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Original Article

Physiology Section

Comparison of Arterial Stiffness among Prehypertensive and Normotensive Subjects using Photo Pulse Plethysmography: A Pilot Study

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ABSTRACT

Introduction: Increased arterial stiffness is a marker of Cardiovascular Disease (CVD), even before clinical signs and symptoms become evident. Hypertension is an established risk factor for CVD. However, recent studies have revealed increased arterial stiffness even among prehypertensives. Photo Pulse Plethysmography (PPG) is an efficient non-invasive, and cost-effective technique to measure arterial stiffness. Studying arterial stiffness using PPG can serve as a surrogate marker of Cardiovascular (CV) risk among prehypertensives.

Aim: To compare arterial wall stiffness among prehypertensives and normotensives using PPG.

Materials and Methods: This pilot study was conducted at the Sri Ramachandra Institute of Higher Education and Research, Chennai, TamilNadu, India from December 2022 to February 2023. The study population included 10 non diabetic prehypertensives and 10 normotensives, aged between 30-50 years, with normal lipid profiles. The peripheral pulse was recorded using a PPG module and digitised using AUDACITY software. The Arterial Stiffness Index (SI) was calculated and compared between the two groups. The correlation between anthropometry and arterial SI was also determined. Pearson's correlation test was used to assess the association using Statistical Package for Social Sciences (SPSS) version 24.0.

Results: The SI was found to be higher in prehypertensives compared to normotensives, and this difference was statistically significant (p-value=0.04). SI showed a positive correlation with increasing Blood Pressure (BP) and anthropometric variables (Body Mass Index [BMI] and Waist-Hip Ratio [WHR]; r=0.2 and r=0.15, respectively); however, no significant relationship was observed among these variables.

Conclusion: This study concludes that the SI, an important CV risk marker, shows a significant increase in prehypertensive subjects compared to normotensive subjects. However, SI showed mild positive correlation with BP and other anthropometric measurements, though not statistically significant.

Keywords: Anthropometric measurements, Cardiovascular disease, Stiffness Index

INTRODUCTION

According to the World Health Organisation (WHO), 1.28 billion adults between 30-79 years worldwide have hypertension, with two-thirds of them living in low and middle-income countries [1]. The overall prevalence of hypertension in India was 29.8%, and the prevalence of prehypertension among young adults was high at 45.2% [1]. Additionally, the prevalence of prehypertension among adults in South India was 55%, while in North India it was 40.8%, indicating an alarming increase [2,3].

In 2003, the Joint National Committee (JNC) 7 on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure introduced the term "Prehypertension" [4]. Prehypertension is defined as individuals with a Systolic Blood Pressure (SBP) of 120-139 mmHg, and/or Diastolic Blood Pressure (DBP) of 80-89 mmHg. Prehypertension carries an increased risk of converting to full-blown hypertension and cardiovascular events if left unnoticed [5]. The sustained increase in blood pressure promotes matrix synthesis, resulting in reorganisation of the spatial distribution of vascular smooth muscle cells and extracellular matrix, resulting in vascular thickening and increased arterial stiffness [6]. Arterial stiffness is emerging as an interesting tissue biomarker for cardiovascular risk stratification [7]. Stiffness affects the microvascular beds of the brain, kidneys, and heart by increasing the left ventricular systolic load necessary for coronary perfusion [5].

Arterial stiffness parameters such as the SI were measured. SI is calculated as the subject's height (h) divided by the Pulse Transit Time (PTT), which is the time difference between the systolic and diastolic peaks in the pulse wave. SI measures large arterial stiffness [8]. One common non invasive technique using simple and cost-effective optical technology is PPG. It is a waveform signal that indicates the pulsation of the chest wall and great arteries followed by the heartbeat.

The principle behind using this technique is to determine the propagation of blood pressure and vascular diameter changes during the cardiac cycle to the peripheral vascular system. The primary aim of PPG is to observe the mechanical movement of the heart and the kinetics of blood flow [9]. Since increased arterial stiffness is the hallmark of many cardiovascular disorders, early detection can reduce associated morbidity and mortality. PPG, being a non invasive, portable, and cost-effective tool, facilitates better patient compliance and the screening of large groups of subjects. The aim of the study was to compare arterial wall stiffness among prehypertensives and normotensives using PPG. The primary objective was to measure and compare SI among prehypertensives and normotensives using the PPG module, and the secondary objective was to correlate anthropometric measures such as BMI and WHR with SI.

MATERIALS AND METHODS

A pilot study was conducted at Sri Ramachandra Institute of Higher Education and Research, Chennai, TamilNadu, India from December 2022 to February 2023 after obtaining approval from the

Institutional Ethics Committee (CSP-MED/21/JUL/70/116). A total of 20 male subjects were selected based on the following inclusion and exclusion criteria.

Inclusion criteria: Male subjects between 30-50 years of age were included in the study. Individuals with a SBP of 120-139 mmHg, and/or DBP of 80-89 mmHg were included in the prehypertensive group, while individuals with a SBP of 90-119 mmHg, and/or DBP of 60-79 mmHg were included in the normotensive group.

Exclusion criteria: Subjects suffering from cardiovascular diseases such as atrial fibrillation, frequent ventricular ectopic heartbeats, and conditions such as Raynaud's phenomenon, significant limb tremor, deformation of limbs or measurement digit deformities, diabetes mellitus, hypercholesterolemia, and any other chronic diseases, as well as those who were on treatment or drugs, were excluded. Female subjects were also excluded from the study.

Sample size: The present study was a pilot for a larger study on the assessment of vascular aging through select parameters, and it included a total of 20 male subjects (N=10 normotensive and N=10 prehypertensive subjects).

Study protocol: After obtaining informed written consent from all the subjects, anthropometric data such as height (in metres) was measured using a stadiometer, weight (in kilograms) was measured using a weighing scale, and BMI was calculated using weight (in kg)/height (in m^2) (as per WHO classification) [10]. Blood pressure was measured after the subjects had rested for five minutes, and the average of three readings was considered. Waist Circumference (WC) and Hip Circumference (HC) were measured using an inch tape, and Waist-Hip Ratio (WHR) was calculated. Personal history regarding diet, smoking, alcohol use was obtained. Family history (chronic diseases like Hypertension, diabetes mellitus, hypercholesterolemia, etc.), Medical history, Drug history, Marital history, etc., were collected. Fasting Blood Sugar (FBS) levels, Serum Triglycerides (TGL), and Serum Low Density Lipoprotein (LDL) levels were also noted.

The pulse waveform reflects the systolic and diastolic events during the cardiac cycle. The stiffening of the arteries with ageing can affect the waveform and, therefore, the above haemodynamic events, which eventually lead to raised blood pressure even before obvious manifestations of frank hypertension [11]. Hence, the measurement of SI may be more useful in the early identification of vascular changes, even in the absence of clinically apparent disease [11].

In the current study, the peripheral finger pulse was recorded using a PPG module and digitised using AUDACITY software. This PPG module records the Digital Volume Pulse (DVP), which has two peaks-SBP and DBP peaks. The former peak is caused by pulse waves that are directly transmitted from the left ventricle to the finger. The diastolic peak results from pulse waves that are carried via the aorta to the small arteries in the lower body, where they are subsequently reflected back along the aorta as a reflected wave. The length of this path corresponds to the subject's height (h). The time interval between the diastolic and systolic peaks is known as the PTT [11].

SI is a tissue biomarker used to measure arterial stiffness [7]. It was calculated using the formula SI (m/sec)=Subject height (m) / Peak to peak time [7]. Reference value: SI=8.76±1.90 m/sec [7].

STATISTICAL ANALYSIS

After obtaining the data, statistical analysis was performed using SPSS version 24.0 The distribution of the data was analysed using the Kolmogorov-Smirnov test and expressed as mean±SD. The difference between the means of the two groups was analysed using an Independent t-test. Pearson's correlation test was used to test the correlation between SI with anthropometric parameters and BP. A p-value of ≤0.05 was considered significant.

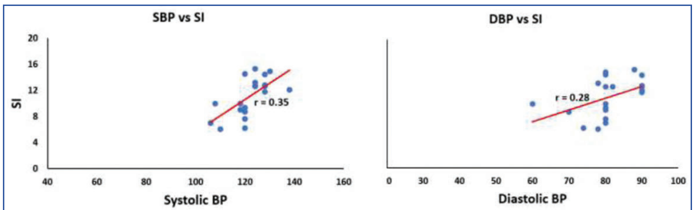
RESULTS

[Table/Fig-1] shows that the mean age of the samples was found to be 33.9±5.08 years. The mean height and weight of the samples were 176.4±7.39 cm and 83.9±15.0 kg, respectively. BMI and WHR showed a significant difference between normotensive and prehypertensive subjects, with p-values of 0.03 and 0.003, respectively. SI significantly increased in prehypertensives than normotensives (p=0.04) (Prehypertensives 11.2±2.51 and Normotensives 9.01±2.55).

Variable	Overall N=20	Normotensives (N=10)	Prehypertensives (N=10)	p-value
Age (years)	33.9±5.08	32.9±2.88	34.9±6.62	0.39
Height (cm)	176.4±7.39	175.6±6.97	177±8.08	0.66
Weight (kg)	83.9±15.0	78.9±11.2	88.9±17.2	0.14
BMI (kg/m²)	26.6±3.61	25.5±3.47	28.37±3.54	0.03*
W/H ratio	0.91±0.06	0.87±0.05	0.95±0.05	0.003*
Pulse Rate (/minute)	81.55±6.24	79.7±5.75	83.4±6.44	0.19
Systolic BP (mmHg)	121.8±7.70	116±5.65	127.6±4.29	0.001*
Diastolic BP (mmHg)	81±7.58	76.2±5.75	85.8±5.11	0.001*
Stiffness Index (SI)	10.25±2.77	9.01±2.55	11.2±2.51	0.04*

[Table/Fig-1]: Description of the study participants (Normotensives vs Prehypertensives).
W/H ratio: Waist Hip Ratio
Data expressed as mean±SD; Independent t-test
*p-value-≤ 0.05-significant

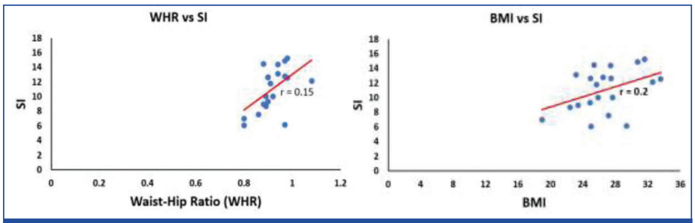
Pearson's correlation was applied to find the correlation between SI and other objective parameters such as BMI and WHR, SBP, and DBP. [Table/Fig-2-4] show a mild positive correlation of SI with SBP, DBP, BMI, and WHR, where their correlation coefficients (r) were found to be 0.35, 0.28, 0.2, and 0.15, respectively. However, there was no significant relationship among them.



[Table/Fig-2]: Pearson correlations of Stiffness Index (SI) with (a) Systolic BP (SBP) and (b) Diastolic BP (DBP).

Variables	Stiffness Index (SI) Correlation coefficient (r)	p-value
Systolic BP (SBP)	0.35	0.4
Diastolic BP (DBP)	0.28	0.9
Body Mass Index (BMI)	0.2	0.1
Waist Hip Ratio (WHR)	0.15	0.2

[Table/Fig-3]: Pearson correlations of Stiffness Index (SI) with Systolic BP (SBP), Diastolic BP (DBP), Body Mass Index (BMI) &Waist-Hip Ratio (WHR).
r=Pearson correlation coefficient
p≤0.05-significant



[Table/Fig-4]: Pearson correlations of Stiffness Index (SI) with (a) Waist Hip Ratio (WHR) and (b) Body Mass Index (BMI).

DISCUSSION

In the present study, arterial stiffness was evaluated using SI, which is a measure of large artery stiffness. SI was found to be increased in prehypertensives compared to normotensives [12,13]. Prehypertensives with increased BMI and increased WHR (>0.90) showed an increase in SI in this study. In normotensives, subjects with higher BMI (≥25 kg/m^2) showed a significant increase in SI. Higher BMI with increased SI would lead to vascular damage. In overweight and obese individuals, the increased serum leptin concentrations may predict arterial stiffness in patients with coronary artery disease [14]. Increased serum leptin may augment the release of endothelin-I (vasoconstrictor), leading to vascular remodeling and thus stiffening of vessels, which would lead to vascular damage [15]. Hyperleptinemia is an independent contributor to cardiometabolic syndrome in hypertensive patients [16].

WHR had a significant association with the development of large artery stiffness in prehypertensives. This might increase the after-load of the heart and thus increase BP [17]. The pathophysiological mechanism in the above could be due to raised levels of angiotensin II in visceral obesity, which is known to induce collagen cross-link formation in the extracellular matrix, leading to vascular stiffness [18]. Pearson's correlation coefficient test between SI and parameters such as SBP, DBP, BMI, and WHR showed a mild positive correlation. Thus, if these parameters were likely to increase, there would be stiffening of arteries and the risk for CVDs would be high [19,20].

A recent study conducted on children and adolescents revealed a noteworthy rise in arterial stiffness characteristics, serving as a stand-alone indicator for evaluating risk factors linked to CV illnesses [21]. Latest research findings on the effects of prolonged exposure to ozone and emotional changes have shown both functional and anatomical alterations to the arterial wall in hypertensives and prehypertensives, respectively [22,23]. Thus, a potentially useful strategy for reducing morbidity and mortality associated with CVDs is the non invasive, economical technique of measuring arterial stiffness in conjunction with health promotion initiatives [24-26]. Molecular studies, such as the role of free radicals to explain the actual cause and pathophysiological basis of prehypertension in young individuals, can be done in the future. Multicentric trials to evaluate the impact of emotional changes and environmental pollutants on arterial stiffness shall also be undertaken. Interventional studies, such as the role of relaxation exercises and meditation on lowering peripheral resistance and thereby arterial stiffness, can also be undertaken. Studies on the primordial prevention of CVDs by lifestyle modifications, such as consumption of Mediterranean diets rich in antioxidants and their effects on the SI, can also form part of cause and effect relationships.

Limitation(s)

The sample size of the current study was too small to establish the causal relationship of the variation in arterial SI in prehypertensives. In this study, authors were unable to establish the gender variation in SI, as the sample consisted of only male subjects.

CONCLUSION(S)

This study concludes that SI, which is an important CV risk marker, shows a significant increase in prehypertensive subjects when compared to normotensive subjects. However, SI showed mild positive correlation with BP and other anthropometric measurements, though not statistically significant.

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