

Relationship between Three Ayurvedic Doshas and Heart Rate Variability Frequency Bands: A Pilot Study

A Dissertation submitted in fulfillment of the requirements for the Degree
of

MASTER OF ENGINEERING
In
Electronic Instrumentation & Control Engineering

Submitted by

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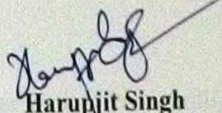
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DECLARATION


I hereby declare that the report entitled "Relationship between Three Ayurvedic Doshas and Heart Rate Variability Frequency Bands: A Pilot Study" is an authentic record of my own work carried out as a requirement for the award of degree of M.E. (Electronics instrumentation and Control Engineering) at Thapar University, Patiala, under the supervision of **Dr. Man deep Singh** (Associate Professor, EIED). The matter presented in this thesis has not been submitted, neither in part or in full to any other university or institute for award of any degree.

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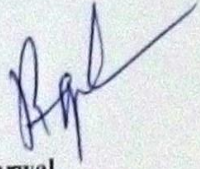

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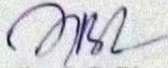
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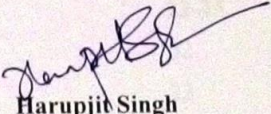

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LIST OF ABBREVIATIONS

ECG - Electrocardiogram

HRV - Heart Rate Variability

VLF - Very Low Frequency

LF - Low Frequency

HF - High Frequency

ULF - Ultra Low Frequency

nu - Normalized unit

PPG - Photoplethysmograph

MATLAB - Matrix Laboratory

NI - National Instruments

ABSTRACT

As per Ayurveda disease is consequence of living out of harmony with one's Prakriti. The Prakriti is innate doshas balance in an individual and imbalance in doshas leads to disease. In Ayurveda diagnosis is done to find the dosha imbalance. Nadi Pariksha or Pulse examination is very important technique. In Nadi Pariksha the radial artery is checked by placing three fingers at the root of thumb. Currently, this technique is subjective and the accuracy of the diagnosis depends upon the expertise and experience of the Ayurvedic physician. In this research we have analyzed the Heart rate variability (HRV) of 25 patients diagnosed by Ayurvedic physician. The analysis is done in frequency domain. The normalized parameters VLF nu, LF nu and HF nu are calculated. The mean value of VLF nu is greater than the mean values of LF nu and HF nu in Vata patients. Similarly we observed in the Pitta patients the mean value of LF nu is greater. We also applied Chi Square test and the value of the P was 0.0042. It may be concluded from the results that the VLF nu is related to Vata and LF nu is related to the Pitta dosha.

CHAPTER 1

INTRODUCTION

1.1 Ayurveda

Ayurveda is the oldest holistic system of healing and natural medicine dating at least 3000 BC in India. Ayurveda can be defined as the science of the life. As per Ayurveda the health and the wellness of an individual depends upon the balance between the mind and the body. It focuses on overall physical, emotional, mental and spiritual health rather than just curing. The major emphasis is done on healing. Curing can be defined as mere treatment of the symptoms whereas healing is defined as treating the body as whole considering the physical, mental, emotional and spiritual wellness. Ayurveda aims to help an individual achieve balance between mind and body so one can reach to state of everlasting and supreme bliss i.e. Moksha and become living expression of the divinity.

1.1.1 Panchamahabhutas

The Panchamahabhuta theory is foundation of the Ayurveda and states everything in this cosmos is made up of five basic elements as in Figure 1.1. The different types of substances present in the universe are formed by combination of the Panchamahabhutas [1].

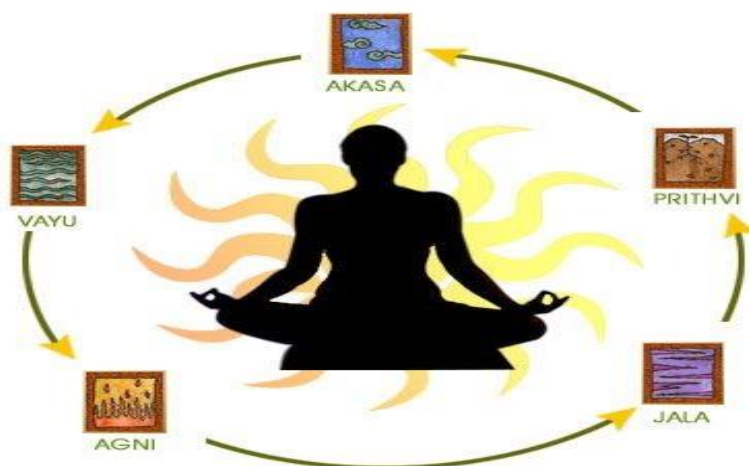


Figure 1.1 Panchamahabhutas [2]

These basic five elements are known as:

- Akasa (ether or space)
- Vayu (air)
- Agni (fire)
- Jala (water)
- Prithvi (earth)

Akasa should not be considered as the sky. It is the synonymous to the Space. In our body all the channels, pores or empty spaces symbolize Akasa.

Vayu is translates to the air. In our body it is responsible for various movement like that electric pulses in nerves, Gastro intestinal movement of food, joints motion etc.

Agni literally means the fire. The property of the fire is it transforms the state of any substance. It is responsible for biotransformation. In our body Agni bio transforms the food we intake is done into substances our body can utilize.

Jala translates to the water. In our body it is present in bodily fluids like blood, cerebrospinal fluid etc. These fluids help in distribution of energy, maintaining optimal temperature, and hormones transportation in body, removal of wastes.

Prithvi literal meaning is the earth. It implies steadiness and firmness. In our body Earth element is present in skeleton, cells and tissues.

The other features of the Panchamahabhutas as per Ayurveda are tabulated in Table 1.1.

Table 1.1 Panchamahabhutas properties and other description

	Akasa	Vayu	Agni	Jala	Prithvi
Properties	Light, smooth, soft, Inactive, clear minute, neither hot nor cold, separation, differentiation	Light, rough, clear, minute, atomic, neither hot nor cold, active movement	Light, rough, sharp, clear minute, atomic, hot, dry luminous, active spread high speed	Heavy, fluid, soft, inactive, slimy, cold, dense, Large molecules viscid wet, moving in the direction of	Heavy, rough, hard, slow, Inactive, steady, firm, clear, dense, large, bulky, neither hot nor cold

				gravity	
Present in body part	All body passage and cavities	Inspired air, Expired air, all movements in the body	Pitta, heat, lustre	Body fluids blood, fatty tissue kapha pitta, urine, stool, sweat, semen	Nails, bones, tendons, teeth muscles skin, stool, hair, spinal cord
Special organ	Ear	Skin	Eye	Tongue	Nose
Special sense	Sound	Touch	Vision	Taste	Smell

1.1.2 Tridoshas

The Tridosha theory is further developed from the Panchamahabhutas theory [1]. It can be viewed as the application of the Panchamahabhutas in the living beings. The three living body constituents (Vata, Pitta and Kapha) are defined depending upon the degree of predominance of Vayu, Agni and Jala respectively, as in Table 1.2. Each individual is a unique combination of tridoshas. Vata, Pitta and Kapha are present in each living organism and play a vital role in determining overall health of individual. The tridoshas control various functions in a living being. The imbalance in the doshas is major cause of the disease in the Ayurveda [3].

Table 1.2 Dosha and major elements

DOSHA	ELEMENTS
Vata	Vayu , Akasa
Pitta	Agni
Kapha	Jala, Prithvi

1.1.2.1 The Doshas and Subdoshas

- **Vata** is combination of Vayu (air) and Ether (space). The Vayu is the dominating element amongst two. Vata controls all movement in the mind and body. It governs the blood flow, elimination of wastes, breathing, creative thinking, reasoning, enthusiasm etc. There are 5 forms of Vata called subdoshas, as in Table 1.3.
- **Pitta** is an Agni (Fire) element present in the body. The Agni controls digestion, metabolism, and enzymes, hormones, body chemistry, transformation and heat

production. Predominance of the Pitta doshas in an individual is indicated by a fiery behaviour that exhibits in mind as well as body. The 5 major pitta subdoshas are given in Table 1.4.

Table 1.3 Vata Subdoshas

Subdoshas	Location
Prana Vata	Inhalation, swallowing, thought
Vyana Vata	Exhalation/lungs, speech/throat
Samana Vata	Peristalsis, stomach, intestine
Apana Vata	Urination, defecation, menstruation
Vyana Vata	Entire nervous system

Table 1.4 Pitta Subdoshas

Subdoshas	Location
Alochaka Pitta	Eye/Sight
Sadhaka Pitta	Heart/Consciousness
Pachaka Pitta	Stomach/Digestion
Ranjaka Pitta	Liver/Bile
Bhrajaka Pitta	Entire skin/Feeling

- **Kapha** is the blend of Jala (Water) and Earth (Prithvi). Kapha supports all body structure and governs lubrication. It is related to growth, joints lubrication, tissue's growth and body weight. The 5 kapha subdoshas are as in Table 1.5.

Table 1.5 Kapha Subdoshas

Subdoshas	Location
Tarpaka Kapha	Sinuses, cerebral, and spinal fluid
Bodhaka Kapha	Saliva, digestion and taste
Avalambaka Kapha	Fluids of heart and lungs
Kledaka Kapha	Mucous of stomach
Slesaka Kapha	Lubrication and fluid of joints

1.1.2.2 Doshas Balance and Imbalance

- **Vata Dosh:** The colon is the primary seat of the vata and hearing and touch are primary senses. The features of balanced and imbalanced vata, cause of imbalance and restoring balance are discussed in Table 1.6.

Table 1.6 Balanced and imbalanced vata, cause of imbalance and restoring balance

Balanced Vata	Imbalanced Vata	Imbalance due to	How to balance
Vibrant, enthusiastic, energetic	Restless, anxious, fear, unsettled	Irregular routine	Regular routine
Clear and alert mind	Sadness, grief	Staying up late	Early bedtime, lots of rest
Flexible, changeable	Interrupted sleep	Irregular meals	Warm, cooked foods
Exhilarated, excitable	Tendency to overexert, gain fatigue	Cold, dry weather	Warmth
Imaginative, sensitive, lively	Chronic constipation or gas	Excessive mental work	Abhyanga (daily oil massage)
Quick and acute response	Tendency to worry	Too much bitter, astringent, pungent food	Heavy, more unctuous diet
	Tendency to be underweight	Injury, falling or travelling	
	Intolerance of cold		

- Pitta Dosha:** The small intestine is the primary seat of the pitta and sight is primary sense. The features of balanced and imbalanced pitta, cause of imbalance and restoring balance are discussed in Table 1.7.

Table 1.7 Balanced and imbalanced pitta, cause of imbalance and restoring balance

Balanced Pitta	Imbalanced Pitta	Imbalance due to	How to balance
Strong digestion	Demanding, perfectionist	Excessive eating and sun	Cool environments
Warm, loving, contended	Tendency towards anger, hatred, envy, frustration, jealousy	Alcohol, smoking, drugs	Sweet, bitter, astringent tastes
Enjoy challenges, intellectual, knowledge	Tendency towards skin rashes	Time pressure, deadline	Limit salt intake
Lustrous complexion	Irritable and impatient	Excessive activity	Looking at natural beauty
Good power of concentration	Heartburn	Too much spicy, sour, salty food	Regular mealtimes, especially at noon
Articulate and precise speech	Early greying or hair loss	Skipping meals	Leisure time
Courageous, bold, sharp			

- **Kapha Dosha:** The chest is the primary seat of the kapha and taste and smell are primary senses. The features of balanced and imbalanced kapha, cause of imbalance and restoring balance are discussed in Table 1.8.

Table 1.8 Balanced and imbalanced kapha, cause of imbalance and restoring balance

Balanced Kapha	Imbalanced Kapha	Imbalance due to	How to balance
Affectionate, compassionate	Complacent, dull, lethargic	Excessive rest and sleep	Vigorous regular exercise
Forgiving	Stubborn	Excessive food intake	Pungent, bitter, astringent taste
Love	Sinus congestion, allergies	Insufficient exercise	Warm, light food
Steady emotionally, relaxed	Possessive, over attached	Not enough variety in life	Warm, dry environment
Slow, methodical	Tendency to oversleep	Heavy, unctuous or cold food	Fruits, vegetables and legumes
Good memory	Overweight, slow digestion	Too much sweet, sour and salty food	Varying routine
Good stamina, stability	Deep confusion, depression	Cold weather, wet weather	
Natural resistance to sickness			

1.1.3 Prakriti

Prakriti translates to nature, is inborn balance of the doshas of an individual. The imbalance of doshas is called Vikruti (diseased state). The sperm and ovum constitutes the dosha of father and mother respectively. During the conjugation the neutralisation or exaggeration of the dosha from both sperm and ovum occurs [1]. On basis of this seven type of prakriti are described as:

- Vata
- Pitta
- Kapha
- Vata-pitta or Pitta-Vata
- Pitta-Kapha or Kapha-Pitta
- Kapha-Vata or Vata-Kapha
- Vata-Pitta-Kapha (Samadosha)

1.1.4 Saptadhatus

Saptadhatus means seven tissues, necessary for support and nourishment of the body [1]. As per Ayurveda the Saptadhatus are regularly created, destroyed and reformed in the body. The Saptadhatus are:

- Rasa (plasma)
- Rakta (blood)
- Mamsa (muscle tissue)
- Meda (Adipose tissue)
- Asthi (bone tissue)
- Majja(marrow)
- Sukra (reproductive elements)

1.1.5 Astha Sthana Pariksha

Astha Sthana Pariksha is eight point diagnosis in Ayurveda [11]. It consist of examination of variois body parts and products by just looking, listening, touching etc. The various typre of examination are:

- Nadi Pariksha(Pulse Examination)
- Mutra Pariksha(Urine Examination)
- Mala Pariksha (Stool Examination)
- Jihva Pariksha(Tongue Examination)
- Sabda Pariksha(Bodily Sounds Examination)
- Netra Pariksha(Eyes Examination)
- Twacha Pariksha (Skin Examination)
- Akriti Pariksha(Total Body Appearance Examination)

Amonst all the 8 methods of the examinations used, Nadi Parikshan is done to find any disproportion in tridoshas by feeling throbbing in the radial pulse near wrist.

1.1.6 Nadi Pariksha

The Nadi Pariksha or Pulse Examination is done on the most common nadi called Jivanadi or the radial artery [14]. The index finger (first finger), middle finger and ring finger are placed

on the wrist. The position of the first finger is just below radial styloid and followed by the middle finger and the ring finger, as in Figure 1.2.

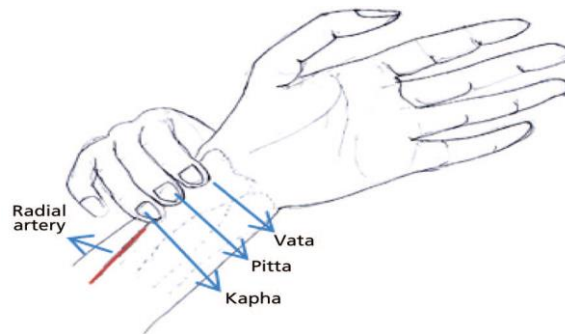


Figure 1.2 Nadi or Pulse Examination [14]

The examination of the pulse is done by feeling pulse from right hand of the male patients. In case of female patients left hand's pulse is examined. The three doshas have different pulse signatures as in Table 1.9. The vata pulse is felt as fast, feeble and snake's scrawling like sensation under the first or index finger. The pitta pulse is felt under the middle finger and marked by sensation like jumping frog and was prominent and strong. The kapha pulse is similar to swimming swan, slow and smooth movement and is felt under the ring finger [4].

Table 1.9 Pulses properties [4]

	Vata Pulse	Pitta Pulse	Kapha Pulse
Characteristics	Fast, feeble, cold, light, thin, disappears on pressure	Prominent, strong, high amplitude, forceful, lifts up the palpating fingers	Deep, slow, wavy, broad, regular
Location	Index finger	Middle finger	Ring finger
Gati or Movement	Moves like snake	Moves like frog	Moves like swimming swan
Vega or Rate	80-95	70-80	50-60

The prominence of the particular dosha is stated by feeling the pressure exerted on the each fingertip. Vata dosha marks its presence felt under first finger while pitta dosha is felt under middle finger and kapha dosha is observed below ring finger. The throbbing of pulse can be felt under more than one finger tip. In case the pulse beats are felt prominently under two fingertips the person is affected by two doshas. If the pulse beats are felt under all three fingertips then the person is affected by all three doshas [4] [5], as shown in Figure 1.3.

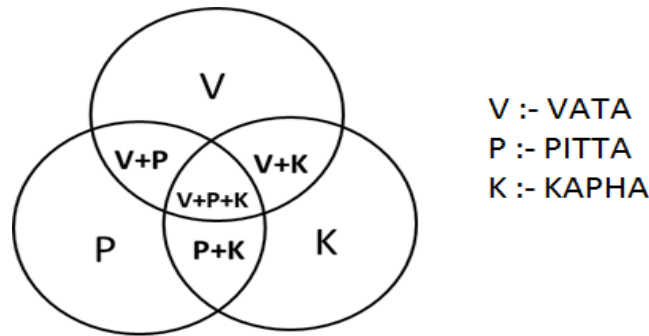


Figure1.3 Different combinations of Vata, Pitta and Kapha

The standard questionnaire are used to know the Prakriti of the individual [13] and the Ayurvedic practitioner does the Nadi Pariksha to find the imbalance in the doshas i.e. Vikruti. The other examinations like jihva pariksha, netra pariksha, twacha pariksha etc. further helps in confirming the diagnosis in an individual. Generally Nadi pariksha is considered sufficient for knowing the imbalance in the doshas. The difference in the Prakriti and vikruti helps in determining the disease in the individual.

1.2 Heart Rate Variability

Heart Rate Variability (HRV) is changes or variation in the beat to beat intervals of the heart, as shown in Figure 1.4. R is point which represents the peak of the QRS complex of the Electrocardiogram waveform [10]. The R to R duration is also called RR interval (NN interval is used to highlight the fact that processed beats are normal beats).



Figure 1.4 Peak to peak variation in the heat rate [29]

The alteration of the time interval in between the heartbeats is measured and then assessment of the data is usually done using mathematical manipulations. There are different methods and devices used to detect peaks. The ECG, the pulse waveform obtained from a

Photoplethysmograph (PPG) and ballistocardiograms [7]. Amongst all the methods ECG gained popularity because R peak is clearly distinguishable in QRS complex of ECG.

The analysis of the Heart Rate Variability is generally done in two domains [10].

- Time Domain Analysis
- Frequency Domain Analysis

1.2.1 Time Domain Analysis

The RR intervals are recorded for the analysis. The different time domain parameters or indices can be defined which are the mean RR interval, average heart rate, variation in day and night heart rate, difference between the greatest and smallest RR duration etc. The time domain analysis can be divided into two categories [10].

- **Statistical Analysis** involves calculation of the various parameters done using statistical operators like mean, variance etc. The table 1.10 contains the list of various variables used for statistical analysis.

Table 1.10 Statistical measures [10]

Variables	Units	Description
SDNN	ms	Standard deviation of all NN Intervals
SDANN	ms	Standard deviation of the average of NN Intervals in all 5 min segment of the entire recording
RMSSD	ms	The square root of the mean of the sum of the squares of the difference between adjacent NN intervals
SDNN index	ms	Mean of the standard deviation of all NN intervals for all 5 min segments of the entire recording
NN50 count		Number of pairs of the adjacent NN intervals differing by more than 50 ms in the entire recording
pNN50	%	NN50 count divided by the total number of all NN intervals

- **Geometrical Analysis** involves representation of the RR intervals in the geometric patterns and various graphic and geometric properties are studied. Some of the geometric measures are listed in Table 1.11.

Table 1.11 Geometric measures [10]

Variable	Units	Description
HRV triangular index		Total number of all NN intervals divided by the height of the histogram of all NN intervals measured on a discrete scale with bins of 7.8125 ms (1/128 s)
TINN	ms	Baseline width of the minimum square difference triangular interpolation of the highest peak of the histogram of all NN intervals
Differential index	ms	Difference between the widths of the histogram of differences between adjacent NN intervals measured at selected heights

1.2.2 Frequency Domain Analysis

The frequency domain analysis is done by conversion of the time domain signal into frequency domain. The magnitude of the RR intervals is plotted against time. The time domain signal from RR intervals is generated, as shown in Figure 1.5.

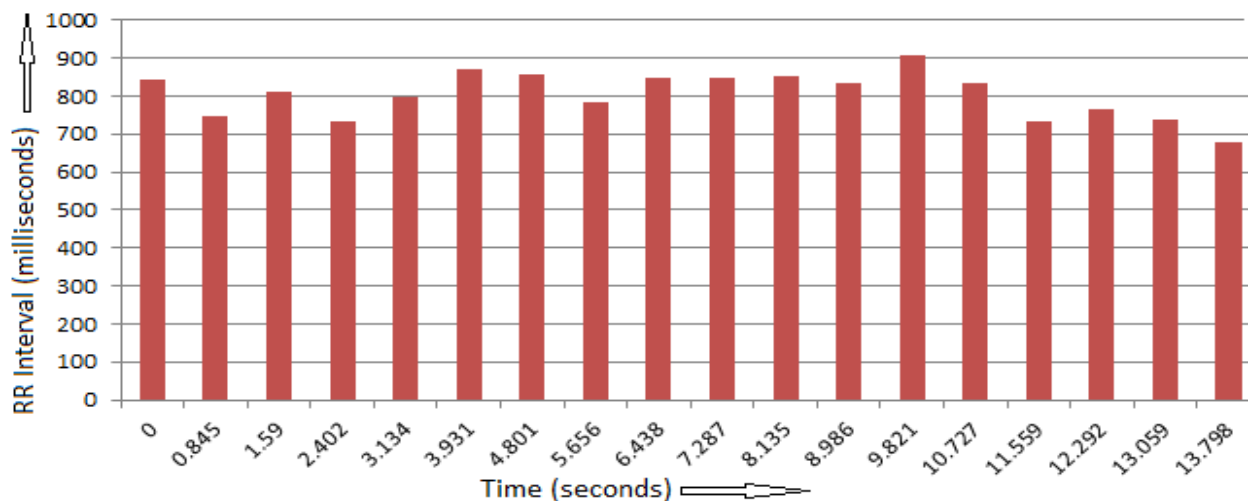


Figure 1.5 RR intervals vs. Time

The ECG data obtained is then analysis using mathematical computation algorithm such as Fast Fourier transforms (FFT) or auto regression techniques to quantify cyclic variations in RR interval [10]. The FFT is generally preferred because of simplicity of algorithm and the fast processing speed. The N point FFT of a discrete signal $x(n)$ is given by

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-\frac{i2\pi kn}{N}} ; \text{ And } k = 0, 1, 2 \dots N-1$$

Thus after FFT we get the Power Spectral Density plot, as in Figure 1.6.

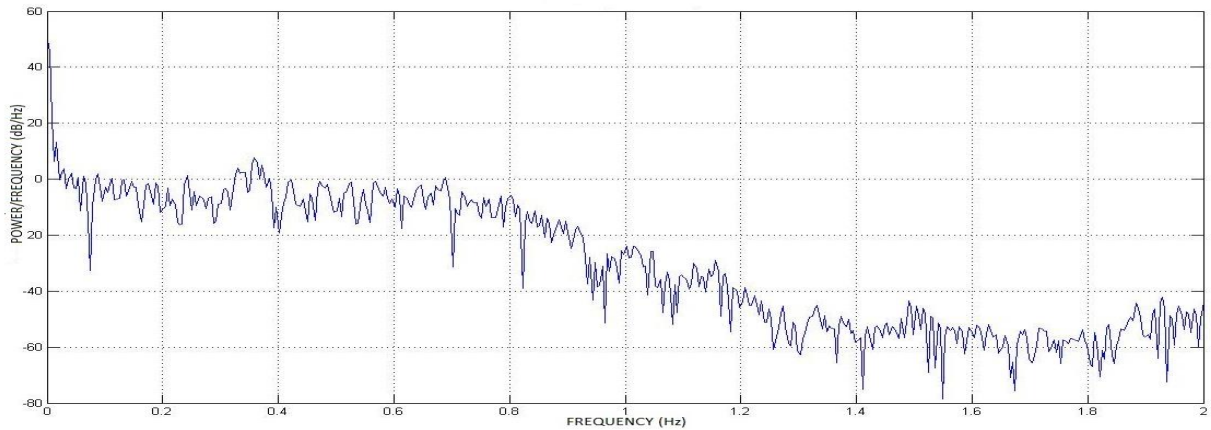


Figure 1.6 Power Spectral Density plot

The frequency spectrum of the ECG is further divided into three bands i.e. Very Low Frequency (VLF), Low Frequency (LF) and High Frequency (HF). The spectral range of each band is defined as VLF (0.0033 to 0.04 Hz), LF (0.04 to 0.15 Hz) and HF (0.15 to 0.4Hz) [8] [10] Table 1.12.

Table 1.12 Different frequency bands [10]

Bands	Frequency Range (Hz)
Very Low Frequency	0.0033 - 0.04
Low Frequency	0.04 - 0.15
High Frequency	0.15 - 0.4

The total power and the power of each band are calculated. The various measures of the frequency domain are given in Table 1.13.

Table 1.13 Frequency domain measures [10]

Variables	Units	Description
Total Power	ms^2	Variance of NN interval
VLF	ms^2	Power of very low frequency band
LF	ms^2	Power of low frequency band
LF norm	n.u.	LF power in normalized units $\frac{\text{LF power}}{\text{Total power} - \text{VLF power}} \times 100$
HF	ms^2	Power of high frequency band
HF norm	n.u.	HF power in normalized units $\frac{\text{HF power}}{\text{Total power} - \text{VLF power}} \times 100$
LF/HF		Ratio of LF power/ HF power

CHAPTER 2

LITERATURE SURVEY AND RESEARCH GAP

2.1 Literature Review

The literature study was done related to Ayurveda and Heart Rate Variability. The fundamentals concepts of Ayurveda were studied like Panchamahabhutas, Tridosha, Nadi Pariksha, Saptadhatus etc. The basic concepts of disease and diagnosis of disease as per Ayurveda were studied. The various devices and methods used to study pulse were explored. Heart rate variability is a modern approach towards health monitoring. There are various methods used for analysis of the heart rate variability in time domain and frequency domain. The detailed literature survey regarding Ayurveda, Pulse examination and Heart rate variability is as following.

2.1.1 Ayurveda

In 2015, D.K. Meena et al. brought to attention the fundamental principles of the Ayurveda. The fundamental principles of Ayurveda are used to define creation of living beings and their functioning. The major principles Panchamahabuta, Trioshas, Saptadhatu, Mala, Prakriti, Ojas, Agni, Manas, Atma etc. The Panchamahabuta theory defines the creation and constitution of living in terms of five eternal substances Ether, Earth, Air, Fire and Water. The concepts of Tridoshas, Saptadhatus and Malas plays a major role in defining the healthy state and diagnosing the diseased individual. The Tridosha theory defines the balance and imbalance in the Panchamahabutas in the body in terms of Vata (Vayu,Akasa), Pitta (Agni) and Kapha (Jala, Prithvi). The disharmony of these three doshas causes the illness in an individual. The Saptadhatu theory deals with the seven dhatus (tissues) which are support of the body and provide nourishment. Malas, the excretory products of the body are also indicator of the health status and are considered while diagnosis in Ayurveda [1].

In 2001, L.C. Mishra et al. had introduced the procedures of diagnosis , treatment and general healthcare in Ayurveda. The Astha Sthana Pariksha (8 point diagnosis) in Ayurveda consist of Nadi Pariksha(Pulse Examination), Jihva Pariksha(Tongue Examination), Mala Pariksha

(Stool Examination), Mutra Pariksha(Urine Examination), Sabda Pariksha(Bodily Sounds Examination), Netra Pariksha(Eyes Examination), Twacha Pariksha (Skin Examination), and Akriti Pariksha(Total Body Appearance Examination). The diagnosis on basis of Astha Sthana Parisha as well as various type the treatments used were discussed. Amongst all the 8 methods of the examinations used Nadi Parikshan is done to find any disproportion in tridoshas by feeling throbbing in the radial pulse near wrist [11].

In 2001, L.C. Mishra et al. had discussed about the major body compositions as per the Ayurveda system. Each individual's body is made up of three bodily doshas, three mental doshas, saptadhatus and malas. The three bodily doshas are generally called Tridoshas i.e Vata, Pitta and Kapha. The three mental doshas are Satogun (Godly), Rajas (Kingly) and Tamas (Evil). The harmony amongst the bodily doshas as well as the mental doshas defines healthy state and the disharmony constitutes diseased state. The properties and indications of the disturbed doshas were also discussed as per the Ayurvedic system. The objective of the treatment in Ayurveda was to restore the balance in the doshas as per the Prakriti (innate dosha balance) of the person. The intervention in lifestyle, spiritual nurturing, herbs and mineral based remedies were used for treatment [12].

In 2004, R.R. Joshi had quantified the tridoshas from the qualitative features/characteristics used by the Ayurvedic physicians. The data of 280 persons was collected which were the residents, visitors, students etc at the Brahmvarchas Research Centre and Shantikuj Hardwar India. The algorithmic and heuristic techniques were used on the vast list of the qualitative factors for quantitative measurement of the doshas. The knowledge based notion of fuzzy multiattribute decision functions and worth coefficients were used for regression analysis and model designing. Statistical confirmation was done for large samples and the results shown the statistical validation level above 90 percent. The quantitative estimation of the tridoshas along with the nadi pariksha can be used for diagnostic as well as therapeutic purposes. Thus the ample empirical basis of the theory of doshas was established [15].

In 2005, A. Hankey had explained the popularity ayurveda gained in the last two decade and that how many practitioners of the western medicine started putting efforts for understanding and explaining the concepts of ayurveda. The research began to empirically establish and confirm validation of tridosha theory. The objective of research was to understand basic biology behind the ayurveda theories and practice. Concept of the tridosha inheritance was proposed on the context of the inheritance of the protein enzymes as per modern modern

biology. The work on verification of the genome basis of the vata, pitta , kapkha traits (morphological) and metabolic tendencies showed promising results. It would further help to lay a framework towards establishing and certifying tridosha theory [16].

In 2010, A. Hankey had scientifically validated the concept of Tridosha, Subdoshas, Prakriti (innate dosha balance in individual) and Vikriti (Dosha imbalance). It was shown that how the theory of tridosha is applicable to each organism from the stage when it was a single cell. It was explained how doshas were inherited and diversified throughout the life. And finally how the imbalance in doshas was major cause of illness in an individual. The scientific approach called system theory states that every open system has functions of input/output, turnover and storage. Since living organisms are an open systems, the doshas might be explained using this theory. The hypothesis used was: Vata was related to input/output system, Pitta to turnover and Kapha to storage. The functions associated with the doshas and subdoshas as per Ayurveda were studied and validated using the hypothesis. The agreement between the dosha theory and the hypothesis established the doshas theory. The Prakriti of an individual was studied in terms of the difference in physiology of different individuals. The questionnaires were designed to study the differences in the physiologies. The statistical analysis of the questionnaires used to determine patient's physiological differences was done. The validation of the dosha theory helped in designing the optimal and efficient questionnaires for Prakriti analysis. The Prakriti was shown to be an empirical fact in terms of the differences in individual's physiology and system theory gave the unquestionable confirmation for doshas theory [13].

In 2012, V. Kurande et al. had studied the repeatability of pulse examination and the body constitution examination. The Pulse Examination was done on the most common nadi called Jivanadi or the radial artery. The first middle and ring fingers were placed on the wrist. The position of the index finger was just below radial styloid and followed by other two finger. The examination of the pulse was done on right hand of the males and in the female other hand was examined. The three doshas have different pulse signatures. The vata pulse was felt as fast, feeble and snake's scrawling like sensation under the first or index finger. The pitta pulse was felt under the middle finger and marked by sensation like jumping frog and was prominent and strong. The kapha pulse was similar to swan's slow and smooth movement and is felt under the ring finger. The doctor done the diagnosis on 17 subjects twice hence giving 34 pulse diagnosis. Since the objective is to study repeatability the randomization and the blinding was used during the second time keeping other conditions alike. Then the results

of the diagnosis were examined statistically and there was high consistency between the two diagnosis performed and hence the repeatability of the diagnosis was established [14].

In 2015, R. Kaur et al. had discussed about the pulse diagnosis as important method to understand the Prakriti and Vikriti of the an individual. Along with the with conventional methods used the author also discussed about the modern scientific methods that could be used for quantification and the standardization of pulse diagnosis. The modern sensors which were already implemented for studying the pulse were discussed. Till now the pressure sensors used for studying pulse were piezoelectric materials based, ultrasonic, capacitive, optical etc. Due to growing research in the pulse examination many feature extraction techniques had been used. The time domain features in standard pulse waveform are valley (V) percussion wave (P), dicrotic wave (D), tidal wave (T) and). These feautres vary with the type of disease or illness present in the person. It was suggested that analysis of the heart rate variability was of much importance than the Heart Rate (HR) itself. The time domain and frequency domain features of the heart rate variability extracted were introduced. Till date the major reasearch done in the pulse diagnosis using modern scientific techniques was presented and future scope of research in the field was discussed [17].

2.1.2 Pulse Examination Devices and Dosha Related Research

In 2007, A. Joshi et al. had developed a system for examination of the pulse to determine the tridoshas imbalance. The system was based on the concept of nadi pariksha. The system used three strain gauge based pressure sensor with tiny diaphragm at the centre to read minute pulsating pressure at three points on the wrist. The signal was digitized by 16 bit data acquisition card by National Instruments, was interfaced with computer. The sampling rate of system used was 500 Hz. The signal was freed of any high frequencies using the wavelet denoising. The time domain features in standard pulse waveform were studied using machine learning methods. The difference between the pulse of healthy and unhealthy subject was studied in terms of morphology of pulse. The system was able to discover the small changes in pulse morphology due to diseased state of an individual. The pulse waveform was different for different age groups. The different contact pressure of sensor provided different waveform which could be used for getting insight about the body. The system resolution of system was far better than previous developed systems. The suggestion for implementation of the machine learning algorithms was given to further classify the pulse into different different nadi types using nadi tarangini system [18].

In 2008, M. Sareen et al. had developed the device for the pulse diagnosis i.e. Nadi Yantra. The system works on the similar principle of using three pressure sensors on the tridosh points on the wrist as in earlier devices. The sensors used for the study were piezoelectric pressure sensors, the signal conditioning was done using amplifier and filter circuit, and data acquisition system (BioPac-150) at sampling frequency of 1000 Hz. The major change was in the mechanical design of the system. The design had mimicked the physicians fingers and used a springs in order to damp the external motion artifacts. Thus eliminated any error in the recording. The signal was studied in the time as well as frequency domain. The control used was the set of 20 signals acquired from the same subject through a period of time before lunch. The signal after lunch was matched with control signals. It was observed that amplitude of channel first (Vata pulse) rose steadily before lunch and then fell after the lunch. The amplitude of the second channel (Pitta pulse) and third channel (Kapha pulse) rose after lunch. In frequency domain, the amplitude of power in first channel increased before lunch and then fell post lunch. The dynamic properties of the obtained signals (amplitude of power and frequency domain details) change before lunch and after lunch. The increase in the band power of the third channel is observed 30 minutes after the lunch. The results suggested that the device could objectively record and show the difference occurred in the radial pulse in agreement with Ayurveda. Future research will be done on discovering relationship of waveform features with the concepts of ancient medical sciences [19].

In 2010, P. Kelkar et al. developed the Peripheral Pulse Analyser (PPA) based on the principle of Impedance Plethysmography at Electronics Division of BARC. Impedance Plethysmography is non invasive medical test involves impedance measurement in person's body for the calculation of central and peripheral flow of the blood. The substantial difference in the variability spectrum of impedance plethysmographic signals of healthy and diseased subjects, has led to study of Tridosha. The trials on control subjects had given 78% agreement between HRV and subjective evaluation of Prakruti of subject. The different morphology of the peripheral pulse had observed from person to person and within the same subject at various times. A previous analysis of these signals had put forward that manifestation of Vata, Pitta and Kapha in various periods of the cardiac cycle and an inverse proportionality between magnitude of high frequency, mid frequency and low frequency in variability spectrum and that of diagnosis done by an Ayurvedic doctor. The further research would be done to prove the hypothesis that that Vata, Pitta and kapha are represented by diastolic phase, mid systolic phase and pre and early systolic phase respectively [22].

In 2011, T.T. Selvan and M.S. Begum developed a pulse diagnosis device using a piezo film sensor. The three sensors set up was used to pick up the pulse signal from the wrist. The signal was amplified and digitized using 32 bit digitizer. In mechanical design, finger like projections were constructed with the spring attached to them for damping. The time domain feaatures were studied in the both healthy and unhealthy subjects. The normal pulse had a main maxima and two secondary maxima with regular behavior and pulse was very irregular in diseased person. The correlation between different conditions and time domain fetaures and amplitude of pulse were studied. The system developed was able to pick up and display the pulse waveform but the further research suggested should in the direction of finding the correlation between different conditions and the pulse waveform features using Nadi Aridha [20].

In 2012, A.E. Kalange et al. developed portable personal computer based 3 point pulse analysis system named as Nadi Parikshan Yantra for recording the pulse data. Pressure sensors operating at the ultrasonic frequency were used to measure the pulse. The diameter of the sensor used was 10mm and are 6mm apart. The conatct pressure was varied and it was noticed that the optimal contact pressure needed to obtain maximun pulse amplitude was 40-80 mm of Hg. The amplitudes of the waveforms and dominant dosha were correlated and it was found that 62% results correlated well. To find the better correlation the analysis of the pulse was carried out in frequency and time domain. The frequency analysis done suggested that signal recorded was accurate as the spectral energy was distributed within 10 Hz. The amplitude parameters P1 (amplitude of percussion wave), P2 (length of dicrotic wave) and V (valley in pulse) were calculated from the baseline. The time doamin analysis results suggested that parameter P2/P1 could be used to distinguish amongst three doshas [23].

In 2013, R. Walia and M. Singh used Photoplethysmography (PPG), an optically recoreded plethysmogram from a particular organ for volumetric measurement in an individual. In PPG the recording is generally done from an ear, forehead or finger and represents the volume or amount of the blood in the vessels present at location from which measurement is done. The PPG pulse waveform was acquired from the fingertip. The pulse waveforms were obtained from three subjects from three fingers (first, tall and ring fingers) of both right and left hand; before and after taking meal at 10Khz frequency. In total the set of more than fourty five pulses were recorded. The features were extracted manually with the help of MP150 kit and its acqknowledge softwareas. Since the first order and the second order derivatives of the signal obtained before and after meals was different therefore pulse waveform could be used

for pitta dosha detection. It was suggested that further features extraction methods could be implemented in order to develop system for quantifying the pitta dosha[5].

In 2014, M. Singh and S. Bansal used the APG (Accelerated Plethysmography) signal for detecting pre lunch pitta enhancement. The APG is the signal obtained by taking second order derivative of the captured PPG signal. The PPG waveform was obtained from first, middle and ring finger of the both hands ; once in morning session and another before the lunch. Thus the two set of the data was obtained from 25 subjects. The parameters were automatically extracted from the APG signal. The different others indices were calculated from the parameters and were studied for finding higher pitta levels. The 6 out of 48 parameters showed statistically significant difference after morning session and just before the lunch. Given that the pitta levels goes up after meals and at the noon time; the parameters identified could be used for studying the pitta dosha. It was suggested that study of the parameters change should be done for morning session and post lunch also [24].

2.1.3 Heart Rate Variability (HRV)

In 1996, Task Force of the European Society of Cardiology developed appropriate standards for HRV recording and its interpretation. The experts from different fields like mathematics, medicine, physiology etc standardized the methods of measurements, defined correlations between physiology and diseases and explored areas of future research. The major focus was on HRV. The various methods for analysis of the HRV were discussed elaborately. The recording requirements for the measurement of the RR duration were discussed and standardized. Various time domain and frequency domain measures were defined and studied. The recommendations were given for interpretation of the components of the HRV. Effects of various diseases on the HRV and its parameters were discussed. It was found that heart rate variability can be used to measure the role of ANS (Autonomic Nervous System) variations in normal as well as in unhealthy person. It was suggested that prospective longitudinal studies were needed for determining value of HRV in the identification of persons at verge of getting a particular health condition [10].

In 1997, V.K. Yerahani et al. observed the relationship between age and long-term heart rate variability. The ECG signal in 33 healthy subjects consisting 11 children and 22 adults was recorded for 24 hours. The frequency analysis of the heart rate signal was done. During awake and sleep sessions, the significant negative correlation between age and VLF (0.0033-

0.04 Hz), LF (0.04-0.15 Hz) and HF (0.15-0.5 Hz) powers and fractal dimensions was found. The results also showed positive correlation between age and low frequency to high frequency ratios. The effect on ULF (< 0.0033 Hz) was studied and found that age is negatively correlated to it when subject was awake. While asleep ULF power was constant with the age significantly.

In 1999, P.K. Stein and R.E. Kleiger studied the parameters or measures of heart rate variability (HRV) and gave an insight onto autonomic variation of the heart. It was found that time domain and frequency domain parameters of HRV are closely associated and reflected the sympathetic and parasympathetic activity. In the studies, it was found that low HRV can provide predictive value for mortality in healthy subjects. The low HRV had given mixed probability for finding congestive heart failure. The decreased HRV helped in identification of the diabetic patients with autonomic neuropathy. The heart rate variability analysis could help in identifying cardiac patients which are at greater risk of mortality. It was found that most of the interventions related with high HRV are also linked with higher survival rates.

In 2006, U.R. Acharya studied that Heart rate variability (HRV) is a gives insight of the various physiological aspects controlling the rhythms of the heart. It was helpful in observing the sympathetic activities as well as the parasympathetic activities nervous systems. The variation in the heart rate could be indicators of present disease. Some indicators might be observed during any time of the day while some are observed at particular duartion of a day. The volumetric data collection for analysis consumes lot of the time. That was the reason that the HRV analysis became popular noninvasive tool. The HRV signal parameters (time domain and frequency domain) were highly useful in diagnostics. The discussion on the various applications of HRV and methods for analysis of heart rate variability like linear and non linear techniques, frequency domain, wavelet domain, nonlinear etc was done in the paper.

2.2 Research Gap

The concept of Tridosha is well established and is basis of the Ayurvedic system of medicine. The imbalance in the doshas is major cause of the illness in an individual. In the Ayurveda radial pulse examination is carried out to assess the imbalance. The accuracy of the diagnosis depends on the knowledge and proficiency of the physician. Due to this reason modern

instruments and systems were developed to capture the pulse signal and to analyse it using various techniques for finding dosha imbalance.

Heart Rate Variability is linked with the various health conditions in an individual. The changes in the heart rate, calculated over different durations of time help to determine the cardiac ailments as well as other diseases. Much of the work had been carried out successfully in finding the correlation between different diseases and HRV signal parameters. But till date none of the work has been done in studying the three doshas imbalance in terms of HRV bands. Since Tridosha imbalance is associated with diseases and diseases are associated with HRV bands, there is a prospect of relationship between three doshas and HRV bands.

2.3 Objective

In this pilot study, we are analysing the heart rate variability of the patients with the dosha imbalance. The aim of the study is to determine a relationship between the three doshas and the three frequency bands of the heart rate variability signal. It is hypothesised that Vata, Pitta and Kapha are related to VLF, LF and HF bands of HRV respectively.

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Electrocardiogram (ECG)

The process of recording the voltage produced due to the electrical activity in the heart by placing surface electrodes on different points on the body is called Electrocardiography. The graph obtained is called Electrocardiogram. The Electrocardiogram is the instrument used to obtain the electrocardiogram. In the heart, the electrical signal originates in the Sino-atrial node (SA node). This electrical impulse then stimulates the contraction of atrial muscles. After the atrial contraction, the signal is collected at the Atrioventricular node (AV node). Then the signal is delayed by 0.12 seconds approximately. The delay introduced gives sufficient time for completion of the atrial contraction and it ensures that the atria have emptied the blood into the ventricles before ventricular contraction begins. The electrical impulse then travels through the bundle of His and Purkinje fibres for stimulating the contraction in the ventricles [28]. The typical ECG waveform is shown in Figure 3.1.

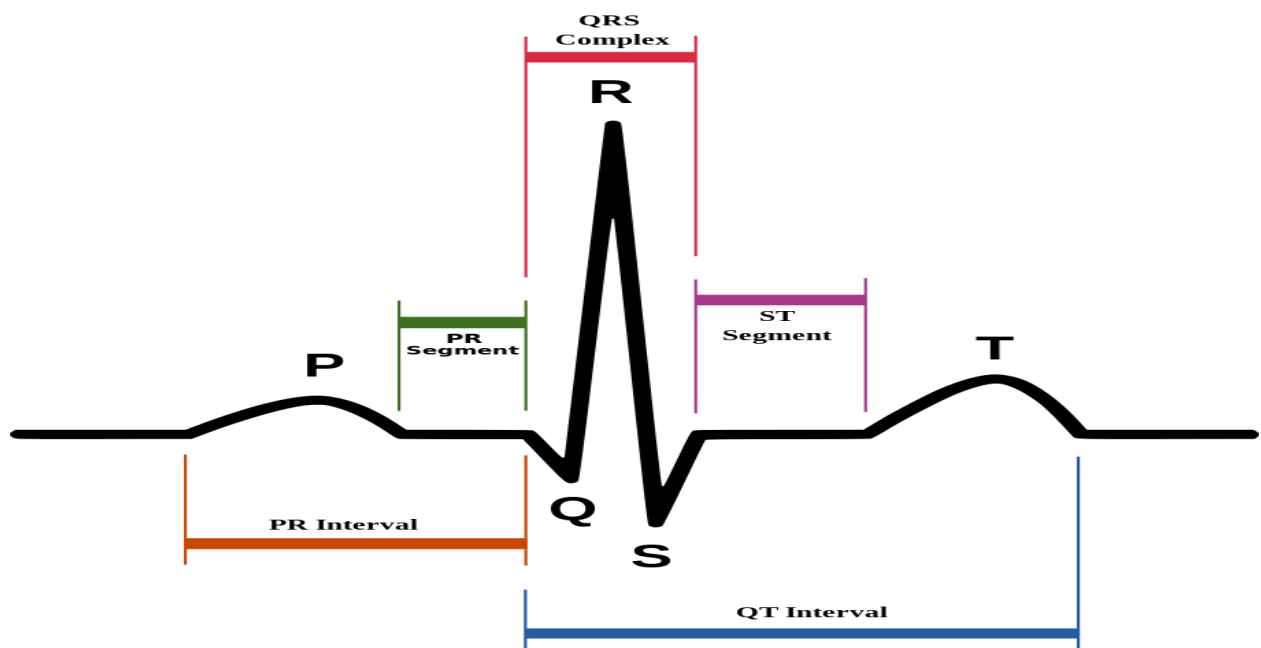


Figure 3.1 ECG waveform [30]

Heart Rate Variability is the variation in the R to R interval. The term RR variability is also generally used instead of HRV where R is the peak point of ECG waveform and RR is the time intervals between consecutive beats. Since R peak is clearly distinguishable in the ECG waveform, it is superior method for obtaining RR intervals. The various QRS detection algorithms as digital filter based, template matching techniques, nonlinear transformation based, wavelet based, amplitude and derivative based are used [31]. Once the RR intervals are calculated then the heart rate variability study can done in time domain or frequency domain.

3.2 Methodology

The examination of the subject should be done by the Ayurvedic physician using Nadi Pariksha. The physician would classify the patients as vata patient, pitta patient or kapha patient after the examination the radial artery. Then the ECG record of the patient should be taken using a portable ECG machine interfaced with the personal computer. The ECG data obtained would be analysed using the different mathematical operations. The major steps involved are shown in the Figure 3.2.

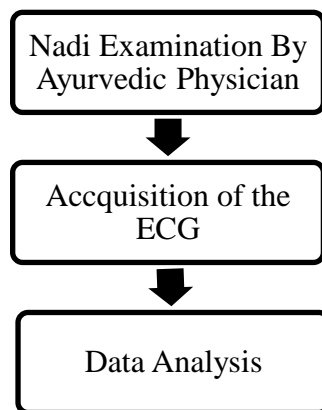


Figure 3.2 Major steps in methodology adopted

3.2.1 Nadi Examination by Ayurvedic Physician

First step was examination the patient's Jivanadi i.e. radial artery for dosha imbalance by Ayurvedic Physician. In male patients, the right hand's pulse was examined and in female patients the left hand's pulse was examined. The patient should not have eaten anything for at

least 2 hours prior to the examination. The examination was done in sitting position as shown in Figure 3.3.



Figure 3.3 Ayurvedic Physician (left) doing examination of patient (right)

3.2.2 Acquisition of the ECG

The ECG data was acquired using the portable ECG machine which was interfaced with the personal computer. Only 3 limb electrodes (disposable) were used for tracing ECG waveform. Three limbs electrodes were sufficient for R peak detection and calculating RR intervals. The ECG data i.e. value of the RR intervals were stored in the personal computer. The 4 minutes ECG record was taken while the patient was sitting as shown in the Figure 3.4.



Figure 3.4 Placement of electrodes on Patient

3.2.3 Data Analysis

The ECG data i.e. RR intervals acquired were plotted as a discrete time signal. This discrete time signal obtained was non-uniformly sampled signal. The signal was interpolated using suitable interpolation function. The signal resampling was done at 4 Hz to make it a uniformly sampled signal. In order to analyze this signal in frequency domain the Discrete Fourier Transform (DFT) was obtained. The distribution of the power across the frequencies present in the signal is studied. The band powers of three different frequency bands of HRV were calculated. From the power calculations various parameters were calculated for further analysis.

CHAPTER 4

THEORY AND CALCULATION

MATLAB (Matrix Laboratory) is a programming environment designed for scientific and engineering use, developed by MathWorks. It is also used for performing various matrix-based operations and calculations. The algorithm development, visualization of data, numerical calculation, data analysis etc. is performed using this software. MATLAB is used in extensive range of applications consisting communications, test and measurement, control design, signal and image processing etc. The raw data obtained from the patients was processed using MATLAB. The various steps involved are shown in the Figure 4.1.

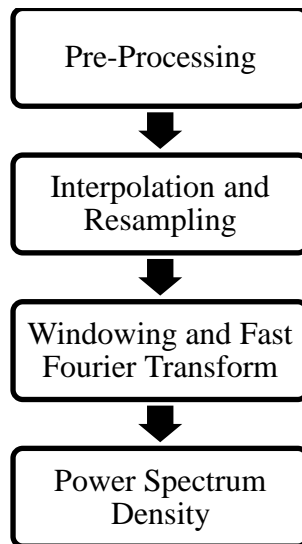


Figure 4.1 Steps involved in data processing

4.1 Pre-Processing

The data obtained by the ECG machine contains the numerical value of the RR intervals in milliseconds recorded over the interval of the 4 minutes. In order to remove any unnecessary maxima or minima from the data set we applied following limits.

$$\begin{aligned} \text{RR intervals data set} &= X \text{ then,} \\ \text{Upper Limit} &= \text{Average}(X) + 3 * \text{Sigma}(X) \\ \text{Lower Limit} &= \text{Average}(X) - 3 * \text{Sigma}(X) \end{aligned}$$

Samples which did not lie in the limits were replaced by Average(X). It was observed that approximately more than 99% data fell between the limits defined. This data when plotted against the time gives us the non-uniformly sampled signal as shown in the Figure 4.2.

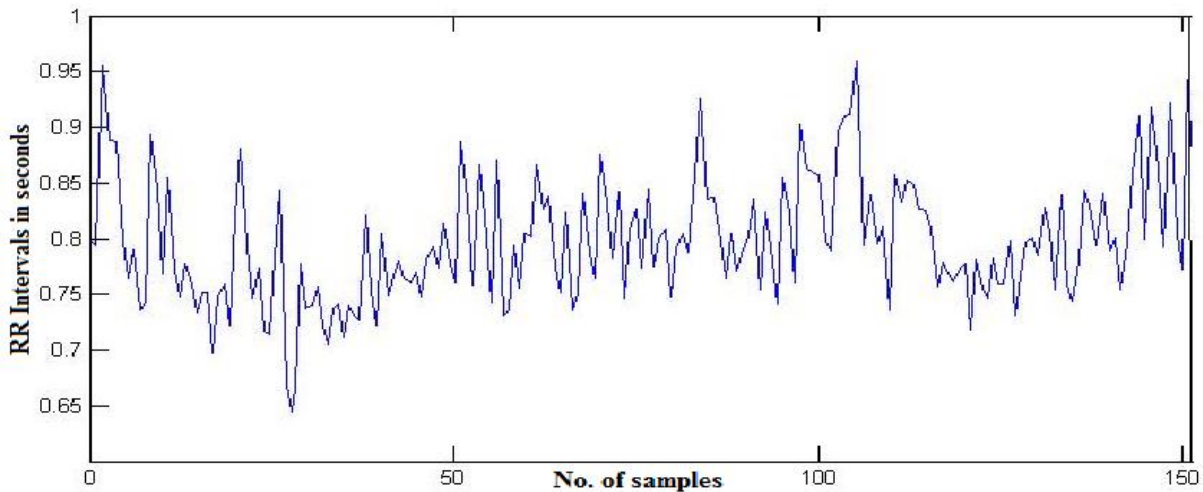


Figure 4.2 Non uniformly sampled signal

The plot of the RR intervals shows sharp peaks which will be removed after interpolation and resampling of the data.

4.2 Interpolation and Resampling

Interpolation is a technique used to find the new data points between two discrete sets of known data points. It is very useful in digital signal processing and is used to convert a previously sampled signal to that of a higher sampling rate. This process of increasing the sampling rate is called up-sampling. The function used for the estimation of the values between known data points is called an interpolant. Various types of interpolation are piecewise constant or nearest neighbor interpolation, polynomial interpolation, spline interpolation, etc. We used cubic spline interpolation to interpolate the signal. The signal was uniformly sampled at 4 Hz. The signal after interpolation and resampling is shown in Figure 4.3.

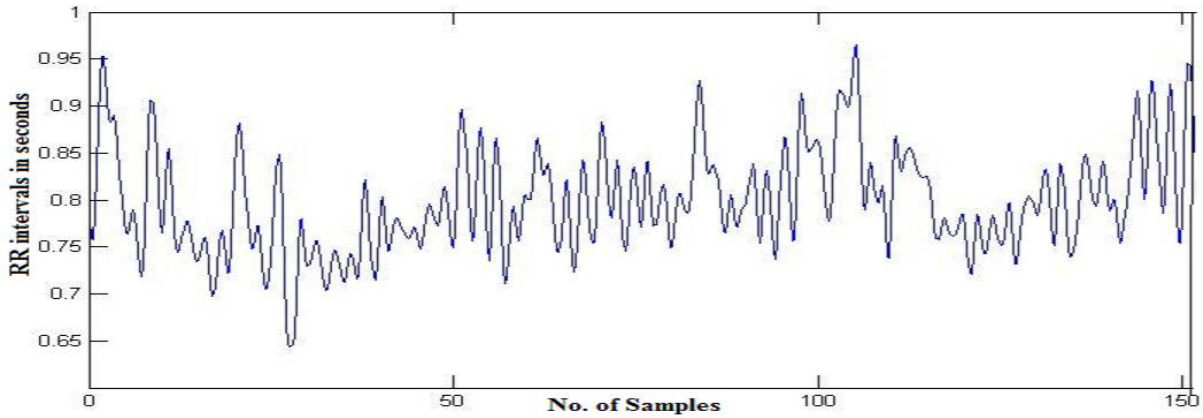


Figure 4.3 Uniformly sampled signal after interpolation and resampling

4.3 Windowing and Fast Fourier Transform

Window function is a mathematical function which is non-zero inside an interval but zero outside that particular interval. When a given function is multiplied by a window function, the function overlap with window function inside the interval and becomes zero outside the interval. This process is generally called windowing. The end point discontinuities present in a signal analysed appears in the FFT as high frequency components which are not there in signal originally. These unnecessary high frequency components cause spectral leakage i.e. the fine spectral lines spread into wider signals. Windowing decreases the amplitude of the end discontinuities of each finite signal which smoothly and slowly tends to zero at end points. Thus the endpoints of the waveform meet to form continuous signal without sharp transitions. The FFT of a signal after windowing gives frequency spectrum without any unnecessary components. We applied hanning window to our sampled signal for FFT analysis. The mathematical formula of the hanning window is given as

$$w(n) = \frac{1}{2} \left(1 - \cos \left(\frac{2\pi n}{N-1} \right) \right) \quad \text{Where, } n=0, 1, 2 \dots N-1.$$

The hann window function when plotted looks as shown in Figure 4.4.

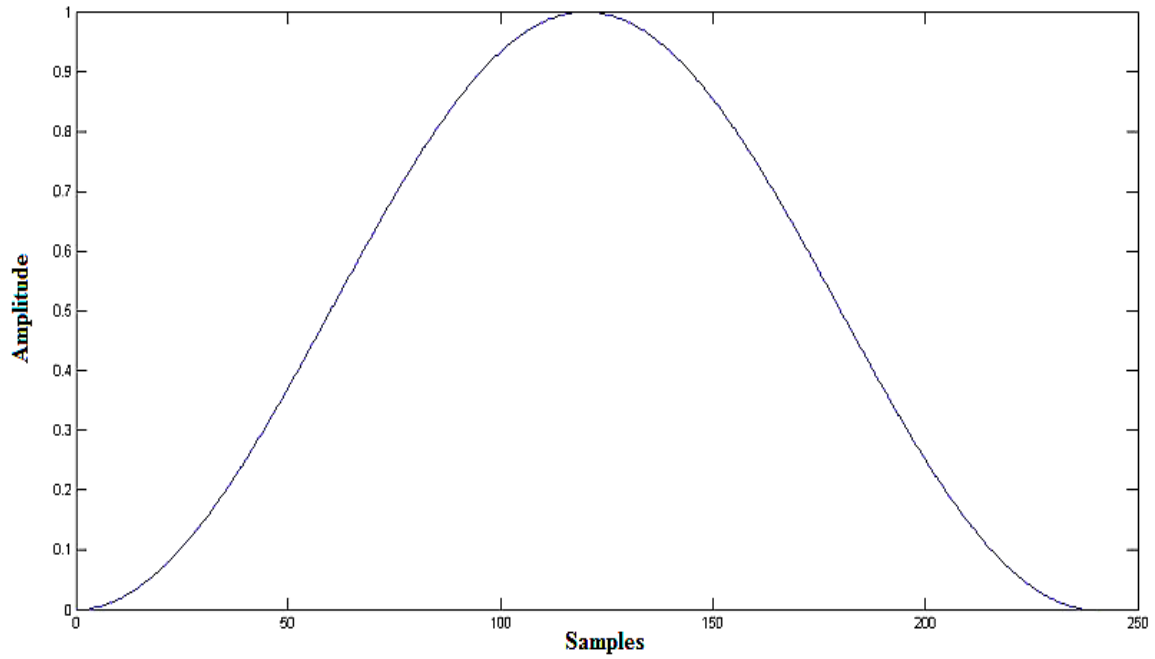


Figure 4.4 Plot of Hann Window

The multiplication of the window function with the interpolated signal is shown in Figure 4.5.

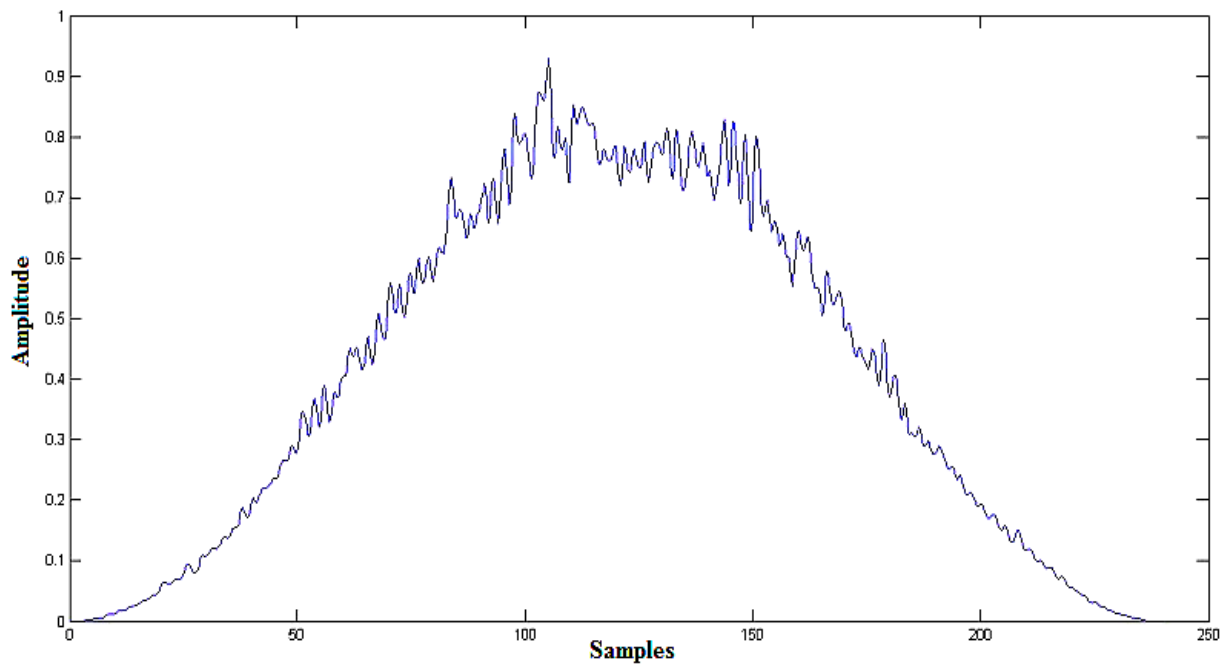


Fig 4.5 Signal after multiplication with Hann Window

The formula used for calculation of the N point FFT of a signal $x(n)$ is given as

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-i2\pi kn/N} \text{ Where, } n=0, 1, 2 \dots N-1$$

4.4 Power Spectral Density

Power Spectral Density (PSD) gives us the distribution or spread of the power of a particular signal over different frequencies present in signal. The magnitude of the variation (energy) is shown as a function of frequency. The power spectral density function simply shows us at which frequencies variations are weak and at which frequencies variations are strong. The PSD is calculated from the FFT spectrum of a signal. The PSD offers a useful method to describe the amplitude versus frequency components of a particular signal. The following plot shows the PSD of signal as in Figure 4.6.

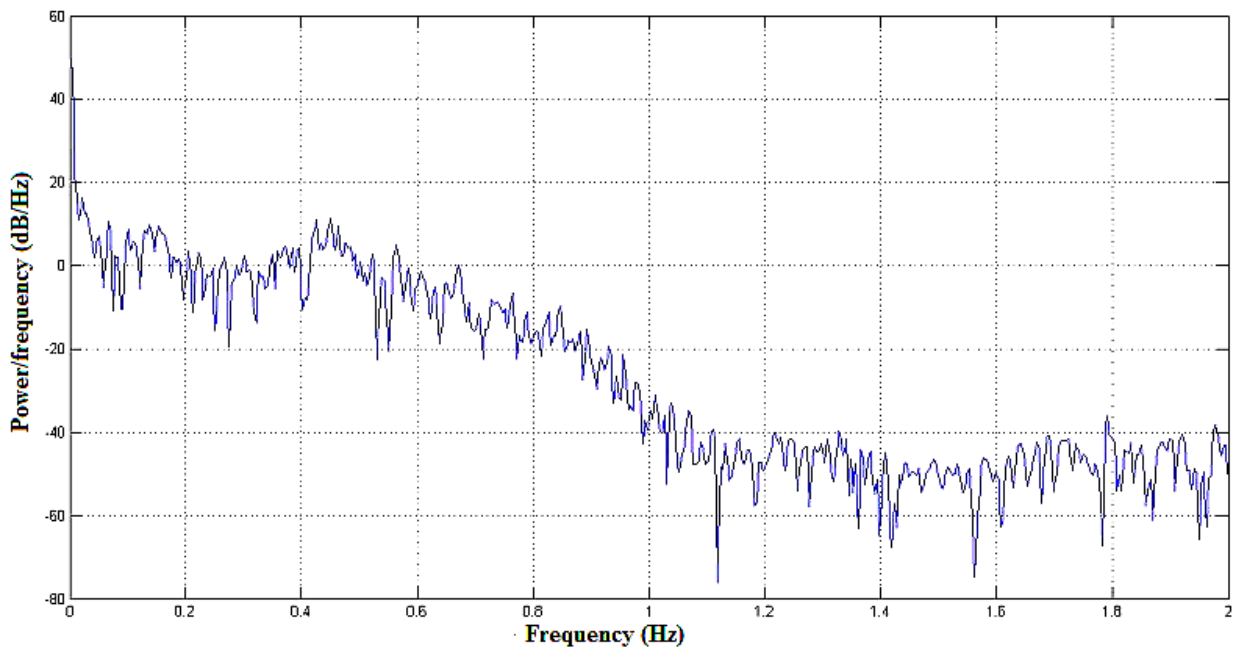


Figure 4.6 Power Spectral Density plot

The value of different HRV bands powers is calculated for the analysis of the signal. Various frequency domain parameters are calculated for the study.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Vata Dosha Patients

In this pilot study, the results suggests that the mean of very low frequency normalized values (VLF nu) for vata patients is significantly different from mean of low frequency normalized values (LF nu) and mean of the high frequency normalized values. The mean of VLF nu is greater than the mean of LF nu and HF nu. The data of 15 vata patients is given in Table 5.1.

Table 5.1 Normalized power of vata patients

Patients	VLF nu	LF nu	HF nu
1.	0.356034	0.320451	0.323515
2.	0.871134	0.032077	0.09679
3.	0.551862	0.326392	0.121746
4.	0.490284	0.132179	0.377537
5.	0.379258	0.534271	0.086471
6.	0.323654	0.541106	0.13524
7.	0.862369	0.110449	0.027182
8.	0.75632	0.200882	0.042798
9.	0.308077	0.488424	0.203499
10.	0.205608	0.41476	0.379631
11.	0.336533	0.470762	0.192706
12.	0.190284	0.429524	0.380193
13.	0.645435	0.300033	0.054532
14.	0.438564	0.456962	0.104474
15.	0.576274	0.358535	0.065191
Mean values	0.486112	0.34112	0.172767

We applied the T-Test between the normalized values and found that for vata patients there is statistically significant difference between the VLF nu, LF nu and HF nu. The results are given in Table 5.2

Table 5.2 T-test between normalized values of vata patients

Between	P value
VLF nu , LF nu	0.049188
LF nu, HF nu	0.003837
HF nu, VLF nu	9.01E-05

5.2 Pitta Dosha Patients

For pitta patients the mean of low frequency normalized values (LF nu) is different from mean of very low frequency normalized values (VLF nu) and mean of the high frequency normalized values. The mean of LF nu is greater than the mean of VLF nu and HF nu. The data of 10 pitta patients is given in Table 5.3.

Table 5.3 Normalized power of pitta patients

Patients	VLF (n.u.)	LF (n.u.)	HF (n.u.)
1.	0.074752	0.184197	0.741051
2.	0.353986	0.454324	0.19169
3.	0.590587	0.380473	0.02894
4.	0.383145	0.306218	0.310637
5.	0.284593	0.538586	0.17682
6.	0.156445	0.454183	0.389372
7.	0.313894	0.477429	0.208677
8.	0.279819	0.398313	0.321869
9.	0.277919	0.4917	0.230381
10.	0.279975	0.366984	0.353041
Mean value	0.299511	0.405241	0.295248

We applied the T-Test for the VLF nu, LF nu and HF nu. The results were not statistically significant as the P values were greater than 0.05. The results of the T-test are given below in Table 5.4.

Table 5.4 T-test between normalized values of pitta patients

Between	P value
VLF nu , LF nu	0.067537
LF nu, HF nu	0.127761
HF nu, VLF nu	0.954461

From above table, the P value of T-test between the VLF nu and LF nu is close to 0.05.

5.3 Comparison of Mean Values between Vata and Pitta Patients

The Table 5.5 compares the mean values of the VLF nu, LF nu and HF nu in both vata and pitta patients.

Table 5.5 Comparison of the mean values of the VLF nu, LF nu and HF nu in both vata and pitta patients

	Mean	
	Vata	Pitta
VLF nu	0.486112	0.299511
LF nu	0.34112	0.405241
HF nu	0.172767	0.295248

We also compared the VLF nu, LF nu and HF nu of vata patients with the VLF nu, LF nu and HF nu of pitta patients as in table 5.6. The comparison suggested there is significant difference between VLF nu of vata patients and VLF nu of pitta patient as the P value is less than 0.05.

Table 5.6 Comparison the VLF nu, LF nu and HF nu of vata patients with the VLF nu, LF nu and HF nu of pitta patients

Vata-Pitta	P value
VLF nu – VLF nu	0.015462
LF nu – LF nu	0.235299
HF nu – HF nu	0.093941

5.4 Plot of Normalized Values of Vata Patients

Total number of the patients = 15

No. of patients with greater value of VLF nu = 8

$$\% \text{ accuracy} = \frac{8}{15} \times 100 = 53.33 \%$$

The VLF nu, LF nu and HF nu values in each vata patient are plotted as in Figure 5.1.

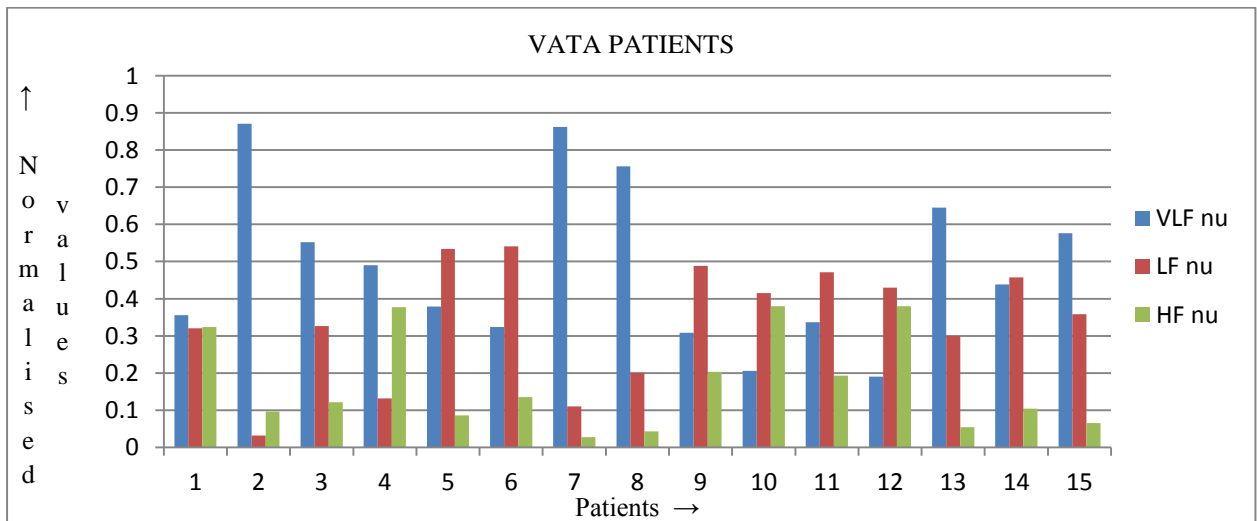


Figure 5.1 Plot of VLF nu, LF nu and HF nu values in each vata patient

5.5 Plot of Normalized Values of Pitta Patients

Total number of the patients = 10

No. of patients with greater value of LF nu = 7

$$\% \text{ accuracy} = \frac{7}{10} \times 100 = 70 \%$$

The VLF nu, LF nu and HF nu values in each pitta patient are plotted as in Figure 5.2.

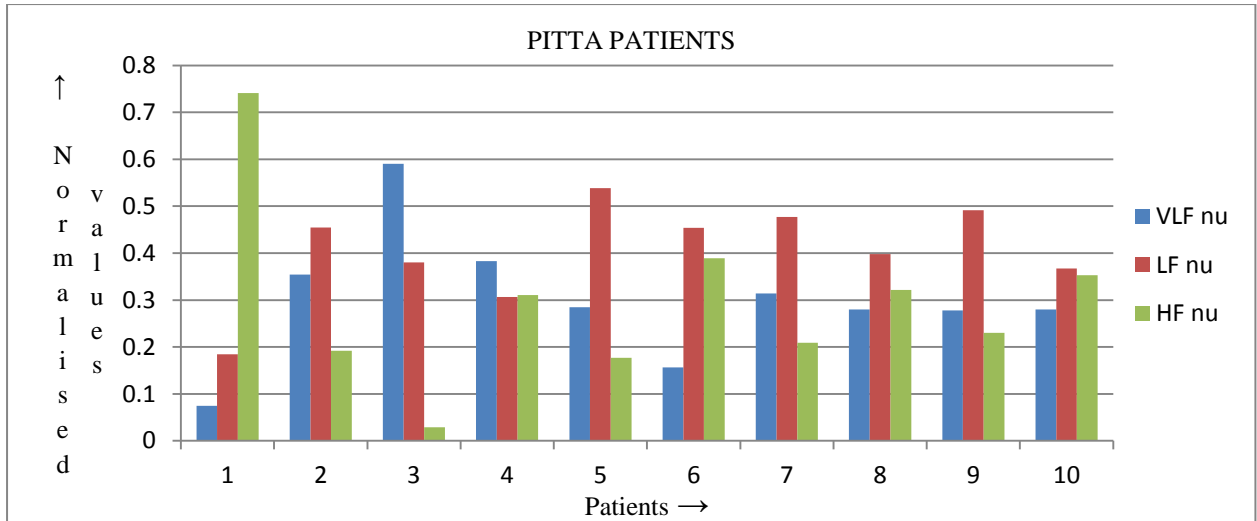


Figure 5.2 Plot of VLF nu, LF nu and HF nu values in each pitta patient

5.6 Chi Square Test

Table 5.7 shows the observed accuracy for Chi square Test

Table 5.7 Chi Square test data

	Observed accuracy	Expected accuracy
VATA	53.33	50
PITTA	70	50

We have also applied Chi Square Test on the data set of vata and pitta patients. The P value was **0.0042** which is less than 0.05.

5.7 Two Class Classification

The basic terms used are defined as

- True positives (TP): Predicted yes and actually yes.
- True negatives (TN): Predicted no and actually no.
- False positives (FP): Predicted yes but actually no.
- False negatives (FN): Predicted no but actually yes.
- Accuracy is how often classifier is correct.
- Sensitivity is how often it detects particular dosha.

- Specificity is how often it detects particular non dosha.

5.7.1 Pitta Classification Taking Pitta and non-pitta as two classes the confusion matrix can be given as shown in Figure 5.8. The results can be categorized as following.

Table 5.8 Confusion matrix for pitta classification

	Predicted Non-pitta	Predicted pitta
Actual Non-pitta	TN= 8	FP= 7
Actual pitta	FN= 3	TP=7

$$\text{Accuracy} = \frac{\text{TP}+\text{TN}}{\text{Total}} \times 100 = 60\%$$

$$\text{Sensitivity} = \frac{\text{TP}}{\text{Actual pitta}} \times 100 = 70\%$$

$$\text{Specificity} = \frac{\text{TN}}{\text{Actual non pitta}} \times 100 = 53.33\%$$

5.7.2 Vata Classification Taking Vata and non vata as two classes the confusion matrix can be given as shown in Figure 5.9. The results can be categorized as following.

Table 5.9 Confusion matrix for Vata classification

	Predicted Non-vata	Predicted vata
Actual Non-vata	TN= 7	FP= 3
Actual vata	FN= 7	TP=8

$$\text{Accuracy} = \frac{\text{TP}+\text{TN}}{\text{Total}} \times 100 = 60\%$$

$$\text{Sensitivity} = \frac{\text{TP}}{\text{Actual vata}} \times 100 = 53.33\%$$

$$\text{Specificity} = \frac{\text{TN}}{\text{Actual non vata}} \times 100 = 70\%$$

5.8 Kapha Dosha There is total 25 patients and none of them is affected by kapha dosha. With our method we detected only 1 patient as kapha and remaining 24 were detected as non kapha.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In this pilot study we collected the HRV data from different patients annotated by the Ayurvedic physician. We collected data from 25 patients. Out of which 15 patients were affected by vata dosha and 10 patients were affected by pitta dosha. The following conclusions have been drawn from the results obtained

1. We have calculated the mean of VLF nu, LF nu and HF nu values in the vata patients. The mean value of VLF nu was greater than mean values of remaining two bands. It may be concluded that VLF band might be related to the vata dosha.
2. We have calculated the mean of VLF nu, LF nu and HF nu values in the pitta patients. The mean value of LF nu was greater than mean values of remaining two bands. It may be concluded that LF band might be related to the pitta dosha.
3. We have also compared the VLF nu, LF nu and HF nu of vata patients with the VLF nu, LF nu and HF nu of pitta patients. The comparison suggested there is significant difference between VLF nu of vata patients and VLF nu of pitta patients. It may be concluded that VLF band in vata patients is more dominant as compared to VLF band in pitta patients.
4. We have also applied Chi Square Test on the data set of vata and pitta patients. The P value was **0.0042**. It may be concluded that the data might be classified into binary classes.
5. Taking Pitta as disease and Vata as normal (control group) the results of the confusion matrix are encouraging to carry out the further research.
6. Taking Vata as disease and Pitta as normal (control group) the results of the confusion matrix are encouraging to carry out the further research.
7. Since we had the all 25 non Kapha patient, with our method we are able to identify 24 patients as non kapha. The better classification accuracies will be achieved with increased kapha subjects.

6.2 FUTURE SCOPE

The present study involved only 25 patients and we achieved classification accuracy of 53% in case of the vata dosha and 70% in case of the pitta dosha with our method. The data size should be increased for better classification accuracy. The patients affected with kapha dosha should be included for Tridosha study. The patients with Samdosha should be used as control subjects. This will be helpful in four class classification with better results and accuracy.

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