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ORIGINAL ARTICLE

Assessment of liver function in two groups of outdoor workers exposed to arsenic

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Abstract
Purpose To evaluate whether the exposure to arsenic (As) causes alterations of liver enzymes in two groups of outdoor workers.
Methods Total urinary As and the levels of AST/GOT, ALT/GPT, and GGT were measured on 80 traffic policemen and 50 police drivers. Personal air samples were obtained for assessing the exposure to As on a subgroup of 20 traffic policemen and 20 police drivers.
Results Mean values of personal exposure to As, urinary As, AST/GOT, and ALT/GPT were significantly higher in traffic policemen than in the police drivers. Multiple linear regression models showed associations between urinary As and airborne As, ALT/GPT and the job variables, and BMI and urinary As.
Conclusions These findings contribute toward the evaluation of the hepatic effects of exposure to As in the urban workers.

Keywords Arsenic · Liver disease · Urban pollution · Inhalation exposure

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Introduction

Chronic exposure to arsenic (As) is a worldwide public health problem. The toxicity observed after chronic exposure to inorganic As (iAs) has been associated with a number of adverse effects on human health, such as cancer of the bladder, lung, skin, urinary tract and maybe of the kidney, prostate, and liver (IARC 2004). The exposure to As has also been linked to cardiovascular diseases, kidney diseases, neuropathy, diabetes mellitus, and to effects on reproductive health (ATSDR 2007). The liver is the primary organ where As is metabolized (Drobná et al. 2010).

Studies on humans and animals have associated the exposure to As with hepatomegaly, hyperbilirubinemia, fibrosis, portal hypertension, liver cirrhosis, and abnormal expression of genes involved in cell cycle regulation of hepatocytes, apoptosis, and response to DNA damage (Das et al. 2012; Guha Mazumder 2001; Patlolla et al. 2012).

Other studies have observed elevated liver enzymes aspartate aminotransferase–glutamate oxaloacetate transaminase (AST/GOT) and/or alanine aminotransferase–glutamate pyruvate transaminase (ALT/GPT) in animals (Pari and Mohamed Jalaludeen 2011; Patlolla et al. 2012) or in humans exposed to As (Das et al. 2012; Guha Mazumder 2001).

Arsenic is a ubiquitous element that is present in the air, water, and soil; it is released into the environment from natural sources (such as, volcanoes and forest fires) and anthropogenic sources (such as, coal power plants, industrial sources, use of pesticide, and incineration of different kinds of waste) (ATSDR 2007). In air, arsenic exists predominantly adsorbed on particulate matters; it is usually present as a mixture of arsenite and arsenate (Davidson et al. 1985), and therefore, people who work in these areas are potential receptors of airborne metals.

The present research follows previous studies that we had conducted in which we looked at whether the differences in the exposure to arsenic were because of different job types (Ciarrocca et al. 2012a, b). The results obtained have shown that the exposure to As was higher in traffic policemen when compared to drivers and in outdoor workers in urban areas compared to outdoor workers in rural areas. In this study, we evaluate, on a new set of samples, whether and how the increased occupational exposure to arsenic correlates with the effects on liver tests.

Alteration of the transaminases is not considered as a pathognomonic marker of hepatocellular damage (Schmidt and Schmidt 1993; Scheig 1996). However, the authors believe that the study of the activity of the liver enzymes, which are routinely used in clinical practice, could be a useful method in health surveillance in workers exposed to arsenic. In the field of prevention, it would be important to use quick methods and rapid responses in order to intervene as early as possible.

The aim of this study was to evaluate whether the exposure to As could cause alterations of the liver enzymes AST/GOT, ALT/GPT, and γ-GT in a group of traffic policemen in comparison with a group of police drivers of a big Italian city.

Materials and methods

Study population

The study started on an initial sample of 278 outdoor male workers (traffic policemen and police drivers) of the Municipal Police of a big city in central Italy who were exposed to urban air pollutants.

Traffic policemen were assigned to control the flow of vehicles in roads and areas with high and medium traffic intensity and to monitor and regulate traffic at road junctions, parking areas, and traffic-limited areas. Traffic policemen were not provided with personal protective equipment for their protection against dust and fumes in the urban workplace.

Police drivers were assigned to the control of traffic and to specific interventions in case of road accidents and other activities, including driving the car as a driver or as a "second patrol". Their cars were all provided with air conditioning units and pollen filters that are able to trap particles.

Both traffic policemen and police drivers were carrying out their activities in an outdoor environment and inside the car, respectively, for at least 80 % of their working time (7 h a day for at least 5 days a week).

To be included in the study, each traffic policeman and police driver was administered a clinical anamnestic questionnaire in the presence of a physician. The questionnaire included the following items: age, length of service, height, and weight [to calculate the body mass index (BMI)] (Syczewska et al. 2004); area of residence in the last 5 years; physiological anamnesis with special reference to dietary habits (weekly intake of food, such as rice and corn) (Abernathy et al. 2003); water consumption details such as from the municipal water supply or mineral water and number of glasses of water per day (Abernathy et al. 2003); alcohol drinking habit (number of glasses of wine/beer per day) (Stranges et al. 2004); cigarette-smoking habit (number of cigarettes smoked per day and years of smoking) (ATSDR 2007); drug history; past and current pathological anamnesis with special reference to hepatic diseases (hepatitis A, B, C, or D, cytomegalovirus and Epstein–Barr virus, Wilson' disease, celiac disease, hemochromatosis, α1-antitrypsin deficiency, and autoimmune diseases); and information about possible exposure to As during time off (use of paints, solvents, and pesticides).

In order to avoid the influence of the main confounding factors, 148 subjects were excluded from the study: 95 subjects because of their alcohol drinking habit (at least one glass of wine or beer a day) (Stranges et al. 2004), 30 subjects because of their cigarette-smoking history (ATSDR 2007), and 23 subjects because of their daily intake of drugs. The final number of subjects included in the study was 130 (50 police drivers and 80 traffic policemen).

Biomonitoring of total urinary As and levels of AST/GOT, ALT/GPT, and γ-GT was carried out on the total sample of 130 subjects. Moreover, personal air samplings for assessing the exposure to As was performed on a subgroup of 40 subjects, and these subjects were raffled off with a random method: 20 subjects from the group of traffic policemen and 20 subjects from the group of police drivers.

Each subject was monitored only once during the morning shift (7.00–14.00 h). The air, blood, and urinary samples were measured on traffic policemen and police drivers on the same day in order to avoid the influence of weather conditions on airborne As. Blood and spot urine samples of each worker were collected at the end of the work shift for four working days in succession.

All the subjects agreed to processing of their data and understood that this information was categorized as "sensitive data." All the subjects were informed that the data from the research protocol would be treated in an anonymous and collective way, with scientific methods, and for scientific purposes in accordance with the principles of the Helsinki Declaration.

Biomonitoring of total urinary AS and personal air samplings of As in air

Spot urine samples were collected in polypropylene tubes and were kept in a cooler at +4 °C and then stored in the lab at −20 °C until analysis. The Jaffé method (Liu et al. 2012) was used to assess urinary creatinine. After mineralization in an acidic environment, the urine samples were analyzed by hydride generation atomic absorption spectroscopy (Anawar 2012) (reduction of arsenic to arsine). The limit of detection (LoD) for total urinary As was 2.0 μg/L. With attention to concentration dilution in the urine samples, we divided the urine As (μg/L) by urine creatinine (g/L) and expressed the concentrations of total urine As in terms of μg/g creatinine.

The individual samplings of As in air were performed on a subgroup of 40 subjects on the same day of the spot urinary sampling.

The air samples were collected by using the Dorr–Oliver cyclones with an aerodynamic 5-μm cut-off-point diameter. Each cyclone was connected to a sampling pump; the pump was calibrated to a flow rate of 1.7 L/min of air (as recommended by the National Institute for Occupational Safety and Health, NIOSH). Each cyclone was equipped with a cassette holding a 37-mm polyvinylchloride (PVC) membrane filter. The cyclone and the cassette were attached to the shirt collar, within the subject's breathing zone. The pump was placed in a padded pouch. It did not rain during the sampling period. After sampling, the cyclone was carefully disassembled. Filters containing the collected particulate were analyzed according to the NIOSH Method 7900 for As (NIOSH 1998). The collected particulate samples were analyzed by atomic absorption spectrometry (Perkin-Elmer, mod. 403). Each subject wore the air sampler for the entire work shift (7 h). For each air sample, the time-weighted average (TWA) level of individual exposure to As over 7 h was calculated.

Assay of AST/GOT, ALT/GPT, and γ-GT

On the same day of the air samplings and the spot urine samplings, a 10 mL sample of peripheral venous blood was taken from 80 traffic policemen and 50 police drivers to evaluate the AST/GOT, ALT/GPT, and γ-GT concentrations. The normal ranges used in the laboratory analysis were as follows: AST/GOT 10–37 U/L, ALT/GPT 10–65 U/L, and γ-GT 0–70 U/L. The values of the AST/GOT, ALT/GPT, and γ-GT were analyzed with the kinetic method (Schumann and Klauke 2003).

Statistical analysis

The normal distribution of the variables was determined by the Kolmogorov–Smirnov test. The results were expressed as the mean, standard deviation (SD), and range. The geometric mean (GM), geometric standard deviation (GSD), and range (min–max) were reported for the values of As in air and for the values of urinary As. The single-variable frequencies were compared by using the chi-square test with the Yates' correction. The differences between the means were compared by using the Student's *t* test for unpaired data after logarithmic transformation of the non-normally distributed variables.

For the log transformed data, Pearson correlation coefficients were used to assess the associations between the airborne As and the total urinary As on the subgroup of 40 subjects; among airborne As, AST/GOT, ALT/GPT, and γ-GT on the subgroup of 40 subjects; and among total urinary As, AST/GOT, ALT/GPT, and γ-GT on the subgroup of 40 subjects and on the total sample (130 subjects).

Multiple linear regression models were used to examine the association between the total urinary As values and the independent variables (age, working life, job title, BMI, values of individual samplings, diet, and water consumption) and between the AST/GOT, ALT/GPT, and γ-GT values and the independent variables (age, working life, job title, BMI, urinary As values, or values of personal exposure to As). Covariates with a p value of <0.10 were selected for inclusion in the multivariate model.

These analyses were performed on the subgroup of 20 traffic policemen and 20 police drivers, analyzed as a single group ($n = 40$ subjects), and the total sample of traffic policemen ($n = 80$ subjects), and police drivers ($n = 50$ subjects), and analyzed as a single group ($n = 130$ subjects).

The differences were considered statistically significant when the p values were <0.05. Statistical analysis was carried out by using the SPSS statistical program for Windows.

Results

The characteristics of the total population studied (130 subjects) and that of the subgroup of 40 subjects are shown in Table 1. The traffic policemen and police drivers were well matched for mean age, working life, BMI (kg/m^2), weekly intake of some foods, and daily consumption of water from the local supply, and/or mineral water (number of glasses per day) (Table 1). No subject reported past or current liver diseases, or activities implying exposure to As during a time off, hobby, gardening for instance, that may include the use of arsenical herbicides. All the subjects were working in the same urban area where they had lived for at least 5 years.

The mean value of individual exposure to As in air was significantly higher in the traffic policemen than in the police drivers ($p = 0.000$; Table 2).

In the subgroup of 40 subjects and in the total sample of 130 subjects, the mean values of the total urinary As were significantly higher in the traffic policemen than in the

Table 1 Characteristics of the total population studied (130 subjects) and of the subgroup of 40 subjects

	Subgroup of 40 subjects		Total sample of 130 subjects	
	Traffic policemen ($n = 20$) Mean (SD) Min–max	Police drivers ($n = 20$) Mean (SD) Min–max	Traffic policemen ($n = 80$) Mean (SD) Min–max	Police drivers ($n = 50$) Mean (SD) Min–max
Age (years)	42.1 (8.4)[a]	42.5 (8.1)	43.8 (8.7)[a]	43.9 (7.8)
	33–60	34–59	29–64	28–59
Working life (years)	11.9 (5.3)[a]	12.1 (4.9)	12.6 (6.4)[a]	12.0 (7.8)
	3–23	2–21	2–24	2–21
BMI (kg/m^2)	25.0 (2.6)[a]	25.4 (5.3)	24.8 (3.1)[a]	25.1 (4.6)
	21.0–29.7	19.5–35.7	18.8–34.7	17.5–40.9
Consumption of water from water supplies (number of glasses per day)	2.9 (1.2)[a]	3.0 (1.3)	3.1 (1.4)[a]	3.8 (1.4)
	2–6	2–5	2–6	2–8
Consumption of water from mineral water (number of glasses per day)	4.4 (1.7)[a]	4.5 (1.8)	3.5 (1.3)[a]	3.7 (1.6)
	1–8	1–8	1–8	1–8
Intake of fish (number of times per week)	0.7 (0.5)[a]	0.6 (0.4)	0.8 (0.6)[a]	0.9 (0.7)
	0–2	0–2	0–3	0–3
Intake of shellfish (number of times per week)	0.3 (0.5)[a]	0.4 (0.2)	0.4 (0.5)[a]	0.5 (0.4)
	0–1	0–2	0–2	0–2
Intake of rice (number of times per week)	1.4 (0.8)[a]	1.7 (0.9)	1.3 (0.6)[a]	1.4 (0.7)
	1–4	2–5	1–5	1–5
Intake of corn (number of times per week)	0.9 (0.3)[a]	1.0 (0.4)	0.8 (0.7)[a]	0.9 (0.6)
	0–1	0–2	0–3	0–3

SD standard deviation

[a] $p > 0.05$ = not significant in traffic policemen versus police drivers of the subgroup of 40 subjects and in the total sample of 130 subjects (student's *t* test)

police drivers ($p = 0.04$ and $p = 0.018$, respectively; Table 2). All the values of urinary creatinine were within the reference range (0.3–3.0 g/L) that is recommended by the World Health Organization. None of the traffic policemen and police drivers had As values lower than the LoD.

In the subgroup of 40 subjects, the mean values of AST/GOT were significantly higher in the traffic policemen than in the police driver ($p = 0.032$; Table 2). No significant differences were observed for ALT/GPT and γ-GT mean values in the traffic policemen when compared to the police drivers in the subgroup of 40 subjects ($p > 0.05$; Table 2).

In the total sample, the mean values of AST/GOT and ALT/GPT were significantly higher in the traffic policemen than in the police drivers ($p = 0.025$ and $p = 0.046$, respectively; Table 2). No significant differences were observed for γ-GT mean values in the traffic policemen when compared to the police drivers in the total sample ($p > 0.05$; Table 2).

AST/GOT values higher than the normal range were found in 12.5 % (10 subjects) of the traffic policemen, while no police drivers had levels above the standard ($p = 0.024$; chi-square test with Yates' correction).

ALT/GPT values higher than the normal range were found in 8.7 % (7 subjects) of the traffic policemen, while no police driver had levels above the standard ($p > 0.05$; chi-square test with the Yates' correction).

γ-GT values higher than the normal range were found in 6.2 % (5 subjects) of the traffic policemen and in 8.0 % (4 subjects) of the police drivers ($p > 0.05$; chi-square test with Yates' correction).

In the subgroup of 40 subjects that was analyzed as a single group, the log values of the total urinary As were significantly correlated with the log values of As in the air ($r = 0.22$, $p = 0.03$, one-tailed test) as well as the log values of As in air were correlated to the values of ALT/GPT ($r = 0.15$, $p = 0.04$, one-tailed test). In the subgroup of 40 subjects, no significant correlation was found among the log values of As in air and the values of AST/GOT and γ-GT.

In the total sample of 130 subjects that was analyzed as a single group, the log values of the total urinary As were significantly correlated with the log values of AST/GOT and ALT/GPT ($r = 0.20$, $p = 0.02$ and $r = 0.35$, $p = 0.01$, one-tailed test). In the total sample, no

Table 2 Personal exposure to arsenic, total urinary arsenic, GOT/AST, GPT/ALT e GGT values in the subgroup of 40 subjects and in the total sample studied

	Subgroup of 40 subjects		Total sample of 130 subjects	
	Traffic policemen ($n = 20$) Geometric mean (GSD) Min–max	Police drivers ($n = 20$) Geometric mean (GSD) Min–max	Traffic policemen ($n = 80$) Geometric mean (GSD) Min–max	Police drivers ($n = 50$) Geometric mean (GSD) Min–max
Personal exposure to arsenic in air (TWA over 7 h, ng/m^3)	3.2 (1.5)[a]	0.6 (0.4)	n.d.	n.d.
	1.7–7.5	0.1–1.7		
Total urinary arsenic (μg/g creat)	13.1 (6.8)[b]	9.0 (5.3)	12.8 (7.7)[e]	9.7 (6.2)
	4.0–22.7	2.6–20.1	2.7–54.7	2.6–24.4
GOT/AST (U/L)	30.7 (16.8)[c]	22.1 (4.1)	25.8 (13.2)[f]	21.4 (4.5)
	12.0–67.0	15.0–28.0	12.0–69.0	15.0–32.0
GPT/ALT (U/L)	36.1 (13.5)[d]	32.2 (8.7)	41.3 (17.4)[b]	35.5 (13.3)
	12.0–56.0	15.0–44.0	15.0–97.0	12.0–60.0
GGT (U/L)	34.0 (23.0)[d]	27.9 (17.3)	31.7 (17.0)[d]	32.7 (18.5)
	15.0–92.0	12.0–83.0	11.0–152.0	14.0–83.0

SD standard deviation, *n.d* not determined on the total sample

[a] $p = 0.000$: significant in traffic policemen versus police drivers (student's *t* test on the log transformed data)

[b] $p = 0.04$: significant in traffic policemen versus police drivers of the subgroup of 40 subjects and in the total sample of 130 subjects (student's *t* test on the log transformed data)

[c] $p = 0.032$: significant in traffic policemen versus police drivers of the subgroup of 40 subjects (student's *t* test)

[d] $p > 0.05$: not significant in traffic policemen versus police drivers of the subgroup of 40 subjects and in the total sample of 130 subjects (student's *t* test)

[e] $p = 0.018$: significant in traffic policemen versus police drivers of the total sample of 130 subjects (student's *t* test on the log transformed data)

[f] $p = 0.025$: significant in traffic policemen versus police drivers of the total sample of 130 subjects (student's *t* test)

significant correlation was found between the log values of total urinary As and the values of γ-GT.

The multiple linear regression analysis performed on the subgroup of 40 subjects showed that the log values of total urinary As were dependent on the log values of As in the air and on the "job title" variable (traffic policeman or driver) ($R^2 = 0.312$, $p = 0.038$; Table 3). The values of the total urinary As were not dependent on the other variables used in the model, such as age, working life, BMI, diet, and water consumption (Table 3).

The multiple linear regression analysis performed on the total sample of 130 subjects showed that the log values of total urinary As were dependent on the "job title" variable (traffic policeman or driver) ($R^2 = 0.27$, $p = 0.040$; Table 4) but not dependent on the other variables used in the regression model.

The multiple linear regression analysis performed on the total sample of 130 subjects showed that: (1) the values of AST/GOT were dependent on the BMI variable ($R^2 = 0.156$, $p = 0.017$; Table 5); (2) the values of ALT/GPT were dependent on the three variables "job title," BMI, and log values of the total urinary As ($R^2 = 0.256$, $p = 0.009$; Table 5); and (3) the values of γ-GT were dependent on the age and on the BMI ($R^2 = 0.352$, $p = 0.000$; Table 5).

Discussion

This study is the first research that reports on occupational exposure to As in urban outdoor workers (traffic policemen and police drivers) and the effects of such exposure on AST, ALT, and γ-GT.

In the present study, the individual exposure to As in air of traffic policemen, although at low doses, resulted significantly higher than the exposure of police drivers.

This finding confirms what has already been observed in two of our recent studies (Ciarrocca et al. 2012a, b) and supports the hypothesis that anti-pollen filters present in the cars used by the police drivers are capable of retaining the particulate matter.

The intake of water contaminated with As (Abernathy et al. 2003) and the consumption of food such as corn and rice (Abernathy et al. 2003) are the main sources of exposure to iAs. Other source of exposure to As is represented by the cigarette-smoking habit (ATSDR 2007).

Table 3 Multiple linear regression analysis in the subgroup of $n = 40$ subjects using as dependent variable the log urinary arsenic values

Independent variables	Dependent variable: log total urinary arsenic (μg/g creat)		
	Sample: traffic policemen and police drivers ($n = 40$)		
	β (standardized coefficients)	t	p
Constant	–	2.501	0.018
Age (years)	0.042	0.250	0.804
Working life (years)	0.030	0.320	0.903
Job title (traffic policemen or police drivers)	0.408	2.567	**0.045**
BMI (kg/m^2)	−0.218	−1.175	0.250
Consumption of water from water supplies (number of glasses per day)	0.655	1.555	0.131
Consumption of water from mineral water (number of glasses per day)	0.420	1.114	0.264
Intake of fish (number of times per week)	0.098	0.437	0.665
Intake of shellfish (number of times per week)	0.478	0.963	0.344
Intake of rice (number of times per week)	0.071	0.392	0.698
Intake of corn (number of times per week)	0.057	0.244	0.809
Log Arsenic in air (ng/m^3)	0.387	2.247	**0.033**
Model	F	p	R^2 adjusted
	4.446	**0.038**	0.312

Bold values are statistically significant (p<0.05)

The main sources of introduction of As were the same for the traffic policemen and the police drivers evaluated in this study. All the subjects who reported cigarette-smoking habit were excluded from the study.

The above considerations lead to the assumption that the significant increase in the values of the total urinary As observed in traffic policemen versus police drivers may depend on the levels of individual exposure to As in the air. The results of the correlation analysis confirm these findings.

Similarly, the results of the multiple linear regression analysis showed that both individual exposure to As in the air and the “job title” variable explain about 31 % of the variability in the concentrations of total urinary As. It is to be noted that the values of total urinary As were not influenced by the dietary habits and the quality of water taken.

In the subgroup of 40 subjects, individual exposure to the As present in urban air by the traffic policemen rather than the police drivers could cause a significant increase in the mean values of AST/GOT but not of the mean values of ALT/GPT.

It can be assumed that the nonsignificant differences between the mean values of ALT/GPT in the traffic policemen and the police drivers of the subgroup of 40 subjects may be due to the small sample size.

Besides, a significant increase in the mean values of AST/GPT and ALT/GPT in the traffic policemen when compared to the police drivers was also observed in the total sample.

No significant difference was found between the traffic policemen and police drivers as regards the mean values of γ-GT, both in the subgroup of 40 subjects and in the total sample of 130 subjects.

Correlation analysis and multiple linear regression analysis confirmed the association among: (1) the values of As in air and ALT/GPT; (2) the values of the total urinary As, job title, BMI, and ALT/GPT values; (3) the values of AST/GOT and BMI; and (4) the values of γ-GT values, age, and BMI.

The mean values of the studied liver enzymes are within the normal limits, although there was a higher and significant percentage of traffic policemen compared to police drivers with values of AST/GOT (12.5 %) and ALT/GPT (8.5 %) above the normal range of our laboratory.

The persistent alteration of the liver function tests in the general Italian population is between 10 and 17 %, and the primary etiological factors are alcohol abuse and viral hepatitis (Maio et al. 2000; Pendino et al. 2005).

Another study showed that, among Italians, the prevalence of non-virus- and non-alcohol-related hypertransaminasemia was 23 %, and it was closely related to the BMI (Morisco et al. 2001). These data are consistent with those found in other countries and in particular in the USA (Clark et al. 2003; Ruhl and Everhart 2003).

Table 4 Multiple linear regression analysis in the total sample of $n = 130$ subjects using as dependent variable the log urinary arsenic values

Independent variables	Dependent variable: log total urinary arsenic (μg/g creat)		
	Sample: traffic policemen and police drivers ($n = 130$)		
	β (standardized coefficients)	t	p
Constant	–	3.501	0.118
Age (years)	0.055	0.597	0.552
Working life (years)	0.060	0.620	0.603
Job title (traffic policemen or police drivers)	0.510	3.477	**0.030**
BMI (kg/m^2)	−0.117	−1.375	0.240
Consumption of water from water supplies (number of glasses per day)	0.080	0.510	0.730
Consumption of water from mineral water (number of glasses per day)	0.010	1.114	0.964
Intake of fish (number of times per week)	0.088	0.437	0.665
Intake of shellfish (number of times per week)	0.035	0.333	0.454
Intake of rice (number of times per week)	0.062	0.664	0.508
Intake of corn (number of times per week)	0.025	0.233	0.816
Model	F	p	R^2 adjusted
	3.586	**0.040**	0.278

Bold values are statistically significant ($p<0.05$)

Table 5 Multiple linear regression analysis in the total sample of $n = 130$ subjects using as dependent variable GOT/AST, GPT/ALT e GGT values

Independent variables	Sample: traffic policemen and police drivers ($n = 130$)								
	Dependent variables								
	GOT/AST (U/L)			GPT/ALT (U/L)			GGT (U/L)		
	β*	t	p	β*	t	p	β*	t	p
Constant	–	0.884	0.379	–	0.399	0.691	–	2.019	0.046
Age (years)	0.062	0.723	0.471	0.064	0.749	0.456	0.320	3.932	**0.000**
Working life (years)	0.052	0.676	0.673	0.074	0.805	0.567	0.174	1.180	0.240
Job title (traffic policemen or police drivers)	0.089	0.896	0.098	0.243	3.007	**0.004**	0.084	1.131	0.258
BMI (kg/m^2)	0.265	3.088	**0.002**	0.229	2.684	**0.008**	0.244	2.998	**0.003**
Log total urinary arsenic (μg/g creat)	0.083	0.963	0.337	0.374	0.188	**0.045**	0.060	0.740	0.461
Model	F	p	R^2 adjusted	F	p	R^2 adjusted	F	p	R^2 adjusted
	3.528	**0.017**	0.156	4.028	**0.009**	0.256	8.717	**0.000**	0.352

* Standardized coefficients

Bold values are statistically significant ($p<0.05$)

The significant differences observed in the present study as to the liver enzymes AST/GOT and ALT/GPT in traffic policemen versus police drivers acquire greater significance of an effect, when we consider that (1) no subjects had factors that were able to alter the concentrations of AST/GOT and ALT/GPT (such as, alcohol consumption, cigarette-smoking habit, liver disease, and daily intake of hepatotoxic drugs), and (2) all participants were comparable as for age, working life, and BMI.

The present study has some limitations:

- we analyzed the total urinary As but did not check the value of the exposure to iAS and to organic As (Francesconi and Kuehnelt 2004);
- we studied a limited number of subjects.

In spite of these limitations, our results are in agreement with what has already been observed by other authors in the literature, although none of these studies was conducted in subjects exposed to As present in urban air.

In a study conducted in India, Guha Mazumder et al. (2001) observed an increase in AST/GOT and ALT/GPT in subjects exposed to As through the intake of contaminated water.

In two other studies carried out in Bangladesh and India, an increase in liver transaminases was observed in subjects exposed to As through the intake of contaminated water (Islam et al. 2011; Maiti et al. 2012).

In a recent study carried out in India, in agreement with our results, Das et al. (2012) observed significantly increased values of the total urinary As, AST/GOT, and ALT/GPT but not of γ-GT values in subjects exposed to As through the intake of contaminated water (Das et al. 2012).

Conclusions

The attention on the effects of the exposure to As is currently focused on the subjects exposed through the intake of contaminated food and water. It should be noted that the effects of the exposure to As in the air in large cities need to be better analyzed in further research.

In this context, our study provides an initial contribution for the assessment of individual exposure to As in urban air and for the evaluation of the hepatic effects of such exposure.

The results of this study can provide information about the occupational exposure to As in the street and in the car, and about the effects on the liver function, and for other categories of outdoor workers exposed to As.

Conflict of interest The authors declare that they have no conflict of interest.

References

Abernathy CO, Thomas DJ, Calderon RL (2003) Health effects and risk assessment of arsenic. J Nutr 133(5 Suppl 1):1536S–1538S

Anawar HM (2012) Arsenic speciation in environmental samples by hydride generation and electrothermal atomic absorption spectrometry. Talanta 88:30–42

ATSDR (2007) Toxicological profile for arsenic. Atlanta GA: Agency for Toxic Substances and Disease Registry. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp2.pdf. Accessed 21 Oct 2012

Ciarrocca M, Tomei F, Caciari T et al (2012a) Exposure to arsenic in urban and rural areas and effects on thyroid hormones. Inhal Toxicol 24:589–598

Ciarrocca M, Tomei G, Palermo P et al (2012b) Environmental and biological monitoring of arsenic in outdoor workers exposed to urban air pollutants. Int J Hyg Environ Health 215:555–561

Clark JM, Brancati FL, Diehl AM (2003) The prevalence and etiology of elevated aminotransferase levels in the United States. Am J Gastroenterol 98:960–967

Das N, Paul S, Chatterjee D et al (2012) Arsenic exposure through drinking water increases the risk of liver and cardiovascular diseases in the population of West Bengal, India. BMC Public Health 12:639

Davidson CI, Goold WD, Mathison TP, Wiersma GB, Brown KW, Reilly MT (1985) Airborne trace elements in Great Smoky Mountains, Olympic, and Glacier National Parks. Environ Sci Technol 19(1):27–35

Drobná Z, Walton FS, Paul DS, Xing W, Thomas DJ, Stýblo M (2010) Metabolism of arsenic in human liver: the role of membrane transporters. Arch Toxicol 84:3–16

Francesconi KA, Kuehnelt D (2004) Determination of arsenic species: a critical review of methods and applications, 2000–2003. Analyst 129:373–395

Guha Mazumder DN (2001) Arsenic and Liver diseases. J Indian Med Assoc 99:311, 314–315, 318–320

International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans (2004) Some drinking-water disinfectants and contaminants, including arsenic, vol 84. Lyon: IARC Press, pp 39–267

Islam K, Haque A, Karim R et al (2011) Dose-response relationship between arsenic exposure and the serum enzymes for liver function tests in the individuals exposed to arsenic: a cross sectional study in Bangladesh. Environ Health 10:64

Liu WS, Chung YT, Yang CY, Lin CC, Tsai KH, Yang WC et al (2012) Serum creatinine determined by Jaffe, enzymatic method, and isotope dilution-liquid chromatography-mass spectrometry in patients under hemodialysis. J Clin Lab Anal 26(3):206–214

Maio G, D'Argenio P, Stroffolini T et al (2000) Hepatitis C virus infection and alanine transaminase levels in the general population: a survey in a southern Italian town. J Hepatol 33:116–120

Maiti S, Chattopadhyay S, Deb B et al (2012) Antioxidant and metabolic impairment result in DNA damage in arsenic-exposed individuals with severe dermatological manifestations in Eastern India. Environ Toxicol 27:342–350

Morisco F, Di Lonardo A, Stroffolini T, Leone D, Caporaso N (2001) High prevalence of non-virus/non-alcohol-related alanine-aminotransferase increase in blood donors. Haematologica 86:1116

National Institute for Occupational Safety and Health (NIOSH) (1998) Manual of analytical methods, 4th edn. Method 7900 Elements by ICP. DHHS NIOSH Publication No. 98-119

Pari L, Mohamed Jalaludeen A (2011) Protective role of sinapic acid against arsenic: induced toxicity in rats. Chem Biol Interact 194:40–47

Patlolla AK, Todorov TI, Tchounwou PB, van der Voet G, Centeno JA (2012) Arsenic-induced biochemical and genotoxic effects and distribution in tissues of Sprague–Dawley rats. Microchem J 105:101–107

Pendino GM, Mariano A, Surace P et al (2005) Prevalence and etiology of altered liver tests: a population-based survey in a Mediterranean town. Hepatology 41:1151–1159

Ruhl CE, Everhart JE (2003) Determinants of the association of overweight with elevated serum alanine aminotransferase activity in the United States. Gastroenterology 124:71–79

Scheig R (1996) Evaluation of tests used to screen patients with liver disorders. Prim Care 23:551–560

Schmidt E, Schmidt FW (1993) Enzyme diagnosis of liver diseases. Clin Biochem 26:241–251

Schumann G, Klauke R (2003) New IFCC reference procedures for the determination of catalytic activity concentrations of five enzymes in serum: preliminary upper reference limits obtained in hospitalized subjects. Clin Chim Acta 327:69–79

Stranges S, Freudenheim JL, Muti P et al (2004) Differential effect of alcohol drinking pattern on liver enzymes in men and women. Alcohol Clin Exp Res 28:949–956

Syczewska M, Urbanowicz W, Rzechuła H, Boroń-Kaczmarska A (2004) Relationship of serum alanine aminotransferase (ALT) to body weight, age and sex in blood donors population. Wiad Lek 57:427–430