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Enhancing *Ayurvedic* Diagnostics: Correlation and Validation of Sensor-Based *Prakriti Parikshan* through Comprehensive Questionnaire Analysis

Research Article

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Abstract

Ayurveda is the traditional, scientific branch of Indian medicine. From ancient days the Indians are using this knowledge to cure body and mind related ailments. *Ayurveda* believes that the body is the blend of five elements (space, water, fire, earth and air) which develops three constituents (*Prakriti*), *Vata*, *Pitta*, and *Kapha*. The science of *Prakriti Parikshan* (examination) supports understanding one's present and future ailments. The correlation between the sensor-based *Prakriti Parikshan* and questionnaire-based *Prakriti Parikshan* will lead to more enhanced use of *Ayurveda* by non *Ayurvedic* experts' community. The field of *Ayurveda* seeks to modernize traditional *Ayurvedic* practices using contemporary technological methods. This study introduces an innovative method for *Ayurvedic Prakriti Parikshan*, the evaluation of individual constitutions using sensor-based *Nadi Pariksha* (radial artery pulse examination on wrist done in specific way) and validating it using analysis of questionnaire responses. The proposed method includes the use of an extensive questionnaire consisting of 76 questions, validated by *Ayurvedic* experts, in conjunction with sensor-based pulse readings to identify *Vata*, *Pitta*, and *Kapha Dosha*s. Techniques such as Baseline wander removal filters for preprocessing, feature extraction using the 1-dimensional discrete wavelet transform (1D DWT) and Fast Fourier Transform (FFT). The gathered data is consolidated and analyzed to determine the predominant *Dosha* in each person. Later the *Dosha*s obtained from sensor data are validated using the *Dosha*s obtained from the questionnaire-data demonstrating an accuracy rate of 95%.

Keywords: Ayurvedic Engineering, Prakriti Parikshan, Sensor Technology, Questionnaire Analysis, Dosha Evaluation, Personalized Healthcare.

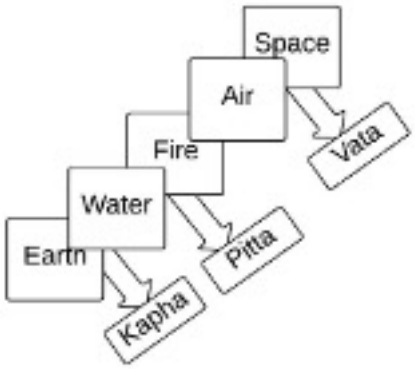
Introduction

Ayurveda, the ancient Indian system of medicine, offers a profound understanding of human health and well-being, rooted in the concept of balance and harmony within the body and mind (1). With a history spanning thousands of years, *Ayurveda* continues to be a source of inspiration for modern healthcare practices, particularly in the realm of personalized medicine. Central to *Ayurvedic* philosophy is the notion of *Prakriti*, the inherent constitution of an individual which encompasses a unique combination of physical, mental, and emotional attributes.

Prakriti is intricately linked to the concept of *Dosha*, representing fundamental physiological principles that govern various bodily functions (2). The three primary *Dosha*s *Vata*, *Pitta*, and *Kapha* (VPK) reflect distinct combinations of elemental forces (space, air, fire, water, and earth) within the body. Understanding one's *Prakriti* and *Dosha* composition is essential for maintaining health and preventing diseases, as imbalances in *Dosha*s are believed to be the root cause of illnesses according to *Ayurvedic* principles (3).

To elucidate the profound *Ayurvedic* notion of *Prakriti* and *Dosha*, please refer to Figure 1 for visual representation. Figure 1 shows that *Vata Prakriti* is formed from Air and Space, *Pitta Prakriti* is the combination of fire and water, whereas *Kapha Prakriti* is the blend of water and earth.

Figure 1: *Ayurvedic* Concept of *Prakriti* & *Dosha*



Prakriti Parikshan encompasses three main approaches: Sparshana (*Nadi Pariksha* or pulse examination), Darshana (visual inspection), and Prashna

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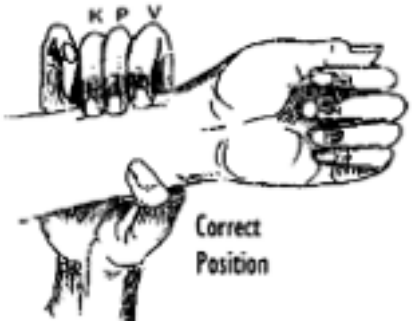
(questionnaire-based assessment). These methods allow practitioners to discern the unique constitution of an individual, guiding personalized healthcare interventions tailored to their specific needs (4). Figure 2 shows how the *Nadi Pariksha* is performed by experts according to *Ayurveda* literature (5).

Figure 2: How to hold wrist for *Nadi Pariksha*



This study proposes a novel approach to *Prakriti Parikshan* by integrating sensor-based *Nadi Pariksha* with questionnaire-based assessment. By leveraging advancements in sensor technology, particularly optical sensors, the study aims to obtain objective physiological data to complement subjective self-reported information obtained through questionnaires. This combined approach holds promise for validating the accuracy and efficiency of *Prakriti* assessment, facilitating personalized healthcare interventions aligned with *Ayurvedic* principles. Additionally, according to *Ayurveda* literature there is always a correlation between *Dosha*s and specific organs in the human body, as well as the diseases are associated with *Dosha* imbalances, to underscore the clinical relevance of *Prakriti Parikshan* (3). Table 1 (a, b and c) provides a comprehensive explanation of *Dosha*s and their attributes (5).

Table 1(a): *Vata Dosha*

Vata Dosha Description	
Description	Its attributes include qualities like dryness, lightness, coldness, roughness, subtlety, mobility, and clarity. Imbalances in *Vata* can lead to issues such as anxiety, insomnia, and digestive problems
Affected Human Organs	Colon, Lung, Small Intestine, Heart
Functions Assigned	Communication, Transport, Movement

Table 1(b): *Pitta Dosha*

Pitta Dosha Description	
Description	*Pitta*'s attributes include qualities like heat, sharpness, lightness, oiliness, liquidity, spreading, and sourness. When *Pitta* is out of balance, it can manifest as irritability, inflammation,
Affected Human Organs	Gall Bladder, Liver, Stomach, Spleen, Eyes, Retina, Skin
Functions Assigned	Digestion, Transportation,

Table 1(c): *Kapha Dosha*

Kapha Dosha Description	
Description	Its attributes include qualities such as heaviness, slowness, steadiness, solidity, density, softness, and oiliness. Imbalances in *Kapha* may result in lethargy, weight gain, or respiratory issues.
Affected Human Organs	Pericardium, VPK circulation, Kidney, Bladder
Functions Assigned	Connecting structure, Cohesion, Lubrication

Prakriti Parikshan, the assessment of individual's constitutions, forms the cornerstone of *Ayurvedic* diagnosis and treatment planning. To enrich the domain understanding, relevant literature and additional reference papers on wrist pulse analysis are referred. Few rounds of discussions with *Ayurveda* practitioners helped understanding the anatomical and pathological associations of *Dosha*s within the human body, as well as *Ayurveda* diagnosis and its relevance in contemporary healthcare practice.

Through this comprehensive exploration, the study aims to contribute to the advancement of *Ayurvedic* engineering and personalized healthcare delivery, rooted in the ancient wisdom of *Ayurveda*. Furthermore, the concept of *Dwidosha* and *Tridosha Prakriti* adds complexity to understanding individual constitutions. In *Dwidosha Prakriti* in some situations one *Prakriti* is dominant while in some situations other *Prakriti* is dominant. Most individuals are Dwidoshic in *Dosha* constitution. *Dwidosha Prakriti* indicates the dominance of two *Dosha*s in an individual's constitution, while *Tridosha Prakriti* signifies a balanced combination of all three *Dosha*s (6). Recognizing these variations in *Prakriti* is vital for tailoring therapeutic interventions and promoting overall well-being.

Dosha dominance, where one or more *Dosha*s prevail over others, significantly influences an individual's susceptibility to diseases and health outcomes. Identifying *Dosha* dominance through *Prakriti Parikshan* enables *Ayurvedic* practitioners to design targeted interventions to restore balance and alleviate symptoms associated with *Dosha* imbalances.

With these major understandings about one's *Prakriti*, the futuristic approach towards healthcare can be developed. Hence deciding the individuals' *Prakriti* is a matter of concern.

Comparatively, Chinese Traditional Medicine (TCM) offers a parallel perspective on health and disease, emphasizing the balance of vital energies within the body. Although both *Ayurveda* and TCM share holistic healthcare approaches, each system provides unique insights into diagnosis, treatment modalities, and herbal remedies tailored to individual constitutions (7–9).

Prakriti Parikshan, done based on questionnaire-based approach, helps the *Ayurveda* expert to decide one's body constituents and the remedies according to the ailments present. The *Prakriti Parikshan* is a way of

examination which elaborates many hidden things from the daily life of any individual. *Prakriti Parikshan* can also be done based on pulse examination or *Nadi Pariksha*. These results must also be the same as the result of questionnaire-based results.

Performing *Nadi Pariksha* is the art, which is possessed only by the experts now a days. This technique is expert based technique and now a days it is vanishing. Sensor based *Nadi Pariksha* is maybe a solution provided for the lack of expertise in this field.

In summary, this study aims to explore the intricate nuances of *Prakriti Parikshan*, blending traditional *Ayurvedic* wisdom with modern technological advancements to enhance personalized healthcare delivery. Through a detailed examination of *Dosha* dominance, and empirical insights from wrist pulse analysis, the study strives to contribute to the ongoing discourse in *Ayurvedic* engineering and promote holistic approaches to health and wellness.

Literature Review

Ayurvedic medicine, deeply rooted in ancient texts such as the Charaka Samhita and Sushruta Samhita, presents a holistic approach to healthcare. This traditional knowledge finds validation in modern research. For instance, Kumar et al. emphasizes the significance of *Nadi Pariksha* in both traditional and contemporary healthcare contexts (10). Loukas et al (11) underscore the enduring relevance of *Ayurvedic* principles, while Vishwakarma and Goswami delve into key concepts from the Charaka Samhita (12). Galib et al. traces the historical evolution of *Ayurvedic* treatment methodologies. Thus, *Ayurveda*, blending ancient insights with contemporary research findings, provides a comprehensive framework for promoting health and well-being (13).

Sensor technology is revolutionizing *Ayurvedic* medicine by introducing objective physiological measurements that complement traditional diagnostic techniques. A significant advancement involves the utilization of optical sensors within *Nadi Pariksha*, enabling a non-invasive, real-time approach to pulse monitoring. This integration of contemporary technology with ancient *Ayurvedic* methodologies enhances diagnostic precision and effectiveness (14).

Optical sensors are used by many researchers in data acquisition process of pulse diagnosis. Optical sensor gives better accuracy and easy to install and use for data acquisition (14–17)]. The detailed study of optical is also useful while one decides to use the sensor (18).

Moreover, the emergence of wearable devices presents vast opportunities for *Ayurvedic* diagnosis and treatment. These gadgets, designed to capture various physiological parameters, assist in evaluating *Dosha* imbalances and individual constitutions. Through continuous monitoring of vital signs and other health markers, they furnish essential data for personalized healthcare, facilitating early detection of imbalances and timely interventions (19).

Questionnaire-based analysis plays a crucial role in *Ayurvedic* medicine. Gathering subjective data on lifestyle, diet, and health concerns is helpful. Questionnaire helps in understanding coping mechanisms (20,21). By tailoring treatments to individual constitutions, it enhances precision and holistic well-being. Through systematic data collection on symptoms and habits, questionnaires enable personalized treatment plans. Their effectiveness, demonstrated across various fields, underscores their potential in *Ayurvedic* medicine. Ultimately, questionnaire-based approaches empower both practitioners and patients in their journey toward optimal health outcomes (22).

Emerging studies suggest combining sensor-based *Nadi Pariksha* with questionnaire analysis to improve the accuracy and efficiency of *Prakriti* assessment (23). This involves utilizing signal processing algorithms such as discrete wavelet transform (DWT) and FFT to extract *Dosha* characteristics from sensor data. Additionally, (24) McIntosh and Mišić have shown the effectiveness of Principal Component Analysis (PCA) for analyzing neuroimaging data, which aids in feature selection and *Dosha* classification based on both sensor data and questionnaire responses. By employing multivariate statistical analyses like PCA, researchers can derive meaningful patterns from complex datasets, thereby enhancing the accuracy and efficiency of *Prakriti* assessment.

Moreover, (25) Daaleman et al.'s study emphasizes the broader impact of patient-centered care interventions, advocating for personalized healthcare to improve satisfaction and reduce costs. These insights underscore the clinical relevance of personalized interventions and highlight the potential of traditional diagnostic methods to revolutionize patient care.

Incorporating such practices into healthcare systems can pave the way for a more personalized and effective delivery system, addressing rising costs and evolving patient needs while fostering holistic approaches to care.

A comparative study conducted by Patwardhan et al. sheds light on the shared principles and distinctive methodologies between *Ayurveda* and Traditional Chinese Medicine (TCM), advocating for a holistic approach to healthcare (9). Li et al. delves into the diverse pharmacological practices of both traditions, highlighting the potential for collaboration across cultures (26). They underscore the parallels between *Ayurvedic Prakriti Parikshan* and TCM diagnostics, which offer opportunities for advancing personalized medicine. By employing machine learning techniques, diagnostic accuracy and treatment customization can be enhanced by integrating genetic, lifestyle, and environmental data. Collaborations across disciplines and the utilization of innovative technologies facilitate synergy between traditional and modern healthcare, ultimately contributing to global wellness and improved patient outcomes.

In a study, a machine learning based approach to analyzing questionnaires is proposed. Classic algorithms such as support Vector Machine (SVM), Decision Tree (DT), Artificial Neural Networks (ANN),

and K-Nearest Neighbor (KNN) Algorithms along with hyper parameter tuning to extract features are used. This may facilitate refined *Prakriti* assessment accuracy. This approach facilitates continuous learning and adaptation, evolving with new data inputs and clinical outcomes. Such an interdisciplinary approach holds the promise of revolutionizing personalized healthcare delivery (2).

Research Contribution

Amalgamation of Traditional *Ayurvedic* Practices with Modern Sensor Technology

This study tries to merge the timeless knowledge of *Ayurveda* with cutting-edge sensor technology, introducing an innovative method for *Prakriti Parikshan*. Through the integration of traditional techniques, *Nadi Pariksha* with modern sensor-based pulse examinations, a comprehensive evaluation of individual constitutions is offered. This approach uses subjective self-reported information to validate objective physiological data, providing a holistic assessment.

Development of a Comprehensive Questionnaire-Based Assessment Tool

An elaborate questionnaire has been developed, consisting of 75 validated questions meticulously designed to encompass various aspects of an individual's lifestyle, dietary patterns, and health-related issues. This exhaustive tool significantly improves the precision of *Prakriti* assessment by systematically collecting subjective data crucial for discerning *Dosha* dominance and steering tailored healthcare strategies.

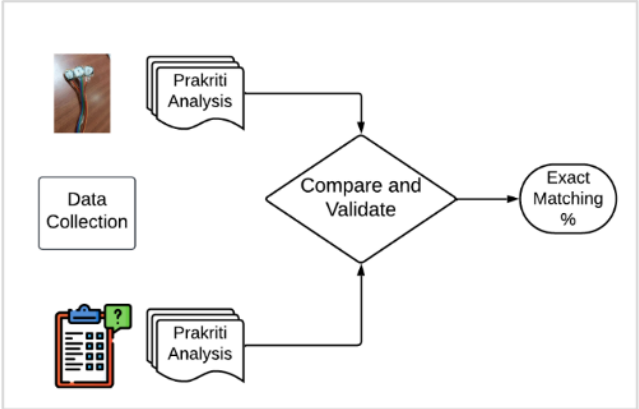
Visualization and Interpretation of *Dosha* Patterns Across Different Age Groups

An innovative visual representation, such as violin plot, demonstrates the distribution of specific *Dosha*s across different age groups is used. This examination unveils age-related fluctuations in *Dosha* constitution, providing valuable insights into how individual constitutions evolve over time. These visualization techniques amplify the clinical applicability of *Prakriti Parikshan* by facilitating precise interventions customized for diverse age groups.

Proposed Methodology

In the proposed methodology, the work is done in three modules. 1. Sensor based *Prakriti Parikshan*. 2. Questionnaire based *Prakriti Parikshan*. 3. Validation. The amalgamated data from questionnaire responses and sensor readings are scrutinized to discern *Dosha* dominance, with an accuracy evaluation conducted on the obtained results. After the accuracy evaluation, the results obtained from the questionnaire and pulse detection are compared to determine the dominance of a particular *Dosha* for everyone. Comparative evaluation permits an accurate understanding of the individual's body constitution and health profile, increasing the efficacy of personalized healthcare possibilities(27). Proposed method offers a holistic approach to categorize *Vata*, *Pitta*, and *Kapha Dosha*s. Figure 3 shows the basic proposed system architecture.

Figure 3: Basic system architecture



Module 1: Sensor Data Based Analysis

Instrument for data collection

Pulse data is collected from subjects using the instruments as shown in the figure 3.

The instrument collects the data and in turn the digital data is storedin the form of csv for analysis. As per *Ayurveda* literature the *Nadi* pulse data is collected from the left hand wrist if the subbject is a female and it is collceted from the right hand if the subject is male (5,28,29).

Data was acquired from a total of 250 subjects, ensuring a diverse sample that encompassed various demographic characteristics. The number of male and female is maintained for a balanced collection of data. This sample size was deemed sufficient to yield statistically significant results and facilitate robust analysis. People between the age group 18-25 are mostly in a healthy state of body. Hence their responses are accurate. Such responses are collected from these people which leads to accurate data about *Dosha* dominance.

Figure 4: Instrument to collect Pulse Data

When discussed with *Ayurveda* expert the *Nadi* signal does vary as per the time of the day. Hence the data collection was done mostly at the same time of the day, in morning half. Any kind of stress or movement may vary the *Nadi* signals, hence while collecting the data, subjects were asked to sit calmly, without mobile, without communicating with anyone, and their consent was also acquired. The subjects' demography is shown in figure 5.

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Figure 5: Subject demography

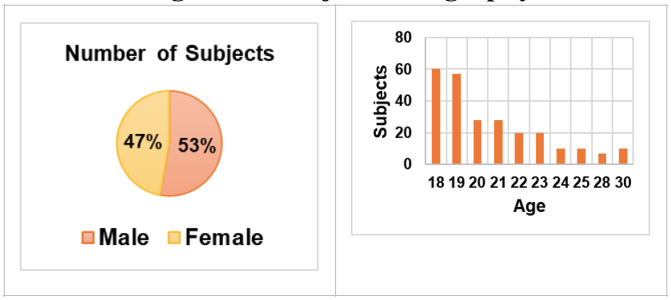
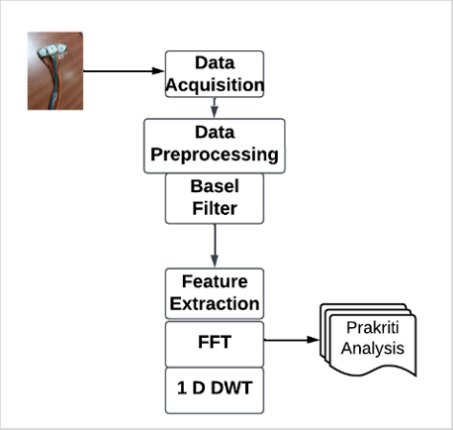


Figure 6 shows the basic module for the sensor based *Prakriti Parikshan*. This includes sensors, data acquisition, data preprocessing, feature extraction, data analysis and *Prakriti Parikshan*.

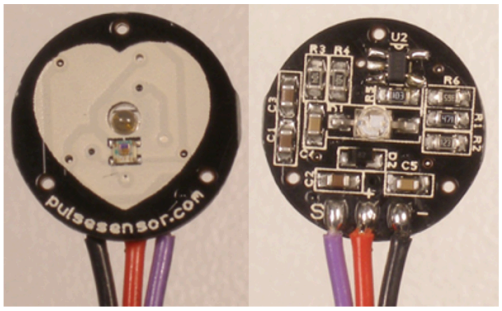
Figure 6: Module 1-sensor based *Prakriti Parikshan*



Optical Sensor Information

In this study, three optical sensors are utilized. This sensor consists of an infrared light source and a photodetector, arranged in a compact and non-invasive design. Its operation relies on the transmission of infrared light through the subject's fingertip, where it interacts with blood vessels. Variations in light absorption, caused by blood flow, are captured by the photodetector, producing a raw signal representing the pulse waveform. This optical sensor enables real-time monitoring of pulse characteristics such as rate, rhythm, and amplitude, thereby facilitating accurate assessment of individual constitutions according to *Ayurvedic* principles (14,30). The sensor is shown in figure 7. It works with any Microcontroller unit (MCU) with an Analog to digital converter (ADC).

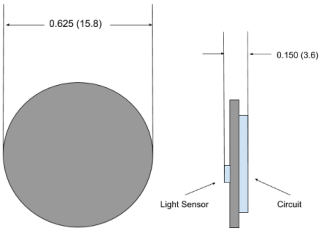
Figure 7: Optical sensor(18)



(RED +3V to +5V, BLACK – Ground, PURPLE – Signal)

The dimensions of pulse sensor are suitable to fit on the human wrist. As for *Nadi Pariksha*, it needs 3 sensors to be fitted on the wrist to capture *Vata*, *Pitta* and *Kapha* signals from the *Nadi*. Figure 8 shows the suitable dimentions of pulse sensors .

Figure 8: Optical Sensor Dimensions (31)

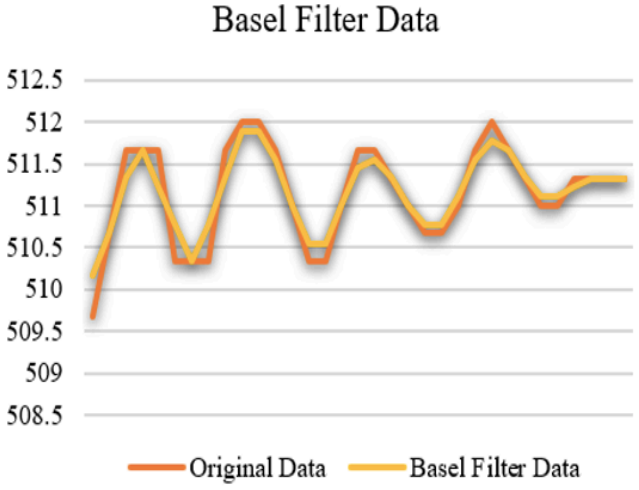


Preprocessing

The baseline wander removal filter plays a crucial role in enhancing the accuracy of sensor data collected during *Nadi Pariksha* by eliminating low-frequency fluctuations in pulse signals (32). These fluctuations can arise from various factors such as movement artefacts or environmental interference, obscuring the underlying pulse waveform and making *Dosha* classification challenging (33,34). Mathematically, the filter subtracts low-frequency baseline components from the original pulse signals using digital signal processing techniques like finite impulse response (FIR) or infinite impulse response (IIR) filters. This process optimally attenuates low-frequency components while preserving higher-frequency components corresponding to the pulse waveform (35,36).

Before applying the filter, pulse signals may exhibit noticeable fluctuations and distortions, hindering accurate *Dosha* classification. However, post-filtering, these fluctuations are effectively attenuated, resulting in smoother and more uniform pulse waveforms visually demonstrated through a line graph provided below. This improvement is visually demonstrated through a line graph, showing a significant reduction in low-frequency baseline variations after filtering. Below figure 9 shows this difference clearly.

Figure 9: Smoothness Achieved by Baseline Filter



The enhanced smoothness achieved by the filter facilitates more accurate feature extraction and *Dosha* classification during subsequent analysis stages, contributing to the overall reliability and validity of the study's findings.

Feature Extraction

Feature extraction plays a crucial role in analyzing pulse signals to discern *Dosha* characteristics in *Ayurvedic* diagnosis. Two prominent techniques employed for feature extraction are FFT and 1D DWT. These methods enable the extraction of informative features from pre-processed sensor data, facilitating the identification and classification of *Dosha* attributes (17,37,38).

FFT (Fast Fourier Transform)

Fast Fourier Transform is utilized to transform pulse signals from the time domain into the frequency domain, allowing for the extraction of frequency domain features(39). This transformation enables the analysis of the spectral composition of pulse waveforms, providing insights into the periodicity and frequency distribution of signal components. FFT captures the spectral characteristics of pulse signals with precision (40). These features offer valuable information regarding the frequency content and dynamics of the signal, which are indicative of *Dosha*-related attributes (41). These frequency domain features provide insights into the spectral composition, periodicity, and dynamics of pulse signals, which are essential in *Dosha* characterization and *Prakriti* assessment in *Ayurveda*.

1D Discrete Wavelet Transform (DWT)

1-dimensional Discrete Wavelet Transform is employed to decompose pulse signals into time-frequency components, facilitating the extraction of time-frequency domain features. Unlike FFT, which provides information solely in the frequency domain, DWT offers a time-frequency representation of pulse waveforms, capturing both temporal and spectral characteristics(42). This comprehensive approach to feature extraction enables the characterization of *Dosha* attributes based on both temporal and spectral aspects of pulse waveforms (43).

Sensor based *Prakriti Parikshan*

During this phase of the study, sensor-wise data aggregation to identify the dominant *Prakriti* associated with each *Dosha* (*Vata*, *Pitta*, and *Kapha*) is implemented. The mean values of the extracted features to facilitate this analysis are calculated (44).

Calculating the total mean for each subject

$$mean\ \bar{X} = \frac{\sum_{i=1}^{n} Xi}{n} \qquad (1)$$

- Xi Value of i^th feature
- n is the total number of features.
- X $_{Vata}$, X $_{Pitta}$, X $_{Kapha}$ are calculated.

Calculating the total mean

$$\bar{Y}\iota = \sum_{j=1}^{3} Xj \qquad (2)$$

- j = V/P/K Sensors
- This is Total mean $\bar{Y}_i$ for ith subject as the sum of VPK means Xj where j is the sensor.

Calculating Percentage

$$\left(\%\bar{Z}j = \frac{\bar{X}_j}{\bar{Y}_j}\right) i \qquad (3)$$

- $[\%\bar{Z}_j]_i$ = Percentage of (VPK) jth sensor for i^th subject
- $[\bar{X}_j]_i$ = mean of jth sensor for ith subject.
- $[\bar{Y}_j]_i$ = total mean of jth sensor for i^th subject.

Once the mean values are calculated, the results are presented graphically using violin plots. These plots preserves the raw data information, they help to compare score distribution effectively, they also represent density estimates which lead to ease in detailed comparison (45). These plots are used by many researchers for the reson that they enhance the functionality of box plot, helps in outlier detection and exhibit versatality. The violin plot in this case will display the distribution of aggregated sensor data, and density of values. The plot shows red color *Vata*, yellow color *Pitta* and purple color *Kapha*, which are overlapping each other, as the plot shows spread, shape and density of the sensor data. These plots visually depict *Dosha* dominance across different age groups, offering valuable insights into the distribution and prevalence of each *Dosha* within the studied population.

After analyzing the sensor-based feature extraction data the *Dosha* dominance can be viewed. The sample plots in Figure 10 illustrate the dominance of specific *Dosha*s within distinct subjects. By analysing the violin plots, researchers can discern patterns of *Dosha* dominance across different age groups, contributing to a better understanding of the relationship between *Dosha* constitutions.

(1) *Vata* Dominant (age 19): This plot shows the prevalence of *Vata Dosha* dominance among individuals aged 19, indicating the proportion of subjects exhibiting *Vata* dominance within this age bracket.
(2) *Kapha* Dominant (age 20): Similarly, this plot showcases the prevalence of *Kapha Dosha* dominance among individuals aged 20, providing insights into the distribution of *Kapha* dominance within this age group.
(3) *Pitta* Dominant (age 30): Lastly, the plot for age 30 portrays the dominance of *Pitta Dosha* within this age cohort, highlighting the prevalence of *Pitta* dominance among individuals of this age.

Module 2: Questionnaire – Data Based Analysis

Following the sensor-based analysis that identified the predominant *Dosha* associated with each

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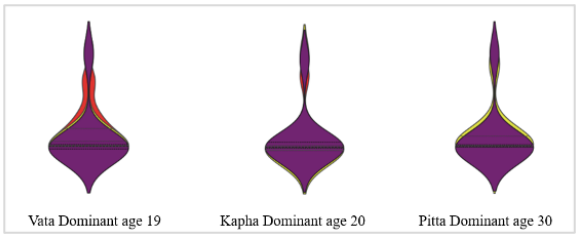
participant, the *Dosha* constitution through a questionnaire-based assessment, is done. Figure 11 shows the module 2 system flow. This includes major steps as questionnaire development, mathematical calculations on the gathered numerical data, data analysis and *Prakriti Parikshan*.

Figure 10: Violin Plots - *Dosha* Dominance of single subject



Questionnaire Design

Process to develop the questionnaire: following major steps were followed to create the questionnaire

(1) Study of *Ayurveda* literature to conceptualize the *Vata*, *Pitta* and *Kapha Prakriti*s.

(2) The various aspects related to individual habits, lifestyle, and physiological characteristics, providing a thorough evaluation of *Dosha* attributes were considered for question text building. Such 103 questions were formulated.

(3) Few subjects were given the questionnaire and asked to fill out it, which provided an insight on how long it takes to complete the questionnaire by an individual, as well as whether it is tiresome to fill it.

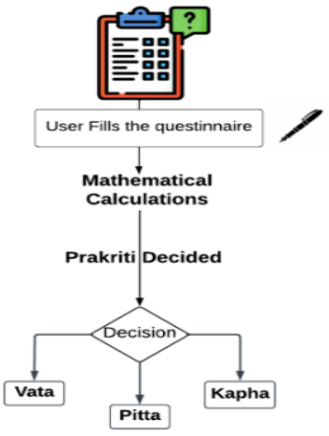
(4) The questionnaire underwent a rigorous validation process by two experienced *Ayurveda* practitioners to ensure its effectiveness in capturing relevant information about participants' constitution, health status, and lifestyle.

(5) During the process some questions having repeated meaning or having less importance in deciding the *Prakriti* were omitted from the questionnaire set and only 76 questions were considered out of 113 questions.

(6) Due to this process the questionnaire became consolidated, easy to be filled by the subjects, and incorporating all aspects of human body.

(7) Validation by *Ayurveda* experts ensured clarity, relevance, and comprehensiveness aligned with *Ayurveda* principles and diagnostic practices.

Figure 11: Module 2-Questionnaire Design



Questionnaire contents: This questionnaire covered various aspects related to individual habits, lifestyle, and physiological characteristics, providing a thorough evaluation of *Dosha* attributes. The questionnaire includes following major attributes,

(1) Information regarding participants' permanent health status, lifestyle, dietary habits, and health concerns was collected through a structured questionnaire.

(2) The questionnaire aimed to capture holistic insights into participants' overall well-being.

Following figure 12 shows the way how the questions are framed from various categories of human health. Table 2 shows the sample questions and the weightage assigned to those questions for statistical analysis.

Figure 12: Questionnaire Design

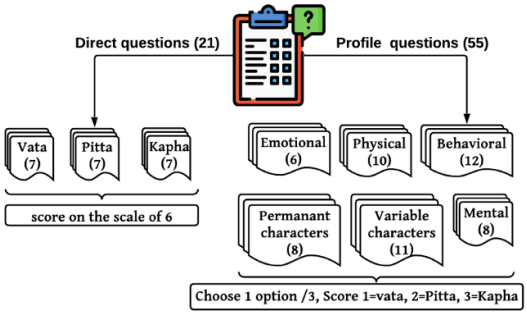


Table 2: Sample questions

Type	Question	Answer Options	Weightages assigned
Permanent Characteristics	Body Size	V) Slim; P) Medium; K) Large	V-1, P-1, K-1
Variable Characteristics	Body weight	V) Low; P) Medium; K) Overweight	V-1, P-2, K-1,
Mental Profile	Voice	V) High pitch; P) Medium pitch; K) Low pitch	V-2, P-1, K-1
Behavioral Profile	Eating speed	V) Quick; P) Medium; K) Slow	V-2, P-1, K-1
Emotional	When feeling hurt	V) Cries; P) Argues; K) Withdraws	V-1, P-1, K-1
Physical	Amount of hair	V) Average; P) Thinning; K) Thick	V-1, P-1, K-2

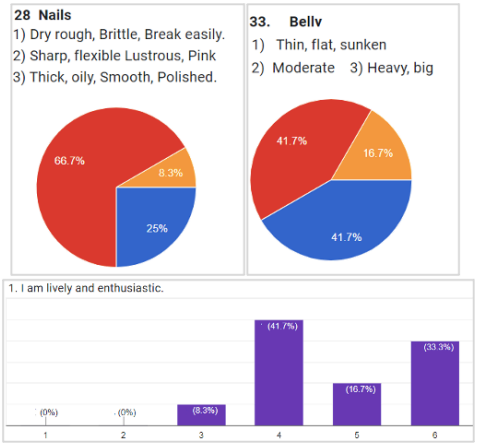
Process to fill the questionnaire: All the 250 subjects from whom the pulse data was collected, were asked to fill the questionnaire. The self reported questionnaire data may be incorrect due to some lacuna in filling process. The subjects must have prior knowledge of the concept and must be following some specific rules while filling the questionnaire.

(1) They were asked to sit calmly, without mobile and communicating with anyone.

(2) The questionnaire was explained first to them to let them understand the concept.
(3) It is advised to answer in regard with the long lasting *Prakriti* and not to the temparary symptoms.
(4) They were requested to be honest while marking the answer, so as to maintain the integrity with the study.
(5) This approach led the study towards an unbiased and impartial questionnaire response data collection.

Figure 13 shows the data about how the subjects responded to the questionnaire. Responses from the questionnaire provided essential contextual information for subsequent analysis.

Figure 13: Response to various questions



Questionnaire Based *Prakriti Parikshan*

Total *Dosha* Score Calculation based on questions having answer on a scale of 1 to 6.

To gauge the *Dosha* constitution of each participant, the total score for each *Dosha* (*Vata*, *Pitta*, and *Kapha*) based on their questionnaire responses is calculated. These scores were aggregated to offer an overall indication of *Dosha* dominance.

$$Xi = \frac{\sum_{i=0}^{n} S_i}{n} \quad (4)$$

- Xi = total score of ith *Dosha* (UPK)

Dosha Score Distribution based on questions having any one answer from 3 options.

By tallying *Dosha* scores (1, 2, 3) across all questionnaire responses, the distribution of *Dosha* attributes within the studied population is examined. This analysis shed light on the prevalence of each *Dosha* and its relative dominance among participants.

$$Count_i = \sum_{j=0}^{n} S(1/2/3) \quad (5)$$

- $Count_i$ = *Dosha* Score Count
- 1 = *Vata*, 2 = *Pitta*, 3 = *Kapha*

Percentage Calculation: Each answer is assigned with weightage for vata, pitta and kapha prakriti. This weightage is decided as per the ayurveda literature. Depending on how the parameter contributes to the prakriti calculations. Questions are assigned with the weightage as 1 or 2 or 3 for either vata, pitta or kapha dosha. When a subject answers the question, according to the answer given by the user, the value of vata, pitta or kapha variable is increased. At the end of the questionnaire the variable values are checked and the percentage constituents of prakriti of the subject are declared. To understand the proportion of each *Dosha* relative to the total count of all *Dosha*s combined, the percentages for each *Dosha* score count are calculated. This step facilitated a comparative assessment of *Dosha* distribution across the population. The obtained percentages are normalized, to ensure that they were collectively summed up to 100%. This normalization process enhanced the interpretability of *Dosha* distribution patterns and enabled meaningful comparisons between different *Dosha* categories.

$$\%Z = \frac{\%Z_i}{\sum_{i=1}^{3} Z_i} \quad (6)$$

- $\%Z_i$ = % ith *Dosha*

The individual person which is considered for the % calculation of VPK has answered all the questions in the following manner, 39 questions in the relevance with Vata, 8 questions in the relevance with Pitta and remaining 29 questions in favor of Kapha dosha. After calculations the Vata dominant result is given to the subject.

Validating the Results and Discussion

During this critical stage of the study, the obtained results from sensor data undergo thorough validation against those derived from the questionnaire. The primary aim is to ensure the consistency and accuracy of the findings across both data collection methods. This analysis and validation aids in elucidating the complex interplay between individual constitutions providing valuable insights for personalized healthcare interventions and disease prevention strategies. It has been observed that the significance of FFT and 1D DWT lies in their ability to capture diverse aspects of pulse signals, ranging from frequency composition to temporal dynamics (35). By leveraging these methods for feature extraction, practitioners can obtain a holistic understanding of *Dosha* characteristics encoded within pulse waveforms, thereby enhancing the accuracy and efficacy of *Ayurvedic* diagnosis and *Prakriti* assessment.

When the sensor data is analyzed, depending on the feature extraction the *Prakriti* is decided. It is observed that generally people fall to be Dwidoshic (dual *Dosha*). Figure 14 shows the results of *Prakriti Parikshan*. According to the study very few subjects are single *Dosha* dominant. Similar observations are found while the questionnaire results were analyzed. The results obtained show the distribution of subjects among various *Prakriti*s. The characteristics about the specific prakriti are specifically more it is considered as the *ekdosha prakriti*. Few subjects have *Vata Dosha*, few with *Pitta Dosha* or *Kapha Dosha*. When the characteristics from two doshas are equally prominat in

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the subject it is considered as the *dwidhosha prakriti.* According to *Ayurvedic* literature this type of *prakriti* is not considered as very good *prakriti.* Some of them fall under *Dwidosha* category like *Vata-Pitta Dosha*, *Vata-Kapha* or *Pitta-Kapha Dosha*. Rarely do subjects fall under balanced category *Vata-Pitta-Kapha*. Similarly male and female were also observed under the above categories.

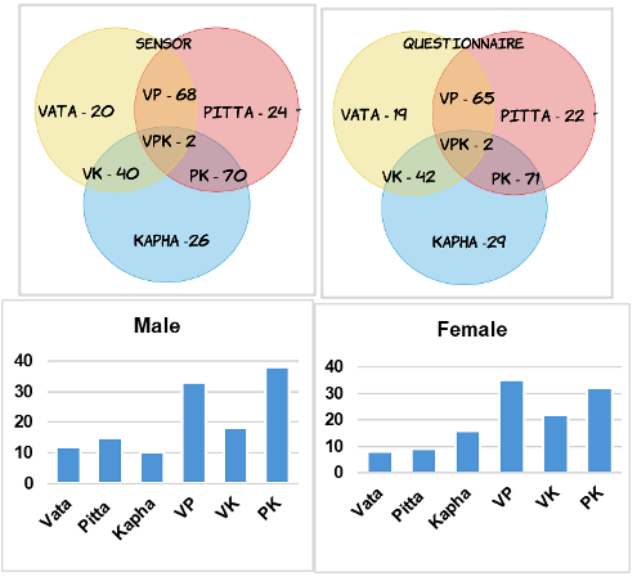
The sample result from 2 subjects is shown below in table 3, where the percentage data is written obtained from sensors as well as questionnaire based analysis.

The validation process entails a meticulous comparison of the *Dosha* classification outcomes obtained from sensor data analysis with the *Dosha* profiles derived from questionnaire responses. By aligning the results from these two distinct sources, researchers seek to identify any disparities or inconsistencies that may arise during the assessment of individual constitutions.

Table 3: Dominant *Prakriti* Decision

Name	*Vata*	*Pitta*	*Kapha*	Dominant *Prakriti*	
Subject 0	19	60	21	Pitta	**Sensor Data**
Subject 1	56	22	21	Vata	
Subject 0	21	59	20	Pitta	**Questionnaire Data**
Subject 1	56	22	21	Vata	

Figure 14: *Prakriti*-wise subjects' distribution



Upon conducting the validation, it was observed that approximately 95% of the outcomes obtained from sensor data analysis matched those derived from the questionnaire responses. This high level of agreement between the two data collection methods underscores the reliability and robustness of the research findings. Table 4 shows the results of proposed work.

Table 4: Results obtained

Number of subjects	250
Matching with questionnaire result	238
Accuracy obtained	95%

However, it is crucial to acknowledge that around 5% of the results exhibited disparities between the sensor data-based classification and the questionnaire-based classification. These differences highlight the inherent complexity of *Dosha* assessment and the multifaceted nature of individual constitutions, which may not always align perfectly across different evaluation modalities.

Overall, the validation process strengthens the credibility of the research outcomes by demonstrating a strong agreement between sensor data analysis and questionnaire-based assessment. Despite minor differences, the consistent alignment of most results underscores the validity and reliability of the proposed methodology for assessing individual constitutions based on sensor data and questionnaire responses.

Limitations

While the data is being collected using sensor it is observed that, the standardization is very crucial, terms of pulse location, pressure and interpretaion. The *ayurveda* experts uses their traditional knowledge to interpret the pulse and capture the subtle information which may not be captured in the sensor based information. Sensor sensitivity is dependant on environmental changes like temparature, humidity, skin condition, sweating. Sensors always lacks in the personal touch, like the long observations of subject done by any practioner. Thus the sensor based *Nadi parikshan* is under progress and requires much attention from both sides, engineering researchers and *ayurveda* practioners.

Conclusion

In the dynamic realm of healthcare, study exploration into Ayurvedic engineering has unveiled a pathway toward a future where ancient wisdom harmonizes with modern technology to redefine personalized medicine. This study reaffirms the enduring value of traditional Ayurvedic practices and emphasizes the transformative potential of integrating sensor technology with time-honoured diagnostic principles. It embarked on a quest to decipher individual constitutions through sensor data analysis and validate it using traditional questionnaire-based assessments. This rigorously validated methodology stands as a testament to the fusion of tradition and innovation, bridging ancient wisdom with contemporary healthcare demands.

Reflecting on the insights gleaned from comprehensive analysis, a clear narrative emerges—one of precision, efficacy, and relevance. These findings affirm the strength of the approach and underscore its significance in redefining Ayurvedic diagnosis and healthcare delivery. Through comparative analyses and statistical validations, the power of data-driven insights in unravelling individual constitutions is demonstrated. By harnessing the predictive capabilities of sensor technology and the understanding derived from traditional Ayurvedic knowledge, the groundwork is laid for personalized, holistic, and patient-centred healthcare.

The work to predict or diagnose specific diseases from sensor-based Nadi Pariksha is the real requirement of the era. Prakriti is the hidden foundation of an individual's health life. Many future diseases are hidden in the individual's Prakriti. Knowing the Prakriti and maintaining it as per Ayurveda literature may avoid many lifestyle diseases. Dosha imbalance leads to lifestyle disorders, and these can be avoided if a watch on Prakriti is kept. Sensor-based Prakriti Parikshan, which can be performed easily, will be very useful in Ayurveda-based treatments. In the future, knowing Dosha imbalance and diagnosing diseases from sensor-based Nadi Pariksha will definitely be helpful for humankind.

In essence, this study serves as an invitation to embrace innovation while honouring tradition, to utilize technology in the pursuit of human well-being, and to embark on a journey toward a future where wellness is boundless. To conclude this study, let us carry forward its lessons, insights, and aspirations as guiding lights toward a healthier, more fulfilling tomorrow.

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Nomenclature

Nadi	Radial Artery Pulse on wrist
Pariksha Parikshan	Examination
Prakriti	Body constituents
Ayurveda	Ancient Indian Medical Science

Appendix:

Questionnaire 2: 21 Questions

Vata (V) Section	For each question (Answer Options: 0, 1, 2, 3, 4, 5 or 6)
1	I am lively and enthusiastic.
2	I am easily excited.
3	I am slightly anxious and apprehensive.
4	I find cold water unpleasant.
5	I am quick to take in something new.
6	I have trouble falling asleep and often wake during the night.
7	I have a slim figure and have difficulty gaining weight.
Pitta (P) Section	For each question (Answer Options: 0, 1, 2, 3, 4, 5 or 6)
1	I have a sharp mind.
2	I tend to be a perfectionist.
3	I am slightly impatient.
4	I flare up easily but can calm myself down quickly.
5	My digestion is good and I can tolerate all foods.
6	I feel unwell or irritable if I eat late or miss a meal.
7	I feel unwell in hot weather.
Kapha (K) Section	For each question (Answer Options: 0, 1, 2, 3, 4, 5 or 6)
1	Other people think I have a pleasant character.
2	My gait is slow, steady, and assured.
3	My skin is soft and smooth.
4	I sleep deeply and soundly.
5	I am prone to a build-up of mucous in the airways and to feeling bloated.
6	I tend to be chubby. I gain weight very easily.
7	My build is quite athletic.

Questionnaire 2: 55 Questions

	Mental Profile	**Answer Options**
1	Mental activity	V) Quick mind, restless. P) Sharp intellect, aggressive; K) Calm, steady, stable
2	Memory	V) Short-term best; P) Good general memory; K) Long-term best)
3	Thoughts	V) Constantly changing; P) Fairly steady; K) Steady, stable, fixed
4	Ability to learn	V) Quick grasp of learning; P) Medium to moderate grasp; K) Slow to learn
5	Dreams	V) Fearful, flying, running, jumping; P) Angry, fiery, violent, adventurous K) Include water, clouds, relationships, romance
6	Sleep	V) Interrupted, light; P) Sound, medium; K) Sound, heavy, long
7	Speech	V) Fast, sometimes missing words; P) Fast, sharp, clear-cut; K) Slow, clear, sweet
8	Voice	V) High pitch; P) Medium pitch; K) Low pitch
	Behavioral Profile	**Answer Options**
9	Eating speed	V) Quick; P) Medium; K) Slow
10	Hunger level	V) Quick; P) Medium; K) Slow
11	Food and drink	V) Prefers warm; P) Prefers cold; K) Prefers dry and warm
12	Achieving goals	V) Easily distracted; P) Focused and driven; K) Slow and steady
13	Giving/Donations	V) Gives small amounts; P) Give nothing, or large amounts infrequently; K) Give regularly and generously
14	Relationships	V) Many casual; P) Intense; K) Long and deep
15	Sex drive	V) Variable or low; P) Moderate; K) Strong
16	Works best	V) While supervised; P) Alone; K) In groups
17	Weather preference	V) Dislike to cold; P) Dislike to heat; K) Dislike to damp, cool
18	Reaction to stress	V) Excites quickly; P) Medium; K) Slow to get excited
19	Finances	V) Doesn't save, spends quickly; P) Saves, but big spender; K) Save regularly, accumulates wealth
20	Friendships	V) Tends toward short-term friendships, makes friends quickly; P) Tends to be a loner, friends related to occupation; K) Tends to form long-lasting friendships
	Emotional Profile	**Answer Options**
21	Moods	V) Change quickly; P) Change slowly; K) Steady, unchanging

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22	Reacts to stress with	V) Own feelings; P) Anger; K) Indifference
23	Expresses affection	V) With words; P) With gifts; K) With touch
24	When feeling hurt	V) Cries; P) Argues; K) Withdraws
25	Emotional trauma causes	V) Anxiety; P) Denial; K) Depression
26	Confidence level	V) Timid; P) Outwardly self-confident; K) Inner confidence
	Physical Profile	**Answer Options**
27	Amount of hair	V) Average; P) Thinning; K) Thick
28	Hair type	V) Dry; P) Normal; K) Oily
29	Hair color	V) Light brown, blonde; P) Red, auburn; K) Dark brown, black
30	Skin	V) Dry, rough, or both; P) Soft, normal to oily; K) Oily, moist, cool
31	Skin temperature	V) Cold hands/feet; P) Warm; K) Cool
32	Complexion	V) Darker; P) Pink-red; K) Pale-white
33	Whites of eyes	V) Blue/brown; P) Yellow or red; K) Glossy white
34	Weight	V) Thin, hard to gain; P) Medium; K) Heavy, gains easily
35	Bowel movements	V) Dry, hard, thin, easily constipated; P) Many during day, soft to normal. K) Heavy, slow, thick, regular
36	Heartbeats per minute	V) 70-90; P) 60-70; K) 50-60
	Permanent Characteristics	**Answer Options**
37	Chin	V) Thin, angular; P) Tapering; K) Rounded, double
38	Cheeks	V) Wrinkled, sunken; P) Smooth, flat; K) Rounded, double
39	Eyes	V) Small, sunken, dry, active, black, brown, nervous; P) Sharp, bright, gray, green, yellow/ red, sensitive to light; K) Big, beautiful, blue, calm, loving
40	Nose	V) Uneven shape, deviated septum; P) Long pointed, red nose-tip; K) Short rounded, button nose
41	Teeth	V) Stick out, big, roomy, thin gums; P) Medium, soft, tender gums; K) Healthy, white, strong gums
42	Nails	V) Dry, rough, brittle, break easily; P) Sharp, flexible, pink, lustrous; K) Thick, oily, smooth, polished
43	Chest	V) Flat, sunken; P) Moderate; K) Expanded, round
44	Joints	V) Cold, cracking; P) Moderate; K) Large, lubricated
	Variable Characteristics	Answer Options
45	Body weight	V) Low; P) Medium; K) Overweight
46	Hips	V) Slender, thin; P) Moderate; K) Heavy, big
47	Belly	V) Thin, flat, P) Moderate; K) Heavy, big
48	Neck	V) Thin, tall; P) Medium; K) Big, folded
49	Lips	V) Dry, cracked, black/brown tinge; P) Red, inflamed, yellowish; K) Smooth, oily, pale, whitish
50	Digestion	V) Irregular, forms gas; P) Quick, causes burning; K) Prolonged, forms mucous
51	Taste	V) Sweet, sour, salty; P) Sweet, bitter, astringent; K) Bitter, pungent, astringent
52	Thirst	V) Changeable; P) Surplus; K) Sparse
53	Physical Activity	V) Hyperactive; P) Moderate; K) Slow
54	Faith	V) Variable; P) Extremist; K) Consistent
55	Intellect	V) Quick, but faulty response; P) Accurate response; K) Slow, exact

*****