



Research Article

ISSN: 2454-5023
J. Ayu. Herb. Med.
2016; 2(6): 218-223
November- December
© 2016, All rights reserved
www.ayurvedjournal.com

Association of arterial stiffness measured from *Tridoshas* with diabetes- A cross sectional study

P.Venkata Giri Kumar¹, Sudheer Deshpande², Aniruddha Joshi³, Pooja More⁴, H.R. Nagendra⁵

¹ Research Scholar, Division of Yoga and Physical Sciences, S-VYASA Yoga University, Bengaluru, Karnataka-560019, India

² Joint Director, S-VYASA, Eknath Bhavan, Bengaluru, Karnataka-560019, India

³ Director, Atreya Innovations Pvt Ltd, Pune, Maharashtra-411057, India

⁴ Research Scholar, NIMHANS Integrated Centre For Yoga, National Institute of Mental Health and Neurosciences (NIMHANS), Bengaluru, Karnataka- 560029, India

⁵ Chancellor, S-VYASA Yoga University, Bengaluru, Karnataka-560019, India

ABSTRACT

Background: The arterial stiffness is well established pulse parameter in modern science and has shown significant results in assessing the cardio vascular risks such as diabetes. The association of arterial stiffness measured from *Tridoshas* with diabetes is not established in *Ayurveda*. **Objective:** The aim of this study is to investigate the association of arterial stiffness measured from *Tridoshas* with Type 2 diabetes. **Materials and Methods:** A total of 192 participants were included in this study. The pulse data was collected from *Tridosha* locations using *Nadi Tarangini*. The arterial stiffness parameters, stiffness index (SI) and reflection index (RI) were considered for the study. The participants were divided into two groups based on fasting plasma glucose (FPG) as defined by American Diabetes Association. The SI and RI were measured from *Tridoshas* and studied across diabetes and non-diabetes groups. **Results:** The SI at vata was negatively correlated with FPG ($p < 0.05$) for non-diabetes group whereas for diabetes group there was no significant correlation. The RI was not significantly correlating with FPG. There was a significant positive correlation between SI and RI ($p < 0.01$). The SI at vata was significantly higher in diabetes group (5.898 ± 0.786) compared to non-diabetes group (5.414 ± 1.179), SI at pitta was significantly low in diabetes group (7.308 ± 1.929) compared to non-diabetes group (8.726 ± 3.474) and SI at kapha was significantly low in diabetes group (6.529 ± 1.389) compared to non-diabetes group (6.529 ± 1.389). **Conclusion:** The results confirmed that the arterial stiffness measured from *Tridoshas* is significantly varying across diabetes and non diabetes groups.

Keywords: Arterial stiffness, Stiffness index, *Nadi Tarangini*.

INTRODUCTION

Diabetes Mellitus (DM) is a group of metabolic diseases characterized by hyperglycemia due to defects in insulin secretion, insulin action or both.^[1] The prevalence of diabetes is increasing globally and is estimated to be 334 million in 2030 when compared to 171 million in 2000.^[2] Diabetes is well known to *Ayurveda* as *madhumeha*. The classical texts *Caraka Samhita*^[3] and *Sushruta Samhita*^[4] have discussed in detail the prognosis and diagnosis of diabetes and they termed it as *madhumeha*, one of the varieties of *prameha*. According to *Caraka*, addiction to pleasure of sedentary habits and all *kapha* aggravating factors are responsible for *prameha* which may lead to *madhumeha*, if not treated in time. *Caraka* classified *pramehas* into *kaphaja*, *pittaja* and *vataja* based on *Tridosha* analysis which forms the basis for disease diagnosis and treatment in *Ayurveda*. The classical texts *Sarangadhara Samhita*^[5], *Yoga Ratnakara*^[6] and *Bhava Prakasha*^[7] have discussed *Tridoshas* based pulse examination in detail. The traditional *Ayurvedic* physicians were adept in pulse based diagnosis and used to diagnose the diseases effectively by just placing the hand at the wrist. In recent past bio-medical instruments based laboratory tests and reports have gained importance in diagnosing the disease and there is a need to bring the *Tridosha* analysis to instrumentation level.

The criteria for diagnosis and classification of diabetes defined by American Diabetes Association is well established clinical practice in diagnosing the diabetes^[8] but considering the rapid growth of diabetes there has been a growing research interest in finding alternate indicators for early identification of diabetes. In the recent past arterial stiffness measured from pulse wave velocity (PWV) has gained much of research importance and is considered to be strong predictor of cardio vascular events.^{[9], [10]} Alberto et.al have discussed in detail the role of arterial pulse wave analysis in enhancing the cardio vascular risk assessment.^[11] The methods and techniques have been standardized for arterial stiffness based studies

*Corresponding author:

P Venkata Giri Kumar
Division of Yoga and Physical
Sciences, S-VYASA Yoga
University, Bengaluru, Karnataka-
560019, India
Email: girikumarpv[at]gmail.com

which includes carotid-femoral pulse wave velocity (cfPWV), brachial-ankle pulse wave velocity (baPWV), photoplethysmography (PPG) and the arterial stiffness measured using cfPWV is considered as gold standard.^[12] Recent studies on cardio vascular risk factors such as Type 2 diabetes using these techniques have shown that arterial stiffness is closely associated to various risk factors in patients with diabetes and established the importance of arterial stiffness and its association with Type 2 diabetes.^{[13]–[21]}

The pulse wave measured from radial artery is similar to the digital volume pulse measured from PPG and is related by a transfer function^[22] but the significance of arterial stiffness measured from radial artery is yet to be established. The digital volume pulse measured from PPG comprises of forward and reflected waves with clear systolic and diastolic peaks respectively. The stiffness index (SI) and reflection index (RI) are the indices measured from systolic and diastolic peaks which are used to assess the arterial stiffness and endothelial function^[23] respectively. The SI is computed as the ratio of height of the person to the time interval between systolic and diastolic peaks and is considered as a measure of arterial stiffness. The reflection index (RI) is the ratio of diastolic to systolic peak amplitudes and it is related to endothelial function. Kim et al have shown that arterial stiffness measured from radial artery was associated to left ventricular diastolic dysfunction^[24] but they have used radial augmentation index in their study but not SI and RI. Hsien-Tsai et.al have studied the significance of SI and RI in monitoring the progression of arterial stiffness and endothelial function of elderly persons with diabetes.^[25]

As the arterial stiffness measured with standard techniques has shown significant results with diabetes, we investigated the significant variations in arterial stiffness measured from *Tridoshas* (*vata*, *pitta* and *kapha* locations) across diabetes and non diabetes groups. We have identified *Nadi Tarangini*, a non-invasive pulse acquisition system, for our study which acquires the pulse from *Tridosha* locations at the wrist.^[26] The reproducibility and completeness of *Nadi Tarangini* has been validated and studies have shown that the harmonics of the pulse wave and beat to beat alterations were varying significantly with age and disorder.^[27] The pulse rate variability of the pulse measured using *Nadi Tarangini* has shown similar effects as in heart rate variability^[28] The spectral analysis of pulse data acquired by *Nadi Tarangini* showed variations in range and area based on age and disorder of the person.^[29]

The aim of our study was to investigate the association of arterial stiffness measured from *Tridoshas* using *Nadi Tarangini* with Type 2 diabetes. We hypothesized that SI and RI measured from *Tridoshas* show significant variations across diabetes and non-diabetes.

MATERIALS AND METHODS

Subjects

In the present study, we took the data from the yoga camps conducted by S-VYASA as part of its ongoing studies on Yoga Therapy for Type 2 diabetes.^[30] We aimed at studying the arterial stiffness measured from *Tridoshas* across diabetes and non diabetes groups. The pulse data corresponding to 192 participants (non diabetes – 104, diabetes – 88) were analyzed as part of our study.

Inclusion Criteria

All men and women above 20 years were considered for this study and participants with and without diabetes were included. The medical history of the participants was examined by an *ayurvedic* doctor. The participants without any pre diagnosed diseases and were not under any medication were included in non diabetes group. The participants with pre diagnosed diabetes were included in diabetes group.

Exclusion Criteria

The participants who were on regular medication were excluded from the study. The participants who were not willing to participate in the study were excluded.

Ethics Consideration

The study was approved by Institutional Ethics Committee of S-VYASA. We have explained the study to all the participants and the written informed consent was obtained from all the participants. We have considered only those participants who were willing to be part of the study.

Study Design

The age, height, body mass index (BMI), systolic blood pressure (SBP), and diastolic blood pressure (DBP) of the participants were measured. The fasting plasma glucose of the participants was measured after overnight fasting. All the measurements were done at the beginning of the camp. The blood pressure was measured using Sphygmomanometer.

The participants were divided into two groups based on fasting plasma glucose levels as per criteria defined by American Diabetes Association. The participants with FPG < 126 mg/dl were included in non-diabetes group and the participants with FPG ≥ 126 mg/dl were included in diabetes group. As part of our study we have included participants with normal glucose level (FPG < 100) and impaired fasting glucose (100 ≤ FPG < 126) into non-diabetes group.

Pulse Measurement

Nadi Tarangini, a simple, cost effective and non-invasive pulse acquisition system, was used for collecting pulse data which has three linearly placed pressure transducers, a 16bit multifunction data acquisition card NI USB-6210 (National Instruments, TX, USA) and LABVIEW, a data acquisition software. The pulse data was sampled at 500Hz and LABVIEW was used for acquiring the sensor data and storing it in personal computer. The pulse data was acquired from participants from 6am to 1pm and 2 to 4pm. The pulse data was collected for one minute by placing the sensors on *vata*, *pitta* and *kapha dosha* locations on the wrist. Initially the pulse was sensed with fingers to identify the exact *vata*, *pitta* and *kapha* locations and then the sensors were placed by closely aligning it with the sensed locations. The pulse data was collected in multiple sessions of the day. The pulse data consists of time and amplitudes of the pulse at *vata*, *pitta* and *kapha* locations. As the pulse data gets corrupted due to the noise induced by electrical and electronic sources, it was cleaned up using wavelet transformation. The *vata* *pitta* and *kapha* data with clear systolic and diastolic peaks was considered for the study and after analyzing the pulse data we considered 53 *vata*, 49 *pitta*, 42 *kapha* pulses in non

diabetes group and 47 *vata*, 40 *pitta* and 41 *kapha* pulses in diabetes group for our study. The remaining pulse data was discarded as the systolic and diastolic peaks were not proper and reasons for not having proper systolic and diastolic peaks needs further investigation. As per our initial analysis the pulse would have been weak in those locations for *Nadi Tarangini* to acquire it precisely, secondly if the sensors were not precisely aligned with *Tridosha* locations the pulse acquisition may get distorted. The stiffness index SI and reflection index RI were computed for each of the *vata*, *pitta* and *kapha* pulses from these proper systolic and diastolic peaks. We aimed at studying the SI and RI measured from *vata*, *pitta* and *kapha* pulses independently across diabetes and non-diabetes groups. The SI of *vata* pulse from diabetes group was compared with SI of *vata* pulse from non-diabetes group and similar analysis was done for *pitta* and *kapha* pulses also.

Stiffness Parameters

The stiffness parameters SI and RI were computed from the pulse as shown in Figure 1

- stiffness index (SI) = height of the person / (T4 – T1)
- reflection index (RI) = Diastolic Peak (P4) / Systolic Peak (P1)

Statistical Analysis

The data were analyzed using SPSS Statistics Version 10. The data was presented as mean \pm standard deviation. The data was assessed for normality using Kolmogorov-Smirnov test and stiffness indices (SI) was found to be normally distributed and RI was not normal. The mean values of SI and RI at *Tridosha* locations across diabetes and non-diabetes groups were tested using independent samples t test. The Cohen's d effect size was computed for assessing the difference in stiffness parameters across diabetes and non-diabetes groups. Pearson's correlation coefficient was used to study the relationship

between FPG and stiffness indices measured from pulse data. A two tailed p value <0.05 is considered statistically significant for all comparisons. Data were reported to three significant figures.

RESULTS

The characteristics of the study population are listed in **Table 1**.

A total of 192 participants were included in the study with 104 subjects in non-diabetes group and 88 subjects in diabetes group. The subjects in non-diabetes group were of the age between 38 and 81 years and in diabetes group between 22 and 76. The summary of independent samples t test is shown in **Table 2**. The SI at *vata* ($p < 0.05$) was significantly higher in diabetes group compared to non-diabetes group with medium effect size. The SI at *pitta* ($p < 0.05$) and *kapha* ($p < 0.05$) were significantly lower in diabetes group compared to non-diabetes group with moderately large effect size. There was no significant difference in RI ($p = 0.405$) in all the *dosha* locations when compared between diabetes and non-diabetes groups.

In univariate analysis SI has shown significant differences in Pearson correlation coefficient between the two groups as shown in **Table 3**. There was a significant negative correlation between SI at *vata* and fasting plasma glucose ($r = -0.313$; $p < 0.05$) in non-diabetes group where as in diabetes group SI at *vata* was not significantly correlated with fasting plasma glucose ($r = 0.075$; $p = 0.615$). There were no significant correlations between FPG and SI at *pitta* and *kapha* locations. There was no significant correlation between RI and fasting plasma glucose in both the groups. There was a significant positive correlation between SI and RI at *vata* in non-diabetes group ($r = 0.387$; $p < 0.01$), at *pitta* in both diabetes ($r = 0.362$; $p < 0.05$) and non diabetes groups ($r = 0.337$; $p < 0.05$) and at *kapha* in diabetes group ($r = 0.344$; $p < 0.05$).

Table 1 : Characteristics of Study Population across *vata*, *pitta* and *kapha* groups

Parameters		vata	pitta	kapha
Age	Non Diabetes	58.17 \pm 9.756	58.44 \pm 10.897	55.88 \pm 9.247
	Diabetes	53.98 \pm 11.324	57.95 \pm 12.048	57.08 \pm 11.893
Height (cm)	Non Diabetes	164.111 \pm 9.131	165.012 \pm 8.632	166.467 \pm 8.283
	Diabetes	166.002 \pm 8.131	164.495 \pm 9.058	163.944 \pm 13.605
BMI (Kg/m ²)	Non Diabetets	24.970 \pm 4.071	24.843 \pm 4.102	25.185 \pm 4.740
	Diabetes	25.351 \pm 4.209	24.388 \pm 4.679	25.357 \pm 8.265
SBP (mm Hg)	Non Diabetes	133.88 \pm 23.155	132.17 \pm 20.864	127.24 \pm 14.681
	Diabetes	126.94 \pm 25.510	123.67 \pm 26.967	127.90 \pm 16.004
DBP (mm Hg)	Non Diabetes	79.87 \pm 10.568	79.17 \pm 10.303	81.83 \pm 9.680
	Diabetes	80.21 \pm 10.213	77.46 \pm 10.733	81.65 \pm 11.026
FPG (mg/dl)	Non Diabetes	101.021 \pm 14.319	102.231 \pm 13.803	100.905 \pm 13.910
	Diabetes	186.609 \pm 67.104	194.375 \pm 61.219	188.210 \pm 61.067

Data are shown as mean \pm s.d

BMI, Body Mass Index; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; FPG, Fasting Plasma Glucose; SI, Stiffness Index; RI, Reflection Index;

Table 2: Means of SI and RI compared across diabetes and non-diabetes groups

Tridosha	Parameters	Non-Diabetes	Diabetes	p value*	ES [CI]
vata	SI (m/s)	5.414 ± 1.179	5.898 ± 0.786	0.019	0.483 [-0.177, -0.016]
	RI	0.837 ± 0.076	0.851 ± 0.073	0.326	0.188 [-0.044, 0.149]
	Ht (cm)	164.111 ± 9.131	166.002 ± 8.131	0.276	
pitta	SI (m/s)	8.726 ± 3.474	7.308 ± 1.929	0.023	-0.505 [0.039, 0.528]
	RI	0.945 ± 0.041	0.946 ± 0.032	0.966	0.027 [-0.016, 0.015]
	Ht (cm)	165.012 ± 8.632	164.495 ± 9.058	0.784	
kapha	SI (m/s)	8.021 ± 2.814	6.529 ± 1.389	0.003	-0.671 [0.104, 0.493]
	RI	0.952 ± 0.033	0.951 ± 0.036	0.953	-0.028 [-0.147, 0.016]
	Ht (cm)	166.467 ± 8.283	163.944 ± 13.605	0.313	

Data are shown as mean ± s.d

SI, Stiffness Index; RI, Reflection Index; Ht, Height of the person;

* p value comparing diabetes and non-diabetes groups; significance at 0.05 level

ES: Effect Size computed as the ratio of difference in means of two groups to pooled standard deviation

CS: 95% Confidence Interval of the Mean difference of the two groups

Table 3: The correlations between stiffness indices and Fasting Plasma Glucose

Tridosha		SI (m/s)		RI	
		r value	p value*	r value	p value*
vata	Non-diabetes	-0.313	0.023	-0.132	0.347
	Diabetes	-0.020	0.893	0.128	0.393
pitta	Non-diabetes	-0.076	0.605	0.119	0.414
	Diabetes	-0.015	0.926	0.024	0.885
kapha	Non-diabetes	-0.059	0.709	0.206	0.190
	Diabetes	0.290	0.066	0.249	0.117

SI, Stiffness Index; RI, Reflection Index;

* Pvalue comparing diabetes and non-diabetes groups; significance at 0.05 level

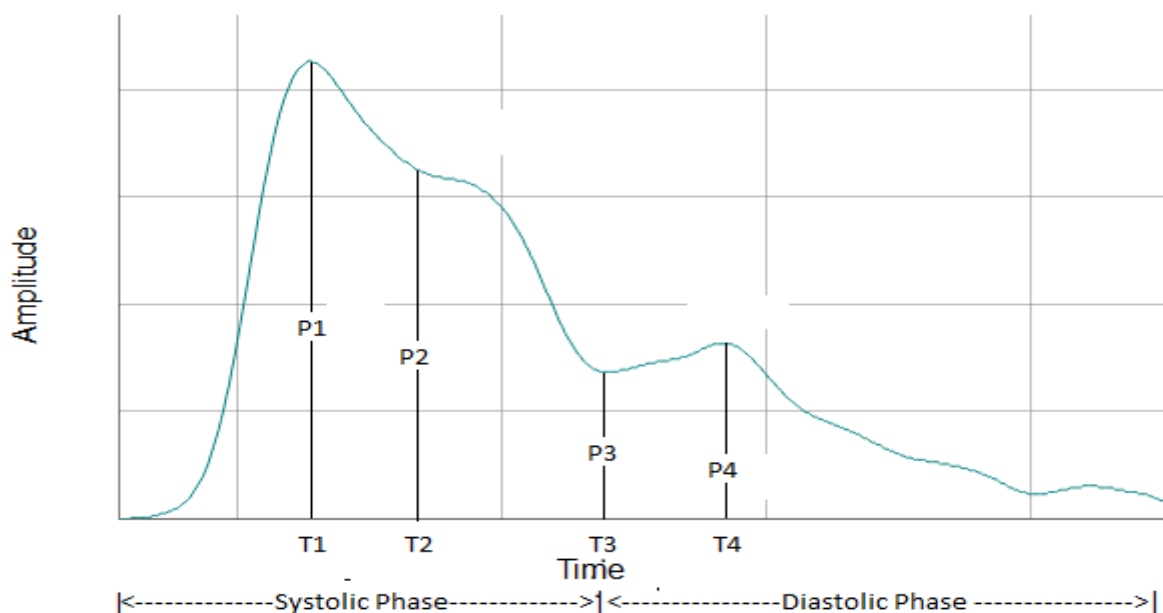


Figure 1: Pulse wave acquired using Nadi Tarangini, representing various peaks and time periods of the radial pulse

P1 = pulse amplitude at systolic peak; P2 = pulse amplitude at inflection point; P3 = pulse amplitude at dichrotic notch;

P4 = pulse amplitude at Diastolic Peak;

Time periods T1, T2, T3, T4 are measured from start of the systolic phase

T1 = time period at systolic peak; T2 = time period at inflection point; T3 = time period at dichrotic notch;

T4 = time period at diastolic peak

stiffness index = height of the person / (T4 – T1)

reflection index = diastolic peak / systolic peak (P4/P1)

DISCUSSION

The focus of our study was to measure the arterial stiffness at *Tridoshas* and investigate how these stiffness parameters were associated to diabetes. The study was done across diabetes and non-diabetes populations. In our study SI at *vata* of non-diabetes group was negatively correlated with fasting plasma glucose which confirms with the previous study^[25] measuring the arterial stiffness from radial artery. In the previous study, association of SI with FPG was studied by including both diabetes and non-diabetes into a single group. In our study, we observed the association of SI with fasting plasma glucose only in non-diabetes group and there was no such association in diabetes group which is a significant result. There were no such correlations for SI at *pitta* and *kapha* locations for both the groups. The SI at *Tridosha* locations were significantly different with large effect size across both the groups. The SI at *vata* of diabetes group was high compared to non-diabetes. The diabetes group has shown significantly lower SI at *pitta* and *kapha* locations when compared to non-diabetes group. Mizuho *et al.* in their study based on baPWV technique^[31] reported higher values of arterial stiffness in diabetes compared to non-diabetes. As the stiffness index computation included height of the person, we have tested the mean heights of the subjects in both the groups using independent t test and found that the difference was not significant which confirmed that the significance of difference in SI was mainly due to arterial stiffness and not due to height of the persons. The stiffness index represents the time interval between systolic and diastolic peaks and based on the results we see that the diastolic peak at *vata* arrived earlier in diabetes group compared to non diabetes group where as the diastolic peaks at *pitta* and *kapha* arrived late in diabetes group compared to non diabetes group. The pilot study has shown variations in systolic to diastolic peaks across *Tridoshas* which is a significant result and there is a need to in depth studies on arterial stiffness to understand the nature *vata*, *pitta* and *kapha doshas* and diagnosing diabetes from *Tridoshas*.

In our study RI was not significantly correlated to FPG at *Tridoshas* in both the groups and the mean value of RI was not significantly varying across both the groups. Mizuho *et al.* have reported similar results in their study wherein they have measured endothelial function using flow-mediated vasodilation.^[31] The endothelial dysfunction and arterial stiffness are considered as independent markers for cardio vascular risks such as Type 2 diabetes and Mizuho *et al.* demonstrated the significant association of these two parameters in their study. In our study the positive correlation ($p < 0.01$) between SI and RI at *Tridoshas* confirmed the association of these parameters with arterial stiffness and endothelial function. In non diabetes group SI and RI were correlated at *vata* and *pitta* locations whereas in diabetes group they were correlated at *pitta* and *kapha* locations. Both diabetes and non-diabetes groups have shown significant correlation between SI and RI at *pitta* location. The results of our study confirmed that SI measured at *Tridoshas* was significantly varying across diabetes and non diabetes groups.

The study based on cfPWV has shown that arterial stiffness was positively correlated with fasting plasma glucose^[32] and in another study based on baPWV technique has shown positive correlation between arterial stiffness fasting plasma glucose in non-diabetes group.^[15] These studies have shown positive correlation between fasting plasma glucose and arterial stiffness whereas our study has

shown negative correlation. The reason for such a difference in the direction of the correlation may be due to the location of the pulse which need to be investigated further. In another study based on PPG stiffness index was not significantly correlating with fasting plasma glucose^[21] and these results were not matching with our results and also with other results.

There were some limitations in our study. The sample size was relatively small which included the age group ranging from 22 to 81 years, There is a need to study the significance of the results with larger sample size by grouping the subjects according to age, BMI and blood pressure. The screening of participants to form diabetes and non-diabetes groups was done based on fasting plasma glucose values and the other diabetes risk factors such as obesity, hypertension, cholesterol, genetics etc., were not considered for screening but included into the study. The triglycerides have shown positive association with arterial stiffness measured using cfPWV^[33] which signifies the importance of considering triglycerides while screening. The study considered fasting plasma glucose values based on which diabetes and non-diabetes groups were formed but did not include glucose tolerance test in diagnosing diabetes. The current study did not include impaired fasting glucose as a separate group and future studies can focus on this study. Further studies need to be done to establish the relationship between endothelial function and RI.

The results of our study confirmed that SI measured at *Tridoshas* was significantly varying across diabetes and non-diabetes. The association of arterial stiffness with FPG and RI was established with other techniques and in our study, we have confirmed the same with *Tridoshas*. RI is related to endothelial function and was strongly associated to SI representing arterial stiffness. As arterial stiffness, may increase due to many other factors there is a need to prospectively study the significance of arterial stiffness in assessing the risk of Type 2 diabetes.

Ayurveda is well known for pulse based diagnosis and classical texts of Ayurveda provide a detailed description of pulse based diagnosis and treatment. The pulse parameters SI and RI have shown new direction to the pulse based research in Ayurveda and these parameters need to be studied in depth to prove the concepts of *Tridoshas* as defined in Ayurveda texts. We think this is the first attempt in investigating the association of arterial stiffness measured at *Tridoshas* with diabetes. In future, the study can be extended to investigate the significance of stiffness parameters measured from *Tridoshas* in diagnosing other diseases.

CONCLUSIONS

In conclusion, the arterial stiffness measured from *Tridoshas* was significantly varying across diabetes and non-diabetes groups. The results of our study are promising and further prospective studies need to be done to understand the nature of *Tridoshas* objectively which can aid in diagnosing diabetes at early stage.

Acknowledgements

We express our sincere thanks to S-VYASA in supporting this study and all the volunteers of S-VYASA who helped us at various stages of the project. We sincerely thank Dr. Judu Ilavarasu for reviewing the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial or non-for-profit sectors.

REFERENCES

1. The Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. "Report of the Expert Committee on the DESCRIPTION OF DIABETES CATEGORIES OF GLUCOSE". *Diabetes Care* 2003;26(1):5-20.
2. Wild. "Estimates for the year 2000 and projections for 2030". *World Health* 2004;27(5):1047-53.
3. Dash RKSB. *Caraka Samhita*. Chowkambha Sanskrit Series Office, Varanasi, 1995.
4. Shastry KA. *Sushruta Samhita*. Chowkambha Sanskrit Samsthana, Varanasi, 1997.
5. Murthy PHC. *Śārṅgadhara Samhita of Śārṅgadharaçārya*, 2n Edition. Varanasi: Chowkamha Sanskrit Series Office, 2007.
6. M. SSB. *Yoga Ratnakara (Vol I)*, 2nd Editio. Varanasi: Chowkamha Sanskrit Series Office, 2011.
7. Murthy. *Bhavaprakasa of Bhavamisra (Vol I)*. Varanasi: Chowkambha Krishnada Academy, 2008.
8. American Diabetes Association. *Diabetes Mellitus and other categories of description of Diabetes*. 2004;27:5-10.
9. Zoungas S Asmar RP. Arterial stiffness and cardiovascular outcome. *Clin Exp Pharmacol Physiol* 2007;34(7):647-51.
10. Vlachopoulos C, Aznaouridis K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness. A systematic review and meta-analysis. *J Am Coll Cardiol* 2010;55(13):1318-27.
11. Avolio AP, Butlin M, Walsh A. Arterial blood pressure measurement and pulse wave analysis--their role in enhancing cardiovascular assessment. *Physiol Meas* 2010;31(1):R1-47.
12. Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, Böhm M. *et al*. 2013 ESH/ESC guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *Eur Heart J* 2013;34(28):2159-2219.
13. Wu N, Cai X, Ye K, Li Y, He M, Zhao W *et al*. Association between Brachial-Ankle pulse wave velocity and cardiac autonomic neuropathy in type 2 diabetes. *Diabetol Metab Syndr* 2014;6(1):82.
14. Katakami N, Osonoi T, Takahara M, Saitou M, Matsuoka TA, Yamasaki Y *et al*. Clinical utility of brachial-ankle pulse wave velocity in the prediction of cardiovascular events in diabetic patients. *Cardiovasc Diabetol* 2014;13(1):128.
15. Shin JY, Lee HR, Lee DC. Increased arterial stiffness in healthy subjects with high-normal glucose levels and in subjects with pre-diabetes. *Cardiovasc Diabetol* 2011;10:30.
16. Bouchi R, Asakawa M, Ohara N, Nakano Y, Takeuchi T, Murakami M *et al*. Indirect measure of visceral adiposity 'A Body Shape Index' (ABSI) is associated with arterial stiffness in patients with type 2 diabetes. *BMJ Open Diabetes Res Care* 2016;4(1):e000188.
17. Sheen YJ, Lin JL, Li TC, Bau CT, Sheu WH. Peripheral arterial stiffness is independently associated with a rapid decline in estimated glomerular filtration rate in patients with type 2 diabetes. *Biomed Res Int* 2013; 309294.
18. Osonoi Y, Mita T, Osonoi T, Saito M, Tamasawa A, Nakayama S *et al*. Poor sleep quality is associated with increased arterial stiffness in Japanese patients with type 2 diabetes mellitus. *BMC Endocr Disord* 2015;15(1):1-7.
19. Nordstrand N, Gjevestad E, N-Dinh K, Hofso D, Roislien J, Saltvedt E. *et al*. The relationship between various measures of obesity and arterial stiffness in morbidly obese patients. *BMC Cardiovasc Disord* 2011;11(1):7.
20. Shim SH, Kim CY, Kim JM, Kim DY, Kim YJ, Bae JH *et al*. The role of systemic arterial stiffness in open-angle glaucoma with Diabetes Mellitus. *Biomed Res Int* 2015;15.
21. Gunarathne A, Patel JV, Hughes EA, Lip GYH. Measurement of stiffness index by digital volume pulse analysis technique: clinical utility in cardiovascular disease risk stratification. *Am J Hypertens* 2008;21(8):866-72.
22. Millasseau, Guigui FG, Kelly RP, Prasad K, Cockcroft JR, Ritter JM *et al*. Noninvasive assessment of the digital volume pulse. Comparison with the peripheral pressure pulse. *Hypertension* 2000;36(6):952-56.
23. Millasseau SC, Ritter JM, Takazawa K, Chowienzyk PJ. Contour analysis of the photoplethysmographic pulse measured at the finger. *J Hypertens* 2006;24(8):1449-56.
24. Kim G, Kim JH, Moon KW, Yoo KD, Kim CM, Moon D *et al*. The relationships between the arterial stiffness index measured at the radial artery and left ventricular diastolic dysfunction in asymptomatic high risk patients without atherosclerotic cardiovascular disease. *Int Heart J* 2016;57(1):73-79.
25. Hsien-Tsai W, Lee CH, Liu AB, Chung WS, Tang CJ, Sun CK *et al*. Arterial stiffness using radial arterial waveforms measured at the wrist as an indicator of diabetic control in the elderly. *IEEE Trans Biomed Eng* 2011;58(2):243-52.
26. Joshi A, Kulkarni A, Chandran S, Jayaraman VK, Kulkarni BD. Nadi Tarangini: a pulse based diagnostic system. *Conf Proc IEEE Eng Med Biol Soc* 2007; Jan 2207-10.
27. Joshi, Chandran S, Jayaraman VK, Kulkarni BD. Arterial pulse system: modern methods for traditional Indian medicine. *Conf. Proc. Annu Int Conf IEEE Eng Med Biol Soc Annu. Conf.* 2007, Jan 608-11.
28. Joshi, Chandran S, Jayaraman VK, Kulkarni BD. Arterial pulse rate variability analysis for diagnoses. *2008 19th Int Conf Pattern Recognit.* 2008; Dec. 1-4.
29. Joshi, S. Chandran, V. K. Jayaraman, and B. D. Kulkarni, "Multifractality in arterial pulse," *2008 19th Int. Conf. Pattern Recognit.*, pp. 1-4, Dec. 2008.
30. More P, Joshi A, Nagendra H. Developing a diagnostic tool for Type 2 diabetes based on Tridosha analysis through Nadi Pariksha. *Int Ayurvedic Med J* 2014;2(6):9.
31. Kinouchi M, Aihara K, Fujinaka Y, Yoshida S, Ooguro Y, Kurahashi K *et al*. Diabetic conditions differentially affect the endothelial function, arterial stiffness and carotid atherosclerosis. *J Atheroscler Thromb* 2014;21(5):486-500.
32. De Oliveira Alvim RD, Mourao-Junior CA, De Oliveira CM, De Faria Lima R, Horimoto ARVR, Hong VAC. Glycemic control and arterial stiffness in a Brazilian rural population: Baependi Heart Study. *Diabetol Metab Syndr* 2015;7(1):86.
33. Wang X, Ye P, Cao R, Yang X, Xiao W, Zhang Y *et al*. Triglycerides are a predictive factor for arterial stiffness: a community-based 4.8-year prospective study. *Lipids Health Dis* 2016;15(1):97.

HOW TO CITE THIS ARTICLE

Kumar PVG, Deshpande S, Joshi A, More P, Nagendr HR. Association of arterial stiffness measured from *Tridoshas* with diabetes- A cross sectional study. *J Ayu Herb Med* 2016;2(6):218-223.