Exploring the Ayurvedic Concept of Body Types and Their Relevance to Heart Rate Variability (HRV)

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Abstract. Heart rate variability (HRV) is a significant physiological indicator of autonomic nervous activity and cardiovascular flexibility. Based on the psychological and physiological nature, all human individuals belong to three main *doshas* (biological energies) in the Ayurveda traditional system of medicine: *Vata (*wind, associated with movement and change*)*, *Pitta (*bile, associated with digestion and metabolism), and *Kapha* (phlegm, associated with structure and lubrication). Utilizing sophisticated signal processing methods such as Phase Space Reconstruction (PSR) and Approximate Entropy (ApEn), this paper examines the correlation between HRV and Ayurvedic *dosha* types.

Typical patterns for each dosha were observed with HRV analysis: *Pitta*-dominant subjects had intermediate variability, *Kapha*-dominant subjects had stable and periodic rhythms, and *Vata*-dominant subjects had high heart rate variability. The deep impact of doshic dominance on HRV dynamics was also established by phase spectrum analysis and approximate entropy measurement. The present investigation represents a modern approach in estimating cardiovascular health from an individual viewpoint, combining both the concept of ancient Ayurveda and current computational techniques. The proposed portable approach makes use of wearable technologies with photoplethysmography (PPG) to continuously measure HRV even in daily scenarios. The results illustrate the potential of HRV-derived indices to identify individual physiological trends and offer guidance for the integration of contemporary biomedical science and ancient medicine.

Keywords: Heart Rate Variability (HRV), Ayurvedic Doshas, Phase Space Reconstruction (PSR), Approximate Entropy (ApEn).

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1 Introduction

An important physiological indicator of autonomic nervous system function and overall cardiovascular health is heart rate variability (HRV) [1]. It is the dynamic interplay between sympathetic and parasympathetic nervous system control of heart rhythms in response to internal and external stimuli [2,3]. Numerous medical disorders, such as metabolic disease, psychological stress, and cardiovascular disease, have been associated with alterations in HRV [4]. While the HRV itself, in view of modern medicine, has been the subject of a huge number of studies, little is known with regard to its relationship to constitutionally different physiological types defined by traditional medicine. In this respect, the hypothesis that quantification using state-of-the-art signal processing methods is able to uncover different HRV patterns displayed by the Ayurvedic body types (*doshas*) is examined in the present work [5]. The findings may support the scientific basis for the integration of Ayurvedic diagnosis into conventional medicine and contribute to moving personalized medicine forward.

There are classical systems of medicine, such as Ayurveda, that approach differently and categorize physiological and psychological differences into constitutional types called *doshas* [6], whereas contemporary science rigorously explores HRV using statistical and nonlinear methods [7]. According to their natural physiological, metabolic, and behavioral characteristics, human beings are divided into three fundamental *doshas* according to the traditional Indian medicine system Ayurveda: *Vata, Pitta,* and *Kapha* [8]. All these *doshas* together, which are referred to as *Vikriti*, control an individual's vulnerability to disease, reaction to external factors, and health status [9]. Each person has one dominant *Dwandvaja dosha* (balance or influence of two *doshas*), or a mix of two or all three. Among them, one *dosha* has the greatest impact, and another is not [10]. The determination of *Dosha* Type may be important as a component in disease diagnosis and dietary or personal treatment measure determination [11].

There is a scientific rationale for analyzing the physiological effects of Ayurvedic *dosha* types through the means of HRV analysis. According to previous research, different *dosha* types correspond to different levels of autonomic nervous system activity, reflected in measures of HRV [12]. From prior research, *Kapha*-predominant individuals have been discovered to have a tendency to have steady and regular heart rate patterns, suggesting predominant parasympathetic control [13]. In contrast, *Vata*-dominant persons possess high variability and irregular rhythms, which is consistent with their greater nervous system activity and physiological instability [14]. Intermediate HRV changes are a manifestation of the metabolic efficiency and adaptability of *Pitta*-dominant persons, who possess a balance of *Vata* and *Kapha* [15]. The research hypothesis is that the different Ayurvedic dosha types are associated with different patterns of heart rate variability (HRV), which can be quantified and examined scientifically using advanced signal processing techniques.

Furthermore, the heart rate variability is treated with various signal processing techniques [16,17,18,19]. Therefore, in this research work, sophisticated signal processing techniques, i.e., PSR and ApEn, are utilized to evaluate HRV patterns in various *dosha* types with the aim of scientifically authenticating the relationship between *Tridosha* and heart rate variability.

The study acknowledges the differences that may exist across demographic and cultural contexts by including a diverse sample population to increase generalizability [20]. Other traditional medical systems would be compared as well in order to place the Ayurvedic classification in an international context, searching for analogous HRV patterns across cultures and traditional medical systems.

In fact, the practical value of the *dosha* classification based on HRV has been demonstrated beyond its theoretical validation in clinical situations in the present study. A completely new portable HRV measurement technique, wearable by PPG sensors, has been proposed for comfortable and continuous monitoring of *Prakriti* from the digital artery. Novel approach for heart rate variability tracking in day-to-day life: a technique for more comfort and utility in clinical or wellness applications. HRV analysis is more applicable for the assessment of *Prakriti* in realistic scenarios, since it forms a part of the current revolution on digital health and personalized health improvement [21].

Moreover, this study will contribute to achieving the United Nations' Sustainable Development Goals (SDGs), specifically SDG-9 (Industry, Innovation, and Infrastructure) and SDG-3 (Good Health and Well-Being) [22]. Such efforts would support the creation of sustainable health care solutions using computational techniques with knowledge from Ayurveda in poor countries where conventional medicine still continues to play an important role in health management. *Prakriti* assessment using portable HRV gadgets will probably facilitate a leap in personalized treatment and health disparities research through the translation gaps between knowledge drawn from Ayurveda and modern scientific methodology.

2 Methods and Materials

The study used signal processing techniques, namely, Approximate Entropy (ApEn) and Phase Spectrum Analysis (PCA), to examine the correlation between cardiac variation and the three Ayurvedic *doshas*, namely, *Pitta, Kapha,* and *Vata*. Designing a custom optical sensor-integrated device to capture pulse signals from the digital artery of fingertips was the initial of a number of milestones within the research exercise. To offer accurate and reliable measurements of PPG signals, this equipment has been calibrated. PPG signal data were recorded from each subject, which were stored in a database securely for analysis. The dominant *dosha* of the subjects was identified prior to data collection with the aid of a validated Ayurvedic questionnaire, and according to that, they were grouped into three groups. The participants, around 500 in total, ranged in age from 18 to 65 years; both sexes were well represented and came from a broad demographic base that ensured generalizability. People were excluded in cases of significant comorbidities that may affect HRV, such as diabetes, hypertension, or prior cardiovascular disease.

HRV values were calculated and retrieved from PPG signals acquired for the three *dosha* categories by means of software designed specifically for the purpose after the data collection process. Statistical parameters such as Approximate Entropy (ApEn), Sample Entropy (SampEn), Mean, Variance, Standard Deviation (SD), Skewness, and Kurtosis were some of the calculated statistics.

The readings reflect subject heart rate pattern variability and complexity. Further, frequency-domain parameters of HRV were analyzed by phase spectrum analysis to understand the *dosha*-specific heart rate variability. This helped in real-world implementation related to digital health platforms, personalized wellness initiatives, and Ayurvedic health assessments. MATLAB and Python statistical packages were used to examine the data. Descriptive statistics were computed to merge physiological measures and demographic variables. ANOVA tests were used to contrast the three *dosha* groups' mean values of the HRV measures, and post-hoc Tukey's HSD test analyses were used to determine significant differences. Pearson correlation coefficients were computed to investigate relationships between cardiac variation measures and approximate entropy for the three *dosha* groups.

Ethical permission for this study was granted by the Institutional Review Board (IRB) of the University of Sri Jayewardenepura's Faculty of Human and Social Sciences. Consent was provided by all respondents prior to the collection of data, and they were made aware of the aims, methods, possible risks, and benefits of the research. All of the collected data were anonymized to facilitate participant confidentiality. The main instruments of investigation in this study were a low-cost, embedded optical sensor device for PPG signal detection, open-source data processing software Python and MATLAB, and a validated Ayurvedic *dosha* categorization questionnaire. In the use of wearable sensors, the developed solution is assured to be affordable, hence sustainable healthcare solutions and guaranteed accessibility for both clinical and wellness applications, especially in resource-poor healthcare settings. Ayurvedic *doshas*, such an analytical framework provides a systematic method to investigate the correlation between cardiac variability and approximate entropy, providing meaningful information about cardiovascular health from an integrative point of view.

2.1 Mathematical Concepts

Phase Space Reconstruction of RR Interval Time Series. Phase space reconstruction is a powerful technique for analyzing the temporal evolution of time series data. In this study, it was applied to RR interval time series to examine how heart rate variability evolves over time in a multi-dimensional state space.

Data Preparation. The RR interval time series, $\{r_1, r_2, r_3, \ldots, r_n\}$, represents the time intervals between successive R-peaks in the ECG signal. These intervals serve as the input for phase space reconstruction.

Delay Embedding. Phase space reconstruction was performed using delay embedding with embedding dimension $m=3$ and the time delay $r=1$.
The time series was transformed into a multi-dimensional state space, where each state vector $x(i)$ is formed from three consecutive RR intervals, as shown in Equation 1;

$$x(i) = [r_i, r_{i+1}, r_{i+2}] \tag{1}$$

For $i = 1, 2, 3, \ldots, N-m.r$

This transformation provides a 3-dimensional representation of the RR intervals, capturing the dynamics of heart rate variability.

Autoregressive (AR) model. To predict future RR intervals, an autoregressive (AR) model was trained on the first dimension of the reconstructed phase space. The AR model used 5 lags to capture temporal dependencies, and it was used to predict the next 10 RR intervals based on the past observations. Let the AR model be represented as shown in Equation 2:

$$r_i = \emptyset_1 r_{i-1} + \emptyset_2 r_{i-2} + \ldots + \emptyset_5 r_{i-5} + \epsilon_i \tag{2}$$

Where $\emptyset_1, \emptyset_2, \ldots, \emptyset_5$ are the model coefficients, and ϵ_i is the error term.

Approximate Entropy (ApEn). Approximate Entropy (ApEn) is a statistical measure used to quantify the regularity and unpredictability of fluctuations in a time series. It is commonly applied to physiological signals to assess heart rate variability. The ApEn calculation involves the following steps:

Defining Segments. Given a time series $U=[u_{1,},u_{2,}\ldots,u_n]$, we first construct *m*-length segments for analysis. For each point *i,* an *m*-dimensional vector $X_i = [u_i, u_{i+1,} \ldots, u_{i+m-1}]$ is created.

To evaluate the similarity between these segments, we set a distance threshold *r* as a fraction of the signal's standard deviation, with $r=0.2\times\mathrm{std}(U)$. This threshold is used to identify patterns within the time series that fall within an acceptable range of similarity.

The similarity proportion for each vector $X_i, C_i^{(m)}(r)$, is calculated by counting all pairs where the maximum distance between X_i and other segment vectors are less than or equal to *r.* The similarity count for segments of length *m* is given by Equation 3:

$$C_i^{(m)}(r) = \frac{\text{Number of pairs within threshold}}{N-m+1} \tag{3}$$

The natural logarithm of $C_i^{(m)}(r)$ values is averaged over all segments, yielding the function $\Phi^{(m)}(r)$, and the relation is shown in Equation 4;

$$\Phi^{(m)}(r) = \frac{1}{N-m+1} \sum_{i=1}^{N-m+1} \ln\left(C_i^{(m)}(r)\right) \tag{4}$$

The ApEn value is then defined as the difference between the averaged logarithmic counts for segment lengths *m* and *m+1,* as shown in Equation 5;

$$\mathrm{ApEn}(m,r) = \Phi^{(m)}(r) - \Phi^{(m+1)}(r) \tag{4}$$

Higher ApEn values indicate greater signal complexity and lower predictability, while lower values imply more regular, predictable patterns in the signal.

3 Results and Discussion

3.1 Classification Analysis of PPG Signals: Kapha, Vata, and Pitta

For analytical purposes, three primary groups were selected that possess three different body types—Kapha, Vata, and Pitta. To represent the patterns and trends with time in a clear manner, graphs were plotted using the PPG data collected for each body type. *Figure 1(a)* illustrates how *Kapha* behaves over time, with straight and consistent waveforms indicating constant rhythms. *Figure 1(b)* indicates how *Pitta* behaves, mid-way between the highly fluctuating *Vata* and constant *Kapha*, and consists of waves moderate in amplitude. *Figure 1(c)* illustrates how *Vata* behaves over time, where waveforms of large amplitude demonstrate greater variability and irregular rhythms.
These waveform features reflect different physiological reactions in each *dosha*: *Pitta* maintains a balanced rhythm with flexibility, *Vata* shows dynamic variation, and *Kapha* maintains stability.

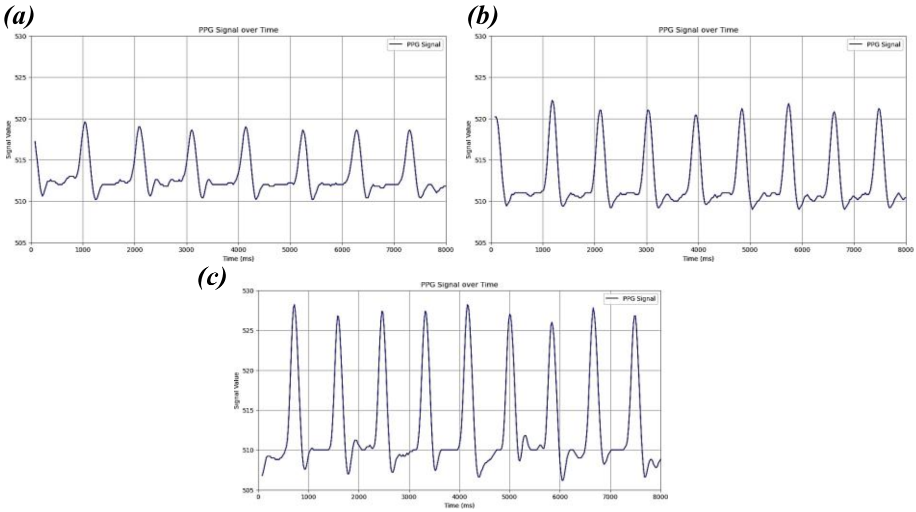

Figure 1: PPG signal waveform; (a) PPG signal waveform for Kapha, (b) PPG signal waveform for Pitta, and (c) PPG signal waveform for Vata

3.2 Phase Space Reconstruction of RR Interval Time Series

As further support of chaotic and nonlinear dynamics in heart rate variability, phase space reconstruction analyzes RR interval fluctuations in time. It is quite useful for investigating the responses of the heart rate to physiological stimuli like exercise and stress. *Figure 2* graphically visualizes the distribution of the data points within the 3D space of the phase space analysis, mirroring the heart rate variability for each class.
It would be observed from *Figure 2a* that, in the case of *Kapha*, the heart rate variability had been very much regular, with the data points clinging close to each other in a tightly clustered manner. *Figure 2b* represents the *Vata* individual whose HRV presented an

erratic irregularity with scattering in a broadly dispersed manner. In *Figure 2c,* the *Pitta* is showing a moderate variability, hence a compromise existing between stability and flexibility.

This investigation is done to establish this fact that PSR can exhibit different patterns of HRV due to their different *doshas*: *Kapha* is stable, *Vata* has dynamic variation, and *Pitta* responds well to stimuli.

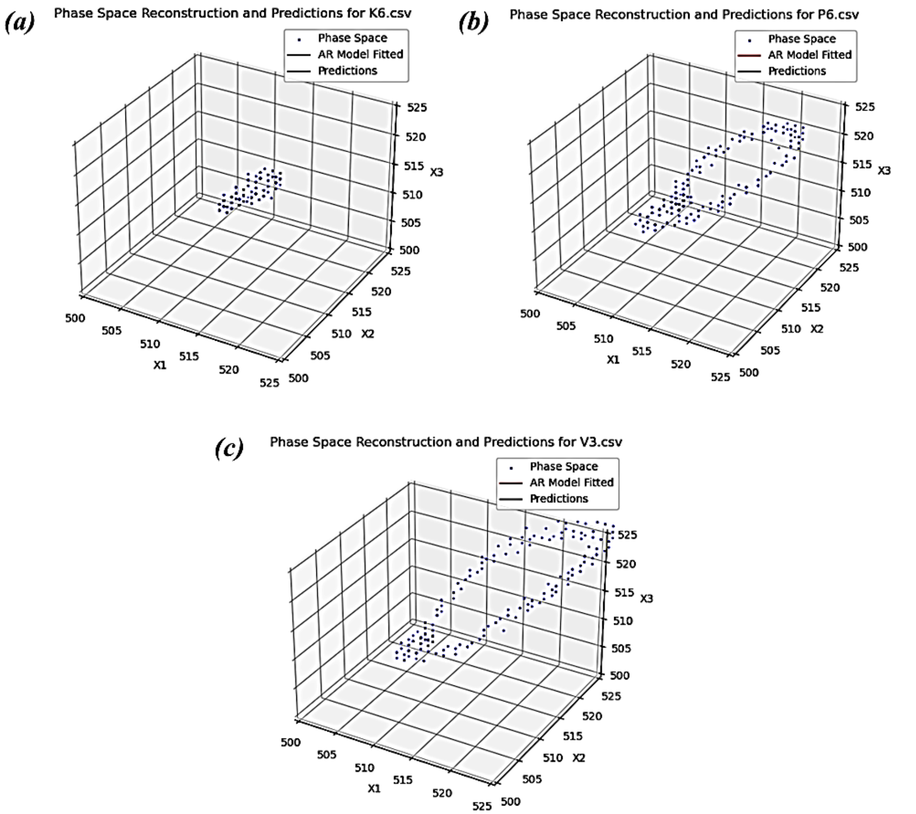

Figure 2: Phase Space Reconstruction & Prediction for Signal Classes; (a) PSR image for Kapha, (b) PSR image for Pitta, and (c) PSR image for Vata

3.3 Approximate Entropy Analysis

In order to quantify the complexity of HRV, the data of ApEn has been plotted as a function of the two statistical factors of signal variance and skewness. The variation of ApEn with skewness has been shown in *Figure 3*. *Figure 3a* shows the scatter plot of *Kapha* skewness vs. ApEn. Low ApEn and skewness are indicative of more regular and predictable rhythms. On the other hand, *Vata* persons have high ApEn and skewness as shown in *Figure 3c,* and therefore, their rhythms in heart rates are highly irregular and rapidly changing. Contrarily, the *Pitta* individuals reflected mean values that represented stability interspersed with fluctuations, as depicted in *Figure 3b.*

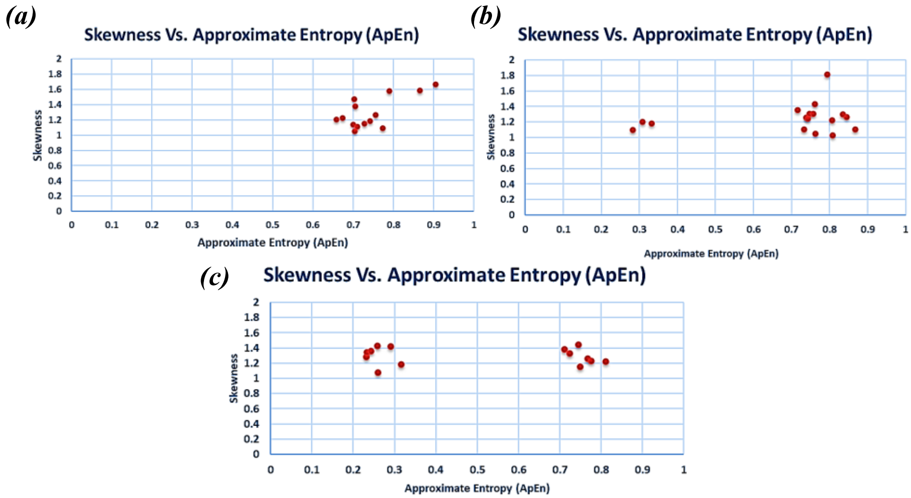

Figure 3: Graphs of Skewness Vs. Approximate Entropy (ApEn) for Signal Classes; (a) Kapha class, (b) Pitta class, and (c) Vata class

All these inferences were further ensured by the Variance vs. ApEn comparitive analysis, as shown below in *Figure 4*. The *Kapha* group revealed a closely knitted cluster, represented in *Figure 4a* below, depicting the characteristic pattern of variation in heart rate with more steady and dependable rhythms. On the other hand, *Figure 4b* shows that the variation in heart rate among *Vata* individuals took the shape of 'J', therefore showing two clear states. The *Pitta* individuals showed rhythm continuity through forming a kernel cluster with minor fluctuations as represented by *Figure 4c.*

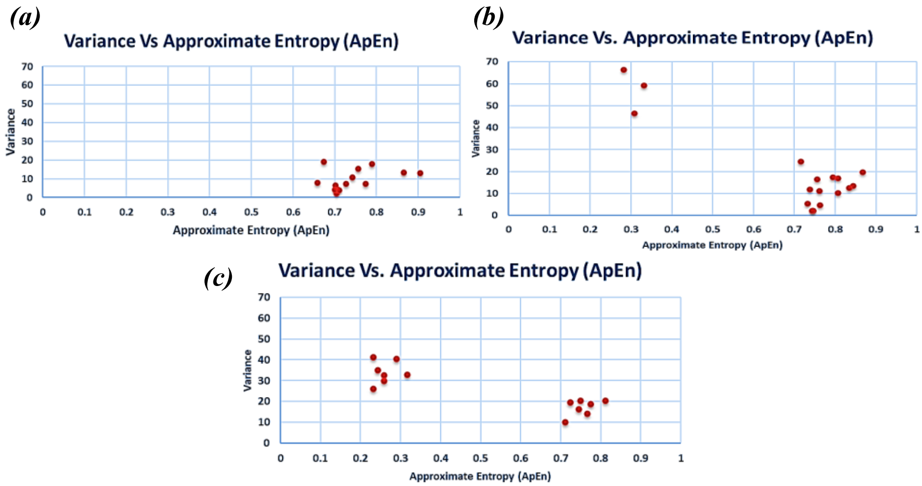

Figure 4: Graphs of Variance Vs. Approximate Entropy (ApEn) for Signal Classes; (a) Kapha class, (b) Pitta class, and (c) Vata class

4 Conclusion

Based on phase space reconstruction and approximate entropy analysis, different patterns of heart rate variability could be observed for each of the three *dosha* classes. The heart rate in *Kapha* is regular, reflecting minimal fluctuation in phase space, with the physiological response remaining consistent and predictable. Lower values of ApEn confirm stability; this means lesser complexity and thus greater resistance against stress for *Kapha* people.

Vata, represented by a larger scatter in phase space, showed higher variability and ApEn. This could be seen to indicate that there is a less stable, more dynamic heart rate rhythm, reflecting increased sensitivity to stress and greater adaptability in fluctuation of heart rate. *Pitta* reflects a balanced autonomic response with modest ApEn values and an intermediate distribution in the phase space. People of *Pitta* constitution may easily feel changes in the environment, but their heart rate will remain stable.

These results, therefore, reflect that heart rate variability is different among the *dosha* types, with *Pitta* balancing the two, *Vata* showing variability, and *Kapha* showing stability. These results show a means of applying nonlinear analysis methods, such as phase space reconstruction and approximate entropy, to the characterization of HRV patterns across Ayurvedic *dosha* types. These results demonstrate the potential of integrating contemporary customized healthcare techniques with Ayurvedic diagnostics. This work points to a new direction for the integration of traditional knowledge with state-of-the-art biomedical analysis through the use of computational techniques for distinguishing physiological variability.

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