RESEARCH ARTICLE

THE RELATIONSHIP BETWEEN NUTRITIONAL STATUS WITH MALONDIALDEHYDE (MDA) AND VITAMIN D LEVEL

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ABSTRACT

Introduction: Nutritional status has been found to be correlated with malondialdehyde (MDA) profiles in the blood. MDA is a marker of oxidative stress in the body and is the final product of lipid peroxidation chain reactions. The long-term undernutrition and excess status will be closely related to metabolic disorders and degenerative diseases. Street cleaning staff are often exposed to free radicals that will improve lipid peroxidation, which will also break down into MDA. Vitamin D serum levels have an inverse correlation with adipose tissue mass, where the higher the BMI and body fat mass of a person, the lower the levels of vitamin D serum. The purpose of this study was to determine the relationship of nutritional status with MDA and vitamin D levels in the blood.

Methods: This research conducted from July 2024 to February 2025, using a cross-sectional design at the Faculty of Medicine, Trisakti University, with the target population being the street cleaning staff in Jakarta. The samples were taken by consecutive sampling for all street cleaning staff who met the inclusion and exclusion criteria, with a total of 76 samples.

Results: BMI showed no significant relationship with either MDA or vitamin D, but there was a significant relationship between vitamin D and MDA (r=0.190. p=0.047).

Coclusion: Higher BMI is associated with a relative reduction in musclemass percentage and a substantial increase in visceral adiposity,irrespective of sex. These findings suggest that BMI alone may notadequately represent body composition or metabolic risk and supportthe routine use of body composition assessment as a complementarytool in clinical obesity evaluation.

Keywords: Nutritional, status, MDA, vitamin D.

INTRODUCTION

Oxidative stress plays a central role in the pathogenesis of metabolic and degenerative diseases. It occurs when the production of reactive oxygen species (ROS) exceeds the body's antioxidant defense capacity, leading to cellular and molecular damage. One of the most widely used biomarkers to assess oxidative stress is malondialdehyde (MDA), a product of lipid peroxidation that reflects oxidative injury within biological systems.[1] Oxidative stress is defined as a condition where there is an imbalance between the oxidation process by free radicals and the process of penetration by antioxidants in the body. Oxidative stress conditions are formed *Reactive Oxygen Species* (ROS) consisting of oxygen free radicals (super oxides) and their derivatives (hydroxyl radicals) O^2-, OH^- and H^2O^2.[2] As the nature of free radicals, ROS are active and always find other electrons in order to be able to pair and can cause cell damage, membrane dysfunction, protein modification, enzyme activation, and rupture of DNA chains. Damage to the intracellular structure directly affects the arrangement of cell metabolism. ROS can attack molecules on cell membranes and networks; for example, the disruption of the lysosome membrane causes the release of lysosomal hydrolytic enzymes that further cause intracellular damage and strengthen the ability of free radicals to induce cell damage.[3]

Vitamin D has been recognized not only for its classical role in calcium homeostasis and bone metabolism but also for its emerging functions in modulating inflammation and oxidative stress. Vitamin D deficiency has been associated with increased oxidative damage, yet the relationship between vitamin D status and MDA levels remains controversial across different populations and clinical contexts. Vitamin D deficiency can decrease the response of weight loss therapy, so the bioavailability of vitamin D serum is low due to the increase of vitamin D circulation into high fat cell deposits, and deposits of vitamin D increase in adipose tissue.[4] Vitamin D deficiency is generally defined as a serum 25-hydroxyvitamin D (25(OH)D) level below 20 ng/mL. Additionally, low levels of vitamin D have been associated with a higher risk of chronic diseases, including cardiovascular disease, diabetes, and autoimmune conditions. High levels of fat in the body are one of the risk factors for vitamin D deficiency.[5] Vitamin D insufficiency refers to serum levels between 20 ng/mL and 29 ng/mL. While not as severe as deficiency, insufficiency still poses risks to health. Insufficiency is often more common in individuals who do not get enough sunlight exposure, those with darker skin, older adults, and individuals with obesity.[6] Street cleaning staff are at risk of exposure to free radicals such as vehicle pollution, UV light, and various other pollutants. A radical increase will be at risk of oxidative stress causing lipid peroxidase in the body and causing degenerative diseases. Nutritional status greatly affects both the bad risks caused by these free radicals.[7] Furthermore, most previous studies were conducted in clinical or laboratory settings, with limited data on outdoor workers who experience chronic environmental stressors such as ultraviolet exposure, air pollution, and heat. These environmental factors may further amplify oxidative stress and alter vitamin D metabolism, leading to unique physiological adaptations.[8]

Body mass index (BMI), a marker of nutritional and adiposity status, has been linked to both oxidative stress and vitamin D levels. Individuals with higher BMI often exhibit increased oxidative stress due to chronic inflammation and lipid peroxidation, alongside reduced circulating vitamin D resulting from its sequestration in adipose tissue. Despite this, the interplay between BMI, vitamin D, and oxidative stress (MDA) has not been fully elucidated, particularly in populations exposed to environmental stressors such as air pollution and ultraviolet radiation.[9] Elevated BMI has been associated with higher oxidative stress through increased lipid peroxidation, while vitamin D deficiency is often observed in individuals with excessive adiposity due to its sequestration in fat tissue. However, research exploring whether low vitamin D levels correlate with elevated MDA concentrations across different BMI categories has shown inconsistent and population-specific findings.[1]

Therefore, this study aims to investigate the relationship between serum MDA levels, vitamin D concentration, and BMI among street cleaning workers in Jakarta. This population provides a unique model to explore how nutritional and environmental factors influence oxidative stress dynamics, filling the research gap on the triangular relationship between oxidative biomarkers, vitamin D status, and body composition.

METHODS

Study Design

This study is a descriptive analytic observational research with a cross sectional design, aiming to determine the relationship between nutritional status, MDA, and vitamin D levels among street cleaning staff.This research was approved by the Ethics Committee Faculty of Medicine Universitas Trisakti, with number 086/KER/FK/08/2024.

Population and Sampling

This study involved 76 street cleaning staff employed by the Jakarta Provincial Government. The research was conducted between July 2024 and February 2025 at the Faculty of Medicine, Trisakti University, Jakarta. Samples were selected using a consecutive sampling method from participants who met the inclusion and exclusion criteria. The inclusion criteria were individuals who agreed to sign an informed consent form, were actively working as street cleaning staff, and had no history of cardiovascular disease or diabetes mellitus. Exclusion criteria included pregnancy or lactation, physical disabilities (such as post-injury or post-stroke conditions), and chronic or infectious diseases such as cancer, tuberculosis, chronic renal failure, or heart failure. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ–short form), and participants with extremely high or low activity levels were excluded. The resulting activity scores were also included as covariates during data analysis to account for their potential effect on oxidative stress markers. Ultraviolet (UV) exposure was documented through a structured questionnaire that recorded average daily sunlight exposure, time of day, and use of sun protection. Participants with unusual UV exposure patterns, such as night-shift workers or those using full protective clothing, were excluded to maintain homogeneity. Dietary intake was evaluated using both a 24-hour food recall and a semi-quantitative Food Frequency Questionnaire (FFQ) focusing on vitamin D–rich and antioxidant-containing foods. Participants were instructed to maintain their usual dietary habits during the study period, and dietary intake was statistically adjusted as a confounding factor in the analysis.

Data collection

Demographic information, height and weight, medical history, as well as blood test results for MDA and vitamin D, are some data collected.

MDA Measurement

Blood samples (3 mL) were collected in EDTA tubes and centrifuged at 3000 rpm for 10 minutes. The serum malondialdehyde (MDA) level was measured using the Thiobarbituric Acid Reactive Substances (TBARS) assay method. The absorbance was read at 532 nm wavelength

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using a Shimadzu UV-1800 spectrophotometer (Japan). Reagents used included thiobarbituric acid (TBA) 0.67% and trichloroacetic acid (TCA) 10%.

Vitamin D Measurement

Serum vitamin D levels (25(OH)D) were measured using the Enzyme-Linked Immunosorbent Assay (ELISA) method with Human 25-OH Vitamin D ELISA Kit (Cat. No. E-EL-0025, Elabscience, USA). The optical density was read at 450 nm wavelength using a Bio-Rad iMark™ microplate reader.The MDA values were examined using spectrophotometry with a 532 nm wavelength with maximal absorption, while vitamin D examination was determined by measuring the concentration of 25 (OH)-D in blood plasma using the ELISA method.

Data Analysis

Data were analyzed using SPSS software to examine the relationship between nutritional status, malondialdehyde (MDA) profile, and vitamin D levels among street cleaning staff. An Independent T-test was applied to compare mean differences between two independent groups. For normally distributed numerical data, the Pearson correlation test was applied, while for non-normally distributed data, the Spearman rank correlation test was used. In this study, the Pearson correlation coefficient was used to assess the strength and direction of the linear association between two numerical variables, such as vitamin D and MDA levels.

RESULTS

The primary objective of this study was to investigate the correlation between nutritional status, malondialdehyde (MDA) profile, and vitamin D levels among street cleaning staff. Nutritional status plays a crucial role in maintaining metabolic balance, while MDA serves as a biomarker of oxidative stress, and vitamin D is essential for immune regulation and overall health. This research aims to provide scientific evidence by quantifying and analyzing the relationships among these variables, with the goal of understanding how nutritional factors and oxidative stress contribute to the health outcomes of individuals exposed to occupational and environmental stressors. Table 1 describes the characteristics of research respondents.

Table 1. Characteristic Sample

Variable	N (76)
Age	
Mean±Std	41.01±8.916
Median	41.00
Range (min-max)	21.00-56.00
95% CI	40.09-42.21
Gender	
Man	70 (92.1%)
Woman	6 (7.8%)
Ethnic	
Javanese	22 (28.9%)
Sundanese	10 (13.2%)
Betawi	42 (55.3%)
Melayu	1 (1.3%)
West Sumatera	1 (1.3%)
Education	
Elementary School	3 (3.9%)
Junior High School	12 (15.8%)
Senior High School	58 (76.3%)
University	3 (3.9%)
Marriage Status	
Married	66 (86.8%)
Non married	5 (6.6%)
Divorce	5(6.6%)
Duration of Work in Hours	
Mean±Std	7.97±0.231
Median	8.00
Range (min-max)	6.00-8.00
95% CI	7.92-8.02
Height (cm)	
Mean±Std	162.01±6.979
Median	162.00
Range (min-max)	145.00-185.00
95% CI	160.5-163.7
Weight (kg)	
Mean±Std	63.85±11.020
Median	64.00
Range (min-max)	45.50-111.60
95% CI	61.3-66.3
Body Mass Index (BMI)	
Mean±Std	24.34±3.832
Median	24.50
Range (min-max)	17.16-32.61
95% CI	23.4-25.1
BMI Category	
Obese	17 (22.4%)
Non-obese	59 (77.6%)
Vitamin D (ng/mL)	
Mean±Std	25.7±6.23
Median	25.6
Range (min-max)	9.00-38.00
95% CI	24.3-27.2
MDA (µM)	
Mean±Std	0.78±0.21
Median	0.75
Range (min-max)	0.40-1.78
95% CI	0.73-0.83

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Table 1 shows a diverse group of 76 participants, with a majority being male (92.1%) and from the Betawi ethnic group (55.3%). The average age of the participants is 41.01 years, with most having completed Senior High School (76.3%) and a high proportion being married (86.8%). In terms of health indicators, the average BMI is 24.34, placing most participants in the healthy weight range, though 22.4% fall into the obese category, indicating a potential area of concern. The average work duration is 7.97 hours per day, and participants generally have an average height of 162.01 cm and an average weight of 63.85 kg. The data reveals that the average Vitamin D level in the sample is 25.7 ng/mL, with a standard deviation of 6.23, indicating some variability around the mean. The median value of 25.6 ng/mL is quite close to the mean, suggesting that the data distribution is fairly symmetrical. The 95% Confidence Interval (CI) for Vitamin D is 24.3 - 27.2 ng/mL, meaning that we can be 95% confident that the true average Vitamin D level in the population falls within this range. As for MDA the average level is 0.78 µM, with a standard deviation of 0.21, suggesting moderate variability. The median value is 0.75 µM, indicating that the data points are clustered around the mean. The 95% CI for MDA is 0.73 - 0.83 µM, which means we can be 95% confident that the true mean MDA level in the population lies within this range.

Table 2. Correlation Analysis between Nutritional Status and MDA

Variable	Correlation	R	P *Value*
Correlation between BMI and MDA	*Pearson*	**-0.074**	**0.521**

The Pearson correlation coefficient between BMI and MDA showed in table 2 is -0.074, indicating a very weak negative correlation between these two variables. This suggests that as one variable increases, the other tends to decrease slightly, but the relationship is so weak that it is practically negligible. The p-value of 0.521 means that the observed correlation is not statistically significant, and the chance that it occurred due to random variation is high. Therefore, this result indicates that there is no meaningful or reliable relationship between BMI and MDA levels in the sample studied. The weak negative correlation and the non-significant p-value suggest that any observed association should be interpreted with caution and is unlikely to reflect a true underlying relationship.

Table 3. Correlation Analysis between Nutritional Status and Vitamin D

Variable	Correlation	R	P *Value*
Correlation between BMI and Vitamin D	*Pearson*	**-0.016**	**0.892**

The analysis of table 3 shows a very weak negative correlation of -0.016 between BMI and Vitamin D levels, meaning there is almost no relationship between the two. The negative value suggests that as one increases, the other might decrease slightly, but the effect is so small that it doesn't really matter in practice. Additionally, the p-value is 0.892 means that the observed relationship is not significant, and it's highly likely that it happened by chance.So, based on these findings, we can conclude that changes in BMI don't seem to have an effect on Vitamin D levels, and vice versa.

Table 4. Correlation Analysis between MDA and Vitamin D

Variable	Correlation	R	P *Value*
Correlation between MDA and Vitamin D	*Pearson*	**-0.190**	**0.047***

According to Table 4 above, The Pearson correlation coefficient between MDA and Vitamin indicating a weak negative correlation between these two variables. This means that as one variable increases, the other tends to decrease slightly, although the strength of this relationship is quite weak. The p-value of 0.047 is significant suggests that the observed negative correlation is unlikely to have occurred by chance, making it a statistically valid result. However, despite the statistical significance, the weak magnitude of the correlation implies that the relationship between MDA and Vitamin D is not strong, and other factors may be influencing these variables. The finding suggests that while there is a measurable relationship, it is not substantial enough to draw any definitive conclusions about a direct cause and effect relationship between MDA and Vitamin D levels. Further research may be required to explore other potential factors or confounders affecting this relationship.

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Table 5. Correlation between Duration of Working and MDA

Variable	Correlation	R	P *Value*
Correlation between duration of working and MDA	*Pearson*	**0.172**	**0.135**

Table 5 shows the correlation analysis between the duration of working and MDA shows a Pearson correlation coefficient of 0.172, indicating a very weak positive relationship between these two variables. This means that as the duration of working increases, MDA levels may slightly increase as well. However, the correlation is so weak that it suggests only a minimal association. Additionally, the p-value of 0.135 implies that the observed relationship is not statistically significant, and the chance of it being a random occurrence is high. In academic terms, this result indicates that there is no strong or meaningful correlation between the duration of working and MDA levels in the sample studied. Therefore, it is reasonable to conclude that working duration does not have a significant effect on MDA levels, and any observed association should not be interpreted as a reliable or causative factor.

Table 6. Correlation between Duration of Working and BMI

Variable	Correlation	R	P *Value*
Correlation between duration of working and BMI	*Pearson*	**0.082**	**0.478**

The correlation between the duration of working and BMI implies that as the number of hours worked increases, BMI may increase slightly, but the relationship is extremely weak and practically negligible. The the correlation also shows that is not statistically significant, meaning the observed relationship is likely due to random chance rather than a true underlying connection between the duration of working and BMI. This analysis shows that there is no meaningful relationship between the duration of working and BMI in the sample. The weak correlation and high p-value suggest that any potential association should be interpreted with caution and does not provide reliable evidence for a direct connection between these two variables.

DISCUSSION

Characteristic of Subject

This study was conducted on 76 street cleaning staff in Jakarta. The characteristics of respondents included age, gender, ethnicity, education, marriage status, duration of working (hours), height, weight, BMI, BMI category, Vitamin D and MDA. The average age of respondents is 41.01 ± 8.92 years, with an age range between 21 and 56 years. Research shows that street cleaning staff are generally within the productive age range. The majority of respondents are male, as many as 92.1%. This is in line with the characteristics of fieldwork that often demands physical strength, so it is more filled by male workers.[10] The majority of respondents came from the Betawi tribe as much as 55.3%, followed by Javanese (28.9%) and Sundanese (13.2%). These results are caused by the location of the research, which is located in the area of Jakarta, where the majority of the original population is from the Betawi tribe. This characteristic has not been discussed specifically in previous research on street cleaning staff. The majority of respondents last education was high school, which is as much as 76.3%. This is in line with previous research that shows that 78.1% of street cleaning staff have higher education, which reflects the general administrative requirements of street cleaning staff recruitment.[11] Most of the respondents were married (86.8%). Marriage status in street cleaning staff is not specifically available in previous studies, but it is generally found that street cleaning staff are mostly married, which shows this work is generally in demand by individuals who have had family dependents.[12]

The average duration of work is 7.97 ± 0.23 hours per day. Street cleaning staff in Jakarta are required to work for 8 hours every day (working day), with 3 working times (shifts) in 24 hours. That is, the working hours of street cleaning staff may be in the morning-afternoon, afternoon-night, or early morning until morning. Studies have shown that longer work hours can significantly impact physical health, mental well-being, and oxidative stress levels. Prolonged working hours are associated with increased fatigue, stress, and increased risk of metabolic disorders. Longer working hours in physically demanding jobs like street cleaning contribute to higher body weight and metabolic imbalances due to reduced time for physical activity and rest.[13] The average height of respondents was 162.01 ± 6.98 cm, while the average weight was 63.85 ± 11.02 kg with a BMI average value of 24.34 ± 3.83 kg/m². This is often due to unhealthy or irregular diets and volatile physical activity. Outdoor workers exposed to poor environmental conditions, such as lack of proper shelter and hygiene, often show lower-than-average height compared to workers in better environments.

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However, this issue is more significant in low-income areas where nutritional deficiencies are common during childhood, leading to stunted growth.[14]

The average level of Vitamin D in the sample is 25.7 ng/mL, indicating that cleaning staff have normal range vitamin D. Another study also showed that outdoor workers generally have higher vitamin D levels and lower deficiency rates than indoor workers due to greater sun exposure, but many can still be deficient, especially in winter or if using sunscreen/wearing heavy clothing, with factors like age, skin tone, latitude, and work habits influencing status. While outdoor roles (farming, construction) offer protection, some studies show significant percentages of outdoor workers still experiencing insufficiency, highlighting that just being outside isn't enough for optimal levels year-round.[15] The average MDA level in this study is 0.78 µM. This result relevant with another study that showed the prevalence of high MDA levels is often associated with chronic exposure to pollutants and long working hours. Another study of street cleaning workers in Jakarta, MDA levels were found to be elevated in 50-60% of participants, reflecting the impact of prolonged exposure to environmental stressors.[16]

Correlation Between Nutritional Satus and MDA

The results of this study showed that there was no significant negative relationship between BMI and MDA levels. Althougsh higher BMI tended to be associated with lower MDA levels, this relationship was not statistically meaningful. This finding is interesting because obesity is generally linked to higher oxidative stress, which is commonly reflected by increased MDA levels. Biologically, the relationship between BMI and MDA can be explained through oxidative stress pathways. Oxidative stress occurs when the production of reactive oxygen species (ROS) exceeds the body's antioxidant capacity. MDA is formed as the final product of lipid peroxidation when ROS interact with fatty acids in cell membranes. In individuals with obesity, an increase in adipose tissue usually triggers chronic inflammation and elevated ROS production, which may raise MDA levels

However, previous research has reported mixed results regarding this relationship. A study show that found no significant association between BMI and serum MDA levels and even noted that higher body fat percentages were sometimes linked with lower MDA levels, possibly due to adaptive physiological responses to oxidative stress.[17] Meanwhile, studies by Widiastuti (2022) and Ashar (2023) reported that individuals with obesity tended to have higher MDA levels than those with normal BMI, although the association was still not statistically significant.[18] Higher MDA levels among those with obesity, particularly central obesity. These inconsistencies suggest that the relationship between BMI and oxidative stress is complex and influenced by many factors.[19]

In this study, BMI was not significantly correlated with MDA or vitamin D levels. Several possible explanations may underlie this finding. BMI alone may not accurately reflect adiposity or fat distribution, as it does not differentiate between lean mass and fat mass. Many participants in this study were physically active due to their occupation as street cleaning workers, which could result in higher muscle mass despite a similar BMI range.[20] This may have masked the association typically observed between higher adiposity and oxidative stress or vitamin D deficiency, where vitamin D deficiency is commonly defined as serum levels below 20 ng/mL[4] The relatively narrow BMI range among participants might have reduced variability, limiting statistical power to detect a meaningful correlation. Unlike general population samples with wider nutritional diversity, this occupational group tends to have moderate body composition due to regular physical activity and caloric expenditure.[21] Environmental and lifestyle factors such as UV exposure, dietary intake, and physical workload may have had a stronger influence on vitamin D metabolism and oxidative stress than BMI itself. High sunlight exposure can increase endogenous vitamin D synthesis, offsetting the expected inverse relationship between BMI and vitamin D. Similarly, oxidative stress in this population may be driven more by external pollutants and workload-induced metabolic demands rather than adiposity.[22] Taken together, these findings suggest that BMI is not a sufficient predictor of oxidative stress or vitamin D status in physically active outdoor workers. Future research should incorporate more sensitive measures of body composition, such as body fat percentage or waist circumference, and consider multifactorial models integrating environmental exposure, diet, and physical activity to better explain variations in oxidative biomarkers.[8]

The Relationship between Nutritional Status and Vitamin D Levels

The results of this study showed a non-significant and negative correlation between nutritional status and vitamin D levels among street cleaning staff in Jakarta. This means that individuals with higher BMI tended to have lower vitamin D levels, although the relationship was not statistically strong. These findings are consistent with previous studies. Similarly, a study in Iran examining children aged 8–18 years with type 1 diabetes found a similar negative association between BMI and vitamin D levels.[23] A cohort study in Abu Dhabi also reported that vitamin D levels decreased as adiposity increased.[4]

Sunlight exposure accounts for approximately 90–95% of vitamin D synthesis in the body. UVB radiation (280–320 nm) stimulates the conversion of 7-dehydrocholesterol in the skin to pre-vitamin D3, which then undergoes thermal isomerization into vitamin D3 (cholecalciferol). Individuals with obesity tend to have

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lower serum 25(OH)D concentrations. This may be due to several factors, including reduced outdoor activity, sequestration of vitamin D into adipose tissue, and an increased proportion of vitamin D being stored rather than circulated in the bloodstream.[24]

Vitamin D is fat-soluble, meaning that when body fat increases, more vitamin D becomes stored in adipose tissue. This reduces the amount of circulating vitamin D available for physiological functions. In addition, inflammation in adipose tissue may further accelerate vitamin D breakdown, lowering serum levels. Vitamin D also affects calcium absorption and parathyroid hormone (PTH) regulation. When vitamin D levels are low, calcium absorption decreases, which can activate metabolic pathways that promote fat storage, including increased fatty acid synthase (FAS) activity and reduced lipolysis. This suggests that vitamin D deficiency not only results from increased adiposity but may also contribute to the maintenance or progression of obesity.[25]

The Relationship between MDA Levels and Vitamin D Levels

This study found a significant negative correlation between MDA levels and vitamin D levels among street cleaning staff in Jakarta. In other words, higher MDA levels were associated with lower vitamin D levels, and individuals with higher vitamin D levels tended to have lower oxidative stress. This suggests that vitamin D may play a role in reducing oxidative stress by supporting the body's antioxidant defense system. Patients with type 2 diabetes who had low 25(OH)D levels exhibited increased plasma MDA and myeloperoxidase activity, both of which contribute to inflammatory oxidative reactions.[26]

Vitamin D exerts its protective effects through binding to vitamin D receptors (VDR), influencing both genomic and non-genomic signaling pathways. Supplementation with vitamin D3 has been shown to activate the Nrf2 transcription factor, which enhances antioxidant defense by promoting the expression of genes involved in antioxidant responses. Increased Nrf2 activity helps reduce cellular damage caused by oxidative stress. This is supported by evidence of interaction between the NF-κB and Nrf2 pathways, where activation of NF-κB (p65) promotes inflammation, while Nrf2 activation counters oxidative and inflammatory damage.[27]

Vitamin D3 also supports endothelial health by stimulating endothelial nitric oxide synthase (eNOS), increasing the production of nitric oxide (NO). NO plays a crucial role in maintaining normal vascular function, including vasodilation, inhibition of platelet aggregation, and prevention of smooth muscle cell proliferation. Reduced NO availability can lead to endothelial dysfunction, which contributes to atherosclerosis development. Oxidative stress markers such as MDA are often elevated when NO bioavailability is impaired. Additionally, treatment with calcitriol, the active form of vitamin D, has been shown to reduce oxidative stress, enhance antioxidant defenses, and improve endothelial function. Therefore, higher circulating vitamin D levels may help lower MDA levels and protect against oxidative damage.[28]

The Relationship Between Duration of Work and Levels of MDA, Vitamin D, and Nutritional Status

This study did not find a statistically significant relationship between length of work and nutritional status or MDA levels; however, the correlation values showed a positive direction (R = 0.083 and 0.172). This suggests a tendency in which longer working duration may be associated with a greater likelihood of increased BMI and MDA levels. Street cleaning staff who work longer hours are more frequently exposed to air pollutants such as particulate matter (PM), nitrogen oxides (NOx), ozone (O_3), and polycyclic aromatic hydrocarbons (PAHs), all of which can contribute to oxidative stress and weight gain.[29] Similarly, Kim et al. (2016) found that working more than nine hours per day increased the risk of obesity, particularly among older women, and night shift work has been linked to increased body weight and waist circumference.[28] According to the World Health Organization, lifestyle-related diseases including obesity are projected to account for as much as 30% of global deaths by 2030, highlighting the importance of prevention and early intervention.[30]

High working hours can also reduce the time and energy available for physical activity, which is necessary for maintaining a healthy metabolic balance. Most respondents in this study had a high school education level (76.3%), which may limit awareness of the importance of exercise, balanced nutrition, and antioxidant or vitamin D intake in managing oxidative stress.[31] Respondents with even lower educational backgrounds may face greater challenges in accessing and interpreting health information. Although digital information is widely available today, misinformation remains common and may negatively influence health behaviors.[32] The lack of awareness regarding vitamin D was evident in this study, where 59.7% of participants had insufficient levels and 18.2% were deficient. None of the workers reported taking vitamin D supplements. This suggests that knowledge about the role of vitamin D in protecting cells from oxidative stress may be limited, and financial constraints may also prevent workers from purchasing supplements .[33]

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CONCLUSION

The findings of this study indicate a significant association between MDA (Malondialdehyde) and vitamin D levels, suggesting that higher levels of vitamin D are linked to lower oxidative stress, as reflected by MDA. However, no significant relationship was found between BMI and either MDA or vitamin D, implying that BMI alone may not be a reliable indicator of oxidative stress or nutritional status, particularly among outdoor workers. The results emphasize that oxidative stress and vitamin D metabolism are influenced by multiple factors, including environmental exposure, occupational activity, and diet, rather than just body weight.

IMPLICATION

The study contributes to a deeper understanding of how oxidative stress (MDA) and vitamin D status interact independently of BMI, particularly in populations exposed to chronic environmental stressors. This suggests that the traditional use of BMI as a sole indicator of metabolic and oxidative health may be inadequate, and future research should focus on comprehensive models integrating environmental exposure, physical activity, and nutritional biomarkers. From a practical standpoint, these findings underline the need for occupation-specific health interventions among outdoor workers. Regular monitoring of oxidative stress markers and vitamin D levels, alongside education on balanced nutrition and sun exposure, could help reduce the risk of oxidative-related diseases. Policymakers and occupational health authorities should consider developing targeted preventive strategies including antioxidant supplementation and vitamin D optimization programs to protect workers exposed to pollution, ultraviolet radiation, and heat stress. Overall, this research emphasizes the necessity of a multifactorial approach to understanding oxidative balance, moving beyond body weight metrics toward more precise, environment-aware health assessments.

STRENGTHS AND LIMITATIONS

This study offers valuable new insight into how oxidative stress, vitamin D levels, and BMI interact in outdoor workers a population that has rarely been studied in this context. One of the main strengths of this research is the use of objective biochemical measurements for both MDA and vitamin D, providing reliable markers of oxidative balance. In addition, lifestyle and environmental factors such as physical activity, UV exposure, and diet were carefully recorded and statistically controlled, allowing for a more accurate interpretation of the findings. By focusing on street cleaning staff, this study also captures the real-world complexity of occupational health, rather than relying solely on controlled laboratory conditions. Despite these strengths, several limitations should be noted. Because this research used a cross-sectional design, it cannot establish a cause-and-effect relationship between the studied variables. There is also a possibility of selection bias, since the participants came from a single occupational group, which may limit how well the results apply to other populations. Self-reported information about diet, physical activity, and sun exposure could be affected by recall bias, even though trained interviewers and standardized questionnaires were used to minimize this issue. Finally, BMI alone may not accurately reflect body composition or fat distribution, suggesting that future research should use more precise measurements such as body fat percentage or waist-to-hip ratio and include longitudinal data to confirm the observed patterns.

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DECLARATION OF USING AI

The authors affirm that artificial intelligence (AI) tools were used to assist in the writing process solely for language enhancement purposes, such as grammar checking, paraphrasing, and improving clarity. No Al tools such as chat GPT or Gemini were employed to generate original content, conduct data analysis, or interpret research findings. The authors take full responsibility for the content, interpretations, and conclusions presented in this manuscript.

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