

mRNA RELATIVE EXPRESSION CATALASE IN HYPERTENSION

by dr.Yohana

Submission date: 17-Oct-2024 01:55PM (UTC+0700)


Submission ID: 2405214327

File name: dr_yohana_full.pdf (1.48M)

Word count: 3097

Character count: 17565

BIOSCIENTIST : JURNAL ILMIAH BIOLOGI

Initials	BJIB
Abbreviation	Bioscientist j. ilm. bosbiol.
Online First	June 2013
Frequency	2 Issues per Year (June December)
DOI	Prefix 10.33394 by  Crossref
E-ISSN	2654-4571
P-ISSN	2338-5006
Editor in Chief	Ika Nurani Dewi
Associate Editor	Agus Muliadi Taufik Samsuri
Email	
Published by	Mandalika University of Education
Citation Analysis	Dimensions Google Scholar
Editorial Address	Pemuda Street No. 59A, Catur Building Floor I, Mataram City, West Nusa Tenggara Province, Indonesia.

Bioscientist : Jurnal Ilmiah Biologi, managed and published by the Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia.



EDITORIAL TEAM

EDITOR IN CHIEF

[Mrs. Ika Nurani Dewi](#), (Scopus ID: 5709220205); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

ASSOCIATE EDITOR

[Mr. Agus Muliadi](#), (Scopus ID: 57214133134); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Taufik Samsuri](#), Universitas Pendidikan Mandalika, Indonesia

EDITORIAL BOARD

[Mr. Safnowandi Safnowandi](#), (Scopus ID: 57222540999); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mrs. Baiq Muli Harisanti](#), (Scopus ID: 57216954862); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mrs. Herdiyana Fitriani](#), (Scopus ID: 56038559800); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mrs. Ida Royani](#), (Sinta ID: 6190973); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mr. Ismail Efendi](#), (Scopus ID: 57216156433); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mr. Iwan Doddy Dharmawibawa](#), (Sinta ID: 6158933); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mr. Saidil Mursali](#), (Sinta ID: 5985957); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mrs. Septiana Dwi Utami](#), (Scopus ID: 57214721950); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mrs. Sri Nopita Primawati](#), (Scopus ID: 57207833283); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

[Mrs. Sucika Armiani](#), (Sinta ID: 6168302); Department of Biology Education, Faculty of Applied Science and Engineering, Mandalika University of Education, Indonesia

VOL 12, NO 2 (2024)

DECEMBER

Accepted Paper

TABLE OF CONTENTS

ARTICLES

The Correlation Between Age, Comorbidities, and Vaccination With The Mortality Rate of Covid-19 Patients

PDF

1526-1543


 DOI : [10.33394/bioscientist.v12i2.12307](https://doi.org/10.33394/bioscientist.v12i2.12307) | Read : 227 times | Downloads: 103 times

Abdul Muin, Menap Menap

Hubungan Tingkat Pengetahuan Perawat Tentang Standar Asuhan Keperawatan dengan Kelengkapan Dokumentasi Asuhan Keperawatan di Puskesmas Korleko

PDF

1544-1554

 DOI : [10.33394/bioscientist.v12i2.12339](https://doi.org/10.33394/bioscientist.v12i2.12339) | Read : 202 times | Downloads: 82 times

Hartini Hartini, Menap Menap, Maruli Taufandas

The Relationship Knowledge and Attitudes of Patients in Preventing Hypertension Recurrence

PDF

1555-1568


 DOI : [10.33394/bioscientist.v12i2.12340](https://doi.org/10.33394/bioscientist.v12i2.12340) | Read : 118 times | Downloads: 25 times

Subari Subari, Sulaiman Sulaiman, Karjono Karjono

Analisis Faktor-Faktor yang Mempengaruhi Kepatuhan Perawat dalam Melaksanakan Standar Asuhan Keperawatan

PDF

1569-1583

 DOI : [10.33394/bioscientist.v12i2.12341](https://doi.org/10.33394/bioscientist.v12i2.12341) | Read : 195 times | Downloads: 78 times

Andi Asmadi, Menap Menap

Burung Lanskap Pedesaan di Wilayah Sukabumi Provinsi Jawa Barat

PDF

1584-1600

 DOI : [10.33394/bioscientist.v12i2.11947](https://doi.org/10.33394/bioscientist.v12i2.11947) | Read : 152 times | Downloads: 46 times

Bilal Maulana Assaf, Insan Kurnia








Estimation of Ripitability, MPPA, Livestock Ranking and The Relationship of Morning and Afternoon Milk Production in The Second and Fourth Lactation

PDF

1601-1610

 DOI : [10.33394/bioscientist.v12i2.12367](https://doi.org/10.33394/bioscientist.v12i2.12367) | Read : 92 times | Downloads: 11 times

Waliyyul Ahdi Alhikami, Mudawamah Mudawamah, Inggit Kentjonowaty

<p>Distribusi Jenis Asing Invasif <i>Melothria pendula</i> L. (Cucurbitaceae) di Kawasan Konservasi Ilmiah Kebun Raya Bogor</p> <p> DOI : 10.33394/bioscientist.v12i2.12369 Read : 240 times Downloads: 87 times</p> <p><i>Cristina Mega Meyfiani Kekung, Iln Pertiwi A Husaini, Turhadi Turhadi</i></p>	<p>PDF 1611-1621</p>
<p>Evaluasi Kandungan Fitokimia, Kapasitas Antioksidan, dan Toksisitas Ekstrak Daun <i>Stevia rebaudiana</i></p> <p> DOI : 10.33394/bioscientist.v12i2.12151 Read : 225 times Downloads: 119 times</p> <p><i>Desvin Frankson, Siulul Hendrawan, Frans Ferdinal</i></p>	<p>PDF 1622-1635</p>
<p>Optimization of Hospital Health Services: Insights from Recent Literature</p> <p> DOI : 10.33394/bioscientist.v12i2.12467 Read : 71 times Downloads: 5 times</p> <p><i>I Ketut Parindra, Menap Menap, Lalu Abdul Khalik</i></p>	<p>PDF 1636-1655</p>
<p>Keanekaragaman Spesies Burung Pada Beberapa Tipe Habitat di Kawasan Pesisir Gerupuk Lombok Tengah</p> <p> DOI : 10.33394/bioscientist.v12i2.12362 Read : 127 times Downloads: 29 times</p> <p><i>Mawaddah Shihab, I Wayan Suana, Gito Hadiprayitno</i></p>	<p>PDF 1656-1667</p>
<p>Evaluation of Information Security at the Radin Inten II Lampung Meteorological Station Using the KAMI Index</p> <p> DOI : 10.33394/bioscientist.v12i2.12498 Read : 118 times Downloads: 19 times</p> <p><i>Ardiansyah Ardiansyah, Suhendro Yusuf Irianto, M. Said Hasibuan</i></p>	<p>PDF 1668-1678</p>
<p>Isolation and Identification of Bacteria Producing Antibiotic Compounds from The Rhizosphere of <i>Avicennia Marina</i> Against Pathogenic Bacteria in The Mangrove Ecosystem Area of West Kalimantan</p> <p> DOI : 10.33394/bioscientist.v12i2.12527 Read : 181 times Downloads: 48 times</p> <p><i>Yuyun Nisaul Khairillah, Hasria Alang, Haryanto Haryanto, Fitriagustiani Fitriagustiani, Indri Erwhani, Ditha Astuti Purnamawati, Annisa Rahmawati, Surtikanti Surtikanti, Adelia Triwahyuni</i></p>	<p>PDF 1679-1691</p>
<p>Analisis Kemampuan Calon Guru dalam Menyusun Lembar Kerja Peserta Didik yang Membangun Keterampilan Abad 21</p> <p> DOI : 10.33394/bioscientist.v12i2.12472 Read : 76 times Downloads: 11 times</p> <p><i>Nyoman Sridana, I Ketut Sukarma, Taufik Samsuri, Rendi Gunawan</i></p>	<p>PDF 1692-1703</p>
<p>Wave Height Characteristics Due to The Influence of Land and Sea Breezes on Fishermen's Activities in The Coastal Area of Makassar City Using Doppler Weather Radar</p>	<p>PDF 1704-1720</p>

Pengembangan Penuntun Praktikum Pada Materi Sel dan Pelintasan Zat Melalui Membran Kelas XI SMA/MA dengan Pendekatan Inkuiri Bebas Dimodifikasi

PDF
1721-1733

 DOI : [10.33394/bioscientist.v12i2.12184](https://doi.org/10.33394/bioscientist.v12i2.12184) | Read : 163 times | Downloads: 36 times

Nurhadi Nurhadi, Mimin Mardhiah Zural, Dora Oktafially

The Relationship Between Early Marriage and Parenting Styles for Children Aged 3-5 Years

PDF
1734-1748

 DOI : [10.33394/bioscientist.v12i2.12571](https://doi.org/10.33394/bioscientist.v12i2.12571) | Read : 82 times | Downloads: 15 times

Baiq Wiwik Yastutik, Lalu Sulaiman, Lalu Abdul Khalik

Potensi Bakteri Endofit dari Tanaman Jahe Sebagai Agens Pengandali Hayati

PDF
1749-1760

 DOI : [10.33394/bioscientist.v12i2.12263](https://doi.org/10.33394/bioscientist.v12i2.12263) | Read : 122 times | Downloads: 56 times

Sabrina Ayu Kristianingrum, Andree Wijaya Setiawan, Ruth Melke Jayanti

Analisis Kompetensi Kepribadian dan Sosial Mahasiswa Pendidikan Biologi di Lampung sebagai Calon Guru Biologi

PDF
1761-1774

 DOI : [10.33394/bioscientist.v12i2.11397](https://doi.org/10.33394/bioscientist.v12i2.11397) | Read : 91 times | Downloads: 26 times

Nikmatus Saniah, Dwi Kurnia Hayati

Daya Hambat Ekstrak Kasar dan Fraksi Ekstrak Etanol Daun Gribong (*Archidendron clypearia* (Jack) I.C. Nielsen) Terhadap Bakteri Penyebab Jerawat


PDF
1775-1784

 DOI : [10.33394/bioscientist.v12i2.12480](https://doi.org/10.33394/bioscientist.v12i2.12480) | Read : 99 times | Downloads: 31 times

Rania Insyira, Rahmad Lingga, Salmi Salmi

The Relationship Between Parenting Styles and Adolescent Sexual Behavior

PDF
1785-1796

 DOI : [10.33394/bioscientist.v12i2.12778](https://doi.org/10.33394/bioscientist.v12i2.12778) | Read : 33 times | Downloads: 10 times

Ermy Setiani, Lalu Sulaiman, Sismulyanto Sismulyanto

Teknik RAPD (Random Applied Polymorphic DNA) untuk Analisis Keanekaragaman Genetik pada Tanaman Ciplukan (*Physalis angulata* L.) di Kabupaten Labuhan Batu Utara


PDF
1797-1809

 DOI : [10.33394/bioscientist.v12i2.12889](https://doi.org/10.33394/bioscientist.v12i2.12889) | Read : 115 times | Downloads: 53 times

Diana Yusvita, Zahratul Idami

Pengembangan Penuntun Praktikum Materi Mobilitas Pada Manusia Kelas XI SMA/MA dengan Pendekatan Inkuiri Bebas Dimodifikasi

PDF
1810-1820

 DOI : [10.33394/bioscientist.v12i2.12188](https://doi.org/10.33394/bioscientist.v12i2.12188) | Read : 33 times | Downloads: 7 times

Nurhadi Nurhadi, Annika Maizeli, Mimin Mardhiah Zural, Mayeni Mayeni



mRNA RELATIVE EXPRESSION CATALASE IN HYPERTENSION

Yohana^{1*}, Meutia Atika Faradilla², Meiyan³, Monica Dwi Hartanti⁴,
Eveline Margo⁵, Karina Shasri Anastasya⁶

^{1,2,3,4,5,6}Program Studi Sarjana Kedokteran, Fakultas Kedokteran, Universitas Trisakti,
Indonesia

^{1,4,6}Pusat Studi Gizi, Fakultas Kedokteran, Universitas Trisakti, Indonesia
Email: dryohana@trisakti.ac.id

DOI: <https://doi.org/10.33394/bioscientist.v12i2.12825>

Submit: 27-08-2024; Revised: 22-09-2024; Accepted: 29-09-2024; Published: 30-12-2024

ABSTRACT: Hypertension is number one worldwide disease which lead to death. Initially hypertension is caused by changes in the walls of blood vessels. These vascular changes are due to the accumulation of ROS (Reactive Oxygen Species). ROS is the result of the balance between antioxidants and oxidants, but uncontrolled conditions will cause vascular damage. One of ROS product from metabolism which could played role in downregulation antioxidant gene expression is hydrogen peroxide. Hydrogen peroxide could be neutralized by catalase enzyme. Studies about catalase expression in hypertension subject is still limited. This research aims to determine mRNA relative expression catalase in hypertension. In this case control study, thirty subject hypertension and normotension subject were recruited within the age of 50-60 years. Hypertension subject was chosen according to JNC 8. Two millilitres vein blood was isolated into RNA. mRNA expression was detected by qRT PCR with 2 steps. Relative expression was determined using livak method. The data was analyzed using Mann Withney test with GraphPad software. Research results show that (1) catalase mRNA relative expression was 0,6 fold in hypertension; (2) catalase relative expression was not significantly lower in hypertension; (3) other antioxidants might have other mechanism to detoxify ROS and prevent hypertension.

Keywords: hypertension, mRNA, catalase, expression

How to Cite: Yohana, Y., Faradilla, M., Meiyan, M., Hartanti, M., Margo, E., & Anastasya, K. (2024). mRNA Relative Expression Catalase in Hypertension. *Bioscientist: Jurnal Ilmiah Biologi*, 12(2), 1821-1827. <https://doi.org/10.33394/bioscientist.v12i2.12825>



Bioscientist: Jurnal Ilmiah Biologi is Licensed Under a CC BY-SA [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/).

INTRODUCTION

Hypertension is an aging disease which characterized by an increasing blood pressure above 120/80 mmHg. Uncontrolled blood pressure will be one of the risk factors for cardiovascular disease (Krentz & Chilton, 2023). The prevalence of hypertension is increased with age around 22% (18-39 years), 54,5% (40-49 years) and 74,5% (over 60 years). Prevalence of hypertension in men (31,9%) is higher than women (30,1%). Increased blood pressure might develop the risk of disability and death (Mills et al., 2021). According to Riskesdas 2018, the prevalence of hypertension in Indonesia, based on the age of 44-54 years about 45.32%. The etiology of hypertension is still controversial but some evidence showed oxidative stress could be the one of it. Oxidative stress in hypertension plays a role in vascular changes such as endothelial, arterial fibrosis, renal disfunction and stimulation simpatic nerve (Touyz et al., 2020).

Uniform Resource Locator: <https://e-journal.undikma.ac.id/index.php/bioscientist>



Oxidative stress is a state of balance between reactive oxygen species (ROS) and antioxidant enzymes. ROS is a product from metabolic reaction of the respiratory chain. In cardiac, ROS product came from respiratory chain, xanthine oxidase, NADPH oxidase and NO synthase. They are superoxide anions, hydroxyl, hydroperoxyl and hydrogen peroxide (Mills et al., 2021). This imbalance ROS production and antioxidant capacity will lead to cellular pathological conditions such as protein, lipid and nucleic acid damage including vascular changes (Baradaran et al., 2014). One form of ROS that has a role in the pathogenesis of hypertension is hydrogen peroxide (H_2O_2). H_2O_2 is one of the molecules that has a role in various cellular signalling such as vasodilator on the endothelium, protein modification, vascular remodelling, enhancing cell phosphorylation on cell migration and angiogenesis (Griendling et al., 2021).

Accumulation hydrogen peroxide induced endothel dysfunction, vascular damage, inflammation and organ failure. It could impact vascular ability to dilate even as well as its effect on blood pressure. Vascular endothel released inflammation factor that influence vasoconstrictor molecule and made worst hypertension condition. The enzymes that act to neutralize H_2O_2 are catalase, glutathione peroxidase and other peroxidase (Chrissobolis et al., 2008). Catalase is very common enzyme found in eukaryotic cells. It presents in peroxisome which has function to convert H_2O_2 to H_2O and O_2 . It depends on hydrogen peroxide concentration. When H_2O_2 level detected higher then catalytic agent would be stimulate to detoxify however when H_2O_2 level detected lower, it would stimulate peroxidase agent to act (Nandi et al., 2019). Catalase could be found in hepatocyte, kidney cell, erythrocyte and many other cells. Catalase which located in cytosol has a role to protect erythrocyte membrane from degradation. Catalase expression in mitochondria liver was influenced by fatty acid level which led to uprise catalytic activity. Decreasing catalase activity caused H_2O_2 accumulation that led to increase incidence oxidative stress and triggers potential for inflammation associated with hypertension 29/09/2024 07:44:00.

Recently there is study about catalase and glutathione peroxidase activity enzyme in schizophrenic patient. The study showed the presence of oxidative stress in first-year patients who had symptoms characteristic of schizophrenia. Erythrocyte catalase and glutathione peroxidase activity were significantly lower in schizophrenic patients than healthy person. It conclude that clinical manifestation patients depends on the duration of the illness, the episode of symptoms and the intake of antipsychotic drugs (Djordjević et al., 2022). Other studies found mRNA expression superoxide dismutase-1 (SOD1) was significantly lower in hypertension than normotension subjects. SOD1 was another antioxidant enzyme which could combat ROS. This evidence showed ROS could be higher in hypertension (Meiyanti et al., 2024). Conversely, catalase expression was higher when induced with oxidant in short term. This research was conducted on rat which was observing the changes in hepatocyte and astrocytes. Evidence suggests that catalase expression depends on oxidant concentration, exposure time and antioxidant enzyme capacity (Glorieux et al., 2015). Antioxidant expression has been widely studied in animal model but the research about catalase mRNA expression in



hypertension subjects 50-60 years old is still limited. Therefore, the aim of this study is to analyze mRNA relative expression of catalase in hypertension.

METHOD

The research was approved by the ethics committee of the Faculty of Medicine of the University of Trisakti under the number 001/KER/FK/2024. This case control study used 60 subjects age 50-60 years were selected and classified into two groups based on blood pressure according to JNC VIII. This research is located in Kelurahan Angke, West Jakarta at September, 2023. The inclusion criteria are those who are willing to follow the research and are 50-60 years of age. The exclusion criteria is those who have liver disease, cancer, diabetes mellitus and autoimmune. Venous blood samples of 2 ml were taken with a tube given EDTA and an immediate RNA isolation was performed.

RNA was extracted from 2 ml of venous blood with Quick RNA Miniprep kit (Zymoresearch). Briefly blood samples were added to the cell lysis buffer then added Proteinase K. Sample incubated for 30 minutes at a temperature of 20-30 degrees. Later isopropanolol is added 50% (v/v) and homogenized. After that sample was transferred to spin column and centrifugated at a speed of 16,000 g for 30 seconds, washed with RNA wash buffer and centrifuged 15,000 g over 30 seconds. The result was removed and added DNase buffer and mixed until homogeneous. The process continued with incubation at room temperature 20-30 °C for 15 minutes. After incubating, the sample was added RNA buffer and centrifuged. The result was removed and added another RNA wash buffer and centrifuge. After the centrifuge, added other RNA wash buffer and centrifuged for 1 minute. At the end, RNase free water and centrifuged for 1 minutes. Amount total RNA purification were measured for concentration and purity by spectrophotometer with wavelength of 260 nm. The sample is kept at -80°C (Hardiany et al., 2022).

Relative expression analysis of mRNA performed with 2 step qRT-PCR (Rotorgene 6000). cDNA synthesis used SensiFAST cDNA Synthesis kit and amplified by PCR machine with a 95 °C for denaturation about 15 seconds, annealing 60 °C for 60 seconds for 40 cycles. qPCR was completed by adding SensiFAST SYBR Green No-ROX marker, forward and reverse primer into cDNA. (Artika et al., 2022) CAT sequence primer is GTG CGG AGA TTC AAC ACT GCC A (forward) and CGG CAA TGT TCT CAC ACA GAC G (reverse) with product size 109 bp while GAPDH as a housekeeping gene which sequence is GTC TCC TCT GAC TTC AAC AGC G (forward) and ACC ACC CTG TTG CTG TAG CCA A (reverse). mRNA level expression was measured by Ct value of the target gene. Calculation of expression results using Livak method $2^{-\Delta\Delta C_t}$ ratio (Livak & Schmittgen, 2001).

Data distribution was not well distributed with the Shapiro wilk test. Mann Withney test was used to assess the difference between the two groups with a significance $p < 0,05$. The results are presented in a median form with 95% CI.

RESULT AND DISCUSSION

Sixty subjects was measured and baseline characteristic was presented in Table 1.



Table 1. Baseline of Characteristics Subject (n=60)

Characteristics	Normotension N=30	Hypertension N=30	
Gender			
Female	20 (66,67%)	22 (73,33%)	p=0,573
Male	8 (26,67%)	10 (33,33%)	
Mean of Age (years)	48,53	56,30	

Female subject diagnosed with hypertension was higher than male subject. In total sixty subject female was 66,67% with normotension and 73,33% diagnosed with hypertension. In male subject, there are 33,33% diagnosed with hypertension and 26,67% with normotension. Mean of age subject diagnosed with hypertension 56,3 years while mean of age with normotension 48,53 years. There was not statistically significantly gender with mRNA catalase expression (p=0,573).

Comparison catalase relative expression level toward GAPDH in hypertension and normotension subject, namely mRNA catalase relative expression in hypertension subject was 0,03 and normotension was 0,05. The comparison is presented in Figure 1.

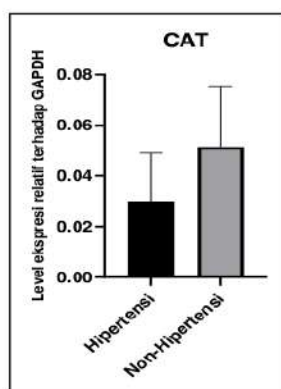


Figure 1. mRNA Relative Expression Catalase in Hypertension

The purpose our study was to analyze mRNA relative expression in hypertension. Our study discovered catalase expression was 0.6 fold in hypertension as shown in figure 1. This study also revealed the number of female subjects found was higher than that of males. In table 1 aligned with Novi et.al which found a higher number of female subject with hypertension than men at the age of 60 years (Kirana et al., 2020). Furthermore, a lot of women diagnosed with hypertension and to be treated with antihypertension drugs more than men (Defianna et al., 2021). Another finding was the average age subjects which diagnosed with hypertension was 56,3 years. This is leveled with Riskedas 2018 which disclosed subject with range of 54-65 years as the third number cases of hypertension in Indonesia. According to Suvila et.al, if someone was diagnosed with hipertension at the age of ≤ 55 years, then the incidence of cardiovascular disease and risk of death might increase. On the same study, subject who was doing



medical check-up in Japan at the age of < 30 years, hereditary factor was found (Suvila, 2020).

Catalase is an antioxidant enzyme found in aerobic organisms. It transformed hydrogen peroxide into oxygen and water. Catalase deficiency might caused various diseases such as diabetes mellitus, hypertension, schizophrenia, bipolar and skin disorders. (Griendling et al., 2021). In this study, the relative expression of mRNA catalase was found lower in hypertensive patients compared to normotension (Tain & Hsu, 2022). Our findings was in accordance with the results found by Azer B et.al, which demonstrates decreasing activity of superoxide dismutase and glutathione peroxidase enzyme in subject with early diagnosed hypertension. Hydrogen peroxide is found to be increasing in the early diagnosed hypertension (Griendling et al., 2021). In conclusion, antioxidant plays an important role in vascular damage by detoxifying ROS. Along with Vladimir et. al. showed that a decrease in enzyme catalase and glutathione peroxidase activity in patients with schizophrenia would lead to a reduction in H₂O₂ degradation into oxygen and water (Djordjević et al., 2022).

In physiology condition, ROS level plays a role in the cellular level such as gene expression, growth, differentiation cell, and apoptosis. When H₂O₂ level detected higher, catalase would respond and transform it to become less harmful. Previous study using rat as model for oxidative stress illustration in heart tissue. Higher ROS level might give consequence on blood pressure, atherosclerosis, endothelial dysfunction, hypertrophy cardiomyocyte, decreasing antioxidant enzyme, decreasing mitochondria function and activation protein kinase such as JNKs, Erk1/2, p38 MAPK, CAMK which lead to apoptosis cells (Dubois-Deruy et al., 2020). Further, relative expression superoxide dismutase SOD1 and SOD2 in hypertension was lower than normotension. Malondialdehyde (MDA) was also detected higher in normotension than hypertension. Overproduction ROS might caused cardiovascular disease and disrupt respiratory chain in mitochondria (Meiyanti et al., 2024).

CONCLUSION

Based on the result of this study, it can be concluded that expression of mRNA catalase is lower in hypertension. Hypertension might be the outcome from oxidative stress. Catalase relative expression was not significantly lower because there is various other mechanism to detoxify ROS. The degree of antioxidant activity is depended on the type of tissue. Limitation our research are limited blood sample subject and we didn't measure protein level. Our suggestion is that further research is needed on the addition of antioxidants as a supplement to hypertension to see changes in expression in the levels of gene and proteins.

ACKNOWLEDGMENT

The researcher would like to thank the DRPMF, Faculty of Medicine, Trisakti University, which has funded this research through the 2023-2024 internal grant program.



REFERENCES

- Artika, I. M., Dewi, Y. P., Nainggolan, I. M., Siregar, J. E., & Antonjaya, U. (2022). Real-time polymerase chain reaction: Current techniques, applications, and role in COVID-19 diagnosis. *Genes*, *13*(12), 2387.
- Baradaran, A., Nasri, H., & Ra, M. (2014). Oxidative stress and hypertension: Possibility of hypertension therapy with antioxidants. *Journal of Research in Medical Sciences*.
- Chrissobolis, S., Didion, S. P., Kinzenbaw, D. A., Schrader, L. I., Dayal, S., Lentz, S. R., & Faraci, F. M. (n.d.). *Glutathione Peroxidase-1 Plays a Major Role in Protecting Against Angiotensin II-Induced Vascular Dysfunction*.
- Defianna, S. R., Santosa, A., Probandari, A., & Dewi, F. S. T. (2021). Gender differences in prevalence and risk factors for hypertension among adult populations: A cross-sectional study in Indonesia. *International Journal of Environmental Research and Public Health*, *18*(12), 6259.
- Djordjević, V. V., Kostić, J., Krivokapić, Ž., Krtinić, D., Ranković, M., Petković, M., & Čosić, V. (2022a). *Decreased Activity of Erythrocyte Catalase and Glutathione Peroxidase in Patients with Schizophrenia*.
- Djordjević, V. V., Kostić, J., Krivokapić, Ž., Krtinić, D., Ranković, M., Petković, M., & Čosić, V. (2022b). Decreased activity of Erythrocyte Catalase and glutathione peroxidase in patients with Schizophrenia. *Medicina*, *58*(10), 1491.
- Dubois-Deruy, E., Peugnet, V., Turkieh, A., & Pinet, F. (2020). Oxidative stress in cardiovascular diseases. *Antioxidants*, *9*(9), 864.
- Glorieux, C., Zamocky, M., Sandoval, J. M., Verrax, J., & Calderon, P. B. (2015). Regulation of catalase expression in healthy and cancerous cells. *Free Radical Biology and Medicine*, *87*, 84–97.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (n.d.). Oxidative Stress and Hypertension. *Circulation Research*.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (2021a). Oxidative stress and hypertension. *Circulation Research*, *128*(7), 993–1020.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (2021b). Oxidative stress and hypertension. *Circulation Research*, *128*(7), 993–1020.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (2021c). Oxidative stress and hypertension. *Circulation Research*, *128*(7), 993–1020.
- Hardiany, N. S., Karman, A. P., Calista, A. S. P., Anindyanari, B. G., Rahardjo, D. E., Novira, P. R., Taufiq, R. R., Imtiyaz, S., & Antarianto, R. D. (2022). The effect of fasting on oxidative stress in the vital organs of New Zealand white rabbit. *Reports of Biochemistry & Molecular Biology*, *11*(2), 190.
- Kirana, A. N., Prafiyanti, E., & Hardiany, N. S. (2020). Correlation Between Age, Body Mass Index, And Blood Selenium Level with Glutathione Peroxidase Activity Among Elderly in South Jakarta. *Health*, *11*, 2.
- Krentz, A. J., & Chilton, R. J. (2023). *Cardiovascular Endocrinology and Metabolism: Theory and Practice of Cardiometabolic Medicine*. Academic Press.
- Livak, K. J., & Schmittgen, T. D. (2001). Analysis of relative gene expression data using real-time quantitative PCR and the 2- $\Delta\Delta$ CT method. *Methods*, *25*(4), 402–408.
- Mills, K. T., Stefanescu, A., & He, J. (2021). *The global epidemiology of hypertension*.
- Nandi, A., Yan, L.-J., Jana, C. K., & Das, N. (2019). Role of catalase in oxidative stress and age-associated degenerative diseases. *Oxidative Medicine and Cellular Longevity*, *2019*(1), 9613090.



- Suvila, K. (2020). Age of Hypertension Onset: Overview of Research and How to Apply in Practice. *Curr Hypertens Rep*.
- Tain, Y.-L., & Hsu, C.-N. (2022). Oxidative stress-induced hypertension of developmental origins: Preventive aspects of antioxidant therapy. *Antioxidants*, 11(3), 511.
- Touyz, R. M., Rios, F. J., Alves-Lopes, R., Neves, K. B., Camargo, L. L., & Montezano, A. C. (2020). Oxidative stress: A unifying paradigm in hypertension. *Canadian Journal of Cardiology*, 36(5), 659–670.

mRNA RELATIVE EXPRESSION CATALASE IN HYPERTENSION

ORIGINALITY REPORT

16%

SIMILARITY INDEX

13%

INTERNET SOURCES

8%

PUBLICATIONS

6%

STUDENT PAPERS

PRIMARY SOURCES

1

e-journal.undikma.ac.id

Internet Source

4%

2

Submitted to Badan PPSDM Kesehatan
Kementerian Kesehatan

Student Paper

4%

3

Systems Biology of Free Radicals and
Antioxidants, 2014.

Publication

3%

4

www.ncbi.nlm.nih.gov

Internet Source

1%

5

www.nature.com

Internet Source

1%

6

www.mdpi.com

Internet Source

1%

7

embomolmed.embopress.org

Internet Source

1%

8

Giuseppe Mancia, Guido Grassi, Konstantinos
P. Tsioufis, Anna F. Dominiczak, Enrico Agabiti
Rosei. "Manual of Hypertension of the

1%

European Society of Hypertension", CRC Press, 2019

Publication

9

ijbs.ipmi.ac.id
Internet Source

<1 %

Exclude quotes On

Exclude matches < 10 words

Exclude bibliography On



mRNA RELATIVE EXPRESSION CATALASE IN HYPERTENSION

**Yohana^{1*}, Meutia Atika Faradilla², Meiyanti³, Monica Dwi Hartanti⁴,
Eveline Margo⁵, Karina Shasri Anastasya⁶**

^{1,2,3,4,5,6}Program Studi Sarjana Kedokteran, Fakultas Kedokteran, Universitas Trisakti,
Indonesia

^{1,4,6} Pusat Studi Gizi, Fakultas Kedokteran, Universitas Trisakti, Indonesia

Email: dryohana@trisakti.ac.id

DOI: <https://doi.org/10.33394/bioscientist.v12i2.12825>

Submit: 27-08-2024; Revised: 22-09-2024; Accepted: 29-09-2024; Published: 30-12-2024

ABSTRACT: Hypertension is number one worldwide disease which lead to death. Initially hypertension is caused by changes in the walls of blood vessels. These vascular changes are due to the accumulation of ROS (Reactive Oxygen Species). ROS is the result of the balance between antioxidants and oxidants, but uncontrolled conditions will cause vascular damage. One of ROS product from metabolism which could played role in downregulation antioxidant gene expression is hydrogen peroxide. Hydrogen peroxide could be neutralized by catalase enzyme. Studies about catalase expression in hypertension subject is still limited. This research aims to determine mRNA relative expression catalase in hypertension. In this case control study, thirty subject hypertension and normotension subject were recruited within the age of 50-60 years. Hypertension subject was chosen according to JNC 8. Two millilitres vein blood was isolated into RNA. mRNA expression was detected by qRT PCR with 2 steps. Relative expression was determined using livak method. The data was analyzed using Mann Withney test with GraphPad software. Research results show that (1) catalase mRNA relative expression was 0,6 fold in hypertension; (2) catalase relative expression was not significantly lower in hypertension; (3) other antioxidants might have other mechanism to detoxify ROS and prevent hypertension.

Keywords: hypertension, mRNA, catalase, expression

How to Cite: Yohana, Y., Faradilla, M., Meiyanti, M., Hartanti, M., Margo, E., & Anastasya, K. (2024). mRNA Relative Expression Catalase in Hypertension. *Bioscientist: Jurnal Ilmiah Biologi*, 12(2), 1821-1827. <https://doi.org/10.33394/bioscientist.v12i2.12825>



Bioscientist: Jurnal Ilmiah Biologi is Licensed Under a CC BY-SA [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/).

INTRODUCTION

Hypertension is an aging disease which characterized by an increasing blood pressure above 120/80 mmHg. Uncontrolled blood pressure will be one of the risk factors for cardiovascular disease (Krentz & Chilton, 2023). The prevalence of hypertension is increased with age around 22% (18-39 years), 54,5% (40-49 years) and 74,5% (over 60 years). Prevalence of hypertension in men (31,9%) is higher than women (30,1%). Increased blood pressure might develop the risk of disability and death (Mills et al., 2021). According to Riskesdas 2018, the prevalence of hypertension in Indonesia, based on the age of 44-54 years about 45.32%. The etiology of hypertension is still controversial but some evidence showed oxidative stress could be the one of it. Oxidative stress in hypertension plays a role in vascular changes such as endothelial, arterial fibrosis, renal disfunction and stimulation simpatic nerve (Touyz et al., 2020).



Oxidative stress is a state of balance between reactive oxygen species (ROS) and antioxidant enzymes. ROS is a product from metabolic reaction of the respiratory chain. In cardiac, ROS product came from respiratory chain, xanthine oxidase, NADPH oxidase and NO synthase. They are superoxide anions, hydroxyl, hydroperoxyl and hydrogen peroxide (Mills et al., 2021). This imbalance ROS production and antioxidant capacity will lead to cellular pathological conditions such as protein, lipid and nucleic acid damage including vascular changes (Baradaran et al., 2014). One form of ROS that has a role in the pathogenesis of hypertension is hydrogen peroxide (H_2O_2). H_2O_2 is one of the molecules that has a role in various cellular signalling such as vasodilator on the endothelium, protein modification, vascular remodelling, enhancing cell phosphorylation on cell migration and angiogenesis (Griendling et al., 2021).

Accumulation hydrogen peroxide induced endothel dysfunction, vascular damage, inflammation and organ failure. It could impact vascular ability to dilate even as well as its effect on blood pressure. Vascular endothel released inflammation factor that influence vasoconstrictor molecule and made worst hypertension condition. The enzymes that act to neutralize H_2O_2 are catalase, glutathione peroxidase and other peroxidase (Chrissobolis et al., 2008). Catalase is very common enzyme found in eukaryotic cells. It presents in peroxisome which has function to convert H_2O_2 to H_2O and O_2 . It depends on hydrogen peroxide concentration. When H_2O_2 level detected higher then catalytic agent would be stimulate to detoxify however when H_2O_2 level detected lower, it would stimulate peroxidase agent to act (Nandi et al., 2019). Catalase could be found in hepatocyte, kidney cell, erythrocyte and many other cells. Catalase which located in cytosol has a role to protect erythrocyte membrane from degradation. Catalase expression in mitochondria liver was influenced by fatty acid level which led to uprise catalytic activity. Decreasing catalase activity caused H_2O_2 accumulation that led to increase incidence oxidative stress and triggers potential for inflammation associated with hypertension 29/09/2024 07:44:00.

Recently there is study about catalase and glutathione peroxidase activity enzyme in schizophrenic patient. The study showed the presence of oxidative stress in first-year patients who had symptoms characteristic of schizophrenia. Erythrocyte catalase and glutathione peroxidase activity were significantly lower in schizophrenic patients than healthy person. It conclude that clinical manifestation patients depends on the duration of the illness, the episode of symptoms and the intake of antipsychotic drugs (Djordjević et al., 2022). Other studies found mRNA expression superoxide dismutase-1 (SOD1) was significantly lower in hypertension than normotension subjects. SOD1 was another antioxidant enzyme which could combat ROS. This evidence showed ROS could be higher in hypertension (Meiyanti et al., 2024). Conversely, catalase expression was higher when induced with oxidant in short term. This research was conducted on rat which was observing the changes in hepatocyte and astrocytes. Evidence suggests that catalase expression depends on oxidant concentration, exposure time and antioxidant enzyme capacity (Glorieux et al., 2015). Antioxidant expression has been widely studied in animal model but the research about catalase mRNA expression in



hypertension subjects 50-60 years old is still limited. Therefore, the aim of this study is to analyze mRNA relative expression of catalase in hypertension.

METHOD

The research was approved by the ethics committee of the Faculty of Medicine of the University of Trisakti under the number 001/KER/FK/2024. This case control study used 60 subjects age 50-60 years were selected and classified into two groups based on blood pressure according to JNC VIII. This research is located in Kelurahan Angke, West Jakarta at September, 2023. The inclusion criteria are those who are willing to follow the research and are 50-60 years of age. The exclusion criteria is those who have liver disease, cancer, diabetes mellitus and autoimmune. Venous blood samples of 2 ml were taken with a tube given EDTA and an immediate RNA isolation was performed.

RNA was extracted from 2 ml of venous blood with Quick RNA Miniprep kit (Zymoresearch). Briefly blood samples were added to the cell lysis buffer then added Proteinase K. Sample incubated for 30 minutes at a temperature of 20-30 degrees. Later isopropanolol is added 50% (v/v) and homogenized. After that sample was transferred to spin column and centrifugated at a speed of 16,000 g for 30 seconds, washed with RNA wash buffer and centrifuged 15,000 g over 30 seconds. The result was removed and added DNase buffer and mixed until homogeneous. The process continued with incubation at room temperature 20-30 °C for 15 minutes. After incubating, the sample was added RNA buffer and centrifuged. The result was removed and added another RNA wash buffer and centrifuge. After the centrifuge, added other RNA wash buffer and centrifuged for 1 minute. At the end, RNase free water and centrifuged for 1 minutes. Amount total RNA purification were measured for concentration and purity by spectrophotometer with wavelength of 260 nm. The sample is kept at -80°C (Hardiany et al., 2022).

Relative expression analysis of mRNA performed with 2 step qRT-PCR (Rotorgene 6000). cDNA synthesis used SensiFAST cDNA Synthesis kit and amplified by PCR machine with a 95 °C for denaturation about 15 seconds, annealing 60 °C for 60 seconds for 40 cycles. qPCR was completed by adding SensiFAST SYBR Green No-ROX marker, forward and reverse primer into cDNA. (Artika et al., 2022) CAT sequence primer is GTG CGG AGA TTC AAC ACT GCC A (forward) and CGG CAA TGT TCT CAC ACA GAC G (reverse) with product size 109 bp while GAPDH as a housekeeping gene which sequence is GTC TCC TCT GAC TTC AAC AGC G (forward) and ACC ACC CTG TTG CTG TAG CCA A (reverse). mRNA level expression was measured by Ct value of the target gene. Calculation of expression results using Livak method $2^{-\Delta\Delta C_t}$ ratio (Livak & Schmittgen, 2001).

Data distribution was not well distributed with the Shapiro wilk test. Mann Withney test was used to assess the difference between the two groups with a significance $p < 0,05$. The results are presented in a median form with 95% CI.

RESULT AND DISCUSSION

Sixty subjects was measured and baseline characteristic was presented in Table 1.

Table 1. Baseline of Characteristics Subject (n=60)

Characteristics	Normotension N=30	Hypertension N=30	
Gender			
Female	20 (66,67%)	22 (73,33%)	p=0.573
Male	8 (26,67%)	10 (33,33%)	
Mean of Age (years)	48,53	56,30	

Female subject diagnosed with hypertension was higher than male subject. In total sixty subject female was 66,67% with normotension and 73,33% diagnosed with hypertension. In male subject, there are 33,33% diagnosed with hypertension and 26,67% with normotension. Mean of age subject diagnosed with hypertension 56,3 years while mean of age with normotension 48,53 years. There was not statistically significantly gender with mRNA catalase expression (p=0,573).

Comparison catalase relative expression level toward GAPDH in hypertension and normotension subject, namely mRNA catalase relative expression in hypertension subject was 0,03 and normotension was 0,05. The comparison is presented in Figure 1.

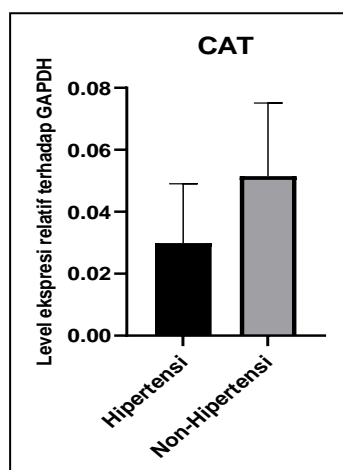


Figure 1. mRNA Relative Expression Catalase in Hypertension

The purpose our study was to analyze mRNA relative expression in hypertension. Our study discovered catalase expression was 0.6 fold in hypertension as shown in figure 1. This study also revealed the number of female subjects found was higher than that of males. In table 1 aligned with Novi et.al which found a higher number of female subject with hypertension than men at the age of 60 years (Kirana et al., 2020). Furthermore, a lot of women diagnosed with hypertension and to be treated with antihypertension drugs more than men (Defianna et al., 2021). Another finding was the average age subjects which diagnosed with hypertension was 56,3 years. This is leveled with Riskedas 2018 which disclosed subject with range of 54-65 years as the third number cases of hypertension in Indonesia. According to Suvila et.al, if someone was diagnosed with hipertension at the age of ≤ 55 years, then the incidence of cardiovascular disease and risk of death might increase. On the same study, subject who was doing



medical check-up in Japan at the age of < 30 years, hereditary factor was found (Suvila, 2020).

Catalase is an antioxidant enzyme found in aerobic organisms. It transformed hydrogen peroxide into oxygen and water. Catalase deficiency might caused various diseases such as diabetes mellitus, hypertension, schizophrenia, bipolar and skin disorders. (Griendling et al., 2021). In this study, the relative expression of mRNA catalase was found lower in hypertensive patients compared to normotension (Tain & Hsu, 2022). Our findings was in accordance with the results found by Azer B et.al, which demonstrates decreasing activity of superoxide dismutase and glutathione peroxidase enzyme in subject with early diagnosed hypertension. Hydrogen peroxide is found to be increasing in the early diagnosed hypertension (Griendling et al., 2021). In conclusion, antioxidant plays an important role in vascular damage by detoxifying ROS. Along with Vladimir et. al. showed that a decrease in enzyme catalase and glutathione peroxidase activity in patients with schizophrenia would lead to a reduction in H₂O₂ degradation into oxygen and water (Djordjević et al., 2022).

In physiology condition, ROS level plays a role in the cellular level such as gene expression, growth, deferencial cell, and apoptosis. When H₂O₂ level detected higher, catalase would respond and transform it to become less harmful. Previous study using rat as model for oxidative stress illustration in heart tissue. Higher ROS level might give consequence on blood pressure, atherosclerosis, endotel disfunction, hyperthrophy cardiomyocyte, decreasing antioxidant enzyme, decreasing mitochondria function and activation protein kinase such as JNKs, Erk1/2, p38 MAPK, CAMK which lead to apoptosis cells (Dubois-Deruy et al., 2020). Further, relative expression superoxide dismutase SOD1 and SOD2 in hypertension was lower than normotension. Malondialdehyde (MDA) was also detected higher in normotension than hypertension. Overproduction ROS might caused cardiovascular disease and disrupt respiratory chain in mitochondria (Meiyanti et al., 2024).

CONCLUSION

Based on the result of this study, it can be concluded that expression of mRNA catalase is lower in hypertension. Hypertension might be the outcome from oxidative stress. Catalase relative expression was not significantly lower because there is various other mechanism to detoxify ROS. The degree of antioxidant activity is depended on the type of tissue. Limitation our research are limited blood sample subject and we didn't measure protein level. Our suggestion is that further research is needed on the addition of antioxidants as a supplement to hypertension to see changes in expression in the levels of gene and proteins.

ACKNOWLEDGMENT

The researcher would like to thank the DRPMF, Faculty of Medicine, Trisakti University, which has funded this research through the 2023-2024 internal grant program.



REFERENCES

- Artika, I. M., Dewi, Y. P., Nainggolan, I. M., Siregar, J. E., & Antonjaya, U. (2022). Real-time polymerase chain reaction: Current techniques, applications, and role in COVID-19 diagnosis. *Genes*, 13(12), 2387.
- Baradaran, A., Nasri, H., & Ra, M. (2014). Oxidative stress and hypertension: Possibility of hypertension therapy with antioxidants. *Journal of Research in Medical Sciences*.
- Chrissobolis, S., Didion, S. P., Kinzenbaw, D. A., Schrader, L. I., Dayal, S., Lentz, S. R., & Faraci, F. M. (n.d.). *Glutathione Peroxidase-1 Plays a Major Role in Protecting Against Angiotensin II-Induced Vascular Dysfunction*.
- Defianna, S. R., Santosa, A., Probandari, A., & Dewi, F. S. T. (2021). Gender differences in prevalence and risk factors for hypertension among adult populations: A cross-sectional study in Indonesia. *International Journal of Environmental Research and Public Health*, 18(12), 6259.
- Djordjević, V. V., Kostić, J., Krivokapić, Ž., Krtinić, D., Ranković, M., Petković, M., & Ćosić, V. (2022a). *Decreased Activity of Erythrocyte Catalase and Glutathione Peroxidase in Patients with Schizophrenia*.
- Djordjević, V. V., Kostić, J., Krivokapić, Ž., Krtinić, D., Ranković, M., Petković, M., & Ćosić, V. (2022b). Decreased activity of Erythrocyte Catalase and glutathione peroxidase in patients with Schizophrenia. *Medicina*, 58(10), 1491.
- Dubois-Deruy, E., Peugnet, V., Turkieh, A., & Pinet, F. (2020). Oxidative stress in cardiovascular diseases. *Antioxidants*, 9(9), 864.
- Glorieux, C., Zamocky, M., Sandoval, J. M., Verrax, J., & Calderon, P. B. (2015). Regulation of catalase expression in healthy and cancerous cells. *Free Radical Biology and Medicine*, 87, 84–97.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (n.d.). Oxidative Stress and Hypertension. *Circulation Research*.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (2021a). Oxidative stress and hypertension. *Circulation Research*, 128(7), 993–1020.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (2021b). Oxidative stress and hypertension. *Circulation Research*, 128(7), 993–1020.
- Griendling, K. K., Camargo, L. L., Rios, F. J., Alves-Lopes, R., Montezano, A. C., & Touyz, R. M. (2021c). Oxidative stress and hypertension. *Circulation Research*, 128(7), 993–1020.
- Hardiany, N. S., Karman, A. P., Calista, A. S. P., Anindyanari, B. G., Rahardjo, D. E., Novira, P. R., Taufiq, R. R., Imtiyaz, S., & Antariantono, R. D. (2022). The effect of fasting on oxidative stress in the vital organs of New Zealand white rabbit. *Reports of Biochemistry & Molecular Biology*, 11(2), 190.
- Kirana, A. N., Prafiyanti, E., & Hardiany, N. S. (2020). Correlation Between Age, Body Mass Index, And Blood Selenium Level with Glutathione Peroxidase Activity Among Elderly in South Jakarta. *Health*, 11, 2.
- Krentz, A. J., & Chilton, R. J. (2023). *Cardiovascular Endocrinology and Metabolism: Theory and Practice of Cardiometabolic Medicine*. Academic Press.
- Livak, K. J., & Schmittgen, T. D. (2001). Analysis of relative gene expression data using real-time quantitative PCR and the 2⁻ΔΔCT method. *Methods*, 25(4), 402–408.
- Mills, K. T., Stefanescu, A., & He, J. (2021). *The global epidemiology of hypertension*.
- Nandi, A., Yan, L.-J., Jana, C. K., & Das, N. (2019). Role of catalase in oxidative stress- and age-associated degenerative diseases. *Oxidative Medicine and Cellular Longevity*, 2019(1), 9613090.



- Suvila, K. (2020). Age of Hypertension Onset: Overview of Research and How to Apply in Practice. *Curr Hypertens Rep*.
- Tain, Y.-L., & Hsu, C.-N. (2022). Oxidative stress-induced hypertension of developmental origins: Preventive aspects of antioxidant therapy. *Antioxidants*, 11(3), 511.
- Touyz, R. M., Rios, F. J., Alves-Lopes, R., Neves, K. B., Camargo, L. L., & Montezano, A. C. (2020). Oxidative stress: A unifying paradigm in hypertension. *Canadian Journal of Cardiology*, 36(5), 659–670.