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OCCUPATIONAL EXPOSURE TO CALCIUM SULFATE IMPACTED NEGATIVELY ON LIVER FUNCTION, OXIDATIVE STRESS BIOMARKERS AND REPRODUCTIVE PARAMETERS AMONG MALE ARTISANS IN RIVERS STATE, NIGERIA

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ABSTRACT

Background: Occupational exposure to calcium sulfate, commonly known as gypsum, is prevalent among artisans in the construction and manufacturing industries. This study evaluated the liver function, reproductive parameters and oxidative stress biomarkers among artisans exposed to calcium sulfate in Rivers State, Nigeria, by comparing them with a non-exposed control group.
Methods: A cross-sectional comparative study was conducted involving 60 male artisans exposed to calcium sulfate and 60 non-exposed males. Liver function parameters, including Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), Alkaline Phosphatase (ALP), Total Bilirubin, Direct Bilirubin, Albumin, and Total Protein, were measured. Reproductive parameters like sperm count, motility, and morphology were also assessed, along with oxidative stress markers such as Malondialdehyde (MDA), Reduced Glutathione (GSH), Reactive Oxygen Species (ROS), Glutathione Peroxidase (GPx), Catalase (CAT), and Total Antioxidant Capacity (TAC). Statistical analysis was performed using descriptive statistics and independent t-tests, with significance set at $p<0.05$.
Results: The exposed group exhibited significantly higher levels of ALT (50.7 ± 4.5 U/L) compared to the non-exposed group (44.0 ± 2.3 U/L, $p<0.001$). ALP levels were also elevated in the exposed group (85.1 ± 13.3 U/L) versus the non-exposed group (72.8 ± 7.2 U/L, $p<0.001$). Reproductive parameters, such as sperm count and motility, were significantly lower in the exposed group (50.3 ± 7.3 million/mL vs. 61.2 ± 3.3 million/mL, $p<0.001$). Oxidative stress markers were elevated, with MDA being higher in the exposed group (3.5 ± 0.8 nmol/mL) compared to the control (2.3 ± 0.2 nmol/mL, $p<0.001$).
Conclusions: The study identified significant alterations in liver function, reproductive function and oxidative stress among artisans exposed to calcium sulfate, indicating potential hepatic stress and reproductive impairment. Elevated ALT, ALP, and oxidative stress markers suggest the need for regular health monitoring and protective measures to mitigate health risks.
Keywords: Calcium sulfate exposure, Gypsum, Liver function, oxidative stress biomarkers, Reproductive parameters Occupational health, Artisans

Introduction

Calcium sulfate, known as gypsum, is a widely utilized material in construction and manufacturing due to its beneficial properties such as fire resistance, sound insulation, and ease of use. However, prolonged exposure to gypsum dust has raised health concerns, particularly regarding its potential effects on respiratory and systemic health, including liver function (Smith et al., 2019). The liver is a vital organ responsible for various metabolic processes, including detoxification, protein synthesis, and the production of biochemicals necessary for digestion. Exposure to harmful substances can compromise liver function, leading to potential health complications (Gowda et al., 2009).

In industrial settings, artisans often work in environments with high levels of dust and particulate matter, increasing their risk of exposure to potentially harmful substances, including calcium sulfate. The liver's response to such exposure can be assessed through various biochemical parameters, which serve as indicators of liver function and overall health (Ahmed et al., 2021).

Occupational exposure to dust and industrial chemicals poses a significant public health concern worldwide. Workers in various industries, including construction, mining, and manufacturing, are at risk of inhaling or coming into contact with harmful substances, leading to various health complications. Among these substances, calcium sulfate, commonly known as gypsum, is extensively used in construction materials, ceramics, and as a soil conditioner (Berti et al., 2018). While gypsum is generally considered safe, prolonged exposure to its dust can result in respiratory and systemic effects, raising concerns about its potential impact on liver function.

Liver Function and Occupational Exposure

The liver plays a crucial role in detoxifying substances, synthesizing essential proteins, and regulating metabolism. Exposure to harmful substances can disrupt these functions, leading to hepatocellular damage, cholestasis, and other liver-related conditions (Gowda et al., 2009). Occupational exposure to various industrial chemicals, including solvents, metals, and dust, has been associated with alterations in liver function tests (LFTs), which are biomarkers used to assess the liver's health and functionality (Schumacher et al., 2021).

Relevance of Calcium Sulfate Exposure

Calcium sulfate is a widely used material due to its versatility and beneficial properties, such as ease of molding, non-combustibility, and sound insulation (Smith, Brown, & Adams, 2019). However, despite its widespread use, there is a paucity of comprehensive studies examining its potential health effects, particularly concerning liver function. Most existing research has focused on respiratory issues, such as chronic bronchitis and pneumoconiosis, associated with dust inhalation (Jones et al., 2017). The lack of data on the hepatic implications of gypsum exposure necessitates focused investigations, especially given the liver's central role in metabolizing and detoxifying absorbed substances.

Occupational Health in Developing Countries

In developing countries like Nigeria, the regulatory framework and enforcement of occupational health standards are often less stringent compared to developed nations (World Health Organization, 2019). This situation exacerbates the risk of occupational hazards, as workers may lack access to adequate protective equipment and health monitoring. Artisans, particularly those in the informal sector, are frequently exposed to various occupational hazards without proper safety measures. The construction sector in Nigeria, where gypsum is widely used, employs many such workers, often under conditions that do not prioritize health and safety.

Study Significance

This study aimed to address the gap in knowledge regarding the impact of calcium sulfate exposure on liver function among artisans in Rivers State, Nigeria. By comparing liver function parameters between artisans exposed to gypsum and a non-exposed control group, this research seeks to provide empirical data on the potential hepatic effects of this occupational exposure. The findings could inform policy and practice, emphasizing the need for improved occupational health standards and preventive measures to protect workers' health.

This research contributes to the broader understanding of occupational health risks associated with dust exposure, particularly in low- and middle-income countries (LMICs), where the burden of occupational diseases is often underreported and underexplored (International Labour Organization, 2021). It also highlights the importance of regular health monitoring and the implementation of safety protocols to mitigate the adverse effects of occupational exposures.

Objectives

This study aims to evaluate the liver function profile of artisans exposed to calcium sulfate in Rivers State, Nigeria. Specifically, the study seeks to:

1. Assess reproductive profile parameters (sperm count, sperm motility, sperm morphology, testosterone levels, FSH levels, LH levels) of male artisans exposed to calcium sulfate against those of apparently healthy artisans not exposed to calcium sulfate across their duration of exposure in Rivers State.
2. Evaluate the liver function parameters (ALT, AST, ALP, total bilirubin, albumin, total protein) levels of male artisans exposed to calcium sulfate against those of apparently healthy artisans not exposed to calcium sulfate in Rivers State.
3. Compare the oxidative stress parameters (MDA levels, GPx activity, CAT activity, TAC) of male artisans exposed to calcium sulfate against those of apparently healthy artisans not exposed to calcium sulfate in Rivers State.

Materials and Methods

Study Design and Participants

This cross-sectional comparative study involved 120 male participants: 60 artisans with known exposure to calcium sulfate for more than five years and 60 control subjects with no known exposure. Participants were recruited from Rivers State, Nigeria, and were matched for age and socioeconomic status.

Data Collection

Blood samples were collected from each participant and analyzed for liver function markers, including ALT, AST, ALP, Total Bilirubin, Direct Bilirubin, Albumin, and Total Protein. Reproductive parameters were also evaluated, focusing on sperm count, motility, morphology, and testosterone levels. Oxidative stress markers, including MDA, GSH, ROS, GPx, CAT, and TAC, were measured.

Statistical Analysis

Descriptive statistics were used to calculate the mean and standard deviation for each group. Independent t-tests were employed to assess the statistical significance of differences between the exposed and control groups, with a significance threshold set at $p<0.05$.

Results

Reproductive Parameters

The exposed group demonstrated significantly lower sperm count, motility, and morphology compared to the control group. This suggests that calcium sulfate exposure may negatively impact male reproductive health.

Descriptive Statistics and t-test Results

The table below summarizes the means, standard deviations, t-values, significance levels (p-values), and mean differences for each parameter:

Table 1: Comparison of reproductive parameters between the exposed and non-exposed groups

Parameter	**Exposed**		**Non-exposed**		**T**	**p-value**
	Mean	**SD**	**Mean**	**SD**		
Sperm Count	50.3	7.3	61.2	3.3	-10.464	**<0.001***
Motility	54.2	8.0	65.1	2.5	-10.095	**<0.001***
Morphology	61.3	7.6	70.3	4.1	-8.159	**<0.001***
Testosterone	471.5	57.4	533.3	34.9	-7.129	**<0.009***
FSH	6.2	0.6	5.3	0.1	11.600	**<0.001***
LH	4.7	0.6	3.9	0.3	9.786	**<0.001***

SD=Standard Deviation; *=Statistically Significant at $p<0.05$

Liver Function Parameters

Liver function parameters showed significant differences between the exposed and control groups. ALT and ALP levels were significantly higher in the exposed group, suggesting hepatic stress. Bilirubin levels were also elevated in the exposed group, indicating potential liver dysfunction.

Descriptive Statistics and t-test Results

Table 4.2 below summarizes the means, standard deviations, t-values, significance levels (p-values), and mean differences for each parameter:

Table 4.2: Comparison of liver function parameters between the exposed and non-exposed groups

Parameter	**Exposed**		**Non-exposed**		**t**	**p-value**
	Mean	**SD**	**Mean**	**SD**		
ALT	50.7	4.5	44.0	2.3	10.217	**<0.001***
AST	50.9	4.0	43.9	2.8	11.198	**<0.152***
ALP	85.1	13.3	72.8	7.2	6.323	**<0.001***
Total Bilirubin	1.4	0.2	1.1	0.1	8.000	**<0.001***
Direct Bilirubin	0.6	0.1	0.5	0.1	7.209	**<0.001***
Albumin	4.5	0.2	4.7	0.1	-7.33	**<0.001***
Total Protein	7.6	0.3	7.5	0.2	3.444	**<0.001***

SD=Standard Deviation; *=Statistically Significant at $p<0.05$

Oxidative Stress Markers

Oxidative stress parameters were significantly altered in the exposed group, with higher MDA levels and reduced antioxidant capacity (GSH, GPx, CAT, and TAC). This highlights the role of oxidative stress in the adverse health outcomes observed.

Descriptive Statistics and t-test Results

The table 4.3 below summarizes the means, standard deviations, t-values, significance levels (p-values), and mean differences for each parameter

Table 3: Comparison of oxidative stress parameters between the exposed and non-exposed groups

Parameter	Exposed		Non-exposed		t	p-value
	Mean	SD	Mean	SD		
MDA	3.5	0.8	2.3	0.2	10.857	**<0.001***
GSH	2.6	0.6	3.4	0.2	-8.997	**<0.001***
ROS	4.4	0.8	3.3	0.1	10.153	**<0.001***
GPx	47.1	4.5	53.1	2.0	-9.563	**<0.001***
CAT	32.3	5.5	40.2	3.7	-9.113	**<0.010***
TAC	1.0	0.3	1.2	0.1	-5.233	**<0.001***

SD=Standard Deviation; *=Statistically Significant at $p<0.05$

Discussion of Findings

The findings from this study indicate that exposure to calcium sulfate is associated with several adverse effects on male reproductive health, particularly affecting sperm parameters and hormonal levels.

Sperm Count

The mean sperm count in individuals exposed to calcium sulfate is significantly lower than that in the control group. The exposed group has a mean sperm count of 50.3 million/ml, whereas the control group has a mean of 61.2 million/ml. This observation, supported by a p-value of 0.001, indicates robust statistical significance, suggesting that exposure to calcium sulfate is linked with a marked reduction in sperm count. Similar findings have been reported in studies where occupational exposure to various chemicals and environmental pollutants negatively impacted sperm count. For instance, a study by Pant et al. (2003) found that workers exposed to heavy metals had significantly lower sperm counts compared to non-exposed workers. Additionally, Hauser et al. (2006) demonstrated that exposure to phthalates was associated with decreased sperm count in men, further supporting the adverse effects of environmental toxins on sperm production.

4.5.2Sperm Motility

The mean motility of sperm is significantly lower in the exposed group compared to the control group. The exposed group has a mean motility of 54.2%, while the control group has a mean of 65.1%. The p-value of 0.001 reinforces this finding, suggesting that exposure to calcium sulfate has a detrimental effect on sperm motility. This aligns with previous research indicating that environmental toxins can impair sperm motility. A study by Li et al. (2015) reported decreased sperm motility in individuals exposed to air pollutants, further supporting the adverse effects of environmental contaminants on sperm function. Moreover, studies on pesticide exposure, such as those by Younglai et al. (2002), have shown significant reductions in sperm motility, underscoring the broader impact of environmental exposures on reproductive health.

Sperm Morphology

The mean morphology score, which assesses the shape and structure of sperm, is significantly lower in individuals exposed to calcium sulfate. The exposed group has a mean morphology score of 61.3%, compared to 70.3% in the control group. The p-value of 0.001 signifies strong statistical significance, indicating that exposure negatively impacts sperm morphology. Altered sperm morphology has been linked to various environmental exposures, with studies like that of Duty et al. (2003) showing that exposure to certain chemicals can lead to abnormal sperm shapes, which can impair fertility. Additionally, research by Meeker et al. (2008) found that men exposed to bisphenol A (BPA) had significantly poorer sperm morphology, highlighting the susceptibility of sperm structure to chemical exposures.

Testosterone Levels

Testosterone levels are also affected, with the mean level being significantly lower in the exposed group. The exposed group has a mean testosterone level of 471.5 ng/dL, while the control group has a mean of 533.3 ng/dL. This finding is statistically significant, as evidenced by a p-value of 0.009, suggesting that exposure to calcium sulfate may reduce testosterone levels. Low testosterone levels can have numerous implications on male reproductive health, including reduced libido and impaired spermatogenesis. Studies have shown that environmental pollutants can disrupt endocrine function, leading to lower testosterone levels (Sharpe & Skakkebaek, 1993). Additionally, Sweeney et al. (2015) found that exposure to polychlorinated biphenyls (PCBs) was associated with lower testosterone levels, reinforcing the endocrine-disrupting potential of environmental contaminants.

FSH Levels

The mean FSH level is significantly higher in individuals exposed to calcium sulfate, with a mean difference of 0.884. The exposed group has a mean FSH level of 6.2 IU/L, compared to 5.3 IU/L in the control group. The strong statistical significance, supported by a p-value of 0.001, indicates that exposure may disrupt the reproductive hormonal balance, particularly increasing FSH levels. Elevated FSH levels can be indicative of testicular dysfunction or damage. Research by Joffe (2003) has shown that exposure to environmental toxins can result in elevated FSH levels, reflecting underlying reproductive health issues. Furthermore, the study by Duty et al. (2003) highlighted that exposure to phthalates could lead to elevated FSH levels, underscoring the disruptive impact of chemical exposures on hormonal regulation.

LH Levels

Lastly, the mean LH level is significantly higher in the exposed group, with a mean difference of 0.802. The exposed group has a mean LH level of 4.7 IU/L, compared to 3.9 IU/L in the control group. The p-value of 0.001 provides strong evidence of statistical significance, suggesting that exposure to calcium sulfate may alter LH levels. LH is crucial for the regulation of testosterone production, and its alteration can have significant implications for male reproductive health. Studies like those by Hauser et al. (2002) have documented that environmental exposures can lead to altered LH levels, further supporting these findings. Additionally, Chia et al. (2000) found that occupational exposure to solvents was associated with altered LH levels, highlighting the broader impact of environmental factors on endocrine function.

The analysis of liver function markers in individuals exposed to calcium sulfate reveals significant alterations when compared to a control group. These findings are supported by a substantial body of literature, providing insights into potential liver damage and dysfunction associated with calcium sulfate exposure.

Alanine Aminotransferase (ALT)

The significantly elevated mean ALT level in the exposed group (50.7 U/L) compared to the control group (44.0 U/L) is indicative of liver stress or damage, as evidenced by a p-value of 0.001. ALT, primarily found in the liver, is a sensitive marker for liver injury. Elevated ALT levels are commonly associated with hepatocellular damage and inflammation (Jiang et al., 2012). This finding is consistent with studies on environmental toxins and their impact on liver enzymes. For instance, research by Kaur et al. (2015) demonstrated that exposure to industrial pollutants led to increased ALT levels, reflecting liver dysfunction. Similarly, a study by Hsiao et al. (2017) found that exposure to certain chemicals, including heavy metals, was associated with elevated ALT, suggesting liver damage due to oxidative stress and inflammation.

Aspartate Aminotransferase (AST)

Despite a higher mean AST level in the exposed group (50.9 U/L) compared to the control group (43.9 U/L), the p-value of 0.152 indicates that this difference is not statistically significant. AST is less specific than ALT for liver injury as it is also present in other tissues such as the heart and muscles (Kallwitz et al., 2016). Previous studies have reported that AST levels can be influenced by a variety of factors, including muscle damage and cardiovascular conditions, which may overshadow its specificity for liver injury (Singh et al., 2013). For example, research by Hsu et al. (2010) observed elevated AST levels in subjects exposed to environmental pollutants but noted that AST's role as a marker for liver damage is less distinct compared to ALT.

Alkaline Phosphatase (ALP)

The significantly higher mean ALP level in the exposed group (85.1 U/L) compared to the control group (72.8 U/L) with a p-value of 0.001 suggests potential liver dysfunction or biliary obstruction. ALP is associated with bile duct function and is a marker for cholestasis or biliary obstruction (Miyazaki et al., 2018). Elevated ALP levels have been documented in individuals exposed to various environmental toxins. A study by Tzeng et al. (2011) highlighted that exposure to heavy metals led to increased ALP levels, indicating possible biliary or hepatic impairment. Additionally, research by Dehghan et al. (2014) found similar associations between environmental pollutants and elevated ALP levels, further supporting the finding of potential liver dysfunction in the exposed group.

Total Bilirubin

The significantly higher mean Total Bilirubin level in the exposed group (1.4 mg/dL) compared to the control group (1.1 mg/dL), with a p-value of 0.001, suggests impaired liver function or increased bilirubin production. Total bilirubin levels reflect the liver's ability to process and excrete bilirubin, and elevated levels can indicate liver dysfunction or increased hemolysis (Szalai et al., 2019). Studies have demonstrated that exposure to environmental toxins can lead to elevated bilirubin levels. For instance, research by Liu et al. (2014) showed that exposure to pollutants resulted in increased bilirubin levels, suggesting liver stress or damage. Similarly, a study by Zhang et al. (2016) found elevated total bilirubin in individuals exposed to industrial chemicals, reflecting impaired liver function.

Direct Bilirubin

The mean Direct Bilirubin level is significantly higher in the exposed group (0.6 mg/dL) compared to the control group (0.5 mg/dL), with a p-value of 0.001. Direct bilirubin, or conjugated bilirubin, increases with cholestasis or hepatic dysfunction (Gong et al., 2017).

Elevated direct bilirubin levels in response to environmental pollutants have been reported in several studies. For example, research by Hossain et al. (2015) observed increased direct bilirubin levels in individuals exposed to environmental contaminants, indicating possible cholestasis or liver damage. Similarly, a study by Bae et al. (2018) found elevated direct bilirubin in subjects exposed to certain chemicals, supporting the notion of cholestatic liver injury.

Albumin

The mean Albumin level is lower in the exposed group (4.5 g/dL) compared to the control group (4.7 g/dL), with a p-value of 0.001. Albumin, synthesized by the liver, is a key indicator of liver synthetic function. Reduced albumin levels can reflect compromised liver function or increased protein loss (Kumar et al., 2016). Studies have reported decreased albumin levels in response to environmental exposures. For instance, research by Wang et al. (2017) found that exposure to heavy metals was associated with reduced albumin levels, indicative of liver dysfunction. Additionally, a study by Patel et al. (2019) observed similar trends in albumin levels in individuals exposed to industrial pollutants, highlighting liver synthetic impairment.

Total Protein

Exposed individuals have slightly higher Total Protein levels, with a mean of 7.6 g/dL compared to 7.5 g/dL in the control group. The p-value of 0.001 suggests statistical significance, indicating potential alterations in protein metabolism. Total protein levels encompass both albumin and globulins, and changes can reflect various physiological conditions or disruptions in protein metabolism. Research by Cai et al. (2020) has shown that environmental exposures can lead to alterations in total protein levels, indicating possible metabolic disruptions. Additionally, a study by Zhu et al. (2021) found that exposure to pollutants resulted in changes in total protein levels, reflecting potential impacts on protein metabolism and liver function.

Impact of Calcium Sulfate Exposure on Oxidative Stress Markers

Introduction

Exposure to environmental pollutants, including calcium sulfate (gypsum), is increasingly recognized for its potential to induce oxidative stress, leading to various health problems. This expanded discussion delves deeper into the changes in oxidative stress markers—Malondialdehyde (MDA), Glutathione (GSH), Reactive Oxygen Species (ROS), Glutathione Peroxidase (GPx), Catalase (CAT), and Total Antioxidant Capacity (TAC)—in individuals exposed to calcium sulfate, supported by a broader review of literature.

Malondialdehyde (MDA) Levels

Malondialdehyde (MDA) is a byproduct of lipid peroxidation, serving as a reliable marker for oxidative stress. Elevated MDA levels in exposed individuals (3.5 nmol/mL) compared to controls (2.3 nmol/mL) with a p-value of 0.001 indicate significant lipid peroxidation. The increase in MDA levels suggests that calcium sulfate exposure enhances oxidative damage to cell membranes. Similar findings have been reported in other studies where environmental pollutants elevated MDA levels, indicating oxidative stress (Gutteridge, 1995; Niki, 2009). For instance, a study by Klaunig et al. (2010) demonstrated that exposure to various industrial pollutants increased lipid peroxidation and MDA levels, reinforcing the connection between pollutant exposure and oxidative stress.

Glutathione (GSH) Levels

Glutathione (GSH) is a vital intracellular antioxidant, crucial for detoxifying reactive oxygen species (ROS). The significant reduction in GSH levels in exposed individuals (2.6 µmol/gHb) compared to controls (3.4 μmol/gHb) with a p-value of 0.001 suggests that calcium sulfate exposure depletes this critical antioxidant. Reduced GSH levels imply compromised cellular defense mechanisms against oxidative damage. Studies have shown that decreased GSH levels are associated with increased susceptibility to oxidative stress and related pathologies (Wu et al., 2004; Rahman et al., 2006). For example, a study by Valko et al. (2007) highlighted the role of GSH in neutralizing oxidative stress and its depletion in response to various environmental toxins.

Reactive Oxygen Species (ROS) Levels

Reactive Oxygen Species (ROS) are highly reactive molecules that can cause substantial cellular damage. The significantly higher ROS levels in the exposed group (4.4 units) compared to controls (3.3 units) with a p-value of 0.001 indicate that calcium sulfate exposure increases oxidative stress. Elevated ROS levels can damage cellular components, including DNA, proteins, and lipids, leading to various diseases (Halliwell & Gutteridge, 2015). The link between environmental exposures and increased ROS production is well-documented. A study by Mates et al. (1999) found that environmental pollutants like heavy metals and particulate matter significantly increased ROS production, supporting the findings of this study.

Glutathione Peroxidase (GPx) Levels

Glutathione Peroxidase (GPx) is an essential enzyme in the antioxidant defense system, reducing hydrogen peroxide and lipid hydroperoxides to water and alcohols, respectively. The significantly lower GPx levels in the exposed group (47.1 U/gHb) compared to controls (53.1 U/gHb) with a p-value of 0.001 suggest that calcium sulfate exposure impairs GPx activity. Reduced GPx activity compromises the body’s ability to neutralize peroxides, leading to increased oxidative stress (Brigelius-Flohé & Maiorino, 2013). Studies have shown similar reductions in GPx activity in response to various environmental toxins, indicating the critical role of GPx in managing oxidative stress (Arthur, 2000).

Catalase (CAT) Levels

Catalase (CAT) catalyzes the decomposition of hydrogen peroxide into water and oxygen, protecting cells from oxidative damage. The significantly lower CAT levels in the exposed group (32.3 U/mg protein) compared to controls (40.2 U/mg protein) with a p-value of 0.010 indicate impaired catalase activity due to calcium sulfate exposure. Reduced CAT activity suggests a decreased ability to detoxify hydrogen peroxide, contributing to oxidative stress (Aebi, 1984). Research by Chelikani et al. (2004) has shown that various environmental pollutants can inhibit catalase activity, increasing cellular susceptibility to oxidative damage.

Total Antioxidant Capacity (TAC) Levels

Total Antioxidant Capacity (TAC) reflects the cumulative action of all antioxidants present in the body. The significantly lower TAC levels in the exposed group (1.0 mmol/L) compared to controls (1.2 mmol/L) with a p-value of 0.001 indicate a reduced overall antioxidant defense due to calcium sulfate exposure. Decreased TAC suggests a diminished ability to neutralize oxidative stress, making individuals more vulnerable to oxidative damage (Prior & Cao, 1999). Studies have correlated reduced TAC with increased exposure to environmental pollutants, highlighting the critical role of overall antioxidant capacity in maintaining cellular health (Ghiselli et al., 2000).

Conclusion

This study demonstrates that occupational exposure to calcium sulfate is associated with significant alterations in liver function, oxidative stress, and reproductive health among male artisans. These findings highlight the need for proactive health monitoring, protective measures, and further research into the long-term health implications of gypsum exposure. The implementation of safety protocols, including proper ventilation and the use of PPE, is critical in mitigating the health risks faced by these workers.

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