Serum selenium level in acute myocardial infarction

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Introduction
Although remarkable developments have been made in the management of cardiovascular disease, myocardial infarction (MI) remains the most common cause of death worldwide. MI is an acute condition of myocardial cell death that occurs as a result of imbalance between the coronary blood supply and myocardial requirements. Lipid peroxidation and excessive production of reactive oxygen species (ROS), such as superoxide anions ($O2^{\bullet}-$) and hydrogen peroxide, play a major role in the mechanism of MI. ROS directly damage the cell membrane and cause cell necrosis. However, ROS also stimulate signal transfer to upregulate inflammatory cytokines, for example, tumor necrosis factor-α in the ischemic area and the neighboring myocardium.
Aim
The aims of this article were: (a) to determine serum selenium (Se) and the cut-off value in acute MI patients and the correlation between serum Se and other cardiac biomarkers such as troponin, creatine kinase (CK), creatine kinase myocardial brand (CK-MB), C-reactive protein, and lipogram; and (b) to determine the most predictor risk factor of MI.
Materials and methods
The study was carried out on 120 individuals (60 patients and 60 controls). The patients presented to the Internal Medicine Department and Coronary Care Unit at Assiut University Hospital. The healthy controls were selected and matched for age and sex, and only those who were found to be in good health and free from any signs of chronic diseases or disorders were included.
Results
The main finding of this analysis that there is a statistical difference between patients and controls in serum Se as the mean Se level in patients was 80.3±20.5 and in controls it was 97.2±14.0 and *P* value of less than 0.001, Thus, serum Se is significantly low in MI patients. Also, there was no statistical difference in serum Se in terms of sex, smoking, accompanying diseases (diabetes or hypertension), or type of infarction.
Conclusion
This study supports a significant association between deficient serum Se concentration with cut-off value of up to 84 ng/ml and MI. Strikingly, the most predictor of MI is serum Se, followed by total cholesterol, diabetes mellitus, low-density lipoprotein, and hypertension.

Keywords:
myocardial infarction, selenium, trace elements

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Introduction

Selenium (Se) is a unique essential element as it replaces sulfur in cysteine to form the 21st amino acid selenocysteine and is, thereby, directly attached to proteins, compared with other metals that act as cofactors or prosthetic groups [1]. This unique biology necessitates a complex metabolic fate for dietary sources of Se before the Se structure becomes biologically active.

Several selenoproteins have antioxidant functions; however, the full biological repertoire of selenoproteins is still incompletely known. Hence, the action of Se is complex and interlinked with many metabolic pathways. Selenoprotein expression in tissues shows a hierarchical relation, with the liver and the heart affected more than the endocrine organs and the brain by Se deficiency [2].

The antioxidant effects have led to investigations into the link of Se deficiency to pro-oxidant pathologic states such as atherothrombotic cardiovascular disease and heart failure [3].

Numerous investigations have examined the relation of plasma Se, a simple and likely inadequate measure of body Se status, with cardiovascular disease. Although several studies have shown that low Se status is associated with cardiovascular disease and mortality, other studies have shown a lack of a relationship. Furthermore, recent studies of Se supplementation in the generally Se-replete population of the USA have shown an increased risk of diabetes mellitus (DM) in patients administered Se in modest supplemental doses [3].

Hence, even though Se is an attractive nutraceutical because of its significant effects on many biological functions relevant to cardiovascular disease prevention, an incomplete understanding of its biology in health and disease prevents its routine use in humans [3].

Moreover, Benstoem *et al.* [4] consider Se a marker in coronary heart disease.

Reductions in the circulating levels of the essential trace elements, Se [5], zinc, and chromium [6], are found in patients and experimental models of MI. Reduction of serum levels of zinc and Se was found in patients with high levels of cardiac markers, which implies that trace element levels are associated with the degree of myocardial injury and may play a role in the pathological process of ischemic heart disease [7].

Being essential metals integral to the activity of antioxidant enzymes, this nutrient imbalance favors the progression of oxidative stress and the generation of reactive oxygen species (ROS) that overwhelm the internal antioxidant defenses [8]. Hence, the supplementation of microminerals could be useful for the prevention of MI through antioxidant mechanisms.

The results from previous clinical trials indicate no overall benefit of supplementation with Se only in the prevention of cardiovascular disease. Thus, a combination of Se with trace elements such as zinc and chromium was used to evaluate the possible synergistic effects. Se supplements are available in two forms: inorganic mineral salts, typically sodium selenite or selenate, and organic forms such as Se-enriched yeasts [9]. Among the different types of Se, Se yeast has been found to be the best bioavailable form, being more effective than sodium selenite and selenate in increasing tissue Se retention [10].

Materials and methods

The study was carried out on 120 individuals (60 patients and 60 controls). The patients presented to the Internal Medicine Department and Coronary Care Unit at Assiut University Hospital. The healthy controls were selected and matched for age and sex, and only those who were found to be in good health and free from any signs of chronic diseases or disorders were included.

Eligibility for enrollment in the current study was defined by the following inclusion and exclusion criteria:

Inclusion criteria

Acute myocardial infarction (MI) patients diagnosed by assessment of history, clinical examination, determination of cardiac biomarkers [troponin, creatine kinase (CK), creatine kinase myocardial brand (CK-MB)], ECG, and echocardiography.

Exclusion criteria

Patients on Se supplementations were excluded from the study.

Methods

An informed consent was obtained for all patients and the approval of the Research Ethics Committee of Assiut Faculty of Medicine was obtained before the study.

(1) All studied patients were subjected to the following:
(2) Assessment of history.
(3) Physical examination.
(4) Laboratory investigations including the following: serum Se, troponin, CK, CK-MB, C-reactive protein (CRP), and lipid profile.
(5) ECG and echocardiography.

Statistical analysis

The data were tested for normality using the Anderson–Darling test and for homogeneity variances before further statistical analysis. Categorical variables were described by number and percent, where continuous variables were described by mean and SD. χ^2-Test and the Fisher exact test were used to compare between categorical variables; continuous variables were compared using a *t*-test and analysis of variance. Receiver operating characteristic curve was used to predict the cut-off value. Multiple linear regression analysis was carried out to detect the most important predictor of MI. A two-tailed *P* value of less than 0.05 was considered statistically significant. All analyses were carried out using the IBM SPSS 20.0 software (IBM Corporation, Armonk, NY, USA).

Results

Results are shown in Tables 1–9 and Figs 1 and 2.

Table 2 shows that there is a statistical difference between the patients and the controls in serum Se as the mean Se in patients was 80.3±20.5 and in controls it was 97.2±14.0 and *P* value of less than 0.001. Thus, serum Se is significantly low in MI patients.

Among the 36 cases of our study who were diagnosed with acute MI, four (11.1%) only had low Se (below the cut-off value <84 ng/ml) as a risk factor for MI and were nondiabetic, nonhypertensive, and nonsmokers.

Also, among these 36 cases, five (13.9%) had low Se and were smokers, which represent two risk factors for MI.

Five (13.9%) of these 36 cases had low Se and were diabetic.

Also, four (11.1%) cases had low serum Se and were hypertensive, which represent two risk factors for MI.

As three risk factors for MI in four (11.1%) cases were diabetes, smoking habit, and low Se levels.

In contrast, only two (5.6%) cases were hypertensive, smokers, and had low serum Se.

Also, four (11.1%) cases were diabetic, hypertensive, and had low Se levels.

Table 1 Demographic data of patients and controls

	Group [*n* (%)]		*P* value
	Patients	Controls	
Sex			
Male	42 (70.0)	39 (65.0)	0.559
Female	18 (30.0)	21 (35.0)	
Age (years)	55.9±13.9	58.8±9.9	0.180

No statistical difference between patients and controls in age (*P*=0.180) or sex (*P*=0.559).

Table 2 Comparison between patients and control in terms of serum selenium

	Patients	Control	*P* value
Serum selenium	80.3±20.5	97.2±14.0	<0.001**

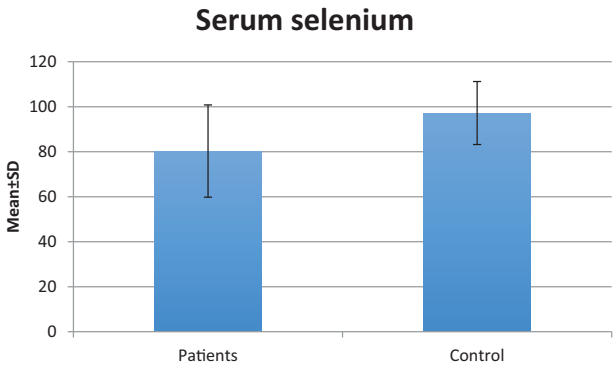
**Statistically significant difference (*P*<0.01).

On combining the four risk factors of MI (DM, hypertension, smoking, and low Se), we found that eight (22.2%) cases had these four risk factors (Table 10).

Discussion

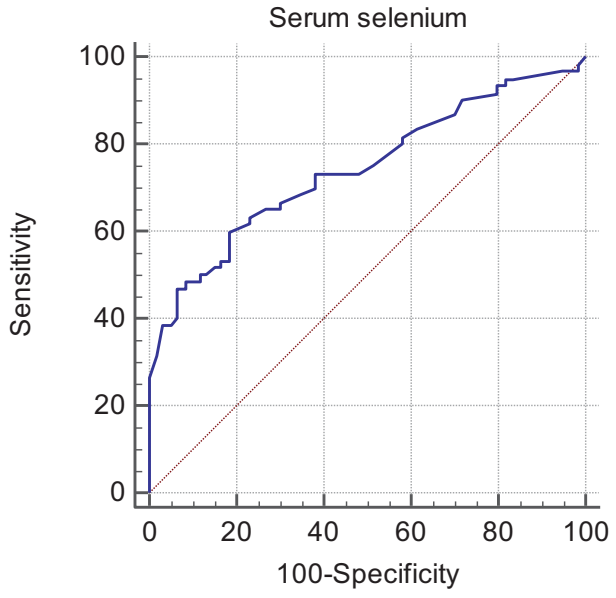
Atherosclerosis is a well-known precursor of ischemic heart disease because of accumulation of lipids and fibrous elements in the arteries [11]. Development of atherosclerosis depends on a balance between

Figure 1



Variations in serum selenim between patients and control.

Figure 2



Receiver operating characteristic curve to detect the cut-off value of selenium between patients and controls.

Table 3 Illustration ROC curve classification table

	AUC	Cut-off (ng/ml)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Selenium	0.742	≤84	60	81.7	76.6	67.1	70.9

AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value.

proinflammatory stimuli, anti-inflammatory, and antioxidant defense mechanisms [12]. The disturbance of Se may cause MI because of a direct effect on the vascular system or indirectly by lipoprotein metabolism [5].

Lipoprotein oxidation is inhibited by enzymatic antioxidants, such as glutathione peroxidase and selenoenzyme glutathione peroxidase, the activities of which depend on an adequate Se supply. Se-binding antioxidants are designed to prevent the occurrence of free radical-induced injury under normal conditions [13].

This study found that there is no correlation between serum Se and high-density lipoprotein (HDL) cholesterol. This is in agreement with the result obtained by Christensen *et al.* [14], who found that HDL cholesterol did not vary with Se.

This study shows that serum Se has a significant negative correlation with the low-density lipoprotein cholesterol level [14]. In addition, the authors found a significant reduction in non-HDL cholesterol levels. Nonetheless, the effects of Se substitution on the lipid profile remain partially understood [15].

Moreover, previous studies have shown that Se supplementation may affect and thus control the migration, adherence, and phagocytosis of leukocytes [16].

Table 4 Frequency of the studied parameters in the patient group

	N (%)
Smoking	
Smoker	33 (55.0)
Nonsmoker	27 (45.0)
C-reactive protein	
Positive	50 (83.3)
Negative	10 (16.7)
ECG	
Anterior MI	30 (50.0)
Extensive anterior	2 (3.3)
Inferior MI	23 (38.3)
Inferior post-MI	5 (8.3)
Diabetes mellitus	
Yes	32 (53.3)
No	28 (46.7)
Hypertension	
Yes	31 (51.7)
No	29 (48.3)
STEMI	49 (81.7)
NSTEMI	11 (18.3)

MI, myocardial infarction; NSTEMI, non-ST-segment myocardial infarction; STEMI, ST-segment myocardial infarction.

Table 5 Range, mean, and SD of the studied parameters in the patient group

	Range	Mean±SD
Age	28–75	57.52±9.68
Serum selenium	40.8–120	80.32±20.53
Troponin	0.064–50	6.19±9.68
CK-protein	26–4680	903.3±1215.53
CK-MB	4–486	120.78±110.89
TG	42.8–347	134.47±65.34
CHOL	58–365	167.05±52.64
LDL	27–238	93.43±42.9
HDL	29–79.5	50.43±13.41
EF	33–72	53.15±9.28
C-reactive protein	3–30	19.6±6.9

CHOL, cholesterol; EF, ejection fraction; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides.

Table 6 Correlation between serum selenium and other parameters

Parameters list	Serum selenium	
	r	*P*
Age	−0.078	0.555
Troponin	−0.078	0.552
CK	−0.002	0.990
CK-MB	0.023	0.861
TG	0.145	0.272
CHOL	0.249	0.044*
LDL	−0.278	0.033*
HDL	0.183	0.166
EF	0.016	0.905
C-reactive protein	−0.667	0.001**

This table shows:-negative correlation between selenium and C-reactive protein, negative correlation between selenium and LDL and positive correlation between selenium and total cholesterol. HDL, high-density lipoprotein; LDL, low-density lipoprotein. *Weak correlation. **Strong correlation.

Table 7 Serum selenium in association with other risk factors

	Serum selenium (mean±SD)	*P* value
Sex		
Male	78.6±20	0.319
Female	84.4±21.7	
Smoking		
Smoker	82.3±21.3	0.407
Nonsmoker	77.9±19.7	
DM		
Yes	79.9±21.4	0.869
No	80.8±19.9	
Hypertension		
Yes	81.9±22.4	0.549
No	78.7±18.5	
STEMI	81.5±18.5	0.348
Non-STEMI	75±28.4	

This table shows that there is no statistical difference in serum selenium in terms of sex, smoking, accompanying diseases (diabetes or hypertension), or type of infarction. DM, diabetes mellitus; NSTEMI, non-ST-segment myocardial infarction; STEMI, ST-segment myocardial infarction.

Table 8 Relation between serum selenium and infarction site

	ECG				*P* value
	Anterior MI	Extensive ANT	Inferior MI	Inferior post-MI	
Serum selenium	83.2±20.4	62.5±17.7	77.6±20.3	82.5±24.3	0.474

This table shows no correlation between serum selenium and the site of infarction (*P*=0.474). MI, myocardial infarction.

Table 9 Risk factors of myocardial infarction

	≤84 [*N* (%)]
Low serum selenium (total)	36 (72.0)
Low serum selenium with smoker	5 (13.9)
Low serum selenium with DM	5 (13.9)
Low serum selenium with HTN	4 (11.1)
Low serum selenium with smoker+DM+HTN	8 (22.2)
Low serum selenium with smoker+DM	4 (11.1)
Low serum selenium with smoker+HTN	2 (5.6)
Low serum selenium with DM+HTN	4 (11.1)
Low serum selenium only	4 (11.1)

DM, diabetes mellitus; HTN, hypertension; MI, myocardial infarction.

Table 10 Multivariate analysis using multiple binary logistic regressions to assess the predictors of myocardial infarction

	Odds ratio (95% CI)	*P* value
Smoking	0.62 (0.11–3.52)	0.587
Serum selenium	6.2 (2.5–13.7)	<0.001**
DM	3.2 (1.2–14.3)	0.033*
HTN	1.5 (0.22–10.41)	0.680
TG	0.99 (0.98–1.01)	0.447
CHOL	4.2 (1.3–9.2)	0.005**
LDL	2.1 (1.1–5.7)	0.038*
HDL	0.85 (0.78–0.93)	0.003**

This table shows that the most important risk factor of MI is serum selenium, followed by total cholesterol, DM, LDL, and hypertension. CI, confidence interval; DM, diabetes mellitus; HDL, high-density lipoprotein; HTN, hypertension; LDL, low-density lipoprotein; MI, myocardial infarction. *$P<0.05$, statistically significant predictor. **$P<0.01$, statistically significant predictor.

Se influences the inflammatory signaling pathways that modulate ROS by inhibiting the nuclear factor-κB cascade, resulting in a suppressed production of interleukins and tumor necrosis factor-α [17].

Also, Stranges *et al.* [18] concluded that there was no association of HDL cholesterol with biomarkers of Se status. Nawrot *et al.* [19] found that elevated baseline Se levels were associated with a lower risk for hypertension in men, but data from the Lipid Analytic Cologne cohort suggested that higher serum Se concentrations were associated with higher blood pressure levels and a higher prevalence of hypertension [20].

This result is in agreement with that reported by Zhuravlyova and Filonenko [21], who found that Se levels were related to the extent of myocardial injury during infarction. It was also reported that Se level in the acute phase of MI is closely correlated with the peak number of cardiac biomarkers, as well as the activity of metabolic oxygen-dependent reactions [21].

This result is in agreement with that reported by Li *et al.* [12], who concluded that there is a significant correlation between serum Se and MI, and they concluded that although Se deficiency is plausibly linked to an increased risk of MI, the inconsistency among the findings of previous studies precludes definitive recommendations at present [12].

The present study found a significant negative correlation between serum Se and CRP as serum Se plays a role in the regulation of the inflammatory response as reported by Benstoem [3].

This result is in agreement with that reported by Ghashut *et al.* [22], who found that the magnitude of systemic inflammatory response as evidenced by CRP is a major factor associated with lower Se.

The present study found no correlation between serum Se and the site of MI; this result is in agreement with that reported by Radchenko *et al.* [23], who found no difference in Se concentration depending on the location of MI.

The present study found no statistical difference in serum Se in terms of age, sex, smoking, diabetes, or hypertension. This result is in agreement with that reported by Radchenko *et al.* [23], who found no difference in Se concentration depending on age, sex, smoking, and accompanying diseases.

Trace elements, for example Se, are increasingly being recognized as essential mediators in the development and progression of MI [24]. The discrepancy between the studies of the association between Se levels and coronary heart disease risk could be explained by the fact that most studies have been carried out in European countries with markedly lower Se intake compared with that in the USA. Epidemiological studies support the possibility that the deficiency of certain essential elements may increase the risk of MI. Afridi *et al.* [25] found that

there was a significant relationship between Se deficiency and MI risk.

In another study aimed to estimate alterations in serum Se levels in the acute phase of MI. Serum Se levels were measured at admission and after 24 h in 60 consecutive patients with acute coronary syndrome. A positive correlation was also found between the peak TnI and the difference from baseline to 24 h. Moreover, a close negative correlation was observed between baseline Se levels and the difference from baseline to 24 h. These results suggest that alterations in serum Se may be related to the extent of MI [26].

However, some studies suggest that there is no correlation between Se levels and MI risk. Xun *et al.* [27] found no association between Se levels and measures of subclinical atherosclerosis among young American adults.

MI occurs when myocardial ischemia, diminished blood supply to the heart, exceeds a critical threshold and overwhelms myocardial cellular repair mechanisms designed to maintain normal operating function and homeostasis [28].

Tang *et al.* [29] found that the genetic variant in glutathione peroxidase 1 gene is associated with an increased risk of coronary artery disease in a Chinese population.

Hassanzadeh *et al.* [30] found that patients with acute MI have lower plasma concentrations of Se and higher concentrations of proinflammatory cytokines of tumor necrosis factor-α and interleukin-6.

The present study found no correlation between serum Se and serum triglycerides; this result is in agreement with that reported by Wells *et al.* [31].

A meta-analysis of 14 prospective cohort studies found a modest but statistically significant inverse association between Se levels and coronary heart disease [32].

Also, Altekin *et al.* [7] found that Se deficiency is plausibly linked to an increased risk of MI. Also, Se deficiency in acute coronary syndrome is associated with increased other cardiac biomarkers and CRP.

Alanne *et al.* [33] have shown that polymorphisms in the Selenoprotein S gene have significant effects on cardiovascular morbidity, especially in women.

Lubos *et al.* [34] concluded that low Se concentrations were associated with the risk of future cardiovascular death in patients with acute coronary syndrome.

Moreover, the Se content of grains and vegetables generally depends on the Se content in the corresponding soils [35].

The atmosphere plays an important role in the biogeochemical cycling of Se. It influences the transport and transformation of Se [36].

The present study found that serum Se is significantly low in MI patients.

The present study found a negative correlation between serum Se and peak troponin as reported by Kutil *et al.* [26], who found a negative correlation between peak troponin level and serum Se.

The present study found no correlation between serum Se and CK or CK-MB.

The present study found a positive correlation between serum Se and ejection fraction, but the correlation was insignificant.

No statistical difference was found in our study between serum Se in ST-segment MI and non-ST-segment MI.

Strikingly, using multivariate analysis with multiple binary logistic regressions to assess the predictor of MI, we found that the most important risk factor to predict of MI is serum Se, followed by total cholesterol, DM, low-density lipoprotein, and hypertension, respectively. This supports the result found in this study as no statistical difference was found in serum Se in terms of age, sex, smoking, diabetes, or hypertension.

From the above data, it can be stated that low serum Se with a cut-off value of up to 84 ng/ml is an important risk factor for MI. Se acts as an antioxidant that protects the cardiac muscle against the damaging effects of free radicals.

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Conflicts of interest
There are no conflicts of interest.

References

1 Stadtman TC. Selenoproteins – tracing the role of a trace element in protein function. PLoS Biol 2005; 3:e421.

2 Bermano G, Nicol F, Dyer JA, Sunde RA, Beckett GJ, Arthur JR, Hesketh JE. Tissue-specific regulation of selenoenzyme gene expression during selenium deficiency in rats. Biochem J 1995; 311:425–430.

3 Joseph J, Loscalzo J. Selenistasis: epistatic effects of selenium on cardiovascular phenotype. Nutrients 2013; 5:340–358.

4 Benstoem C, Goetzenich A, Kraemer S, Borosch S, Manzanares W, Hardy G, Stoppe C. Selenium and its supplementation in cardiovascular disease – What do we know? Nutrients 2015; 7:3094–3118.

5 Panicker S, Swathy SS, John F, Madambath I. Impact of selenium on NFkappaB translocation in isoproterenol-induced myocardial infarction in rats. Biol Trace Elem Res 2010; 138:202–211.

6 Afridi HI, Kazi TG, Kazi N, Sirajuddin, Kandhro GA, Baig JA, *et al.* Chromium and manganese levels in biological samples of Pakistani myocardial infarction patients at different stages as related to controls. Biol Trace Elem Res 2011; 142:259–273.

7 Altekin E, Coker C, Sisman AR, Onvural B, Kuralay F, Kirimli O. The relationship between trace elements and cardiac markers in acute coronary syndromes. J Trace Elem Med Biol 2005; 18:235–242.

8 Weber KT, Weglicki WB, Simpson RU. Macroand micronutrient dyshomeostasis in the adverse structural remodeling of myocardium. Cardiovasc Res 2009; 81:500–508.

9 Alimohamady R, Aliarabi H, Bahari A, Dezfoulian AH. Influence of different amounts and sources of selenium supplementation on performance, some blood parameters, and nutrient digestibility in lambs. Biol Trace Elem Res 2013; 154:45–54.

10 Thiry C, Schneider YJ, Pussemier L, De Temmerman L, Ruttens A. Selenium bioaccessibility and bioavailability in Se-enriched food supplements. Biol Trace Elem Res 2013; 152:152–160.

11 Dutta P, Courties G, Wei Y, Leuschner F, Gorbatov R, Robbins CS, *et al.* Myocardial infarction accelerates atherosclerosis. Nature 2012; 487:325–329.

12 Li F, Gao1 J, Zhang B. Association between deficient selenium levels and myocardial infarction: a meta-analysis. Int J Clin Exp Med 2016; 9:6086–6609.

13 Nomoto A, Higuchi Y, Kobiki Y, Ogawa A. Synthesis of selenium compounds by free radical addition based on visible-light-activated sese bond cleavage. Mini Rev Med Chem 2013; 13:814–823.

14 Christensen K, Werner M, Malecki K. Serum selenium and lipid levels association observed in the national health and nutrition examination survey (NHANES); 2011–2012. Environ Res 2015; 140:76–84.

15 Navas-Acien A, Bleys J, Guallar E. Selenium intake and cardiovascular risk: What is new? Curr Opin Lipidol 2008; 19:43–49.

16 Ahrens I, Ellwanger C, Smith BK, Bassler N, Chen YC, Neudorfer I, *et al.* Selenium supplementation induces metalloproteinase-dependent L-selectin shedding from monocytes. J Leukoc Biol 2008; 83:1388–1395.

17 Forman HJ, Torres M. Reactive oxygen species and cell signaling: Respiratory burst in macrophage signaling. Am J Respir Crit Care Med 2002; 166:S4–S8.

18 Stranges S, Laclustra M, Ji C, Cappuccio FP, Navas-Acien A, Ordovas JM, *et al.* Higher selenium status is associated with adverse blood lipid profile in British adults. J Nutr 2010; 140:81–87.

19 Nawrot TS, Staessen JA, Roels HA, Den Hond E, Thijs L, Fagard RH, *et al.* Blood pressure and blood selenium: a cross-sectional and longitudinal population study. Eur Heart J 2007; 28:628–633.

20 Berthold HK, Michalke B, Krone W, Guallar E, Gouni-Berthold I. Influence of serum selenium concentrations on hypertension: the lipid analytic cologne cross-sectional study. J Hypertens 2012; 30:1328–1335.

21 Zhuravlyova L, Filonenko M. The correlation between serum selenium level and cardiac biomarkers in patients with acute myocardial infarction. Arch Cardiovasc Dis Suppl 2016; 8:12.

22 Ghashut RA, Mc Millan DC, Kinsella J, Vasilaki AT, Talwar D, Duncan A. The effect of the systemic inflammatory response on plasma zinc and selenium adjusted for albumin. Clin Nutr 2016; 2:381–387.

23 Radchenko EN, Nizov AA, Ivanova AY, Sidorova YS. The content of selen in blood plasma in patients with acute Q-wave myocardial infarction. Vopr Pitan 2015; 84:64–69.

24 Chen A, Li G, Liu Y. Association between copper levels and myocardial infarction: a meta-analysis. Inhal Toxicol 2015; 27:237–246.

25 Afridi HI, Kazi TG, Talpur FN, Kazi A, Arain SS, Arain SA, *et al.* Interaction between selenium and mercury in biological samples of Pakistani myocardial infarction patients at different stages as related to controls. Biol Trace Elem Res 2014; 158:143–151.

26 Kutil B, Ostadal P, Vejvoda J, Kukacka J, Cepova J, Alan D, *et al.* Alteration in serum selenium levels and their relation to troponin I in acute myocardial infarction. Mol Cell Biochem 2010; 345:23–27.

27 Xun P, Liu K, Morris JS, Daviglus ML, He K. Longitudinal association between toenail selenium levels and measures of subclinical atherosclerosis: The CARDIA trace element study. Atherosclerosis 2010; 210:662–667.

28 Li S, Zheng MQ, Rozanski GJ. Glutathione homeostasis in ventricular myocytes from rat hearts with chronic myocardial infarction. Exp Physiol 2009; 94:815–824.

29 Tang NP, Wang LS, Yang L, Gu HJ, Sun QM, Cong RH, *et al.* Genetic variant in glutathione peroxidase 1 gene is associated with an increased risk of coronary artery disease in a Chinese population. Clin Chim Acta 2008; 395:89–93.

30 Hassanzadeh M, Faridhosseini R, Mahini M, Faridhosseini F, Ranjbar A. Serum levels of TNF-, IL-6, and selenium in patients with acute and chronic coronary artery disease. Iran J Immunol 2006; 3:142–145.

31 Wells EM, Navas-Acien A, Apelberg BJ, Herbstman JB. Association of selenium and copper with lipids in umbilical cord blood. J Dev Orig Health Dis 2014; 281:281–287.

32 Flores-Mateo G, Navas-Acien A, Pastor-Barriuso R, Guallar E. Selenium and coronary heart disease: a meta-analysis. Am J Clin Nutr 2006; 84:762–773.

33 Alanne M, Kristiansson K, Auro K, Silander K, Kuulasmaa K, Peltonen L, *et al.* Variation in the selenoprotein s gene locus is associated with coronary heart disease and ischemic stroke in two independent finnish cohorts. Hum Genet 2007; 122:355–365.

34 Lubos E, Sinning CR, Schnabel RB, Wild PS, Zeller T, Rupprecht HJ, *et al.* Serum selenium and prognosis in cardiovascular disease: results from the AtheroGene study. Atherosclerosis 2010; 209:271–277.

35 Navarro-Alarcon M, Cabrera-Vique C. Selenium in food and the human body: a review. Sci Total Environ 2008; 400:115–141.

36 Wen H, Carignan J. Reviews on atmospheric selenium: emissions, speciation and fate. Atmospheric Environ 2007; 41:7151–7165.