Trends in Clinical and Medical Sciences

PSR Press

Original Research Article

An observational study of uric acid, dyslipidaemia and BMI as risk factors in young hypertensives

Yadavendra C Reddy[1] and Veeranna Addanki[2,*]

[1] Associate Professor, Department of Medicine, MRIMS Suraram, Hyderabad, Telangana, India.
[2] Assistant Professor, Department of Medicine, ESIC Medical College, Sanathnagar, Hyderabad, Telangana, India.
* Correspondence: chamareddy_07@yahoo.com

Received: 22 September 2022; Accepted: 1 March 2023; Published: 15 April 2023.

Abstract: Background: Hypertension is a major cause of death worldwide. The increasing prevalence of hypertension in young individuals is a warning sign of the impending cardiovascular, cerebrovascular, and renal diseases in the future. Hypertension affects 1 in 8 adults between the ages of 20 and 40 years and this number is likely to increase with unhealthy lifestyle behaviors and the lowering of hypertension diagnostic thresholds. Although the mechanisms are unclear, early-life factors have been found to influence blood pressure (BP), and BP tracks strongly within individuals from adolescence through to later life. Higher BP at a young age is associated with abnormalities on heart and brain imaging and increases the likelihood of cardiovascular events by middle age. However, young patients often have lower diagnosis rates, and their treatment is often delayed.
Methods: This prospective observational study was conducted from January 2021 to March 2021 in a tertiary care hospital. A total of 50 cases, male and female, were studied based on inclusion and exclusion criteria. Routine investigations were done on all patients, and uric acid and lipid profiles were sent to evaluate the association. Patients' height and weight were recorded to calculate BMI. Patients below 12 years, pregnant women, and patients with previous cardiovascular and secondary causes of hypertension were excluded from the study. The study was carried out in all patients who fulfilled the inclusion and exclusion criteria.
Results: During the study period, a total of 50 patients (27 females and 23 males) were included. Our study revealed a female preponderance in the ratio of 1:1.1. More patients were in the age group of 40-45 years. Overweight was significantly noted with BMI >25 in 30 patients and >30 in 10 patients. Uric acid was significantly increased in 27 patients. Lipid abnormalities were noted: LDL increased in 30 patients, TGL increased in 32 patients, HDL increased in 20 patients, Total Cholesterol in 25 patients, and VLDL increased in 25 patients.
Conclusions: Our study showed that BMI was significantly higher in hypertensive patients. Furthermore, lipid abnormalities were present in overweight patients, contributing to hypertension. Although uric acid was elevated in a significant number of patients, it did not emerge as a risk factor in young hypertensives. We recommend a healthy lifestyle and a disciplined diet to avoid the hazards of hypertension.

Keywords: Hypertension; Young adults; BMI; Lipid abnormalities; Uric acid.

1. Introduction

Hypertension, often accompanied by other factors such as dyslipidemia and increased uric acid, is a major contributor to cardiovascular diseases, accounting for more than 80% of deaths and disability in developing countries [1,2]. Hypertension is also the most common and reversible risk factor for various cardiovascular conditions such as myocardial infarction, stroke, heart failure, atrial fibrillation, peripheral arterial disease, and cognitive decline. The global burden of hypertension is expected to affect approximately one-third of the world's population, primarily due to escalating obesity and population aging [2].

The prevalence of hypertension is rapidly increasing in developing countries, where poor hypertension treatment and control contribute to the growing epidemic of cardiovascular diseases [2]. Recent urbanization, unhealthy diet, and lifestyle changes have led to an increased rate of cardiovascular diseases in Southeast Asia [3].

Numerous epidemiological studies have established a strong association between hypertension, coronary artery disease, and chronic kidney disease, and the risk is further exacerbated by increased levels of LDL, total cholesterol, and triglycerides. Conversely, low levels of HDL are a risk factor for mortality from cardiovascular diseases [1–3].

Hypertension is also prevalent among young people, affecting one in eight adults aged between 20 and 40 years, and this number is likely to increase with unhealthy lifestyle behaviors and the lowering of hypertension diagnostic thresholds. Blood pressure in adulthood may also be influenced by factors occurring many years earlier, as proposed by the developmental origins of health and disease hypothesis [4,5]. While fetal growth restriction may play a role, other factors such as genetic and environmental influences are likely to be more significant [6]. This is supported by studies demonstrating higher blood pressure in adolescents whose mothers had experienced hypertensive disorders during pregnancy [7–9].

Long-term studies have consistently shown an increased risk of cardiovascular disease and mortality in young people with hypertension [10–12]. The CARDIA longitudinal study has played an important role in investigating the contribution of early-life risk factors to the development of coronary heart disease in later life. This study followed a cohort of 5,115 young adults in the United States aged 18 to 30 years and showed that elevated blood pressure at baseline was a stronger predictor of coronary artery calcium 15 years later than the risk factor profile at the point of follow-up [11,13].

Data from the National Health and Nutrition Examination Survey (NHANES) conducted between 2003-2010 revealed that over half of the US adults aged 18 years and older with hypertension were unaware of their condition, and more than 30% of them had uncontrolled hypertension [14].

1.1. Hypertension and lipid profile

Hypertension and dyslipidaemia are recognized as significant risk factors for cardiovascular disease. The coexistence of these conditions is frequently observed in clinical practice, and this finding is consistent with the baseline characteristics of study participants in clinical research [15–18]. Population-based epidemiological studies have also revealed that gradual increases in blood pressure or prevalence of hypertension are associated with increased blood lipid levels [19–21]. One possible explanation for this relationship is that hypertension and dyslipidaemia share common pathophysiological mechanisms, such as obesity and the resulting dysregulation of adipocytokine release from adipose tissue [22].

Moreover, dyslipidaemia has been shown to adversely affect the functional and structural properties of arteries and promote atherosclerosis [23–25]. These changes may impair BP regulation, which, in turn, predisposes individuals with dyslipidaemia to the development of hypertension.

The co-occurrence of dyslipidaemia and hypertension cannot be explained by chance alone; however, the precise nature of this relationship remains unclear. Atherogenic dyslipidaemias may lead to hypertension through several mechanisms. For instance, atherosclerosis can lead to structural changes in large conduit arteries, resulting in reduced elasticity [18]. Endothelial dysfunction due to lipid abnormalities [19–21] resulting in reduced nitric oxide production, release, and activity and abnormal vasomotor activity, could also contribute to the development of hypertension [22]. Elevated total cholesterol levels impair endothelium-dependent vasodilation [23]. Lipid-mediated damage to the renal microvasculature could also result in hypertension, as shown by an association between lipid abnormalities and early renal dysfunction [24]. Finally, dyslipidaemia and hypertension represent two of several components of the metabolic syndrome that may share common mechanistic pathways [25,26].

Recent studies suggest that routine lipid profiles reported by hospital laboratories may not substantially differ between patients with CVD and healthy individuals. Evaluating subfractions/subpopulations of individual lipoproteins is more likely to be relevant. LDL and HDL particles are known to be heterogeneous, with subfractions defined based on particle size and density. Based on gel electrophoresis, LDL particles have been classified into seven subfractions (LDL 1-7), while at least ten subfractions of HDL exist (HDL 1-10), although more recent methods permit the differentiation of up to 26 subfractions.

The anti-atherosclerotic effects of HDL seem to be mediated by two subfractions, namely HDL 2 and 3, which are known as the large particle HDL subpopulation [3]. The heterogeneity of LDL and HDL particles is also associated with their various levels of bioactivity. Subfractions LDL 1 and 2, which are large LDL particles, have been associated with only a moderate risk of CVD, whereas small dense LDL (sdLDL)

subfractions (LDL 3-7) increase the risk up to fourfold [27–29]. The subfraction of larger HDL particles (HDL 2) may be responsible for the clinically beneficial effects that have been generally associated with HDL cholesterol [3]. On the other hand, the HDL 3 subfraction, and mostly other subpopulations of smaller HDL particles (intermediate and small HDL), may even have an undesirable atherogenic effect without inhibiting inflammation - although there are still many conflicting results on this issue.

The described biological differences are likely to be the result of the fact that sdLDLs (subpopulations 3-7) can easily penetrate vascular walls, undergo oxidation, and have a lower affinity for the LDL receptor. Conversely, small dense HDL particles contain scarcely any apolipoproteins (Apo) AI and AII, are less effective in the reverse cholesterol transport from peripheral tissues to the liver, and may be catabolized more rapidly, losing their endothelium-protective properties.

Several processes may be involved in structural and functional changes in LDL and HDL, with inflammation and oxidative stress, which often accompany atherosclerotic CVD, being particularly important. A shift in the balance in favor of one LDL or HDL atherogenic subfraction can play a role in the development of obesity, metabolic syndrome, insulin resistance, and consequently, diabetes mellitus [30–33], as well as in the development of hypertension.

If dyslipidemia is causally associated with the development of hypertension, evaluating the lipid profile in normotensive patients would allow early targeted pharmacological intervention in susceptible patients. This approach could extend the time period before hypertension develops or avoid hypertension (and its associated complications) altogether. This approach would likely result in substantial gains in public health since hypertension is one of the greatest epidemiological challenges in Poland, Europe, and around the world.

Based on data from the NATPOL 2011 and POLSENIOR 2011 registries, nearly 11 million people are affected by hypertension in Poland, and in the elderly population, this percentage can be as high as 75%. Moreover, hypertension is still undiagnosed in 30% of affected patients and ineffectively treated in 36% of cases.

1.2. BMI and Hypertension

Due to industrialization and urbanization, the standard of living continues to rise, particularly in developing countries. This has led to weight gain and obesity, which pose a threat to the health of citizens. Obesity is perhaps the most prevalent form of malnutrition in developing countries, affecting both adults and children. Studies have demonstrated that obesity is related to elevated systolic and diastolic blood pressure, dyslipidaemia, and diabetes [34–36].

Obesity and its associated health consequences, along with the consequent health burden, are expected to reach epidemic proportions in developing countries like India [37]. A study in Delhi revealed an even higher prevalence (32-50%) of overweight (BMI > 25) among adults belonging to high-income groups compared to 16.2-20% in those belonging to middle-income groups.

BMI, calculated as weight in kg/height in meters squared, is widely used to estimate the prevalence of obesity or underweight within a population. The relationship between BMI and blood pressure has also been reported among Asian populations. India, in the process of rapid economic development and modernization with changing lifestyle factors, has an increasing trend of hypertension, especially among the urban population.

From a public health perspective, it is important to have data on the characteristics and health of a population and its subgroups because of racial/ethnic disparities in terms of long-term health consequences. It is necessary to identify individuals and populations at risk.

Several studies have been conducted in different parts of India on factors affecting cardiovascular functions [38]. Obesity or excess relative weight is found to be associated with an increased risk of disease morbidity and mortality [39]. BMI is widely accepted as one of the best indicators of nutritional status in adults [40–43]. The importance of BMI and skinfolds has been recognized for estimating cardiovascular disease risk factors, particularly due to their positive association with hypertension [44]. Linear regression showed that BMI and waist circumference are important predictors of hypertension [45]. Many investigators have previously reported a significant positive correlation between BMI and SBP and DBP [46–51].

1.3. Hypertension and uric acid

Hypertension in adults is the most common form of cardiovascular diseases. The prevalence of hypertension grows higher with aging, resulting in an increase in morbidity and mortality through various events such as myocardial infarction, heart failure, stroke, and renal failure.

Hyperuricemia has been proposed to have an association with hypertension in various studies. Serum uric acid (UA) levels were demonstrated to be an independent predictor for developing hypertension. Regardless of the different ethnic origins, a continuous relationship between serum UA and blood pressure was observed in African-American and whites as well as in Asians including Koreans.

Hypertension is the leading cause of premature death and cardiovascular diseases (CVD) worldwide. The prevalence of CVD and hypertension has not decreased throughout the last decades, and CVD is still responsible for nearly 33% of all global deaths.

The first report of the association between serum UA (SUA) and hypertension dates back to 1879, by Frederick Akbar Mahomed [52]. Since then, numerous studies have confirmed this strong association [53–69]. Several mechanisms have been proposed to explain the potential role of SUA in the development of hypertension, including UA-mediated kidney afferent arteriolopathy, renin-angiotensin-aldosterone system (RAAS) activation, oxidative stress, inflammation, and endothelial dysfunction [70–82]. However, the precise pathophysiologic patterns remain elusive.

For determining the causal role of serum UA in the development of hypertension, Mazzali et al. [70] demonstrated an elevation in serum UA followed by an increase in BP via a crystal independent mechanism in rat models. Reduction of serum uric acid was associated with a decrease in BP through the regulation of renin-angiotensin and nitric oxide system.

2. Methods

The present prospective observational study was conducted in the Department of General Medicine at ESIC MCH from January 2021 to March 2021. A total of 50 cases of young hypertensives were studied during this period, based on predefined inclusion and exclusion criteria. All patients underwent routine investigations such as complete blood count, lipid profile, and serum electrolyte levels. Additionally, special investigations, including uric acid, were conducted in all enrolled patients. The patients' body mass index (BMI) was measured by recording their weight and height simultaneously.

2.1. Inclusion Criteria

1. All young hypertensives less than 45 years of age.
2. All newly detected hypertensives.

2.2. Exclusion Criteria

1. Patients less than 12 years of age.
2. Pregnant women.
3. All young hypertensives with previously diagnosed cases of secondary hypertension.
4. All young hypertensives with a previous history of CAD, CKD, etc.

The statistical software SPSS was used to analyze the data, while Microsoft Word and Excel were used to generate graphs and figures.

3. Results

In this prospective observational study, a total of 50 young hypertensive cases were enrolled in the Department of General Medicine at ESIC MCH from January 2021 to March 2021, based on pre-defined inclusion and exclusion criteria. Routine investigations such as complete blood count, lipid profile, and serum electrolytes were conducted in all patients, while special investigations like uric acid were performed only in enrolled patients. BMI was calculated by measuring weight and height simultaneously.

Of the enrolled patients, 23 (46%) were male and 27 (54%) were female, with a female preponderance. The majority of patients (46%) were in the age group of 40-45 years, followed by 18% in the age group of 35-40 years. BMI was normal in only 20% of patients, while 60% were overweight (BMI > 25) and 20% were obese (BMI >

30). Increased uric acid levels were observed in 54% of patients. Lipid profile analysis showed increased levels of triglycerides and LDL in 64% and 60% of patients, respectively. Total cholesterol was increased in 50% of patients, while VLDL and HDL were increased in 50% and 40% of patients, respectively.

Figure 1 shows the female preponderance with a ratio of females to males of 1:1.1. Figure 2 depicts the age distribution of young hypertensives, with the highest number of patients in the age group of 40-45 years. Figure 3 displays the distribution of BMI among young hypertensives. Figure 4 depicts the percentage of patients with elevated uric acid levels. Figure 5 shows the variations in lipid profile among young hypertensives.

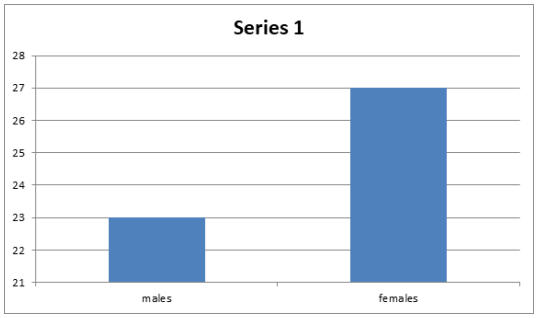

Figure 1. Gender Distribution

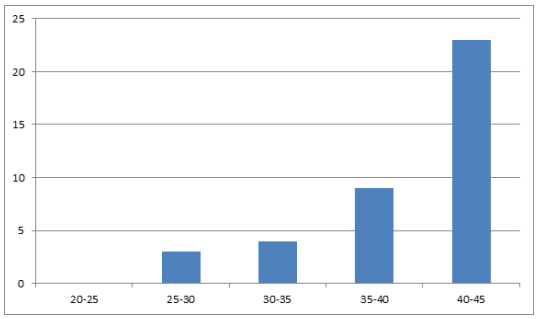

Figure 2. Age Group

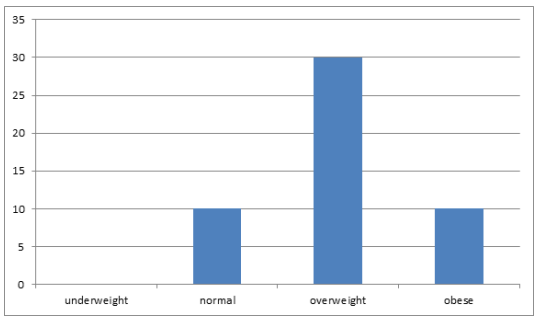

Figure 3. BMI

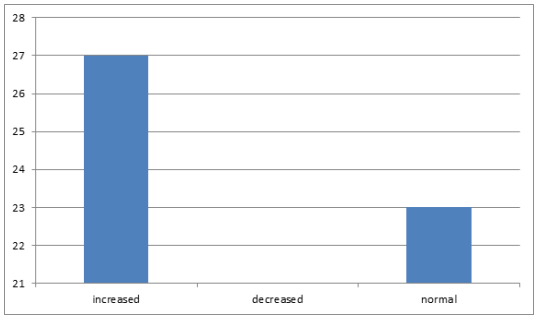

Figure 4. Uric acid levels

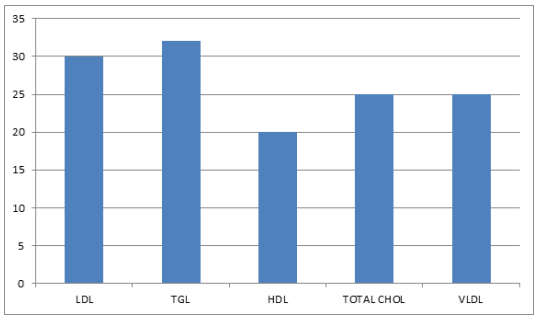

Figure 5. Lipid levels

4. Discussion

Hypertension is a well-known global risk factor for cardiovascular diseases, stroke, diabetes, and renal diseases, affecting about 80% of hypertensive persons with comorbidities like obesity, glucose intolerance, and abnormalities in lipid metabolism, among others.

The present study aimed to investigate the association between hypertension in young individuals and lipid profile, BMI, and uric acid levels at ESIC Medical College and Hospital, Sanathnagar. The study population consisted of 50 individuals, and the results showed that females constituted the majority (54%) compared to males. The highest number of patients was in the age group of 40-45 years (46%) followed by the age group of 35-40 years (18%).

The study also assessed the lipid profile of the participants, revealing that TGL and LDL levels were increased in 32 (64%) and 30 (60%) patients, respectively. Total cholesterol was increased in 25 patients (50%), VLDL in 25 patients (50%), and HDL in 20 patients (40%).

A study conducted by Piotr Chru'scie et al. [84] showed a positive correlation between the total HDL and HDL-3 concentrations with a tendency to develop hypertension. However, this finding may seem surprising considering the definition of metabolic syndrome, in which increased blood pressure often coexists with lipid metabolism disorders, such as increased fasting triglycerides and decreased HDL cholesterol concentrations.

On the other hand, several studies have suggested that in healthy individuals, different risk factors, including obesity, smoking, diabetes, and hypertension, might impair HDL functions and increase the level of large (including HDL 3) and intermediate HDL, which might have a pro-atherogenic effect. Therefore, the observed increase in HDL-C should not be considered a potentially protective effect in those patients.

Furthermore, BMI was evaluated in the study population, and the findings revealed that 10 (20%) patients had normal BMI, while 30 (60%) were overweight with BMI over 25, and 10 (20%) had obesity with BMI over 30.

A long-term prospective study, The John Hopkins Precursors Study, reported that men who were overweight or obese in early adulthood or middle age were at higher risk of developing hypertension later in life. Even after accounting for changes in lifestyle factors over the life course, overweight or obese men were consistently at higher risk of hypertension. Obesity in young adulthood conferred a 3-fold risk of hypertension, while men who were of normal weight in early adulthood but who became overweight or obese in midlife were twice as likely to develop hypertension as men who maintained a normal weight.

This study examined young adults and tracked their body weight and blood pressure through middle age, drawing strength from very high response rates, adjudication of incident hypertension diagnosis, and repeated measures of blood pressure and lifestyle factors over 46 years. Unlike other studies, individual trajectories of weight over the life course were estimated using random effects models that allowed each person to have their own intercept and slope rather than being assigned a population average.

Uric acid has been shown to play a crucial role in the pathogenesis of hypertension and kidney disease progression. Possible pathophysiological mechanisms involve upregulation of the renin-angiotensin-aldosterone system, kidney afferent arteriolopathy, endothelial dysfunction, oxidative stress, and systemic inflammation.

In our study, uric acid levels were increased in 27 (54%) of patients, as compared to other studies:

Kahn et al., 1972 [83]: 3829 normotensive Israeli men aged 40 years or older at enrollment for 5 years. Serum uric acid was significantly associated with the incidence of hypertension. Selby et al., 1990 [4]: 1900 hypertensive and 950 normotensive American multi-ethnic cohort for 6 years. Serum uric acid was an independent risk factor for the development of hypertension. Hunt et al., 1991 [5]: 1482 American adults belonging to 98 multigenerational pedigrees associated with the occurrence of coronary death, stroke death, or hypertension for 7 years. Serum uric acid was associated with an increased risk of hypertension. Jossa et al., 1994 [6]: 619 normotensive Italian men enrolled in the Olivetti Heart Study for 12 years. There was an independent positive association between serum uric acid levels and the development of hypertension. Dyer et al., 1999 [7]: 4195 American black and white adults aged 18-30 years at enrollment in the CARDIA study for 10 years. Serum uric acid was a predictor of the 10-year incidence of hypertension. Taniguchi et al., 2001 [8]: 6356 Japanese men aged 35-60 years without hypertension and diabetes at enrollment for 10 years. Serum uric acid was associated with an increased risk for hypertension after adjustment for known risk factors.

Nakanishi et al., 2003 [9], studied 2,310 Japanese male office workers aged 35-59 years who did not have hypertension, impaired fasting glucose, Type II diabetes, or past history of cardiovascular disease at study entry. After 6 years of controlling for potential predictors of hypertension and diabetes, the relative risk for hypertension compared with quintiles of serum uric acid (SUA) was progressively increased. Nagahama et al., 2004 [10], conducted a study on 4,489 Japanese adults who did not have hypertension and were not currently using antihypertensive medication for three years. They found that hyperuricemia predicted the development of hypertension after multivariate analysis. Sundström et al., 2005 [11], investigated 3,329 Framingham Study participants (mean age 48.7 years; 55.6% women) who were free of hypertension, myocardial infarction, heart failure, renal failure, or gout for four years. They observed that age- and sex-adjusted rates of hypertension incidence increased progressively from 9.8% for the lowest quartile to 15.6% for the top quartile of SUA. Perlstein et al., 2006 [12], studied 2,062 healthy adult men aged 22 years and found that SUA independently predicted the development of hypertension in age-adjusted and multivariable models. Mellen et al., 2006 [13], investigated 9,104 American black and white adults aged 45 to 64 years without hypertension at baseline for nine years. They found that higher serum uric acid was associated with a greater risk of hypertension in the overall cohort after multivariate adjustment.

5. Conclusion

It was observed from the study that BMI was significantly higher in the patients with hypertension. Furthermore, lipid abnormalities were present in overweight patients, contributing to hypertension. Uric acid was elevated in a significant number of patients but could not be identified as a risk factor in young hypertensives. It is advised to maintain a healthy lifestyle and disciplined diet to avoid the hazards of hypertension. Our results may contribute to the accumulation of evidence that dyslipidaemia increases the risk of hypertension in Asian populations. From a clinical perspective, the importance of strict BP management in patients with dyslipidaemia was indicated. Clinical trials that examine whether treatment of dyslipidaemia reduces the risk of developing hypertension are needed to verify the results of this observational study.

Almost one in three adults suffers from hypertension, with an increasing burden of disease worldwide. The most challenging consequence of hypertension is the so-called hypertension-mediated organ damage. It remains partially unexplained why some patients develop hypertension-mediated organ damage and others do not. Apart from efficient BP control strategies, other CV risk factors could play a synergistic effect with hypertension, leading to organ damage and CVD development. One of those CV risk factors is without a

doubt SUA. In fact, UA and hypertension are intimately associated. Several mechanisms for this association have been proposed, including RAAS regulation and systemic endotheliopathy. Anti-hypertensive drugs have been shown to influence SUA levels and, in turn, most hypouricemic agents have demonstrated an effect on BP values. In addition, pharmacological drug classes used to treat other CV risk factors, such as diabetes, have also shown to exert an effect on SUA levels. A holistic approach to preventing and treating CV risk factors appears to be of critical importance. Large controlled studies on the effect of long-term anti-hyperuricemic agents on BP and CV risk reduction are warranted, with a specific focus on the highest risk population, such as patients with gout and high SUA levels.

Conflicts of Interest: The author declares no conflict of interest.

References

[1] Reddy, K. S. (2004). Cardiovascular disease in non-Western countries. *New England Journal of Medicine*, *350*(24), 2438-2440.

[2] Murray, C. J., & Lopez, A. D. (1997). Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. *The Lancet*, *349*(9063), 1436-1442.

[3] Joshi, P., Islam, S., Pais, P., et al. (2007). Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. *Journal of the American Medical Association*, *297*(3), 286-294.

[4] Juonala, M., Magnussen, C. G., Berenson, G. S., et al. (2011). Childhood adiposity, adult adiposity, and cardiovascular risk factors. *New England Journal of Medicine*, *365*, 1876-1885.

[5] Radi, S., Lang, T., Lauwers-Cances, V., Chatellier, G., Fauvel, J. P., Larabi, L., & De Gaudemaris, R. (2004). One-year hypertension incidence and its predictors in a working population: The IHPAF study. *Journal of Human Hypertension*, *18*, 487-494.

[6] Nyamdorj, R., Qiao, Q., Soderberg, S., Pitkaniemi, J., Zimmet, P., Shaw, J., Alberti, G., Nan, H., Uusitalo, U., Pauvaday, V., Chitson, P., & Tuomilehto, J. (2008). Comparison of body mass index with waist circumference, waist-to-hip ratio, and waist-to-stature ratio as a predictor of hypertension incidence in Mauritius. *Journal of Hypertension*, *26*, 866-870.

[7] Lakoski, S. G., Cushman, M., Siscovick, D. S., Blumenthal, R. S., Palmas, W., Burke, G., & Herrington, D. M. (2011). The relationship between inflammation, obesity and risk for hypertension in the Multi-Ethnic Study of Atherosclerosis (MESA). Journal of Human Hypertension, 25, 73-79.

[8] Arici, M., Turgan, C., Altun, B., Sindel, S., Erbay, B., Derici, U., ... Caglar, S. (2010). Hypertension incidence in Turkey (HinT): A population-based study. Journal of Hypertension, 28, 240-244.

[9] Wang, W., Lee, E. T., Fabsitz, R. R., Devereux, R., Best, L., Welty, T. K., & Howard, B. V. (2006). A longitudinal study of hypertension risk factors and their relation to cardiovascular disease: The Strong Heart Study. Hypertension, 47.

[10] Cutler, J. A., Sorlie, P. D., Wolz, M., Thom, T., Fields, L. E., & Roccella, E. J. (2008). Trends in hypertension prevalence, awareness, treatment, and control rates in United States adults between 1988-1994 and 1999-2004. Hypertension, 52, 818-827.

[11] Flegal, K. M., Carroll, M. D., Ogden, C. L., & Curtin, L. R. (2010). Prevalence and trends in obesity among US adults, 1999-2008. JAMA, 303, 235-241.

[12] Chuang, S. Y., Chou, P., Hsu, P. F., Cheng, H. M., Tsai, S. T., Lin, I. F., & Chen, C. H. (2006). Presence and progression of abdominal obesity are predictors of future high blood pressure and hypertension. American Journal of Hypertension, 19, 788-795.

[13] Neser, W. B., Thomas, J., Semenya, K., Thomas, D. J., & Gillum, R. F. (1986). Obesity and hypertension in a longitudinal study of black physicians: The Meharry Cohort Study. Journal of Chronic Diseases, 39, 105-113.

[14] Centers for Disease Control and Prevention (CDC). (2012). Vital signs: Awareness and treatment of uncontrolled hypertension among adults-United States, 2003-2010. MMWR, 61, 703-709.

[15] Nakamura, H., Arakawa, K., Itakura, H., Kitabatake, A., Goto, Y., Toyota, T., ... Ohashi, Y. (2006). Primary prevention of cardiovascular disease with pravastatin in Japan (MEGA study): A prospective randomized controlled trial. The Lancet, 368, 1155-1163.

[16] Yokoyama, M., Origasa, H., Matsuzaki, M., Matsuzawa, Y., Saito, Y., Ishikawa, Y., ... Shirato, K. (2007). Effects of eicosapentaenoic acid on major coronary events in hypercholesterolaemic patients (JELIS): A randomised open-label, blinded endpoint analysis. The Lancet, 369, 1090-1098.

[17] Shepherd, J., Cobbe, S. M., Ford, I., Isles, C. G., Lorimer, A. R., MacFarlane, P. W., ... Packard, C. J. (1995). Prevention of coronary heart disease with pravastatin in men with hypercholesterolemia. West of Scotland Coronary Prevention Study Group. New England Journal of Medicine, 333, 1301-1307.

[18] Kario, K., Saito, I., Kushiro, T., Teramukai, S., Ishikawa, Y., Mori, Y., ... Shimada, K. (2014). Home blood pressure and cardiovascular outcomes in patients during antihypertensive therapy: Primary results of HONEST, a large-scale prospective, real-world observational study. Hypertension, 64, 989-996.

[19] Ebrahim, S., Sung, J., Song, Y. M., Ferrer, R. L., Lawlor, D. A., & Davey Smith, G. (2006). Serum cholesterol, haemorrhagic stroke, ischaemic stroke, and myocardial infarction: Korean national health system prospective cohort study. BMJ, 333, 22.

[20] Elias, P. K., Elias, M. F., D'Agostino, R. B., Sullivan, L. M., & Wolf, P. A. (2005). Serum cholesterol and cognitive performance in the Framingham Heart Study. Psychosomatic Medicine, 67, 24-30.

[21] Freiberg, J. J., Tybjaerg-Hansen, A., Jensen, J. S., & Nordestgaard, B. G. (2008). Nonfasting triglycerides and risk of ischemic stroke in the general population. JAMA, 300, 2142-2152.

[22] Okamura, T., Tanaka, H., Miyamatsu, N., Hayakawa, T., Kadowaki, T., Kita, Y., ... Ueshima, H. (2007). The relationship between serum total cholesterol and all-cause or cause-specific mortality in a 17.3-year study of a Japanese cohort. Atherosclerosis, 190, 216-223.

[23] McGill, J. B., Haffner, S., Rees, T. J., Sowers, J. R., Tershakovec, A. M., & Weber, M. (2009). Progress and controversies: Treating obesity and insulin resistance in the context of hypertension. Journal of Clinical Hypertension (Greenwich), 11, 36-41.

[24] Casino, P. R., Kilcoyne, C. M., Quyyumi, A. A., Hoeg, J. M., & Panza, J. A. (1993). The role of nitric oxide in endothelium-dependent vasodilation of hypercholesterolemic patients. Circulation, 88, 2541-2547.

[25] Creager, M. A., Cooke, J. P., Mendelsohn, M. E., Gallagher, S. J., Coleman, S. M., Loscalzo, J., & Dzau, V. J. (1990). Impaired vasodilation of forearm resistance vessels in hypercholesterolemic humans. Journal of Clinical Investigation, 86, 228-234.

[26] Wilkinson, I. B., Prasad, K., Hall, I. R., Thomas, A., MacCallum, H., Webb, D. J., Frenneaux, M. P., & Cockcroft, J. R. (2002). Increased central pulse pressure and augmentation index in subjects with hypercholesterolemia. Journal of the American College of Cardiology, 39, 1005-1011.

[27] Afonso, L. C., Edelson, G. W., & Sowers, J. R. (1997). Metabolic abnormalities in hypertension. Current Opinion in Nephrology and Hypertension, 6, 219-223.

[28] Gaziano, J. M., Sesso, H. D., Breslow, J. L., Hennekens, C. H., & Buring, J. E. (1999). Relation between systemic hypertension and blood lipids on the risk of myocardial infarction. The American Journal of Cardiology, 84, 768-773.

[29] Oparil, S., Zaman, M. A., & Calhoun, D. A. (2003). Pathogenesis of hypertension. Annals of Internal Medicine, 139, 761-776.

[30] Rubba, P., & Mancini, M. (1995). Lipid-lowering treatment: Effects on endothelial dysfunction. Current Opinion in Lipidology, 6, 348-353.

[31] Kool, M., Lustermans, F., Kragten, H., et al. (1995). Does lowering of cholesterol levels influence functional properties of large arteries? European Journal of Clinical Pharmacology, 48, 217-223.

[32] Pearson, T. A., & Swan, H. J. (1996). Lipid lowering: the case for identifying and treating the high-risk patient. Cardiology clinics, 14(1), 117-130.

[33] Zeiher, A. M., Drexler, H., Saurbier, B., & Just, H. (1993). Endothelium-mediated coronary blood flow modulation in humans: effects of age, atherosclerosis, hypercholesterolemia, and hypertension. Journal of Clinical Investigation, 92(2), 652-662.

[34] Vallance, P., Collier, J., & Moncada, S. (1989). Effects of endothelium-derived nitric oxide on peripheral arteriolar tone in man. The Lancet, 334(8670), 997-1000.

[35] Schaeffner, E. S., Kurth, T., Curhan, G. C., et al. (2003). Cholesterol and the risk of renal dysfunction in apparently healthy men. Journal of the American Society of Nephrology, 14(8), 2084-2091.

[36] Reaven, G. M. (1991). Insulin resistance, hyperinsulinemia, hypertriglyceridemia, and hypertension: parallels between human disease and rodent models. Diabetes care, 14(2), 195-202.

[37] Zavaroni, I., Mazza, S., Dall'Aglio, E., Gasparini, P., Passeri, M., & Reaven, G. M. (1992). Prevalence of hyperinsulinemia in patients with high blood pressure. Journal of internal medicine, 231(3), 235-240.

[38] Banach, M., & Aronow, W. S. (2012). Hypertension therapy in the older adults - do we know the answers to all the questions? The status after publication of the ACCF/AHA 2011 expert consensus document on hypertension in the elderly. Journal of human hypertension, 26(10), 641-643.

[39] Zdrojewski T, Rutkowski M, Bandosz P, et al. Rozpowszechnienie i kontrola czynników ryzyka sercowo-naczyniowego w Polsce. Cele i sposób realizacji badania NATPOL 2011. Kardiol Pol 2013; 71: 381-92.

[40] Otocka-Kmiecik, A., Mikhailidis, D. P., Nicholls, S. J., Davidson, M., Rysz, J., & Banach, M. (2012). Dysfunctional HDL: a novel important diagnostic and therapeutic target in cardiovascular disease? Progress in lipid research, 51(4), 314-324.

[41] Sesso, H. D., Buring, J. E., Chown, M. J., Ridker, P. M., & Gaziano, J. M. (2005). A prospective study of plasma lipid levels and hypertension in women. Archives of Internal Medicine, 165(20), 2420-2427.

[42] Halperin, R. O., Sesso, H. D., Ma, J., Buring, J. E., Stampfer, M. J., & Gaziano, J. M. (2006). Dyslipidemia and the risk of incident hypertension in men. Hypertension, 47(1), 45-50.

[43] de Simone, G., Devereux, R. B., Chinali, M., et al.; Strong Heart Study Investigators. (2006). Risk factors for arterial hypertension in adults with initial optimal blood pressure: the strong heart study. Hypertension, 47(2), 162-167.

[44] Han, S. H., Quon, M. J., & Koh, K. K. (2007). Reciprocal relationships between abnormal metabolic parameters and endothelial dysfunction. Current Opinion in Lipidology, 18(1), 58-65.

[45] Sacks, F. M., & Campos, H. (2003). Clinical review 163: cardiovascular endocrinology: low-density lipoprotein size and cardiovascular disease: a reappraisal. The Journal of Clinical Endocrinology & Metabolism, 88(10), 4525-4532.

[46] Urbina, E. M., Srinivasan, S. R., Kieltyka, R. L., et al. (2004). Correlates of carotid artery stiffness in young adults: the Bogalusa Heart Study. Atherosclerosis, 176(1), 157-164.

[47] Sesso, H. D., Buring, J. E., Rifai, N., Blake, G. J., Gaziano, J. M., & Ridker, P. M. (2003). C-reactive protein and the risk of developing hypertension. JAMA, 290(22), 2945-2951.

[48] Freedman, D. S., & Perry, G. (2000). Body composition and health status among children and adolescents. Preventive Medicine, 31(2), 34-53.

[49] Sorof, J., & Daniels, S. (2002). Obesity and hypertension in children: A problem of epidemic proportions. Hypertension, 40(4), 441-447.

[50] Yusuf, S., Hawken, S., Ounpuu, S., Bautista, L., Franzosi, M. G., Commerford, P., et al. (2005). INTERHEART study investigators. Obesity and risk of myocardial infarction in 27,000 participants from 52 different countries: A case control study. The Lancet, 366(9497), 1640-1649.

[51] Srikanth, J., Jayant Kumar, K., & Narasimha, N. S. (2011). Factors influencing obesity among urban high school children Bangalore City. Indian Journal of Nutrition and Dietetics, 48(1), 8-17.

[52] Barylski, M., Toth, P. P., Nikolic, D., Banach, M., Rizzo, M., & Montalto, G. (2014). Emerging therapies for raising high-density lipoprotein cholesterol (HDL-C) and augmenting HDL-particle functionality. Best Practice & Research Clinical Endocrinology & Metabolism, 28(3), 453-461.

[53] James, W. P., Ferro-Luzzi, A., & Waterlow, J. C. (1988). Definition of chronic energy deficiency in adults. European Journal of Clinical Nutrition, 42(12), 969-981.

[54] Ferro-Luzzi, A., Sette, S., Franklin, M., & James, W. P. (1992). A simplified approach of assessing adult energy deficiency. European Journal of Clinical Nutrition, 46(3), 173-186.

[55] Shetty, P. S., & James, W. P. (1994). Body mass index: A measure of chronic energy deficiency in adults. Food and Nutrition Paper, 56.

[56] Kapoor, S., Dhall, M., & Kapoor, A. K. (2010). Nutritional status and ageing among populations inhabiting varied geological regions in India. Biennial Book of EAA, 6, 85-100.

[57] Wang, H., Cao, J., Li, J., Chen, J., Wu, X., Duan, X., et al. (2010). Blood pressure, body mass index and risk of cardiovascular disease in Chinese men and women. BMC Public Health, 10, 189.

[58] Ferguson, T. S., Younger, N. O., Tulloch-Reid, M. K., Wright, M. B., Ward, E. M., Ashley, D. E., et al. (2008). Prevalence of prehypertension and its relationship to risk factors for cardiovascular disease in Jamaica: Analysis from a cross-sectional survey. BMC Cardiovascular Disorders, 8(1), 20.

[59] Dua, S., & Kapoor, S. (2000). Blood pressure, waist to hip ratio and body mass index among affluent Punjabi girls of Delhi. Acta Medica Auxologica, 32(3), 153-157.

[60] Okosun, I. S., Prewitt, T. E., & Cooper, R. S. (1999). Abdominal obesity in the United States: Prevalence and attributable risk of hypertension. Journal of Human Hypertension, 13(7), 425-430.

[61] Weder, A. B. (1993). Membrane sodium transport. In J. L. Izzo Jr. & H. R. Black (Eds.), Hypertension primer (pp. 36-37). American Heart Association.

[62] Poulter, N. R., Khaw, K. T., Hopwood, B. E., Mugambi, M., Peart, W. S., Rose, G., & Sever, P. S. (1990). The Kenyan Luo migration study: Observations on the initiation of a rise in blood pressure. BMJ (Clinical research ed.), 300(6731), 967-972.

[63] Sautin, Y. Y., & Johnson, R. J. (2008). Uric acid: The oxidant-antioxidant paradox. Nucleosides, Nucleotides & Nucleic Acids, 27(6), 608-619.

[64] Watanabe, S., Kang, D. H., Feng, L., & Nakagawa, T. (2002). Uric acid, hominoid evolution, and the pathogenesis of salt-sensitivity. Hypertension, 40(3), 355-360.

[65] MacIsaac, R. L., Salatzki, J., Higgins, P., Walters, M. R., & Padmanabhan, S. (2016). Allopurinol and cardiovascular outcomes in adults with hypertension. Hypertension, 67(3), 535-540.

[66] Mehta, T., Nuccio, E., McFann, K., Madero, M., Sarnak, M. J., Jalal, D., & Johnson, R. J. (2015). Association of uric acid with vascular stiffness in the Framingham heart study. American Journal of Hypertension, 28(7), 877-883.

[67] Ofori, S. N., & Odia, O. J. (2014). Serum uric acid and target organ damage in essential hypertension. Vascular Health and Risk Management, 10, 253-261.

[68] Weinberger, M. H. (1996). Salt sensitivity of blood pressure in humans. Hypertension, 27(3 Pt 2), 481-490.

[69] Whelton, P. K., He, J., Appel, L. J., et al. (2002). Primary prevention of hypertension: Clinical and public health advisory from The National High Blood Pressure Education Program. JAMA, 288(15), 1882-88.

[70] Lauer, R. M., & Clarke, W. R. (1989). Childhood risk factors for high adult blood pressure: The Muscatine Study. Pediatrics, 84(4), 633-41.

[71] Zinner, S. H., Rosner, B., Oh, W., et al. (1985). Significance of blood pressure in infancy. Familial aggregation and predictive effect on later blood pressure. Hypertension, 7(3 Pt 1), 411-16.

[72] Loeffler, L. F., Navas-Acien, A., Brady, T. M., et al. (2012). Uric acid level and elevated blood pressure in US adolescents: National Health and Nutrition Examination Survey, 1999-2006. Hypertension, 59(4), 811-17.

[73] Alper, A. J., Chen, W., Yau, L., et al. (2005). Childhood uric acid predicts adult blood pressure: The Bogalusa Heart Study. Hypertension, 45(1), 34-38.

[74] Sundstrom, J., Sullivan, L., D'Agostino, R. B., et al. (2005). Relations of serum uric acid to longitudinal blood pressure tracking and hypertension incidence. Hypertension, 45(1), 28-33.

[75] Rovda, I., Kazakova, L. M., & Plaksina, E. A. (1990). Parameters of uric acid metabolism in healthy children and in patients with arterial hypertension. Pediatriia, (8), 19-22.

[76] Torok, E., Gyarfas, I., & Csukas, M. (1985). Factors associated with stable high blood pressure in adolescents. J Hypertens Suppl, 3(3), S389-90.

[77] Viazzi, F., Antolini, L., Giussani, M., et al. (2013). Serum uric acid and blood pressure in children at cardiovascular risk. Pediatrics, 132(1), e93-99.

[78] Sun, H. L., Pei, D., Lue, K. H., et al. (2015). Uric acid levels can predict metabolic syndrome and hypertension in adolescents: A 10-year longitudinal study. PLoS One, 10(11), e143786.

[79] Yildirim, A., Keles, F., Kosger, P., et al. (2015). Uric acid levels in normotensive children of hypertensive parents. International Journal of Chronic Diseases, 2015, 747082.

[80] Robinson, R. F., Batisky, D. L., Hayes, J. R., et al. (2004). Body mass index in primary and secondary pediatric hypertension. Pediatric Nephrology, 19(12), 1379-1384.

[81] Lotufo, P. A., Baena, C. P., Santos, I. S., et al. (2016). Serum uric acid and prehypertension among adults free of cardiovascular diseases and diabetes: Baseline of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). Angiology, 67(2), 180-186.

[82] Jiang, L., Mo, D., Yang, R., et al. (2015). Joint effects of serum uric acid and body mass index on risk of prehypertension in Chinese population. Clinical Chimica Acta, 446, 1-5.

[83] Mora, S., Glynn, R. J., & Ridker, P. M. (2013). High-density lipoprotein cholesterol, size, particle number, and residual vascular risk after potent statin therapy. *Circulation*, *128*(11), 1189-1197.

[84] Chrusciel, P., Stemplewska, P., Stemplewski, A., Wattad, M., Bielecka-Dabrowa, A., Maciejewski, M., ... & Banach, M. (2022). Associations between the lipid profile and the development of hypertension in young individuals-the preliminary study. *Archives of Medical Science: AMS*, *18*(1), 25.