

Jurnal Info Kesehatan

Vol. 23, No. 3, September 2025, pp. 679-687

P-ISSN 0216-504X, E-ISSN 2620-536X

DOI: [10.31965/infokes.Vol23.Iss3.1884](https://doi.org/10.31965/infokes.Vol23.Iss3.1884)

Journal homepage: <https://jurnal.poltekkeskupang.ac.id/index.php/infokes>



RESEARCH

Open Access

The Relationship between Prediabetes and Prehypertension with Vascular Elasticity in Medical Students

Kia Iglesias Pangaribuan^{1a}, Nurfitri Bustamam^{2b*}, Aulia Chairani^{3c}, Marlina Dewiastuti^{4d}

¹ Undergraduate Medical Program, Universitas Pembangunan Nasional Veteran Jakarta, Jakarta, Indonesia

² Department of Physiology, Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta, Jakarta, Indonesia

³ Department of Public Health, Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta, Jakarta, Indonesia

⁴ Department of Internal Medicine, Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta, Jakarta, Indonesia

^a Email: kiaiglesiaspangaribuan@gmail.com

^b Email: nurfitri.bustamam@upnvj.ac.id

^c Email: auliachairani@upnvj.ac.id

^d Email: marlina_malik@upnvj.ac.id

Received: 13 January 2025

Revised: 8 April 2025

Accepted: 30 May 2025

Abstract

Prediabetes and prehypertension are known to affect vascular elasticity, and the prevalence of these conditions among young adults is increasing. This study examines the relationship between prediabetes and prehypertension with vascular elasticity in medical students. The study utilized a cross-sectional design and the technique of simple random sampling, involving a total of 69 students. The research subjects' criteria were medical students aged 18–25 years who were non-smokers, did not consume alcohol, had no history of diabetes or hypertension, and were not taking medications affecting blood pressure or blood glucose levels. Vascular elasticity, blood pressure, and fasting blood glucose levels were measured using an Accelerated Photoplethysmograph Analyzer SA-3000P, a digital sphygmomanometer, and a glucometer, respectively. The findings indicated no differences in gender, BMI, age, and physical activity between the suboptimal vascular elasticity and the normal+optimal elasticity groups ($p > 0.05$). The Chi-square test identified significant differences in vascular elasticity between the prediabetes and normal groups ($p = 0.009$; $PR = 1.6$; $CI = 1.1–2.2$), the prehypertension and normal groups ($p = 0.026$; $PR = 1.5$; $CI = 1.1–2.2$), and the prediabetes+prehypertension and normal groups ($p = 0.002$; $PR = 3.5$; $CI = 1.4–8.3$). These findings indicate that prediabetes, prehypertension, or both conditions are associated with reduced vascular elasticity.

Keywords: Medical Students, Prediabetes, Prehypertension, Vascular Elasticity.

Corresponding Author:

Nurfitri Bustamam

Department of Physiology, Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta, Jakarta, Indonesia

Email: nurfitri.bustamam@upnvj.ac.id



©The Author(s) 2025. This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

1. INTRODUCTION

Decreased vascular elasticity can result from diabetes and hypertension, both of which are preceded by prediabetes and prehypertension (Szaló et al., 2021). The prevalence of prediabetes and prehypertension among young individuals is on the rise. Globally, the prevalence of prediabetes among individuals aged 20-24 years was 5% in 2021 (Rooney et al., 2023). A total of 4 out of 34 medical students (11.76%) from Udayana University were found to have prediabetes (Wijaya et al., 2019). Furthermore, data from the National Heart, Lung, and Blood Institute indicate that the prevalence of prehypertension continues to rise among individuals aged 18-29 years and is often undiagnosed (Rafan et al., 2018). Other research indicates that the prevalence of prehypertension among adolescents in Indonesia is 16.8% (Sudikno et al., 2023), while 61.2% of medical students at the University of Indonesia have prehypertension (Bawazier et al., 2019).

Prediabetes is diagnosed when fasting plasma glucose levels are 100-125 mg/dL or when oral glucose tolerance levels are 140-199 mg/dL (PERKENI, 2021), while prehypertension is identified when systolic blood pressure falls within 120 to 139 mmHg and/or diastolic blood pressure ranges from 80 to 89 mmHg (Unger et al., 2020). Like diabetes and hypertension, prediabetes and prehypertension are primarily attributed to unhealthy lifestyle habits. Students, in particular, are prone to adopting unhealthy behaviors, such as frequent consumption of fast foods high in sugar or salt and limited engagement in physical activity, which significantly increases their risk of developing prediabetes and prehypertension (Kumalasari et al., 2023).

Vascular stiffness refers to the decreased elasticity of blood vessels, leading to increased blood pressure. Stiff arterial walls require higher systolic pressure to overcome arterial rigidity (Alghamdi et al., 2021). Pulse wave velocity (PWV) is a noninvasive method of assessing the stiffness of arteries. The American Heart Association (AHA) and the European Society of Cardiology (ESC) recommend carotid-femoral PWV (cf-PWV) as a key indicator for evaluating the risk of cardiovascular complications in individuals with hypertension. Another indicator of vascular stiffness is the photoplethysmogram (PPG). In terms of practicality, PPG is significantly simpler than PWV measurement, requiring only a single PPG transducer attached to the index finger, with an examination duration of less than five minutes. The second derivative of PPG, known as the Accelerated Photoplethysmograph (APG), demonstrates sensitivity and specificity of 71.45 and 90.1%, respectively, in measuring vascular stiffness (Murakami et al., 2019).

Research comparing arterial stiffness between prehypertensive and normotensive groups revealed that arterial stiffness was higher in the prehypertensive group. This study used PPG with male subjects aged 30–50 years (Jeyashree et al., 2024). A similar study involving subjects aged 30-40 years reported that the ankle-brachial index was lower in the prehypertensive group, indicating higher arterial stiffness compared to the normotensive group (Rubio-Guerra et al., 2018). A different study indicated that cf-PWV was elevated in the prediabetic group (Firmino et al., 2023).

Given the rising prevalence of prehypertension and prediabetes among younger individuals and the impact of both conditions on arterial elasticity, this study examines the relationship between prediabetes and prehypertension with vascular elasticity in medical students. Utilizing non-invasive vascular assessments, this study investigated early vascular changes in individuals with borderline metabolic indicators, which are often overlooked in routine health screenings. The novelty of this study lies in its focus on a young adult demographic, highlighting that vascular alterations may begin much earlier than commonly assumed. The findings aim to provide a basis for preventive measures to reduce the risk of vascular dysfunction.

2. RESEARCH METHOD

A cross-sectional design was employed in the study, using simple random sampling. The study population consisted of students from the Faculty of Medicine Universitas Pembangunan Nasional Veteran Jakarta (FM UPNVJ). The sample size was calculated using the hypothesis testing formula for comparing two proportions, with $\alpha = 5\%$, $\beta = 90\%$, $P_1 = 0.697$, and $P_2 = 0.347$. The calculation determined a required sample size of 62 subjects. To account for a potential 10% dropout rate, the final minimum sample size was 69 subjects.

The research subjects were selected based on the inclusion criteria of being medical students aged 18–25 years with low or moderate physical activity levels. Subjects who smoked, consumed alcohol, had a history of diabetes or hypertension, or were taking medications affecting blood sugar or blood pressure were excluded.

Subject characteristics were collected using a questionnaire that included demographic information and the Global Physical Activity Questionnaire (GPAQ). The GPAQ is a validated and reliable instrument for assessing physical activity (Keating et al., 2019). Blood glucose level was measured using an Easy Touch glucometer. Blood pressure was measured using an Omron digital sphygmomanometer.

Subjects were asked to fast for at least 8 hours before their blood glucose test. The procedure began with the insertion of a glucose strip into the glucometer. The fingertip to be pricked was cleaned with alcohol, followed by a puncture using a lancet. Blood flowed onto the glucose strip inserted into the glucometer, and the resulting blood glucose readings were recorded. Prior to blood pressure measurement, subjects were instructed to abstain from physical activity, caffeine consumption, and smoking for at least 30 minutes. They were also required to empty their bladder before the examination. During the measurement, subjects were seated in a quiet room, resting both feet flat on the floor (uncrossed), relaxed, and refrained from talking. The cuff was positioned on the upper arm, two fingers above the cubital fossa. The start button on the device was pressed to initiate the measurement. Measurement of blood pressure was taken twice, with a 1- to 2-minute interval between measurements (Unger et al., 2020). Vascular elasticity was evaluated using the SA-3000P APG Analyzer. The procedure was performed in an environment with appropriate lighting, minimal noise, and a comfortable temperature. Subjects were instructed to refrain from caffeine, smoking, and eating for at least 2 hours before the examination. During the procedure, subjects were seated comfortably, refrained from speaking or moving, kept their eyes open, avoided sleeping, and maintained regular breathing. The APG sensor was attached to the left index finger, and measurements were conducted for 3 minutes.

SPSS software was used to analyze the relationship between prediabetes and prehypertension with vascular elasticity. Since the measurement scale of the variables was ordinal (categorical), The hypothesis was tested using the Chi-square test. In this study, statistical tests were performed to compare the characteristics of the two groups as follows: (1) the Mann–Whitney test for numerical data that did not follow a normal distribution, (2) the Chi-square test for categorical variables, and (3) Fisher's exact test as an alternative when the assumptions required for the Chi-square test were not fulfilled. A p-value of ≤ 0.05 was considered statistically significant.

This study was carried out at the Medical Education and Research Center UPNVJ, from August to November 2024. This study was ethically approved by the UPNVJ Research Ethics Committee (Approval No.374/IX/2024/KEP).

3. RESULTS AND DISCUSSION

Table 1 presents the research subjects' characteristics. The subjects' median age was between 20 and 21 years. Most of the subjects were male, had a normal body mass index, and engaged in moderate levels of physical activity. Vascular elasticity decreases with age. The increase in arterial stiffness associated with aging is influenced by two primary mechanisms:

the extracellular matrix mechanism and the cellular mechanism. Changes in the extracellular matrix are driven by decreased elastin and increased collagen. Collagen deposition in the vasculature increases with age, resulting in alteration of the normal extracellular matrix (ECM) tissue. Moreover, elastin fiber degradation increases with age, driven by the upregulation of matrix metalloproteinase. These changes increase the collagen-to-elastin ratio, ultimately leading to vascular stiffness. The cellular mechanism is attributed to endothelial dysfunction. As age increases, the bioavailability of nitric oxide (NO) decreases. Endothelial dysfunction and reduced NO bioavailability can lead to a pro-inflammatory state and vasoconstriction, contributing to increased arterial stiffness and vascular fibrosis (Vatner et al., 2021). The result of the Mann-Whitney test indicated no difference in age between groups with varying levels of vascular elasticity ($p = 0.514$) (Table 1). Therefore, age appears to have no significant effect on the variations in vascular elasticity observed in this study.

Table 1. Characteristics of Research Subjects (n=69).

Characteristic	Vascular Elasticity		p-value
	Suboptimal n=46	Normal+Optimal n= 23	
Age (median (min-max))	21 (18-22)	20 (18-23)	0.514 ^a
Gender n (%)			
Male	30 (75)	10 (25)	0.556 ^b
Female	19 (65.5)	10 (34.5)	
BMI n (%)			
Underweight	2 (66.7)	1 (33.3)	0.305 ^c
Normal	23 (63.9)	13 (36.1)	
Overweight	11 (91.7)	1 (8.3)	
Obese 1	10 (71.4)	4 (28.6)	
Obese 2	3 (75)	1 (25)	
Physical Activity n (%)			
Low	15 (62.5)	9 (37.5)	0.390 ^b
Moderate	34 (75.6)	11 (24.4)	

Note: ^aMann-Whitney test, ^bChi-square test, ^cFischer's exact test

The occurrence of vascular stiffness differs between males and females due to hormonal differences. After puberty, arterial increases in males and decreases in females (DuPont et al., 2019). This circumstance is attributed to the high estrogen levels in females, which enhance nitric oxide (NO) production. A decline in estrogen levels resulting from reduced ovarian function during postmenopause may diminish these beneficial effects of estrogen, ultimately contributing to arterial stiffness mechanisms and increasing cardiovascular risk (Lan et al., 2019). In this study, no differences in gender were noticed between groups with varying levels of vascular elasticity ($p = 0.556$). Therefore, it can be inferred that gender does not influence vascular elasticity in this study.

High levels of physical activity can reduce arterial stiffness risk. Physical activity lowers fat mass, which inhibits the secretion of a range of inflammatory mediators including tumor necrosis factor (TNF)- α , interleukin (IL)-6, and IL-1 β . Furthermore, physical activity enhances blood circulation and promotes the release of the vasodilator NO, which protects the endothelium (Li et al., 2023). However, in this study, physical activity levels did not differ significantly among groups with different vascular elasticity ($p = 0.390$). Thus, it can be concluded that physical activity does not influence vascular elasticity in this study.

Body mass index (BMI) is correlated with increased arterial stiffness though it does not independently predict arterial stiffness (Tang et al., 2020). Obesity accelerates arterial stiffness

progression through various pathways, including insulin resistance and inflammation. Elevated levels of circulating inflammatory cytokines derived from adipocytes can negatively affect vascular insulin sensitivity and promote pro-inflammatory immune cell recruitment and activation in the vasculature, contributing to arterial stiffness development (Aroor et al., 2018). This study identified no differences in BMI between groups with varying vascular elasticity ($p = 0.305$). Therefore, it can be concluded that BMI does not influence vascular elasticity in this study.

Table 2 demonstrates a significant difference in vascular elasticity between the normal fasting blood glucose and the prediabetes groups ($p = 0.009$). Subjects in the prediabetes group were 1.6 times more likely to exhibit suboptimal vascular elasticity in comparison to those with normal fasting blood glucose. This finding is consistent with a meta-analysis and a systematic review of 37 studies. Seven of these studies, which compared cf-PWV (carotid-femoral pulse wave velocity) between non-diabetic (non-DM) and prediabetic subjects, found that prediabetic subjects exhibited higher vascular stiffness than non-DM subjects (Liang et al., 2024). Similar results were observed in a study conducted at Tangdu Hospital, China, involving 207 prediabetic subjects and 130 healthy or non-DM subjects as the control group. Ultrasonic measurements of vascular stiffness were used to assess carotid-femoral PWV, brachial-radial PWV, and ankle-femoral PWV. The overall results indicated that prediabetic individuals had higher cf-PWV values than non-DM individuals (Liang et al., 2023).

Table 2. Vascular Elasticity in the Prediabetes and Normal Fasting Blood Glucose Groups

Group	Vascular Elasticity						PR (95% CI)	p- value
	Suboptimal		Normal+ Optimal		Total			
	n	%	n	%	n	%		
Prediabetes	28	84.8	5	15.2	33	100	1.608	0.009
Normal	19	52.8	17	47.2	36	100	(1.143-2.261)	

Several potential mechanisms by which hyperglycemia affects vascular stiffness include: 1) deposition of advanced glycation end products (AGEs) on the arteries, a biochemical process that involves glycosylation of the vascular wall; 2) the genesis of cross-link between collagen molecules, resulting in the loss of collagen elasticity; and 3) the thinning of elastin fibers, which results in increased arterial stiffness. Additionally, AGEs can interact with receptors, inducing intracellular signaling through increased oxidative stress, triggering inflammatory processes, and ultimately contributing to increased arterial stiffness. Insulin resistance further exacerbates this condition by hyperinsulinemia, promoting collagen deposition, smooth muscle cell proliferation, and, consequently, increased arterial stiffness (Liang, et al., 2024).

Table 3. Vascular Elasticity in the Prehypertension and the Normal Blood Pressure Groups

Group	Vascular Elasticity						PR (95% CI)	p-value
	Suboptimal		Normal+ Optimal		Total			
	n	%	n	%	n	%		
Prehypertension	30	81.1	7	18.9	37	100	1.526	0.026
Normal	17	53.1	15	46.9	32	100	(1.064-2.189)	

Table 3 shows the difference in vascular elasticity between the prehypertension and normal blood pressure groups ($p = 0.026$). Subjects in the prehypertension group had a 1.5-fold increased risk of having suboptimal vascular elasticity compared to those with normal blood pressure. Similar findings were reported in a study conducted at the Government Medical College, India, where pulse wave velocity values were elevated in the prehypertension group compared to the normal blood pressure group (Solanki et al., 2024).

The prolonged elevation of blood pressure stimulates extracellular matrix production, resulting in the reorganization of the spatial arrangement of the extracellular matrix and

vascular smooth muscle cells (VSMCs). This process results in the thickening of vascular and increased arterial stiffness. Chronic high blood pressure can damage the arterial walls through mechanical stress, oxidative stress, increased inflammation, dysfunction of the endothelium, and activation of the renin-angiotensin-aldosterone system (RAAS). Additionally, hypertension accelerates the degradation of elastin fibers and increases collagen fiber production. Stiff arteries raise systolic blood pressure and pulse pressure. Furthermore, the subsequent increase in systolic pressure induces arterial stiffening, promoting a detrimental cycle of inflammation and calcification (Kim, 2023).

The result of the Chi-square test identified a significant difference in vascular elasticity between subjects with both prehypertension and prediabetes and those with normal blood pressure and fasting blood glucose levels ($p = 0.002$) (Table 4). Subjects in the prehypertension+prediabetes group had a 3.5-fold higher likelihood of experiencing suboptimal vascular elasticity than subjects with normal blood pressure and fasting blood glucose. These findings align with a study conducted at the Zagreb-West Health Center on subjects with a median age of 54, which demonstrated a significant association between prediabetes and prehypertension with vascular elasticity. In that study, vascular elasticity was measured using PWV, fasting blood glucose was measured with a glucometer, and blood pressure was assessed using a sphygmomanometer with 24-hour ambulatory blood pressure monitoring (Jug & Prkačin, 2023). A similar study evaluating vascular stiffness in young adult subjects with metabolic syndrome, including hyperglycemia and increased blood pressure, also showed increased vascular elasticity, with cf-PWV results higher in that group (Agbaje, 2023).

Table 4. Vascular Elasticity in the Prediabetes+Prehypertension and the Normal Blood Pressure and Fasting Blood Glucose Groups

Group	Vascular Elasticity						PR (95% CI)	p-value
	Suboptimal		Normal+ Optimal		Total			
	n	%	n	%	n	%		
Prediabetes+ Prehypertension	13	86.7	2	13.3	15	100	3.467 (1.450-8.288)	0.002
Normal	4	25	12	75	16	100		

It can be stated that prediabetes and prehypertension are risk factors for arterial stiffness due to increased collagen deposition and elastin degradation. Additionally, RAAS activation contributes to structural alterations in the arterial wall by promoting the proliferation of VSMCs, triggering inflammation, increasing collagen production, and facilitating the formation of AGEs. Chronic exposure to hyperglycemia also induces the proliferation of VSMCs and increases AGEs and collagen cross-linking, leading to the arterial wall's stiffening. Furthermore, matrix metalloproteinases (MMP)-2 and MMP-9 expression and angiotensin II receptors in vascular tissue are elevated. Insulin resistance stimulates the synthesis of collagen and increases several gene expressions involved in inflammatory processes, ultimately leading to vascular stiffness (Lacolley et al., 2020).

The study indicated that those with prediabetes, prehypertension, or both conditions exhibited significantly reduced vascular elasticity compared to individuals with normal fasting blood glucose and blood pressure. These findings indicate the presence of early subclinical alterations in vascular function, which may predispose affected individuals to long-term cardiovascular complications.

The results have important implications for public health strategies aimed at preventing non-communicable diseases. Early identification and lifestyle intervention in individuals exhibiting preclinical metabolic changes may help mitigate future cardiovascular risk and reduce the burden on healthcare systems. The study supports the integration of vascular health

assessments into routine medical check-ups, particularly among young adults who may be asymptomatic yet already progressing toward cardiovascular disease.

Despite following established methodologies, this study has several limitations. First, its cross-sectional design precludes causal inferences between metabolic status and vascular elasticity. Second, the sample consisted solely of medical students, which may limit the generalizability of the findings to the broader young adult population. Additionally, unmeasured factors such as dietary habits, stress levels, and sleep quality may have influenced the observed associations.

Future studies are encouraged to utilize longitudinal designs to determine causal relationships and monitor the progression of vascular stiffness over time in individuals with prediabetes and prehypertension. Expanding the sample to include non-medical populations would improve the generalizability of the findings. Furthermore, investigating the potential reversibility of early vascular changes through targeted lifestyle or pharmacological interventions could provide valuable insights for preventive healthcare.

4. CONCLUSION

This study reveals a significant association between prediabetes and prehypertension with reduced vascular elasticity. Individuals with prediabetes had a 1.6-fold greater risk of having suboptimal vascular elasticity than those with normal fasting blood glucose levels. Similarly, individuals with prehypertension had a 1.5-fold greater risk than those with normal blood pressure. Notably, individuals with both prediabetes and prehypertension faced a 3.5-fold greater risk of suboptimal vascular elasticity compared to those with normal fasting glucose and blood pressure.

These findings underscore the importance of early identification and intervention in individuals with preclinical metabolic alterations. To maintain vascular elasticity and reduce long-term cardiovascular risk, individuals with prediabetes, prehypertension, or both are strongly encouraged to adopt a healthy lifestyle. This includes engaging in regular physical activity and limiting the consumption of foods high in sugar and salt.

REFERENCES

- Agbaje, A. O. (2023). Arterial stiffness preceding metabolic syndrome in 3,862 adolescents: a mediation and temporal causal longitudinal birth cohort study. *American Journal of Physiology - Heart and Circulatory Physiology*, 324(6), H905-H911. <https://doi.org/10.1152/ajpheart.00126.2023>
- Alghamdi, Y. A., Al-Shahrani, F. S., Alanazi, S. S., Alshammari, F. A., Alkhudair, A. M., & Jatoi, N.-A. (2021). The association of blood glucose levels and arterial stiffness (cardio-ankle vascular index) in patients with type 2 diabetes mellitus. *Cureus*, 13(12), e20408. <https://doi.org/10.7759/cureus.20408>
- Aroor, A. R., Jia, G., & Sowers, J. R. (2018). Cellular mechanisms underlying obesity-induced arterial stiffness. *American Journal of Physiology - Regulatory Integrative and Comparative Physiology*, 314(3), R387-R398. <https://doi.org/10.1152/AJPREGU.00235.2016>
- Bawazier, L. A., Buntaran, S., Sianipar, W., & Kekalih, A. (2019). Blood Pressure Profile of Young Adults at the Faculty of Medicine Universitas Indonesia. *Acta Medica Indonesiana*, 51(1), 54-58. Retrieved from: <https://www.actamedindones.org/index.php/ijim/article/view/856>
- DuPont, J. J., Kenney, R. M., Patel, A. R., & Jaffe, I. Z. (2019). Sex differences in mechanisms of arterial stiffness. *British Journal of Pharmacology*, 176(21), 4208-4225. <https://doi.org/10.1111/bph.14624>
- Firmino, S. M., Goulart, C. D. L., Gregorio, J. P., Wende, K. W., Yuamoto, F. Y., Kummer, L., ... & Roscani, M. G. (2023). Discriminative value of pulse wave velocity for arterial

- stiffness and cardiac injury in prediabetic patients. *Jornal Vascular Brasileiro*, 22, e20230076. <https://doi.org/10.1590/1677-5449.202300762>
- Jeyashree, P., Dilara, K., Maruthy, K., & Dhamodhini, K. (2024). Comparison of Arterial Stiffness among Prehypertensive and Normotensive Subjects using Photo Pulse Plethysmography: A Pilot Study. *Journal of Clinical and Diagnostic Research*, 18(3), 1-4. <https://doi.org/10.7860/jcdr/2024/67377.19131>
- Jug, J., & Prkačin, I. (2023). Arterial stiffness in prehypertensive patients with prediabetes - a pilot study. *Journal of Hypertension*, 41(Suppl 3), e278. <https://doi.org/10.1097/01.hjh.0000941884.90100.31>
- Keating, X. D., Zhou, K., Liu, X., Hodges, M., Liu, J., Guan, J., Phelps, A., & Castro-Piñero, J. (2019). Reliability and concurrent validity of global physical activity questionnaire (GPAQ): A systematic review. *International Journal of Environmental Research and Public Health*, 16(21), 4128. <https://doi.org/10.3390/ijerph16214128>
- Kim, H. L. (2023). Arterial stiffness and hypertension. *Clinical Hypertension*, 29(1), 1-9. <https://doi.org/10.1186/s40885-023-00258-1>
- Kumalasari, K., Putri, T. R., Fatmasari, G., Aliffa, E. J., Kholizah, A., & Kurniawati, D. O. (2023). Pengaruh pola makan yang tidak teratur terhadap kesehatan mahasiswa universitas negeri semarang rombels 2b program studi kesehatan masyarakat. *Jurnal Analis*, 2(1), 62-72. Retrieved from: <https://jurnalilmiah.org/journal/index.php/analisis/article/view/591>
- Lacolley, P., Regnault, V., & Laurent, S. (2020). Mechanisms of arterial stiffening: from mechanotransduction to epigenetics. *Arteriosclerosis, Thrombosis, and Vascular Biology*, 40(5), 1055-1062. <https://doi.org/10.1161/ATVBAHA.119.313129>
- Lan, Y., Liu, H., Liu, J., Zhao, H., & Wang, H. (2019). Gender difference of the relationship between arterial stiffness and blood pressure variability in participants in prehypertension. *International Journal of Hypertension*, 2019. <https://doi.org/10.1155/2019/7457385>
- Li, X., Chattopadhyay, K., Chen, X., Li, J., Xu, M., Chen, X., & Li, L. (2023). Association between physical activity and arterial stiffness in patients with type 2 diabetes in ningbo, china: a cross-sectional study. *Diabetes, Metabolic Syndrome and Obesity*, 16(December), 4133–4141. <https://doi.org/10.2147/DMSO.S438344>
- Liang, X., Li, D., Wang, Z., Cheng, Y., Mou, K., Ye, C., Duan, Y., & Yang, Y. (2024). Aortic stiffness measured by carotid femoral-pulse wave velocity at different stages of normal glucose, prediabetes, and diabetes mellitus: a systematic review and meta-analysis. *Reviews in Cardiovascular Medicine*, 25(9), 339. <https://doi.org/10.31083/j.rcm2509339>
- Liang, X., Yang, Y., Wang, Z., Wang, X., Jingxi, D., Chaohui, H., & Duan, Y. (2023). Investigation of arterial stiffness and its influencing factors in prediabetic population. *Chinese Journal of Ultrasound Imaging*, 32(2), 117–122. <https://doi.org/10.3760/cma.j.cn131148-20220803-00535>
- Murakami, T., Asai, K., Kadono, Y., Nishida, T., Nakamura, H., & Kishima, H. (2019). Assessment of arterial stiffness index calculated from accelerated photoplethysmography. *Artery Research*, 25(1–2), 37–40. <https://doi.org/10.2991/artres.k.191120.001>
- PERKENI. (2021). *Pedoman Pengelolaan dan Pencegahan Diabetes Melitus Tipe 2 Dewasa di Indonesia 2021*. Jakarta: PERKENI.
- Rafan, S. N. H., Zakaria, R., Ismail, S. B., & Muhamad, R. (2018). Prevalence of prehypertension and its associated factors among adults visiting outpatient clinic in Northeast Malaysia. *Journal of Taibah University Medical Sciences*, 13(5), 459–464. <https://doi.org/10.1016/j.jtumed.2018.06.005>

- Rooney, M. R., Fang, M., Ogurtsova, K., Ozkan, B., Echouffo-Tcheugui, J. B., Boyko, E. J., Magliano, D. J., & Selvin, E. (2023). Global prevalence of prediabetes. *Diabetes Care*, 46(7), 1388–1394. <https://doi.org/10.2337/dc22-2376>
- Rubio-Guerra, A. F., Garro-Almendaro, A. K., Lozano-Nuevo, J. J., Arana-Pazos, K. C., Duran-Salgado, M. B., & Morales-López, H. (2018). Prehypertension is associated with peripheral arterial disease and low ankle-brachial index. *Indian Heart Journal*, 70(4), 502–505. <https://doi.org/10.1016/j.ihj.2017.11.013>
- Solanki, J. D., Vohra, A. S., Hirani, C. N., & Bhatt, D. N. (2024). Arterial stiffness is associated with prehypertension in both non-hypertensives and treated hypertensives – A matched case control study. *Indian Heart Journal*, 76(3), 224–228. <https://doi.org/10.1016/j.ihj.2024.06.007>
- Sudikno, S., Mubasyiroh, R., Rachmalina, R., Arfines, P. P., & Puspita, T. (2023). Prevalence and associated factors for prehypertension and hypertension among Indonesian adolescents: a cross-sectional community survey. *BMJ Open*, 13(3), 1–13. <https://doi.org/10.1136/bmjopen-2022-065056>
- Száló, G., Hellgren, M., Allison, M., Råstam, L., Lindblad, U., & Daka, B. (2021). Longitudinal association between leisure-time physical activity and vascular elasticity indices. *BMC Cardiovascular Disorders*, 21(1), 1–8. <https://doi.org/10.1186/s12872-021-01911-z>
- Tang, B., Luo, F., Zhao, J., Ma, J., Tan, I., Butlin, M., Avolio, A., & Zuo, J. (2020). Relationship between body mass index and arterial stiffness in a health assessment Chinese population. *Medicine (United States)*, 99(3), pe18793, January 2020. <https://doi.org/10.1097/MD.00000000000018793>
- 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., & Schutte, A. E. (2020). 2020 International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension*, 75(6), 1334–1357. <https://doi.org/10.1161/HYPERTENSIONAHA.120.15026>
- Vatner, S. F., Zhang, J., Vyzas, C., Mishra, K., Graham, R. M., & Vatner, D. E. (2021). Vascular Stiffness in Aging and Disease. *Frontiers in Physiology*, 12(December), 1–21. <https://doi.org/10.3389/fphys.2021.762437>
- Wijaya, A., Wande, N., & Wirawati, I. A. P. (2019). Hubungan lingkar perut dengan kadar gula darah puasa pada mahasiswa Fakultas Kedokteran Universitas Udayana angkatan 2014. *Intisari Sains Medis*, 10(2), 279–283. <https://doi.org/10.15562/ism.v10i2.191>