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Research Article

ASSESSMENT OF THE CORRELATION BETWEEN PULMONARY FUNCTION AND COGNITIVE IMPAIRMENT IN OCCUPATIONAL HIGH-RISK WORK ENVIRONMENTS

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ABSTRACT

Objectives: This study aimed to investigate the correlation between pulmonary function and cognitive performance, assessed through pulmonary function tests (PFTs) and Montreal Cognitive Assessment (MoCA), among workers in high-risk occupational environments.

Methods: A cross-sectional study was conducted from March 2024 to January 2025 in Chennai, Tamil Nadu, involving 180 male participants (aged 30–55 years) from five occupational groups (carpenters, construction workers, drivers, painters, and welders) and a control group (computer programmers). PFTs measured forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), FEV_1/FVC ratio, and peak expiratory flow (PEF) pre- and post-shift. Cognitive function was assessed using the MoCA, evaluating visuospatial/executive function by the trail making test, naming, attention, language, abstraction, delayed recall, and orientation. Data were analyzed using one-way ANOVA, *post hoc* Tukey's tests, and the Kruskal–Wallis test, with statistical significance set at $p<0.05$.

Results: Significant post-shift declines in pulmonary parameters (FVC, FEV_1, PEF, and maximum voluntary ventilation) were observed across all occupational groups ($p<0.001$), with carpenters and construction workers showing the most pronounced reductions. MoCA scores revealed significant inter-group differences in visuospatial/executive function, language, attention, delayed recall, and orientation ($p<0.01$). Painters and drivers outperformed carpenters and construction workers in most cognitive domains. The control group exhibited superior pulmonary and cognitive performance. A significant inverse correlation was found between reduced pulmonary function and cognitive deficits, particularly in language and delayed recall.

Conclusion: Occupational exposure in high-risk environments is associated with acute pulmonary function decline and specific cognitive impairments, suggesting shared pathophysiological mechanisms such as inflammation and oxidative stress. Routine integration of cognitive and pulmonary assessments in occupational health surveillance is recommended to detect early functional decline and inform intervention strategies.

Keywords: Occupational exposure, Pulmonary function, Cognitive impairment, Montreal Cognitive Assessment, High-risk work environments.

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INTRODUCTION

In contemporary industrialized societies, a significant portion of the workforce faces daily exposure to occupational hazards that insidiously undermine their health and cognitive abilities. The World Health Organization reports that work-related diseases account for over 2 million annual deaths, with respiratory and neurodegenerative conditions being particularly prominent. Furthermore, the International Labor Organization estimates that over 70% of workers worldwide are exposed to at least one workplace risk factor that could negatively impact pulmonary or cognitive function [1]. The convergence of pulmonary and cognitive health is particularly concerning, given the intricate physiological links between respiratory function, systemic inflammation, and central nervous system integrity [2]. Occupational exposures to airborne pollutants, including particulate matter, gases, fumes, and secondhand smoke, have been established as significant contributors to chronic respiratory diseases such as chronic obstructive pulmonary disease and asthma [3]. Prolonged exposure to these pollutants triggers inflammatory cascades within the respiratory tract, leading to structural damage, impaired gas exchange, and systemic dissemination of inflammatory mediators, which can then propagate to the brain, potentially accelerating neurodegenerative processes [4,5]. Moreover, work-related stress, shift work, and sleep deprivation, often associated with demanding occupations, exacerbate the adverse effects of environmental toxins on both pulmonary and cognitive function.

Cognitive functions, encompassing attention, memory, executive functions, and perceptual-motor skills, are fundamental to performing both simple and complex tasks, including those encountered in the workplace [6]. Understanding how these functions change throughout the lifespan and how they are influenced by work is critical [7]. The interplay between work and cognitive aging is multifaceted, involving theoretical frameworks such as the "use-it-or-lose-it" hypothesis and the cognitive reserve hypothesis [7]. The "use-it-or-lose-it" hypothesis posits that engaging in mentally stimulating activities, such as complex jobs or enriched working environments can preserve and protect cognitive functions, leading to healthier cognitive aging [6].

The role of pulmonary health represents an underexplored pathway linking occupational exposure and cognitive impairment. Pulmonary function tests (PFTs), which are commonly used to monitor respiratory fitness in occupational settings, may offer predictive insights into cognitive outcomes [8]. Simultaneously, the Montreal Cognitive Assessment (MoCA) has become a valuable tool for detecting early cognitive changes, yet its integration into occupational health surveillance remains limited. This study aims to address this gap by investigating the relationship between respiratory function and cognitive performance among workers exposed to high-risk environments, such as mining, chemical processing, and manufacturing. This research is significant because it has the potential to reshape occupational health paradigms [9]. Although respiratory function is routinely monitored in hazardous occupations, cognitive assessment is frequently overlooked, despite growing evidence suggesting a correlation between the two. This oversight is particularly concerning, given that early cognitive decline can negatively impact safety, productivity, and long-term neurological health [10]. By incorporating cognitive assessments into routine health surveillance programs, workplaces can implement proactive strategies to mitigate cognitive decline, improve worker safety, and foster a more supportive and productive work environment.

Several key investigations have established a foundation for examining the correlation between occupational exposure, respiratory well-being, and cognitive decline. Sood and Redlich underscored the value of PFTs as essential tools for diagnostics and monitoring in workplace environments, while Townsend emphasized the imperative of longitudinal pulmonary assessments to comprehend the sustained effects of chronic exposure. Hobson presented a succinct clinical overview of the MoCA as a discerning instrument for identifying mild cognitive impairment, which is now extensively utilized in geriatric and neurological practices, albeit less so in occupational health contexts [11]. Recent studies have further enriched this comprehension. Ogawa *et al.* conducted a scoping review that revealed a consistent trend of cognitive impairment among individuals with Chronic Obstructive Pulmonary Disease, particularly those engaged in physically strenuous occupations [12]. In few studies, researchers analyzed MoCA scores in patients with chronic respiratory diseases, reinforcing the premise that compromised pulmonary function may contribute to cognitive deficits [13,14]. Population-based studies, such as that by Gu *et al.*, provide robust epidemiological evidence linking ventilatory function with mild cognitive impairment in rural Chinese adults [15]. On a broader scale, Manee *et al.* offered a global perspective on the utilization of cognitive assessments in occupational therapy, highlighting the necessity for context-specific instruments and protocols to effectively monitor cognitive health across diverse workforces [16]. Many studies look at lung health or brain function separately, missing the connection between the two. There is not enough research that links lung function tests with cognitive assessments in real work environments. This study aims to connect lung function test results with cognitive assessment scores in people with high-risk jobs.

METHODS

This cross-sectional observational study was conducted to examine the relationship between occupational exposure, pulmonary function, and cognitive decline among individuals employed in high-risk work environments. The research was carried out across five industrial zones in and around Chennai, Tamil Nadu, from March 2024 to January 2025. A total of 180 male participants, aged 30–55 years, were purposively selected for the study. The sample consisted of 30 participants from each of six occupational groups: carpenters, construction workers, drivers, painters, welders, and computer programmers (control group). To ensure a homogeneous sample and enhance the validity of the study findings, specific inclusion criteria were applied. Participants were required to have a minimum of 5 years of uninterrupted employment in their respective occupational domains, with an educational background of at least secondary education. In addition, a monthly salary ranging from ₹35,000 to ₹40,000 or higher was considered a prerequisite, indicative of a stable socioeconomic status. In addition, participant's workplaces were characterized by inadequate or non-use of personal protective equipment. Individuals with a prior history of neurological, psychiatric, or severe pulmonary disease, as well as those using neuroactive medications or with substance abuse histories, were excluded to avoid the interference of pre-existing neurological and psychiatric issues and their treatment, as well as established pulmonary disorders with respiratory inhalation stress-induced cognitive impairment in the subjects. All participants gave written informed consent, and the study protocol was approved by the Institutional Ethics Committee (Approval No: IHEC-II/0516/24), in accordance with the Declaration of Helsinki.

Participants were categorized into five predefined groups based on their occupations. All cognitive and pulmonary assessments were performed in occupational health clinics. The MoCA was used to evaluate cognitive domains, including visuospatial/executive functions, by the Trail Making Test, naming, attention, language, abstraction, delayed recall, and orientation. MoCA assessments were conducted by trained psychologists, and a score of ≤25 was indicative of mild cognitive impairment. Pulmonary function was measured using a portable computerized spirometer (SpiroTech SP3), adhering to the American Thoracic Society/European Respiratory Society guidelines [11,17]. The parameters recorded were forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, and peak expiratory flow (PEF). All assessments were conducted under standardized conditions following an 8-h work-free interval to minimize acute exposure effects [18]. The data obtained were analyzed using SPSS version 28. Descriptive statistics, including means and standard deviations, were computed for each cognitive domain across the various occupational groups, and one-way Analysis of Variance was employed to ascertain significant differences between the groups. In instances where significant F-values were observed, *post hoc* Tukey's Honest Significant Difference tests were conducted to pinpoint specific intergroup differences. Statistical significance was predetermined at $p<0.05$, with $p<0.01$ denoting a high level of significance.

RESULTS

The study included 180 participants, equally distributed among six groups: drivers, welders, carpenters, painters, construction workers, and a control group. Initial analysis revealed no statistically significant differences in age (F=1.132, p=0.345), with an overall mean age of 33.06±4.62 years. Similarly, homogeneity was confirmed by the absence of significant differences in height (F=0.552, p=0.737) and weight (F=0.495, p=0.780) across the occupational groups.

PFTs revealed significant differences between morning (AM) and evening (PM) measurements across all occupational groups. FVC (L) showed significant reduction in post-shift measurements compared to pre-shift values in all groups (p<0.001), with the most pronounced decline observed in carpenters (0.588±0.466 L), followed by construction workers (0.353±0.170 L) and drivers (0.354±0.247 L). FEV1 (L) similarly demonstrated significant reductions in all groups when comparing morning to evening measurements (p<0.001). The most substantial decline was observed in carpenters (0.643±0.476 L), followed by construction workers (0.470±0.232 L) and drivers (0.393±0.204 L). The control group exhibited the least reduction (0.197±0.234 L). The FEV1/FVC ratio (FR) showed significant decreases in post-shift measurements for drivers (p=0.005), carpenters (p<0.001), painters (p<0.001), and construction workers (p<0.001). Notably, no significant changes were observed in the welders (p=0.284) or control (p=0.777) groups. Forced expiratory flow (FEF, L/s) demonstrated significant decreases from morning to evening measurements across all groups (p<0.001) except construction workers (p=0.065). The most substantial reductions were noted in welders (0.344±0.193 L/s) and drivers (0.234±0.242 L/s). PEF (L/s) showed significant post-shift reductions across all groups (p<0.01), with the most pronounced decreases in welders (0.558±1.075 L/s) and drivers (0.467±0.257 L/s). Forced expiratory time (FET, s) displayed a different pattern, with significant increases in post-shift measurements compared to pre-shift values in drivers (0.448±0.636 s), carpenters (0.350±0.146 s), painters

(0.553±0.343 s), construction workers (0.462±0.429 s), and controls (0.293±0.340 s) (all p<0.01).

In contrast, welders showed no significant change (p=0.745). Maximum voluntary ventilation (MVV, L/Min) showed significant reductions in post-shift measurements across all groups (p<0.001). The most substantial decreases were observed in construction workers (15.30±11.29 L/min), painters (14.03±8.06 L/min), and drivers (11.74±8.31 L/min). Vital capacity (VC, L) measurements revealed significant post-shift reductions across all groups (p<0.001), with the largest decrease observed in painters (0.487±0.221 L) and drivers (0.465±0.189 L). Inspiratory reserve volume (IRV, L) also showed significant reductions in all groups (p<0.001), with painters (0.443±0.178 L) and construction workers (0.431±0.177 L) demonstrating the most substantial decreases. Inspiratory capacity (IC, L) measurements similarly demonstrated significant post-shift reductions across all groups (p<0.01), with the most pronounced decreases in drivers (0.412±0.212 L) and construction workers (0.408±0.199 L) (Table 1).

Analysis of variance indicated significant differences between the occupational groups in both morning and evening measurements for FVC (L=5.587, p<0.001 for AM; F=12.782, p<0.001 for PM), FEV1 (L=8.699, p<0.001 for AM; F=16.995, p<0.001 for PM), and Forced Expiratory Flow (FEF, s=80.040, p<0.001 for AM; F=49.094, p<0.001 for PM). Significant variations were also evident in PEF (L/s=51.623, p<0.001 for AM; F=150.933, p<0.001 for PM), FET (s=73.740, p<0.001 for AM; F=50.231, p<0.001 for PM), and MVV (L/min=185.554, p<0.001 for AM; F=80.959, p<0.001 for PM). The control group consistently demonstrated superior pulmonary function values compared to all occupational groups (Figs. 1 and 2).

Cognitive function, evaluated via MoCA components, revealed significant inter-group differences across all domains (visuospatial/executive function=13.335, p<0.001; naming=2.937, p=0.014; attention=5.342, p<0.001; language=29.699, p<0.001; abstraction=2.927, p=0.015; delayed recall=19.509, p<0.001; and orientation=18.590, p<0.001). Analysis of the MoCA scores revealed statistically significant differences in cognitive domain performance across the occupational groups. Painters exhibited the highest mean score in visuospatial/executive function, followed by drivers, welders, construction workers, and carpenters (F=4.418, p<0.01). In the naming domain, scores exhibited a narrow range, from 2.7 for carpenters to 2.9 for painters, drivers, and welders, with modest but statistically significant differences observed (F=2.466, p<0.05). Regarding attention, painters demonstrated superior performance, closely followed by drivers, while carpenters scored the lowest, a difference that reached statistical significance (F=4.121, p<0.01). Performance in the language domain varied most significantly, with carpenters 1.5 demonstrating the lowest scores and drivers and painters 2.6 achieving the highest. This variation was statistically significant (F=21.977, p<0.01), in terms of abstraction abilities, the scores exhibited only marginal variation across the groups, ranging from 1.6 to 1.8. Consequently, this cognitive parameter did not yield statistically significant differences between the occupational groups (F=1.579, p>0.1).

Table 1: One-way ANOVA results for pulmonary function parameters across occupational groups (one-way analysis of variance [ANOVA] comparing pulmonary function parameters across five occupational groups [carpenters, construction workers, drivers, painters, and welders] measured during morning [AM] and evening [PM] sessions)

Parameter	Time	F-statistic	p-value	Effect size (η^2)
FVC (L)	AM	5.587	<0.001	0.138
	PM	12.782	<0.001	0.269
FEV_1 (L)	AM	8.699	<0.001	0.2
	PM	16.995	<0.001	0.328
FEV_1/FVC ratio (%)	AM	3.335	<0.01	0.087
	PM	6.863	<0.001	0.165
FEF_{25-75} (L/s)	AM	80.04	<0.001	0.697
	PM	49.094	<0.001	0.585
PEF (L/s)	AM	51.623	<0.001	0.597
	PM	150.933	<0.001	0.813
FET (s)	AM	73.74	<0.001	0.679
	PM	50.231	<0.001	0.591
MVV (L/min)	AM	185.554	<0.001	0.842
	PM	80.959	<0.001	0.699
VC (L)	AM	93.479	<0.001	0.729
	PM	64.739	<0.001	0.65
IRV (L)	AM	48.759	<0.001	0.584
	PM	41.993	<0.001	0.547
IC (L)	AM	8.898	<0.001	0.204
	PM	3.219	<0.01	0.085

FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 s, FEF_{25-75}: Forced expiratory flow between 25–75% of FVC, PEF: Peak expiratory flow, FET: Forced expiratory time, MVV: Maximum voluntary ventilation, VC: Vital capacity, IRV: Inspiratory reserve volume, IC: Inspiratory capacity

In terms of delayed recall, painters and drivers demonstrated the highest levels of performance, while carpenters exhibited the lowest mean score, indicating a significant difference between the groups (F=7.511, p<0.01). Regarding orientation, painters attained the highest scores, followed by drivers and welders, with carpenters again scoring the lowest. These differences were also statistically significant (F=4.67, p<0.01) (Fig. 3).

The data suggest that individuals working in occupations requiring greater mobility or environmental adaptability, such as painters and drivers, consistently outperformed those in more static, high-exposure occupations like carpentry across several cognitive domains, notably language, delayed recall, and orientation. Performance in abstraction tasks was relatively consistent across all groups. These results emphasize the potential impact of occupational context and the nature of workplace exposures on specific aspects of cognitive decline. The substantial variation between occupational groups highlights the importance of implementing occupation-specific cognitive monitoring and early intervention programs.

The Kruskal-Wallis test confirmed these findings, showing significant between-group differences in visuospatial/executive function (χ^2=51.855, p<0.001), naming (χ^2=13.929, p=0.016), attention (χ^2=23.569, p<0.001), language (χ^2=72.510, p<0.001), abstraction (χ^2=13.888, p=0.016), delayed recall (χ^2=60.912, p<0.001), and orientation (χ^2=67.180, p<0.001). Mean rank analysis indicated that the control group consistently demonstrated the highest cognitive scores across all domains, while carpenters showed the lowest mean ranks in most cognitive domains. Painters generally demonstrated better cognitive performance compared to other occupational groups, ranking second in visuospatial/executive function, attention, delayed recall, and orientation domains.

DISCUSSION

This study investigated the correlation between occupational exposures and cognitive decline by examining the relationship between PFT parameters and MoCA scores across various high-risk work environments. The results indicate a consistent and significant decline in pulmonary function during work shifts across all occupational groups, especially among carpenters, drivers, and construction workers. Furthermore, the study reveals distinct inter-occupational differences in cognitive performance, particularly in visuospatial/executive function, language, attention, and delayed recall. These findings suggest a notable association between pulmonary compromise resulting from occupational exposure and the potential for cognitive deterioration.

The decline in pulmonary parameters from pre- to post-shift observed across all occupational groups is in line with previous studies reporting

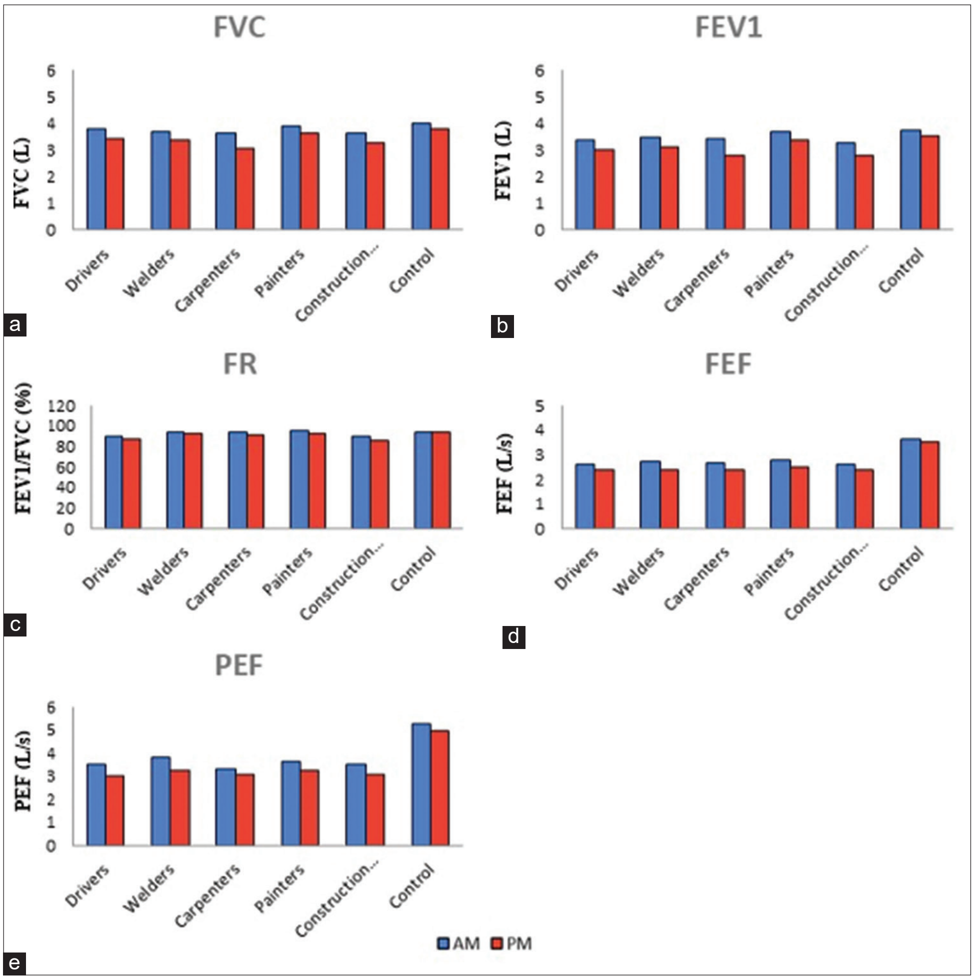

Fig. 1: Diurnal variations in primary pulmonary function parameters across occupational groups and controls (bar charts displaying morning measurements of five primary pulmonary function parameters across six study groups. Parameters include: (a) Vital capacity (VC, L). (b) Forced vital capacity (FVC, L). (c) Peak expiratory flow (PEF, L/s). (d) Forced expiratory flow 25–75% (FEF_{25-75}, L/s). and (e) FEV_1/FVC ratio (FR, %). Values represent mean±standard error

acute and chronic respiratory impairments resulting from occupational exposure to dust, fumes, and pollutants. Notably, significant reductions in FVC (L), FEV_1 (L), PEF (L/s), and MVV (L/min) among carpenters, construction workers, and drivers suggest that repetitive inhalation of particulate matter, volatile organic compounds (VOCs), and diesel exhaust could be directly compromising airway patency and respiratory effort. Study results showed correlation with documented accelerated pulmonary function decline in populations exposed to occupational irritants, particularly in early COPD cases [19,20]. Studies correlates with the current results, that dust-exposed workers exhibited lower FEV_1 and FVC values compared to unexposed controls, a trend we confirmed across our study population. These acute declines are biologically plausible and may result from transient airway inflammation, bronchial constriction, or oxidative stress caused by inhaled irritants [21,22]. As supported by molecular studies inhalation of fine particulates can trigger inflammatory cascades through cytokine release (e.g., interleukin-6, tumor necrosis factor-alpha), leading to reversible airway narrowing and cumulative lung damage [23]. In this study, the welders, despite exposure to metal fumes, demonstrated relatively preserved FEV_1/FVC ratios and non-significant FET changes, possibly due to better ventilation systems or reduced cumulative exposure hours.

Observed group-level differences in MoCA scores, particularly in visuospatial/executive functioning, language, attention, delayed recall, and orientation, emphasize the cognitive variations potentially linked to occupational demands and environmental exposures. Consistently, painters and drivers demonstrated higher scores across multiple domains, while carpenters and construction workers exhibited the lowest cognitive performance, aligning with existing literature that identifies occupational environment and complexity as key determinants of cognitive aging [24,25].

Occupations involving continuous sensory-motor integration (e.g., painting or driving) may offer a form of cognitive stimulation that buffers against decline, aligning with the cognitive reserve theory. The strong inverse correlation observed between pulmonary impairment and cognitive performance is consistent with earlier reports [8]. Few studies demonstrated that reduced FEV_1 and PEF values are significantly associated with lower cognitive scores in older adults, positing hypoxemia and vascular dysfunction as potential mediators. Our findings add to this body of evidence by confirming that even younger occupational cohorts (mean age ~33 years) may exhibit early cognitive changes linked to reduced respiratory capacity [26]. Bremner (2006) proposed that chronic respiratory impairment may lead to decreased cerebral perfusion,

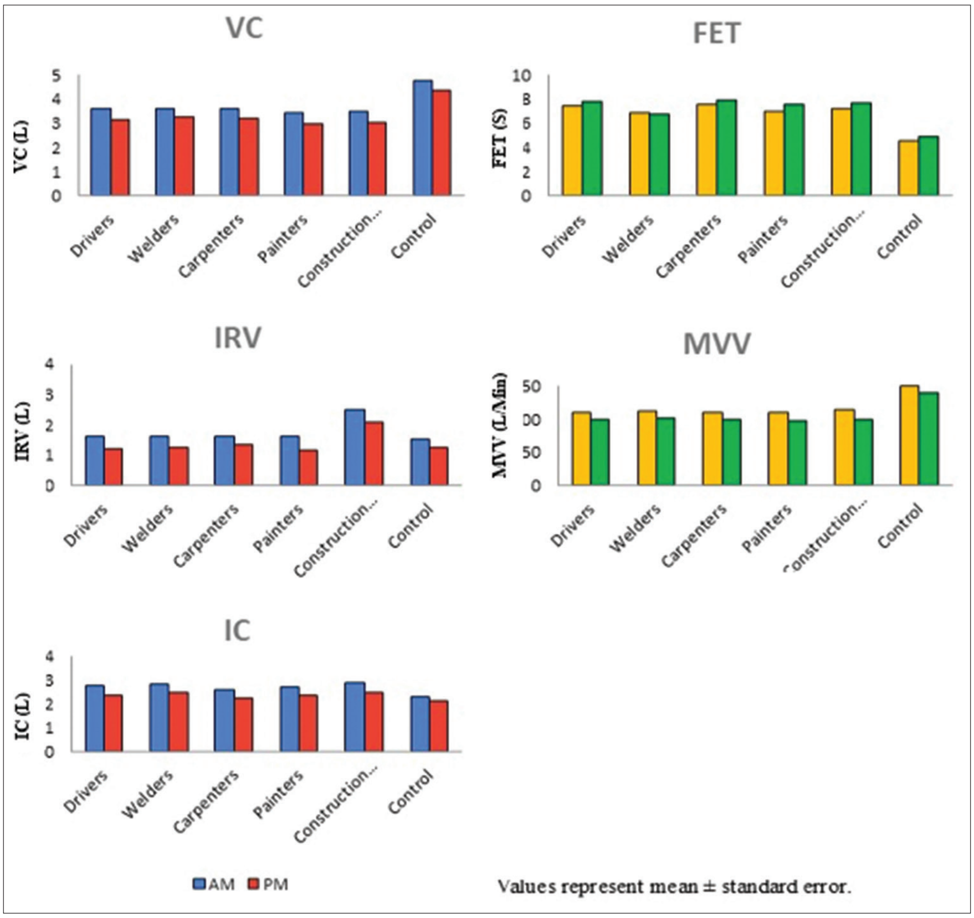

Fig. 2: Comparison of pulmonary function parameters between morning and evening measurements across occupational groups

which affects hippocampal and frontal lobe functions—regions essential for memory and executive function—possibly explaining our observed deficits in delayed recall and visuospatial/executive tasks [27].

Although our findings are supported by numerous studies, some research indicates a weaker or non-significant relationship between pulmonary function and cognitive abilities. For example, Zhou *et al.* suggested the absence of a strong predictive correlation between lung function and cognition in middle-aged individuals, which they explained by potential compensatory mechanisms present in younger adults. Few studies shows significant cognitive decline among patients with severe COPD, but these changes are not consistently observed in milder or moderate pulmonary impairment [28].

However, our data suggest that even in the absence of overt cognitive impairment, subclinical declines may be detectable using sensitive tools like the MoCA, consistent with findings of different studies [8,13,17,29]. Hobson *et al.* posit that the MoCA is more effective than the mini-mental state examination for detecting subtle cognitive changes. Interestingly, welders, despite exhibiting some of the most significant declines in PEF and FEF, did not show equivalent cognitive impairment [11]. This observed variance might stem from the utilization of occupational safety measures or a diminished degree of systemic inflammation resulting from sporadic exposure. It is also plausible that these differences are indicative of variations in inherent cognitive reserve or educational attainment, factors that, while not directly assessed in this investigation, are recognized determinants of cognitive function [30].

Several mechanisms explain the link between impaired pulmonary function and cognitive deficits, including systemic inflammation, oxidative stress, and endothelial dysfunction, all of which can disrupt the blood–brain barrier and contribute to neurodegeneration. Furthermore, prolonged exposure to airborne neurotoxins, which are common in carpentry and construction environments, may directly damage neurons. Research has also indicated that occupational roles lacking cognitive stimulation or autonomy can reduce neuroplasticity, potentially exacerbating the effects of environmental stressors [31-33]. It's much needed to concentrate on proper assessment of pulmonary functions at high risk workplaces and based on the lung functioning stage there should be appropriate therapeutic approach to avoid comorbid complications with proper drug delivery mechanisms [34,35].

The incorporation of a control group, along with standardized pre- and post-shift assessments, bolsters the reliability of the observed changes. Furthermore, the utilization of the MoCA as a sensitive cognitive screening instrument facilitated the detection of subtle impairments that are frequently overlooked in occupational health contexts. Nevertheless, the study is not without limitations. Its cross-sectional design impedes the establishment of causal relationships, and the absence of biochemical or neuroimaging data restricts the investigation of the underlying pathophysiology. The lack of adjustments for educational attainment, socioeconomic status, and occupational tenure may introduce confounding factors in the cognitive outcomes. Future longitudinal studies employing neuroimaging and biomarker analyses are warranted to elucidate causative mechanisms and temporal associations. Additional investigations incorporating longitudinal PFTs

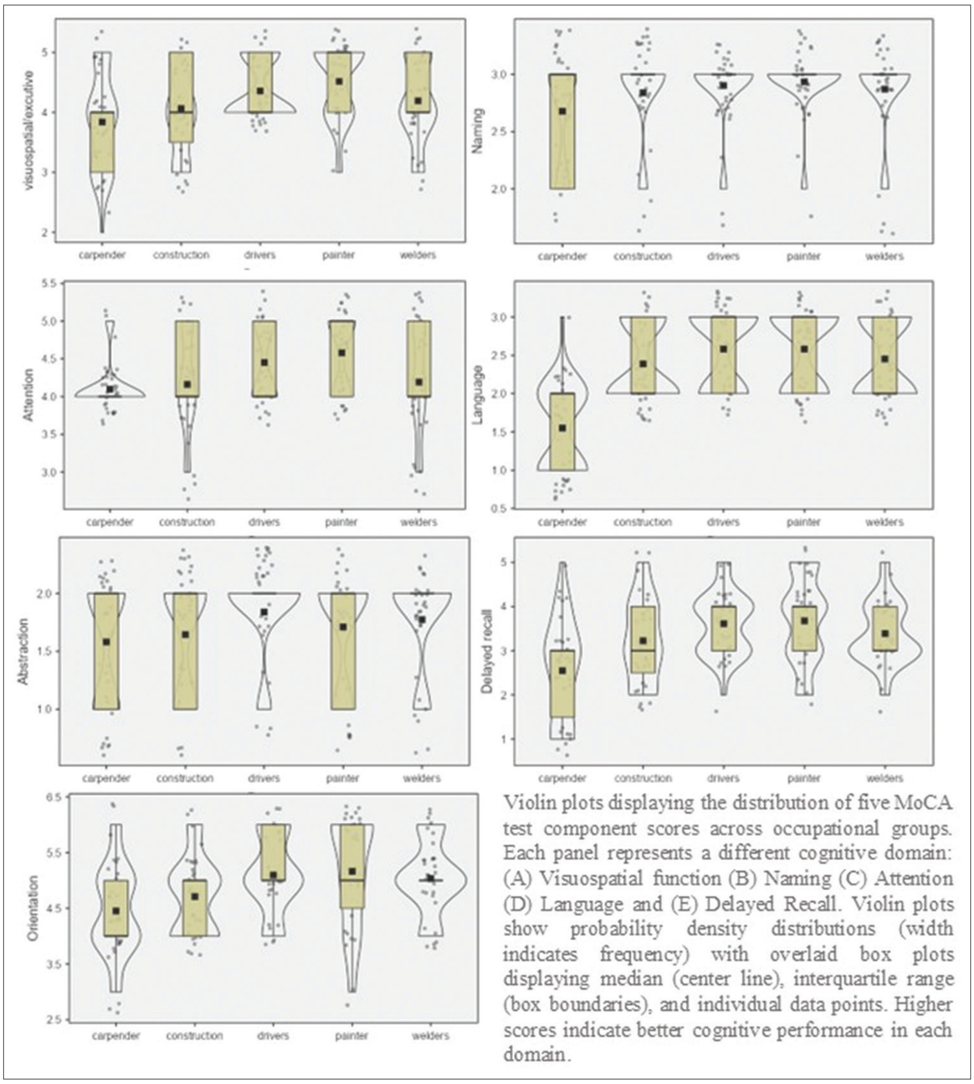

Fig. 3: Distribution of Montreal Cognitive Assessment component scores across high-risk occupational groups

would help to more fully characterize the acute and chronic effects of exposure.

CONCLUSION

This investigation presents substantial evidence indicating a significant association between occupational exposure in hazardous work environments and both immediate reductions in pulmonary function and specific cognitive deficits. Individuals employed in occupations such as carpentry, construction, and driving exhibited notable post-shift decreases in essential respiratory metrics and obtained lower scores on specific domains of the MoCA, particularly in language, attention, and delayed recall. These findings imply a shared pathophysiological mechanism underlying respiratory compromise and diminished cognitive performance, potentially involving chronic inflammation, oxidative stress, and neurovascular alterations. Consequently, this study emphasizes the necessity of implementing comprehensive occupational health monitoring protocols that incorporate both pulmonary and cognitive evaluations to facilitate the early detection of functional decline. Despite inherent limitations, such as its cross-sectional design and limited control of confounding variables, this research underscores the pressing requirement for proactive measures and policy interventions targeting occupational settings characterized by elevated exposure risks. Future longitudinal studies are warranted to further elucidate causative relationships and underlying molecular mechanisms.

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All Authors have equal contribution.

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CONFLICTS OF INTEREST

The authors don't have any conflicting interests.

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