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Türk Hijyen ve Deneysel Biyoloji Dergisi

Does donating blood cause oxidative stress?

Kan bağışı oksidatif strese yol açar mı?

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ABSTRACT

Objective: Blood donation is a life-saving activity. However, it is indispensable to protect the health of blood donors during and after the donation process. This study aimed to evaluate investigate the effect of blood donation on thiol/disulfide homeostasis by the new automated colorimetric method that measures native thiol (NT), total thiol (TT), disulfide and ischemia-modified albumin levels.

Methods: A total of 30 voluntary blood donors who were eligible to donate blood were enrolled in this study. Peripheral venous blood samples were collected just before and after 30 minutes blood donation. Demographic data (age, sex, weight, height), and the number of blood donations within one year period of donors, were recorded. Individuals were classified into four age groups: Group 1, 18-30; Group 2, 31-40; Group 3, 40 and over. A repeat donor was defined as a donor who has donated blood at least once in the past. Body-Mass Index (BMI) measurement was calculated by use of the formula weight (kg)/height (m2). Donors were classified according

ÖZET

Amaç: Kan bağışı hayat kurtarıcı bir işlemdir. Bununla birlikte bağış süreci ve sonrasında kan bağışçılarının sağlığının korunması zorunludur. Bu çalışmada, bağış işleminin oksidatif strese neden olup olmadığının yeni bir otomatik yöntem kullanılarak native tiyol (NT), total tiyol (TT), disülfid ve iskemik-modifiye albümin seviyeleri ölçümü aracılığı ile değerlendirilmesi amaçlandı.

Yöntem: Bu çalışmaya kan bağışı yapmaya uygun 30 gönüllü kan bağışçısı dahil edildi. Kan bağışından hemen önce ve 30 dakika sonra periferik venöz kan örnekleri alındı. Bağışçıların demografik verileri (yaş, cinsiyet, kilo, boy) ve bir yıllık dönemde yapılan kan bağışı sayıları kayıt altına alındı. Katılımcılar Grup 1, 18-30; Grup 2, 31-40; Grup 3, 40 ve üzeri olacak şekilde yaş gruplarına ayrıldı. Mükerrer bağışçı, geçmişte en az bir kez kan bağışlayan bağışçı olarak tanımlandı. Vücut Kitle İndeksi (VKİ), kilogram cinsinden vücut ağırlığının, metre cinsinden boyun karesine bölünmesiyle hesaplandı. Bağışçılar VKİ değerlerine göre <25 ve ≥25 olarak

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to their BMI values as <25 and ≥25. Test parameters of the dynamic thiol/disulfide homeostasis (TDH) were measured by the automated spectrophotometric method.

Results: Nineteen of the individuals were first-time donor and the others were repeat donors. There were no significant differences in TDH parameters after blood donation. The IMA levels of repeat blood donors were statistically significantly higher after blood donation while other parameters of THD were not (p=0.04). Statistically significant decreases were found in the levels of native and total thiol in the 18-30 age group donors (p=0.03).

Conclusion: Test results of this study showed that blood donation does not cause oxidative stress. Further studies designed with the participation of more blood donors needed to be conducted to present more clearly the association between blood donation and oxidative stress. Considering that blood donation has no adverse effects on human health is considerably valuable in terms of encouraging people to donate blood.

Key words: Blood donors, blood donation, oxidative stress, body-mass index, thiol/disulfide homeostasis

sınıflandırıldı. Dinamik tiyol/disülfit homeostazının (TDH) test parametreleri otomatik spektrofotometrik yöntemle ölçüldü.

Bulgular: Katılımcılardan on dokuzu ilk defa kan bağışlayan, geri kalanları ise mükerrer bağışçıydı. Kan bağışından sonra TDH parametrelerinde anlamlı bir fark yoktu. Mükerrer kan bağışçılarının IMA seviyeleri, kan bağışından sonra istatistiksel olarak anlamlı derecede yüksek iken, THD'nin diğer parametreleri açısından anlamlı fark yoktu (p=0.04). 18-30 yaş grubu bağışçılarda nativ ve total tiyol düzeylerindeki azalma istatistiksel olarak anlamlıydı (p=0.03).

Sonuç: Bu çalışmanın test sonuçları kan bağışının oksidatif strese neden olmadığını göstermektedir. Kan bağışı ile oksidatif stres arasındaki ilişkiyi daha net ortaya koymak için daha fazla kan bağışçısının katılımını sağlayan ileri çalışmaların yapılması gerekmektedir. Kan bağışının insan sağlığına olumsuz etkisinin olmadığının ortaya konulması, insanları kan bağışına teşvik etmesi açısından oldukça değerlidir.

Anahtar Kelimeler: Kan bağışçıları, kan bağışı, oksidatif stres, vücut kitle indeksi, tiyol/disülfit homeostazı

INTRODUCTION

Blood is a life-saving biological vital fluid, the source of which is only human. Over 118 million blood donations are donated globally every year (1). It is essential to ensure the health and safety of donors during blood donation. Some criteria have been identified to avoid the harmful effects of blood donation on donors such as the minimum donor weight for whole blood donation should be at least 50 kg, and the volume of whole blood donated should not exceed 13% of the total blood volume (2).

Since it can only be supplied through the voluntary donors and has a limited shelf life, there may be a shortage of blood and blood components time to time. Therefore, it is crucial to increase the number of regular and volunteer non-remunerated blood donors to ensure a reliable supply of safe blood for patients whose lives depend on it. In order to encourage people to donate blood regularly, it is important to explain to them that blood donation does not harm their bodies as well as the benefits of blood donation to the health.

The balance between oxidant-antioxidant mechanisms is crucially important for maintaining a healthy life. Oxidative stress is defined as the deterioration of this balance as a result of an increase in production and accumulation of oxygen reactive species (ROS) such as hydroxyl radical, superoxide radical, and hydrogen peroxide formed during cellular metabolism and the inadequacy of the antioxidant system to detoxify these reactive products. Aerobic organisms have evolved integrated enzymatic and non-enzymatic antioxidant systems that are effective in preventing the harmful effects of these indigenously generated ROS. Primary antioxidants, including superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT), are enzymatic antioxidants, which all contain the amino acid cysteine in their active centers (3,4). Thiols are one of the most important organic compounds of the non-enzymatic antioxidant system, which are also known as secondary antioxidants. Thiols are functional sulfur-containing compounds that react with reactive oxygen radicals and form disulfide bonds. These bonds can be reduced back to thiol groups to maintain dynamic thiol/disulfide homeostatic status. Dynamic thiol/disulfide homeostasis (TDH) plays a key role in several biochemical processes such as antioxidation, cellular signal transduction, apoptosis, and enzymatic regulation (5). As a novel marker of oxidative stress, it has been studied in several diseases, including diabetes mellitus, inflammatory bowel diseases, hypertension, Behçet disease, migraine, Familial Mediterranean Fever, basal cell carcinoma, etc.(6-12).

As authors, we wanted to search whether the donation process causes oxidative stress, even though the limited volume of blood that does not endanger donors' health is collected. In this study, we aimed to investigate the effect of blood donation on thiol/disulfide homeostasis by the new automated colorimetric method that measures native thiol (NT), total thiol (TT), disulfide, and ischemia-modified albumin levels.

MATERIAL and METHOD

Study design

According to statistical power analysis, it was determined that at least 30 participants were required for the study. A total of 30 voluntary blood donors who were eligible to donate blood in accordance with the National Guide to Preparation, Use, and Quality Assurance of Blood and Blood Components were included in this study. Blood donation and sampling processes have been performed at the Regional Blood Center of Gülhane Training and Research Hospital. Peripheral venous blood samples were collected to measure biochemical values and thiol-disulfide parameters just before blood donation and 30 minutes after blood donation, and placed into serum tubes (The BD Vacutainer® SST™ II Advance). Whole blood samples were centrifuged at 1600 x g for 10 minutes at room temperature. Sera were then stored at -80°C until required for analysis. Demographic data (age, sex, weight, height), and the number of blood donations within one year period of donors, were recorded. Individuals were classified into four age groups: Group 1, 18-30; Group 2, 31-40; Group 3, 40 and over. A repeat donor was defined as a donor who has donated blood at least once in the past. Body-Mass Index (BMI) measurement was calculated by use of the formula weight (kg)/height (m2). Donors were classified according to their BMI values as 25< and ≥25.

Blood sampling and measurement of study parameter

Measurement of TDH parameters: TDH tests were measured by the automated spectrophotometric method described by Erel & Neselioglu. Primarily, disulphide bonds were reduced to constitute free functional thiol groups with sodium borohydride. Unused reductant sodium borohydride was consumed and removed with formaldehyde to prevent reduction of DTNB (5,5'-dithiobis-(2-nitrobenzoic) acid), and all of the thiol groups including reduced

and native thiol groups were determined after the reaction with DTNB. The dynamic disulfide amount was calculated by subtracting the total thiols from the native thiols amount and dividing the results by two. After the determination of native and total thiols, disulfide amounts, disulfide/total thiol percent ratios (SS/SH+SS), disulfide/native thiol percent ratios (SS/SH), and native thiol/total thiol percent ratios (SH/SH+SS) were calculated (13). Venous blood samples accepted within 1 hour after collection were kept at room temperature for 30 minutes and then centrifuged at 3500 rpm for 5 minutes. Serum samples were transferred to Eppendorf tubes and stored at -80°C until tests were performed. Measurement of the ischemia-modified albumin (IMA): Venous blood samples accepted within 1 hour after collection were stored at room temperature for 30 minutes and then centrifuged at 3500 rpm for 5 minutes. The serum samples were transferred into Eppendorf tubes and stored at -80°C until tests were performed. The existence of IMA was detected using Albumin Cobalt Binding Test. This test was performed by adding 50 mL 0.1% cobalt (II) chloride ($CoCl_2$,$6H_2O$) (Sigma-Aldrich Chemie GmbH Riedstrasse 2, Steinheim, Germany) to the patient's serum. Following the mixing stage, a 10-minute incubation period was allowed for albumin cobalt binding. Subsequently, 50 mL of a solution containing 1.5 mg/mL dithiothreitol was added. Following a further mixing stage and a two-minute incubation period, 1.0 mL of a 0.9% sodium chloride solution was added in order to reduce the binding capacity. The blank preparation was conducted in a similar manner, with distilled water replacing the dithiothreitol. The absorbance of samples at 470 nm was detected with a spectrophotometer. The results of the analyses were shown as absorbance units (ABSU) (14).

Statistical analysis

All analyses were performed using SPSS version 18 for Windows (SPSS Inc, Chicago, IL, USA). Analysis of data was primarily descriptive for continuous variables using standard deviations, ranges, mean, and median values. Data were analyzed for normality of distribution using the Kolmogorov-Smirnov test. Differences in continuous variables were compared using a dependent samples t-test or a Wilcoxon rank-sum test based on the normality of distribution. For categorical variables, the chi-square test was used. P value ≤ of 0.05 was statistically significant.

The study was approved by the University of Health Sciences Ankara City Hospital Ethics Committee (Date: 02.03.2022 and Number: 2022-E2-22-1243). This study complies with the Declaration of Helsinki and informed consent was obtained from participants in the study.

RESULTS

A total of 30 volunteer blood donors, 29 male, and 1 female, were included in this study. The mean age of the blood donors was 35.2 ± 9.8 years. Nineteen of the individuals were first-time donors and the rest were repeat donors. There were no significant differences in TDH parameters after blood donation (Table 1). The IMA levels of repeat blood donors were statistically significantly higher after blood donation while other parameters of THD were not (p =0.043) (Table 2). There was no statistical difference between the groups with regard to BMI. A statistically significant decrease was detected in the levels of native and total thiol in the 18-30 age group donors (Table 3).

DISCUSSION

Blood donation is a crucial part of healthcare in worldwide for over a century. The need for blood and blood components is increasing in all around the world. It can be associated with the improvement in the health services provided to patients in both routine and emergency medical conditions.

Table 1. Thiol/disulfide homeostasis values of blood donors pre- and after donation.

	Pre-blood donation	After blood donation	p-value*
Native thiol (µmol/L)	495.4±70.2	476.9±71.7	0.231
Total thiol (µmol/L)	537±73.6	516.7±71	0.192
Disulphide (µmol/L)	20.7±6,2	19,8±7	0.550
Disulphide/total thiol percent ratio (SS/SH+SS)	4,2±1.3	4.3±1,7	0.921
Disulfide/native thiol percent ratio (SS/SH)	3.8±1.1	3.9±1.4	0.874
Native thiol/total thiol percent ratio (SH/SH+SS)	92.2±2.2	92.1±2.9	0.921
Ischemia-modified albumin	0.79±0.16	0.83±0.15	0.231

* dependent samples t-test

Table 2. Thiol/disulfide homeostasis values of blood donors according to the donation status.

Parameters	**Donation status**					
	First-time (n=19)			Regular (n=11)		
	Pre-blood donation	After-blood donation	p value*	Pre-blood donation	After-blood donation	p value*
Native thiol (µmol/L)	486.5±63.7	493.2±65.2	0.604	510.9±80.9	448.9±76.7	0.787
Total thiol (µmol/L)	527.4±61.7	532±62.9	0.723	553.6±91.6	490.3±79.3	0.755
Disulphide (µmol/L)	20.4±5	19.4±5.3	0.483	21.3±8.1	20.7±9.4	0.842
Disulphide/total thiol percent ratio (SS/SH+SS)	4.3±1.3	4±1.1	0.455	4.1±1.2	4.7±2.1	0.441
Disulfide/native thiol percent ratio (SS/SH)	3.9±1.2	3.7±1.2	0.435	3.8±1.1	4.2±1.7	0.484
Native thiol/total thiol percent ratio (SH/SH+SS)	92.1±2.3	92.5±2.4	0.438	92.4±2.2	91.4±3.5	0.484
Ischemia-modified albumin	083±0.14	0.80±±0.14	0.337	0.72±0.18	0.88±0.17	0.041

* dependent samples t-test

Table 3. Thiol/disulfide homeostasis values of blood donors according to the age groups

	18-30 years (n=10)			31-40 years (n=10)			≥41 years (n=10)		
	Pre-blood donation	After-blood donation	p value*	Pre-blood donation	After-blood donation	p value**	Pre-blood donation	After-blood donation	p value*
Native thiol (μmol/L)	534.6±64.3	493.3±31.8	0.031	482,5±74.5	456.1±93.8	0.551	463.4±48.7	492.2±63.7	0.171
Total thiol (μmol/L)	576.1±75	534.7±31.2	0.032	553.6±91.6	525.1±78.1	0.382	503.1±37.2	532.1±65.4	0.172
Disulphide (μmol/L)	20.7±5.8	20.7±8.5	0.872	21.2±6.6	19.2±5.7	0.345	19.8±6.9	19.9±7.7	0.956
Disulphide/total thiol percent ratio (SS/SH+SS)	3.8±0.6	4,2±1.8	0.447	4.4±1.3	4.4±1.8	0.706	4.4±1.9	4.1±1.6	0.612
Disulfide/native thiol percent ratio (SS/SH)	3.5±0.5	3.8±1.5	0.447	4±1.1	4±1.5	0.606	4±1.6	3.7±1.4	0.618
Native thiol/total thiol percent ratio (SH/SH+SS)	92.9±1.1	92.2±3	0.519	91.8±2.3	91.8±3	0.608	91.9±3.2	92.4±2.8	0.614
Ischemia-modified albumin	0.74±0.13	0.80±0.05	0.128	0.79±0.1	0.87±0.2	0.348	0.8±0.1	0.79±0.9	0.351

* dependent samples t-test
** wilcoxon rank-sum test

In 2017, the global blood need was over 304 million while the global blood supply was approximately 272 million, and of the 195 countries, 119 (61%) did not have sufficient blood supply to meet their need (15). Presenting the changes that occur in the body during the blood donation process can be a source of motivation for people to encourage them to donate blood. Our data showed that TDH as an indicator of oxidative stress was not affected by the blood donation process and there was also no significant difference among the individuals when they were grouped by BMI and age. However, IMA values were found significantly higher in repeat blood donors than in first-time donors.

Several methods and approaches have been used to measure oxidative stress in clinical samples: (i) direct measurement of ROS through the use of fluorogenic probes, (ii) indirect measurement of oxidative damage formed by ROS in the cell lipids, proteins, and nucleic acids, (iii) assessment of total antioxidant status (TAS) (16). A new spectrophotometric method developed by Erel and Neşelioğlu is used for assessing TAS (13). Recently, this method has been widely used to reveal the role of oxidative stress in several clinical conditions including inflammatory diseases, cancer, infectious disease, and rheumatologic disorders. In this study, using this new method, it was investigated whether 450 ± 10 ml of blood lost during blood donation causes oxidative stress.

The action of sulfur-containing compounds, which was called thiol groups, is crucial for the antioxidant system since they act as electron donors and extinguishing unstable free radicals. Disulphid compounds, which were the earliest indicator of oxidation created by ROS, are formed during this oxidation process. This transformation may also lead to a decrease in thiol levels. Thus, native thiol is considered as an antioxidant indicator while disulfide is considered as an oxidative stress indicator (17,18). In this study, thiol levels were found to be lower after blood donation than before donation. Although this decrease is not significant, it may be associated with oxidative stress generated through the blood donation process.

The relationship between blood donation and oxidative stress has been examined in a limited number of studies. Yunce et al. investigated the effect of blood donation on oxidative stress markers by measuring the activities of superoxide dismutase (SOD), myeloperoxidase (MPO), and the levels of malondialdehyde (MDA), nitric oxide (NOx). The results of this study showed that the level of oxidative markers (MPO and MDA) was reduced and the activity of the antioxidant enzyme SOD significantly increased 24 h. after blood donation (19). Mehrabani et al searched the association between blood donation frequency, antioxidant enzymes (glutathione peroxidase (GPX), SOD), and MDA level. They found a negative association between BMI, SOD activity, and the number of blood donations in a year (20). In our study, we found that THD parameters were not significantly altered after blood donation in blood donors. Our results show that blood donation does not cause oxidative stress or imbalance of thiol/disulfide homeostasis similar to previous studies.

Ischemia-modified albumin (IMA) is considered as a marker for elevated free radical-induced protein oxidative injury. This biomarker is associated with oxidative stress in various clinical conditions including ischaemic events such as stroke, acute mesenteric ischaemia, and some cancer types (21-23). In this study, IMA values were found to be significantly higher in repeat blood donors than in first-time blood donors. It is very well known that high donation frequency increases the risk of depletion of iron stores and iron-deficiency anemia. As a result of one donation, whole blood donors lose 8% (men) to 81% (menstruating women) of their total iron stores (24). Therefore various strategies have been developed to monitor the iron status of blood donors such as hemoglobin-guided donation intervals, ferritin-guided donation intervals, and iron supplementation (25). World Health Organization (WHO) also advises the monitoring of serum ferritin to detect iron deficiency (2). Although the serum ferritin levels in this study were not been investigated, the higher IMA level in repeat blood donors may be associated with the ischemia resulting from the depletion of iron stores.

Obesity may lead to high amounts of circulating glucose and lipids overflowing into adipose and non-adipose cells, resulting in adipocyte hypertrophy and adipose tissue hypoxia which might induce the production of ROS(26,27). Mehrabani et al. reported that as the BMI of the donors increased, the activity of SOD is decreased which is one of the antioxidant enzymes (20). In our study, although the decrease in thiol levels shows an inadequate antioxidant response, this difference was not statistically significant compared to pre-donation in obese donors. We classified the donors into three age groups. The native and total thiol levels as antioxidant indicators were found to be significantly lower after blood donation only in the 18-30 years old age group. To the best of our knowledge, this is the first study that investigates the oxidative stress of donors through the dynamic thiol/disulfide homeostasis by a new spectrophotometric method. The relationship between blood donation and oxidative stress will be better demonstrated by the studies which investigate other variables such as BMI and age in larger groups.

The blood donation process does not cause oxidative stress according to the results of our study.

However, regular blood donation may have a negative impact on THD. Further studies designed with the participation of high number of blood donors need to be conducted to prove an association between blood donation and oxidative stress. In conclusion, demonstrating that blood donation has no adverse effects on human health is extremely valuable in terms of encouraging people to donate blood.

ETHICS COMMITTEE APPROVAL

* The study was approved by the University of Health Sciences Ankara City Hospital Ethics Committee (Date: 02.03.2022 and Number: 2022-E2-22-1243).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Global status report on blood safety and availability 2021. Geneva: World Health Organization; 2022.
2. Blood Donor Selection: Guidelines on Assessing Donor Suitability for Blood Donation. Geneva: World Health Organization;2012.
3. Pizzino G, Irrera N, Cucinotta M, Pallio G, Mannino F, Arcoraci V, et al. Oxidative Stress: Harms and Benefits for Human Health. Oxid Med Cell Longev, 2017;8416763.
4. He L, He T, Farrar S, Ji L, Liu T, Ma X. Antioxidants Maintain Cellular Redox Homeostasis by Elimination of Reactive Oxygen Species. Cell Physiol Biochem, 2017;44(2):532-53.

5. Kükürt A, Gelen V, Başer ÖF, Deveci HA, Karapehlivan M. Thiols: Role in Oxidative Stress-Related Disorders. In (Ed.), Accenting Lipid Peroxidation. IntechOpen; 2021.

6. Hamamcioglu AC, Severcan C, Bayraktaroglu, T. Relationship of thiol/disulphide homeostasis with oxidative stress parameters in non-diabetic, prediabetic and type 2 diabetic Turkish women. Ist J Pharm, 2022;52(2):121-8.

7. Yuksel M, Ates I, Kaplan M, Alısık M, Erel M, Saygılı F, et al. The dynamic thiol/disulphide homeostasis in inflammatory bowel disease and its relation with disease activity and pathogenesis. Int J Colorect Dis, 2016;31(6):1229-31.

8. Ates I, Ozkayar N, Inan B, Yılmaz FM, Topcuoglu C, Neselioglu S, et al. Dynamic thiol/disulphide homeostasis in patients with newly diagnosed primary hypertension. J Am Soc Hyper JASH, 2016;10(2):159-66.

9. Sandikci SC, Colak S, Omma A, Enecek ME, Ozbalkan Z, Neselioglu S, et al. An investigation of thiol/disulfide homeostasis in patients with Behçet's disease. Arch Med Sci, 2020;16(6):1353-9.

10. Gumusyayla S, Vural G, Bektas H, Neselioglu S, Deniz O, Erel O. A novel oxidative stress marker in migraine patients: dynamic thiol-disulphide homeostasis. Neurological sciences: J Neurol Sci, 2016;37(8):1311-7.

11. Doğru A, Balkarlı A, Yıldırım Çetin G, Neşelioğlu S, Erel Ö, Şahin M. Evaluation of dynamic thiol/disulfide homeostasis in patients with Familial Mediterranean Fever. Süleyman Demirel Üni Sağ Bil Derg, 2018; 9(3):21-5.

12. Demirseren DD, Cicek C, Alisik M, Demirseren ME, Aktaş A, Erel, O. Dynamic thiol/disulfide homeostasis in patients with basal cell carcinoma. Cutan Ocu Toxicol, 2017;36(3):278-82.

13. Erel O, Neselioglu S. A novel and automated assay for thiol/disulphide homeostasis. Clin Biochem, 2014;47(18):326-32.

14. Bar-Or D, Lau E, Winkler JV. A novel assay for cobalt albumin binding and its potential as a marker for myocardial ischemia—a preliminary report. J Emerg Med, 2000;19(4):311-5.

15. Roberts N, James S, Delaney M, Fitzmaurice C. The global need and availability of blood products: a modelling study. Lancet Haematol, 2019;6(12):606-5.

16. Katerji M, Filippova M, Duerksen-Hughes P. Approaches and Methods to Measure Oxidative Stress in Clinical Samples: Research Applications in the Cancer Field. Oxid Med Cell Longey, 2019;12:1279250.

17. Sonmez MG, Kozanhan B, Deniz ÇD, Iyisoy MS, Kilinc MT, Ecer G et al. Dynamic thiol/disulfide homeostasis as a novel indicator of oxidative stress in patients with urolithiasis. Investig Clin Urol, 2019;60(4):258-66.

18. Georgescu SR, Mitran CI, Mitran MI, Matei C, Popa GL, Erel O, et al. Thiol-Disulfide Homeostasis in Skin Diseases. J Clin Med, 2022;11(6):1507.

19. Yunce M, Erdamar H, Bayram NA, Gok S. One more health benefit of blood donation: reduces acute-phase reactants, oxidants and increases antioxidant capacity. J Basic Clin Physiol Pharmacol, 2016;27(6):653-7.

20. Mehrabani M, Djalali M, Sadeghi M, Hajibeigi B, Zeraati H, Fatehi F, et al. Association between blood donation frequency, antioxidant enzymes and lipid peroxidation. Acta Med Iran, 2008;46(5):361-6.

21. Sinha MK, Roy D, Gaze DC, Collinson PO, Kaski JC. Role of "Ischemia modified albumin", a new biochemical marker of myocardial ischaemia, in the early diagnosis of acute coronary syndromes. Emerg Med J, 2004;21:29-34.

22. Abboud H, Labreuche J, Meseguer E, Lavallee PC, Simon O, Olivot JM, et al. Ischemia-modified albumin in acute stroke. Cerebrovasc Dis, 2007; 23:216-20.

23. Gunduz A, Turedi S, Mentese A, Karahan SC, Hos G, Tatli O, et al. Ischemia-modified albumin in the diagnosis of acute mesenteric ischemia: a preliminary study. Am J Emerg Med, 2008; 26:202-5.

24. Sweegers MG, Zalpuri S, Quee FA, Huis In 't Veld EMJ, Prinsze FJ, Hoogendijk EO, et al. Ferritin measurement IN Donors—Effectiveness of iron Monitoring to diminish iron deficiency and low hemoglobin in whole blood donors (FIND'EM): study protocol for a stepped wedge cluster randomized trial. Trials, 2020;21:823.

25. Vinkenoog M, van den Hurk K, van Kraaij M, van Leeuwen M, Janssen MP. First results of a ferritin-based blood donor deferral policy in the Netherlands. Transfusion, 2020;60(8):1785-92.

26. McMurray F, Patten DA, Harper ME. Reactive Oxygen Species and Oxidative Stress in Obesity-Recent Findings and Empirical Approaches. Obesity (Silver Spring), 2016;24(11):2301-10.

27. Nono Nankam PA, Nguelefack TB, Goedecke JH, Blüher M. Contribution of Adipose Tissue Oxidative Stress to Obesity-Associated Diabetes Risk and Ethnic Differences: Focus on Women of African Ancestry. Antioxidants (Basel), 2021;10(4):622.