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The Relationship between Body Composition and Hypertension

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Abstract
Hypertension is a serious threat to the health of at least 1.4 billion people worldwide, and exploring the relationship between body composition and hypertension is of great significance for the prevention and control of essential hypertension. Existing studies have shown that a composite body composition index is a more effective predictor of hypertension than a single index, such as BMI. Increased adiposity is strongly associated with an elevated risk of hypertension, particularly visceral fat accumulation, which drives the development of hypertension by influencing body metabolism and hormone levels. Fat distribution also influences the development of hypertension, and indicators of abdominal obesity, such as waist-to-hip ratio, are strongly associated with the prevalence of hypertension and vary across gender. In addition, muscle mass, mineral (e.g., calcium, potassium, sodium, magnesium, etc.) and water balance also play an important role in blood pressure regulation, and decreased muscle mass, abnormal calcium metabolism, and water imbalance may lead to increased blood pressure. Therefore, body composition indexes can be used as an effective basis for assessing the risk of hypertension and the effectiveness of treatment, and provide an important reference for the non-pharmacological treatment of hypertension.
Keywords: Hypertension, Body Composition, Fat, Muscle, Mineral, Water

Introduction

Despite the widespread attention to hypertension as a major global public health challenge, there are still significant limitations in the existing research: (1) current explorations of the association between body composition and hypertension have focused on a single indicator (e.g., adiposity), and systematic analyses of multidimensional body composition (including skeletal muscle, proteins, minerals, water, etc.) are lacking (Robert Prosecky et al. 2023). (2) The research on micro-mechanisms such as genes and metabolic indicators in physiological factors has been more mature, but the application value of macro body composition indicators (such as fat mass and skeletal muscle mass, which can be directly measured by body composition analyzers) has not yet been fully explored in clinical practice. (3) Primary hypertension accounts for 95% of the population, and its core targets for lifestyle interventions (e.g., weight management) urgently need to be supported by more refined body composition data, but existing studies have not established a quantitative relationship between body composition indicators and dynamic changes in blood pressure (Amponsah-Offeh et al. 2023). In addition, inadequate adherence to non-pharmacological treatments (e.g., diet, exercise) in hypertensive patients worldwide is partly attributed to the lack of intuitive and easy-to-use body composition monitoring indicators (Li et al. 2020). This study aims to fill this gap by integrating multidimensional body composition data to reveal its dose-response relationship with blood pressure, providing new targets for early warning and precision intervention of hypertension.

This paper systematically reviews the differential effects of multidimensional body components such as body fat, skeletal muscle, protein, and water on blood pressure, breaking through the traditional single perspective of focusing only on fat, and providing a new theoretical framework for the study of the pathogenesis of hypertension. Provide evidence-based basis for non-pharmacological treatment, clarify the negative correlation between skeletal muscle mass and blood pressure (e.g., for every 1 kg increase in skeletal muscle, systolic blood pressure decreases by 2.3 mmHg, refer to Rinita et al. 2023 data model), and guide patients to optimize body composition through resistance training. In terms of public health strategies to prevent and control hypertension, body composition indicators are incorporated into community hypertension screening criteria (complementing existing blood pressure and BMI indicators), and precise identification of prehypertensive populations is achieved through universal body composition monitoring (Dui et al. 2023).

By analyzing the multidimensional effects of body composition, this study not only deepens the understanding of the pathogenesis of essential hypertension, but also bridges the gap between basic research and clinical practice through quantifiable and easy-to-use body composition indicators. The systematic review of the relationship between different body composition and blood pressure fills the gap in the systematic study of body composition. In the non-pharmacological treatment of hypertension, we can provide precise targets for patients to effectively control their blood pressure levels from the macroscopic perspective of body composition. As a result, we will be able to promote the transition from "experience management" to "data-driven" in the prevention and control of hypertension from a macroscopic operational level, and ultimately provide an innovative solution to reduce the global burden of cardiovascular disease, which is the leading cause of death.

Body Components Affect Hypertension

The body is composed of water, protein, fat, minerals and carbohydrates, which each play an indispensable role in the human body and work together to maintain normal physiological functions. Several studies have shown that a combination of body composition indicators can better predict hypertension. Hsu et al. (2020) found that a prediction model combining fat mass ≥3.65 kg and fat-free mass ≥34.65 kg performed better than BMI alone in predicting hypertension in children in a study of 340 children, suggesting that body composition parameters have an important value in the prediction of hypertension in children is of significant value. From a physiologic perspective, the mechanisms by which body composition affects hypertension are multifaceted and complex, with obesity being particularly strongly associated with hypertension. Obesity, especially abdominal obesity, is recognized as one of the important risk factors for hypertension. When body fat accumulates excessively, it triggers a series of physiological changes that can lead to increased blood pressure. Adipose tissue is not only a place for energy storage, it also has endocrine functions and can secrete a variety of bioactive substances, such as leptin (Hu, Wenting, et al. 2015), lipocalin (Araos et al. 2022), tumor necrosis factor-α (TNF-α) (Huang, Bao-rui, et al. 2014), resistin (Zhang et al. 2017), etc. These adipokines play key roles in regulating inflammatory responses, insulin resistance, and vascular endothelial function in the body.

In addition to the adipose component, muscle mass also has a significant impact on blood pressure. Muscle plays a key role in the body's metabolic processes by taking in large amounts of glucose, lowering blood sugar levels, and also helping to maintain normal blood pressure. Muscle mass is closely related to basal metabolic rate. The more muscle mass you have, the higher your basal metabolic rate and the more energy your body burns. Muscle also secretes some bioactive substances, such as muscle growth inhibitor and irisin, which have a positive effect on vascular endothelial function and blood pressure regulation. Studies have shown that people with higher muscle mass have a relatively low risk of developing hypertension. Decreases in muscle mass, such as muscle wasting syndrome, which is common in older adults, can lead to increased insulin resistance and increased sympathetic nervous system activity, which can elevate blood pressure. A longitudinal study of older adults found that blood pressure levels tended to increase gradually as muscle mass gradually decreased, and that there was a significant negative correlation between muscle mass and blood pressure.

Human minerals are mainly found in the body's bones and in the regulation of physiological activities. There is also a correlation between bone health and high blood pressure. Recent studies have found a common pathophysiological basis between osteoporosis and hypertension, such as abnormal calcium metabolism, oxidative stress, and inflammatory response. Calcium is an important element in maintaining bone health and also plays a key role in regulating the contractile and diastolic functions of vascular smooth muscle. When calcium metabolism is abnormal in the body, it leads to an increase in the concentration of calcium ions in vascular smooth muscle cells, resulting in enhanced vasoconstriction and increased blood pressure. Oxidative stress and inflammation also play an important role in the development of osteoporosis and hypertension, as they lead to impaired endothelial function, thickening and stiffening of blood vessel walls, thus increasing the risk of hypertension. A study of postmenopausal women found that the prevalence of hypertension was significantly higher in patients with osteoporosis than in those with normal bone mass, and that bone density was negatively correlated with blood pressure levels. Other minerals, such as potassium, sodium and magnesium, also play an important role in the regulation of blood pressure. Potassium has the effect of promoting sodium discharge and dilating blood vessels, which can lower blood pressure; while a high sodium diet will lead to sodium retention in the body and increase blood volume, thus raising blood pressure. Magnesium is involved in the diastolic and contractile regulation of vascular smooth muscle, and magnesium deficiency will lead to vasoconstriction and elevated blood pressure. Studies have shown that increasing potassium intake, decreasing sodium intake, and maintaining appropriate magnesium levels can help reduce the risk of developing hypertension. A study of people with different dietary patterns found that blood pressure levels in the high-potassium, low-sodium diet group were significantly lower than those in the low-potassium, high-sodium diet group, and that supplementation with magnesium resulted in effective control of blood pressure in some hypertensive patients.

Normal water balance is essential for maintaining stable blood pressure. When the body is dehydrated, it will lead to blood concentration and decrease in blood volume, which will increase blood pressure. The kidneys play a key role in maintaining water balance by regulating the production and excretion of urine to maintain water and electrolyte balance in the body.

Body Fat and Hypertension

Fat mass is strongly associated with high blood pressure, and studies have shown a correlation between total fat mass and blood pressure. Overall, systolic blood pressure (SBP) and diastolic blood pressure (DBP) tended to increase as total body fat increased. Khaleghi, et al. (2023) showed in a study of 2,419 individuals aged 60 years and older that an increase in the percentage of total body fat mass (FM) was associated with an increase in the odds of developing hypertension. Individuals who had a higher FM-to-fat-free-mass (FFM) ratio were significantly more likely to have high blood pressure. the odds of developing hypertension were significantly elevated. That is, increased fat mass elevates the risk of hypertension. As Han et al. (2019) pointed out after analyzing data from a large number of populations, blood pressure is positively correlated with fat mass and negatively correlated with muscle mass, and both body fat (BF) and skeletal muscle (SM) mass should be considered when analyzing health survey results rather than relying solely on BMI, which cannot distinguish between the two. Thus, changes in body composition affect blood pressure development and dynamic changes in body composition have a significant effect on blood pressure.

Markus, et al. (2010) 10-year follow-up study of 1145 subjects found significant body weight and adiposity in those who developed prehypertension to hypertension. When Liu Jieyu(2023) and others used bioresistive resistance methods to measure body composition in relation to hypertension, they found that higher body fat percentage similarly increased the risk of high diastolic blood pressure, while muscle mass was significantly negatively associated with high diastolic blood pressure. Chinese-based studies also illustrate these points, with results from a cross-sectional study of urban and rural residents in Shanxi province showing that body fat percentage was strongly associated with the development of hypertension, with the OR for body fat percentage being more significant when grouped by quartiles, demonstrating a significant correlation with the risk of developing hypertension (Huang, Yuxian,2021). Similar results were found in a population-based study in rural areas of Henan Province (Li, 2020).

Bhaskar et al. (2017) found that the mean body fat mass, percentage body fat, obesity and visceral fat area of hypertensive patients were significantly higher than those of normal population, and the positive correlation between visceral fat area and systolic blood pressure indicated that fat accumulation, especially increased visceral fat, was closely associated with hypertension. Further residual analysis revealed that total muscle mass exhibited positive correlations with systolic blood pressure (SBP) and diastolic blood pressure (DBP) in men, as well as with systolic blood pressure (SBP) in women, after excluding the confounding factor of total fat mass. Notably, this correlation reached a statistically significant level for both systolic and diastolic blood pressure in men and women (Zhao et al., 2022). This suggests that total fat mass affects blood pressure to some extent, possibly through mechanisms that affect body metabolism, hormone levels, etc., which in turn have an effect on blood pressure. Robert Prosecky et al. (2023) utilized data from KardioVize2030, a population-based study, n=1988, to determine the relationship between body composition parameters related to fat and water content and relationship between hypertension. The results showed that the majority of hypertension prevalence can be determined by body fat and water content, as the development of hypertension is positively associated with an increase in fat-related body composition parameters and water content.

The amount of body fat and body fat percentage in the body affects the blood pressure of an individual, and there are also differences in body fat distribution between males and females, with females having a higher body fat percentage as well as a tendency to accumulate fat in the hips and thighs (Karastergiou et al., 2012), androgens contribute to the redistribution of body fat and its gradual accumulation in the lumbar and abdominal regions, resulting in more abdominal fat in males than in females (Singh et al. 2021). Body fat distribution is centripetal in the abdomen, and there is a large body of epidemiologic evidence that abdominal obesity is an independent risk factor for hypertension. Differences in the site of fat distribution have different effects on hypertension. The results of a cross-sectional study in Brazil proposed that increased fat mass may have a greater effect on elevated systolic blood pressure in men than in women (Zaniqueli, 2020). It was confirmed that accumulation of abdominal fat has a greater impact on the increased prevalence of hypertension, and that the evaluation of abdominal fat can be measured by the waist-to-hip ratio. Kroke et al. (1998) suggested that the waist-to-hip ratio (WHR), which reflects central obesity, correlates with the prevalence of hypertension, and that the advantage ratio of having hypertension in the highest quintile of WHR compared to the lowest quintile in both men and women was 1.8 and 1.5. Kemp,et al. (2011) noted that indicators of abdominal obesity (e.g., waist circumference, waist-to-height ratio, etc.) were strongly associated with hypertension among first-year students in the North West Province of South Africa, and that females from the black community had a significantly higher prevalence of hypertension, proportion with a waist circumference ≥80 cm, proportion with a waist-to-height ratio >0.5 and proportion with a waist-to-hip ratio ≥0.85 than the general female population.

In summary, the effect of body fat on individual hypertension is reflected in the total amount of fat, the location of fat distribution, and different genders. This view was also demonstrated in a large population-based volume study in 2019 (Malden et al., 2019), which encompassed whole-body imaging of body fat distribution and systolic blood pressure in 10,260 participants (mean age, 49 years; 96% white) and found that systolic blood pressure was associated with visceral androgynous fat (3.2 mmHg/SD in men; 2.8 mmHg/SD in women) and fat-free mass (1.92 mmHg/SD in men:1.64 mmHg/SD in women) were positively correlated, but there was no evidence of an association with subcutaneous android or female-like fat. Systolic blood pressure correlated slightly more with BMI than waist circumference or waist-to-hip ratio; these correlations remained unchanged after adjustment for fat-free mass, but adjustment for visceral android fat eliminated the correlations with waist circumference and waist-to-hip ratio and more than halved the correlation with BMI. In conclusion, visceral fat is a major etiologic factor in the development of obesity-related hypertension. This is consistent with the findings of an earlier U.S. study that elevated blood pressure is directly associated with concentrated deposition of body fat, that is, with race and gender, independent of age (Blair et al., 1984). Recent cross-sectional studies have also found (Taurio et al. 2023) that abdominal obesity is independently associated with higher aortic systolic and diastolic blood pressure, systemic vascular resistance, and pulse wave velocity. Therefore, body fat content has good sensitivity and accuracy in the evaluation of hypertension, and can be used as an evaluation index of treatment effects during the treatment of hypertensive patients.

Conclusions & Suggestions

In summary, the elements of body composition, such as fat, muscle, minerals and water, all have a close and complex association with hypertension. Changes in these components affect blood pressure levels through a variety of physiologic mechanisms.

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