ISSN: 2536-7153 SJMLS

Sokoto Journal of Medical Laboratory Science 2023; 8(3): 36 - 45

SJMLS - 8(3) - 004

Assessment of Oxidative Stress and Protein Modification in Essential Hypertensive Subjects

Odewusi O.O., Adigun H.T., Omon E.A.*, Obadire S.O., Egbebi H.A.
Department of Medical Laboratory Science, College of Medicine and Health Sciences, Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria.
*Author for Correspondence**:* omonea@pg.abuad.edu.ng/ ORCiD: 0000-0001-9949-3682/https://dx.doi.org/10.4314/sokjmls.v8i3.5

Abstract
Hypertension has been identified to be the leading cause of cardiovascular disease and premature death worldwide due to its numerous comorbidities and associated risk of damage to vital body organs like the brain, heart and kidneys. The aim of this study was to determine the level of protein modifications and oxidative stress of hypertensive patients. One hundred and fourteen (114) participants were recruited for this study comprising 81 subjects with essential hypertension and 33 control (non-hypertensive) subjects. Body Mass Index (BMI) was calculated, systolic and diastolic blood pressure (SBP and DBP) readings were taken using digital sphygmomanometer, glutathione peroxidase (GPx) and carbonyl (CO) group was estimated using ELISA, while protein sulfhydryl (SH) group was estimated using colorimetric assay. The results obtained showed that BMI of treated hypertensive patients was significantly decreased ($p<0.0001$) compared with control. Systolic and diastolic blood pressure was significantly increased when treated patients were compared with control ($p<0.0001$). GPx and SH groups of treated hypertensive patients were significantly decreased ($p<0.0001$) when compared with control subjects, whereas CO group was significantly increased ($p<0.0001$) in treated hypertensive patients as compared to control. The study concludes that protein modification occurs as a result of oxidative stress resulting in reduced levels of glutathione peroxidase which could be a risk factor associated with the development of essential hypertension. These findings could help in designing quality diagnostic strategies and more effective treatment and management approach for better clinical outcomes.

Keywords: Protein modification, Antioxidant, Glutathione peroxidase, Essential hypertension

Introduction

Hypertension is defined as a systolic blood pressure (SBP) of $\geq$ 140 mmHg and/or a diastolic pressure (DBP) of $\geq$ 90 mmHg following repeated examination (Unger *et al.,* 2020). Hypertension has been identified to be the leading cause of cardiovascular disease and premature death worldwide due to its numerous comorbidities and associated risk of damage to vital body organs like the brain, heart and kidneys (Ayogu *et al.,* 2021). Review analysis of the prevalence of hypertension among Nigerian adults showed an estimated prevalence of 28.9% with a range of 6.2–48.9% for men and 10.0–47.3% for women as well as 30.6 and 26.4% among urban and rural dwellers respectively (Ayogu *et al.,* 2021). Hypertension can be classified into two: primary or essential hypertension and secondary hypertension. Primary or essential hypertension accounts for about 90-95% of all cases of hypertension and is usually defined as elevated blood pressure due to nonspecific lifestyle and genetic factors (Mills *et al.,* 2020). The remaining 5-10% of cases is categorized as secondary hypertension defined as elevated blood pressure due to an identifiable cause, such as chronic kidney disease, narrowing of the kidney arteries, an endocrine disorder, or the use of birth control pills (Poulter *et al.,* 2015).

Proteins are macromolecules that play numerous essential roles in the body. They play a role in structural support of the body, regulatory function, enzymatic catalysis, storage, transport and cell

signaling (Vona *et al*., 2021). Protein modification refers to any chemical or structural alteration that occurs in a protein after it has been synthesized. Protein modifications are essential for a variety of biological functions, including immune response, gene expression and cell communication; meanwhile multiple disorders can result from protein modification dysregulation (Zhong *et al*., 2023). Protein sulfhydryl groups (SH), sometimes referred to as thiol groups, are structural elements on proteins that contain both sulfur and a hydrogen atom (-SH). These groups have a significant role in the structure, regulation and function of proteins and are essential for numerous cellular functions (Garrido *et al*., 2022). Sulfhydryl groups may bond together to form disulfide bonds, which are covalent connections made up of two sulfur atoms (-S-S-). These disulfide bonds are crucial for the stability of many proteins, including enzymes and antibodies, by stabilizing protein structure and maintaining protein shape (Wu *et al*., 2021). The protein carbonyl group is a functional group made up of a carbon atom double-bonded to an oxygen atom (C=O). When a protein undergoes carbonylation, a certain type of amino acid residue, such as lysine, arginine, proline, or threonine, has this group added to its side chain (Gonos *et al.,* 2018). The development of a carbonyl group on amino acid residues occurs as a result of oxidative stress to proteins, which causes the proteins to be modified, a process known as protein carbonylation (Akagawa, 2020).

Oxidative stress is one of several complex factors that have a role in the development of hypertension. Oxidative stress has been linked to the etiology of hypertension and has the potential to modify a number of biomolecules, including proteins, lipids and nucleic acids (García-Sánchez *et al.,* 2020). With the potential importance of the role of oxidative stress in the pathophysiology of hypertension, antioxidants, reactive oxygen species (ROS) scavengers and nitric oxide inhibitors may reduce ROS bioavailability, which may have protective and blood pressure-lowering effects (Griendling *et al.,* 2021). Furthermore, protein structure and function may change as a result of the production of protein carbonyls and the susceptibility of the protein to degradation may also rise. This can have a range of harmful impacts on cellular function and can hasten the onset of several illnesses, including hypertension, cardiovascular disease and neurodegenerative diseases (Kehm *et al.,* 2021). Hence, this study was carried out to determine the oxidative stress and protein modifications of hypertensive patients.

Methods

Study design

A case-control design using stratified sampling method was employed in this study.

Study area

The study was carried out in Ado-Ekiti and its immediate environs. Ado-Ekiti is the capital city of Ekiti State in Southwest Nigeria. It is situated in the northern part of the state where the routes from Oyo, Osun and Kwara State respectively converge. The state is mainly an upland zone, rising over 250 meters above sea level. Its coordinates are 7^0 40'N 5^0 15'E.

Sample size

The minimum sample size (N) was calculated using the formula: $N= Z^2p(1-p)/w^2$

Where Z = confidence level at 95, N=Minimum sample size, w = allowance for error=0.05, P= estimated prevalence of diabetes patients at 8.9% (Adeloye *et al*., 2021).

$q = 1, p = 1 - 0.081 = 0.919$

$$N = \frac{1.96^2 \times 0.081 \times 0.919}{0.05^2} = 114$$

A total of 114 samples comprising eighty-one (81) subjects which were treated and newly diagnosed hypertensive subjects. The remaining thirty-three (33) were apparently healthy individuals which served as controls.

Inclusion criteria

Men and women within the age range 30-80 years who have been diagnosed with essential hypertension whether on therapy or not partook who gave their consent were included in the study. Inclusion was based on the cut-off of at least 140mmHg systolic or 90mmHg diastolic blood pressure.

Exclusion criteria

Patients having underlying health conditions such as cardiovascular diseases or metabolic disorders and those who did not give their consent were excluded from this study.

Ethical clearance
Ethical approval was sought from the Ethics and Health Research Committee of Afe Babalola University, Ado-Ekiti, Ekiti State. Informed consent was obtained from each subject who participated in the study before sample collection.

Sample collection
Venous blood sample of about 5mls was collected under from the cubital fossa using 22G needle and syringe from each participant. The sample was dispensed into plain non-anticoagulated sample bottle and was allowed to clot first before centrifuging at 5000rpm for 5minutes to separate the serum from cells and dispensed into another plain non-anticoagulated sample bottle. The serum samples were stored at temperature of -20^{O}C for a maximun of 21 days before assay for glutathione peroxidase, protein carbonyl and sulfhydryl group.

Sample Analysis
Blood pressure: Blood pressure was measured using digital sphygmomanometer and readings for systolic and diastolic blood pressure were taken and recorded in mmHg.

Principle: The oscillations of pressure in a sphygmomanometer cuff are recorded during gradual deflation; the point of maximal oscillation corresponds to the mean intra-arterial pressure. The oscillations begin at approximately systolic pressure and continue below diastolic, so that systolic and diastolic pressure can only be estimated indirectly according to some empirically derived algorithm.

Height and Weight: Height and weight was obtained using a meter gauge and a bathroom scale respectively.

Body Mass Index (BMI): BMI was derived from the height and weight using the formula:
$$BMI = \frac{Weight\ (kg)}{Height^2\ (m^2)}$$
It is expressed in kg/m^2 (Lee *et al.,* 2018).

Glutathione peroxidase (GPX): GPx was estimated using enzyme-linked immunosorbent assay and procedure was done according to manufacturer's instruction.

Principle: The micro ELISA plate in this kit was pre-coated with an antibody specific to Human GPX1. Samples are added to the micro ELISA plate wells and combined with the specific antibody. A biotinylated detection antibody specific for Human GPX1 and Avidin-Horseradish Peroxidase (HRP) conjugate are added successively to each micro plate well and incubated. Free components are washed away. The substrate solution is added to each well. Only those wells that contain Human GPX1, biotinylated detection antibody and Avidin-HRP conjugate will appear blue in color. The enzyme-substrate reaction is terminated by the addition of stop solution and the color turns yellow. The optical density (OD) is measured spectrophotometrically at a wavelength of 450 nm ± 2 nm. The OD value is proportional to the concentration of Human GPX1. The concentration of Human GPX1 in the samples was calculated by comparing the OD of the samples to the standard curve.

Protein carbonyl group: Protein carbonyl group was estimated using enzyme linked immune-absorbent assay kit and procedure was done according to manufacturer's instruction.

Principle: This kit is an Enzyme-Linked Immunosorbent Assay (ELISA). The plate was pre-coated with Human PC antibody. PC present in the sample is added and binds to antibodies coated on the wells. And then biotinylated Human PC Antibody is added and binds to PC in the sample. Then Streptavidin-HRP is added and binds to the Biotinylated PC antibody. After incubation unbound Streptavidin-HRP is washed away during a washing step. Substrate solution is then added and color develops in proportion to the amount of Human PC. The reaction is terminated by addition of acidic stop solution and absorbance is measured at 450 nm.

Protein sulfhydryl group: Protein sulfhydryl group was estimated using colorimetric assay kit and procedure was done according to manufacturer's instruction.

Principle: Sulfhydryl compounds react with 5, 5'–dithio-bis (2- nitrobenzoic acid) under neutral or alkali conditions to produce a yellow product which has maximum absorption peak at 412nm. And optical density (OD) value is measured.

Statistical analysis

Results obtained presented in tables and charts were statistically analyzed using IBM SPSS version 24.0. Values of all parameters were expressed as mean ± SD. Comparison of parameters between group was done using Student t-test and Pearson correlation and significant difference was pegged at $p<0.05$.

Results

Table 1 showed the SBP, DBP, BMI, GPX, CO and SH groups in treated and treatment naive hypertensive patients compared with control. Result obtained showed that BMI of treated hypertensive patients was significantly decreased ($p<0.0001$) when compared with control. Systolic blood pressure was significantly increased when treated patients were compared with control ($p<0.0001$) as well as diastolic blood pressure which was also significantly increased when compared with control ($p<0.0001$). GPX and SH groups of treated hypertensive patients ($p<0.0001$), ($p<0.0001$) respectively were significantly decreased when compared with control subjects, whereas CO group was significantly increased ($p<0.0001$) in treated hypertensive patients as compared to control. In treatment naive hypertensive patients, result showed BMI (Kg/m^2) was significantly decreased ($p=0.0015$) when compared with control. Systolic blood pressure and diastolic blood pressure ($p<0.0001$), ($p<0.0001$) respectively were significantly increased when treatment naive hypertensive patients were compared with control. Furthermore, GPX and SH groups of treatment naive hypertensive patients ($p<0.0001$), ($p<0.0001$) respectively were significantly decreased when compared with the control subjects, whereas CO group was significantly increased ($p<0.0001$).

Table 2 showed the mean ± SD, p-values in treatment naive hypertensive patients compared to treated hypertensive patients for all parameters (SBP, DBP, BMI, GPX, CO and SH groups). Result obtained showed that BMI (Kg/m^2) was insignificantly decreased ($p=0.0949$) when treatment naive hypertensive patients were compared with treated hypertensive patients, while SBP and DBP were significantly decreased ($p<0.0001$), ($p<0.0001$) respectively when treatment naive hypertensive patients were compared with treated hypertensive patients. GPX of treatment naive hypertensive patients was insignificantly decreased (0.0557) when compared with treated hypertensive patients and also SH group of treatment naive hypertensive patients ($p<0.0001$) was significantly decreased when compared with the treated hypertensive patients, whereas CO group in treatment naive hypertensive patients was significantly increased as compared to untreated.

Figures 1, 2 and 3 showed that CO group and blood pressure seem to exhibit a pattern of increase with advancement in age while the reverse is the case when SH group and GPx are critically assessed.

Table 1: Mean ± SD in treated and treatment naive hypertensive patients compared with control for all parameters (SBP, DBP, BMI, GPX, CO and SH groups)

Groups (N)	Treated Mean ± SD (N=42)	Treatment Naïve Mean ± SD (N=39)	Control Mean ± SD (N=33)
BMI (kg/m^2)	23.65 ± 2.05***	24.45 ± 2.21**	25.75 ± 0.46
SBP (mmHg)	136.76 ± 4.75***	152.8 ± 5.06***	109.53 ± 5.06
DBP (mmHg)	89.24 ± 3.46***	95.65 ± 5.75***	73.18 ± 7.56
GPX (U/L)	90.79 ± 14.26***	86.09 ± 5.18***	133.8 ± 22.03
CO group (mmol/L)	77.93 ± 2.17***	85.67 ± 3.36***	65.8 ± 6.05
SH group (µmol/L)	431.61± 2.38***	383.6 ± 2.53***	455.23 ± 2.53

***Values are significantly different from control group**

Keys: **n**= number of subjects, **BMI**: Body Mass Index, **DBP**: Diastolic Blood Pressure, **SBP**: Systolic Blood Pressure, **GPX: Glutathione Peroxidase, CO group: Carbonyl Group, SH group: Sulfhydryl Group**

Table 2: Mean ± SD, p-values in treated hypertensive patients compared to treatment naive hypertensive patients for all parameters (SBP, DBP, BMI, GPX, CO and SH groups)

Parameters	Treated Mean ± SD (N=42)	Treatment Naive Mean ± SD (N=39)	P – Value
BMI (kg/m^2)	23.65 ± 2.05	24.45 ± 2.21	0.0949
SBP (mmHg)	136.76 ± 4.75	152.8 ± 5.06	<0.0001***
DBP (mmHg)	89.24 ± 3.46	95.65 ± 5.75	< 0.0001***
GPX (U/L)	90.79 ± 14.26	86.09 ± 5.18	0.0557
CO group (mmol/L)	77.93 ± 2.17	85.67 ± 3.36	<0.0001***
SH group (µmol/L)	431.61± 2.38	383.6 ± 2.53	<0.0001***

Keys: **n**= number of subjects, **BMI**: Body Mass Index, **DBP**: Diastolic Blood Pressure, **SBP**: Systolic Blood Pressure, **GPX: Glutathione Peroxidase, CO group: Carbonyl Group, SH group: Sulfhydryl Group**

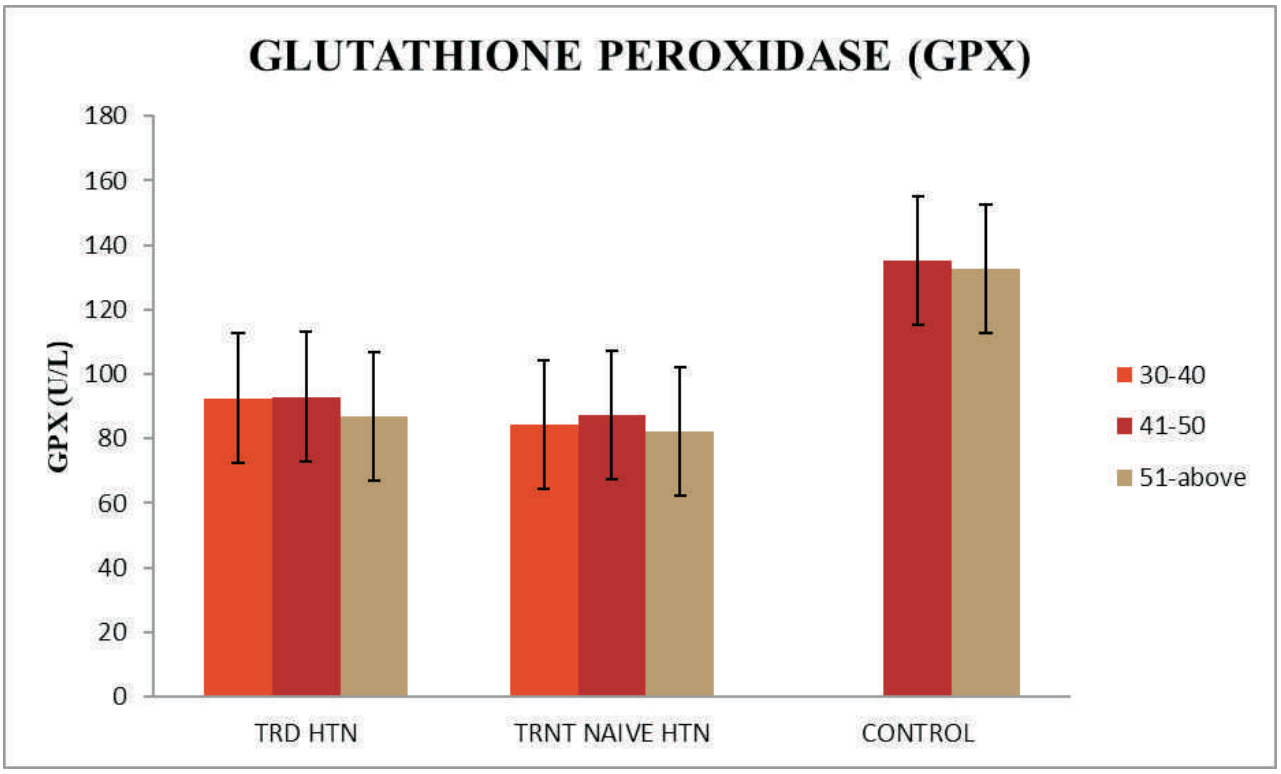

Figure 1. A chart comparing GPX between treated and treatment naive hypertensive patients in different age groups.

Keys:**TRDHTN**: Treated **hypertensive patients; TRNTNAIVEHTN**: **Treatment naive hypertensive patients; GPX**: Glutathione Peroxidase

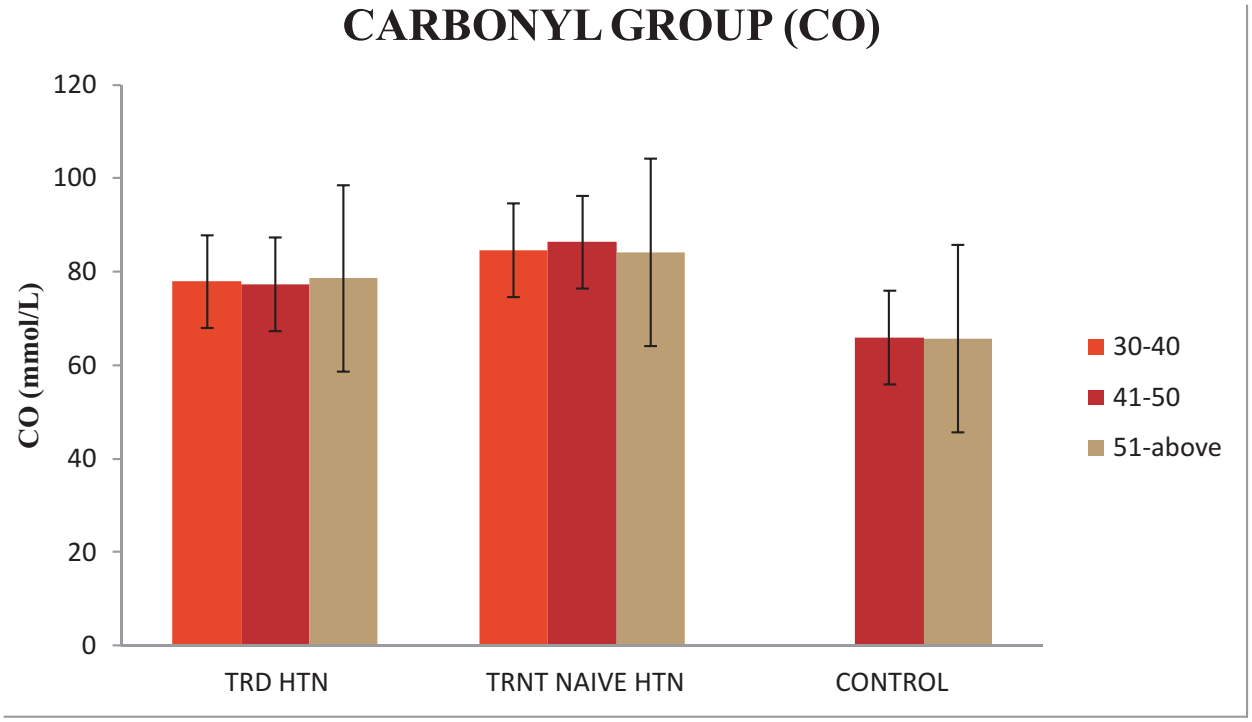

Figure 2. A chart comparing CO group between treated and treatment naïve hypertensive patients in different age groups.

Keys: **TRDHTN**: Treated **hypertensive patients; TRNTNAIVEHTN**: **Treatment naïve hypertensive patients; CO**: Carbonyl Group

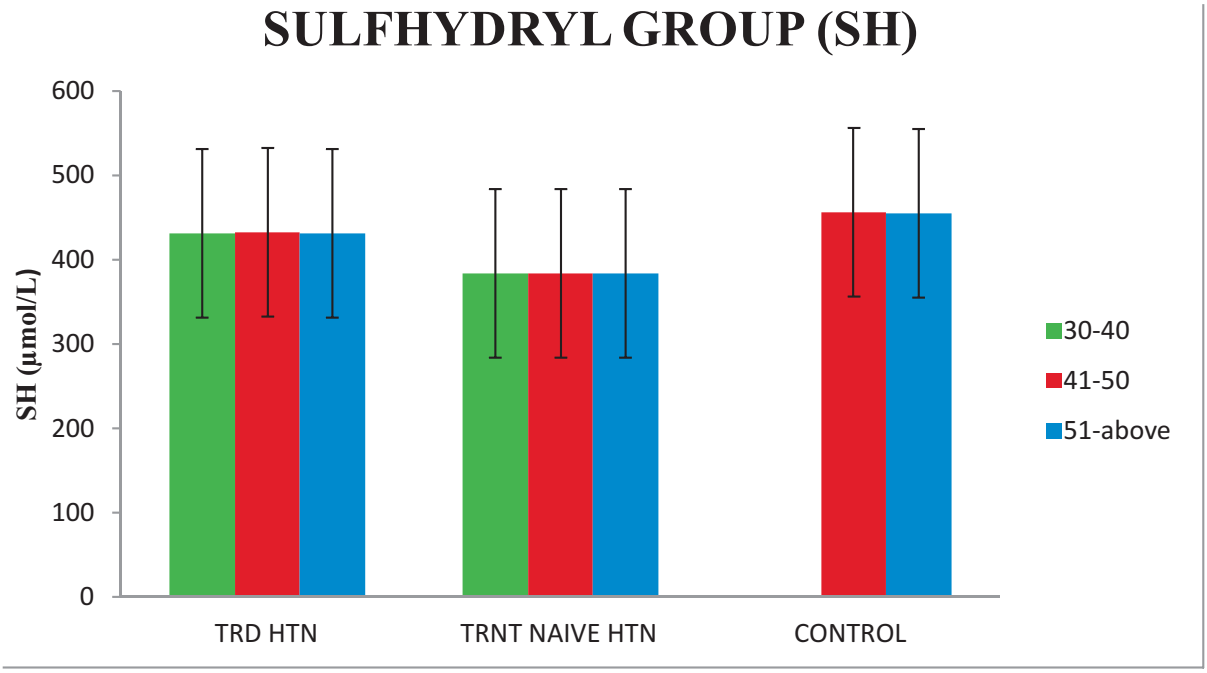

Figure 3. A chart comparing SH group between treated and treatment naïve hypertensive patients in different age groups.

Keys: **TRDHTN**: Treated hypertensive patients; **TRNTNAIVEHTN**: **Treatment naïve hypertensive patients; SH**: Sulfhydryl Group

Discussion

In the quest to get better clinical outcomes for patients with metabolic diseases, it is now a routine for researchers to look for relationship between such conditions and some non-classical parameters, maybe such parameters could end up being confounding factors or prognostic markers. Consequently, this research aims to see if there is any relationship between protein modification and essential hypertension. The result of this study showed that BMI was insignificantly lowered in treatment naïve hypertensive patients when compared with treated hypertensive subjects and significantly decreased in control subjects. Also, BMI was significantly decreased in treated hypertensive patients when compared to control subjects. Decrease in BMI in treatment naïve hypertensive patients compared to control subjects may be due to increased sympathetic nervous system activity, which may result in a greater rate of metabolism and energy expenditure (Valensi, 2021). In hypertensive individuals, this increased metabolic rate may help with weight loss and a drop in BMI (Fantin *et al.*, 2019). However, decrease in BMI in treated hypertensive patients compared to control subjects could be due to lifestyle modifications which include changes in diet and increased physical activity. These lifestyle changes often result in weight loss and decreased BMI (Sukkarieh *et al.,* 2020). This could also be due to some antihypertensive medications. These medications can enhance urine production or reduce fluid retention, resulting in a drop in body weight and BMI. These findings is consistent with the previous studies (Landi *et al.,* 2018; Sukkarieh *et al.,* 2020; Vrettos *et al.,* 2020; Odewusi *et al.,* 2023) who reported that BMI was significantly higher in treatment naïve and treated hypertensive patients relative to control subjects.

In this study, Systolic blood pressure and Diastolic blood pressure was found to be significantly increased in treatment naïve hypertensive patients and also significantly increased in treated hypertensive patients when compared with control. This study also found that Systolic blood pressure and Diastolic blood pressure was significantly increased in treatment naïve hypertensive patients when compared with treated hypertensive patients. These findings agree with previous studies (Odewusi and Osadolor, 2019; Jung, 2022) in which SBP was significantly higher in treated and treatment naïve hypertensive patients as compared to controls which may be partly caused by increased cardiac output, reduced large arteries compliance and the rise in peripheral resistance. This was corroborated by Azeez *et al*. (2019) who reported that anti-hypertensive drug therapy achieves better control of diastolic blood pressure (DBP) than systolic blood pressure (Azeez *et al.,* 2019). Treatment of hypertension with medications would depend on the patients' level of blood pressure, comorbidities like diabetes and end organ involvements. So the treatment has to be individualized depending on the patients (Jung, 2022).

In this study, glutathione peroxidase (GPx) was significantly decreased in treated and treatment naïve hypertensive patients when compared with control ($p<0.05$). This study also found that GPx was insignificantly decreased in treatment naïve hypertensive patients when compared with treated hypertensive patients. This decrease may be due to oxidative stress occasioned by its inactivation as the result of a continuous exposure to hydrogen peroxide and other free radicals and endothelial dysfunction. GPx is also inactivated by a variety of physiological substances including nitric oxide and carbonyl compounds in vitro and in cell culture. Some studies have also shown that this reduction could be due to the down regulation of their gene expression (Ahmad *et al.,* 2013). This finding agrees with the work of Ahmad *et al.* (2013) though the research was only done comparing hypertensive subjects and control subjects, there was a significantly lower level of GPx activity in hypertensive subjects compared to those in control subjects and also significantly lower in hypertensive subjects compared to those in treated hypertensive subjects. The clinical importance of GPx has been underlined by a number of studies. It has been postulated that individuals with lower GPx activity are predisposed to impaired antioxidant protection, which leads to oxidative damage to membrane fatty acid s and functional proteins and by inference, neurotoxic damage (Vona *et al.,* 2021).

From the finding of this study, values of protein carbonyl (CO) group were estimated, and CO group was significantly increased in treated and

treatment naïve hypertensive patients when compared with control ($p<0.05$). This study also found that CO group was significantly increased in treatment naïve hypertensive patients when compared with treated hypertensive patients. This increase may be caused by endothelial dysfunction, characterized by impaired nitric oxide (NO) bioavailability and increased production of ROS (Cyr *et al.,* 2020). Protein structure and function may change as a result of protein carbonyl production and the protein's susceptibility for degradation might increase which as well can adversely affect cellular function in a variety of ways (Kehm *et al.,* 2021). This finding agrees with previous researchers (Rybka *et al.,* 2011; Kumar*et al.,* 2016; Adarsh *et al.,* 2023) where serum protein carbonyl was increased in hypertensive patients when compared to control subjects. Protein carbonylation is one of irreversible oxidative protein modifications and is considered as an early marker of protein oxidative stress-related disorders. Because carbonylated proteins cannot be repaired by cellular enzymes, modified proteins must be degraded by the cell's proteasome system (Song *et al.*, 2020).

Our study showed that the values of Sulfhydryl (SH) group was significantly decreased in treated and treatment naïve hypertensive patients when compared with control ($p<0.05$). This study also found that SH group was significantly decreased in treatment naïve hypertensive patients when compared with treated hypertensive patients ($p<0.05$). Oxidative stress is known to be involved in the development and progression of hypertension, but accurate redox biomarkers predicting the risk of developing hypertension are scarce. The sulphydryl group of amino acids hence protein are very important radical group that helps in their regulatory functions. Serum free sulfhydryl groups have also been shown to accurately reflect systemic oxidative stress in various conditions (Bourgonje *et al.,* 2022). Higher levels of serum free thiols indicate less oxidative stress and are associated with a decreased likelihood of developing hypertension in subjects (Arno *et al.,* 2022). These findings are in accordance with Yavuzer *et al.* (2016) and Arno *et al.* (2022) which reported that serum protein sulfhydryl is seen in decreased concentrations in hypertensive subjects relative to control subjects and this may be due oxidative stress and reduction in endogenous antioxidants. Another reason for the decreased sulphydryl groups in hypertensive patients is that such individuals accumulate heavy metals in their system, replacing the trace metal cofactor (Balali-Mood *et al.,* 2021). Heavy metals, as a result of their configuration have an affinity for sulphydryl groups (Ajsuvakova *et al.,* 2020), when this happens, the protein that have modified will not be able to perform its physiological function. These may explain, at least in part, vital organ damage and some other clinical manifestations of or progression of essential hypertension. Higher levels of free sulfhydryl are often suggestive of a very favorable prognosis. When lowered, it is indicative of systemic oxidative stress, which causes hypertension or progression of hypertension (Bourgonje *et al.,* 2022).

Conclusion

The study concludes that protein modification occurs as a result of oxidative stress resulting in reduced levels of glutathione peroxidase which could be a risk factor associated with the development of essential hypertension. These findings could help in designing quality diagnostic strategies and more effective treatment and management approach for better clinical outcomes.

Conflict of Interest. None declared.

References

Adarsh, R., Krushna, C., Maharana, S.M. and Sanjiv, S. (2023). Endothelial dysfunction and its relation in different disorders: *Recent Update. Health Sciences Review;* **7 (2)**: 2772-6320.

Adeloye, D., Owolabi, E.O., Ojji, D.B., Auta, A., Dewan, M.T., Olanrewaju, T.O., Ogah, O.S., Omoyele, C., Ezeigwe, N., Mpazanje, R.G., Gadanya, M.A., Agogo, E., Alemu, W., Adebiyi, A.O. and Harhay, M.O. (2021). Prevalence, awareness, treatment, and control of hypertension in Nigeria in 1995 and 2020: A systematic analysis of current evidence. *The Journal of Clinical Hypertension;* ***23*****(5)**: 125-129.

Ahmad, A., Singhal, U., Mobark, M.H., Islam, N. and Rizvi, I. (2013). Essential

hypertension, Oxidative Stress, Catalase, Glutathione peroxidase, Superoxide Dismutase Antihypertensive therapy. *Journal of Clinical Sciences; 7***(6)**: 987–990.

Ajsuvakova, O.P., Tinkov, A.A., Aschner, M., Rocha, J.B.T., Michalke, B., Skalnaya, M.G., Skalny, A.V., Butnariu, M., Dadar, M., Sarac, I., Aaseth, J. and Bjørklund, G. (2020). Sulfhydryl groups as targets of mercury toxicity. *Coordination Chemistry Reviews;* **41(7)**: 213343.

Akagawa, M. (2020). Protein carbonylation: molecular mechanisms, biological implications, and analytical approaches. *Free Radical Research; **55*(4)**: 1–37.

Arno, R.B., Martin, F.B., Adrian, P., Sacha, B.G., Lyanne, M.K., Marian, L.C., Sanne, J.G., Ron,

T.G., Stephan, J.L., Douwe, J.M., Andreas, P., Harry, G. and Amaal, E.A. (2022). Systemic oxidative stress is associated with new-onset hypertension in the general population. *Free Radical Biology and Medicine;* **18 (7)**: 123-131.

Ayogu, R.N., Ezeh, M.G. and Okafor, A.M. (2021). Prevalence and predictors of different

patterns of hypertension among adults aged 20–60 years in rural communities of Southeast Nigeria: a cross-sectional study. *Archives of Public Health; 7**9*(1)**: 9–5.

Azeez, I.A., Dairo, M.D. and Akinyemi, J.O. (2019). Treatment response in adult patients with hypertension attending a secondary health care center in South-west Nigeria. *Annals of Iberoboam Postgraduate Medicine;* **17(2)**:138-144.

Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M.R. and Sadeghi, M. (2021). Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic. *Frontiers of Pharmacology;* **12 (1)**: 1-19.

Bourgonje, A.R., Bourgonje, M.F., Post, A., Bastide, G.S., Kieneker, L.M., Bulthuis, M.L., Gordijn, S.J., Gansevoort, R.T, Bakker, S.J.L., Mulder, D.J., Pasch, A., Goor, H. and Abdulle, A.E. (2022). Systemic oxidative stress is associated with new-onset hypertension in the general population. *Free Radical Biology and Medicine; **18 (7)**:* 123–131.

Carmo de Carvalho, M., Silva, A.S., Santos, L., Primo, M.G., Carvalho, V.B. (2022). Biological Indicators of Oxidative Stress [Malondialdehyde, Catalase, Glutathione Peroxidase, and Superoxide Dismutase] and Their Application in Nutrition. *Biomarkers in Disease: Methods, Discoveries and Applications; **5*(11)**: 833–856.

Cyr, A.R., Huckaby, L.V., Shiva, S.S. and Zuckerbraun, B.S. (2020). Nitric Oxide and Endothelial Dysfunction. *Critical Care Clinic;* **36(2)**: 307-321.

Fantin, F., Giani, A., Zoico, E., Rossi, A.P., Mazzali, G. and Zamboni, M. (2019). Weight Loss and Hypertension in Obese Subjects. *Nutrients;* **11(7)**:1667.

García-Sánchez, A., Miranda-Díaz, A.G. and Cardona-Muñoz, E.G. (2020). The Role of Oxidative Stress in Physiopathology and Pharmacological Treatment with Pro- and Antioxidant Properties in Chronic Diseases. *Oxidative Medicine and Cellular Longevity;* **16**: 20-24.

Garrido, R.D., Sandoval-Perez, A., Rangarajan, A.V., Gunderson, E.L. and Jacobson, M.P. (2022). Cysteine Oxidation in Proteins: Structure, Biophysics, and Simulation. *Biochemistry; **61*(20)**: 2165–2176.

Griendling, K.K., Camargo, L.L., Rios, F.J., Alves-Lopes, R., Montezano, A.C. and Touyz, R.M. (2021). Oxidative Stress and Hypertension. *Circulation Research; **128*(7)**: 993–1020.

Ighodaro, O.M. and Akinloye, O.A. (2018). First line defence antioxidants-superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX): Their fundamental role in the entire antioxidant defence grid. *Alexandria Journal of Medicine; **54*(4)**: 287–293.

Jung, J.Y. (2022). Blood pressure management in treatment-naïve hypertensive patients. *Kidney Research and Clinical Practice;* **41(1)**:1-3.

Kehm, R., Baldensperger, T., Raupbach, J. and Höhn, A. (2021). Protein oxidation - Formationmechanisms, detection and relevance as biomarkers in human diseases. *Redox Biology; **42*(101901)**: 101-109.

Kumar, N., Maurya, P.K., Kant, R. and Rizvi, S.I. (2016). (-)-Epicatechin in vitro ameliorates. erythrocyte protein carbonyl content in hypertensive patients: comparison with L-ascorbic acid. *Archives of Physiology and Biochemistry;* **122(3)**: 155-160.

Landi, F., Calvani, R., Picca, A., Tosato, M., Martone, A.M., Ortolani, E., Sisto, A., D'Angelo, E., Serafini, E., Desideri, G., Fuga,

M.T. and Marzetti, E. (2018). Body Mass Index Is Strongly Associated with Hypertension: Results from the Longevity Check-up 7+ Study. *Nutrients;* ***10*****(12)**: 1976.

Lee, D.Y., Lee, M.Y. and Sung, K.C. (2018). Prediction of Mortality with A Body Shape Index in Young Asians: Comparison with Body Mass Index and Waist Circumference. *Obesity;* ***26*****(6)**: 1096–1103.

Mills, K.T., Stefanescu, A. and He, J. (2020). The global epidemiology of hypertension. *Nature Reviews Nephrology;* ***16*****(4)**: 223–237.

Odewusi, O.O. and Osadolor, H.B. (2019). Interleukin 10 and 18 levels in Essential Hypertensive. *Journal of Applied Sciences and Environmental Management;* ***23*****(5)**: 819.

Poulter, N.R., Prabhakaran, D. and Caulfield, M. (2015). Hypertension. *The Lancet;* ***386*****(9995)**: 801–812.

Rybka, J., Kupczyk, D., Kędziora-Kornatowska, K., Pawluk, H., Czuczejko, J., Szewczyk-Golec, K., Kozakiewicz, M., Antonioli, M., Carvalho, L.A. and Kędziora, J. (2011). Age-related changes in an antioxidant defense system in elderly patients with essential hypertension compared with healthy controls. *Redox Report;* ***16*****(2)**: 71–77.

Sarıkaya, E. and Doğan, S. (2020). Glutathione Peroxidase: Review of *Glutathione System and Oxidative Stress in Health and Disease*. *Glutathione System and Oxidative Stress in Health and Disease;* **138**:*2632-2983*.

Song, Y.R., Kim, J.K. and Lee, H.S. (2020). Serum levels of protein carbonyl, a marker of oxidative stress, are associated with overhydration, sarcopenia and mortality in hemodialysis patients. *BMC Nephrology;* **21:** 281.

Sukkarieh, H.H., Bustami, R.T., Al-Khaneen, H. and Saeed, A. (2020). The impact of body mass index and number of antihypertensive medications on clinical management of hypertension in primary health care. *Saudi Journal for Health Sciences;* 9 (3): 450-455

Unger, T., Borghi, C., Charchar, F., Khan, N.A., Poulter, N.R., Prabhakaran, D., Ramirez, A., Schlaich, M., Stergiou, G.S., Tomaszewski, M., Wainford, R.D., Williams, B. and Schutte, A.E. (2020). International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension;* ***75*****(6)**: 1334–1357.

Valensi, P. (2021). Autonomic nervous system activity changes in patients with hypertension and overweight: role and therapeutic implications. *Cardiovascular Diabetology;* **20:** 170.

Vona, R., Pallotta, L., Cappelletti, M., Severi, C. and Matarrese, P. (2021). The Impact of Oxidative Stress in Human Pathology: Focus on Gastrointestinal Disorders. *Antioxidants;* ***10*****(2)**: 201.

Wu, M., Li, Z., Wei, R., Luan, Y., Hu, J., Wang, Q., Liu, R., Ge, Q. and Yu, H. (2021). Role of Disulfide Bonds and Sulfhydryl Blocked by N-Ethylmaleimide on the Properties of Different Protein-Stabilized Emulsions. *Foods*; ***10*****(12)**: 3079.

Yavuzer, S., Yavuzer, H., Cengiz, M., Erman, H., Demirdag, F., Döventaş, A., Balci, H., Erdinçler, D.S. and Uzun, H. (2016). The role of protein oxidation and DNA damage in elderly hypertension. *Aging Clinical and Experimental Research;* ***28*****(4)**: 625–632.

Zhong, Q., Xiao, X., Qiu, Y., Xu, Z., Chen, C., Chong, B., Zhao, X., Hai, S., Li, S., An, Z. and Dai, L. (2023). Protein posttranslational modifications in health and diseases: Functions, regulatory mechanisms, and therapeutic implications. *Medical Communication;* ***4*****(3)**: 364-368.

Citation: Odewusi O.O., Adigun H.T., Omon E.A., Obadire S.O., Egbebi H.A. Assessment of Oxidative Stress and Protein Modification in Essential Hypertensive Subjects. ***Sokoto Journal of Medical Laboratory Science*****; 8(3): 36 - 45**. https://dx.doi.org/10.4314/sokjmls.v8i3.5