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Dissecting the Arterial Stiffness in Hypertensive Individuals and its Intricate Relationship with Vitamin D: A Cross-sectional Study

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ABSTRACT

Introduction: Arterial stiffness is a critical predictor of cardiovascular events and mortality. Recent studies suggest that vitamin D may play a role in modulating arterial stiffness.

Materials and Methods: We conducted a cross-sectional study among 96 age-matched individuals of both genders between the normotensives and hypertensives to explore the intricate relationship between arterial stiffness and total vitamin D level. SPSS software version 20 was used for analysis of data which was presented as mean ± standard deviation (SD) after t-test. Correlation coefficient (r-value) was derived between the parameters by using Pearson's correlation while $p<0.05$ was considered statistically significant.

Results: We found a significant ($p <0.001$) difference for Arterial Stiffness Index (ASI) of different limbs, and vitamin D between our study groups. Our results suggest a positive correlation ($r = 0.67$, $p <0.001$) between arterial stiffness and blood pressure. We also observed a negative correlation ($r = -0.63$, $p <0.001$) of arterial stiffness with serum total vitamin D levels and blood pressure and vitamin D ($r = -0.87$, $p <0.001$) levels respectively.

Conclusions: We conclude that higher vitamin D levels are associated with lower arterial stiffness, and vitamin D supplementation may be beneficial in reducing arterial stiffness, particularly in individuals with low baseline vitamin D levels.

Keywords: Vitamin D, Arterial Stiffness, Arterial Stiffness Index (ASI), Hypertension, Blood Pressure.

INTRODUCTION

Arterial stiffness is a well-established marker for cardiovascular morbidity and mortality. It reflects the rigidity of arterial walls, primarily measured by the Arterial Stiffness Index (ASI) of different limbs [1]. The pathophysiology of arterial stiffness involves endothelial dysfunction, vascular smooth muscle cell alterations, and changes in extracellular matrix composition. Stiffening of arteries is associated with increased blood pressure in such a way that the development of any of the one can be etiological for the other [2]. Vitamin D, a steroid hormone, has been implicated in cardiovascular health through its effects on calcium metabolism, anti-inflammatory properties, and direct vascular actions [3]. Despite these proposed mechanisms, the influence of vitamin D on arterial stiffness remains debatable among the researchers of medicine and physiology. Our cross-sectional study aims to dissect the intricate relationship of vitamin D with arterial stiffness with a special emphasis on its complex association with blood pressure.

MATERIALS AND METHODS

Method of collection of data: The cross-sectional study was conducted in Vijayapura district of Karnataka after the ethical clearance was obtained from the Institutional Ethical Committee of BLDE (Deemed to be University) with 96 age-matched individuals according to the study design after obtaining informed written voluntary consent from all the study participants.

Study design: Age-matched (30 to 50 years) 36 normotensive individuals of both genders were considered participants in group-1 and 60 hypertensive individuals of both genders were considered participants in group-2. The convenience sampling method was applied for the selection of participants and the segregation of participants according to their blood pressure was performed by following the latest American Heart Association (AHA) guidelines [1]. Chronic alcohol abusers, smokers, chronic diseased persons or persons taking any regular medications were excluded from our study.

Assessed parameters: The blood pressure (BP) for each participant was measured manually by using a sphygmomanometer after giving 10 minutes of rest. Systolic Blood Pressure (SBP, mmHg) and Diastolic Blood Pressure (DBP, mmHg) were recorded and the difference between these two components of blood pressure was considered as Pulse pressure (PP, mmHg). The summative value of DBP and one-third of PP was considered as Mean Arterial Pressure (MAP, mmHg) [1]. Arterial Stiffness Index (ASI) of different limbs was recorded using Periscope, an automated device that works under an oscillometric method [4] after the BP was measured for each participant following which the blood sample was collected for analysis of serum levels of vitamin D by using ELISA method [5].

Statistical analysis: All the data were entered in a Microsoft Excel sheet and analyzed by using an SPSS software version 20 after which the data was presented as mean ± SD after performing the t-test. Correlation coefficient (r-value) was derived between the parameters by using Pearson's correlation while $p<0.05$ was considered statistically significant.

RESULTS

Table-1 depicts the comparative analysis of all the parameters that are assessed between the two groups. The increased value of the components of blood pressure in group-2 than group-1 makes it evident that the study participants were segregated according to the study design. The table shows that the level of vitamin D in group-2 is significantly ($p<0.05$) lower than the group-1 and the ASI of all four limbs is higher in group-2 than group-1.

Table-2 depicts the correlation coefficient (r-value) of all the assessed parameters with serum levels of vitamin D. It is quite evident from the table that all the components of blood pressure and the serum levels of total vitamin D are negatively correlated indicating that the individual suffering from either vitamin D deficiency or insufficiency is prone to develop hypertension. We also found a negative correlation of ASI of all four limbs with vitamin D suggesting the insufficiency or deficiency of serum level of vitamin D is associated with the development of arterial stiffness. Although we found a negative correlation of vitamin D with all the components of blood pressure, the highest value was evident with MAP.

Table-3 shows the correlation of MAP with the ASI of all four limbs. We found a positive correlation of MAP with ASI of all four limbs suggesting the association of arterial stiffness with an increase in blood pressure.

Table-1: Comparative analysis of all the parameters between groups

	Group-1 (n = 36)	Group-2 (n = 60)	p value
SBP (mmHg)	115.11 ± 3.40	142.47 ± 9.59	<0.001
DBP (mmHg)	73.28 ± 4.76	87.40 ± 6.34	<0.001
PP (mmHg)	41.83 ± 5.05	55.07 ± 9.09	<0.001
MAP (mmHg)	87.22 ± 3.65	105.76 ± 6.25	<0.001
Vitamin D (ng/ml)	35.92 ± 4.16	20.40 ± 5.60	<0.001
ASI_{RB} (mmHg)	25.40 ± 2.40	32.10 ± 7.52	<0.001
ASI_{LB} (mmHg)	26.08 ± 2.71	32.01 ± 7.65	<0.001
ASI_{RA} (mmHg)	31.36 ± 4.29	41.42 ± 10.17	<0.001
ASI_{LA} (mmHg)	33.79 ± 5.34	43.97 ± 9.65	<0.001

Data is represented in the form of mean ± SD. $p \leq 0.05$ is taken as statistically significant. SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure; ASI_{RB}, Arterial stiffness index right brachial; ASI_{LB}, Arterial stiffness index left brachial; ASI_{RA}, Arterial stiffness index right ankle; ASI_{LA}, Arterial stiffness index left ankle; n, number of participants.

Table-2: Correlation of all the assessed parameters with vitamin-D

	Vitamin D (ng/ml) Total study population (n = 96)	p value
SBP (mmHg)	r = -0.85	<0.001
DBP (mmHg)	r = -0.80	<0.001
PP (mmHg)	r = -0.58	<0.001
MAP (mmHg)	r = -0.87	<0.001
ASI_{RB} (mmHg)	r = -0.63	<0.001
ASI_{LB} (mmHg)	r = -0.56	<0.001
ASI_{RA} (mmHg)	r = -0.53	<0.001
ASI_{LA} (mmHg)	r = -0.51	<0.001

$p \leq 0.05$ is taken as statistically significant. SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure; ASI_{RB}, Arterial stiffness index right brachial; ASI_{LB}, Arterial stiffness index left brachial; ASI_{RA}, Arterial stiffness index right ankle; ASI_{LA}, Arterial stiffness index left ankle; n, number of participants; (-), negatively correlated.

Table-3: Correlation of the ASI of all four limbs with MAP

	MAP (mmHg) Total study population (n = 96)	p value
ASI_{RB} (mmHg)	r = 0.67	<0.001

ASI_{LB} (mmHg)	r = 0.57	<0.001
ASI_{RA} (mmHg)	r = 0.64	<0.001
ASI_{LA} (mmHg)	r = 0.57	<0.001

$p \leq 0.05$ is taken as statistically significant; MAP, mean arterial pressure; ASI_{RB}, Arterial stiffness index right brachial; ASI_{LB}, Arterial stiffness index left brachial; ASI_{RA}, Arterial stiffness index right ankle; ASI_{LA}, Arterial stiffness index left ankle; n, number of participants.

DISCUSSION

Our research provides robust evidence supporting the inverse relationship between vitamin D levels and arterial stiffness and underscores the potential cardiovascular benefits of maintaining adequate vitamin D status.

Involved Mechanisms: Vitamin D may influence arterial stiffness through several pathways, including the regulation of calcium homeostasis, inhibition of vascular smooth muscle cell proliferation, reduction of systemic inflammation, and improvement of endothelial function. However, the exact mechanisms remain to be fully elucidated [3].

Vitamin D and oxidative stress: As vitamin D has anti-oxidant properties, the deficiency or insufficiency of it may increase oxidative stress which in turn may be involved in the mechanisms of increasing blood pressure by modulating the vessels. Increased oxidative stress in turn may increase the arterial pressure and initiate the process of vascular modulation to develop arterial stiffness [3].

Obesity and arterial stiffness: Obesity has been associated with hypertension and its related diseases for a long time. There are a lot of studies that explain the underlying mechanisms by which obesity increases the stiffening of the vessels which in turn regulate the vasculature in such a way that the result is morbidities associated with altered cardiovascular health [1].

Advanced vascular ageing and arterial stiffness: Advanced vascular ageing is a resultant factor derived from the increased free radical activity which increases the reactive oxygen species (ROS) due to which there is the development of oxidative stress. This stress may be the underlying mechanism of the development of arterial stiffness [6].

Clinical Implications: Given the high prevalence of vitamin D deficiency globally, these findings have significant public health implications. Vitamin D supplementation could be a simple and cost-effective strategy to mitigate arterial stiffness and reduce cardiovascular risk, especially in at-risk populations [3].

CONCLUSION

The current evidence suggests that higher serum vitamin D levels are associated with lower arterial stiffness. Increased arterial stiffness may lead to hypertension and its related comorbidities. Vitamin D supplementation can effectively reduce arterial stiffness, particularly in individuals with vitamin D deficiency or insufficiency. These findings support the potential role of vitamin D in cardiovascular disease prevention and highlight the need for further research to confirm these benefits and inform clinical guidelines.

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