Original Article

# Biochemical and Hematological Changes among Saudi Firefighters in the Eastern Province

**Khaled Fikry Salama, Layla Abdullmohsen Bashawri**[1]

Departments of Environmental Health, College of Applied Medical Sciences, University of Dammam, Dammam, Kingdom of Saudi Arabia, [1]Departments of Clinical Laboratory Sciences, College of Applied Medical Sciences, University of Dammam, Dammam, Kingdom of Saudi Arabia

## Abstract

**Aims:** This study aimed to evaluate some relevant serum biochemical and hematological changes in concentration level involved firefighters in comparison to normal controls. **Materials and Methods:** This study involved two groups of male firefighters to participate in the study. The first group included 50 firefighters from Dammam while the second group included 50 firefighters from Khobar. An additional control group of 50 male nonfirefighters from both cities was included in the study. Blood samples were collected from all participants and investigated for some relevant biochemical, hematological differences and blood heavy metals between the three studied groups. **Results:** The results obtained showed that there were statistically significant differences in liver function, serum lipid profile, creatine kinase, lactate dehydrogenase, iron and ferritin, and blood picture in firefighters as compared with normal control group, while there were no statistically significant differences in the levels of blood heavy metals in firefighters as compared to normal controls. These results indicate that fire smoke mainly affects serum biochemical and hematological parameters but does not affect serum heavy metals levels. **Conclusion:** Such results might point out to the need for more health protective and prophylactic measures to try to avoid such hazardous health effects that might endanger firefighters under their highly drastic working conditions, and firefighters must be under continuous medical follow-up through a standard timetabled medical laboratory investigations to allow for the early detection of any biochemical or hematological changes.

**Keywords:** Air pollution, biochemical, firefighters, hematological, occupational safety

## Introduction

The rate of industrialization in the Kingdom of Saudi Arabia has increased significantly over the past two decades. There is growing concern about the health hazards of such industrial technology and the need for implementing effective safety measures for the prevention of possible adverse health effects as well as reduction the number of fires. Smoke is mostly carbon dioxide ($CO_2$) and water vapor, but the remainder is a complex mixture of hundreds of gas-, liquid-, and solid-phase chemicals. The toxicity of $CO_2$ is relatively low despite its dominance in smoke. There is general agreement in the reported literature that the potential hazards to firefighters include carbon monoxide (CO), total (suspended) particulate matter, and respirable particulate matter.[1,2]

Studies of the occupational health problems of firefighters indicate that the principal hazards (aside from asphyxiation) are irritation of the eyes and respiratory tract, polymer fume fever, pulmonary edema, and long-term damage of lungs, heart, and other internal organs.[3-5]

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Firefighters, who are facing fires, are frequently exposed to hazardous materials including CO, hydrogen cyanide, hydrogen chloride, benzene, and sulfur dioxide. Firefighters and other emergency responders are routinely exposed to hazardous atmospheres that contain harmful gases and particulates.[6]

Blood considered as sensitive target organ for a majority of environmental toxic chemicals due to its nature of rapid synthesis and destruction of cells which in turn can be used as a good bio-indicator in different occupational and environmental related studies.[7]

**Address for correspondence:** Prof. Khaled Fikry Salama, Industrial Hygiene and Air Pollution, Environmental Health Department, College of Applied Medical Sciences, University of Dammam, Building E6, P.O.Box 2435, Dammam 31451, Al-Rakkah, Saudi Arabia. E-mail: ksalama@uod.edu.sa



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Long-time exposure to toxic trace metals such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc even at low concentrations can be deleterious to human health.[8]

The main objective of this research is to study the effect of fire smoke on Saudi firefighters of Dammam and Khobar cities in the Eastern Province by evaluation of the serum biochemical, blood hematological, and blood heavy metals changes in those firefighters and compare them with normal controls.

# Materials and Methods

The study protocol was approved by the Local Ethics Committee. A written informed consent was obtained from all participants. Two groups of male firefighters volunteered to participate in the study: The first group included 50 firefighters from Dammam. The second group included 50 firefighters from Khobar. An additional group of 50 male nonfirefighters volunteered from both cities as normal controls, age ranging from 20 to 55 years.

All firefighter volunteers were randomly chosen for participation regardless of the type of burning materials and scale of fire accidents they faced (household or industrial fire). An official coordination was arranged with the civil defense administrations to obtain their consent to conduct the research, and all participants were informed well about the objective and the course of the study. Ten milliliters of venous blood was withdrawn from each participant of the two firefighters groups, without anticoagulant for subsequent separation of serum and measurement of the required biochemical parameters.

## Serum biochemical analysis

Dade Behring (Dimension® Xpand®, Clinical Chemistry System) instrument was used for the measurement of all biochemical parameters as blood urea nitrogen, serum creatinine, sodium, potassium, calcium, uric acid, phosphorus, total bilirubin, direct bilirubin, total protein, albumin, alkaline phosphatase (ALP), aspartate transaminase (AST), alanine transaminase (ALT), and gamma-glutamyl transferase (γ-GT). Lipid profile as total cholesterol, triglyceride, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) and cardiac profile as creatine kinase (CK) and lactic dehydrogenase were investigated. Iron profile by measuring serum iron, total iron-binding capacity, and serum ferritin was observed. This instrument is based on Integrated Multisensory Technology and manufactured by Dade Behring Inc., USA.[9]

## Blood hematological analysis

Coulter's GEN-S automated full blood counter was used to perform a complete blood count, platelets count, and 5-part differential manufacturing by Abbott Park. Peripheral blood smear was made for all participants, using an automated stainer, Wright stain.[10]

## Determination of blood heavy metals

Blood samples were used for analysis of heavy metals by adding 10 ml $HNO_3$ to 1 ml of blood and heated for 3–4 h, and then 1 ml $HClO_4$ was added to the same sample. Digestion process continued until the solution was clear. Inductively coupled plasma method was used to determine blood lead, cadmium, mercury, and antimony levels.[11]

## Statistical analysis

Statistical analysis was performed on a personal computer using Statistical Package for the Social Sciences version 19 (IBM SPSS statistics, 19th edn. IBM, New York). Data are presented as arithmetic mean ± standard deviation. Student's *t*-test was used for the determination of the significance of difference between sample means.

# Results

Table 1 represents the characterization of the population studied where no significant difference in the levels of age or cigarette smoking was found.

From Table 2 and Figure 1, it is evident that mean levels of liver enzymes, AST, ALT, and γ-GT, uric acid, LDL cholesterol (LDL-C), HDL, CK, and lactate dehydrogenase (LDH) were statistically significantly elevated in Dammam firefighters as compared to normal control group, while nonsignificant changes were observed in all other studied parameters as compared to normal control group.

From Table 2, it is evident that mean levels of liver enzymes ALP, ALT, and γ-GT were statistically significantly elevated in Khobar firefighters as compared to normal control group, while nonsignificant changes were observed in all other studied parameters as compared to normal control group.

Table 2 and Figure 1 show that ALT, AST, ALP, γ-GT, serum calcium, cholesterol, triglyceride, and HDL were statistically significantly elevated while nonsignificant changes were observed in all other studied parameters among two firefighters groups.

In Table 3 and Figure 2, no significant differences were found between firefighters and controls for most hematological parameters in both firefighters groups and controls, except for the platelet count in Dammam firefighters and Khobar firefighters in comparison with control group.

There was no statistically significant difference in blood heavy metals in Dammam firefighters as compared to normal control group, Khobar firefighters as compared to normal control group, and Dammam firefighters as compared to Khobar firefighters, respectively, as shown in Table 4 and Figure 3.

**Table 1: Characterization of the population studied**

| | Dammam firefighters | Khobar firefighters | Control subjects | *P* |
|---|---|---|---|---|
| Age (years) | 37.6±8.3 | 35.2±7.7 | 39.7±6.9 | NS |
| Duration of exposure (years) | 16.3±8.3 | 13.6±9.2 | 0 | |
| Smoking | | | | |
| Yes | 32 | 26 | 27 | NS |
| No | 18 | 24 | 23 | NS |

NS: Not significant

**Table 2: Comparison of biochemical parameters among Dammam-Khobar firefighters and control subjects**

| Parameters | Dammam firefighters (1) | Khobar firefighters (2) | Control Subjects (3) | (1-3) *t* | (1-3) *P* | (2-3) *t* | (2-3) *P* | (1-2) *t* | (1-2) *P* |
|---|---|---|---|---|---|---|---|---|---|
| Liver function tests | | | | | | | | | |
| Total bilirubin (mg/dl) | 0.46±0.31 | 0.52±0.35 | 0.47±0.29 | 0.09 | NS | 0.82 | NS | 0.888 | NS |
| Direct bilirubin (mg/L) | 0.04±0.06 | 0.04±0.05 | 0.03±0.05 | 0.9 | NS | 0.54 | NS | 0.169 | NS |
| Total protein (g/dl) | 7.3±1.43 | 7.89±0.4 | 7.5±1.05 | 1.15 | NS | 1.87 | NS | 2.793 | NS |
| Albumin (g/dl) | 4.0±0.23 | 3.9±0.29 | 4.03±0.17 | 0.77 | NS | 1.3 | NS | 0.550 | NS |
| ALP (U/L) | 99.8±23.8 | 103.6±28.7 | 92.1±15.3 | 1.9 | NS | 2.5 | <0.001 | 0.716 | <0.001 |
| AST (U/L) | 42.8±14.1 | 27.8±12.1 | 30.5±9.2 | 5.2 | <0.001 | 1.2 | NS | 5.676 | <0.001 |
| ALT (U/L) | 73.8±20.5 | 58.7±26.1 | 41.7±7.09 | 10.3 | <0.001 | 4.4 | <0.001 | 3.203 | <0.001 |
| γ-GT (U/L) | 76.2±36.3 | 51.7±23.9 | 36.3±8.2 | 7.4 | <0.001 | 4.2 | <0.001 | 3.974 | <0.001 |
| Kidney function tests and electrolytes | | | | | | | | | |
| Creatinine (mg/dl) | 0.96±0.12 | 0.92±0.13 | 0.93±0.13 | 1.1 | NS | 0.65 | NS | 1.771 | NS |
| Sodium (mmol/l) | 139.4±3.1 | 139.7±2.6 | 139±2.8 | 0.73 | NS | 0.72 | NS | 0.561 | NS |
| Potassium (mmol/l) | 4.86±1.76 | 4.2±0.44 | 4.57±1.23 | 0.95 | NS | 1.5 | NS | 2.234 | NS |
| Calcium (mg/dl) | 8.53±1.92 | 9.35±0.35 | 8.97±1.3 | 1.39 | NS | 2.01 | NS | 2.967 | <0.001 |
| Phosphorus (mg/dl) | 3.62±0.54 | 3.47±0.56 | 3.56±0.58 | 0.6 | NS | 0.75 | NS | 1.380 | NS |
| Uric acid (mg/dl) | 5.56±1.35 | 5.4±1.2 | 5.64±1.32 | 0.04 | <0.001 | o. 55 | NS | 0.597 | NS |
| Urea nitrogen (mg/L) | 13.2±3.57 | 12.6±3.11 | 13.0±3.23 | 0.23 | NS | 0.62 | NS | 0.834 | NS |
| Lipid profile | | | | | | | | | |
| Total cholesterol (mg/dl) | 213.6±44 | 182.3±31.4 | 182.9±34 | 3.9 | <0.001 | 0.07 | NS | 4.080 | <0.001 |
| Triglyceride (mg/dl) | 136.7±62.6 | 180.6±32.9 | 153.5±64 | 1.3 | NS | 1.3 | NS | 2.112 | <0.05 |
| HDL-C (mg/dl) | 48±14.8 | 42.8±8.3 | 43.6±10.4 | 2.1 | <0.05 | 0.45 | NS | 2.503 | <0.01 |
| LDL-C (mg/dl) | 130±49 | 116.0±25.6 | 120.9±27 | 1.1 | <0.05 | 0.93 | NS | 1.772 | NS |
| Others | | | | | | | | | |
| Glucose (mg/dl) | 105±38.7 | 124.6±76.8 | 102±69.4 | 0.3 | NS | 0.3 | NS | 1.578 | NS |
| LDH (U/L) | 166±33.7 | 167.6±43.4 | 108.±41 | 4.32 | <0.001 | 0.12 | NS | 0.082 | NS |
| CK (U/L) | 159.7±95 | 152.5±13.2 | 129±57 | 3.9 | <0.001 | 1.12 | NS | 0.312 | NS |

NS: Not significant, CK: Creatine kinase, LDH: Lactate dehydrogenase, LDL-C: Low-density lipoprotein cholesterol, HDL-C: High-density lipoprotein cholesterol, ALP: Alkaline phosphatase; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase, GT: Glutamyl transferase

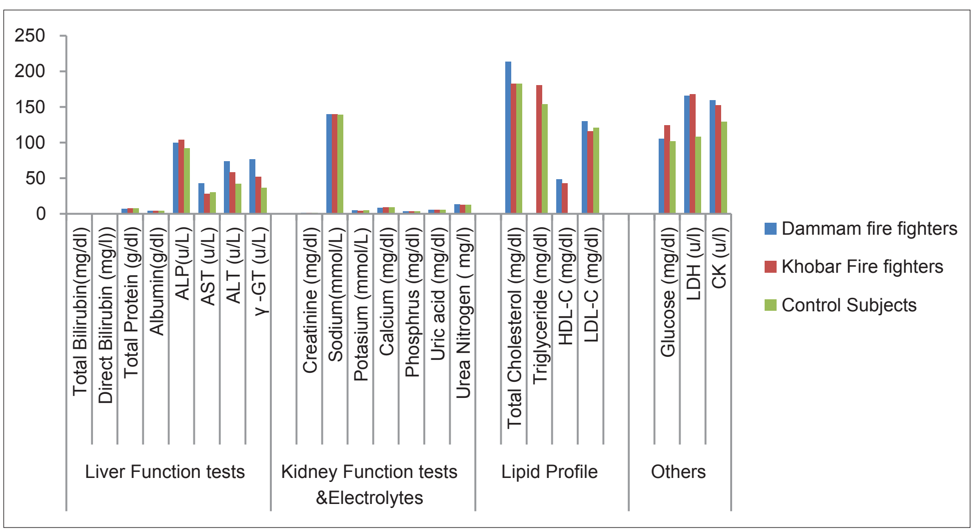


**Figure 1:** Mean levels of biochemical parameters among Dammam, Khobar firefighters and Control subjects

## Discussion

Liver injury has long been associated with occupational exposure to a wide variety of chemicals. Its susceptibility to chemical injury is a result of its unique position within the circulatory system, and also because it is the primary organ for the biotransformation of chemicals within the body, as liver is the main organ involved in the metabolism of toxins and medicinal agents.[9] All body organs and tissues could be affected by such toxic compounds. As liver cells are damaged, ALT leaks into the bloodstream leading to a rise in the serum levels. Any form of hepatic cell damage can result in an elevation in ALT.[12] In the present study, a statistically significant increase ($P < 0.001$) in the level of ALT and γ-GT has been found in Dammam and Khobar firefighters as compared to normal controls [Table 2], indicative of hepatic cell affection.

For routine screening of chemicals that are known or suspected to cause hepatocellular injury, the ALT is considered to be the aminotransferase most specific for the liver.[6] Abnormal ALT can sound as an alarm to alert medical staff to the possibility of some kinds of liver problem, which require further medical workup.[13] Recent studies indicated that γ-GT in addition to ALT and AST is used as sensitive biomarkers for possible hepatocellular damage due to exposure to hazardous materials.[12] The increase in the level of ALT, AST, and γ-GT is a good indicator of hepatic toxicity.

## Concerning aspartate transaminase

It is raised in acute liver damage, but is also present in red cells, cardiac and skeletal muscle, and is therefore not specific to the liver. The ratio of AST to ALT is sometimes useful in differentiating between causes of liver damage. Elevated levels are found in Dammam firefighters in comparison with control group. AST levels are raised in shock and after exercise,[14] which might point out to the difference in the types of fires they fight.

Another enzyme, γ-GT, is an indicator of early liver cell damage or cholestatic disease. Serum level of γ-GT is commonly elevated in patients with acute hepatitis although the rise in γ-GT is usually less than that of the transaminases.[15] Serum γ-GT may also be elevated in response to many toxins.

**Table 3: Comparison of hematological profile in Dammam-Khobar firefighters and control subjects ($n$=50)**

| Parameters | Mean±SD | | | (1-3) $t$ | (1-3) $P$ | (2-3) $t$ | (2-3) $P$ | (1-2) $t$ | (1-2) $P$ |
|---|---|---|---|---|---|---|---|---|---|
| | Dammam firefighters (1) | Khobar firefighters (2) | Control subjects (3) | | | | | | |
| HBG (mg/dl) | 14.8±0.48 | 14.9±1.12 | 14.7±1.02 | 0.61 | NS | 0.61 | NS | 0.33 | NS |
| RBC | 5.33±0.61 | 5.53±0.72 | 5.43±0.66 | 0.35 | NS | 0.75 | NS | 1.45 | NS |
| PLT | 241.7±55.7 | 242.5±73.9 | 189.4±30.4 | 5.88 | <0.001 | 5.82 | <0.001 | | NS |
| Total white blood cell count (×10$^3$/mm$^3$) | 7.7±2.1 | 7.3±2.0 | 7.37±2.17 | 0.88 | NS | 0.88 | NS | 1.01 | NS |
| Neutrophils (%) | 45.1±9.4 | 43.1±7.3 | 43.2±2.98 | 1.33 | NS | 1.33 | NS | 1.2 | NS |
| Lymphocytes (%) | 42.8±10.1 | 43.1±9.9 | 43.3±6.62 | 0.27 | NS | 0.27 | NS | 0.15 | NS |
| Monocytes (%) | 7.3±2.2 | 7.7±2.1 | 7.45±2.1 | 0.37 | NS | 0.37 | NS | 0.76 | NS |
| Eosinophils (%) | 3.3±2.6 | 3.7±2.8 | 3.7±3.08 | 0.73 | NS | 0.73 | NS | 0.79 | NS |
| Basophilis (%) | 0.62±0.63 | 0.56±0.76 | 0.56±0.70 | 0.44 | NS | 0.45 | NS | 0.43 | NS |
| Serum iron (ug/dl) | 99.1±342 | 99.4±40.4 | 87.2±20.3 | 2.1 | <0.05 | 2.1 | <0.05 | 0.05 | NS |
| Serum ferritin (ng/ml) | 209.5±84.7 | 180.7±77.3 | 143±27.5 | 5.3 | <0.001 | 5.3 | <0.001 | 1.77 | NS |

SD: Standard deviation, NS: Not significant, HBG: Hemoglobin, RBC: Red blood cell, PLT: Platelets

**Table 4: Mean levels of blood heavy metals among Dammam-Khobar firefighters and control subjects ($n$=50)**

| Parameters | Mean±SD | | | (1-3) $t$ | (1-3) $P$ | (2-3) $t$ | (2-3) $P$ | (1-2) $t$ | (1-2) $P$ |
|---|---|---|---|---|---|---|---|---|---|
| | Dammam firefighters (1) | Khobar firefighters(2) | Control subjects (3) | | | | | | |
| Lead (ug/dL) | 3.03±1.09 | 3.9±0.8 | 3.06±0.95 | 0.11 | NS | 0.17 | NS | 2.81 | NS |
| Mercury (ug/dL) | 0.41±0.67 | 0.24±0.17 | 0.25±0.06 | 1.67 | NS | 0.84 | NS | 0.11 | NS |
| Cadmium (ug/dL) | 0.24±0.04 | 0.17±0.05 | 0.08±0.04 | 2.4 | NS | 0.66 | NS | 1.1 | NS |
| Antimony (ug/dL) | 0.006±0.002 | 0.0015±0.003 | 0.002±0.004 | 3.1 | NS | 1.6 | NS | 1.4 | NS |

SD: Standard deviation, NS: Not significant

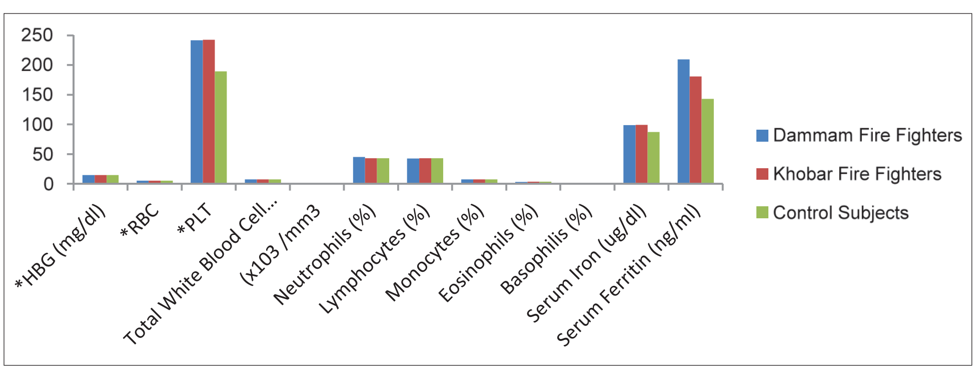


**Figure 2:** Mean levels of hematological profile in Dammam and Khobar firefighters and control subjects

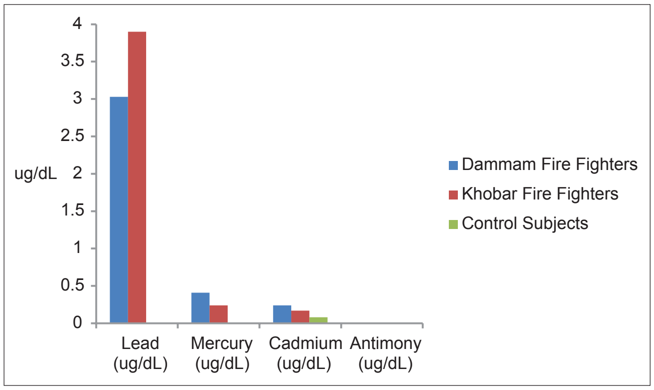


**Figure 3:** Heavy metals are selected and analyzed in the study because of their importance as they mainly results from particulate emission of fires and different burning building materials in residential, commercial and industrial sectors. However chromium and arsenic for example are with less toxic importance in case of fire fighting and exposure to burning materials

Myocardial infarction, cardiac failure, diabetes, and pancreatitis can also increase serum γ-GT.[16] The present work showed statistically significant association in serum γ-GT among the studied groups [Table 2].

Abnormal liver enzyme levels as elevation of total bilirubin level is considered as early signal for liver damage or alteration and might result in alteration in biochemical picture of livers as cirrhosis, hepatitis, and tumors and also observed in cases of intravascular hemolysis.[17] The results of the present study showed no statistically significant differences between the studied groups. However, as direct bilirubin is formed only by the liver, it is specific for hepatic or biliary disease as in obstructive liver diseases. The results of the present study showed no statistically significant differences in the level between the studied groups.

Furthermore, of the most important liver function tests is the measurement of serum protein and protein metabolites such as urea nitrogen. The present study showed nonstatistically significant differences in serum total protein and serum albumin between the studied groups. Serum urea nitrogen measures the amount of urea nitrogen waste product of protein catabolism by the liver. An elevated serum urea nitrogen may be caused by impaired renal function, congestive heart failure as a result of poor renal perfusion and dehydration.[18] The present results revealed that no statistically significant association in the level of serum urea nitrogen between the studied groups. A recent study found significant correlations between serum polycyclic biphenyls concentrations and levels of liver enzymes and lipids profile as HDL and LDL lipoproteins.[16]

Concerning kidney functions tests, no statistically significant differences were found among the three groups, except for serum uric acid between Dammam firefighters and control subjects.

In this study, results of lipid profile in Dammam firefighters indicated that only LDL-C was statistically significantly elevated ($P < 0.01$) as compared to normal control group. However, there was no statistically significant change in all lipid profile of Dammam firefighters as compared to Khobar firefighters and normal control group.

A recent study established a health surveillance program for firefighters. They found that serum lipid profile was normal or unchanged from preexposure baselines. The lipid profile of firefighters did not change much from normal control group, except for the Dammam firefighter LDL-C mentioned above. The lipid profile in relation to other cardiovascular disease risk factors in 321 firefighters was evaluated at a baseline examination.[19]

Our results indicated that there was no statistically significant change in blood glucose level on comparison between all studied groups. The decrease in blood glucose following 90 min of recovery is of potential concern for firefighters. Although the recovery blood glucose value was still within a normal range, it is relatively low among firefighters.[19]

In fact, approximately 30% of the firefighters were clinically hypoglycemic at the end of the recovery period. Given that symptoms of hypoglycemia include weakness, nervousness, anxiety, and sweating, this could be a serious problem for firefighters. The low blood glucose values suggest that following strenuous firefighting activity, a firefighter may benefit from consuming carbohydrates, in addition to replacing fluid loss, prior to subsequent activity.[20] Any elevated CK result automatically reflexes to myocardial infarction and muscle diseases. CK may also be elevated following muscle injury or strenuous exercise.[21] In this study, CK was statistically significantly increased in Dammam firefighters ($P < 0.001$) as compared to normal control group. However, there was no statistically significant difference between Dammam firefighters and Khobar firefighters as shown in Table 2. Asingle case study[22] reported that CK level raised to a maximum of 3277 U/L (normal, <100 U/L) in a 39-year-old cigarette smoking fireman.

LDH is most often measured to evaluate the presence of tissue or cell damage.[23] In the present study, LDH was statistically significantly elevated in Dammam firefighters ($P < 0.001$) as compared to normal control group. However, there was no statistically significant difference between Dammam firefighters and Khobar firefighters as shown in Table 2. A previous study found that there was a significant elevation in LDH activity postexposure to fire smoke in firefighters.[24]

No significant differences were found between firefighters and controls for most hematological parameters in both firefighters groups and controls, except for the platelet count in Dammam firefighters, Khobar firefighters in comparison with control group. Serum iron and serum ferritin levels were statistically significant in Dammam firefighters and Khobar firefighters as compared to normal control group while there was no statistically change in hemoglobin level among all study groups.

The main toxic effects resulting from chronic exposure to cadmium are tubular dysfunction and disturbance in calcium homeostasis and bone metabolism. In humans, cadmium is considered to be a suspect carcinogen for the lung, the kidney, and possible the prostate.[22,25,26]

There was no statistically significant difference in blood heavy metals in Dammam firefighters as compared to normal control group, Khobar firefighters as compared to normal control group and Dammam firefighters as compared to Khobar firefighters, respectively, as shown in Table 4 and Figure 3. Two populations (firefighters and the general population) were surveyed in four cities for urine heavy metal concentrations. Cadmium levels were significantly related to smoke exposure. This is in accordance with the studies[27-29] which stated that mercury levels were not higher in exposed firefighters.

Firefighters exposure to heavy metals has been documented in smoke and on turnout gloves. Firefighters exposure to heavy metals has been documented in both structural and wildland fires. Bolstad-Johnson *et al*.[30] identified lead in air samples taken during overhaul, whereas Fabian *et al*.[31] found metals (including lead, manganese, and mercury) on firefighter gloves from smoke and soot deposition, indicating the potential for additional exposure when gloves are removed. Hence, the most common heavy metals contamination during firefighter exposure to smoke and toxic gases are blood lead, mercury, antimony, and cadmium and also it depends on the burned materials and type of fire.

## Conclusion

From the present study we can conclude that biochemical and hematological changes among Saudi firefighters are mostly affected especially biochemical parameters as mean levels of liver enzymes, AST, ALT, and γ_GT, uric acid, LDL cholesterol (LDL_C), HDL, CK, and lactate dehydrogenase (LDH) were statistically significantly elevated in Dammam firefighters. However, among Khobar firefighters the mean levels of liver enzymes ALP, ALT, and γ_GT were statistically significantly elevated. Nevertheless, the main hematological parameters changed are platelet count in Dammam and Khobar firefighters. Additionally, there was no statistically significant difference in blood heavy metals in Dammam firefighters and Khobar firefighters. Preventive measures should be taken to avoid risk of exposure to toxic air pollutants and hazardous materials and fire products. Such results might point out to the need for more health protective and prophylactic measures to try to avoid such hazardous health effects that might endanger firefighters under their highly drastic working conditions. Besides using of personal protective equipment for firefighters to protect them against exposure to toxic materials of fire smoke, it is recommended that firefighters must be under continuous medical follow-up through a standard timetabled medical laboratory investigations to allow for early detection of any biochemical or hematological changes that might happen during their service lives and to allow for early treatment whenever necessary.

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### Conflicts of interest

There are no conflicts of interest.

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