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A reliability test for the body constitution diagnosis using wrist pulse analysis based on Ayurveda

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Wrist pulse diagnosis is the most primitive and apparent way to know about the human body condition for the diagnosis of disease. Ayurveda, an ancient Indian science, introduced wrist pulse diagnosis in the name of 'Nadi'. Due to the lack of expertise and standardisation, the knowledge of Nadi is limited to very few Ayurvedic practitioners. An automated wrist pulse reading instrument can overcome this problem and help in non-invasive diagnosis using a wrist pulse based on Ayurveda. The primary objective of the research is to develop instrumentation to digitise the three pulse patterns viz., Vata (V), Pitta (P) and Kapha (K). Based on the signals acquired, the nature of the body (Prakriti) is identified and categorised into different classes. Wrist pulses are acquired using three thin-film flexible piezoelectric sensors and processed using a signal conditioning circuit. Signals are quantised using data acquisition module and processed.

The studies carried out in the present work show substantial to moderate (based on the number of classes considered) agreement in the pulse-based classifications done by expert Ayurvedic physician and the developed instrument. Cohen's kappa of 0.719 and 0.454 are obtained as inter-rater reliability between traditional and instrumental readings on wrist pulse taken on basic level (VPK) and sub-levels (VP, VK & PK). An inter-rater reliability test using Cohen's Kappa is adopted for this purpose. Similarly, reliability between Ayurvedic questionnaire-based and wrist pulse-based Prakriti identification are also tested. A Cohen's kappa of 0.587 and 0.476 is obtained between Prakriti and two different pulse reading data sets with basic level of classification viz. instrument and traditional method.

Keywords: Ayurveda, Dosha, Kapha, Pitta, Prakriti, Sensor, Vata

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Ayurveda is one of the ancient medical sciences having a history of more than 5,000 years. In Sanskrit, Ayurveda means science of life. The goal of Ayurveda is to maintain perfect health by preventing and curing disease through medication, proper diet and lifestyle. Nature has given a unique characteristic for every human being. Each person has a unique pattern of energy, which constitutes a combination of physical, mental and emotional characteristics[1-6]. This unique pattern is called 'Prakriti' in Ayurvedic terminology. Prakriti is the characteristic exhibited by the person in the form physical and mental attributes. It is the genetically formed individuality and characteristics that are unique to the personality[1]. According to the principles of Ayurveda, the Prakriti of an individual is decided at the time of conception or zygote formation[2]. Prakriti is treated as a balanced state of energy in the body, which leads to a healthy condition. There are many physiological and psychological factors like emotional state, diet, food, seasons, weather, physical trauma and family relationships, which disturb the Prakriti of a person[3]. Improper diet and lifestyle create imbalance in the levels of Dosha in the body and produce disease. This is called 'Vikriti' in the body.

The unique pattern of energy corresponding to human being is measured using three parameters namely Vata, Pitta and Kapha (VPK)[1]. These three parameters are collectively referred to as Tridosha in Ayurvedic terminology. The Prakriti is formed by the combination of Tridosha and they are of seven types: Vata, Pitta, Kapha, Vata-Pitta, Pitta-Kapha, Vata-Kapha and Vata-Pitta-Kapha Prakriti. These are

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classified as three individual Dosha Prakriti, three Dvandvaja Prakriti and one Sama Doshaja Prakriti[1,4].

In Ayurveda, Tridosha is expressed qualitatively rather than quantitative measures. Nadi pareeksha or pulse reading is considered as one of the diagnosing tools for the physician[4]. Traditionally, an Ayurvedic physician measures Tridosha by sensing the palpation of the patient by holding the wrist as shown in Figure 1[5-9]. It is difficult to quantify Tridosha factors as measurement is a subjective skill and varies from physician to physician. Hence, in order to gain uniformity in the Tridosha assessment and quantifying the VPK factors, an automated wrist pulse measurement and analysis system would be useful. There are a few reports available in literature, which propose the development of automated wrist pulse acquisition and analysis systems suitable for different medicine systems[10-16] Anirudh *et al*., 2007 developed a wrist pulse acquisition system named 'Nadi Tarangini', which captures the pressure variations at the wrist pulse to measure the variations of Tridosha in terms of electric signals[17]. 'Nadi Tarangini' is also used to study the arterial stiffness index and reflection index[18]. Nadi Yantra[19], Nadi Aridhal[20] and Nadiparikshan yantra[21] are also the systems developed to quantify the Tridosha value for various diseases[22]. In all these developed systems, pulse analysis has been carried out based on the wave features of the pulse acquired at radial artery. The major drawback of all these developed systems is that the pulse position has to be located before placing the sensor. This poses a problem in acquiring good quality pulses. This can be overcomed by using the flexible pressure sensors, which can be attached to fingertips for proper sensor placement. These flexible pressure sensors also offer an additional advantage that the partial pressure can be felt at finger tips which also helps in acquiring good quality pulses.

A scientifically proven technique needs to be used to validate the information gathered through radial pulse acquisition. Cohen's weighted kappa statistics has been used as a tool to quantify the intra-rater reliability of pulse and body constitution diagnoses performed by an Ayurvedic physician[23]. Similarly, the proposed system uses Cohen's weighted kappa statistics to quantify the validity of the classification done by pulse acquisition device with respect to the classification by an Ayurvedic physician (expert) and by using standard questioner. An extensive exploration is made in improvising the Prakriti classification more fool proof by improving the conventional method[24]. Pulse based Prakriti classification has been found in ancient texts but has never been tested for its correlation with the conventional approach in a deeper way.

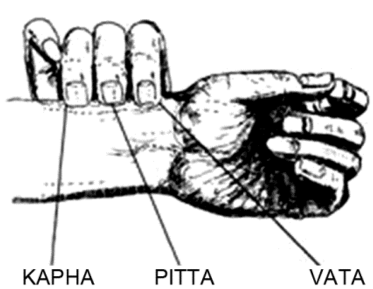

Fig. 1 — Traditional pulse measurement technique[5]

In the proposed system, an attempt is made to identify the Prakriti of a person using wrist pulse analysis. There is no existing report of wrist pulse reliability with the Prakriti assessment to the best of our knowledge. There is a need to make a reliability test for the wrist pulse. In practice, Prakriti can be determined by measuring the wrist pulse under empty stomach and preferably in the morning[7,9]. For a healthy person, Prakrithi and Vikriti must be same[8]. Hence, the readings are considered as Prakriti rather than Vikriti.

Method

Experimental setup

Three flexible piezoelectric sensors (MEAS-LDT0-028K) are used to acquire pulses at the radial artery of wrist. Flexible sensors can be easily attached to physician's fingertips so that he is able to feel the partial pressure exerted by the sensor. This partial pressure sensed by the physician helps to correct the position of the sensor and to judge the correctness of the palpation. Three identical flexible piezoelectric sensors are used to measure the vibrations due to pressure variations at the radial artery of the wrist with help of an expert physician.

Pulse measurement is carried out by applying minimal pressure using fingertips at radial artery of wrist. The partial block in the radial artery creates turbulent flow of blood which produces spikes at the blocked edges. These spikes can be easily felt by the fingers and sensed by flexible sensors attached to fingertips. The radial artery moves close to the skin above the joints of the radius bone; thereafter, the artery vessel continues to enclose deep inside the body. Hence to obtain a good quality pulse, the applied pressure at the radial artery of the wrist using fingers should increase from Vata site to Kapha site. The amount of pressure to be applied can be decided based on the quality of pulse acquired by the pulse acquisition system.

Figure 2 represents the complete functional block diagram of the wrist pulse acquisition system. Figure 3 shows the photograph of working setup. A signal conditioning circuit is built to attenuate the noise and provide required gain to the pulse signal. The pulse output from each sensor is amplified and filtered using a low pass filter having a cutoff frequency of 20Hz (decided based on pulse bandwidth). A typical waveform captured from one of the sensors after filtering is shown in Figure 4. Figure

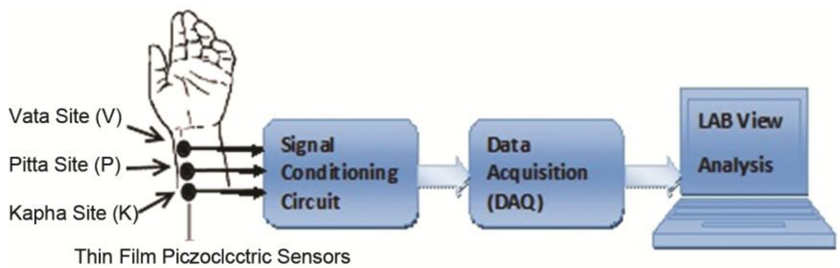

Fig. 2 — Block diagram of pulse acquisition system

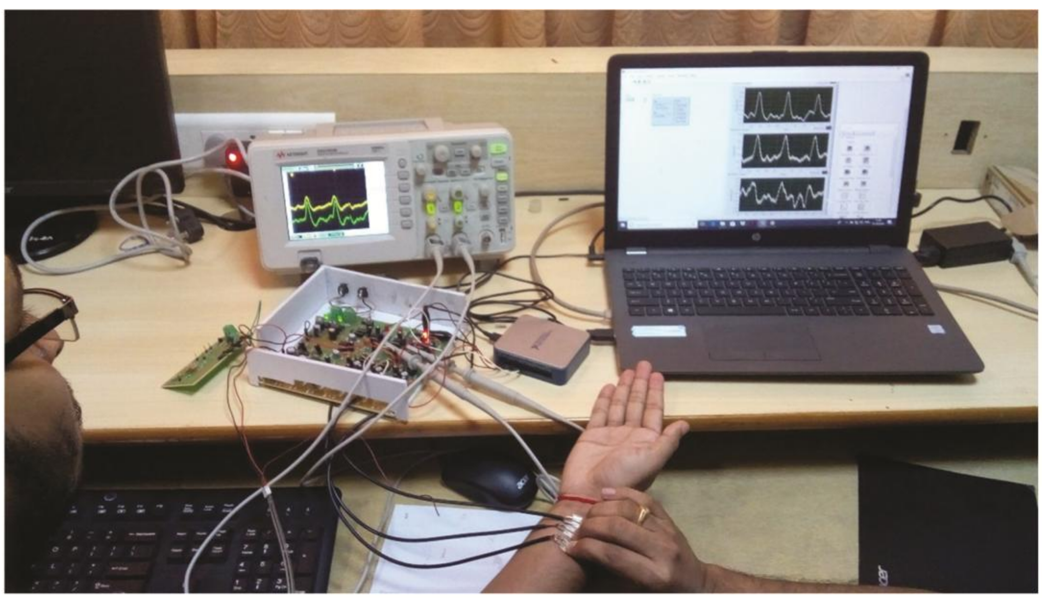

Fig. 3 — Photograph of complete experimental setup

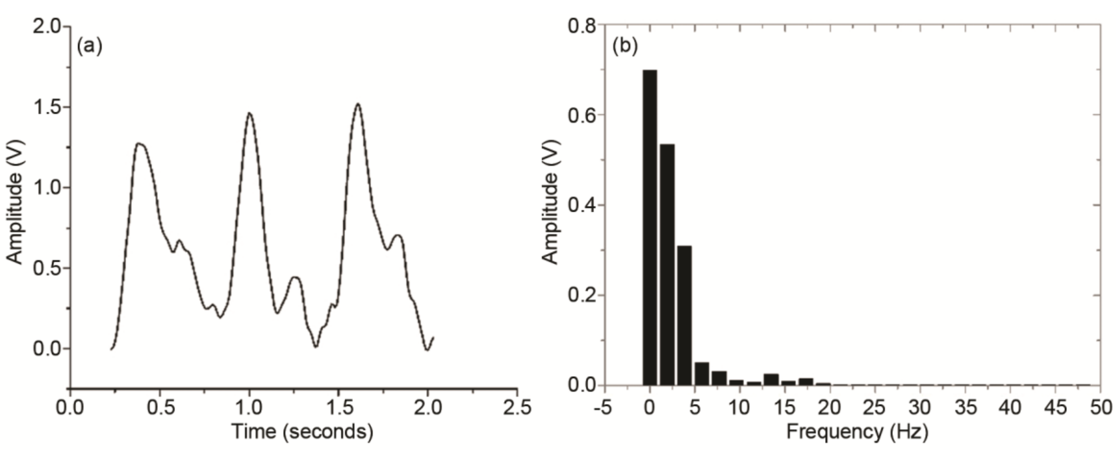

Fig. 4 — Wrist pulse signal (a) Time domain time (b) frequency domain representation

4(a) represents the filtered signal in time domain and Figure 4(b) shows the Fast Fourier Transform coefficients of the filtered signal. A signal is then acquired using USB6003 NI data acquisition module for further processing using the LABVIEW software. Peak detection algorithm is used to find the peak amplitude of each pulse. An average value of peaks of five pulses is considered for the classification process.

An experiment was conducted by reading the wrist pulse of 50 healthy participants. The pulse at VPK sites was captured using the instrumentation system explained earlier. Pulse signals are processed using LABVIEW software after acquiring through DAQ module. Based on the magnitudes of the peaks of VPK signals averaged over five pulses, Prakriti of each of the participant was classified into one of the classes namely, Vata, Pitta, Kappa, Vata-Pitta (VP), Pitta-Kapha (PK), Vata-Kapha (VK). Classification is rarely found in Vata-Pitta-Kapha and hence not considered for the analysis. Even though the Prakriti of an individual can be in one of the seven mentioned classes, initial classification is carried out considering only three classes namely, Vata (V), Pitta (P) and Kappa (V). In order to classify an individual's Prakriti in to one of the V, P or K class using pulse-reading instrument, the peak amplitudes of the pulses are considered. The pulses at all the three pulse sites are recorded, peaks are averaged over five pulses and averaged peak amplitudes at three pulse sites are compared. Among these three pulses if the averaged Vata (V) pulse peak amplitude is maximum as compared to other two pulses, then the corresponding individual is categorized into Vata (V) class and so on. When all six classes are considered for classification, averaged peak amplitudes of two pulses are considered. Dominating two pulse amplitudes decide the Prakriti class of an individual. An expert Ayurvedic physician was also involved in the study, who has classified the Prakriti of same set of people at the same time. The expert Ayurvedic physician also classified the Prakriti of an individual based on the pulse peak sensed by his fingertip without any instrument. The physician placed three fingers as shown in Figure 1 at VPK sites and classified the Prakriti of each individual as one of the three categories based on his judgment. The result of this classification is referred to as traditional measurement. Measurement from the expert physician and instrument readings are tested for the consistency.

One more set of classification was done on same set of people based on their answers to a set of standard questions. The questionnaire used for the assessment purpose is referred from the Ayurvedic Institute® (New Mexico, U.S.A) online resources. These questionnaires are based on the patient's feel, choice, habits, look, etc. This questionnaire-based Prakriti assessment was developed based on the commentaries of ancient texts[1-2,4]. A set quality has been described for each of the classes and based on those observations Prakriti assessment tools are developed. There was no scientific approach and the reasoning for the choosing the questionnaire. However, based on the several years of observations, ancient sages have made commentary and it was successfully adopted by many Ayurvedic practitioners and predecessors.

Results and Discussions

Instrument and traditional pulse reading

The classification based on expert decision and using wrist pulse reading instrument were collectively analysed for correlation. Data from two different sources of examinations are organised into the contingency table as shown in Table 1. The contingency table is a matrix which has inter-rater counts of VPK classes. Generally, to get the perfect agreement in the classification, all the values must appear in the diagonal of the matrix. From the Table 1, it can be observed that the V and P values appear to be spread between each other. As seen from Table 1, a larger proportion of sample is spread over V and P class. The pulse sites of V and P class are in proximity and when the peak values are comparable to each other, there is a possibility of misinterpretation of class. Cohen's kappa is used to evaluate the degree of agreement between instrumental and traditional pulse reading based classification in contingency table. Cohen's kappa is computed for the data in Table 1. Cohen's kappa of 0.719 is obtained for this set of classification which shows a substantial agreement as per the Landis and Koch scale[19]. Hence, the developed instrument is able to classify the Prakrithi of a healthy person in par with the traditional pulse measurement done by the experienced Ayurvedic physician.

Table 1 — Contingency table of Instrument and Traditional pulse classification-V, P and K classes

Instrument Traditional	V	P	K	Total
V	11	7	0	18
P	0	29	0	29
K	0	0	3	3
Total	11	36	3	50

Another set of classification was made including all six possible classes mentioned earlier. Table 2 shows the contingency table corresponding to this classification. As seen from Table 2 none of the samples fall under the categories V,P and K. It was said in the ancient text that the Prakriti class of V, P and K alone are rare to be found [1] and the obtained results agree with this. A kappa value of 0.454 is obtained showing a moderate agreement with VP-PK-VK which represents relatively lower agreement as compared to V, P and K classes. Wrist pulse peaks are having varying peaks at each VPK sites and close variation between any pair of VPK pulses can create significant gap while forming the contingency matrix. The problem aggravates, as two consecutive peaks have to be considered now for classification. However, majority of the class was obtained in VP and least value in VK class distributed as in Table 2.

Pulse and questionnaire-based Prakriti classification

In this section, results of classification based on questionnaire and pulse readings are compared. Table 3 is the contingency table for the classification using the questioner and traditional pulse reading method considering only V, P and K classes. The values of the contingency table are spread across nearby diagonal elements as shown in Table 3. A kappa of 0.587 is obtained showing a moderate agreement between Prakriti assessment based on traditional pulse reading method and questioner.

The questionnaire-based classification is also compared with pulse reading classification using the developed instrument. Table 4 is the contingency table for this classification comparison. As seen from the Table 4, the readings are spread over classes showing moderate correlation with 0.476 kappa value.

Tables 5 and 6 show the contingency values for the traditional pulse and questioner-based Prakriti classification and instrument and questioner-based classification respectively considering all possible six classes mentioned earlier. The pulse-based Prakriti classification against questioner resulted in kappa values of 0.215 and 0.075 for traditional and instrumental reading, respectively. This shows significantly poor classification and fails to correlate the reading from two different ways of Prakriti analysis.

Table 7 represents the overall summary of the Prakriti classification of 50 participants. The questionnaire and pulse measurement methods of Prakriti identifications do not have any direct relation with each other. Both approaches are completely different from each other. The classical method of Prakriti identification using questionnaire is still being used as it was mentioned in the ancient Ayurvedic text. As a matter of concern, the set of questions to be used

Table 2 — Contingency table of Instrument and Traditional pulse classification -VP, VK and PK class

Instrument Traditional	V	P	K	VP	VK	PK	Total
V	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0
VP	0	0	0	32	0	5	37
VK	0	0	0	1	1	1	3
PK	0	0	0	4	0	6	10
Total	0	0	0	37	1	12	50

Table 3 — Contingency table for questioner-based Prakriti and traditional pulse classification-V, P and K classes

Traditional Prakriti (Questioner)	V	P	K	Total
V	15	5	0	20
P	3	20	0	23
K	0	4	3	7
Total	18	29	3	50

Table 4 — Contingency table for questioner-based Prakriti and Instrument classification- V, P and K classes

Instrument Prakriti (Questioner)	V	P	K	Total
V	10	10	0	20
P	1	22	0	23
K	0	4	3	7
Total	11	36	3	50

Table 5 — Contingency table for questioner based Prakriti and traditional pulse classification- VP, PK and VK classes

Traditional Prakriti (Questioner)	V	P	K	VP	VK	PK	Total
V	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0
VP	0	0	0	20	1	2	23
VK	0	0	0	1	1	0	2
PK	0	0	0	16	1	8	25
Total	0	0	0	37	3	10	50

Table 6 — Contingency table for questioner based Prakriti and Instrument classification- VP, PK and VK classes

Instrument Prakriti (Questioner)	V	P	K	VP	VK	PK	Total
V	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0
VP	0	0	0	18	0	5	23
VK	0	0	0	0	1	1	2
PK	0	0	0	19	0	6	25
Total	0	0	0	37	1	12	50

Table 7 — Classification summary

Sl. No	Classification methods	Category of Classes	Cohen's kappa Value	Conclusion
1	Instrument Vs Traditional	Three classes (V, P and K)	0.719	Substantial Agreement
		Six classes (V, P, K, VP,VK, PK)	0.454	Moderate Agreement
2	Traditional Vs Questioner	Three classes (V, P and K)	0.587	Moderate Agreement
		Six classes (V, P, K, VP,VK, PK)	0.215	Fair Agreement
3	Instrument Vs Questioner	Three classes (V, P and K)	0.476	Moderate Agreement
		Six classes (V, P, K, VP,VK, PK)	0.075	Slight Agreement

in examining the Prakriti should also be taken in to consideration. The classification using questionnaire entirely relies on the answers given by the participant. This can also be one of the reasons for increase in the correlation gap between two methods. Both the pulse-based classification methods give agreeing results as the base of classification is the same. However, the traditional method is too subjective and needs careful attention and skill to measure Prakriti. The use of an instrument helps to get a clear vision and quantitative approach for the classification.

Conclusion

Wrist pulse carries significant information about the physiological nature of the body. Ayurveda suggests an approach to measure the wrist pulse and thereafter predict the body condition. An instrument developed to read the Tridosha in terms of quantitative values using flexible thin-film piezoelectric sensor was found to be promising in assessing Prakriti of an individual. It was also found that the applied pressure required to collect good quality pulses increases gradually from Vata pulse site to Kapha pulse site. Statistical observations are made using Cohen’s kappa values to decide on the reliability of instrumental reading-based classification. A Cohen's kappa of 0.719 and 0.454 are obtained as inter-rater reliability between traditional and instrumental readings on wrist pulse taken on basic level (VPK) and sub levels (VP, VK & PK). In basic level, Cohen's kappa exhibits a substantial agreement and moderate agreement in sub level classification as per Landis and Koch scale. Prakriti classification is also carried out based on the standard questioners. A Cohen's kappa of 0.587 and 0.476 is obtained between Prakriti and two different pulse reading data set with basic level of classification viz., instrument and traditional method of wrist pulse. The relation between Prakriti and wrist pulse statistics shows moderate agreement with each other. The same analysis of Prakriti with sub level classification fails as it gives only a slight agreement with Prakriti and pulse reading.

The diseases are formed when the Doshas in the body are in imbalance state. The balance is maintained by the healthy diet and regimen of the person according to the changes in a day and seasons. The life style of diet and regimen against the rules will cause imbalance of Dosha. The aim of Ayurveda is to prevent the manifestation of disease, diagnose the disease early and to treat the pathogenesis.

Pulse reading is helpful for the early diagnosis of the Dosha vitiation and complete manifestation of the disease can be prevented. Physician can advise the patient about the regimen, diet and medical management for the imbalance found early by the pulse reading. Hence the physician can prevent the complications and consequences of the complete disease manifestation. In this context, the Prakriti data base of a person would be useful for early diagnosis of the Dosha imbalance. Hence the developed pulse reading instrument is very promising in the early diagnosis of the Dosha imbalance.

Conflict of Interest

Authors declare there is no conflict of interest on this article.

Author's Contributions

S R M built the experimental setup for obtaining the wrist pulse data. R K helped the in obtaining the Prakriti assessments in based the questionnaire. R R provided the suggestions and review on drafting the article.

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