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# Alteration of Echocardiographic Parameters in Adults with Prehypertension: A Systematic Review

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## ABSTRACT

**Background:** Prehypertension, defined as systolic blood pressure 120–139 mmHg or diastolic blood pressure 80–89 mmHg, is associated with increased cardiovascular risk. Subclinical cardiac remodeling, including structural, geometric, and functional alterations, may occur before the onset of overt hypertension.
**Aim:** To synthesize current evidence on echocardiographic changes in prehypertensive adults across diverse populations.
**Materials and Methods:** A systematic review was conducted using studies published in English language between 2010 and 2025, reporting echocardiographic parameters in prehypertensive adults compared with normotensive controls. Databases searched included PubMed/MEDLINE, Scopus, Web of Science, Embase, and Google Scholar. Study selection, data extraction, and quality assessment were performed independently by two reviewers. Findings were qualitatively synthesized due to heterogeneity in study designs and echocardiographic methods.
**Results:** Fourteen studies encompassing populations from Europe, Asia, Africa, and the USA were included, predominantly cross-sectional, with two longitudinal cohorts. Prehypertensive individuals consistently exhibited higher LV mass and LV mass index, modestly increased wall thickness, and early concentric geometric remodeling. Subclinical systolic dysfunction, detected by strain imaging, was observed despite preserved conventional ejection fraction. LVH prevalence ranged from 2–7% in most populations, with higher rates in African cohorts. Age, sex, body mass index, metabolic factors, and systolic blood pressure were associated with structural and functional alterations.
**Conclusion:** Prehypertension is associated with early structural and functional cardiac changes detectable by echocardiography, emphasizing that it is not a benign condition. Early identification of these alterations provides an opportunity for risk stratification and preventive interventions. Future longitudinal studies with standardized echocardiographic protocols and broader population representation are warranted to clarify progression patterns and guide clinical management.

***Keywords:*** Echocardiography, Prehypertension; Left ventricular mass; LV geometry; Strain imaging; Subclinical cardiac remodeling

## INTRODUCTION

Prehypertension, defined as systolic blood pressure (SBP) between 120 and 139 mmHg or diastolic blood pressure (DBP) between 80 and 89 mmHg, represents an intermediate cardiovascular state between normotension and established hypertension [1]. Globally, approximately 36–38% of adults have prehypertension, though substantial variation exists across regions and populations [2]. In Africa, adult prehypertension prevalence ranges from 33–57% depending on country and population [3].

Individuals within this blood pressure range have an increased likelihood of progressing to sustained hypertension and developing subtle cardiac structural and functional abnormalities [4,5]. Evidence suggests that alterations such as increased left ventricular (LV) mass, early abnormal LV geometric remodeling, and subclinical systolic or diastolic dysfunction may occur before blood pressure reaches hypertensive thresholds [5-8]. Detecting these changes is clinically important, as they may precede overt cardiovascular disease and provide an opportunity for early intervention [4,6,7].

Echocardiography provides a sensitive, non-invasive approach for detecting early cardiac changes, allowing precise measurement of LV mass, characterization of geometric remodeling, and identification of subtle systolic and diastolic dysfunction before the onset of clinical hypertension [9].

Earlier systematic reviews focused predominantly on LV structural changes, particularly LV mass and geometry, and underrepresented populations from Africa and other low- and middle-income countries where the burden of prehypertension and cardiovascular diseases is greatest [6,8,10]. Recent studies, such as Oboirien *et al*[5], demonstrate higher LV mass index, abnormal LV geometry, and increased diastolic dysfunction among Nigerian prehypertensive adults compared with normotensive controls. Longitudinal observational studies also indicate that prehypertension is associated with both high prevalence and incidence of LV hypertrophy over time [8].

Advances in echocardiographic technology, including tissue Doppler imaging, strain assessment, and updated guideline-based methods for LV mass indexing which recently emerged allow more sensitive identification of these subclinical abnormalities [9,11].

This systematic review therefore aimed to provide an up-to-date synthesis of structural, geometric, and functional cardiac changes in adults with prehypertension, evaluate variations across demographic and geographic groups, and highlight methodological and reporting gaps in the existing literature.

## MATERIALS AND METHODS

### Study Design

This systematic review synthesized published evidence on structural, geometric, and functional echocardiographic alterations in adults classified as prehypertensive. The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and transparency.

### Eligibility Criteria

#### Inclusion Criteria

1. Studies were included if they met the following criteria:
2. Published in English between 2010 and 2025.
3. Reported original research on adults (≥18 years) with prehypertension;
4. Reported echocardiographic parameters such as LV mass, wall thickness, LV geometry, or systolic/diastolic function and compared them between prehypertensive and normotensive.
5. Used observational designs (cross-sectional, cohort, or case-control) or clinical trials with baseline echocardiographic data

#### Exclusion Criteria

Studies were excluded if they:

1. Focused exclusively on hypertensive populations without separable prehypertension data;
2. Did not contain primary echocardiographic findings (e.g., reviews, commentaries, case reports); or
3. Non-human studies.

**Information Sources and Search Strategy**

A comprehensive literature search was conducted across PubMed, Scopus, Semantic Scholar and Embase. Google Scholar was used to identify grey literature. The search was carried out between October 2025 and November 2025. Search terms included combinations of MeSH terms and keywords such as "prehypertension," "high-normal blood pressure," "echocardiography," "left ventricular mass," "LV geometry," and "diastolic function." Boolean operators and database-specific filters were applied. Reference lists of included studies and earlier systematic reviews were also screened for additional eligible articles.

**Study Selection**

Two reviewers independently screened the titles and abstracts of 63 articles identified through the database search. Of these, 25 articles were retained based on title relevance, while 38 were excluded. Full texts of the 25 potentially eligible studies were then assessed against the predefined criteria. Following this assessment, 9 articles were excluded for not aligning with the study objectives, and 4 more were removed for failing to meet eligibility criteria. Disagreements during the selection process were resolved through discussion or consultation with a third reviewer when necessary. Additionally, 2 studies were identified through manual reference searches. Ultimately, 14 studies were deemed suitable and included in the final review. The entire study selection process, along with reasons for exclusion at each stage, was documented using a PRISMA flow diagram (See figure 1)

**Data Extraction**

Data were extracted using a standardized template capturing:

- Study characteristics (author, year, country, design, sample size);
- Participant age range
- Echocardiographic parameters (LV mass index, wall thickness, relative wall thickness, geometric classification, systolic and diastolic function);
- key findings comparing prehypertensive and normotensive groups.

Data extraction was performed independently by two reviewers, and discrepancies were resolved through discussion.

**Data Synthesis**

Owing to heterogeneity in study designs, populations, and echocardiographic methods, a meta-analysis was not attempted. Instead, a qualitative synthesis was conducted. Findings were grouped into structural (LV mass, wall thickness), geometric (remodeling and hypertrophy patterns), and functional (systolic and diastolic parameters) categories. Variations across age, sex, ethnicity, and geographic location were described as reported in individual studies.

**Ethics and Dissemination**

Ethical approval was not required because the review utilized data from previously published studies. The findings are intended for dissemination through scientific publication and conference presentation to provide updated evidence on subclinical cardiac remodeling in prehypertension and to inform future research priorities

## RESULTS

**Study Selection and Characteristics**

A total of 14 studies were included, encompassing populations from Europe (Serbia, Italy, Portugal, Turkey), Asia (China, Korea, Japan, India), Africa (Nigeria), and the USA. Study designs were predominantly cross-sectional (n = 12), with two prospective cohorts *[8,12]*. Sample

sizes ranged from 41 to over 52,000 participants. Participant ages varied from 25 to 86 years, with most studies focusing on middle-aged adults. Prehypertension was defined according to standard guideline criteria. Echocardiographic assessments included conventional structural parameters (LVM, LVMI, RWT, IVST, PWT, LVID), diastolic indices (E/A, E/e′, TDI), and, in selected studies, strain imaging (GLS, GCS). The summary of the included studies is presented in Table 1.

**Structural Cardiac Changes in Prehypertension**

Across the included studies, prehypertensive individuals consistently exhibited higher left ventricular mass (LVM) and left ventricular mass index (LVMI) compared with normotensive controls. Mean LVM in prehypertensives ranged from approximately 109 to 166 g across studies, with corresponding increases in LVMI. Left ventricular wall thickness, including interventricular septal thickness (IVST) and posterior wall thickness (PWT)**,** was modestly elevated in several studies [13-15]. Chamber dimensions, such as left ventricular internal diameter in diastole (LVIDd) **and** left atrial diameter, were slightly increased in larger cohorts [16].

**Left Ventricular Geometric Patterns**

Concentric remodeling was the most frequently reported geometric pattern among prehypertensive adults [5,8,14,15,17]. Reported prevalence was as high as 17.5% in Nigeria study [5]. Concentric hypertrophy was less common (<5%), whereas eccentric hypertrophy occurred in 1–7% of participants. Several studies did not classify LV geometry explicitly, which may contribute to variability in prevalence estimates.

Functional Cardiac Changes

**Conventional Systolic Function**

Across most studies, conventional systolic function as measured by ejection fraction was preserved in prehypertensive individuals, with no significant differences compared with normotensive controls [ 5,8,12,13].

**Subclinical Systolic Dysfunction Detected by Strain Imaging**

Advanced echocardiographic techniques, including strain imaging, were used in a subset of studies [18,19]. Prehypertensive participants demonstrated lower global longitudinal strain (GLS: -18.4 to -18.9%) compared with normotensive controls (-20.7 to -23.9%), and reduced global circumferential strain (GCS: -19.9 vs -22.5%)

**Diastolic Function**

Several studies reported subtle diastolic abnormalities, including reduced E/A ratios and prolonged deceleration times, indicating early impairment of LV relaxation and filling patterns [5,8,15,16].

Prevalence, Incidence, and Longitudinal Progression

The prevalence of LVH among prehypertensives varied between 2% and 7% in European and Asian studies, and was higher in African cohorts [15,16]. Longitudinal data were available in only two studies. Cuspidi *et al [8]* reported progressive increases in LV mass and incidence of LVH over 10 years, while Erdogan *et al* [12] observed that reduced coronary flow reserve and metabolic risk markers predicted progression to hypertension over three years.

**Predictors and Effect Modifiers**

Several demographic and metabolic factors were associated with echocardiographic changes in prehypertensive adults. Age, sex, body mass index (BMI), metabolic disturbances (including low HDL and insulin resistance), and elevated systolic blood pressure were consistently linked with higher LVM, LVMI, or diastolic indices. Strain reductions were observed independently of ejection fraction, indicating early subclinical systolic dysfunction.

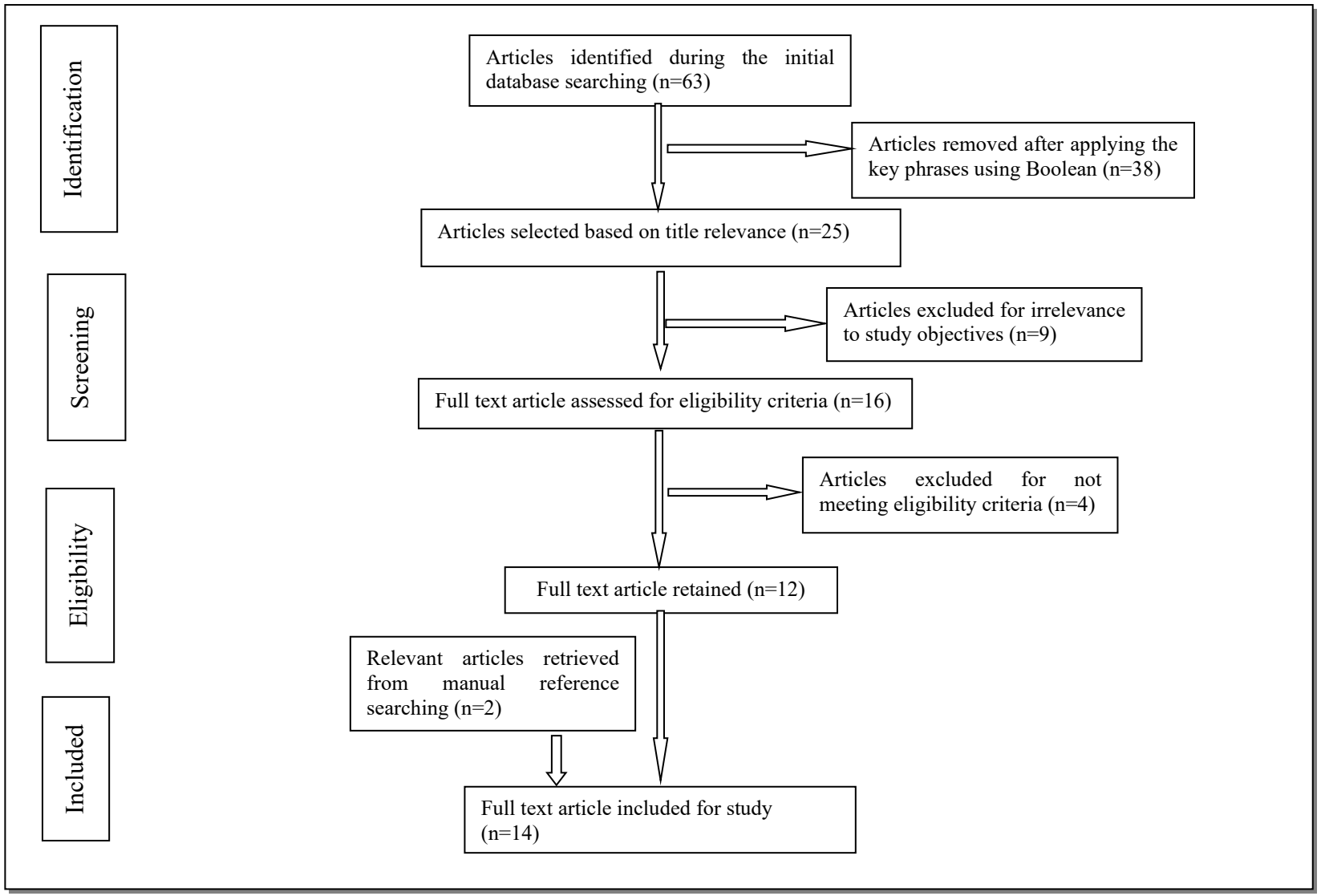


**Figure 1. A flow chart outlining the process of the database search and studies procured**

**Table 1. Echocardiographic Changes in Prehypertension: Summary of Included Studies**

| Author, Year | Country | Study Design | Sample Size (PreHT /NOR) | Age Range (yrs) | Echocardiographic Parameters | Key Findings |
|---|---|---|---|---|---|---|
| Bajpai et al [13]. | India | Cross-sectional | 52 / 50 | 30–60 | LVM, LVMI, IVST, PWT, LVID, EF | PreHT showed higher LVM (151 ± 24 g vs 132 ± 20 g) and LVMI (95 ± 14 g/m² vs 82 ± 11 g/m²); modest ↑wall thickness; EF preserved. |
| Ale et al [14]. | Nigeria | Cross-sectional | 62 / 62 | 25–55 | LVM, LVMI, IVST, PWT, RWT | Elevated LV mass and early concentric remodeling in PreHT; overt LVH uncommon; numeric LVMI not fully specified. |
| Hadiza, et al [15] | Nigeria | Cross-sectional | 62 / 62 | 25–55 | LVM, LV geometry | PreHT associated with higher LV mass; concentric remodeling most common; mild diastolic changes; LVH prevalence low. |
| Li et al., [16] | China | Cross-sectional | 451 / 452 | 30–75 | LVM, LVMI, LA diameter, LVID, EF | PreHT → slightly ↑LV mass/LVMI; LVH prevalence 8.6% (height$^{2\cdot7}$), 5.3% (BSA); geometry: eccentric hypertrophy 7.3%, concentric remodeling 5.3%, concentric hypertrophy 1.4%; EF preserved; mild diastolic dysfunction reported. |
| Tadic et al [18] | Serbia | Cross-sectional | 48 / 50 | 40–65 | GLS, GCS, EF | PreHT → reduced GLS (−18.9 ± 1.4% vs −20.3 ± 1.1%) and GCS; EF preserved; subtle systolic/diastolic dysfunction detectable by speckle tracking. |
| Di Bello et al [19] | Italy | Cross-sectional | 45 / 45 | 45–65 | GLS, GCS, EF | PreHT → early subclinical systolic dysfunction detected by strain imaging; LV mass slightly ↑; LV geometry not specified; EF preserved. |
| Cuspidi et al.,[8] | Italy | Prospective cohort | 5,200 / 5,000 | 35–75 | LVM, LVMI, LV geometry, EF | Progressive ↑LV mass and LVH incidence over 10 years; concentric remodeling more common; EF largely preserved; diastolic function mildly impaired |
| Erdogan et al. [12] | Turkey | Prospective cohort | 141 / 150 | 40–70 | LVM, LVMI, CFR, EF | Reduced coronary flow reserve predicted progression to HT; PreHT → ↑LV mass/LVMI; mild LVH; EF preserved; LV geometry predominantly normal. |
| Oboirien et al [5] | Nigeria | Cross-sectional | 80 / 80 | 25–60 | LVM, LVMI, LV geometry, diastolic function | PreHT → higher LVMI; abnormal geometry (concentric remodeling 17.5%); diastolic dysfunction prevalence 14.5% vs 0.5% in controls; EF preserved. |
| Jung et al [20]. | Korea | Cross-sectional | 120 / 120 | 30–65 | LVM, LV geometry, diastolic indices | PreHT → mild ↑LV mass/LVMI; early LV remodeling and mild diastolic dysfunction; concentric remodeling observed; EF normal. |
| Oyama & Node [17] | Japan | Cross-sectional | 52 / 50 | 40–70 | LVM, LV geometry, EF | PreHT → higher prevalence of LVH; concentric remodeling common; EF preserved; diastolic function not fully detailed. |
| Kim SH et al. [21] | Korea | Cross-sectional | 60 / 60 | 35–65 | LVM, LVMI, diastolic function | PreHT → ↑LV mass/LVMI; early diastolic abnormalities detected (impaired relaxation); EF preserved; mostly normal geometry. |
| Ladeiras-Lopes et al. [22] | Portugal | Cross-sectional | 95 / 90 | 40–75 | LVM, LVMI, LV geometry, EF | PreHT → ↑LV mass/LVMI; early concentric remodeling; EF preserved; mild diastolic dysfunction reported. |

## DISCUSSION

This systematic review aimed to synthesize current evidence on echocardiographic changes in adults with prehypertension, focusing on both structural and functional cardiac parameters. Prehypertension, defined as systolic blood pressure of 120–139 mmHg or diastolic blood pressure of 80–89 mmHg, affects a substantial proportion of the global adult population and is associated with increased risk of progression to overt hypertension and cardiovascular disease.

While prehypertension is often considered a clinically silent condition, emerging evidence indicates that subtle cardiac remodeling may occur even before overt hypertension develops. Early alterations in left ventricular geometry, mass, and function can precede symptomatic cardiovascular disease, highlighting the importance of understanding subclinical cardiac changes in this population.

### Structural Cardiac Changes in Prehypertension

The findings across the included studies indicate that prehypertension is associated with subtle yet consistent structural alterations in the heart. Prehypertensive individuals demonstrated higher left ventricular mass (LVM) and left ventricular mass index (LVMI) compared with normotensive controls, with reported mean LVM values ranging from approximately 109 to 166 g. These increases, although modest, suggest early hypertrophic remodeling even in the absence of overt hypertension.

Left ventricular wall thickness, including interventricular septal thickness (IVST) and posterior wall thickness (PWT), was also modestly elevated in several studies [13-15], consistent with early concentric remodeling. Chamber dimensions, such as left ventricular internal diameter in diastole (LVIDd) and left atrial diameter, were slightly increased in larger cohorts [16], suggesting that prehypertensive blood pressures may influence cardiac chamber geometry.

These observations align closely with findings from prior meta-analyses. A 2018 meta-analysis of 20 echocardiographic studies including approximately 73,500 individuals reported significantly higher LVMI, relative wall thickness (RWT), and left atrial diameter among prehypertensives compared with normotensive adults. The consistency between our review's findings and these large pooled analyses reinforces the notion that structural cardiac remodeling begins early, even before the onset of overt hypertension.

### Left Ventricular Geometric Patterns in Prehypertension

Analysis of the included studies indicates that concentric remodeling is the most frequently observed pattern of left ventricular (LV) geometric adaptation in prehypertensive adults. Reported prevalence varied across populations

These findings are consistent with prior meta-analyses and large-scale echocardiographic studies, which have demonstrated that prehypertension is predominantly associated with concentric remodeling rather than overt hypertrophy. For example, pooled data from a 2019 meta-analysis encompassing over 60,000 participants showed increased odds of concentric remodeling and, to a lesser extent, eccentric or concentric hypertrophy among prehypertensive adults. The predominance of concentric remodeling likely reflects early adaptive responses to elevated hemodynamic load, characterized by increased wall thickness relative to chamber size, before the development of frank LV hypertrophy.

Overall, these observations reinforce the concept that subclinical cardiac structural changes are present even at the prehypertensive stage, with concentric remodeling representing an early, potentially reversible adaptation that may precede overt hypertrophy and clinically significant cardiovascular disease.

**Functional Cardiac Changes in Prehypertension**

Despite clear structural remodeling, conventional measures of systolic function**,** particularly left ventricular ejection fraction (LVEF)**,** were generally preserved across the included studies. Most cohorts reported no significant differences in LVEF between prehypertensive and normotensive adults [5,8,12,16]. This suggests that early structural adaptations in prehypertension do not immediately impair global systolic performance, reinforcing the concept of prehypertension as a subclinical stage of cardiovascular risk**.**

In contrast, diastolic function indices revealed subtle impairments. Several studies reported lower E/A ratios and prolonged deceleration times among prehypertensive individuals [5,8,15,16], \ indicating early changes in LV relaxation and filling patterns. These findings highlight that diastolic dysfunction may emerge before any measurable decrease in conventional systolic function.

Importantly, this review incorporated studies utilizing advanced echocardiographic techniques**,** including speckle-tracking strain imaging and 3D echocardiography**,** providing novel insights into subclinical myocardial dysfunction. Several included studies documented reduced global longitudinal strain (GLS) and, in some cases, impaired circumferential strain in prehypertensive adults [18-19]. Notably, these abnormalities were detectable despite preserved LVEF, demonstrating that strain imaging can reveal early myocardial impairment that conventional indices fail to capture.

**Prevalence, Incidence, and Longitudinal Progression of Cardiac Changes in Prehypertension**

Across the included studies, the prevalence of left ventricular hypertrophy (LVH) among prehypertensive adults was generally low but varied by region. European and Asian cohorts reported LVH prevalence ranging from 2% to 7%, whereas African cohorts, including Nigerian populations, demonstrated higher prevalence rates [14,15]. These differences may reflect population-specific factors such as genetics, baseline cardiovascular risk, and environmental influences, as well as methodological variations in echocardiographic assessment and LVH criteria.

Longitudinal data on prehypertensive cardiac remodeling are limited, with only two studies providing follow-up insights. Cuspidi *et al.* [8] reported progressive increases in LV mass and incidence of LVH over a 10-year period, highlighting that prehypertension is not merely a static condition but may represent an evolving stage of subclinical cardiac remodeling. Similarly, Erdogan *et al.* [12] observed that reductions in coronary flow reserve and the presence of metabolic risk markers were predictive of progression from prehypertension to overt hypertension over a three-year follow-up. These findings underscore the dynamic nature of cardiovascular risk in prehypertensive individuals and suggest that early structural and functional changes may precede clinically manifest hypertension.

**Predictors and Effect Modifiers of Cardiac Remodeling in Prehypertension**

Several studies in this review identified key demographic and cardiometabolic factors that influence the degree of cardiac remodeling in prehypertensive adults. Age, sex, body mass index (BMI), metabolic disturbances (including low HDL cholesterol, insulin resistance, and microalbuminuria), and elevated systolic blood pressure were consistently associated with higher left ventricular mass, concentric remodeling, and diastolic dysfunction [13-16].

These findings align with prior meta-analyses, which identified age, BMI, and blood pressure as significant modifiers of left ventricular structure and geometry in prehypertension. The convergence of evidence from both individual studies and

pooled analyses underscores the multifactorial nature of early cardiac remodeling, suggesting that structural and functional changes are influenced by a combination of hemodynamic, metabolic, and demographic factors.

**Strengths and Limitations**

This review has several notable strengths. It provides a comprehensive synthesis of echocardiographic changes in prehypertension, integrating conventional indices, left ventricular geometric patterns, and advanced imaging modalities such as speckle-tracking strain and 3D echocardiography. By including studies from diverse geographic regions, the review enhances the generalizability of its findings. Moreover, explicit attention to predictors and effect modifiers offers insight into the multifactorial determinants of early cardiac remodeling.

However, there are limitations. The majority of included studies were cross-sectional, limiting the ability to infer causality or temporal progression. Sample sizes varied widely, and some studies did not classify LV geometry or report advanced imaging outcomes, contributing to heterogeneity. Longitudinal data remain sparse, with only two studies providing follow-up, which restricts understanding of the natural history and progression of subclinical remodeling in prehypertension. Additionally, methodological differences in echocardiographic acquisition and interpretation may have influenced the reported results.

## Recommendations

1. **Early Screening:** Adults with prehypertension should be considered for echocardiographic assessment, particularly those with additional cardiometabolic risk factors.
2. **Use of Advanced Imaging:** Incorporation of strain imaging and 3D echocardiography can improve detection of subclinical myocardial dysfunction that is not apparent with conventional measures.
3. **Longitudinal Monitoring:** Prospective studies are needed to track progression from prehypertension to overt hypertension and associated cardiac remodeling, and to identify predictors of adverse outcomes.
4. **Risk Stratification and Intervention:** Lifestyle and therapeutic interventions should target modifiable predictors of remodeling, including elevated blood pressure, obesity, and metabolic disturbances, to potentially reverse or slow early cardiac changes.

## CONCLUSION

Prehypertension is associated with subclinical structural and functional cardiac remodeling, including modest increases in LV mass, concentric remodeling, diastolic dysfunction, and strain abnormalities, even in the presence of preserved ejection fraction. While overt LV hypertrophy is uncommon, these early changes may progress over time, particularly in individuals with adverse cardiometabolic profiles. Advanced echocardiographic techniques enhance the detection of subtle myocardial impairment and provide valuable tools for early risk assessment. Recognizing and monitoring these changes in prehypertensive adults could facilitate timely interventions to prevent progression to overt hypertension and reduce long-term cardiovascular risk.

### *Declaration by Authors*

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