2024-04-040-004). The study adhered to strict ethical standards, ensuring participant confidentiality and data privacy. Survey responses were collected anonymously through a secure online platform accessible only to the principal investigator. Informed consent was implied upon survey completion, and participants were fully briefed on the study's objectives and their rights before participation.

Results

Four hundred sixty-two laboratory professionals from academic, governmental, and industrial settings in Sri Lanka were invited to participate in the study via email. Of these, 271 individuals responded, yielding a response rate of 58.7%. After removing four incomplete submissions, the final analysis included 267 valid responses. Most participants were female (65.2%), with government laboratories having the highest proportion of female respondents (70.3%). The predominant age group was 25 to 34 years (58.1%), with a mean age of 35 years (SD = 10 years). Regarding educational background, 39.3% of respondents held a Bachelor's degree. In comparison, 22.8% had completed a Master's degree, and 6.4% had obtained a Doctoral degree, with doctoral qualifications being more common among industry laboratory workers. Regarding marital status, 53.6% were single, whereas 45.3% were married. Job roles varied across different laboratory sectors. A significant proportion of industry laboratory employees (73.7%) worked as Chemists, while most academic laboratory respondents (82.9%) were Research Scientists. Income levels revealed that nearly half of the participants (49.8%) earned between 155 and 310

USD per month, with academic laboratory professionals being the most represented within this income range (70.7%). The mean reported household income was 215 USD (SD = 141 USD). With respect to laboratory experience, over half of the respondents (55.1%) had been working in laboratories for 2 to 5 years, particularly in industrial settings (54.6%). On average, participants reported six years of laboratory experience (SD = 4 years), with a mean tenure of five years (SD = 4 years) in their current roles. When assessing chemical handling practices, 31.8% of participants reported working with chemicals for 21 to 30 hours per week, with an average weekly exposure of 25 hours (SD = 12 hours). Additionally, 23.2% of respondents handled chemicals for 31 to 40 hours per week, reflecting a high level of chemical interaction across all laboratory sectors.

Analyzing workers' attitudes and perceptions regarding laboratory safety revealed several key findings. Industry workers had the highest percentage of respondents who viewed safety as "very important" (28.9%), while government workers placed the most significant emphasis on safety being "paramount" (52.7%). Regarding the impact of inspections on laboratory safety, a substantial portion of government (58.1%) and academic workers (85.4%) agreed that inspections greatly improve safety. When asked if laboratory inspections and regulations negatively impacted productivity, most academic workers (73.2%) strongly disagreed, with 56% of respondents across all sectors sharing this view. Additionally, opinions on the stringency of safety procedures varied, with a substantial proportion of government workers (48.6%) considering their procedures "moderately stringent." Finally, regarding safety improvements over the past years, 85.4% of academic workers neither agreed nor disagreed, while 42.7% of all workers believed that laboratory safety could be improved.

The analysis of workers' laboratory practices regarding safety revealed several key findings. Across all sectors, a significant proportion of workers believed that appropriate safety measures had been implemented to protect them from injury, with government workers showing the strongest agreement (32.4%). Regarding PPE, a vast majority of industry (84.9%) and government workers (85.1%) reported that all employees are provided with PPE, while only 19.5% of academic workers indicated the same. Safety inspections were reported to occur at least once a quarter by the majority of workers, with 63.5% of government employees and 65.9% of academic workers indicating this frequency. Interestingly, most industry workers (61.8%) noted that inspections were conducted by external employees, contrasting with government employees, who reported that third-party inspections were more common (43.2%).

Regarding access to safety records, 55.4% of government workers agreed they had access to such data, compared to 46.7% in industry and 24.4% in academia. Furthermore, 63.2% of industry workers and 48.6% of government workers reported receiving safety training from their institution's lab safety staff, while supervisors or principal investigators primarily trained academic workers (51.2%). When asked about safety training on specific hazards, 57.2% of industry workers agreed they had received this training, compared to 54.1% of government workers and only 12.2% of academic workers.

On emergency preparedness, 97.8% of all workers indicated they were aware of emergency protocols, with industry and government workers displaying the highest awareness. However, 31.7% of academic workers reported working alone daily, which may pose a safety risk. Finally, 41.5% of academic workers and 44.7% of industry workers reported using their organization's approved risk assessment form before conducting experiments, indicating formalized risk management practices.

Analyzing workers' opinions on laboratory safety in their work environment revealed several important insights. A significant proportion of academic workers (46.3%) and government workers (56.8%) agreed that their laboratories are safe places to work. When assessing the importance of safety, 65.9% of academic workers viewed it as equal to other lab priorities, while 48.6% of government workers emphasized its precedence over other duties. Conversely, a notable percentage of academic workers (70.7%) believed that safety rules negatively impact productivity, a sentiment echoed by 30.3% of industry workers and 27.0% of government employees. Additionally, many academic workers (70.7%) felt that safety rules interfere with the scientific discovery process, with similar views held by 30.3% of industry and 27.0% of government workers.

Regarding perceived risk levels associated with laboratory work, 41.5% of academic workers assessed the risk as low, while 30.3% of industry workers considered it high. Most workers reported confidence in using PPE, with 90.2% of academic workers indicating they can use PPE properly. However, PPE usage among all laboratory staff varied, with only 22.0% of academic workers reporting consistent use, compared to 34.2% in the industry and 32.4% in government labs.

Table 1 presents data on the prevalence of SRDs among survey respondents. The sample's overall mean score on the GHQ was 14.75 ($\pm$ 5.14), with scores ranging from 0.0 to 18.0. According to a Likert scoring system, a cut-off point of $\geqslant$11 was established to screen for SRDs.[15] Individuals scoring 11 or higher were classified as "cases," while those scoring below 11 were classified as "non-cases". Notably, 36.3% of respondents (N = 97) met the criteria for mental health issues, categorized as cases, while 63.7% (N = 170) were classified as non-cases.

Table 1: Prevalence of probable mental health problems among respondents

GHQ score	N (%)	Mean (± SD)	Range	Minimum	Maximum
Non-cases	170 (63.7%)	14.75 (± 5.14)	0.0 - 18.0	9.0	27.0
Cases	97 (36.3%)				

GHQ score represents the General Health Questionnaire score, non-cases denote individuals not meeting criteria for mental health issues, while cases indicate those meeting the requirements, N-Number, SD- Standard deviation

Table 2 presents data on the association between respondents' GHQ scores and socio-demographic and occupational characteristics, analyzed using Pearson correlation tests. Significant relationships were found between the highest level of education attained (Pearson value = 0.135, p = 0.028), role within the laboratory (Pearson value = 0.122, p = 0.046), and duration of chemical handling experience (Pearson value = 0.389, p < 0.001). These findings indicate that educational attainment, job role, and working time with chemicals may significantly impact respondents' GHQ scores and occupational experiences.

Table 2: Relationship between GHQ score with sociodemographic and occupational factors

Variables	Pearson value	p-value
Highest Level of Education Attained	0.135[a]	0.028*
Role within the Laboratory	0.122[a]	0.046*
Duration of Chemical Handling Experience	0.389[a]	< 0.001*

[a]Pearson's Chi-square test, p Value-Asymptotic Significance (2-sided), *Statistical significance of the variable at p value < 0.05

The one-way ANOVA revealed a statistically significant difference in mental health and well-being scores across the three laboratory environments: Academic, Industry, and Government ($F(2, 264) = 4.658$, $p = 0.010$). The effect size ($\eta^2 = 0.034$) indicates that 3.4% of the variance in mental health and well-being scores can be attributed to the laboratory environment.

Post hoc analysis further elucidated these differences, showing a mean difference of 0.324 ($p = 0.942$) between Academic and Government Laboratories, 1.694 ($p = 0.141$) between Industry and Academic Laboratories, and 2.018 ($p = 0.015$) between Industry and Government Laboratories. Workers in Industry laboratories reported higher levels of SRDs, indicating more mental health challenges compared to Government and Academic settings.

The table 3 presents the results of the Pearson correlation tests, demonstrating the relationship between laboratory safety culture and its subscales with GHQ scores. Significant negative correlations were found across all subscales at the 1% significance level. Specifically, attitudes and perceptions toward safety showed a strong negative correlation (Pearson value = -0.782, $p < 0.001$), suggesting that more positive attitudes correspond to lower GHQ scores, indicating better mental health outcomes. The laboratory practices subscale also displayed a significant but weaker negative correlation (Pearson value = -0.251, $p < 0.001$), implying that better safety practices are linked to improved mental health. Additionally, safety opinions demonstrated the strongest negative correlation (Pearson value = -0.807, $p < 0.001$), indicating that more favorable safety opinions correlate with lower GHQ scores.

Table 3: Relationship between GHQ score with Laboratory Safety Culture

Scale	Subscale	Pearson value	p-value
Laboratory Safety Culture	Attitudes and Perceptions	-0.782[a]	< 0.001**
	Laboratory Practices	-0.251[a]	< 0.001**
	Safety Opinions	-0.807[a]	< 0.001**

[a]Pearson's Chi-square test, p Value-Asymptotic Significance (2-sided), **Statistical significance of the variable at p value < 0.01

Table 4: Predicting SRDs in Respondents Through Multiple Linear Regression Analysis

Predictor Variable	B	SE	β	t-value	p-value	95.0% Confidence Interval
Constant	9.772	0.873	-	11.195	< 0.001	(8.05 – 11.49)
Duration of Chemical Handling Experience	1.640	0.237	0.388	6.918	< 0.001*	(1.17 – 2.11)
Constant	27.175	1.110	-	24.476	< 0.001	(24.99 – 29.36)
Workers' attitudes and perceptions	-0.076	0.017	-0.324	-4.505	< 0.001*	(-0.109 – -0.043)
Workers' opinion	-0.124	0.017	-0.521	-7.276	< 0.001*	(-0.158 – -0.091)
Workers' laboratory practices	-0.008	0.018	-0.015	-0.414	0.679	(-0.043 – 0.028)

B-Unstandardized Coefficient, SE-Standard Error, β-Standardized Coefficient, *Statistical significance of the variable at p value < 0.05, t-values indicate predictor significance ($p < 0.05$)

Discussion

This study addresses significant gaps in laboratory safety practices and examines their impact on mental health outcomes, particularly SRDs, among laboratory workers in Sri Lanka. The findings highlight global challenges in laboratory safety, with notable disparities in safety culture and practices across academic, industry, and government sectors. Specifically, academic laboratories in Sri Lanka exhibit substantial deficiencies in safety measures, such as inconsistent safety protocols, inadequate use of PPE, and a lack of standardized safety training, despite regular inspections. These shortcomings amplify the risks associated with laboratory work, especially in environments where workers frequently operate alone, further increasing the dangers. This study aligns with similar findings in Hong Kong, where inadequate PPE usage and safety compliance were also observed. Despite global recognition of these safety gaps, they persist in laboratory settings, even in the presence of established frameworks like the ILO's OSH Management System.[16] The ILO emphasizes the importance of strengthening safety culture through systematic planning, policy implementation, monitoring, and auditing, yet these practices remain underutilized in Sri Lanka's laboratory environment.[17]

The variation in safety practices across the academic, industry, and government sectors can be attributed to differences in priorities, available resources, and the prevailing safety culture within each sector. Government laboratories, for example, generally show greater adherence to safety practices due to stricter regulatory frameworks. In contrast, academic laboratories often prioritize research output over safety, while industry laboratories face the challenge of balancing safety compliance with productivity demands.[18] These sector-specific differences underscore the need for tailored safety interventions that address the unique challenges faced by each sector. Government laboratories, for instance, would benefit from continuous safety training and regular audits. In contrast, academic laboratories might require a shift in organizational culture that positions safety as an integral part of research. The findings suggest that safety culture interventions should be designed to address these sector-specific challenges to foster a safer and healthier working environment for laboratory personnel.[19–22]

The European Agency for Safety and Health at Work highlights that prolonged chemical exposure, combined with workplace stress, is a significant contributor to productivity loss.[23] In Sri Lanka, the study found that younger, educated female laboratory workers, particularly in government roles, are at a higher risk due to their extended exposure to hazardous chemicals. While their working hours fall within the legal limits (8 hours per day, 48 hours per week), many workers reported handling chemicals for 21 to 40 or more hours per week. This extended exposure raises concerns about the cumulative psychological impact of chemical handling, which can exacerbate stress and increase the risk of SRDs. These findings resonate with research conducted by Kumareswaran et al. (2013) in Malaysia, where a significant proportion of laboratory workers reported high levels of workplace stress.[24] However, the prevalence of mental health issues in Sri Lanka was lower, with only 36.3% of respondents meeting the criteria for probable mental health problems, as identified by the GHQ. This discrepancy may be due to differences in safety practices, perceptions of stress, and cultural factors between Sri Lanka and countries like Malaysia.

The study also found significant correlations between GHQ scores and variables such as education level, job role, and chemical handling experience. Workers with longer exposure to hazardous chemicals reported higher levels of SRDs, emphasizing the cumulative impact of chemical handling on mental health. These findings align with those of Robson et al. (2010), who identified the importance of safety training in mitigating stress-related outcomes.[25] The significance of safety training is especially evident in this study, where improved safety practices were associated with fewer SRDs. However, the study also found that merely adhering to safety protocols did not significantly reduce SRDs, highlighting the need for a comprehensive safety culture beyond compliance to promote safety behaviors, attitudes, and practices actively.

The study's findings underscore the safety culture's critical role in reducing SRDs among laboratory workers. Positive safety attitudes and perceptions were found to be significant predictors of fewer SRDs, suggesting that fostering a safety-conscious environment is crucial for mitigating stress. The correlation between safety culture and SRD prevalence indicates that improving safety attitudes and appropriate training and protective measures can help address psychological distress in laboratory settings. However, the study also revealed that industry workers reported fewer SRDs than government workers; no significant differences in SRD prevalence were found between academic and government laboratories or industry and educational settings. This complex relationship suggests that factors other than sector, such as organizational culture, workload management, and the specific implementation of safety practices, also significantly influence mental health outcomes. These findings are consistent with Dehong Chen et al. (2018), who highlighted the importance of mental health education in laboratory settings to foster a culture of safety, teamwork, and emergency preparedness.[26]

This study's multiple linear regression analysis identified key predictors of SRDs, with chemical handling experience being one of the strongest predictors. Each additional year of exposure to hazardous chemicals increased the likelihood of experiencing SRDs by approximately 38.8%. This finding supports existing research linking prolonged exposure to hazardous substances with increased psychological distress. The analysis also found that positive safety attitudes and perceptions were significant negative predictors of SRDs, suggesting that enhancing safety culture could significantly reduce the likelihood of SRDs. However, the study found that strictly adhering to safety protocols alone did not significantly mitigate SRDs, reinforcing that a comprehensive safety culture, which integrates both positive safety attitudes and safety practices, is necessary to protect laboratory workers' health.

While this study offers valuable insights, certain limitations should be considered. Using an online survey may have introduced selection bias, potentially excluding individuals with limited internet access. Additionally, self-reported data are vulnerable to response biases, such as social desirability and recall bias, which could influence the findings. The cross-sectional design further restricts the ability to draw causal inferences between safety culture and mental health outcomes. Future research should employ mixed-methods approaches, integrating quantitative surveys with qualitative interviews to better understand the relationship between safety culture and mental health. Longitudinal studies are essential to robustly establish causality, while larger and more diverse samples will enhance the generalizability and global relevance of the findings.

Conclusion

This study underscores the critical role of safety culture in mitigating SRDs among laboratory workers, providing actionable insights to improve safety practices and enhance worker well-being. Identifying gaps in safety culture and psychosocial risk management highlights the need for evidence-based interventions, such as structured safety training, mental health support programs, and regular risk assessments, to effectively address sector-specific challenges. Although no direct interventions were undertaken in this study, the results establish a robust foundation for future organizational strategies to cultivate safety and resilience. Furthermore, the study calls for advanced research to unravel the complex interactions between safety culture, operational practices, and mental health outcomes, contributing to globally relevant approaches for ensuring sustainable laboratory safety and worker health.

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