Significance of arterial stiffness in Tridosha analysis: A pilot study

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A R T I C L E   I N F O

Article history:
Received 31 October 2016
Received in revised form 15 February 2017
Accepted 17 February 2017
Available online 2 November 2017

Keywords:
Stiffness index
Reflection index
Nadi Tarangini

A B S T R A C T

Background: The variations in Tridoshas are the basis for disease diagnosis and treatment in Ayurveda. The doshas are assessed by sensing the pulse manually with fingers which depends on skill of the physician. There is a need to measure doshas using instruments and study them objectively.

Objective: Arterial stiffness is well established pulse parameter in modern medicine and is closely associated with kathiyana in the context of Ayurveda. The aim of our study was to measure arterial stiffness using Nadi Tarangini, a pulse acquisition system, and investigate the significant variations of stiffness across Tridosha locations.

Materials and methods: A total of 42 samples of vata, pitta and kapha pulses with proper systolic and diastolic peaks were included in the study. The arterial stiffness parameters namely stiffness index (SI) and reflection index (RI) were considered for the study. The data was analyzed using one-way ANOVA followed by Tamhane’s T2 test. The changes in SI and RI between males and females were assessed using independent samples t test.

Results: SI at vata (5.669 ± 1.165) was significantly low compared to pitta (8.910 ± 3.509) and kapha (8.021 ± 2.814); RI at vata (0.846 ± 0.071) was significantly low compared to pitta (0.945 ± 0.043) and kapha (0.952 ± 0.033). SI at kapha was significantly low in females compared to males.

Conclusion: The SI and RI acquired using Nadi Tarangini have shown significant variations across Tridosha locations. The framework developed to measure the arterial stiffness across Tridosha locations can be used for the interventional studies in Ayurveda which in turn can help in disease diagnosis and treatment.

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1. Introduction

Ayurveda is well known for its pulse based diagnosis which is primarily based on Tridoshas namely vata, pitta and kapha. As per Ayurveda, imbalance in Tridoshas is termed as disease and restoring the balance is health. The classical texts Caraka Samhita [1], Sushruta Samhita [2] and Ashtanga Sangraha [3] have discussed in detail the nature of Tridoshas and its usefulness in disease diagnosis and treatment. The art of pulse reading is unique to Ayurveda where physicians place the index, middle and ring fingers on the wrist and assess the intensities of vata, pitta and kapha doshas respectively which forms the basis for diagnosis and treatment. Sarangadhara [4], in his work Sarangadhara Samhita, introduced pulse examination as a means of diagnosis and is considered to be done for the first time in history of Ayurveda. The classical texts Yoga Ratnakara [5] and Bhava Prakasha [6] also emphasized the importance of pulse based diagnosis.

Ayurveda has thousands of years of rich experience and assessment of prakriti plays a critical role in disease diagnosis and treatment. Ayurveda has very strong roots in pulse based diagnosis but it is subjective in nature and depends on the skill of the physician. It lacks the scientific evidence which is the need of the day as evidence based research is gaining importance in accepting any medicine or system of medicine [7,8]. In the recent past there is a growing research interest in studying prakriti in an objective
manner with the help of prakriti assessment tools [9] as Ayurvedic physicians have agreed the need for research based standardized tool for prakriti assessment [10]. The standardized questionnaires such as Sushruta Prakriti Inventory (SPI) [11], Caraka Child Personality Inventory [12], Mysore Tridosha Scale [13] have shown significant results in prakriti assessment. Recent studies on genetics with help of prakriti questionnaires have shown that prakriti and genes are closely associated which emphasizes the significance of questionnaires in assessing prakriti [14–17]. To strengthen the research further there is a need for measuring Tridoshas like any other clinical parameter like blood pressure, fasting blood sugar etc. This necessitates the need for a very precise pulse acquisition system which captures the pulse at vata, pitta and kapha locations. With the advancement of sensor technology pulse vibrations can be acquired very precisely and studies on the pulse acquired using Nadi Tarangini [18], have shown complete and reproducible high quality vata, pitta and kapha signals with significant variations in Tridosha locations with age and disorder which were matching with Ayurvedic literature. Nadi Tarangini based studies on pulse rate variability [19], beat to beat alterations [20], spectral analysis [21] and classification of diabetes [22] have shown significant results. These studies have demonstrated the pulse acquisition capabilities of the instrument which is a key requirement for pulse based research. However, evidence based research still needs parameters which represent the pulse with appropriate physiological basis and good literature support.

As per our literature review we found that arterial stiffness measured from pulse wave is accepted as an important parameter in assessing the cardiovascular risks. Number of studies have been done on arterial stiffness measured using carotid femoral (cfPWV), brachial ankle (baPWV) and photoplethysmography (PPG) techniques. The arterial stiffness measured with brachial ankle pulse wave velocity (baPWV) has gained clinical and research importance and studies have established the significance of arterial stiffness measured with this technique [23]. In similar lines the arterial stiffness measured using PPG has shown significant association with cardiovascular risk scores [24]. The digital volume pulse (DVP) acquired using PPG is composed of forward and reflected waves. Due to the reflected wave a peak appears in the diastolic phase and is known as diastolic peak. The time interval between systolic and diastolic peaks is proportional to the total path length of the pressure wave (from root of the artery to reflection point and back to root of the artery) and height of the person. The stiffness index (SI) is the ratio of height of the person to the time interval between systolic and diastolic peaks and reflection index is the ratio of diastolic to systolic peaks [25].

In Ayurveda, the pulse parameters gati (movement), vega (rate), tala (rhythm), bala (force), tapamana (temperature), akriti (volume and tension) and kathinya (consistency of the vessel wall) are considered to be of clinical importance [26]. The parameter kathinya represents the condition of the vessel wall such as thickness, hardness, elasticity and it is qualitatively assessed by rolling the artery between the finger and radial artery bone. The hardness of the artery was discussed in detail in Basavarajeeyam [27]. As the evidence based research is gaining importance there is a need to quantitatively assess kathinya with the help of instruments. The arterial stiffness measures the stiffness of the arteries and we think it is closely associated to kathinya. We aimed at studying the significance of arterial stiffness measured from radial artery across Tridosha locations. We have identified Nadi Tarangini for this study and the arterial stiffness indices namely stiffness index (SI), and reflection index (RI) were considered for the study. We hypothesized that stiffness indices vary significantly when measured at Tridosha locations. To test this hypothesis, we have measured the arterial stiffness at vata, pitta and kapha locations using Nadi Tarangini and assessed the significance of its variations across Tri-dosha locations.

2. Materials and methods

2.1. Participants

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. The participants of yoga camps include individuals with no diabetes, diabetes and pre-diabetes. Pooja More et al. have investigated the diagnostic capability of Nadi Tarangini instrument in diagnosing diabetes using frequency domain analysis [22]. We have identified 90 participants not having diabetes for our study and investigated the variations of arterial stiffness across Tridosha locations. A total of 42 samples of vata, pitta and kapha pulses with proper systolic and diastolic peaks were included in our study after analyzing 90 participants’ Nadi data acquired using Nadi Tarangini.

2.2. Inclusion criteria

All men and women above 40 years who were not suffering from diabetes or pre-diabetes were included in the study. The health of the participants was assessed by an Ayurvedic doctor by interviewing the participants on their health status. The participants who were currently not having any diseases and were not taking any medicines for any of the diseases were included in the study.

2.3. Exclusion criteria

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

2.4. 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.

2.5. Study design

The aim of the study was to investigate the changes in SI and RI across vata, pitta and kapha locations and accordingly three groups were created. The SI and RI measured at vata location were entered into vata group and similarly for the other two pulse locations. We have not assessed prakriti of the person in our study and groups were not formed based on prakriti but based on the location of the pulse. The age, height, body mass index (BMI), systolic blood pressure (SBP), and diastolic blood pressure (DBP) of the participants were measured. All the measurements were done at the beginning of the camp. The blood pressure was measured using sphygmomanometer.

2.6. 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 500 Hz and LABVIEW was used for acquiring the sensor data and storing it in personal computer. The pulse data collection was done in two sessions 6am to 1pm and 1pm to 4pm. The pulse data was collected for 1 min by placing the sensors on vata, pitta and kapha dosha locations on the wrist. The pulse location on the wrist below the root of the thumb was considered as vata location, next to it as pitta and next to pitta was considered as kapha location. Initially the pulse at vata, pitta and kapha locations was sensed with index, middle and ring fingers respectively to identify the exact vata, pitta and kapha locations and then the sensors were placed on the wrist by closely aligning it with the sensed locations. The pulse data consists of time and amplitudes of the pulse at the wrist by closely aligning it with the sensed locations. The pulse data were presented as mean ± standard deviation. The pulse data with clear systolic and diastolic peaks were considered for the study and remaining data were discarded. We have seen that only some individuals had proper systolic and diastolic peaks in all the three locations and in others peaks were not proper in one or other locations. We think pulse would have been weak in those locations for Nadi Tarangini to acquire it precisely and secondly the sensors would have been slightly misaligned with Tridosha locations which can result into distorted pulse. We have got 42 samples of vata, pitta and kapha pulses after analyzing the data of 90 participants. As the pulse was not having proper peaks in all the three locations the individuals in vata, pitta and kapha groups are not same.

2.7. Pulse parameters

The pulse data acquired by Nadi Tarangini was a continuous wave and Fig. 1 corresponds to single pulse wave isolated from stream of pulse waves. The stiffness indices are computed as follows

- stiffness index (SI) = height of the person/(T4 − T1).
- reflection index (RI) = diastolic peak/systolic peak (P4/P1).

2.8. Statistical analysis

The data were analyzed using SPSS Statistics Version 10. The data were presented as mean ± standard deviation. The pulse data were assessed for normality using Kolmogorov–Smirnov test and both SI and RI were found to be normal. The equality of variance was tested for vata, pitta and kapha groups using Levene's test of homogeneity of variances. The variances were not equal across vata, pitta and kapha groups. The mean values of stiffness parameters (SI and RI) measured from vata, pitta and kapha dosha locations were analyzed using one-way ANOVA followed by Tamhane’s T2 test. The significance of SI and RI across males and females was assessed using independent samples t test. The effect size was computed using Cohen’s d formula (difference in mean/pooled standard deviation of the two groups) for analyzing the results of independent samples t test. For ANOVA the effect size (n2) was computed as the ratio of sum of squares between groups to total sum of squares. The A two tailed P value < 0.05 is considered statistically significant for all comparisons and the data were reported to three significant figures.

3. Results

The characteristics of the study population are shown in Table 1. As the individuals were different in each of the vata, pitta and kapha groups, demographic details of the subjects were given for all the three groups. The one-way ANOVA has reported that means of SI (p < 0.001) and RI (p < 0.001) were significantly different across vata, pitta and kapha doshas as shown in Table 2. As one-way ANOVA reported significant result and variances were not equal we did post hoc analysis using Tamhane’s T2 test. The means of SI and RI were assessed across males and females using independent samples t test as shown in Table 3. The SI for males was higher than females at all the three pulse locations and SI at kapha (p < 0.05) was statistically significant. There were no significant differences in RI between males and females. The means of SI and RI at vata, pitta and kapha locations were analyzed across three age groups as shown in Table 4.

4. Discussion

Arterial stiffness was accepted as an indicator of cardiovascular risk assessment and the arterial stiffness measured from pulse wave velocity using cfPWV is considered as gold standard [28].

![Fig. 1. Pulse wave acquired using Nadi Tarangini, representing various peaks and time periods of the radial pulse.](image)

| Parameter | vata | pitta | kapha |
|-----------|------|-------|-------|
| Age       | 57.830 ± 9.05 | 58.230 ± 11.370 | 55.88 ± 9.247 |
| Males     | 59.840 ± 8.47 | 59.330 ± 11.978 | 56.62 ± 9.310 |
| Females   | 51.400 ± 8.09 | 54.560 ± 8.618 | 52.59 ± 8.674 |
| Height    | 165.64 ± 9.665 | 165.25 ± 9.248 | 166.467 ± 8.283 |
| Males     | 167.437 ± 7.278 | 167.75 ± 8.818 | 168.49 ± 6.611 |
| Females   | 159.89 ± 13.959 | 157.24 ± 5.308 | 156.357 ± 8.335 |
| BMI       | 24.712 ± 4.105 | 24.988 ± 4.323 | 25.185 ± 4.740 |
| Males     | 24.115 ± 3.885 | 24.502 ± 4.318 | 24.537 ± 3.905 |
| Females   | 26.624 ± 4.411 | 26.542 ± 3.718 | 28.424 ± 7.241 |
| SBP       | 130.88 ± 22.815 | 130.68 ± 19.98 | 127.24 ± 14.681 |
| Males     | 131.81 ± 22.737 | 129.39 ± 20.136 | 127.68 ± 15.501 |
| Females   | 128.00 ± 24.042 | 132.44 ± 20.421 | 125.14 ± 10.447 |
| DBP       | 79.120 ± 8.092 | 78.980 ± 9.872 | 81.83 ± 9.680 |
| Males     | 79.55 ± 9.712 | 79.260 ± 10.59 | 82.44 ± 9.998 |
| Females   | 77.80 ± 10.654 | 78.09 ± 7.263 | 78.86 ± 7.904 |

Data are shown as mean ± standard deviation.

BMI, Body Mass Index; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure. Total 42 participants (32 males, 10 females) in each group.
stiffness index measured from PPG was closely associated to pulse wave velocity [29] and many studies were done using these techniques. In the present study, we aimed at studying the significance of SI and RI measured across Tridoshas wherein SI corresponds to arterial stiffness and RI corresponds to endothelial function [25].

We observed clear systolic and diastolic peaks in pulse waves at vata, pitta and kapha locations and the peaks resembled closely with DVP signal from PPG. In the current study, SI and RI measured at vata, pitta and kapha locations were significantly different. The post hoc test has revealed that SI and RI at vata were significantly low compared to pitta and kapha. The SI has shown a gradual increase from kapha to pitta and then decreased at vata. The effect sizes of SI (0.21) and RI (0.485) were significantly high. The results explain that 21% of the variance in SI and 48.5% of variance in RI can be attributed to Tridoshas. The significant difference in SI across the three groups may be due to either height of the person or arterial stiffness and hence we have tested the heights across the three groups using independent t test. The heights were not significantly different across vata-pitta, pitta-kapha and vata-kapha groups which confirmed that SI was significantly different due to the arterial stiffness and not due to height of the person.

The classical texts Sarangadhara Samhita [4], Yoga Ratnakara [5], Bhava Prakasha [6] and Basavarajeyam [27] have discussed the nature of Nadi in detail which includes method of pulse examination, pulse locations, pulse characteristics in various conditions. The hardness of Nadi is discussed in detail in Basavarajeyam and in pratham prakarana of Basavarajeyam it is mentioned that due to increased vata dosha, Nadi will be hard like a string of veena which can be interpreted that arterial stiffness increases with vata dosha. The word kathira has been used to express the hardness instead of kathin. There is no mention of hardness due to pitta and kapha doshas but in the same prakarana it is mentioned that Nadi will be slow due to kapha dosha Nadi. As the pulse wave travels faster in hardened arteries compared to normal arteries, it can be interpreted that Nadi may not be hard but soft due to kapha dosha.

In dwiteeya prakarana while explaining the characteristics of mrityu nadi it is mentioned that kathan nadi is one of the factors which can lead to death. In the recent past arterial stiffness is considered as a significant parameter in assessing cardiovascular risks which seems to be similar to what is explained in mrityu nadi. The thickness of blood vessels has been discussed in sutrasathana of Caraka Samhita [1] and the terms dhamani pravicya and dhamani praticya are used to explain the hardness of arteries which is considered as atherosclerosis in modern medicine. Vasant has summarized the qualities of Nadi and according to him hard and rough artery corresponds to vata, elastic and flexible artery corresponds to pitta and soft thickening artery corresponds to kapha [26]. This implies that there is a gradual increase in thickness of the radial artery from soft at kapha to hard at vata which in turn means pulse will be slow at kapha and fast at vata. As kathinya corresponds to hardness of the artery, there is a gradual increase in kathinya from kapha to vata. There will be a gradual increase in kathinya with age also as dosha predominance varies from kapha in childhood, to pitta in middle age, to vata in old age. As per modern physiology arterial stiffness increases with age and the pulse travels faster in hardened arteries [25]. As per Ayurveda Nadi will be soft in childhood which is kapha age and will become hard in old age which is vata age. This is well understood with respect to both modern medicine and Ayurveda and hence arterial stiffness can be associated to kathinya. The physiological reason behind such variations in arterial stiffness across vata, pitta and kapha locations need further investigation. As the arterial stiffness is closely related to kathinya, we expected SI to increase from kapha to pitta to vata. In our study we observed that SI has increased from kapha to pitta as expected but decreased at vata. The reason for such reduction in SI at vata could be due to age of the subjects. The average age of the subjects in our study was 50–60 years, a pitta dominant age and hence reduction in SI at vata can be attributed to age.

In the present study, we have further divided subjects into three groups based on the age and we have seen that SI and RI at vata and kapha were increasing with age whereas SI and RI at pitta were high at age group 50–60 compared to the other two age groups. The changes in SI were interesting but not statistically significant and it requires further investigation at various age groups with larger sample size to confirm the behavior of SI and RI across age groups.

The SI of males was higher than females at vata, pitta and kapha locations. The SI at kapha was significantly high for males when compared to females with very high effect size (0.878) which signifies the difference in SI between males and females.
sized of SI at vata and pitta were moderately high. The effect size of RI at vata was very low but was moderately high at pitta and kapha. The mean height of males in kapha group was significantly high (p = 0.010) and hence there could be a possibility that the significance could be due to height and not due to arterial stiffness. To confirm whether the significant difference was due to height only or even the arterial stiffness was significantly different, we have removed the height factor by dividing SI with height and we observed that the resultant SI (p < 0.05) was significantly different across males and females in kapha group. This confirmed that there was a significant difference in SI at kapha between males and females. The results were promising but need to be proven with larger sample size. As per classical texts of Ayurveda, pulse examination varies between males and females. Bhavapraksa compiled by Bhavamisra, has given importance to the specification of sides for pulse examination in males and females [6]. The results confirmed the same and further in depth studies are needed to establish the significance of pulse in both genders.

The variations in Tridoshas are the basis for disease diagnosis in Ayurveda and pulse examination plays a key role in assessing Tridoshas. Traditionally pulse examination is done by placing the fingers at three dosha locations to assess the dosha levels which is manual and becomes subjective as it depends on the skill of the physician. In the present study, we have established a framework for measuring pulse parameters SI and RI using Nadi Tarangini across Tridosh locations in a very objective manner and the results of our study confirm the close association of SI with kathinya, one of the seven pulse parameters used in assessing Tridoshas.

There are certain limitations in our study. We have considered relatively small sample size for our study and subjects were not covering the age groups for vata, pitta and kapha. The effect of diurnal variations of doshas was not included in our study as the pulse data was collected throughout the day from 6am to 4pm. We did not include assessing prakriti through questionnaires as part of our study. There are seven types of prakriti based on combinations of Tridoshas which needs very large sample size to validate the arterial stiffness across all prakriti. There is a need to do further studies considering dosha predominance with age and time of the day.

We think this is the first attempt in evaluating the significance of arterial stiffness in Tridosha analysis. The arterial stiffness is well established pulse parameter in research with rich literature support and is closely associated to kathinya in the context of Ayurveda. Hence it can be considered as a significant parameter for Tridosha based studies and extensive interventional studies can be done in Ayurveda to unravel the hidden secrets of pulse.

5. Conclusion

In conclusion, the arterial stiffness parameters SI and RI measured using Nadi Tarangini has shown significant variations across vata, pitta and kapha doshas. The SI was closely associated to kathinya which measures the hardness of artery. The framework developed to measure the arterial stiffness across Tridoshas can be used for the interventional studies in Ayurveda which in turn can help in disease diagnosis and treatment. The studies have shown significant results with arterial stiffness in modern medicine and can be extended to Ayurveda to unravel the hidden secrets of pulse.

Sources of funding

None.

Conflict of interest

None.

Acknowledgements

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

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