Finger Pulse Profile Investigation Inspired by Ayurveda

Thesis submitted in partial fulfillment of the requirement for the award of degree of

Master of Engineering
in
Electronic Instrumentation and Control

Submitted by:
Spiti Gupta
(800951022)

Under the supervision of:
Dr. Mandeep Singh
Assistant Professor
EIED

July2011

Electrical and Instrumentation Engineering Department
Thapar University
Patiala-147004

Declaration

I hereby declare that the report entitled **"Finger Pulse Profile Investigation Inspired By Ayurveda"** *is an authentic record of my own work carried out as requirements for the award of degree of M.E. (Electronic Instrumentation & Control) at Thapar University, Patiala, under the guidance of Dr. Mandeep Singh (AP, EIED) during July 2010 to June 2011.*

Spiti Gupta.

Spiti Gupta

Roll. No. 800951022

Date: 14 June 2011

It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

(----------)

Dr. Mandeep Singh

Assistant Professor, EIED

Thapar University, Patiala.

S. Ghosh 27/6/11

(----------)

Dr. Smarajit Ghosh

Professor & Head, EIED

Thapar University, Patiala.

(----------)

Dr. S. K. Mohapatra

Dean of Academic Affairs

Thapar University, Patiala.

Acknowledgment

The real spirit of achieving a goal is through the way of excellence and austere discipline. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various personalities.

With deep sense of gratitude I express my sincere thanks to my esteemed and worthy supervisor, Dr. Mandeep Singh, Assistant Professor, Department of Electrical & Instrumentation Engineering, Thapar University, Patiala, for his valuable guidance in carrying out this work under his effective supervision, encouragement, enlightenment and cooperation.

I shall be failing in my duties if I do not express my deep sense of gratitude towards Dr. Smarajit Ghosh, Professor & Head of the Department of Electrical & Instrumentation Engineering, Thapar University, Patiala who has been a constant source of inspiration for me throughout this work.

I am also thankful to all the staff members of the Department for their full cooperation and help.

My greatest thanks are to all who wished me success especially my parents. Above all I render my gratitude to the ALMIGHTY who bestowed self-confidence, ability and strength in me to complete this work.

Spiti Gupta.

Spiti Gupta

Place: Thapar University, Patiala

Date: 14 June 2011

Table of Contents

List of Figures

List Of Tables

Abstract

Medical science has the primary objective of providing health care to human beings. Various prevailing medical systems have modeled human being in different ways and thus have different approaches to cure the body suffering from any disease. Fortunately all the systems work. Amongst several endeavors made by the researchers worldwide, some point towards rejuvenating the art of diagnosing three basic Ayurvedic human constituents. These are known as doshas namely vata, pitta, kapha. Many Ayurvedic physicians used to diagnose these doshas by feeling the radial artery in the wrist region under the thumb.

It is important to document and quantize these Ayurvedic techniques using modern electronic equipment. The fusion would perhaps eternalize this dying art/science of Ayurveda. Using PhotoPlethysmoGraphy (PPG) it is quite possible that specific diagnosis may be reached by studying these finger pulse profiles.

In this study the pulse profile of all 10 fingers in 7 healthy subjects were acquired. The pulse profile is recorded by using MP150 data acquisition system by Biopac.

For a given subject the auto correlation (correlation of index finger with index finger) was found to be higher than correlation between different fingers (between index finger and middle finger) in most of the cases (67 out of 70). We may safely conclude that the profile of a given subject is unique for the specific finger. This preliminary study opens up a possibility of studying the pulse profile of different fingers in the same person to find the relative features leading to detection of different doshas in a given person.

This study was further extended to 6 more subjects and correlation between the corresponding fingers of subject was studied. We came across startling results i:e in all 70 cases without exception the auto correlation for a given finger of subject was always higher than correlation with corresponding finger of any other subject. This study therefore may result in establishing uniqueness of the pulse profile of given subject and it may be used for establishing the three doshas based on ancient ayurvedic science.

Keywords

Ayurveda

Human constituents

Doshas

Nadi prediction

PhotoPlethysmoGraphy (PPG)

Finger pulse profile

Correlation

CHAPTER-1 Introduction

1.1 Ayurveda

Ayurveda knowledge has been passed to us in *sutra* or small phrases and its wisdom they contain is to be unlocked by the inquiring mind. Sutra means to suture with thread, it conveys hidden subconscious meaning to consciousness which needs guidance of teacher.

"Ayur- Veda" translated as "The science of life" is the secondary Veda to the four main Vedas. The knowledge contained in Ayurveda deals with the nature, scope and purpose of life. It embraces both the metaphysical and physical, Health and disease, happiness and sorrow, pain and pleasure .the purpose of life is to realize the Creator (cosmic consciousness) and to express this divinity in daily life. There are six Indian philosophies in Ayurveda – *Nyaya, Vaisheshika, Sankhya, Yoga, Mimamsa and Vedanta*. Out of these *sankhya* philosophy is most basic which outlines a model of creation and evolution. Ayurveda is a science of daily living and this system of knowledge evolved from the *'rishis'* practical , philosophical and spiritual illumination, which was rooted in their understanding of creation. Its aim and objectives are to maintain the perfect health of a person through prevention and cure the disease process in unhealthy person.

They perceived how cosmic energy manifests in all living and non-living things .they also realized that the source of all existence is universal consciousness, which manifests as male and female energy – *purusha* and *prakruti*. Purusha is male energy which is formless, colorless, beyond attributes and takes no active part in creation. While prakruti is female energy which yields form, color and attributes in the field of action. It is awareness with choice, divine will, the one who desires to become many. The universe is the child born out of the womb of prakruti, the divine mother. Prakruti creates all forms in the universe while purusha is the witness to this creation.

The three gunas are *sattva, rajas* and *tamas.* These three are the universal qualities within all existence and are contained in prakruti. When their equilibrium is disturbed, there is interaction of the gunas which thus engenders the evolution of universe.

- Sattva (the pure essence) is creative potential "Brahma";

- Rajas (movement) are kinetic protective force “Vishnu”;
- Tamas (inertia) is resistance to change or potential destructive force (Mahesh).

Rajas is active vital life force in body which moves both organic and inorganic aspects to sattva and tamas, respectively. So both sattva and tamas are inactive, potential energies that require the kinetic force of rajas. Creation, protection, and change or destruction are the three manifestations of first cosmic sound “*aum*” which constantly operate in universe.

The figure 1.1 below explains the creation according to sankhya: The first expression of prakruti is *mahad* which means intelligence. From mahad the sense of ego (ahamkara) “i am” is formed. As a result of three gunas, *ahamkara* then manifests into the five senses, the five motor organs and the mind with the help of sattva and rajas,creating organic universe. Ahamkar further manifests into the five basic elements (space, air, fire, water and earth) with the help of rajas and tamas to create inorganic universe.

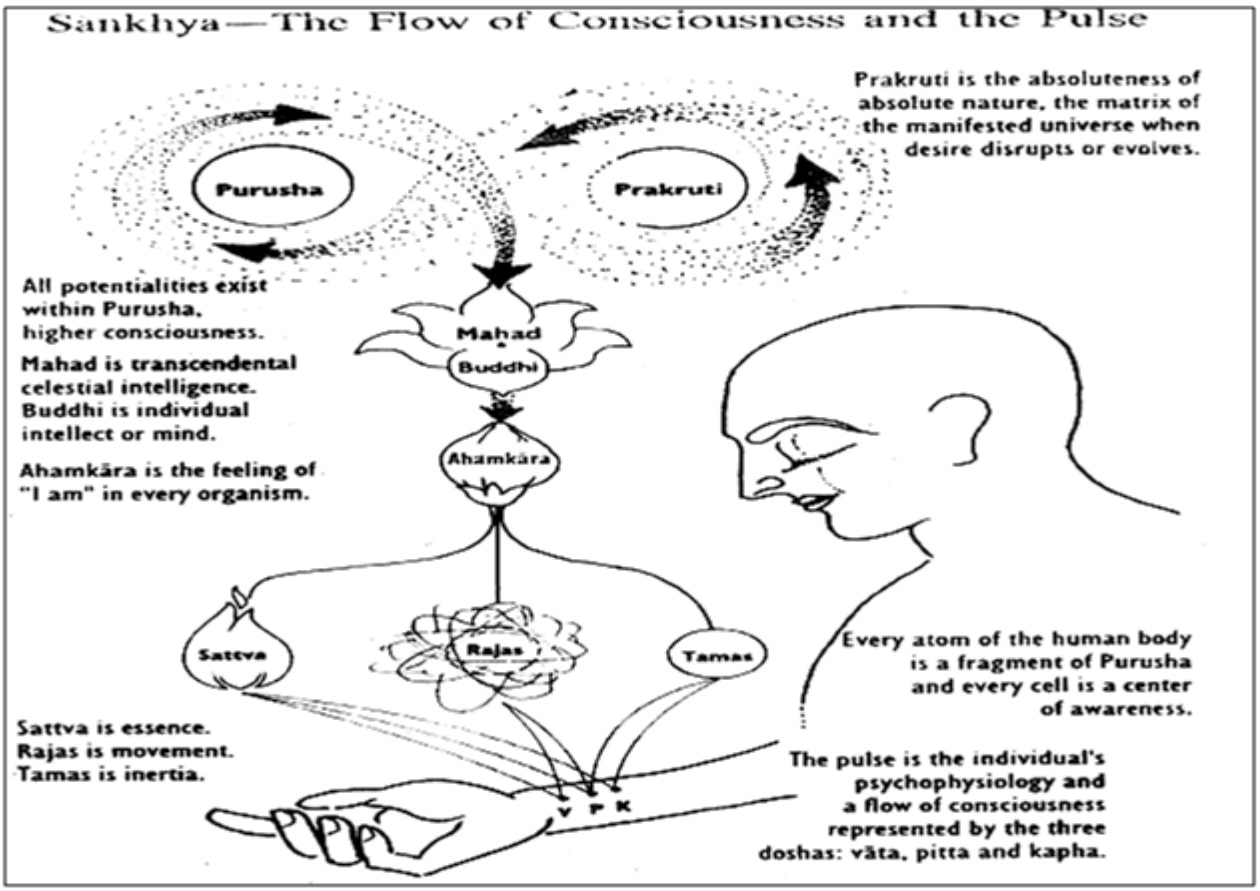


Fig 1.1 - The flow of consciousness and the pulse

1.2 Nadi (pulse)

Ayurveda is practical, clinical, medical sciences. It has its unique methodology of eight clinical limbs-examinations of pulse, urine, faces, eyes, tongue, speech, skin and form. The most important of these limbs is the pulse which means *NADI*. Pulse opens up the door of perception to explore the hidden secrets of life. As we know the pulsation of the blood through the body carries nutrients to the cellular level. There is continuous flow of communication between cells and this flow is intelligence.

Sanskrit contains a number of words that can be translated as pulse:

- *Nadi*: means a river of life expressed through the pulse.
- *Snayu*: translated as subcutaneous tissue or fascia. As pulse lies within subcutaneous tissue.
- *Tantu*: means string of musical instrument through which one can listen to the music of feelings and emotions.
- *Hamsi*: in the breath there is a sound called "*so-hum*" "*hum-sa*". On inhalation "so" goes in which is higher consciousness and on exhalation "hum" goes out which is the ego. "So-hum" is shiva representing male and "hum-sa" is shakti representing female. ."So-hum" is hamsa and it means swan. Hamsa means male swan and hamsi means female swan.
- *Dhamini*: means artery, the pulsation blood vessel which carries blood away from heart. During cardiac activity the heart produces the sound dhum-dhum and through dhamini, prana is supplied to all the dhatus or tissues.
- *Dharani*: means to hold or support. The pulse moves through all organs. Due to which it is called dharani which holds all organs together.
- *Dhara*: means continuous flow of consciousness.
- *Sarita*: a river of daily life.
- *Jiva*: expression of individuals' life.

There are also other usages of word nadi. *Vishwa* means universe and the flow of universal energy is called vishwa nadi which is connected to individual's life through breath. Bring total attention to the breath and try to detect which nostril has most air passing through it. Then note the sensation of where the air is brushing against the inner nostril. The breath of right nostril is male solar energy; the left

nostril breath is lunar female energy. Approximate in every 90 minutes the breath pattern changes alternating between left and right nostril.

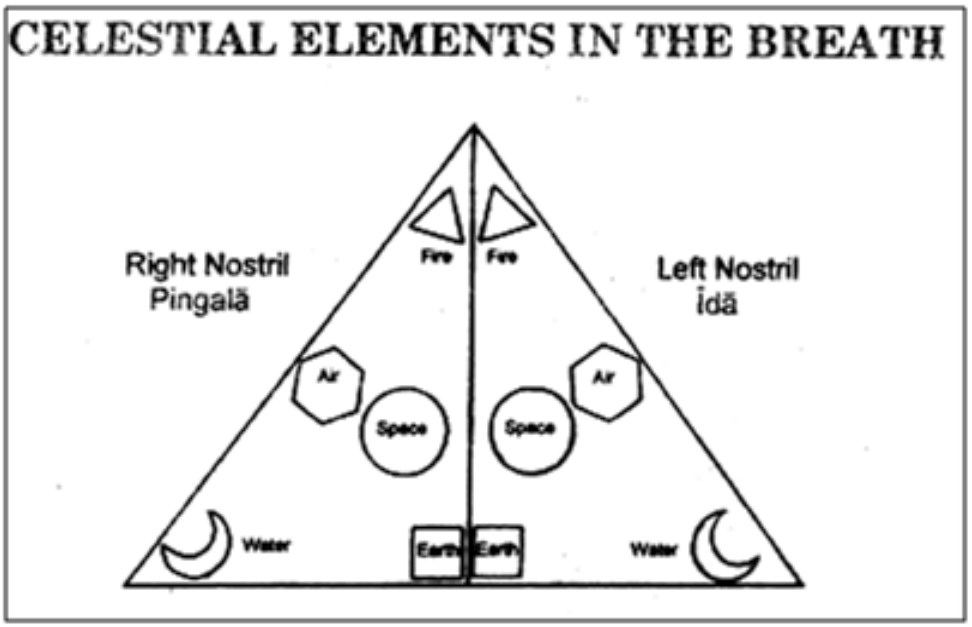


Fig 1.2 - Diagram of celestial elements in the breath

When air is brushing more to the inner sides of the nostrils the *earth* element is vibrating, creating a feeling of groundedness and stability as in fig 1.2. When air is brushing to the sides of nostrils near the cheek *water* element is working and one will feel emotional, compassionate and loving. But when air is touching more at the top of nostrils *fire* element is active and one is prone to feel fiery, judgmental, critical, ambitious and competitive. The *air* element is located at the outer sides of nostrils causing fluctuation, hyperactive and confused mind. When *space* is prominent, the breath is subtle, neither touching the right nor left sides of nostrils. It comes from the central axis of the nose creating tranquility and peace. These all elements are communicated with vishva nadi to the individual life through the breath.

Table 1.1 - Table of celestial elements in the breath

MANTRA	SYMBOL	ELEMENT	EMOTIONS
हँ Hām		Space	Tranquility, peace, freedom, isolation, loneliness
यँ Yam		Air	Hyperactivity, confusion, fear, anxiety, fluctuation of emotions
रँ Rām		Fire	Competition, aggression, judgment, violence
वँ Vam		Water	Love, compassion, attachment, greed
लँ Lam		Earth	Groundedness, stability, depression, heaviness

Another nadi is called *guru na*di. Guru means master, teacher, an enlightened being. When guru nadi starts pulsating, prakruti and vikruti become balanced this opens the central pathway in the spine, creating a state of transformation. Blessed are those whose guru nadi is awakened. Guru nadi is basis of universal polarity, the balancing of opposite principles within individual. When guru nadi is awakened, one can feel ones's own pulse and through that pulse while "looking into third eye of another person, can feel what is happening with that other person. Make your mind completely empty and in that emptiness begin to visualize, welcoming whatever comes. This art of emptiness is the art of awareness and the guru nadi take expression through the timeless state. See as a whole and then go to root cause. This approach sounds rather exotic. However Ayurveda gives us logic and then helps us to go beyond logic.

1.3 Nadi prediction

Ayurveda uses *darshana, sparshana* and *prashna* as the main clinical barometers and also apply to nadi vijnanam. *Darshna* means pure observation and indicates optical perception; one also observes the person's physical makeup. *Sparshana* is the tactile experience of touch. In some cases it is hard to find nadi and may be perceptible to one side only. In these cases first check the position of hand to be sure

the finger placement is correct and in contact with radial artery. In this one is actually feeling various changes taking place in the pulse.

One can touch the carotid, temporal and femoral pulses as well as radial pulses. *Prashna* is questioning. The clinician need to ask questions of the subject related to perceived problems and to take medical history. The radial pulse site is chosen to read the pulse because it is more convenient to read and is readily available than other pulse sites. It reveals characteristics of doshic imbalance, the nature of diseases and expected prognosis.

1.4 General characteristics of Vata, Pitta and Kapha pulses

Five basic elements (ether, air, fire, water and earth) manifests in human body as three basic principles known as tridosha. From either and air element the air principle *vata* is manifested. The fire and water element exist together as fire principle called *pitta*. The earth and water element exhibit as water principle, *kapha*. These three doshas determine individual constitution and governs function of the body in normal condition and when out of balance, they contribute to the disease process. Before going into actual study of pulse, let's discuss general characteristics of doshic pulse.

The rishis described the manner in which the pulse movement is compared with the movement of different animals. This movement is known as gati. The mobility of vata pulse is called *sarpa gati*(cobra pulse), that of pitta is called *manduka gati*(frog pulse) while the motion of kapha pulse is called *hamsa gati*(swan pulse)

Vata pulse is superficial, cold, light, thin, feeble and empty. With more pressure it disappears. It moves fast and may become irregular. It is best felt under index finger. This pulse is colt to the touch because of insufficient insulating material and very little fat which is why people with vata lose heat and hate cold.

Pitta pulse is full with strong throb. It is hot and abrupt with high amplitude, good volume and force. It is best felt under middle finger and moves like a leaping frog. This pulse is hot to the touch because pitta people have strong heat.

Kapha pulse is deep, slow, watery, wavy and cool to the touch. It moves like swimming swan. Kapha people retain heat in the body because of thick fat layer under the skin.

Table 1.2 - The three basic Gatis of Nadi

Characteristics	Fast, feeble, cold, light, thin, disappears on pressure	Prominent, strong, high amplitude, hot, forceful, lifts up the palpating finger	Deep, slow, broad, wavy, thick, cool or warm, regular
Location	Best felt under the index finger	Best felt under middle finger	Best felt under ring finger
Gati	Moves like a cobra	Moves like a frog	Moves like a swimming swam

When hand is correctly placed on the wrist, the ring finger which is closest to heart is proximal. The index finger which is away from the heart is distal. In between them is the middle finger. Fig 1.3 shows the spikes of all the doshas.

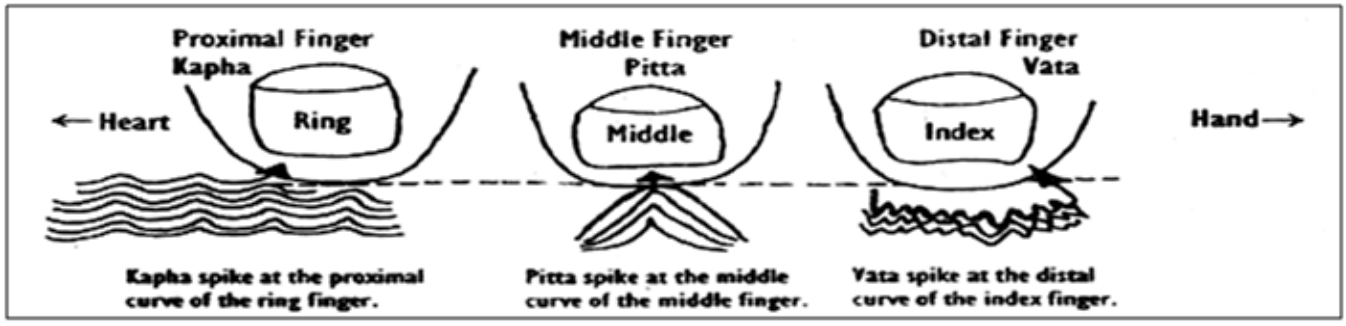


Fig 1.3 - Spikes of Tridoshas

Always feel the pulse from the radial side (outer side next to thumb) and never from the ulnar side (inner side next to little finger).There are two methods of placing finger. The index finger can be placed above or below the radial tubercle, in this case gap is created between distal and middle finger which results in incorrect reading. Prefer all the three fingers together to the radial tubercle and closer to heart (fig 1.4). Do not bunch the finger together but separate them slightly, so that throbbing under each finger can be felt distinctly.

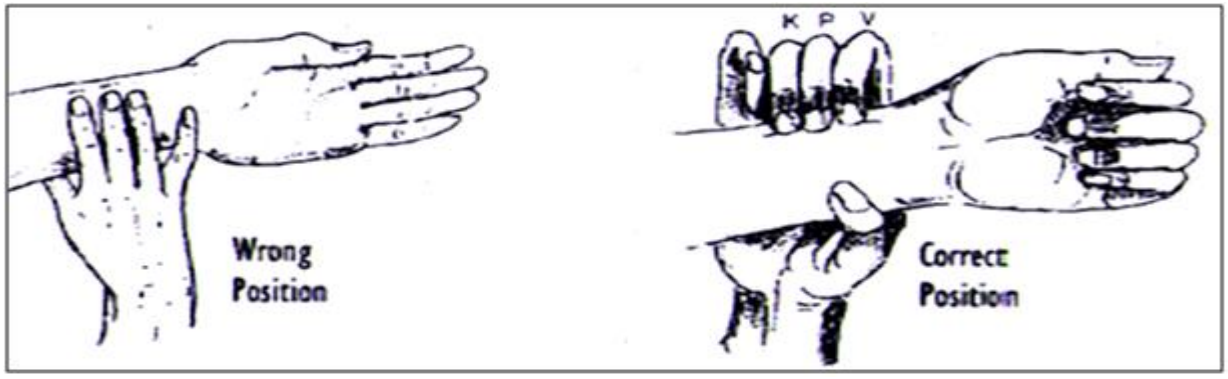


Fig 1.4 - Position of hand for pulse reading

1.5 Seven condition for nadi prediction:

1.5.1 Gati (movement)

Gati means movement. In addition to three doshic gatis there are other pulses which help to indentify certain diseases. In jalanka gati (leech pulse) the pulse touches the fingers of clinician one after another in rhythm like movement of leech leading to gout and arthritis. Under manduka gati, the rishis observed *lavaka*, *tittiraka* and *kaka*. Lavaka is common quail, indicates the possibility of prostatitis in a man or cervivitis in woman. Tittiraka is a partridge which hops and stops, it shows sharp spike under middle finger indicating gastric ulcer. Kaka means crow and denotes an excess pitta disorder in small intestine. The peacock pulse is *mayura gati* which is full and bounding but the distal phase is spreading like the fan of peacock. It is common in arterial hypertension in kapha-pitta people. Another pulse is camel pulse (*ushrta gati*) under vata and pitta which has a hump. Lift the finger and little notch is felt which then drops down. This pulse indicates aortic stenosis with thickening or narrowing of aortic valve. Under kapha, one can observe elephant pulse (*gaja gati*) which moves deeply and slowly with a notch before it collapses. This pulse indicates elephantitis or lymphosarcoma.

One might also find lotus pulse (*padma gati*) under kapha finger which moves to and fro. This is very sacred pulse indicating that the person is enlightened. This pulse is present during deep meditation and indicates blissful state. Feeling the pulse is an art. Awareness should be passive. One should let that awareness act upon the mind. Use the tips of fingers to feel the nature or gati of the pulse. Sarpa gati is a normal vata pulse. Mandeka gati is a normal pitta pulse. Hamsa gati is normal kapha pulse. There are three basic pulses that one should bear in mind.

1.5.2 Vega (rate)

There are several quantities of the pulse which are relatively gross, easy to read and yet important. One of these quantities practiced both in Ayurveda and in modern allopathic medicine is *vega* (rate). It means the rate of pulse, the number of beats per minute. Vega varies due to exercise, anxiety or excitation. To get accurate rating of pulse, take the pulse in the early morning in rest condition. Vega is high in vata, moderate in pitta and low in kapha.

Feel the pulse for one minute and count the number of pulsations.

Vata: 80-95 beats per min.

Pitta: 70-80 beats per min.

Kapha: 50-60 beats per min.

The pulse rate is high in certain pathological conditions. For example: in anemia the blood volume is low and tissues need more oxygen, so heart increases its rate to provide optimum oxygen to the tissues. Vega also increases in cardiac failure or hyperactive thyroid gland which is confirmed by reading the pulse while the person is asleep. The more height, the slower the rate; the lower the height, the greater the rate. So rate is inversely proportional to height. The moment a doctor wait a white coat and stethoscope comes close, the patients rate increases. So it is better to feel the vega at the start and at end of examination in order to get accurate reading.

Table 1.3 - Milestone of age influencing the pulse

Infancy and childhood up to 16 years of age	Kapha is predominant in the pulse
Adult (age 17-50)	Pitta is predominant in the pulse
Adult (age 51-70)	Pitta is predominant in the pulse with gradually increasing vata
Above age 70	Vata is predominant in the pulse

There is only one condition where there is infection with slow Vega and is with typhoid fever. In this condition a person has a high continuous fever for several days but the pulse rate is slow. This is a unique condition.

When some individuals inhale, the pulse rate becomes fast because blood rushes from the lungs into the left chamber of heart and on exhale the pulse rate slows down as blood from right ventricle is pushed into lungs. This alteration of pulse rate is called sinus arrhythmia. Remember the slower the pulse rate the slower the metabolism and the faster the pulse rate, the faster the metabolism. Metabolism is governed by *agni*. When agni is strong the pulse is relatively fast, light and hot. If agni is slow the pulse is slow, heavy and cool. In this way the quality of agni can be understood through a general examination of pulse.

1.5.3 Tala (rhythm)

Tala is rhythm which is defined as the time interval between two consecutive or successive uplifts. In balanced and healthy tala, the time interval is regular, uninterrupted and rhythmic. In irregularity the rhythm will be regularly irregular. Kapha can block vata and pitta and pitta can block vata. However only vata can push pitta and kapha. An irregular tala a very crazy pulse involves both vata and pitta, because both are mobile. This irregular pulse is present in atrial flutter with fibrillation.

1.5.4 Bala (force)

Bala is the force or pressure of the pulse. Press the artery with the three fingers. The amount of force pressing on the blood vessel is being exerted back into the fingers. This is called force, bala. But remember force is equal to difference between systolic and diastolic pressure which produces a ratio called pulse pressure. If the systolic pressure is 200 and diastolic pressure is 30, leading to PP of 170 so at this high pulse pressure the heart is working under great stress. In opposite condition, if systolic is 70 and diastolic is 60, the PP is 10 then the person doesn't receive enough oxygen to the brain. If pulse pressure is feeble the person becomes dizzy, may have transient loss of consciousness and even shock Bala is very low in vata, high in pitta, and moderate in kapha. There is much confusion about bala and how firmly the artery should be pressed in order to feel the force of the pulse. The amount of pressure will vary with the individual depending upon prakruti and volume of blood in the artery. High bala is represented by *three plus* (+++), low by *one plus* (+) and moderate by *two pulse* (++).

If deep pressure of the finger is necessary in order to stop the artery it means the force is strong. Moderate pressure indicates that the force is moderate. If superficial pressure causes the pulse to disappear the force is low. The pulse of the obese person is hard to read because of adipose tissue, but once you feel it the bala is usually moderate.

1.5.5 Akruti (volume and tension)

Akruti means volume and tension. Volume is experienced as the uplift to the palpating finger. It is not necessary to depress the radial artery. Just feel the uplift while the fingers rest lightly on the artery. Volume of pulse corresponds to the systolic blood pressure. If the volume is high the systolic blood pressure is high. If volume is low the systolic blood pressure is low. With high volume a large amount of blood is propelled through arterial and venous system.

Vata people have low volume, Pitta have high volume and Kapha have moderate volume.

The fullness of blood vessel depends upon water intake and the volume of blood. Vata people who usually do not have sufficient fat have prominent veins and thin artery. Kapha people have thin veins and broad arteries. In order to feel the volume try to press the artery gently and feel the throb pushing against the finger. If throbbing is felt under middle finger the volume is three plus, pitta. If throbbing is felt under ring finger it is moderate volume which is kapha. If throbbing is barely felt under index finger the volume is low, vata. Don't press too hard just go in between.

Tension is felt by pressing the ring finger to stop the pulsation of the radial artery and then feeling the tension under the middle and index fingers as the blood vessel is a rubber tube full of water. Tension is the pressure between two uplifts, diastolic pressure which is the constant pressure of blood. Although there is no propelling of the blood through the artery, the vessel is never empty. If the vessel is empty, the life is empty and the patient is in shock. Tension is maintained by *vyana vayu* and kapha , while volume is maintained by *prana vayu* and pitta .There is one pulse called water hammer pulse in modern medicine where the volume is high but tension is low. This pulse has high systolic pressure about 200 and diastolic is only 30. Such a vast difference between pulses creates a collapsing pulse. In modern medicine this pulse is related to aortic regurgitation. In this condition the blood goes back from aorta to the left ventricle and vibrates.

This pulse is very characteristic where there is increased pulse pressure so that even the capillary pulsation is prominent. This condition is further evidenced when pressure on the fingernail causes one portion to be white and one portion to be pink.

1.5.6 Tapamana (temperature)

Tapamana means temperature.

A vata pulse is cold, Pitta pulse is hot and Kapha is warm to cool.

There is relationship between gati of the pulse, wave of the pulse, temperature of the pulse and agni and metabolic fire of the individual. When the pulse is cold, fast and light it means vata is high and agni is low. But in pitta when the pulse is hot, sharp and light to touch there is high agni.

1.5.7 Kathinya (Consistency of the Vessel Wall)

The consistency of vessel wall is felt by rolling the artery between the palpating finger and radial bone, is called *kathinya*. Palpating in this way reveals whether the vessel wall is thick or thin, elastic or plastic, rigid, hard or rough. If vata is high its rough and hard qualities cause the blood vessel to be rough and hard and may manifest as arteriosclerosis. Because of these changes the blood vessel narrow and there is insufficient supply of blood to the brain and other organs which results in condition called Alzheimer's syndrome, which is the slow death of brain cells.

In high pitta the blood vessels are elastic but become fragile, creating tendency to bruise easily. It can cause pressure on the nerves leading to migraine headache. There is also possibility of capillary hemorrhage causing blood vessels to bleed.

In high kapha the blood vessels become broad and thick. The deposition of fat on the wall of blood vessel can lead to artheroma which is one of the causes of hypertension.

There are seven important conditions to be observed in reading the nadi. Using the nadi table (given below) face the partner and read the pulse for one minute. Practice reading the pulse on one hand, right hand on male and left hand on female. Feel the pulse from the outer or thumb side of the radial bone. Try to read the vega, speed per minute; the gati, manner the pulse moves; the tala, rhythm; the bala, force; and the akruti tapamana and kathinya [1].

Table 1.4 - Nadi prediction

Doshas	Vata	Pitta	Kapha
Gati (movement)	Sarpa (cobra)	Manduka (frog)	Hamsa (swan)
Vega (rate)	80-95	70-80	50-60
Tala (rhythm)	Irregular	Regular	Regular
Bala (force)	Low (+)	High (+++)	Moderate (++)
Akruti (tension and volume)	Low	High	Moderate
Tapamana (temperatue)	Cold	Hot	Warm to cool
Kathaniya (consistency of vessel wall)	Rough, hard	Elastic, flexible	Soft thickening

1.6 Mudras

Yoga Mudras are basically postures for the hands and fingers. We have about 4000 nerve endings at the tip of the fingers that are connected to different organs of the body and can influence, relax and bring about a balance in them. These are very simple techniques that can be practiced leisurely by sitting, standing or lying down. They are every effective and can be practiced even at your desk in our office.

The human body is made up of the five elements, fire, air, space, earth and water. An imbalance in these elements causes diseases. These imbalances can be set right by 'Hasta Mudras' (Hand Mudras) which are simple joining of fingers which can energise and cure body ailments. It is interesting to know that each finger is associated with an element. The thumb with fire, index with air, middle with space, ring with earth and the little finger with water. When a finger is brought into contact with the thumb, that particular element is brought into balance [2].

1.6.1 Gyan Mudra

Have the tips of the index finger and the thumb joined and keep the other three fingers stretched out and joined. Fig 1.5

Benefits:

- It increases memory power and enhances the brain.
- It also cures sleeplessness and curbs anger and restlessness.
- It imparts happiness
- Effective for mental ailments

Fig 1.5 – guru nadi

1.6.2 Bronchial & Asthma Mudra

These Mudras are very good for respiratory problems and can be done with both hands. The Bronchial (fig 1.6) and the Asthma Madras (fig 1.7) can be done for a few minutes one after the other until the breathing calms down. For prolonged treatment these two Mudras can be done five times every day for five minutes [3].

- Place the little finger at the base of the thumb, the ring finger on the upper thumb joint and the middle finger or the top soft portion of the thumb. The index finger should be extended. This can be done for a few minutes every day.
- It can be done along with the Asthma Mudra, which is also done with both hands. Press together the fingernails of the middle fingers while keeping the other fingers extended. This is effective for asthma attacks.

Fig 1.6 – bronchial mudra

Fig 1.7 – asthma mudra

1.6.3 Lotus mudra

This mudra belongs to heart chakra and is the symbol for purity. It is good during time of loneliness and despair. It is practiced by placing both hands in front of chest so that only the edges of hands and pads of ones finger touch each other. This forms the bud of lotus flower (fig 1.8). Now open your hands, but maintain the contact between the tips of the little fingers and the outer edges of your thumbs. Spread the other fingers open as wide as possible. After four deep breaths, close both hands back into a bud, place the fingernails of the fingers of both hands on top of each other; now join the backs of the fingers, the backs of the hands, and let your hands hang down relaxed for a while [4].

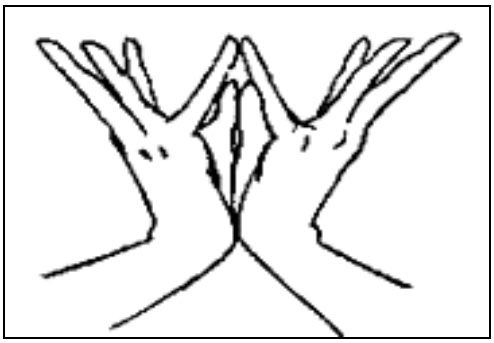


Fig 1.8 lotus mudra

1.6.4 Detoxification mudra

Place each thumb on the inner edge of the third joint of your ring finger as shown in fig 1.9. Do this with each hand. At least once a year, we should all plan a detoxification treatment. It makes no difference whether this is done at a beautiful spa or at home. The important thing is to pamper yourself, and allow yourself rest during this time, while still getting some exercise (walking, yoga, breathing exercises). A rice or potato treatment has a very efficient but gentle effect [5].

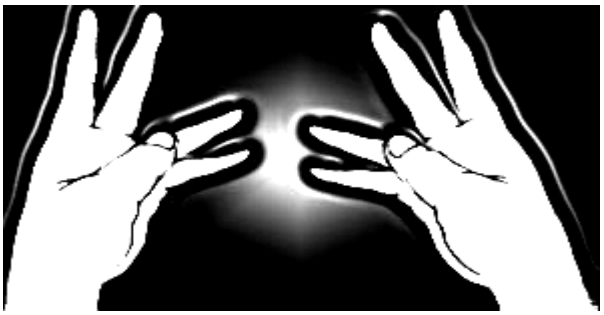


Fig 1.9- detoxification mudra

1.6.5 Chin Mudra

This gesture symbolizes the connected nature of human consciousness. The circle formed by the index finger and thumb represents the true goal of yoga – the merging of the individual soul with the universal soul, or the soul of God. The nail of the index finger is placed into the first joint of the thumb. The last three fingers always face down towards the earth in this mudra. The posture of this mudra is shown in fig 1.10. It is a gesture of receiving. When the finger touches the thumb a circuit is produced which allows the energy that would normally dissipate into the environment to travel back into the body, and up to the brain. When the fingers and hands are placed on the knees the knees are sensitized creating another pranic circuit that maintains and redirects prana within the body [6].

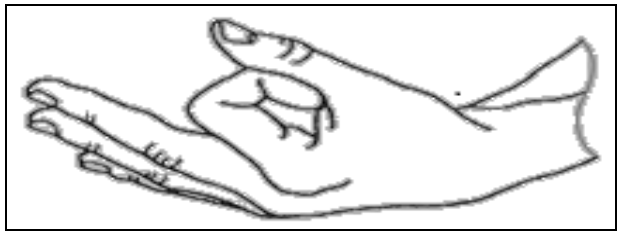


Fig 1.10 – chin mudra

CHAPTER-2 Prakruti(seven level) and Vikruti(one level)

2.1 Spikes of Tridoshas

Vata, pitta and kapha move in blood through the *rasa* and *rakta dhatus*. It is an interesting fact that the doshas are best felt under specific fingers. We feel the qualities of vata best under the index finger because the nerve receptors in that finger best perceive those qualities embraced by vata- light, subtle, mobile, dry, and rough. Same is true with pitta and kapha owing to their respective qualities. Even though the gross manifestations of the three doshas are perceived under the index, middle and ring finger their subtle qualities are felt under each finger at the distal, middle and proximal curvatures.

While feeling the pulse the most subtle dosha is vata. It is light, mobile and subtle. With very little pressure the flow can be blocked. Even if vata is partially blocked by the finger, it will not create spike at the proximal curvature of each palpating finger. It will easily go through to find space to expand and create spike at the distal curvature (fig 2.1). Vata is both *laghu* (light) and *vikasi*(expansive).

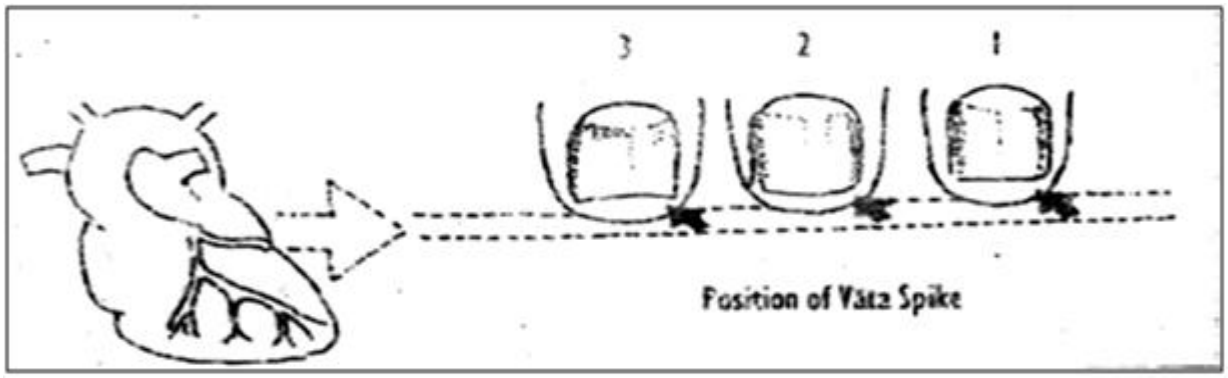


Fig 2.1 - Position of vata spike

The second dosha is pitta. It is also laghu, light but it is liquid and substantial in nature. However because of *laghu* and *drava* (liquid) qualities of pitta, its spike will be felt at the middle curvature of each of the three fingers (fig 2.2).

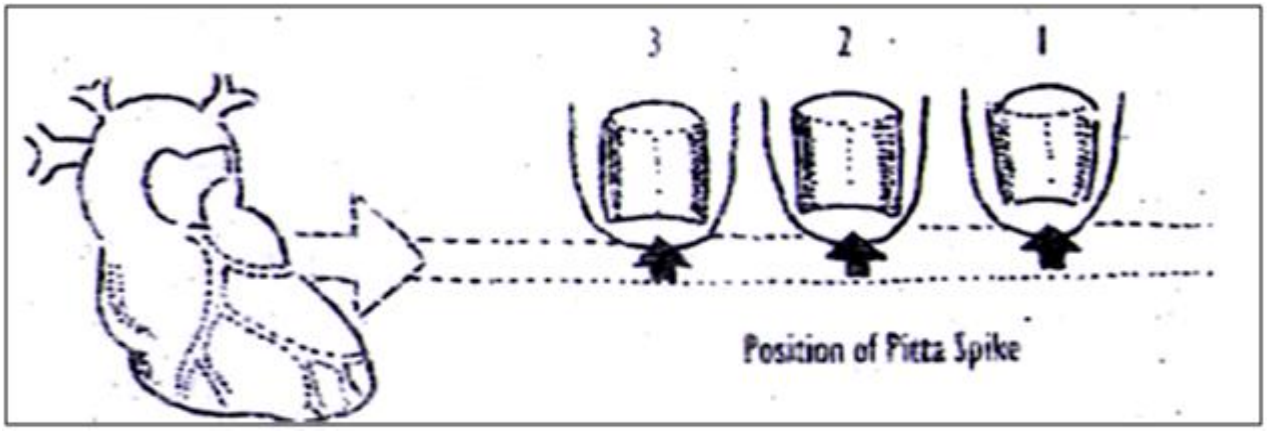


Fig 2.2 - Position of pitta spike

Kapha is guru (heavy), *sthira* (static) and *manda* (slow). Because of these qualities kapha stops at the sight on the finger closest to the heart and creates a spike at the proximal curvature as shown in fig 2.3.

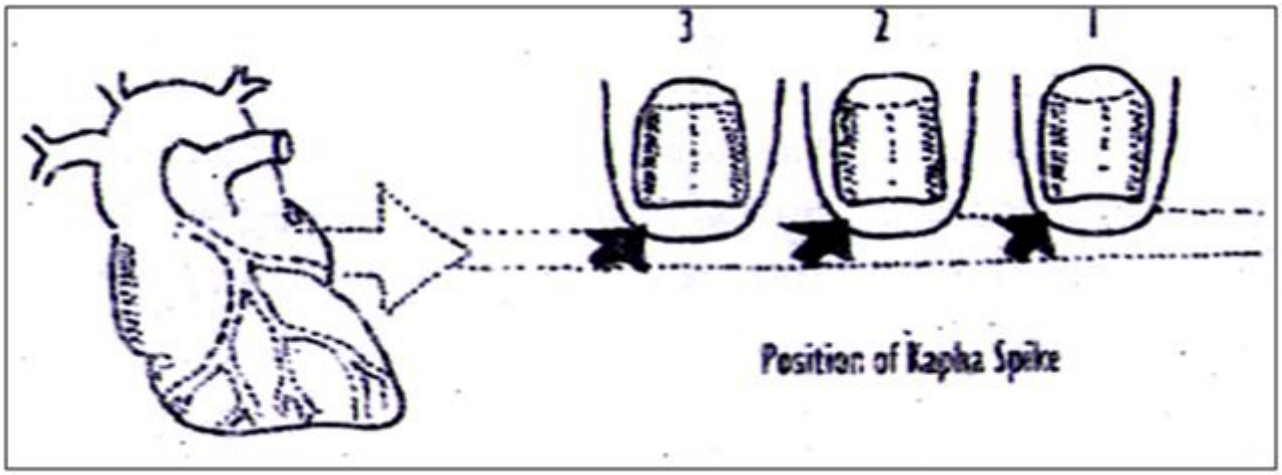


Fig 2.3 - Position of kapha spike

Vata is faster and moves ahead of distal curvature. Pitta is next and moves to a position next to vata. Kapha is very slow and stops at proximal curvature. The curvature of the finger is sensitive instrument, placed directly on the pulse to feel the throb. The art of pulse reading is very subtle and Ayurveda teaches us to be aware of the nature of body, mind and consciousness of individual and quality of spikes felt under each finger separately.

2.2 Seven levels of pulses

It is convenient to divide the reading of the radial pulse in the seven levels fig 2.4 and we will examine each of these levels separately.

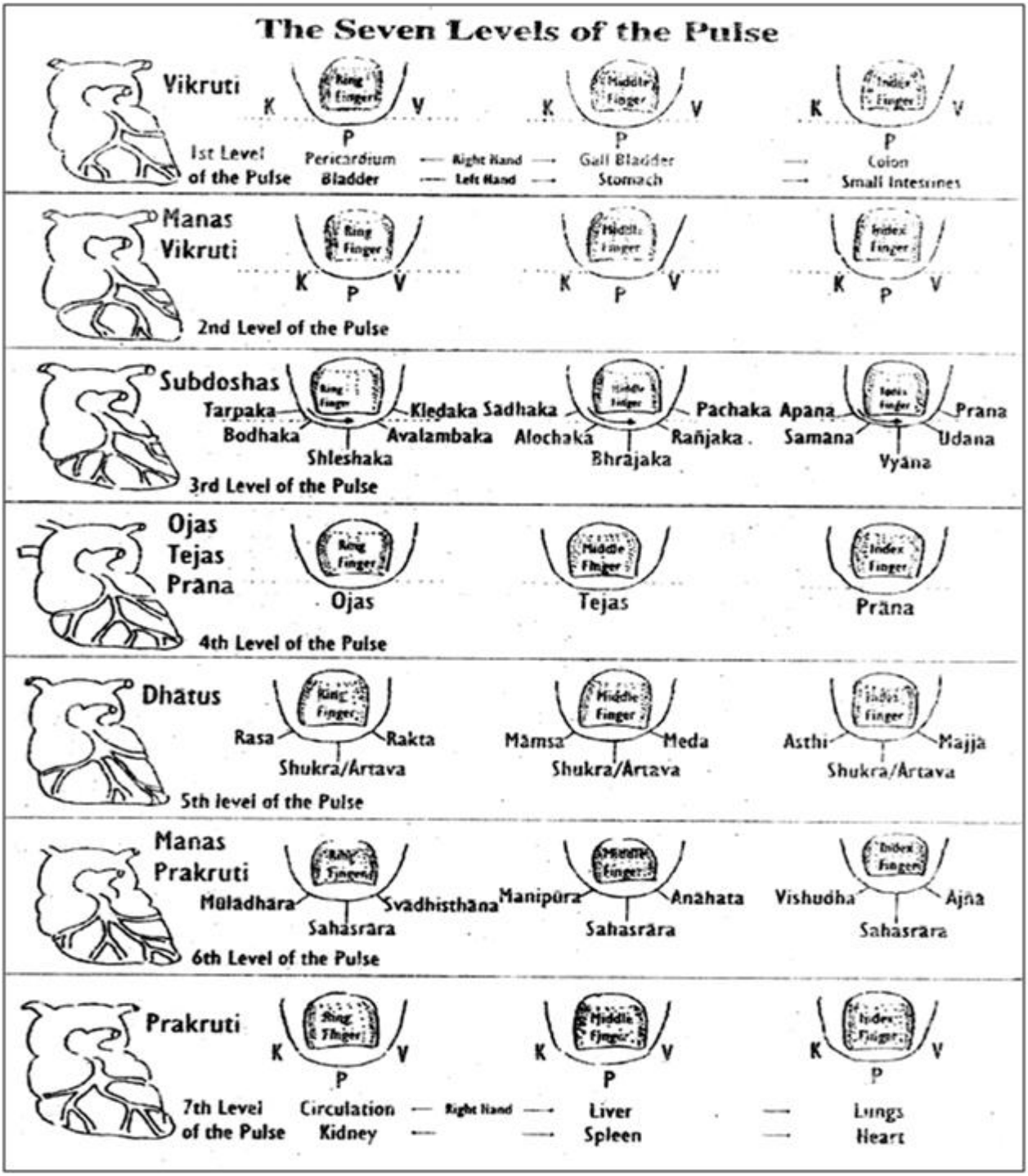


Fig 2.4 - Levels of pulses

At this point we will move our attention to prakruti and vikruti and how to read them on the seventh and the first level of the radial pulse. Be aware that the locations of prakruti and vikruti are referred to in several ways- level seven and one, deep and superficial, balance and imbalance. Prakruti is one's basic constitution established at the time of conception and is read at the seventh, the deepest level. Vikruti is our present state and is read on the first of superficial level of the pulse.

2.3 Prakruti

Ayurveda says that in some individuals the prakruti may be $V_3P_3K_3$, which means all the doshas are present equally, but few people are born with this ideal prakruti, called *sama parkruti*. Most people have variation or combination of the ideals such as $V_2P_1K_3$ or $V_1P_2K_3$. These numbers indicate relative ratios of the doshas present in the individual. If there is no"3" in the reading it indicates the person was born with a depleted dosha, called dosha kshaya. *Kashya* means diminished, deteriorated or deficient. When the deep pulse corresponds to the superficial pulse, that person is healthy and balanced. If a persons prakruti shows $V_2P_3K_1$ and the superficial reading at the first level is same, the person is balanced. Feel the throb of life under the fingers. When the pulse in the right hand side and left hand of the body are just about equal, the male and female energy are balanced and vyana vayu is moving the doshas equally on both sides. In some individuals vayu pushes doshas more to the right side and the right side pulse will be more prominent than the left or vice versa. The pulse may become feeble on one side due to previous surgery on forearm.

If pitta is strong the spike at pitta position will be felt under all three fingers-pitta. If vata is feeble only one spike at the distal position will be noted. If kapha is relatively strong it will create spike at proximal position on two fingers.

2.4 Situation of inaccurate reading

There are many situations that may lead to an inaccurate reading of the pulse. Sometimes the fingers are not at same level. If the ring finger and middle finger press deeply but the index finger is less deep, the reading will not be accurate. In addition the finger is directly on the radial tubercle, the index finger may not get the throb. Sometimes appearance of the person can be deceiving. Though the person may look like a healthy, chubby kapha person, the thick subcutaneous fat may cover the true sensation of the pulse.

If someone is prematurely born and umbilical strangulation may affect the reading. Pulse reading needs persistent and prolonged practice which makes one perfect. This is the technique but unless it is digested and understood insight will never come insight is a product of practice and through repeated practice this art of reading pulse will develop. Select someone to practice on and press the radial artery of either the right or left side deeply enough to cut off the pulsation. Release slightly just to the point where the pulsation returns. This is the seventh level, parkruti level.

2.5 Vikruti

Earlier it was introduced the seventh level of the pulse which is prakruti, the level of the physical constituents. Now we will discuss *vikruti*, the current physical doshic state at the first level of the pulse. It is the deviation, either quantitatively or qualitatively of the doshas from prakruti the states of individuals balance. The change can be mild over a long period of time or great over short one.

Choose a partner and try to read prakruti once again. Go to the seventh level and determine the reading of vata, pitta and kapha on the index, middle and ring finger. Then release the pressure on the radial artery and once comes to superficial pulse to find out vikruti. At this level again read vata, pitta and kapha. When checking the vikruti the quality of spike is very important in determining the state of imbalance. Spikes of kapha can be felt under all the three fingers. But in the superficial pulse there may be extra spike at pitta region which resembles kapha (that is why kapha is counted as 4). Also remember the quality of vata spike which is very quivery. There may be extra vata spike in superficial pulse either under the ring finger, the middle finger or the vata finger. If vata appears under the middle finger at pitta spike that means vata is pushing pitta in vikruti. Half a dosha will never be read in prakruti, only in vikruti. The reading depends upon subjective observation and quality of perception. Many times when reading the pulse of subject, we will observe two examiners arrive at different diagnosis from one another. It is matter of perception and experience.

The Ayurveda art of learning is more than mechanical or technical. For example, when two persons look at an object, they look from different angles. When our perception is at same level at the same time with the same intensity and on the same platform then we will perceive the same object. However there will still be personal differences. That doesn't mean that one person is wrong but in the case of pulse reading the person may be on different level. Prakruti pulse is on the seventh level and if one examiner comes only to the sixth level reading will be different [1].

CHAPTER-3 Organ Pulses

3.1 Kala

In order to deepen our understanding before we discuss the organ pulses, we must consider the concept of *kala*. There are seven dhatus- *rasa* (plasma), *rakta* (red blood cells), *mamsa*, *meda*, *asthi*, *majja* and *shukra*- and each dhatu has its own kala. A kala is membranous structure that maintains the nutrients, transformation and maturation of a dhatu. The rasa dhatu and rakta dhatu are separated by a kala.

Plasma cells, red blood cells, muscle cells, even the cells of bone marrow and majja dhatu have a membranous structure, a sheath or kala. Within that dhatu there is the respective dhatu agni which maintains the unique metabolism of each dhatu.

Unprocessed rasa dhatu is transformed into processed rasa, immature rakta and also into the by-product of rasa along with kapha or dhatu mala. Each dhatu is transformed from unprocessed dhatu to processed dhatu, byproducts and malas.

The kala is the protective barrier and in addition contains enzymes or dhatu agni. If dhatu agni within each respective kala undergoes an increased or decreased condition, it may cause atrophy or hypertrophy of that particular dhatu. If agni is low there is under accumulation of raw dhatu. If agni is high, dhatu will be emaciated.

Ayurveda says shukra dhara kala, the kala which nourishes the *shukra dhatu*, the male reproductive tissue and *artava dhatu* in the female, is present all over the body. The Sanskrit word *srotas* or *srotamsi* means channel. Each dhatu has its srotas and the root of the srotas is present in kala.

Kala is not imagined, intellectural, poetic concept but is actual membranous structure. The nucleus has a membrane, each gene has a membrane and even each individual cell has a membrane. The membrane structures of genes and DNA molecules have their kalas in which memories of our ancestors illnesses is carried.

Kala means time. When food is eaten, *ahara rasa* (chyle), the food processor for cellular nourishment is produced within 6-8 hours. Within 24 hours immature *rasa* dhatu is created from ahara rasa. This *ahara* rase is transformed into mature *rasa* dhatu in 5 days. *Rakta* dhatu needs 10 days and *mamsa* dhatu requires 15 days. Likewise it takes 35 days (one month and five days), for *shukra* dhatu to receive the

benefit of nutrients from food previously eaten. Milk is the highly superfine essence of the *rasa* dhatu of the cow and milk is transformed into *shukra* within 24 hrs.

Every organ has a mucous lining that maintains the normal function of that particular organ and this lining is also called kala. *Ashaya* means vessel. The stomach is a vessel of undigested food called *amashaya*. The stomach has gastric mucous membrane called *shleshma dhara kala*.

When hot food is eaten- for example, hot cayenne pepper stimulates the production of hydrochloric acid, the kala of the stomach dissolves and stimulates more production of kapha. The colon mucous membrane functionally corresponds to periosteum, because colon absorbs minerals such as calcium, magnesium and zinc.

The malfunctioning of any kala creates ama in that particular dhatu. The main center of digestion and most important agni is gastric fire (*jathar agni*) present in the stomach. Sometimes an individual may have strong jathar agni but weak dhatu agni and this condition can directly create ama in the dhatu.

The root of all disease is formation of *ama* and there are many causes for its development. For example, whenever incompatible foods are ingested jathar agni will be directly affected and ama or toxins will be created from the poorly digested food.

Ama is created by the malfunctioning of any dhatu kala. Ama is not always created in the stomach. It can be created in the colon due to constipation or in dhatu because of low dhatu agni or infection. Ama can be created in liver or gallbladder because of repressed emotions such as anxiety, insecurity, nervousness, fear or anger. This condition is called mental ama.

Ayurvedic herbology discusses how each herb has a specific action on each dhatu agni or kala. Like, *ginger* stimulates rasa dhara kala, *manjishtha* works on rakta dhara kala, *ashwagandha* activates mamsa dhara kala. There is logical order in ayurvedic anatomy, physiology and herbology.

3.2 Seasonal time

Time is movement both within and without. The rotation of earth and its movement about its axis are responsible both for sunrise and sunset creating chronological time and for the seasons creating seasonal time. The season is called *rutu*. In ayurvedic literature there are 6 basic rutus in the year: *vasanta*, *grishma*, *varsha*, *sharada*, *hemanta*, and *shishira*. Each season has specific qualities that can influence bodily tridosha (fig 3.1). For instance, spring increase kapha dosha, may stimulate pitta and can normalize vata, as shown below.

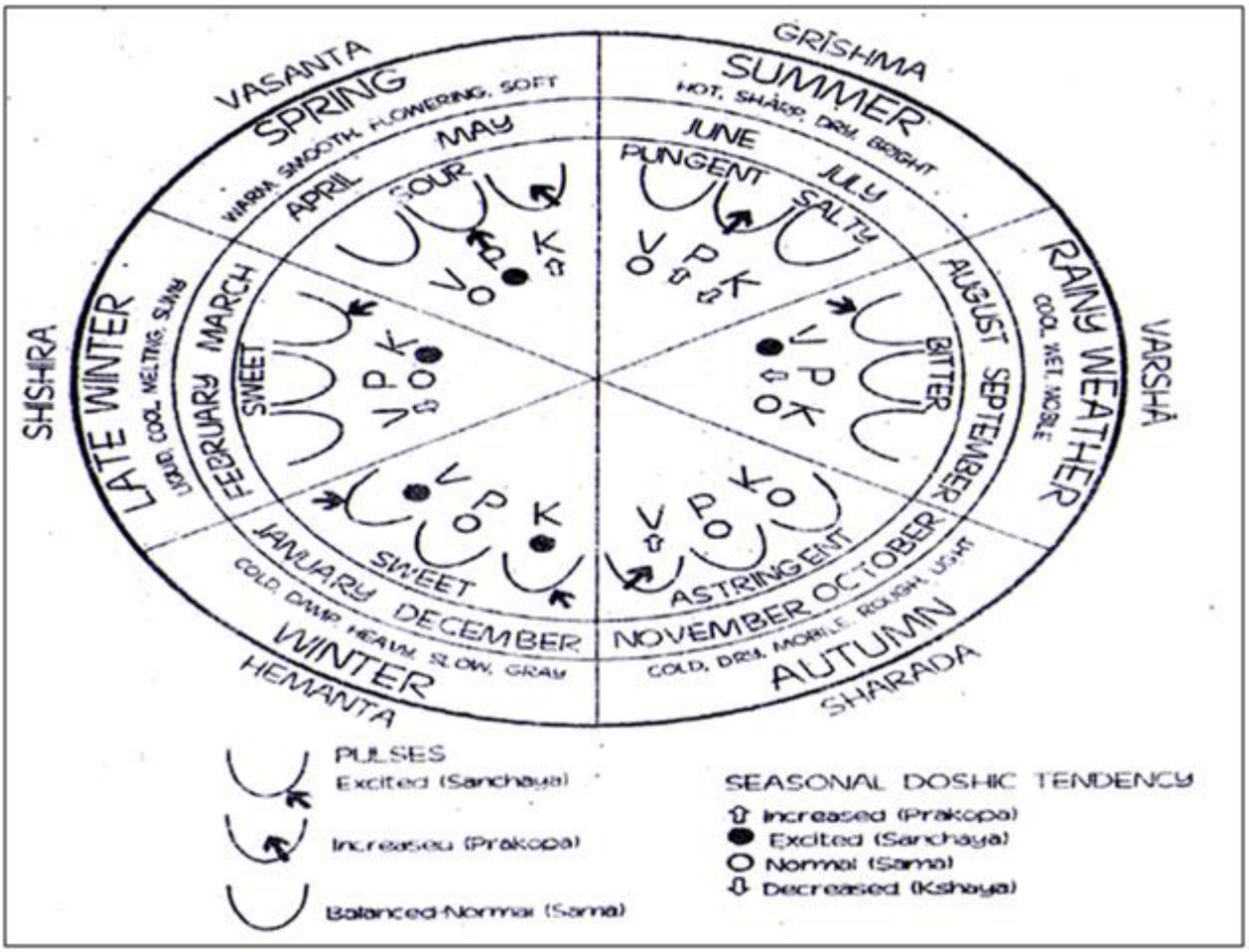


Fig 3.1 - The biological clock and the seasons

The qualitative seasonal variation can produce qualitative doshic changes in the pulse. So one can pay attention to the season by reading and experiencing the excited, increased, decreased or normal spike.

3.3 The biological clock and the pulse

A symbolic representation

Each dhatu has a time of the day when its functional activity is at a peak. One could think of it as a organs biological clock which moves with chronological time. As we studied earlier each dhatu has a kala which is the membranous structure separating one dhatu from another. An organ is made of dhatu, therefore in this context kala also means the specific time of the organ.

The time of rising and setting of the sun are chronological times depending upon movement of the earth. For the convenience of understanding we will say that at 6:00 am the sun rises and therefore from 6:00 to 8:00 is lung time, the two hours following the sun rise. That is why patient of bronchiectesis or mucous problems gets more pulmonary congestion at this time of day and why this is good time to do pranayama shown in fig 3.2. Lung time is the time of kapha. From 8:00 to 10:00 is the time of kloma which means pancreas, an organ related to kapha. It regulates sugar and water metabolism. At 10:00 pitta time begins and by noon the small intestine and stomach secrete pitta which stimulates hunger. From 12:00 to 2:00 is heart time. The heart is continuously circulating blood, but the prana energy activates the heart and after full meal a person is more prone to heart attack.

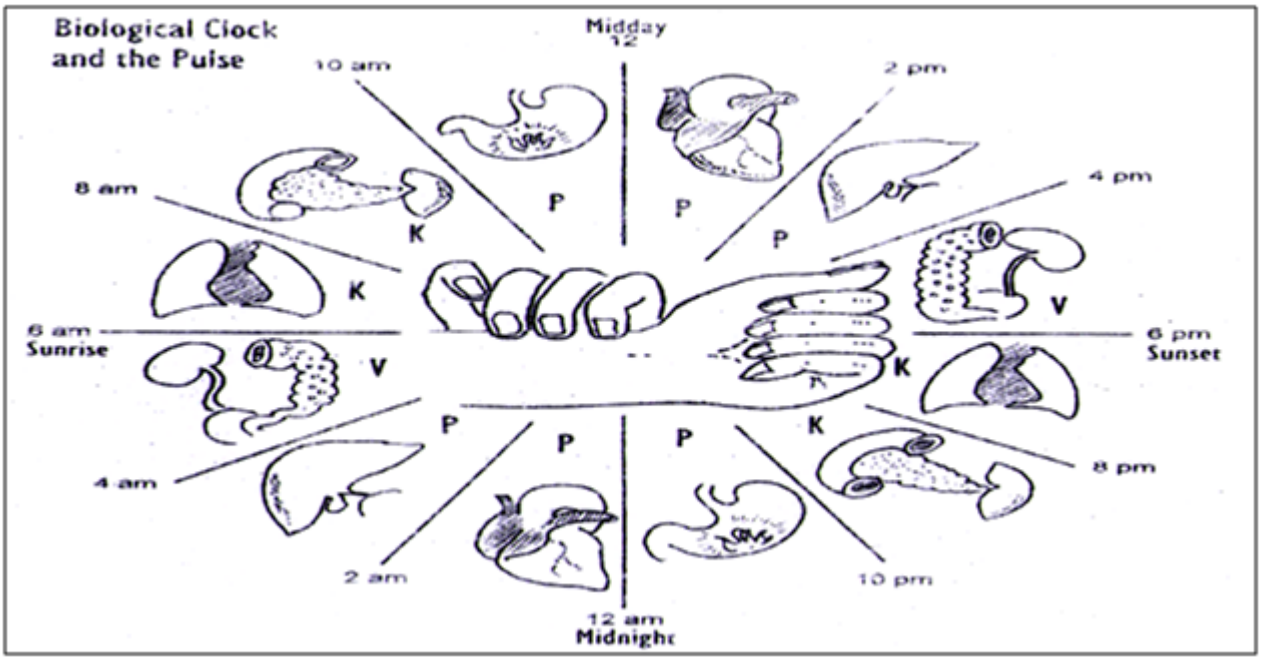


Fig 3.2 - The biological clock and the pulse

From 2:00 to 4:00 is liver and gallbladder time and a patient of hepatitis is more likely to have gallbladder attack during this time. From 4:00 to 6:00 is colon and kidney time. Adrenal function is low at this time and people often feel tired and want a boost from the cup of coffee to make them feel energetic. After sunset from 6:00 to 8:00pm is once again kapha and lung time. People have more congestion and patient of asthma may become wheezing. From 8:00 to 10:00 pancreas time, people feel like munching before going to bed because pancreas become active. Once again 10:00 to 12:00 is again stomach and small intestine time and pitta is active. At midnight because acidity is very high in the stomach an active peptic ulcer is more likely to create perforation. At 12:00 to 2:00 is heart time, though heart is resting a person can have heart attack at this time due to consumption of late dinner. From 2:00 to 4:00 am and pm is the time for spleen which is pitta and 4:00 to 6:00 am and pm represents the descending colon and bladder.

The ideal time for reading the pulse is early morning on an empty stomach. Take into consideration what time pulse is taken and which organ is activated. The solar system is governed by pitta and lunar system by kapha and vata. Generally observations show that in people who have more male energy can be more masculine and sometimes aggressive- the organs become activated during daytime. In those with female dominating energy the organs become active during night.

When the subject is breathing better through the right nostrils then his or her right pulse is more prominent than left. It depends upon where the prana energy is moving. As a whole when person has more male energy the right pulse will be more prominent. If female energy is activated the left pulse will be more prominent. The pulse indicates the polarity of the male and female energy. When the polarity changes, the amplitude of the pulse changes. The change in pulse depends on breathing pattern. Feeling the pulse also reflects polarity between the observer and the observed.

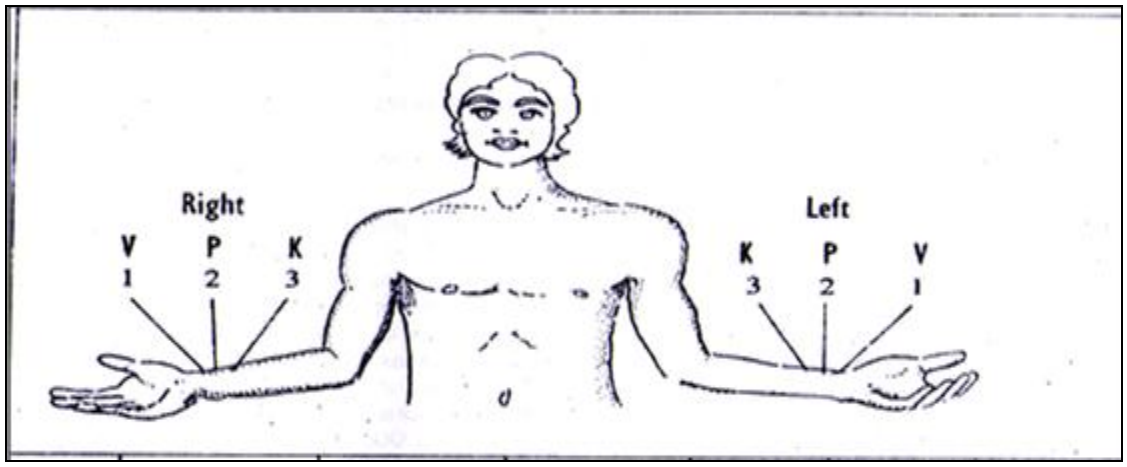
The left brain is masculine which governs all activities of right side. The right brain is feminine which governs all activity of left side. When right brain is active there is more female energy and the person is more compassionate, intuitive and loving. On the other hand the left brain is masculine which is mathematical, calculating, judgmental, critical and scientific.

In deep meditation the primordial brain is activated that is one enters in neutral state that is neither male nor female. At that moment the right and left nostrils breathe equally.

There is bridge between the right and left brain in the third ventricle called *chidakash*. Within the space one can see the formation of light moving along the spine. This river of light moves upwards and passes through the marble of light, merging into third ventricle, where one can see blue pearl. The forth ventricle is shaped like a diamond. At the bottom is central canal of the spinal cord and at the top is rishi kasha. Kasha means hair and rishi means seer of the mantra. The real change is evident within third ventricle of the brain. At the moment of enlightenment both the right and left pulses become harmoniously identical, equal, gentle and balanced in both superficial and deep pulses.

3.4 Organ pulses

Now we will shift our attention to the organ pulses which are also found on the first and seventh levels (fig 3.3). Remember the hollow organs are superficial level and semi-solid organs are present on deep level. To take this pulse, use one finger at a time. Pulse under a healthy condition the prana energy should be equal in the superficial and the deep pulses. But suppose colon is weak indicating a lack of energy. A feeble throb will be felt in the superficial pulse under the index finger on the right hand side of subject. The stronger pulse is represented by a plus(+), a weaker pulse by minus(-).



1	2	3	3	2	1	Pulse
Colon	Gallbladder	Pericardium	Bladder	Stomach	Small intestine	1st level
Lung	Liver	Vata, pitta, kapha circulation	Kidney	Spleen	Heart	7th level

Fig 3.3 - Location of the organ pulses

In ayurvedic texts there is no mention about reading the organs through pulse. However organs are introduced under the concept of srotas. Every srotas and its connecting organs are made up of dhatus. Now choose a partner and read the status of each organ pulse. Try to feel the relative strength of both the pulses under each finger. Find out whether colon is weak or the liver is weak. If the throbbing is strong, the strength of organ is good and vice versa.

Some people have strong deep organs which mean they have strong constitution. But in some the hollow organs are weak, which means their vikruti is more prevalent in superficial organs. So the power and the strength of specific organ pulse become weak due to weakness in that organ. On the other hand the strength of the organ may be depleted due to accumulation of ama or low agni of that particular organ which can be felt under the pulse as a feeble organ pulse without indicating any doshic spike. This shows weakness in that organ as a *khavaigunya*, defective space in the organ where the doshas has not yet reached to create pathological condition. The agni of that organ is low. If this condition is not treated, later any aggravated dosha may lodge in that organ to create changes, at which doshic spike develops.

3.5 Organ pulses of the right hand

3.5.1 Colon

The superficial pulse under the ring finger on the right side of subject corresponds to colon. If a strong spike is felt the colon is strong. When dosha increases and enters into organ it becomes weak, causing feeble pulse. If colon pulse is feeble and throbbing is felt at kapha location there is possibility of excess mucus, parasites, amoebae or some tumoras in fig 3.4. If colon pulse is weak with throb at pitta, it cause colitis, diverticulitis, chronic diarrhea, appendicitis and bleeding polyps. If colon pulse is low and throb is at vata the person may have chronic constipation, gases in the colon.

The qualities of vata are cold, dry, light and mobile. The mobile quality can carry excess pitta from intestine to colon causing colitis. When vata is pushing pitta, it is aggravated and may manifests in colon. But in this case pitta is innocent. Pitta being hot starts burning the colon. One should first treat the symptoms with the most significant manifestations. If the person is bleeding from the rectum and has a burning colon, don’t treat vata. Treat pitta dosha first.

Ayurveda talks about the concept of khavajgunya or defective space within the body. This space may be in the organ, srotas, localized area, dhatu etc. resulting from many possible factors for example, traumas, genetic inheritance, wrong diet or lifestyle. Once the space is weakened a circulating aggravated dosha may begin to accumulate there and initiate pathological changes.

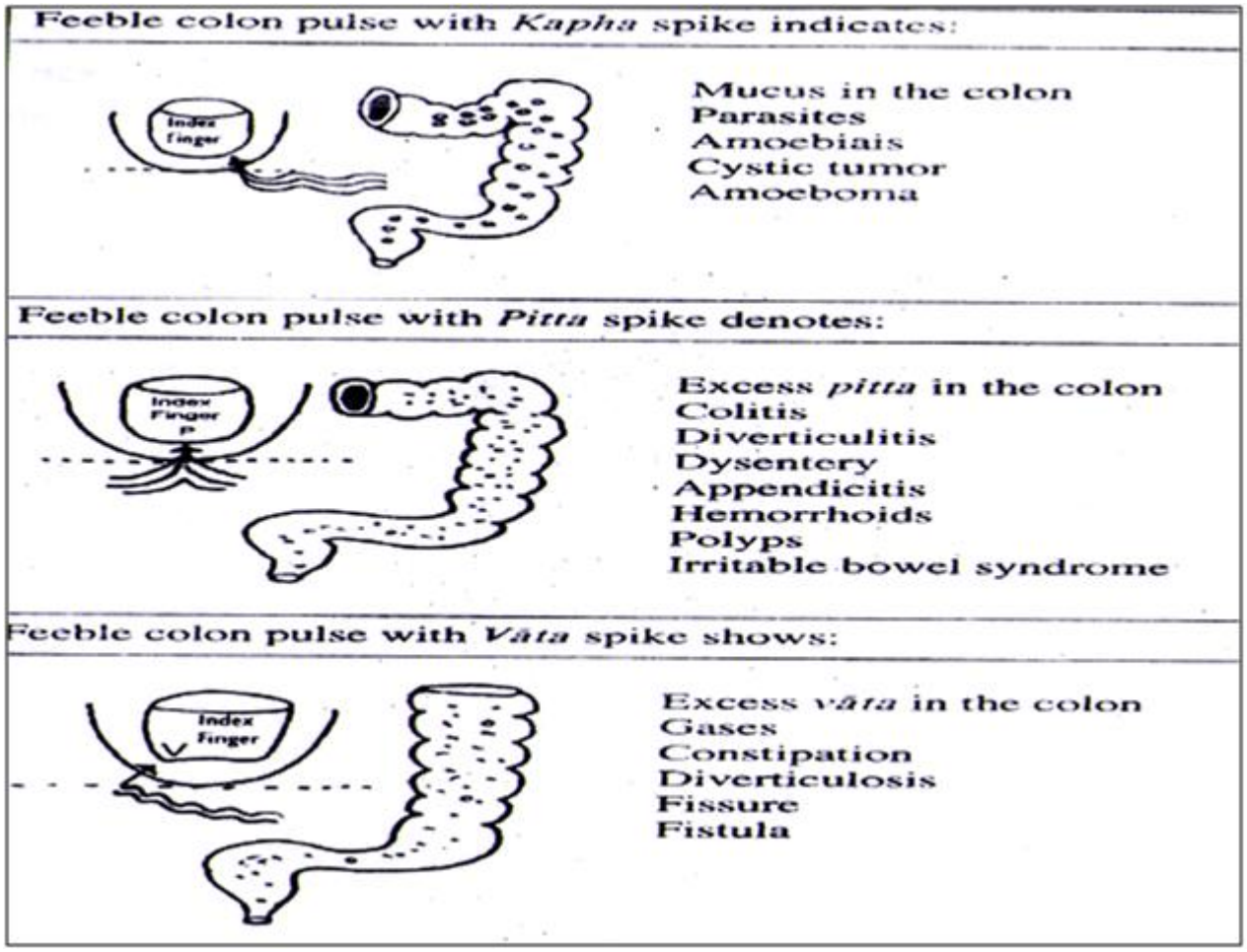


Fig 3.4 - Feeble colon pulse

3.5.2 Lung

The deep pulse under the index finger on the right side of the subject is the lung. If the lung pulse is feeble with the throbbing under kapha position there is possibility of pulmonary congestion, upper respiratory congestion or descending infection. There may be history of pneumonia, bronchiectesis or pleurisy. Kapha is heavy and goes down. With excess kapha the lungs become too damp and cold.

Fungus may also enter the lungs. If person is allergic to mold, damp and cold weather, there is excess kapha in the lungs. If pitta is involved in problem of the lungs, the spike will be at the middle of the index finger indicating a possibility of bacterial infection. Pitta can create bronchitis, trachyitis, alveolitis. It will create a situation of too much heat in the lungs. Excess pitta may cause chemical sensitivity as in fig 3.5. Vata involvement in lungs creates spike at the distal position of the index finger which may indicate respiratory allergy, wheezing, dry cough, or hoarseness of voice. Vata in lungs can cause inflation, an unnatural distention with air. This phenomenon is called emphysema.

For pitta pushing kapha in the lungs, drink one cup of ginger and licorice tea with 10 drops of mahanarayan oil. Ayurveda doesn't treat the organ alone but it deals with the root causative dosha.

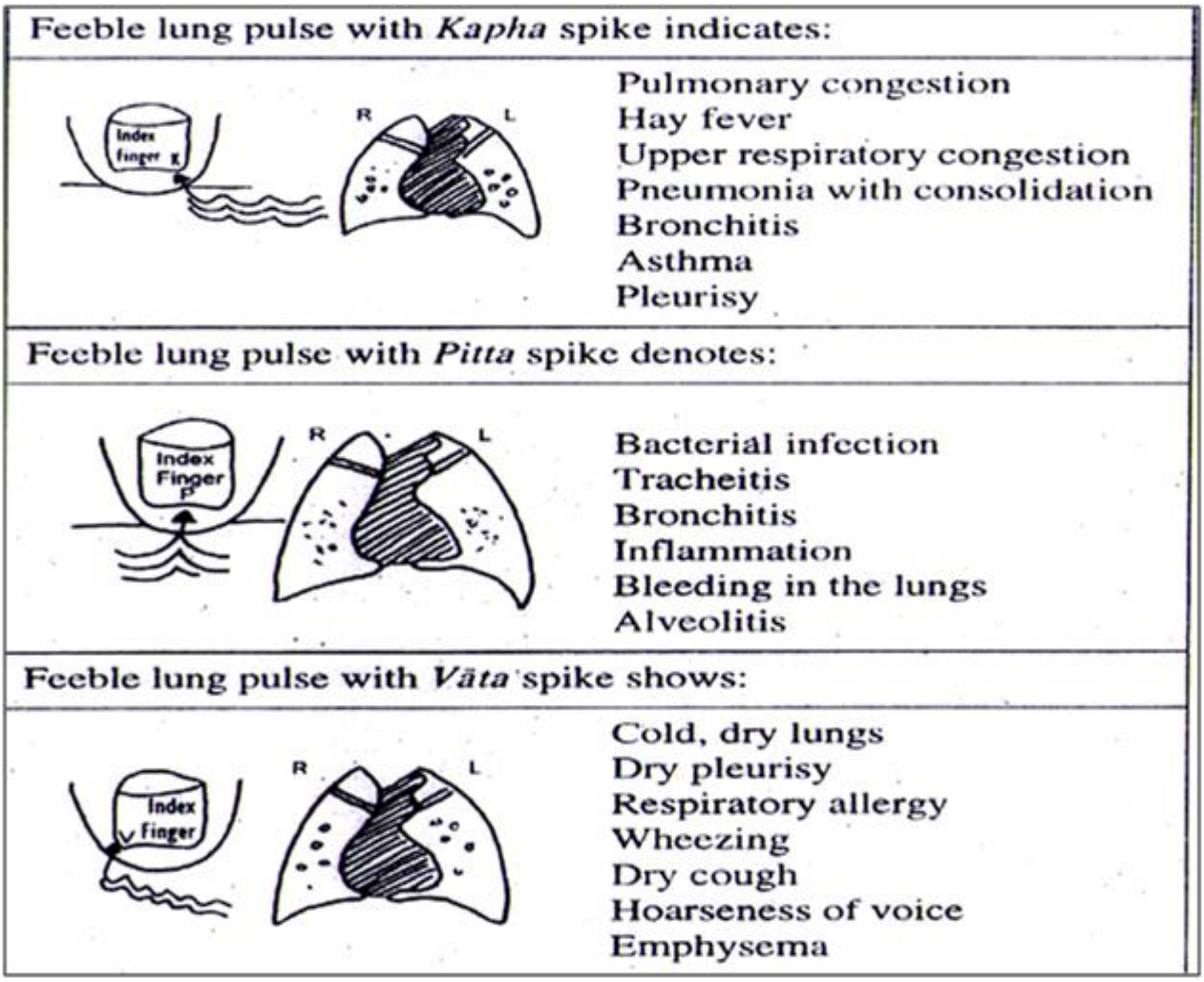


Fig 3.5 - Feeble lung pulse

3.5.3 Gallbladder

The superficial pulse of middle finger on the subject's right side is connected to gallbladder. A feeble pulse at kapha site indicates excess kapha which will make it sluggish creating thick bile and gallstones. Because of excess kapha the person become sensitive to fatty fried food. Even fat from peanut butter may create headache and dull aching pain in liver area.

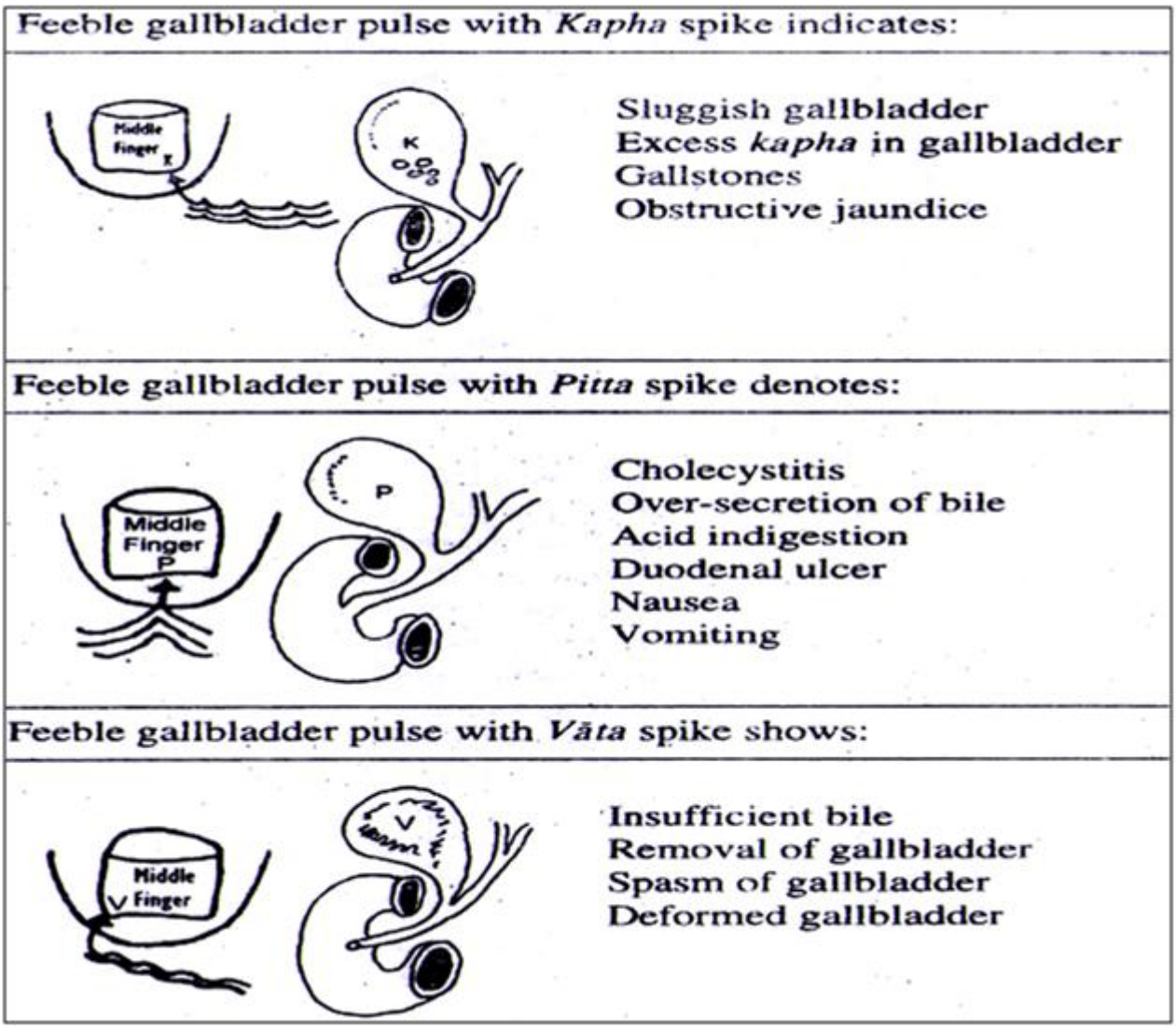


Fig 3.6 - Feeble gallbladder pulse

The feeble spike at pitta indicates excess pitta which may create cholecystitis, an inflamed gallbladder. The person has pain and tenderness and pressure put on gallbladder causes the person to flinch. It may also create acid indigestion and lead to ulcer.

Vata in gallbladder will create tightness in the neck and shoulders. If pulse is feeble at vata spike the gallbladder has insufficient bile (fig 3.6). If it is removed, the pulse of gallbladder will be weak. If the organ is a transplant the prakruti pulse will be felt, but the transplanted pulse of the organ will be feeble.

Ideally it is better to receive an organ from someone's of the same prakruti. If prakruti is not same body will increases the likelihood of rejection of transplant organ. Each organ stores its memory in the connective tissue. Memory is not only stored in brain but also in heart, liver and other organs.

When an organ is transplanted from one body into another, this stored memory goes with the organ and becomes part of the recipient's memory.

3.5.4 Liver

The deep pulse under the middle finger on the right side of subject is liver. A feeble pulse with spike at kapha indicates excess kapha molecules which can create fatty degenerative changes. The liver become large due to which it cannot digest fatty fried food.

Excess kapha may denote serum hepatitis where virus live in molecules of body fluid e:g serum, saliva and semen. The person may get hepatitis B which can become hepatitis C due to post transfusion complications, leading to cirrhotic changes which are tridoshas disorders. It is the death of liver cells, but if detected in early stage liver can be regenerated. Excess liver can create lipomas, which are fatty tumors. And also can create high cholesterol.

One of the causes of obesity is excess kapha in the liver. Obesity, hypertension, high cholesterol and low libido go together.

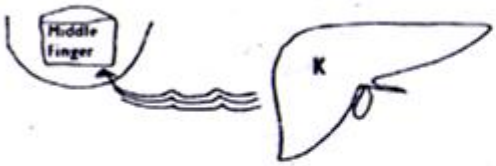
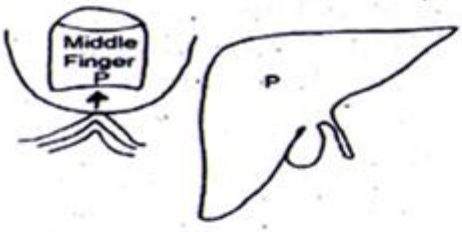
Feeble liver pulse with *Kapha* spike indicates:	
	Fatty, degenerative changes Enlarged liver (hepatomegaly) Hepatitis B (serum hepatitis) Multiple lipomas High cholesterol Obesity Hypertension Low libido
Feeble liver pulse with *Pitta* spike denotes:	
	Hepatitis A (infectious hepatitis) Jaundice Mononucleosis Hemorrhagic condition Deep-seated anger, hate Chronic fatigue syndrome
Feeble liver pulse with *Vāta* spike shows:	
	Suppressed liver enzymes Shrinking of the liver cells Cirrhotic changes Hepatitis C (post-transfusional) Portal hypertension

Fig 3.7 - Feeble liver pulse

Excess systematic pitta in the liver leads to hepatitis A and jaundice. It may create bleeding tendencies such as bleeding gums, piles, bloodshot eyes or capillary hemorrhages that cause a person to bruise easily. High pitta also makes person emotionally judgmental, angry and critical indicating deep seated unresolved anger, envy and hatred stored in the liver. It may also lead to chronic fatigue syndrome and mononucleosis, causing person to feel tired and exhausted. If the enzymes of liver in blood test are elevated, pitta in the liver is high. If these enzymes levels are low in the blood, it may be sign of high vata. When vata is high pitta may be suppressed and liver enzymes may be diminished. High vata can create cirrhotic change. Liver cells shrink and because of this, vata create dying of hepatic cells.

The result is increase in hepatic pressure which leads to portal hypertension and this condition will push pitta. This may cause bleeding, so vata in the liver is the serious condition which is denoted by a vata spike with a weak liver pulse.

Pitta is necessary for coloring the rasa dhatu by producing red blood cells, and excess pitta in the liver can affect the production of red blood cells and may create sickle cell anemia, aplastic anemia as per the condition. The liver maintains the consistency of the blood and coagulation and bleeding time depend upon its function. Therefore ayurveda treats the liver in order to regulate the normal function of rakta srotas. The agni present in liver can regulate the function of spleen (reservoir of blood). When spleen is enlarged pitta ia affected which affects agni in the liver. This condition diminishes the effectiveness of the immune system as explained in fig 3.7.

3.5.5 Pericardium

It has a special pulse under the ring finger at the superficial level on the right hand of the subject. *Hridya dhara kala* means membranous structure around the heart. These are of two types: the parietal pericardium and visceral pericardium and within the space there is fluid which is one of the components of kapha. The myocardium muscles of the heart and endocardium the inner lining of the heart are also *Hridya dhara kala*. kapha is present in the lungs, bronchi, bronchioles and it supports the lungs. And it prevents drying of lung tissue. Kapha enters rasa and rakta dhatu. Through its energy flow it goes to neck, arms and sacrum where it supports all kapha system by circulation through heart. The pericardium moves with the heart and this movement generates electricity which is carried through mucous membrane of blood vessel. This electricity is maintained by *ojas*.

If the pericardial pulse is feeble with spike at kapha curvature there is possibility of congestion which may lead to blocking prana, creating bradycardia or slow heart rate. Emotionally pericardium is related to unresolved, deep-seated attachment and unresolved grief.

If the pulse is feeble and spike is felt at pitta site, there is pericardial inflammation, pericarditis and non-inflammatory burning sensations (fig 3.8). When one eats hot food like pepper and chilly and gets burning sensation it is called non-inflammatory burning sensations.

Because of nerve connection a burning sensation of stomach creates pain in heart. Emotionally there may be unresolved anger, hatred and feeling of rejection struck in the heart and pericardium which may be associated with tuberculosis in the long term.

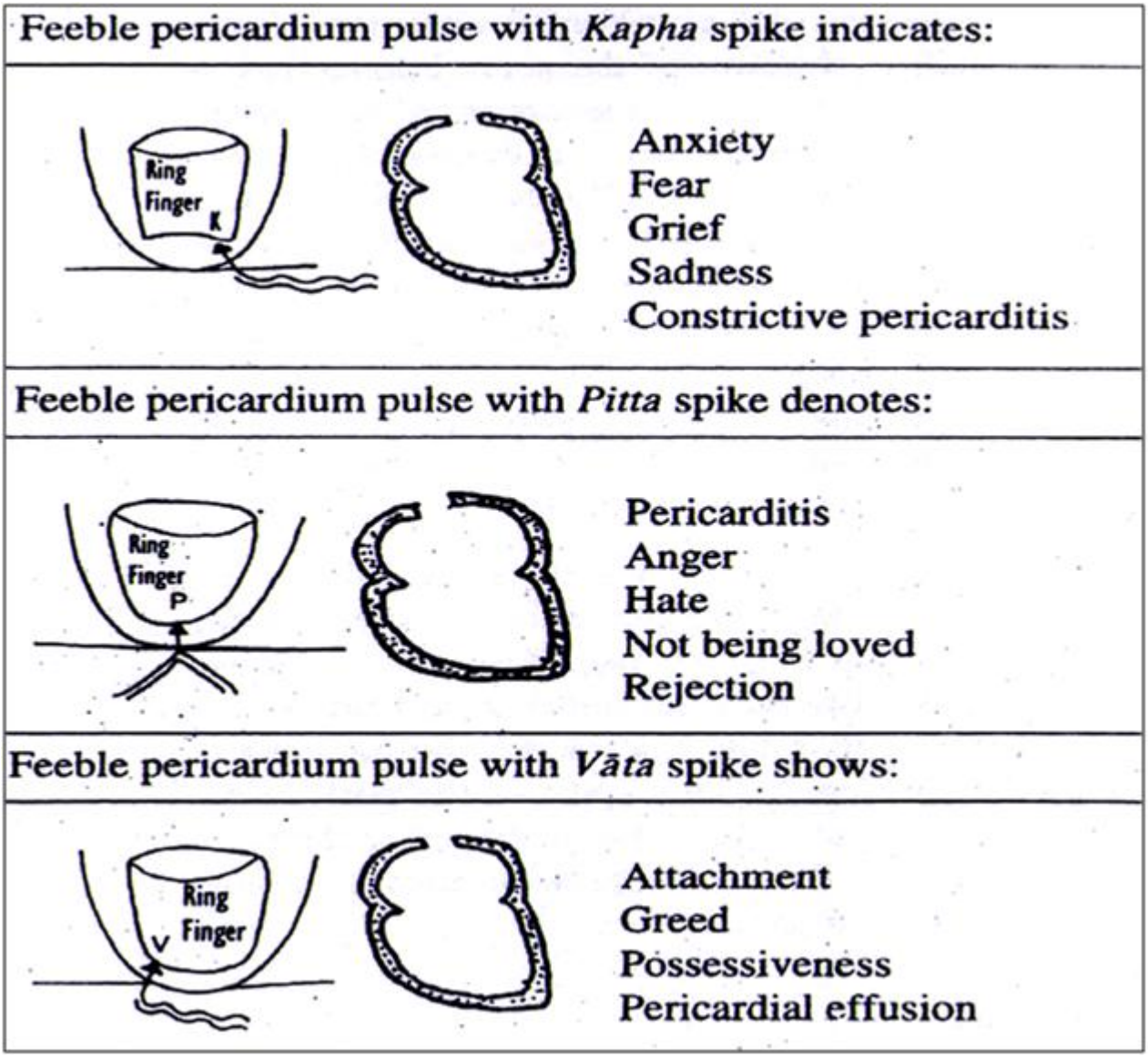


Fig 3.8 - Feeble pericardium pulse

Now we will consider vata. When the pulse is feeble with spike at distal curvature the site of vata may indicate multiple extra systoles. The pulse will be irregular with arterial flutter with fibrillation. A vata spike in the pulse can denote deep seated fear, insecurity and loneliness. Thus this pulse is used to understand the emotional status of subject**.**

3.5.6 Circulation

The deep pulse of the ring finger of the subject's right side corresponds to the circulation. It is fascinating that the heart, such a small organ creates a wave that doesn't die. The pulsation of this wave goes to tip of fingers and toes. This is due to functional integration of vata, pitta and kapha as in fig 3.9.

Vata is expansive and clear. Pitta is hot, sharp, liquid and flowing. Kapha is slow, heavy and oily. The common factor between vata and pitta is light, between vata and kapha is cold, between kapha and pitta is oily. Heat expands and cold contracts. The light quality creates upward movement and heavy quality creates downward movement.

We have three diaphragms – the pelvic, abdominal thoracic and cerebral. The cerebral supports the brain. With gentle movement it acts as pump. The plates of the skull move slightly.

There is thick network of blood vessels in the brain. Some people have a cold scalp, which means prana is weak because the cerebral diaphragm doesn't move properly. The abdominal thoracic diaphragm moves the lungs. Inhalation and exhalation regulate circulation. This diaphragm brings more blood to the arms.

Therefore cold hand means poor circulation from incomplete diaphragmatic breathing. The pelvic diaphragm is governed by vayu and it regulates the circulation in the lower extremities. Cold legs indicate weak apana, cold hands means weak samana, cold scalp means weak prana. Though vayu is responsible for circulation, it is influenced by prana, samana and apana, resp. which can be detected at the seventh level of pulse under ring finger.

Kapha affects circulation because the pulsations created in the heart are carried to the periphery, to the capillaries due to functional integration of tridosha. Kapha doesn't allow impulse to die. When kapha is not carrying sufficient impulse the person will have poor circulation in the head. The scalp and tip of the nose will be cold, sinuses will be congested and person will faint.

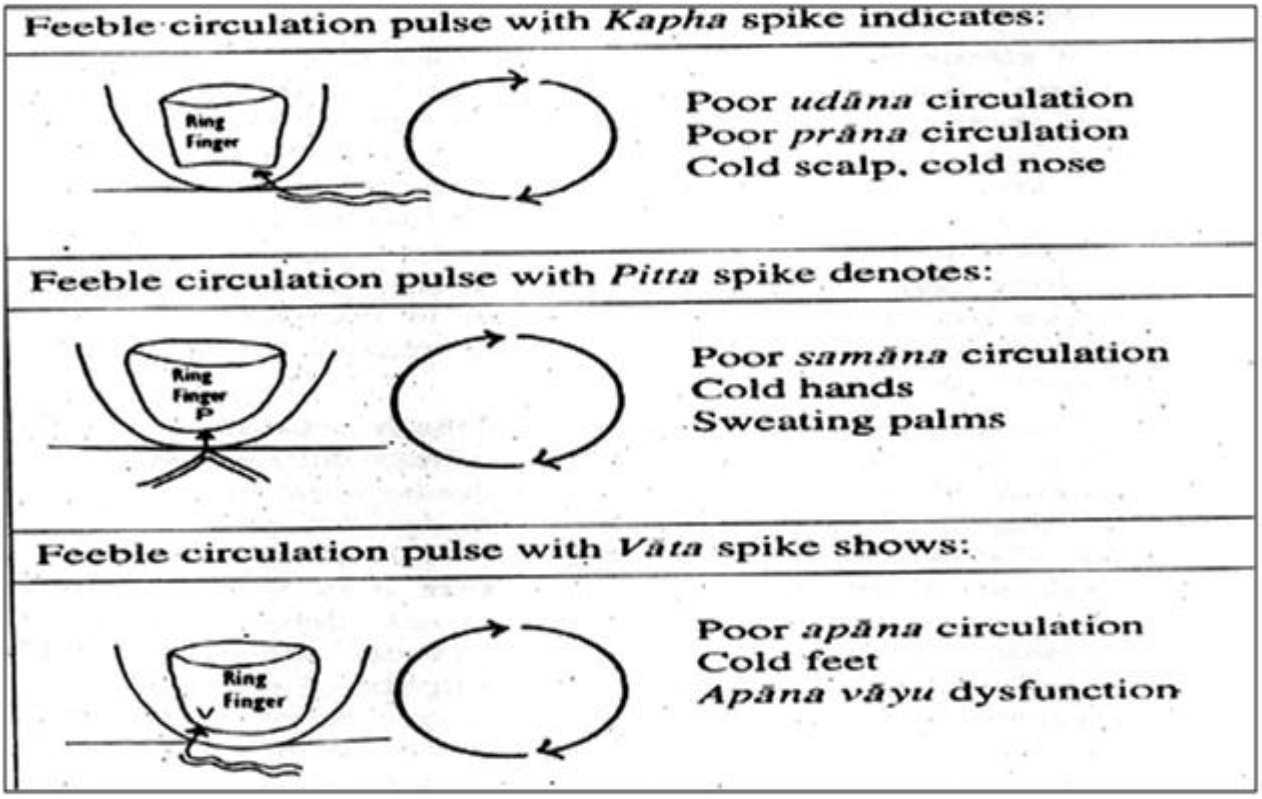


Fig 3.9 - Feeble circulation pulse

On the other hand, due to excessive pitta rushing through the cerebral circulation, one can experience vertigo or dizziness and at same moment can feel much heat at the scalp and tip of the nose. A feeble kapha pulse denotes poor circulation in the head and feeble pitta pulse indicates poor circulation in the hands and seating palms. A weak pulse with a vata spike shows sluggish circulation in the lower extremities.

3.6 Organ pulses of the left hand

3.6.1 Small intestine

The index finger at the superficial level corresponds to the small intestine. A spike at kapha site, the proximal curvature shows excess mucus in the small intestine, slow intestinal digestion or undigested fat in the small intestine leads to fatty diarrhea called steatorrhea. A spike at central curvature of the index finger shows pitta suggesting enteritis, duodenal ulcer, and pre-umbilical burning sensation. The person has alternating diarrhea and constipation.

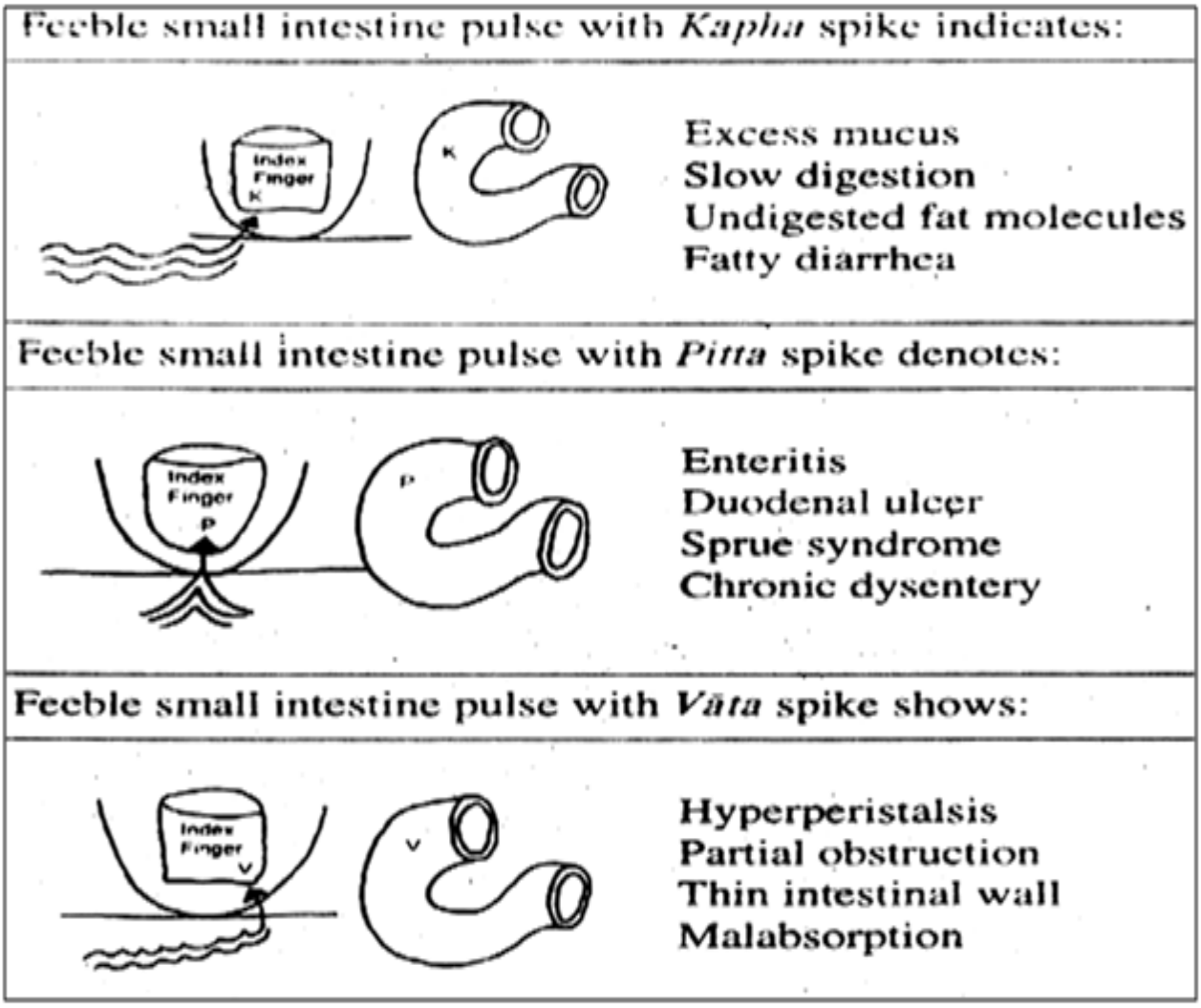


Fig 3.10 - Feeble small intestine pulse

A feeble small intestine pulse with a spike at the distal curvature of the finger indicates hyperperistalsis, intestinal partial obstruction. The condition may lead to papery thin wall of small intestine causing chronic mal-absorption syndrome (fig 3.10).

3.6.2 Heart

The deep pulse at the seventh level under the index finger is the heart. It is composed of heart muscle and inner lining called endocardium. A kapha spike shows slow heart rate, heart block, bundle branch block or malignant hypertension called essential hypertension, which is common in old people. This spike is sigh of high cholesterol and high triglycerides.

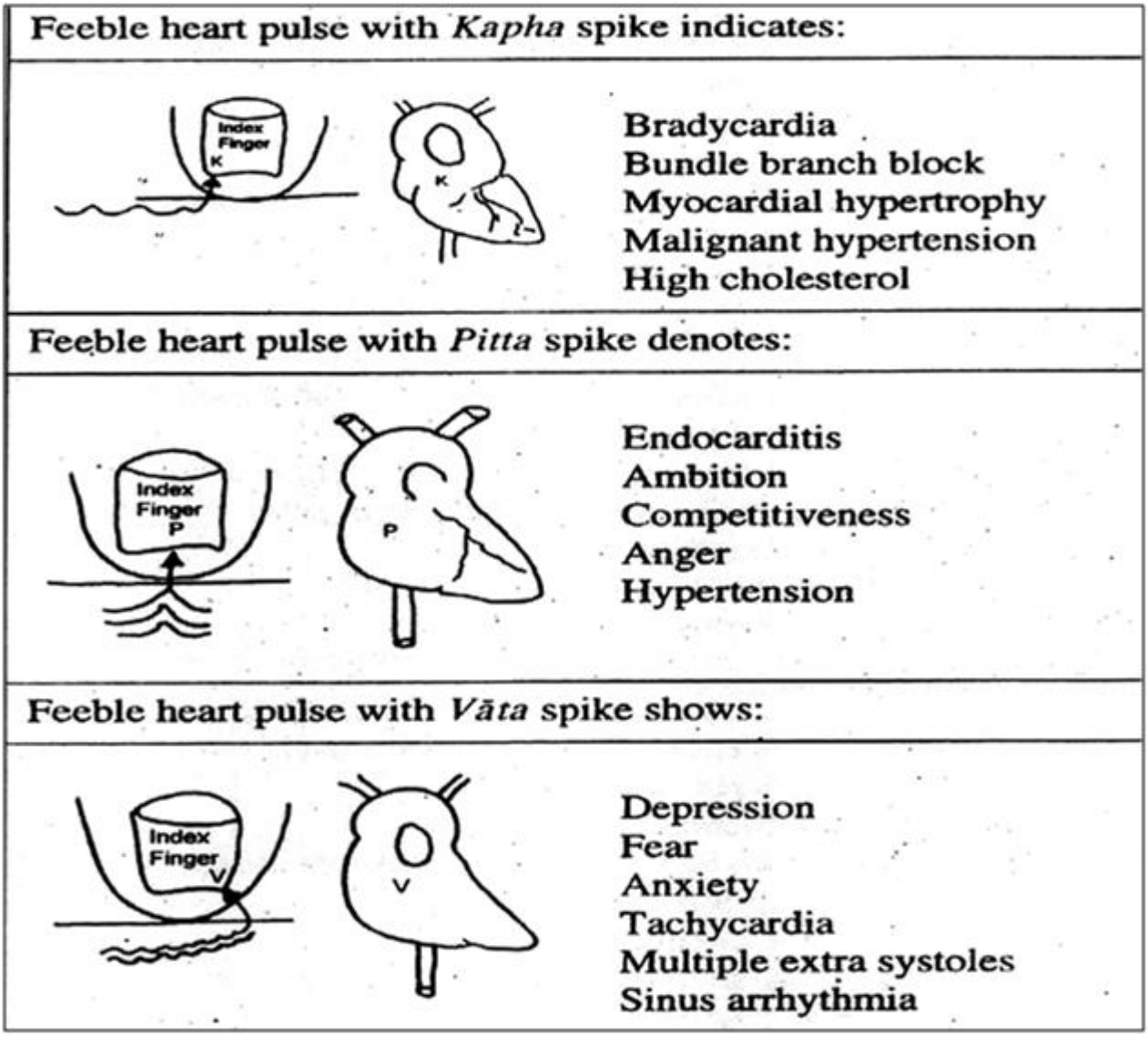


Fig 3.11 - Feeble heart pulse

A strong pitta spike under the index finger denotes myocarditis, endocarditis in the heart. Fig 3.11 explains the feeble heart pulse. When pitta is high person becomes judgmental, critical, ambitious and competitive. This pulse may be of acute hypertension of stressful condition.

One of the functions of pitta in heart is to transform feelings into emotions and maintain self-esteem. Vata type of heart includes tachycardia, atrial flutter with fibrillation, hypotension or alternating pulses. During vata the pulse becomes fast during inhalation and becomes slow on exhalation. This is known called sinus arrhythmia. Vata many times create pseudo cardiac pain. A person may have palpitations, anxiety, insecurity or nervousness.

Depression can be vata, pitta or kapha type. Kapha type of depression is due to lack of sunlight, obesity, diabetes, hypertension or excess sleep. Too much pitta may create thoughts of suicide and is associated with addiction to success or fear of failure. Vata depression is associated with fear, anxiety, insecurity and fear of the unknown. The heart is most vital organ. When the heart stops, consciousness leaves the body in ordinary person. But when yogi stops his heart through yogic practice, his consciousness goes deeper layer of life beyond birth and death. That is called *Samadhi*. The brain cells have a recording of death and birth.

3.6.3 Stomach

Under middle finger the superficial pulse on the left side of the subject is the stomach. A spike at proximal curvature shows excess kapha which will lead to low agni, excessive mucus secretion, chronic indigestion, production of ama and hypochlorhydria which means hydrochloric acid is lower than normal. There may be two spikes on the finger at the site of stomach pulse indicating excess pitta and kapha.

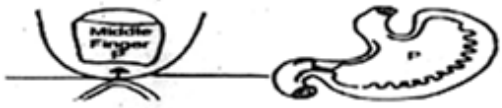
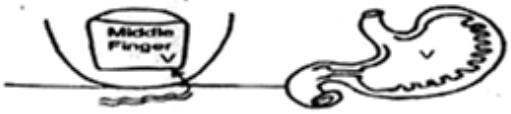
Feeble stomach pulse with *Kapha* spike indicates:
 Excess *kledaka kapha* in the stomach Low *agni (manda agni)* Chronic indigestion *Ama* in the stomach hypochlorhydria (low hydrochloric acid) Pre-diabetic condition
Feeble stomach pulse with *Pitta* spike denotes:
 Excess *pāchaka pitta* in the stomach Hyperacidity Strong appetite but poor digestion due to low *agni* and high *pitta* Gastritis Acid indigestion Peptic ulcer
Feeble stomach pulse with *Vāta* spike shows:
 Hyperactivity in the stomach Nervous stomach Increased peristalsis *Vishama agni* (irregular appetite) Pyloric stenosis Distended stomach Gas in the fundus of the stomach Narrow stomach

Fig 3.12 - Feeble stomach pulse

A pitta spikes denotes its excess and indicates over-secretion of hydrochloric acid(fig 3.12). Pitta is increased by liquid quality leading to low agni which in turn causes acid indigestion, acute gastritis and peptic ulcer. The presence of vata indicates imbalanced agni, irregular appetite and impaired digestion, gases in the fundus of stomach

3.6.4 Spleen

The deep pulse at seventh level under the middle finger on the left side of the subject denotes spleen. A feeble spike at kapha site indicates megaloblastic anemia, red blood cells are large in size but small in number. This spike can indicate fluid in abdominal cavity which is called ascites.

A pitta spike suggests splenitis and excess pitta in spleen can create myeloid leukemia. In this person bleeds. Enlargement of spleen can lead to anemia. Red blood cells are broken and they become deformed as in sickle cell anemia.

When vata is pushing pitta in the bone marrow, the qualities of pitta disturb the red blood cells. Any dosha in the spleen may affect immune system. A vata spike under middle finger at the spleen site can lead to aplastic anemia, where the red blood cells are not properly formed; microcytic anemia, where the cells are smaller than normal size; splenic pain, extreme debility and low immunity. These conditions are very serious and not so common, but people have low spleen energy. Fig 3.13 shows feeble spleen pulse.

Spleen creates white blood cells. These cells are policemen, the guards of the body that catch bacteria and kill the viruses and maintain immunity.

Immunity is also based upon positive thinking. Negative thinking adversely affects the spleen and the entire immune system.

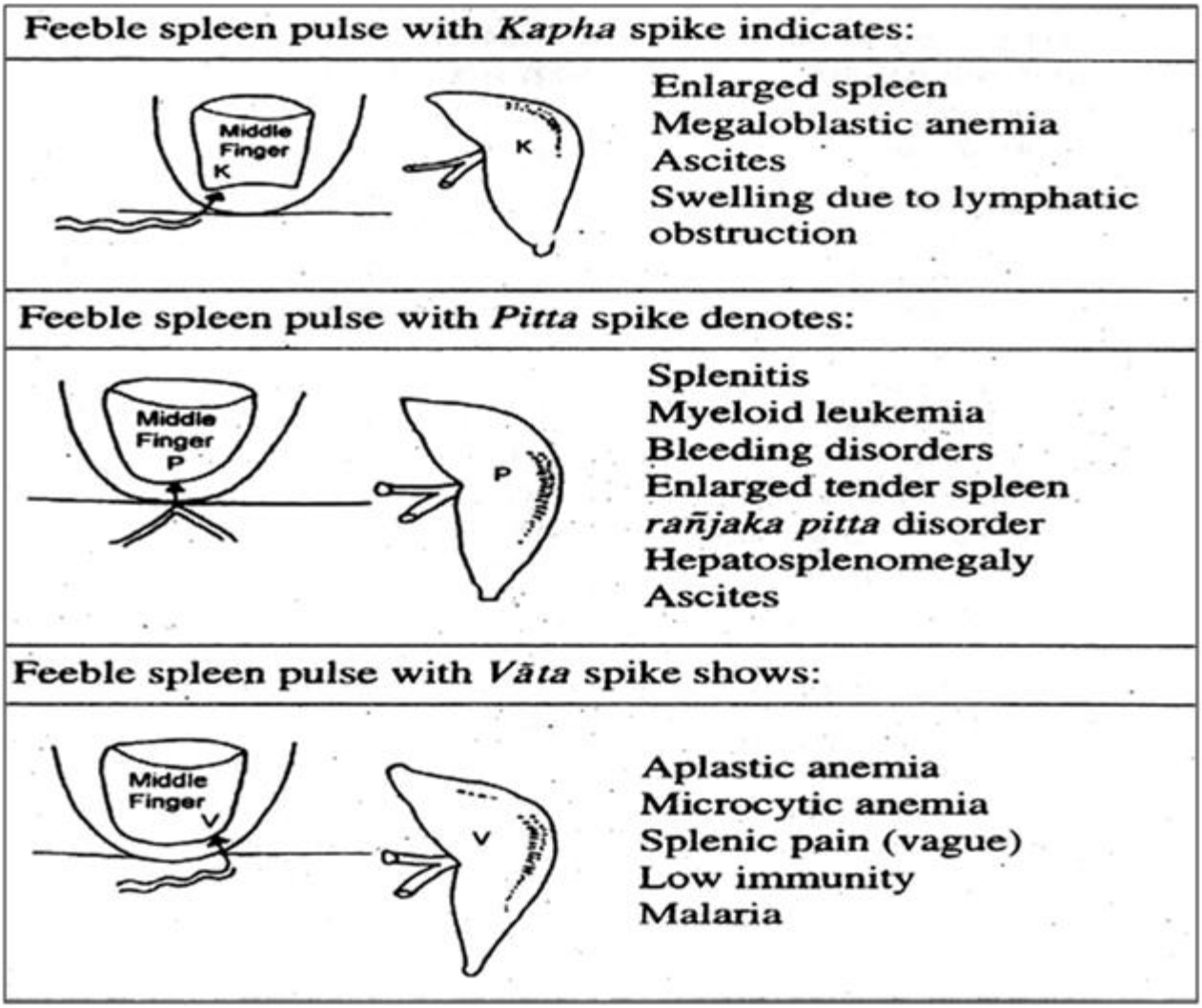


Fig 3.13 - Feeble spleen pulse

3.6.5 Bladder

The last example of the superficial pulse on left side of subject under ring finger is the urinary bladder (*basti)* (fig 3.14). if the bladder pulse is feeble at kapha site with low bladder energy shows excess kapha. Just give a kapha – soothing diet and the condition will be corrected. But if it remains the person will get proteinuria, because kapha resembles protein molecules. Another indication may be excess urination, polyuria which is sign of early diabetes. In pregnancy woman builds more kapha in her body in order to nourish fetus. Kapha conditions include polyuria, diabetes, and frequent urination.

A pitta spikes denotes it's excess and indicates over-secretion of hydrochloric acid. Pitta is increased by liquid quality leading to low agni which in turn causes acid indigestion, acute gastritis and peptic ulcer. The presence of vata indicates imbalanced agni, irregular appetite and impaired digestion, gases in the fundus of stomach.

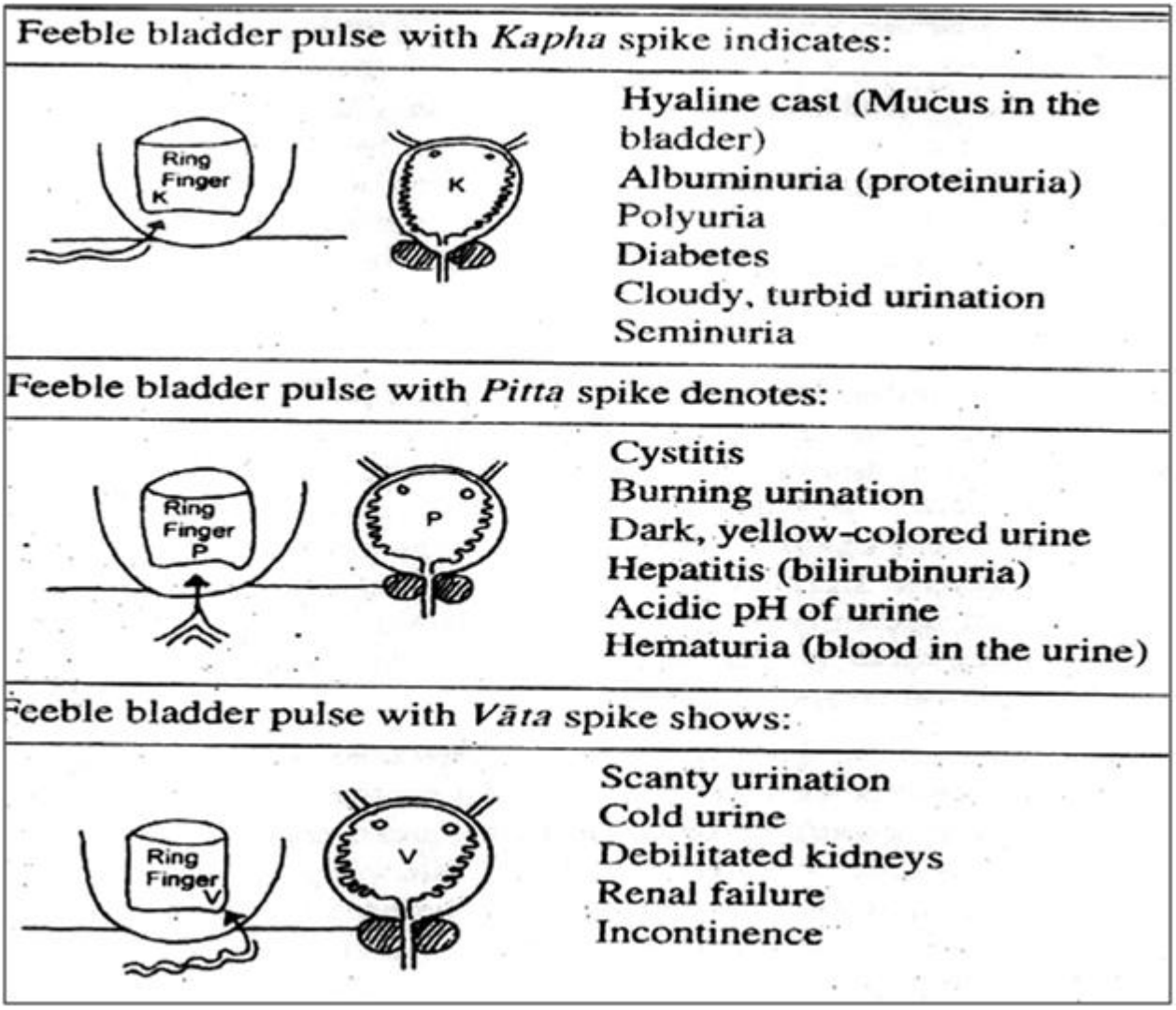


Fig 3.14 - Feeble bladder pulse

A pitta spike indicates excess pitta in the bladder which may create repeated attacks of cystitis, inflammation of the bladder, dark yellow and even blood in urine. A vata spike and low bladder energy may denote scanty urination because urine is not properly filtered by kidney. It may lead to unuria or suppression of urine.

3.6.6 Kidney

The deep pulse under the ring finger on the left hand side of subject is kidney pulse. If kidney energy is low with spike at kapha site, kapha may drain the kidney energy leads to albuminuria. Unabsorbed calcium molecules lodged in the kidney create ceystalluria and these calcium crystals can lead to calcium stones. Other conditions caused by kapha are diabetes, hypertension, polycystic kidney, hydronephrosis and glycosuria. A person having more caffeine, sugar and milk may get excess kapha and dull aching pain in kidney.

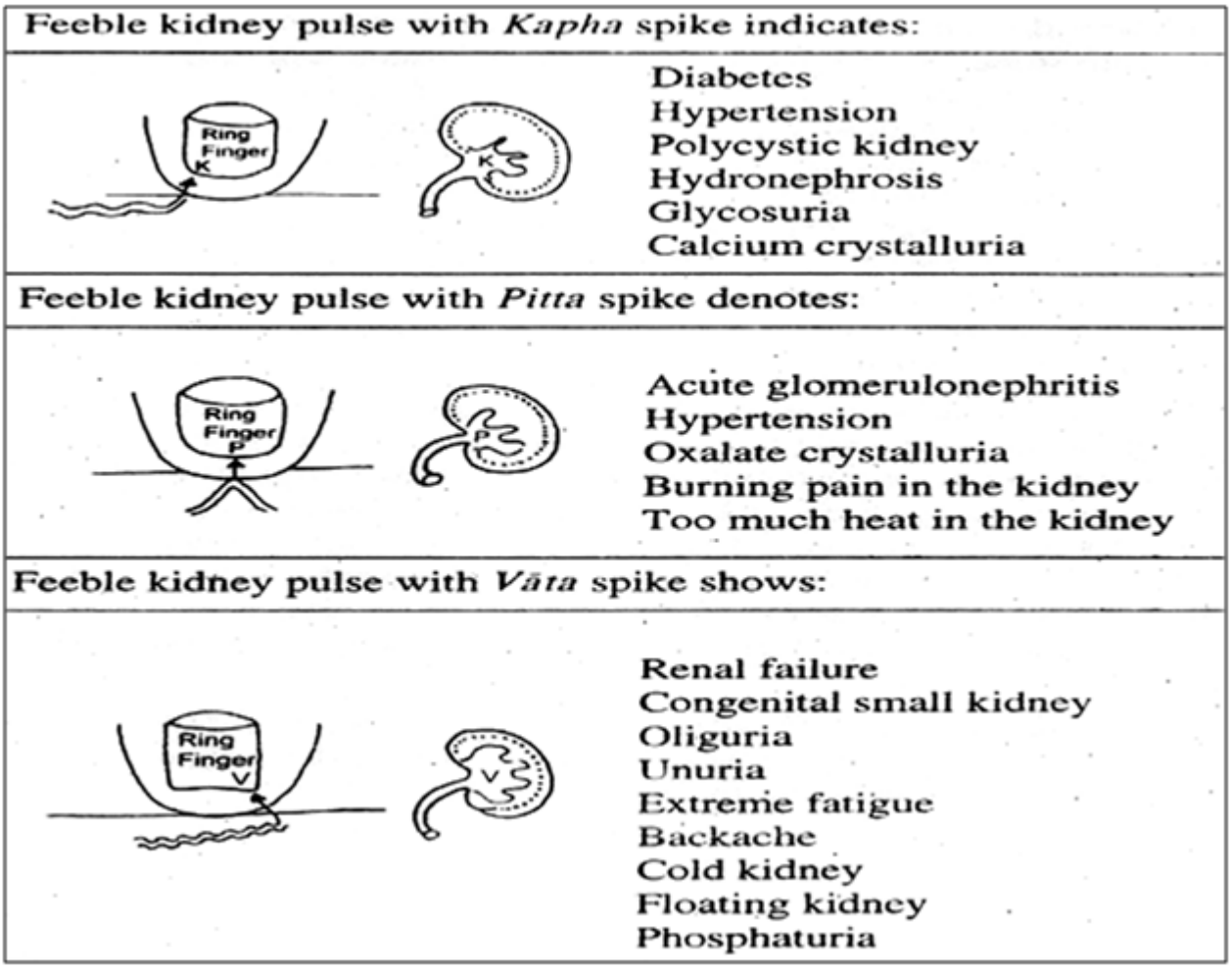


Fig 3.15 - Feeble kidney pulse

Pitta in kidney pulse shows excess pitta in kidney leading to nephritis or infection of the urinary tract, acute glomerulonephritis and hypertension. Pitta attracts oxalate crystals.

People having kidney stone will either have kapha pulse, a pitta pulse or a kapha/pitta pulse which means pitta pushing kapha in the kidney.

Vata in the kidney causes floating kidney, which means kidney are descended. Some people are born with kidneys that never grow to full size, or one kidney is small and one kidney is normal. These people have vata dosha in the kidney as shown in fig 3.15. Other conditions include oliguria, unuria, extreme fatigue, lower backache, phosphate crystals in the kidney leading to calcium phosphate stones.

With this background, again choose a partner and feel the superficial and deep pulses. Try to understand whether there is vata, pitta or kapha in the weak organ pulses [1].

CHAPTER-4 Literature survey

4.1 Intelligent Diagnosis of human disorders based on Ayurveda

In 1996 Kher S. *et al.* discussed the Ayurvedic approach of treatment of human disorders which was tested for over hundred years. The work proposed is an attempt towards diagnosis of human disorders and is based on Ayurveda. The system is configured using the fuzzy logic concept. The paper discusses the Ayurvedic approach of treatment, the design and its implementation. System has been simulated and tested for a number of patients. It is found that performance of the system is satisfactory. It is evaluated in number of cases and the results are consistent with the expert physician. The system can further be augmented with set of rules for diagnosis, if needed [7].

4.2 Pulse Type Classification by Varying Contact Pressure

In 2000 Yoon Y. *et al.* introduced a new technique of quantification of pulse characteristics in connection with contact pressure based on the diagnosis in Traditional Chinese Medicine (TCM). Diagnosis by traditional pulse analysis requires long experiences and a high level of skill, and interpretation is subjective, depending on the practitioner. Thus, it would be of great significance to develop a quantitative and systematic measurement scheme to establish an objective diagnostic system for classifying the pulse, which could be used in the practice of Traditional Chinese Medicine (TCM). They proposed a new quantification scheme of specific pulse characteristics. These characteristics were determined using the pressure-adjusting pulse detector. They provided data only for illustrative purposes, deferring statistical analysis of samples of a larger population. This quantification could be useful for diagnostic purposes; for example, by detecting changes of the three quantities according to the health condition or particular disease of a patient, or by analyzing correlations among these quantities and other physiological variables [8].

4.3 The Scientific Value of Ayurveda

In 2005, Hankey A. discussed about the scientific value of Ayurveda with the example of experimental investigations into the theory of Ayurveda and the Vedic system of medicine from ancient India. He mentioned about Ayurveda that it has had a great increase in popularity in the last 2 decades and many

trained practitioners of Western biomedicine are now putting its simple and profound system of understanding health and disease, known as tridosha, into practice [9].

4.4 A preliminary Research on Analysis of Pulse Diagnosis

In 2007, Chen L. *et al*. presented that the vibration of the surface of the skin caused by pulsation of the artery was measured as a method of settlement of the Pulse diagnosis and the development of the device to analyze pulse taking quantitatively was tried. Firstly, they explained the Pulse diagnosis and listed the problems. The system was developed for solving the problems in diagnosis training, in which the volume change in skin surface due to pulsation was used and amplified into a change of liquid surface, which could be detected and judged visually. The changed behavior of liquid surface was measured with sensors and displayed quantitatively. Measurements were done and the effect of the measuring system was confirmed. There was scope for further study, that require more attention on the construction of such type of system with controllable pushing force, which is so important to obtain repeatedly reliable results [10].

4.5 Nadi Tarangini: A Pulse Based Diagnostic System

In 2007, Joshi A.J. *et al*. worked on Nadi Tarangini, which is a Pulse based diagnostic system. Ayurveda was a traditional medicine and natural healing system in India. Nadi-Nidan (pulse based diagnosis) was a prominent method in Ayurveda, and was known to dictate all the salient features of a human body. In their work, they provided the details of the procedure for obtaining the complete spectrum of the Nadi (pulses) as a time series. The system Nadi Tarangini contained a diaphragm element equipped with strain gauge, a transmitter cum amplifier, and a digitizer for quantifying analog signal. The system acquired the data with 16-bit accuracy with practically no external electronic or interfering noise. The waveforms obtained with their system had been compared with the other similar equipment developed earlier. The pulse waveform shown the desirable variations with respect to age of patients, and the pressure applied at the sensing element. The system was being evaluated by Ayurvedic practitioners as a computer-aided diagnostic tool. Modern pressure sensors could reflect the “feeling” information used in the Indian system of Ayurveda, or in Traditional Chinese Medicine (TCM). Rigorous machine learning algorithms could be applied on these waveforms to classify them into major types of Nadis defined in Ayurvedic literature [11].

4.6 Nadi Yantra: A Robust System Design to Capture the Signals from the Radial Artery for Non-Invasive Diagnosis

In 2008, Abhinav *et al*. presented a robust system Nadi Yantra that monitors pressure variations from the points of interest for pulse diagnosis, thereby eliminating subjective errors and overcomes the limitation of mastering the art of pulse diagnosis with experience. This system comprises of three identical piezo based sensors, amplifier and filter circuit, a mechanical set-up and a data acquisition system (BioPac-150TM) which captures the signal from those three precise positions of the radial artery thereby giving an objective approach to the science of pulse diagnosis. Nadi Yantra allows recording for hours by an automated external pressure on the three positions thereby completely removing the potential for errors incurred when a person does the job of applying pressure. The locking mechanism significantly resists the motion artifacts as well. Repeatability, reproducibility and stability of the system has been verified. Signal processing techniques were applied to obtain morphological features such as amplitude, power spectral density, band power and spectral centroid to reflect variations in signals from the three channels. Data acquired from the system at three points gives unique information and can be used for disease diagnosis [12].

4.7 Application of wavelets based multiresolution analysis to detect relevant points of interest from finger-tip photoplethesmography and pressure signal from the radial artery

In 2008, Prakash P. *et al.* worked on application of wavelets based multiresolution analysis to detect relevant points of interest from finger-tip Photoplethysmography (PPG) and pressure signal from the radial artery. They applied and evaluated the performance of wavelets and selected an appropriate wavelet to detect the peaks and dicrotic notch from the waveform captured from infrared finger-tip Photoplethysmography (PPG) and detect the significant peaks and valleys from the signal captured from the radial artery. Accurate detection of dicrotic notch is important as it finds its usage in various medical applications e.g. pulse oximeters, vascular diagnostics, digital beat-to-beat blood pressure measurement systems and autonomic function analyzers. The method was extended to detect points of interest in pressure signal from radial artery. Radial artery signals were captured from a robust system called ‘Nadi Yantra’ developed for the validation of ancient method of non-invasive pulse diagnosis of ailments. The system uses piezoelectric based pressure system to capture the palpations from the radial artery. To

characterize the signals, wavelets were applied and the percussion wave, tidal wave and dicrotic notch were detected. The techniques developed were executed on a set of 120 data samples from healthy subjects. Daubechies wavelet was found to be suitable for PPG and radial artery pulse analysis. Overall efficiency of 98.45% for PPG signal and 97.89% for radial artery signal was achieved. Wavelet based multiresolution analysis takes advantage of the characteristics of time-scale analysis and effectively filters out noise from signal by rejecting irrelevant detail levels. It also characterizes a radial pulse signal from a novel pulse recording instrument and detects the percussion wave, tidal wave and dichrotic wave. This technique provides an objective approach to the ancient science of pulse diagnosis [13].

4.8 Wavelet Decomposition and Feature Extraction from Pulse Signals of the Radial Artery

In 2008, Sareen M. *et al*. worked on wavelet decomposition and feature extraction from pulse signals of the radial artery. Pressure signals from the radial artery are captured using a novel pulse recording instrument and processed using wavelets. The motivation behind this study is the validation of the noninvasive method of pulse diagnosis. The signals from the radial artery were captured using a robust electromechanical system, 'Nadi Yantra' which uses piezoelectric based pressure sensors to capture the palpations. Percussion peaks were identified and the interval between these was used to calculate heart rate variability (HRV), a useful tool for assessing the status of the autonomic nervous system noninvasively. Time domain indices were calculated from direct measurement of peak-peak (PP) intervals and from differences between the PP intervals. Frequency domain indices such as very low frequency (VLF) power, low frequency (LF) power, high frequency (HF) power, LF/HF ratio were also calculated. A nonlinear Poincare analysis was carried out. Results from datasets were depicted. The wavelet based technique was used to decompose the pressure signal from the radial artery. Multi-resolution wavelet analysis was used to detect the percussion peaks and the P-P time series was obtained. A HRV plot depicting function of the ANS was obtained from the PP time series. Time domain and Spectral analysis of the P-P series gave significant features. This P-P relationship was fit to an ellipse using least squares and characteristic features of the ellipse obtained. These features hold significance in the study of short term and long term variability of the P-P time series. Wavelet based method proved most effective because of its ability to filter out noise and low frequency components and retain relevant detail. The wavelet based detector has advantages of time-scale analysis as well as frequency analysis [14].

4.9 Assessment of heart rate variability derived from finger-tip photoplethysmography as compared to electrocardiography.

In 2008, Selvaraj N. *et al*. worked on assessment of heart rate variability derived from fingertip Photoplethysmography as compared to electrocardiography. Heart rate variability (HRV) is traditionally derived from RR interval time series of electrocardiography (ECG). Photoplethysmography (PPG) also reflects the cardiac rhythm since the mechanical activity of the heart is coupled to its electrical activity. Thus, theoretically, PPG can be used for determining the interval between successive heartbeats and heart rate variability. However, the PPG wave lags behind the ECG signal by the time required for transmission of pulse wave. In their study, finger-tip PPG and standard lead II ECG were recorded for five minutes from 10 healthy subjects at rest. The results showed a high correlation (median = 0.97) between the ECG-derived RR intervals and PPG-derived peak-to-peak (PP) intervals. PP variability was accurate (0.1 ms) as compared to RR variability. The time domain, frequency domain and Poincare plot HRV parameters computed using RR interval method and PP interval method showed no significant differences ($p < 0.05$). The error analysis also showed insignificant differences between the HRV indices obtained by the two methods. Bland-Altman analysis showed high degree of agreement between the two methods for all the parameters of HRV [15].

4.10 Nadi Yantra: a robust system design to capture the signals from the radial artery for assessment of the autonomic nervous system non-invasively

In 2009, Abhinav *et al*. presented a robust electro-mechanical system, 'Nadi Yantra' which uses piezoelectric based pressure sensors to capture the signals from the radial artery. Morphology of the waveforms obtained from our system concurs with standard physiological arterial signals. They verified the reproducibility and stability of the system. Signal processing techniques were applied to obtain features such as amplitude, power spectral density, band power and spectral centroid to reflect variations in signals from the three channels. Further, wavelet based techniques were used to process the pressure signals and percussion peaks were identified. The interval between the percussion peaks was used to calculate heart rate variability (HRV), a useful tool for assessing the status of the autonomic nervous system of the human body non-invasively. Time domain indices were calculated from direct measurement of peak-peak (PP) intervals and from differences between the PP intervals. Frequency domain indices such as very low frequency (VLF) power, low frequency (LF) power, high frequency

(HF) power, LF/HF ratio were also calculated. A map of consecutive PP intervals was fitted to an ellipse using least squares method. A novel pressure pulse recording instrument was developed for the objective assessment of the ancient science of pulse diagnosis. The features calculated using multi resolution wavelet analysis showed potential in the evaluation of the autonomic nervous system of the human body. Wavelet based techniques were used to decompose the pressure signal from the radial artery. Multi-resolution wavelet analysis was used to detect the percussion peaks and the P-P time series was obtained. A HRV plot depicting function of the ANS was obtained from the P-P time series. Time domain and Spectral analysis of the P-P series gave significant features. Non-linear Poincare analysis was carried out to obtain a relationship between consecutive P-P intervals [16].

4.11 Traditional Indian Medicine

In 2010, Ivy & Malini presented that Siddha is a natural treatment and the oldest medical system of healing in the world. Nadi Pariksha is a pulse-based diagnosis method which is the skill of feeling the pulse, and is known to dictate all the salient features of a human body. They provide a complete spectrum of details of their procedure for obtaining three different pulses based on time series. This system contained a strain gauge equipped with a diaphragm element, a transmitter and also an amplifier, a digitizer which quantifies the analog signals. The system was designed with 16-bit accuracy in such a way that it provides no interference noise and no external electronics. Compared with the prior systems like ECG, the system provides a detailed classification of the nadi pulses which produces the waveforms with respect to abnormalities. The varying pressure given to the pulse analyzer classifies vata, pitta and kapha based on the abnormalities captured from a single artery. The Modern sensors reflect the feeling information which is being presently used in Indian ways of Siddha or the regular Traditional Chinese Medicine (TCM). They had taken the pressure sensing based Methodology and the current progress in the instrumentation technologies in the design of high quality pulse acquisition system. They evaluated the use of Nadi Tarangini for diagnostic purposes with the help of Siddha practitioners. Strong machine learning algorithms can be tried on these waveforms to differentiate them into major types of nadis defined in Siddha literature. The obtained output from this module could be fed to the knowledge management system that identifies the diseases based on body type [17].

4.12 E- Health Analysis Element for Supporting Therapeutic through Ancient Indian Medical Science

In 2010, Nawaz G. M. *et al*. worked on E- health analysis element for supporting therapeutic through ancient Indian medical science. There has been a drastic difference in people's demands and expectations of health care systems now a day. A large quantity of information is easily available through the internet, which leads to increased patient knowledge. As the time is passing by, the electronic devices are shrinking in size and price. Taking the advantage of this advanced technology, demands are leading to health care that improve quality of life throughout the continuum of life. People are turning towards the Indian culture and are trying to adapt it into their day today life from the ancient Indian medical sciences for their par in excellence, when compared to the modern allopathic treatment. Health care monitoring can now be done ubiquitously and there are several different research projects into wearable health monitoring. However, all the projects are at a prototype stage and not in wide scale use. Nawaz G. M. *et al.* concentrated their work on creating a wearable E-health analysis element, which will support the medical science of Swayam (self) Nadi Parikshan Various diseases can be controlled by Swayam Nadi Parikshan where by the use of it a transition state of health is maintained from a diseased one. They presented a prototype of a noninvasive wellness monitoring system, capable of recording and analyzing continuous pulse rate, heart beat etc. data received from the human body. This system provides an application for recording activities, events and potentially important medical symptoms. The collected data are taken for further diagnosis. This wearable E- health analysis element helps the patient and the medical practitioner to be well informed about the health condition of the patients. In times of abnormality an alert is sent to both the wearer and the consultant via his personal digital assistant (PDA), for necessary action to be taken. In their work, they gave an overview of the Nadi Pariksha based E-health analysis Element, and highlight recent technology achievements in the field of ancient Indian medications [18].

CHAPTER-5 Problem Definition

Medical science has the primary objective of providing healthcare to human beings. Various prevailing medical systems have modeled human being in different ways and thus have different approaches to cure the body suffering from any disease. Fortunately all the systems work. Apart from the modern medical system commonly referred as Allopathic system we have Homeopathy, Unani medicine, Acupressure/Acupuncture, and Ancient Indian Ayurvedic System. Many advances have been made in modern system in field of diagnostic, therapeutic, prosthesis, surgery and pharmacology. These advances are unfortunately not very effective in curing certain psychosomatic as well as other chronic problems. This system also suffers from several so called side-effects which may be even more dangerous than primary disease. The researcher's throughout the world are working to come up with new disease management techniques to curtail these side effects to the minimum. To the extent, several physicians have now opted for alternative medicines and therapies. In view of this development it is quiet pertinent that we rediscover our ancient heritage of Ayurvedic system, which for the past century is dying a natural death on account of sheer neglect by medical professional and general public.

The first three chapters of this thesis report are written primarily to expose to the reader to the extent of diagnosis and therapies available in Ayurveda. This system includes doshas prediction using nadi parikshan (pulse diagnosis) and other techniques. Surprisingly the remedies many a times include rather simple techniques like dietry and lifestyle changes. One of the major drawbacks of Ayurvedic system is that it is skill based which is to be passed on from master to its disciple. Since these masters are fast, vanishing it is feared that this highly developed Ayurvedic system may not become extinct. It is thus important to document and quantize these techniques using modern electronic equipment. The fusion would perhaps eternalize this dying art/science of Ayurveda. Feeling the pulse with three fingers at different point below thumb pressing the radial artery can give an unimaginable plethora of information. In addition to this, the therapeutic effects of several Mudras utilizing finger tip and thumb contact, has given us a good reason to propose a diagnosis system that is based on pulse profile of the fingers. One of the alternatives to quantize pressure pulses available at radial artery in the wrist region is to design a special hardware for measurement. This has been done by some researchers and technique has not been standardized so far [11]. Moreover this equipment is not available commercially and is in the stage of development. Another alternative is to go in for commercially available standardized PhotoPlethysmoGraph (PPG). Using PhotoPlethysmoGraphy it is quite possible that specific diagnosis

may be reached by studying these finger pulse profiles. To establish this it is first required to study these finger pulse profiles and establish a correlation between various fingers of same subject as well as to prove the uniqueness of this profile based on the individuals.

This thesis work thus aims at investigating the finger pulse profile of human using PhotoPlethysmoGraphy and these investigations may be used later for identifying the doshas present in humanbody.

CHAPTER-6 Materials and Methods

6.1 Introduction to PhotoPlethysmoGraphy

PhotoPlethysmoGraphy (PPG) is an optical measurement technique used to detect blood volume changes in the micro vascular bed of tissues. Invisible infra-red light is sent in the tissue and the back-scattered light corresponds with the variation of the blood volume. PPG waveform comprises a pulsatile ('AC') physiological waveform attributed to cardiac synchronous changes in the blood volume with each heart beat, and is superimposed on a slowly varying ('DC') baseline with various lower frequency components attributed to respiration, sympathetic nervous system activity and thermoregulation.

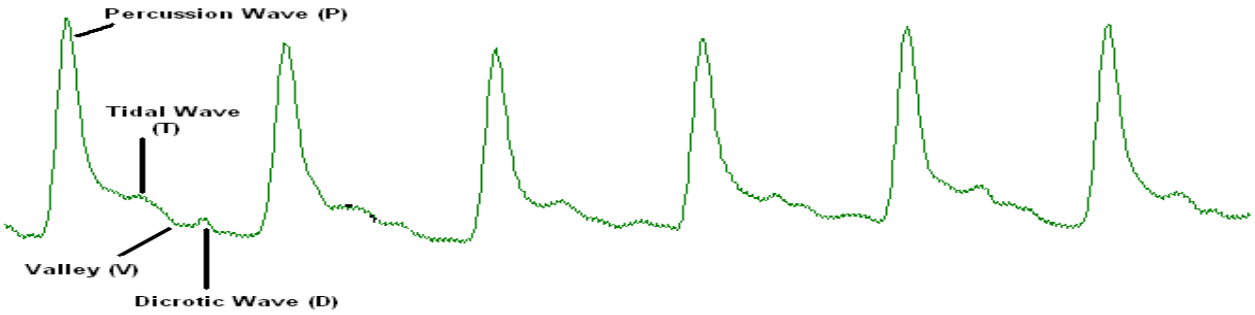


Fig 6.1- PPG waveform

PPG wave complex can be used to study changes in the elastic properties of the vascular system with age and disease. Accurate detection of relevant features is necessary for clinical physiological monitoring such as Blood Oxygen Saturation SpO2, blood pressure, heart rate, cardiac output and breathing interval. The detection of PPG peaks helps in finding the beat-to-beat varying parameters. Dicrotic notch detection is very important in the assessment of hemodynamic parameters. Other applications include autonomic function assessment such as thermoregulation. Additionally, the shape of the PPG waveform differs from subject to subject, and varies with the location and manner in which the pulse oximeter is attached. Because the skin is so richly perfused, it is relatively easy to detect the pulsatile component of the cardiac cycle. The DC component of the signal is attributable to the bulk absorption of the skin tissue, while the AC component is directly attributable to variation in blood volume in the skin caused by the pressure pulse of the cardiac cycle. The height of AC component of the photoplethysmogram is proportional to the pulse pressure, the difference between the systolic and diastolic pressure in the arteries [19].

To validate the science of pulse based diagnosis and provide an objective approach to it, signals are captured from the tip of the individual's finger and analyzed for detection of significant points of interest such as percussion peaks, tidal valleys and dichrotic peaks.

6.2 MP System

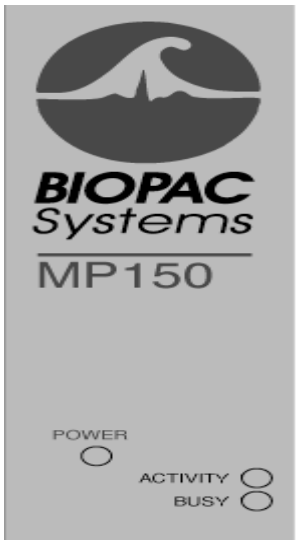
MP System is a complete and expandable data acquisition system. Functions of this system are like an on-screen chart recorder, oscilloscope, and X/Y plotter, allowing to record, view, save, and print data. It includes all the hardware and software required to turn any computer into a powerful data acquisition workstation specifically designed for life science applications. MP System is as powerful as larger and more expensive data acquisition systems, but has a familiar, easy to use graphical interface. This System will reduce your equipment setup time and increase the quality of your results. By harnessing the power of your computer, the MP System gives you publication-quality results with minimum effort. The MP data acquisition unit (MP150 or MP100) is the heart of the MP System. The MP unit takes incoming signals and converts them into digital signals that can be processed with your computer. Data collection generally involves taking incoming signals (usually analog) and sending them to the computer,

Where they are (a) displayed on the screen and (b) stored in the computer's memory (or on the hard disk). These signals can then be stored for future examination, much as a word processor stores a document or a Statistics program saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs.

Fig 6.2- MP150 Data Acquisition Unit

6.3 MP150 Starter System

The MP150 high-speed data acquisition system utilizes the very latest in Ethernet technology. Access multiple MP150 devices located on a local area network and record data to any computer connected to the same LAN. Record multiple channels with variable sample rates to maximize storage efficiency. Record at speeds up to 400 kHz (aggregate).



.

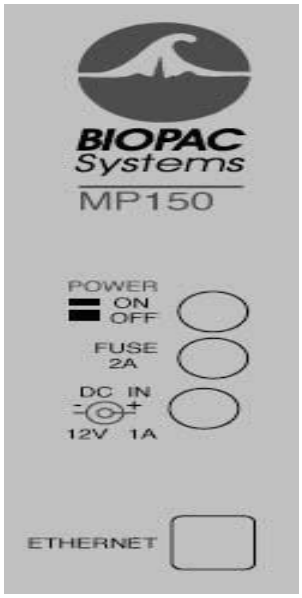
POWER:
Green light: Indicates MP150 Power status.

ACTIVITY:
Amber light: Indicates data traffic to or from MP150— *similar to Hard Disk activity light on any personal computer.*

BUSY:

Green light Indicates MP150 data acquisition

Fig 6.3- Front Panel of MP150



Power: ON push in to power up the MP150
OFF Pop out to cut the flow of power to the MP150.

Fuse 2A: 2 Amp fast-blows fuse holders; the maximum capacity of the fuse is 2 Amps. To remove the fuse, use a screwdriver to remove the fuse cover, which is located below the word **Fuse**.

DC Input: Use the **DC Input** to connect a battery, AC/DC converter or other power supply to the MP150.

Ethernet: The MP150 connects to the computer via the Ethernet port, located just to the right of the word **Ethernet**. Uses a standard RJ-Ethernet connector (10 base T).

Fig 6.4 - Back Panel of MP150

Side panel contains Module connections: The two connector inputs are designed to connect directly to the UIM100C.

Analog signals are transmitted through the 37-pin connector (upper right side)

Digital signals are transmitted through the 25-pin connector (lower-right side)

6.3.1 Isolation of MP150 starter system

Designed to satisfy the following Medical Safety Test Standards affiliated with IEC601-1:

(i) Creepage and Air Clearance, (ii) Dielectric Strength (iii) Patient Leakage Current

6.3.2 Cleaning of System

Be sure to unplug the power supply from the MP150/100 before cleaning. To clean the MP150/100, use a damp, soft cloth. Abrasive cleaners are not recommended as they might damage the housing. Do not immerse the MP150/100 or any of its components, as this can damage the system. Let the unit air-dry until it is safe to reconnect the power supply.

6.4 Interface Module

When connecting the analog output sourcing from external devices to the MP100 or MP150, channel contention must be considered. If an analog channel is used on the UIM100C or HLT100C, make certain that two external devices do not use the same analog channel. If amplifier modules are connected to the MP System then those amplifier modules must be set to a channel which is not used by external devices plugged into the UIM100C or HLT100C. The UIM100C Universal Interface Module is the interface between the MP150/100 and external devices.

Typically, the UIM100C is used to input pre-amplified signals (usually greater than +/- 0.1 volt peak-peak) and/or digital signals to the MP150/100 acquisition unit. Other signals (e.g., those from electrodes or transducers) connect to various signal-conditioning modules. The Universal Interface Module (UIM100C) is designed to serve as a general-purpose interface to most types of laboratory equipment. The UIM100C consists of sixteen 3.5 mm mini-phone jack connectors for analog inputs, two 3.5 mm mini-phone jack connectors for analog outputs, and screw terminals for the 16 digital lines, external trigger, and supply voltages. The UIM100C is typically used alone to connect polygraph and chart recorder analog outputs to the MP System. BIOPAC Systems, Inc. offers a series of cables that permit the UIM100C to connect directly to a number of standard analog signal connectors. Most chart recorders

or polygraphs have analog signal outputs, which can be connected directly to the UIM100C. The UIM100C allows access to 16 analog inputs and 2 analog outputs on one side, and 16 digital Input/output lines, an external trigger, and supply voltages on the other side. The UIM100C is designed to be compatible with a variety of different input devices.

6.4.1 IPS100C Isolated Power Supply Module

Fig 6.5 – Isolated Power Supply Module

The IPS100C is used to operate 100-series amplifier modules independent of an MP data acquisition unit. This module couples the 100-series amplifier outputs directly to any other data acquisition system, Oscilloscope or chart recorder. Amplifier modules snap onto the side of the IPS100C to receive the Necessary isolated power and to direct the modules' output to the front panel of the IPS100C. The IPS100C allows users to operate up to 16 amplifiers on a stand-alone basis. The analog channel outputs are provided via 3.5mm phone jacks on the front panel. The IPS100C is generally used with animal or tissue preparations. When collecting data from electrodes attached to humans, use the HLT100C module with INISO and OUTISO adapters to couple signals to external equipment.

6.5 Transducer Amplifier Module

Fig 6.6 – Transducer Amplifier Module

The photoplethysmogram amplifier module (PPG100C) is a single channel amplifier designed for indirect measurement of blood pressure or density. The PPG100C is designed for use in the following applications:

- General pulse rate determination
- Blood pressure analysis
- Exercise physiology studies
- Psychophysiological investigations

The PPG100C works with the TSD200 photoplethysmogram transducer. The peak measurement Recorded by the PPG100C indicates the point of maximal blood density in the respective location. Indications of blood pressure can be inferred by comparing the point of R-wave onset in the ECG to the point of maximum blood density recorded by the PPG100C. The PPG100C includes lower frequency response selection switches, which permits either absolute (DC) or relative (via 0.05 or 0.5 Hz high pass filters) blood density measurements.

6.5.1 Frequency Response Characteristics

The 0.05 Hz high pass and 0.5 Hz high pass lower frequency response settings are single pole roll-off filters. Modules can be set for 50 Hz or 60 Hz notch options, depending on the destination country.

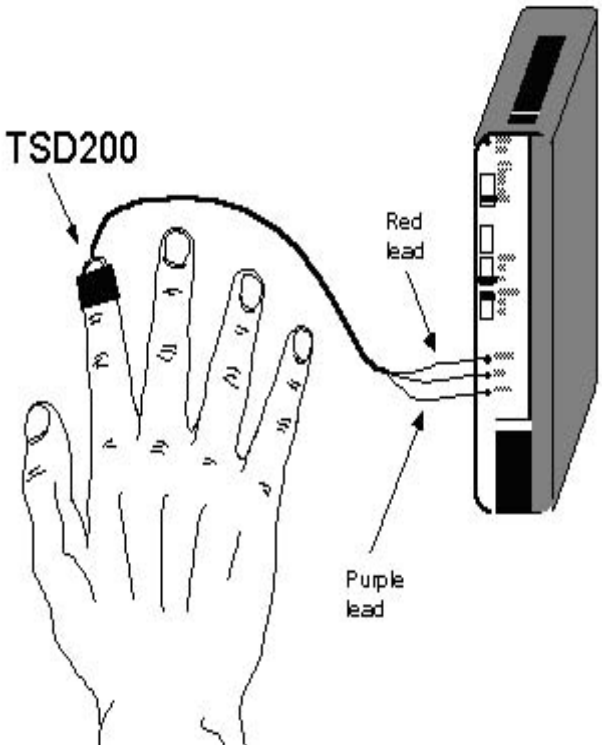


Fig 6.7 - Finger pulse measurement

This illustration shows the proper connections to use the TSD200 with the PPG100C. The TSD200 can be placed on other body locations by employing ADD208 adhesive disks to hold the TSD200 in place. The TSD200 connects to the PPG100C as follows:

TSD200 Lead	PPG100C
Red lead	*+VSUP*
Black lead	GND
Purple or blue lead	INPUT

6.6 Photoplethysmogram Transducer

The TSD200 consists of a matched infrared emitter and photo diode, which transmits changes in blood density (caused by varying blood pressure), in specific body locations. When the TSD200 is attached to the skin, the infrared light is modulated by blood pulsing through the tissue below. The modulated, reflected light results in small changes in the resistance of the photo resistor, which yields a proportional change in voltage output.

The TSD200 includes a shielded 2-meter cable and a stretchable Velcro® strap for easy attachment to the fingers, or it can be taped to other body parts. The TSD200 can also be placed on other body locations by employing ADD208 adhesive disks to hold the TSD200 in place. Use the TSD200C ear clip transducer for easy attachment to the ear. Place the transducer around the finger and adjust the Velcro® closure to provide only slight tension. Blood density readings can vary considerably depending on transducer location and tension changes.

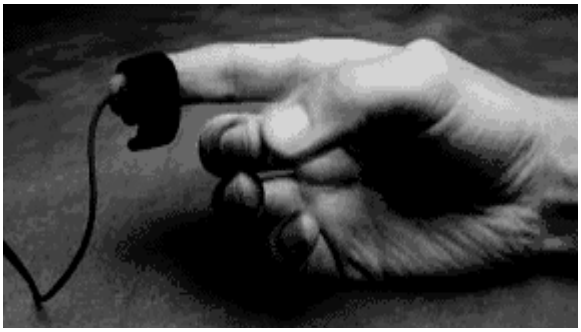


Fig 6.8 - Photoplethysmogram Transducer

6.7 Acq*Knowledge* Overview

The MP System (MP150 or MP36R) software is called Acq*Knowledge* and performs two basic functions: acquisition and analysis. The acquisition settings determine the basic nature of the data to be collected, such as the amount of time data will be collected for and at what rate data will be collected. All of the acquisition parameters can be found under the MP150 menu. The other menu commands pertain to analysis functions such as viewing, editing, and transforming data.

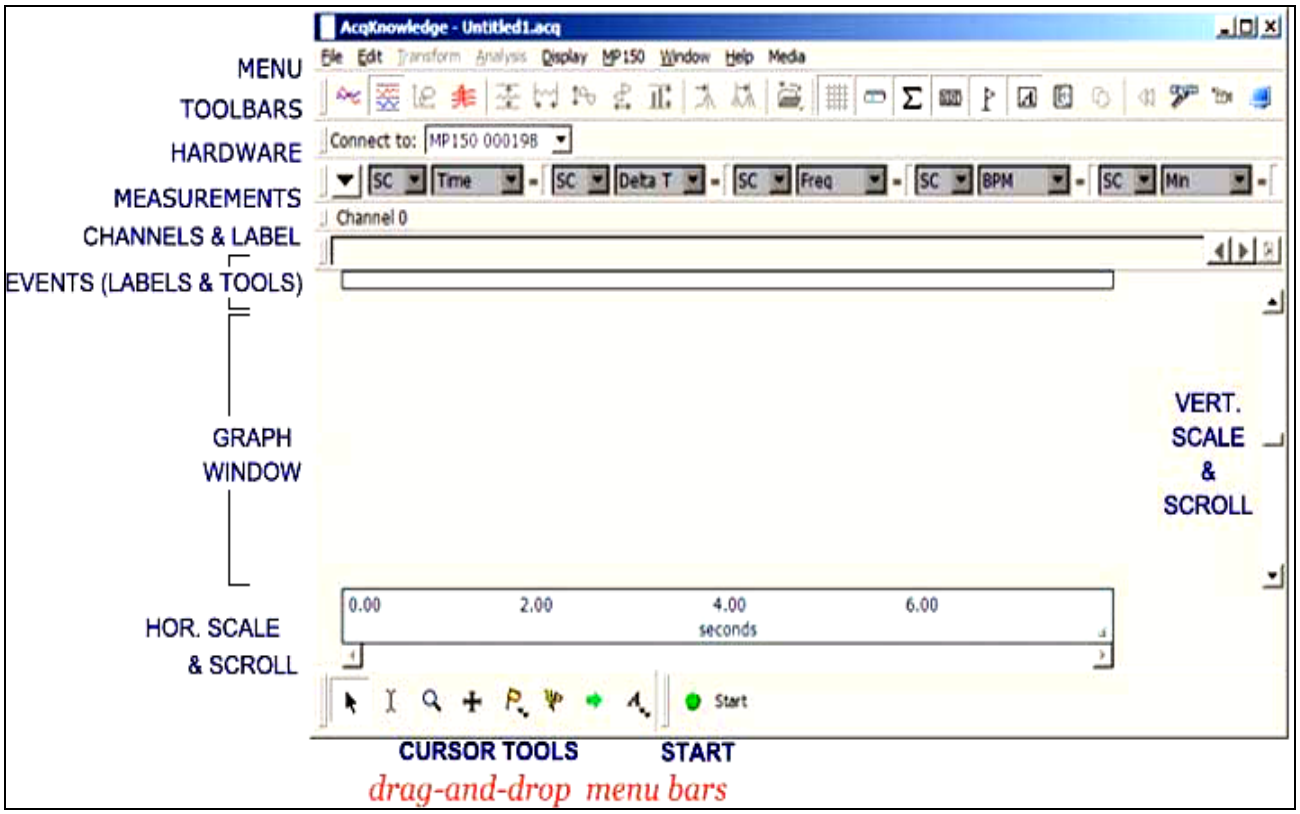


Fig 6.9 – Overview of AcqKnowledge

Assuming everything is properly connected and there are no conflicts, Acq*Knowledge* will open a graph window. A "window" is the term used for the area on your computer's screen where data is displayed and/or manipulated. The graph window on the screen is designed to provide you with a powerful yet easy-to-use interface for working with data.

6.7.1 Acquisition

Once you have connected your system setup and input devices, try a sample acquisition. The most basic and commonly used options are under the MP150 menu. For any acquisition, you will need to specify:

- How many channels there are and which channels contain data (Set up Channels).
- At what rate the MP150 will acquire the data (Sampling rate).
- How long the acquisition will last (Acquisition length).

6.7.2 Starting an Acquisition

Once you have specified which channels will contain data and have defined the channel characteristics, the next step is to start the acquisition. In the lower bar of the screen, next to the Start button, you should see a circular status light. The status light indicates the communication link between your computer and the MP data acquisition unit.

- If the MP data acquisition unit is properly connected to the computer and is turned on, the circle will be solid and green.
- If the MP data acquisition unit is not properly connected or not communicating with the computer, under Windows® OS the circle will be solid and gray and under Mac OS® X the circle may not appear at all or a different symbol, such as double arrows, may be used if the application crashed during acquisition.

Start

To start an acquisition, position the cursor over the start button and click the mouse button, or select **Ctrl+Spacebar**. If there are no input devices (e.g., electrodes or transducers) connected to the MP System (MP150 or MP36R), it will collect a small value of random signal "noise" with a mean of about 0.0 Volts.

Stop

To stop an acquisition at any time, click the stop button in the lower right corner of the screen or select **Ctrl+ Spacebar**. An acquisition will stop automatically when it has recorded an amount of data equal to that indicated in the Total Length box.

Display modes

The display modes are Chart, Scope, X/Y, Stacked Plot, and Playback. You may change the way data appears on the screen at any time, even during an acquisition. To change the display mode, click the corresponding icon in the toolbar.

Playback Mode (Replay)

Playback mode will replay a graph file stored on disk in real time to simulate acquisition. Analog and digital channels are replayed as stored in the graph file, but calculation channels can be re-configured to reproduce online calculation channels that have no offline equivalents. Calculation channels from the original graph can be modified, extended, or removed without affecting the data stored on disk in the original graph file.

Transform data

Acq*Knowledge* includes a library of functions to transform data or perform mathematical calculations on waveform data. All of these options can be found under the Transform and Analysis menus. When performing transformations

- If a section of a waveform is highlighted, the transformation will apply to that section.
- If no area is selected, Acq*Knowledge* will always select a single data point.
- If the transformation can only be performed on a selected area (digital filtering, for instance) and a single point is selected, the entire waveform will be used (and the transform entire wave option will be disabled; close out of the dialog and select an area if desired).

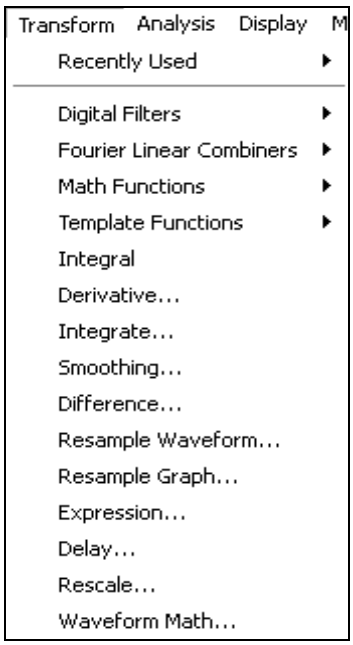


Fig 6.10 – Function to Transform Data

Measurements

Once you have selected a channel to work with, you can quickly and easily take measurements on each wave. The measurements appear in the row of boxes across the top of the graph window. You can specify the number of measurement boxes to show and the display precision in the "Preferences" dialog of the Display menu. Each measurement consists of three parts: (a) the channel selection, (b) the measurement function, and (c) the result or actual measurement value.

6.8 MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN.

You can use MATLAB in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas. MATLAB provides a number of features for documenting and sharing your work. You can integrate your MATLAB code with other languages and applications, and distribute your MATLAB algorithms and applications.

6.8.1 Features of MATLAB

- High-level language for technical computing
- Development environment for managing code, files, and data
- Interactive tools for iterative exploration, design, and problem solving
- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration
- 2-D and 3-D graphics functions for visualizing data
- Tools for building custom graphical user interfaces

- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java, COM, and Microsoft Excel

6.9 Method

The equipment is assembled and made ready to take the measurements. The sensor is placed on the tip of each finger one by one. When start button is pressed the pulse start appearing in the graph .sometimes the pulse is not sensed properly which results in distorted pulse with lots of noise. By changing the position of sensor we can get the required results. Frequency at which we worked is of 10 kHz to make 0.1 changes in the interval width. The data is collected at such a high frequency due to this noise appears in the signal which is removed by using band-stop IIR filter at 50Hz frequency. As the pulse of each finger is taken at different time so it was first normalized on time-scale to eliminate any differences on account of difference in beat to beat interval. This was done by taking 200 pulses from peak to peak of two alternative pulses (between peak1 and peak 3). Then using matlab the correlation of each finger with respect to other fingers of the same person and same finger of the other person is calculated by shifting the pulse over fixed interval of samples. From this we obtain the maximum correlation among the correlations on all the sample points. In this we are not dealing with the thumb as structurally and physically thumb is different with rest of fingers and we are concerned with index, middle and ring finger.

6.10 Program in MATLAB

After getting the values of the pulse profile we calculated the correlation of each and every finger with respect to all other fingers and same finger of other samples. For eg: we calculated co-relation of right hand index finger of subject1 with its own index finger, middle finger, ring finger, little finger of both right and left hand and also with the right hand index finger of rest of the subjects.

We take 120 samples of each finger out of 200 samples of each finger. As correlation is calculated between two signals. We take 120 samples of one signal fixed and shifting other signal of 120 samples over left 80 samples so as to get the maximum correlation between them. Correlation of same finger is known as auto correlation.

The code of finding correlation is as below:

```
>>  % correlation of right index finger w.r.t others
>>  A = xlsread('filename.xls','sheetname');
>>  B=A(42:160,1);
>>  x2=120;
>>  x1=2;
>>  % with self (auto correlation)
>>  for i=1:1:80
>>  c1=x1+i;
>>  c2=x2+i;
>>  C=A(c1:c2,2);
>>  S= corrcoef(B,C);
>>  U(i,1)=S(1,2);
>>  end
>>  ‘correlation of index finger with self'
>>  Umax=max(U)
>>  % with middle
>>  for i=1:1:80
>>  c1=x1+i;
>>  c2=x2+i;
>>  C=A(c1:c2,3);
>>  S= corrcoef(B,C);
>>  U(i,1)=S(1,2);
>>  end
>>  'correlation of index finger with middle'
>>  Umax=max(U)
>>  %with ring
>>  for i=1:1:80
>>  c1=x1+i;
>>  c2=x2+i;
>>  C=A(c1:c2,4);
```

```
>>  S= corrcoef(B,C);
>>  U(i,1)=S(1,2);
>>  end
>>  'correlation of index finger with ring'
>>  Umax=max(U)
>>  %with little
>>  for i=1:1:80
>>  c1=x1+i;
>>  c2=x2+i;
>>  C=A(c1:c2,5);
>>  S= corrcoef(B,C);
>>  U(i,1)=S(1,2);
>>  end
>>  'correlation of index finger with little'
>>  Umax=max(U)
```

Similarly correlation with other fingers can also be calculated.

CHAPTER-7 Result and Discussion

7.1 Pulse Profile Graphs

We obtained the pulse profiles of each finger of number of persons. The shape of each and every individual is different from the other. Simply by viewing we can see the difference in the pulse shape of each finger but our aim is to calculate it mathematically. Some of the pulse profiles are shown below in the form of graphs. The pulse is taken from the tip of each finger of both the hands. The amplitude of pulse may vary from finger to finger.

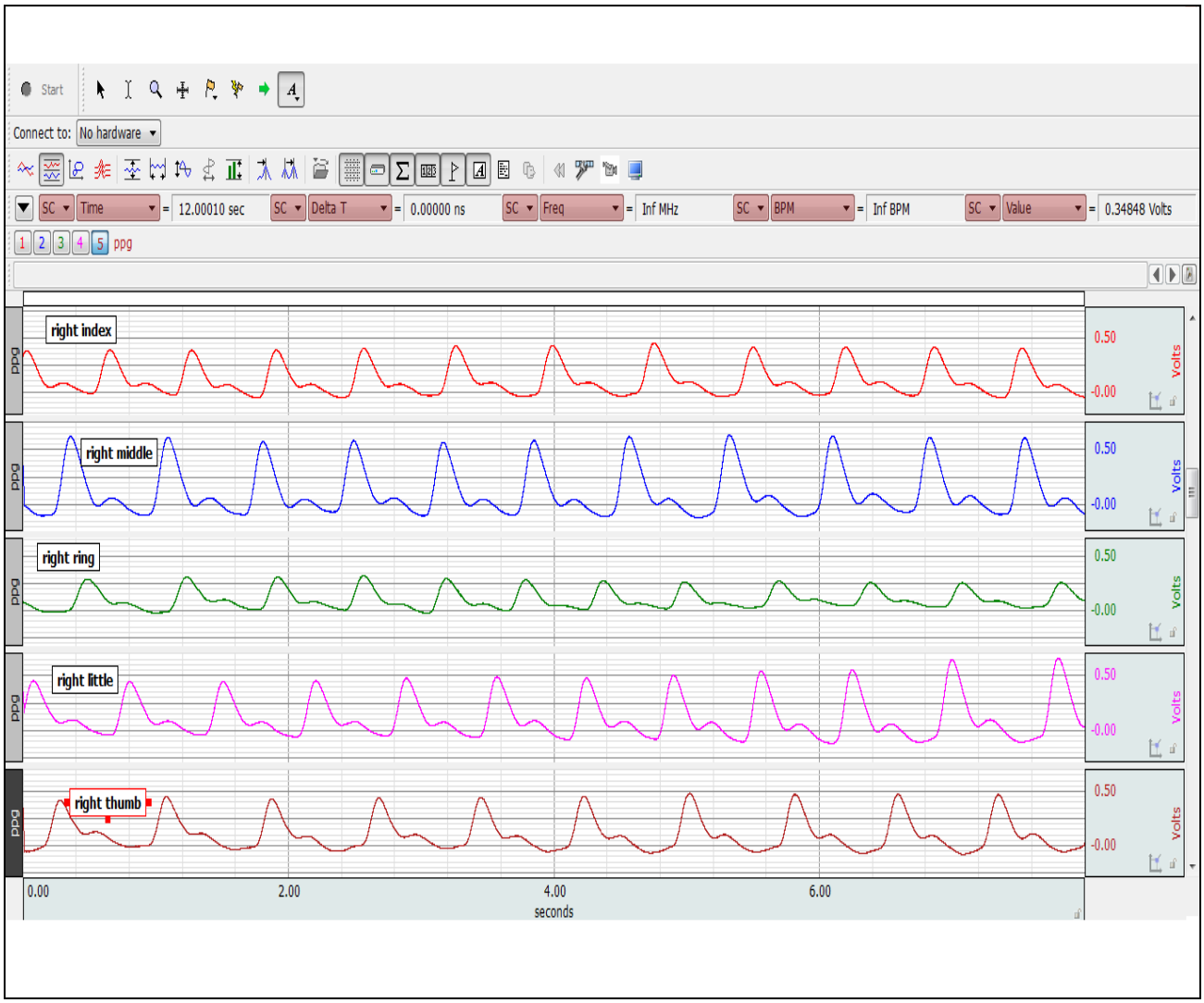


Fig 7.1 – Right hand pulse profile of subject 1

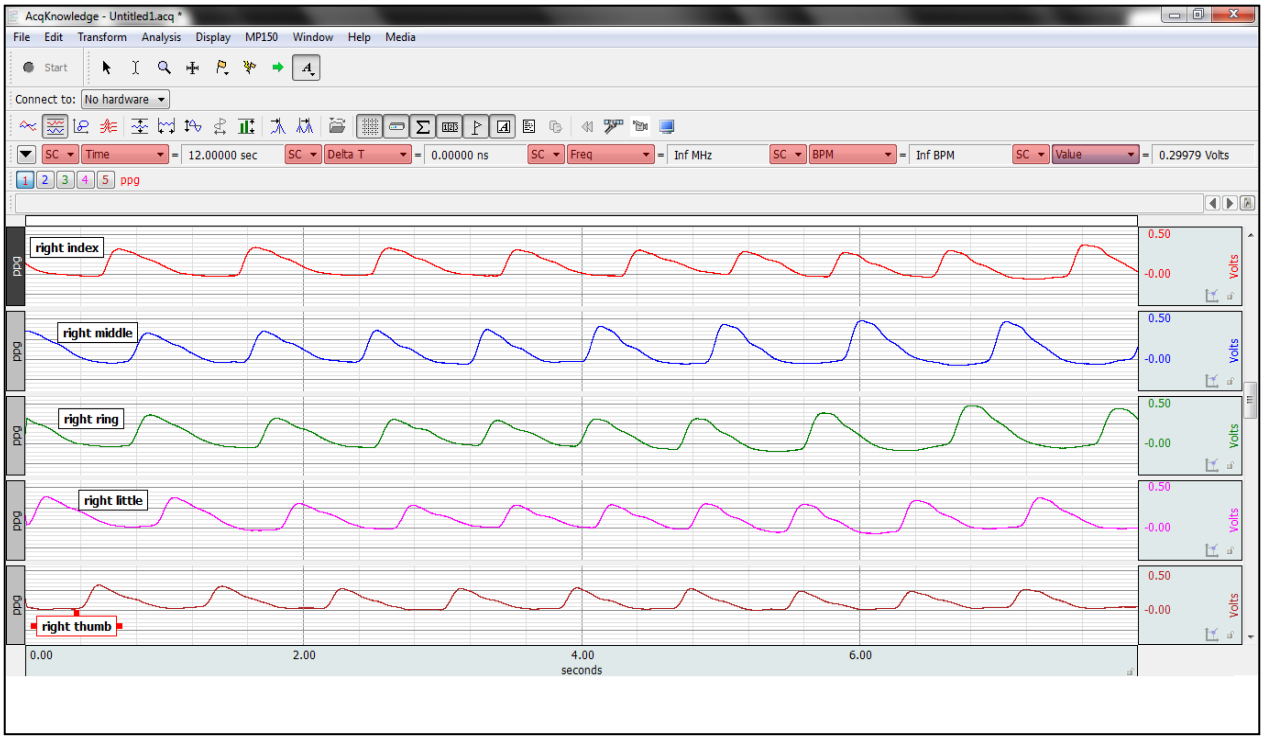


Fig 7.2 – Right hand pulse profile of subject 2

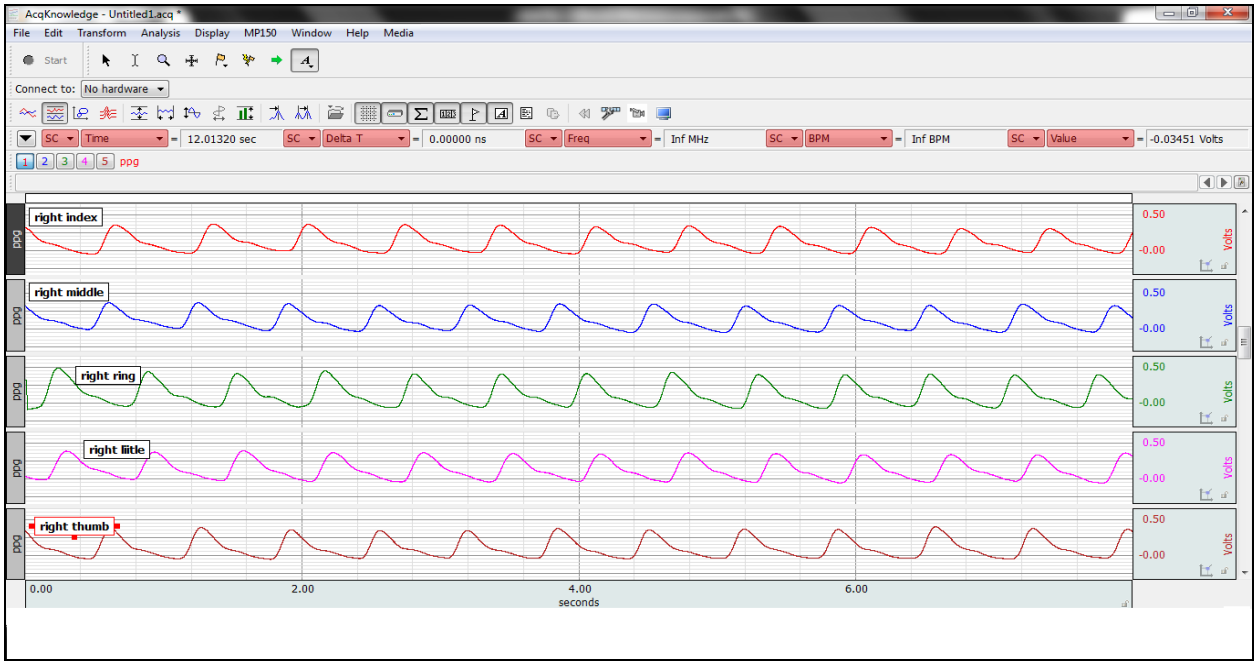
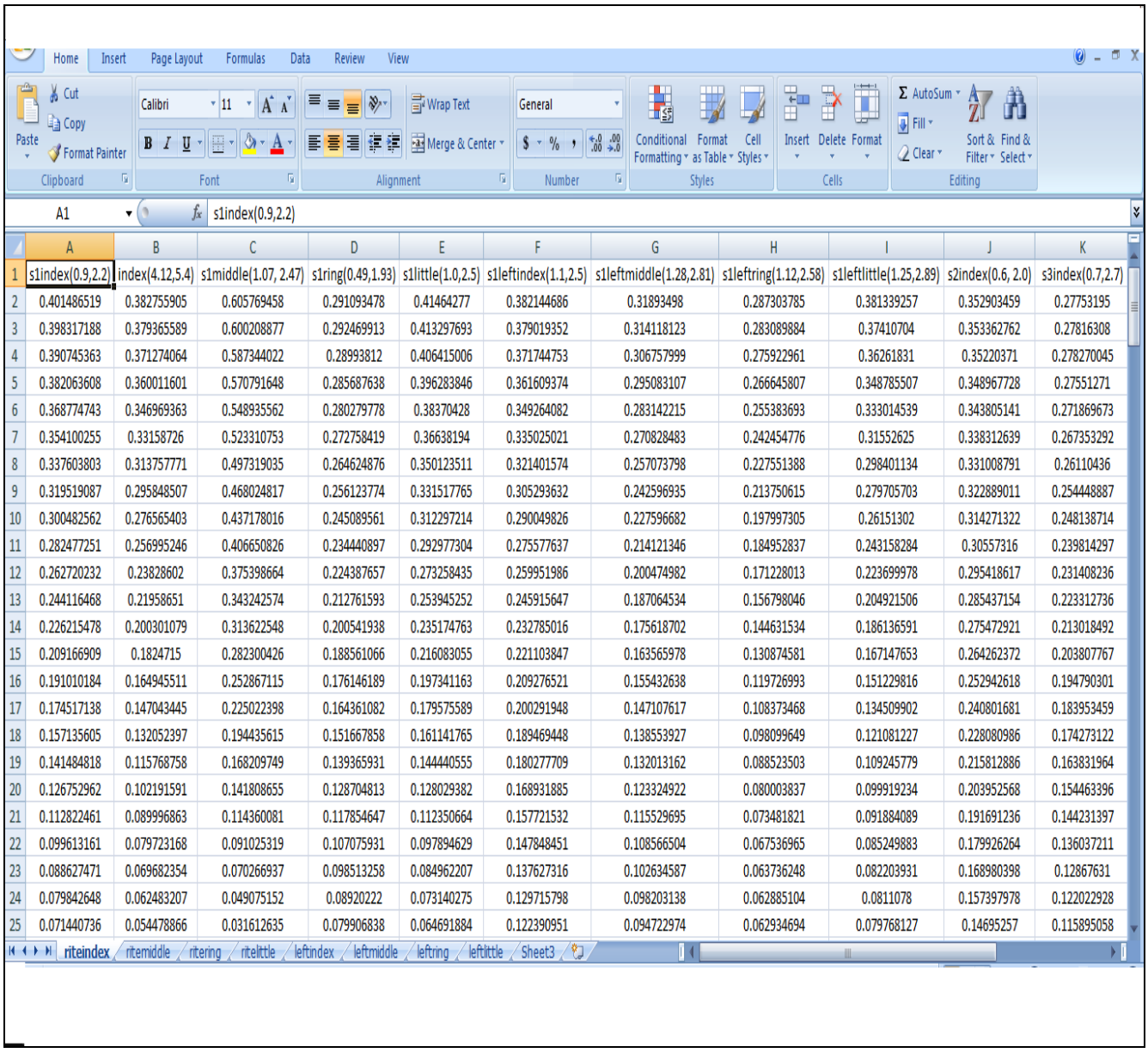


Fig 7.3 – Right hand pulse profile of subject 3

7.2 Value of the pulses

After acquiring the pulses, it was first normalized on time-scale to eliminate any differences on account of difference in beat to beat interval. This was done by taking 200 pulses from peak to peak of two alternative pulses (between peak1 and peak 3). All the values are collected in excel sheet as shown below.

Table 7.1 – Pulses values of subject 1



	A	B	C	D	E	F	G	H	I	J	K
1	s1index(0.9,2.2)	index(4.12,5.4)	s1middle(1.07, 2.47)	s1ring(0.49,1.93)	s1little(1.0,2.5)	s1leftindex(1.1,2.5)	s1leftmiddle(1.28,2.81)	s1leftring(1.12,2.58)	s1leftlittle(1.25,2.89)	s2index(0.6, 2.0)	s3index(0.7,2.7)
2	0.401486519	0.382755905	0.605769458	0.291093478	0.41464277	0.382144686	0.31893498	0.287303785	0.381339257	0.352903459	0.27753195
3	0.398317188	0.379365589	0.600208877	0.292469913	0.413297693	0.379019352	0.314118123	0.283089884	0.37410704	0.353362762	0.27816308
4	0.390745363	0.371274064	0.587344022	0.28993812	0.406415006	0.371744753	0.306757999	0.275922961	0.36261831	0.35220371	0.278270045
5	0.382063608	0.360011601	0.570791648	0.285687638	0.396283846	0.361609374	0.295083107	0.266645807	0.348785507	0.348967728	0.27551271
6	0.368774743	0.346969363	0.548935562	0.280279778	0.38370428	0.349264082	0.283142215	0.255383693	0.333014539	0.343805141	0.271869673
7	0.354100255	0.33158726	0.523310753	0.272758419	0.36638194	0.335025021	0.270828483	0.242454776	0.31552625	0.338312639	0.267353292
8	0.337603803	0.313757771	0.497319035	0.264624876	0.350123511	0.321401574	0.257073798	0.227551388	0.298401134	0.331008791	0.26110436
9	0.319519087	0.295848507	0.468024817	0.256123774	0.331517765	0.305293632	0.242596935	0.213750615	0.279705703	0.322889011	0.254448887
10	0.300482562	0.276565403	0.437178016	0.245089561	0.312297214	0.290049826	0.227596682	0.197997305	0.26151302	0.314271322	0.248138714
11	0.282477251	0.256995246	0.406650826	0.234440897	0.292977304	0.275577637	0.214121346	0.184952837	0.243158284	0.30557316	0.239814297
12	0.262720232	0.23828602	0.375398664	0.224387657	0.273258435	0.259951986	0.200474982	0.171228013	0.223699978	0.295418617	0.231408236
13	0.244116468	0.21958651	0.343242574	0.212761593	0.253945252	0.245915647	0.187064534	0.156798046	0.204921506	0.285437154	0.223312736
14	0.226215478	0.200301079	0.313622548	0.200541938	0.235174763	0.232785016	0.175618702	0.144631534	0.186136591	0.275472921	0.213018492
15	0.209166909	0.1824715	0.282300426	0.188561066	0.216083055	0.221103847	0.163565978	0.130874581	0.167147653	0.264262372	0.203807767
16	0.191010184	0.164945511	0.252867115	0.176146189	0.197341163	0.209276521	0.155432638	0.119726993	0.151229816	0.252942618	0.194790301
17	0.174517138	0.147043445	0.225022398	0.164361082	0.179575589	0.200291948	0.147107617	0.108373468	0.134509902	0.240801681	0.183953459
18	0.157135605	0.132052397	0.194435615	0.151667858	0.161141765	0.189469448	0.138553927	0.098099649	0.121081227	0.228080986	0.174273122
19	0.141484818	0.115768758	0.168209749	0.139365931	0.144440555	0.180277709	0.132013162	0.088523503	0.109245779	0.215812886	0.163831964
20	0.126752962	0.102191591	0.141808655	0.128704813	0.128029382	0.168931885	0.123324922	0.080003837	0.099919234	0.203952568	0.154463396
21	0.112822461	0.089996863	0.114360081	0.117854647	0.112350664	0.157721532	0.115529695	0.073481821	0.091884089	0.191691236	0.144231397
22	0.099613161	0.079723168	0.091025319	0.107075931	0.097894629	0.147848451	0.108566504	0.067536965	0.085249883	0.179926264	0.136037211
23	0.088627471	0.069682354	0.070266937	0.098513258	0.084962207	0.137627316	0.102634587	0.063736248	0.082203931	0.168980398	0.12867631
24	0.079842648	0.062483207	0.049075152	0.08920222	0.073140275	0.129715798	0.098203138	0.062885104	0.0811078	0.157397978	0.122022928
25	0.071440736	0.054478866	0.031612635	0.079906838	0.064691884	0.122390951	0.094722974	0.062934694	0.079768127	0.14695257	0.115895058

Table 7.2 Datasheet of 200 samples pulse profile of subject1 right hand

s1index1	index2	s1middle1	middle2	s1ring1	ring2	s1little1	little2	s1thumb1	thumb2
0.4015	0.3828	0.6058	0.5756	0.2911	0.2673	0.4146	0.4436	0.4720	0.4720
0.3983	0.3794	0.6002	0.5671	0.2925	0.2638	0.4133	0.4386	0.4579	0.4579
0.3907	0.3713	0.5873	0.5522	0.2899	0.2573	0.4064	0.4304	0.4397	0.4397
0.3821	0.3600	0.5708	0.5330	0.2857	0.2519	0.3963	0.4178	0.4169	0.4169
0.3688	0.3470	0.5489	0.5085	0.2803	0.2432	0.3837	0.4016	0.3928	0.3928
0.3541	0.3316	0.5233	0.4797	0.2728	0.2332	0.3664	0.3841	0.3650	0.3650
0.3376	0.3138	0.4973	0.4509	0.2646	0.2255	0.3501	0.3643	0.3364	0.3364
0.3195	0.2958	0.4680	0.4184	0.2561	0.2154	0.3315	0.3435	0.3095	0.3095
0.3005	0.2766	0.4372	0.3858	0.2451	0.2045	0.3123	0.3226	0.2810	0.2810
0.2825	0.2570	0.4067	0.3551	0.2344	0.1943	0.2930	0.3012	0.2544	0.2544
0.2627	0.2383	0.3754	0.3236	0.2244	0.1840	0.2733	0.2811	0.2295	0.2295
0.2441	0.2196	0.3432	0.2930	0.2128	0.1728	0.2539	0.2628	0.2067	0.2067
0.2262	0.2003	0.3136	0.2628	0.2005	0.1628	0.2352	0.2427	0.1858	0.1858
0.2092	0.1825	0.2823	0.2335	0.1886	0.1524	0.2161	0.2251	0.1652	0.1652
0.1910	0.1649	0.2529	0.2043	0.1761	0.1414	0.1973	0.2081	0.1467	0.1467
0.1745	0.1470	0.2250	0.1753	0.1644	0.1320	0.1796	0.1901	0.1305	0.1305
0.1571	0.1321	0.1944	0.1463	0.1517	0.1222	0.1611	0.1745	0.1145	0.1145
0.1415	0.1158	0.1682	0.1209	0.1394	0.1129	0.1444	0.1588	0.1020	0.1020
0.1268	0.1022	0.1418	0.0959	0.1287	0.1040	0.1280	0.1432	0.0909	0.0909
0.1128	0.0900	0.1144	0.0741	0.1179	0.0963	0.1124	0.1296	0.0827	0.0827
0.0996	0.0797	0.0910	0.0538	0.1071	0.0888	0.0979	0.1155	0.0781	0.0781
0.0886	0.0697	0.0703	0.0346	0.0985	0.0832	0.0850	0.1028	0.0736	0.0736
0.0798	0.0625	0.0491	0.0181	0.0892	0.0774	0.0731	0.0940	0.0714	0.0714
0.0714	0.0545	0.0316	0.0053	0.0799	0.0737	0.0647	0.0844	0.0720	0.0720
0.0655	0.0489	0.0168	-0.0054	0.0756	0.0704	0.0563	0.0776	0.0737	0.0737
0.0606	0.0473	0.0028	-0.0123	0.0699	0.0664	0.0494	0.0713	0.0787	0.0787
0.0561	0.0467	-0.0062	-0.0152	0.0674	0.0658	0.0462	0.0667	0.0832	0.0832
0.0543	0.0466	-0.0134	-0.0172	0.0646	0.0645	0.0427	0.0642	0.0879	0.0879
0.0534	0.0485	-0.0178	-0.0176	0.0639	0.0650	0.0411	0.0631	0.0932	0.0932
0.0528	0.0499	-0.0198	-0.0150	0.0644	0.0653	0.0419	0.0627	0.0977	0.0977
0.0545	0.0524	-0.0201	-0.0115	0.0649	0.0674	0.0412	0.0637	0.1005	0.1005
0.0576	0.0559	-0.0164	-0.0059	0.0658	0.0690	0.0436	0.0670	0.1026	0.1026
0.0600	0.0587	-0.0116	-0.0004	0.0679	0.0704	0.0472	0.0690	0.1031	0.1031
0.0626	0.0625	-0.0054	0.0065	0.0697	0.0715	0.0493	0.0735	0.1011	0.1011
0.0664	0.0665	0.0015	0.0143	0.0707	0.0729	0.0539	0.0766	0.0988	0.0988
0.0684	0.0687	0.0097	0.0208	0.0706	0.0738	0.0561	0.0797	0.0957	0.0957
0.0708	0.0709	0.0173	0.0273	0.0717	0.0741	0.0587	0.0822	0.0907	0.0907
0.0737	0.0722	0.0230	0.0331	0.0721	0.0743	0.0619	0.0850	0.0844	0.0844

0.0744	0.0720	0.0304	0.0364	0.0725	0.0733	0.0624	0.0864	0.0784	0.0784
0.0746	0.0719	0.0358	0.0395	0.0714	0.0713	0.0638	0.0885	0.0700	0.0700
0.0752	0.0703	0.0409	0.0410	0.0715	0.0706	0.0651	0.0890	0.0634	0.0634
0.0749	0.0673	0.0446	0.0403	0.0707	0.0691	0.0621	0.0882	0.0555	0.0555
0.0727	0.0633	0.0478	0.0378	0.0696	0.0672	0.0605	0.0886	0.0475	0.0475
0.0732	0.0592	0.0509	0.0344	0.0683	0.0654	0.0558	0.0867	0.0390	0.0390
0.0710	0.0543	0.0530	0.0315	0.0663	0.0644	0.0525	0.0855	0.0297	0.0297
0.0687	0.0491	0.0531	0.0260	0.0633	0.0614	0.0476	0.0829	0.0210	0.0210
0.0674	0.0449	0.0529	0.0202	0.0603	0.0602	0.0422	0.0799	0.0142	0.0142
0.0644	0.0393	0.0516	0.0141	0.0573	0.0587	0.0360	0.0766	0.0058	0.0058
0.0610	0.0330	0.0476	0.0057	0.0532	0.0559	0.0308	0.0706	-0.0010	-0.0010
0.0578	0.0301	0.0449	-0.0015	0.0495	0.0545	0.0245	0.0633	-0.0076	-0.0076
0.0546	0.0240	0.0387	-0.0094	0.0452	0.0525	0.0184	0.0578	-0.0152	-0.0152
0.0491	0.0176	0.0323	-0.0183	0.0412	0.0504	0.0117	0.0512	-0.0212	-0.0212
0.0441	0.0132	0.0265	-0.0258	0.0370	0.0490	0.0053	0.0442	-0.0276	-0.0276
0.0396	0.0079	0.0198	-0.0338	0.0328	0.0483	-0.0014	0.0386	-0.0317	-0.0317
0.0344	0.0036	0.0119	-0.0419	0.0287	0.0460	-0.0078	0.0332	-0.0362	-0.0362
0.0298	0.0000	0.0052	-0.0486	0.0243	0.0447	-0.0137	0.0259	-0.0403	-0.0403
0.0253	-0.0048	-0.0028	-0.0560	0.0194	0.0433	-0.0190	0.0205	-0.0438	-0.0438
0.0206	-0.0087	-0.0103	-0.0633	0.0148	0.0413	-0.0246	0.0145	-0.0472	-0.0472
0.0157	-0.0140	-0.0171	-0.0680	0.0114	0.0392	-0.0306	0.0091	-0.0502	-0.0502
0.0121	-0.0189	-0.0263	-0.0732	0.0064	0.0374	-0.0360	0.0033	-0.0528	-0.0528
0.0067	-0.0235	-0.0328	-0.0785	0.0036	0.0346	-0.0430	-0.0017	-0.0555	-0.0555
0.0011	-0.0281	-0.0405	-0.0836	0.0006	0.0327	-0.0482	-0.0064	-0.0555	-0.0555
-0.0027	-0.0323	-0.0488	-0.0889	-0.0023	0.0312	-0.0505	-0.0094	-0.0575	-0.0575
-0.0076	-0.0360	-0.0560	-0.0928	-0.0044	0.0297	-0.0539	-0.0142	-0.0570	-0.0570
-0.0117	-0.0390	-0.0611	-0.0970	-0.0078	0.0279	-0.0565	-0.0169	-0.0565	-0.0565
-0.0156	-0.0424	-0.0677	-0.1010	-0.0104	0.0276	-0.0579	-0.0196	-0.0564	-0.0564
-0.0194	-0.0453	-0.0719	-0.1054	-0.0120	0.0268	-0.0608	-0.0228	-0.0542	-0.0542
-0.0239	-0.0463	-0.0750	-0.1099	-0.0153	0.0271	-0.0604	-0.0253	-0.0520	-0.0520
-0.0261	-0.0489	-0.0798	-0.1136	-0.0176	0.0268	-0.0623	-0.0278	-0.0495	-0.0495
-0.0284	-0.0492	-0.0817	-0.1151	-0.0185	0.0275	-0.0627	-0.0317	-0.0474	-0.0474
-0.0307	-0.0490	-0.0848	-0.1170	-0.0194	0.0281	-0.0632	-0.0345	-0.0463	-0.0463
-0.0315	-0.0501	-0.0859	-0.1179	-0.0206	0.0284	-0.0642	-0.0373	-0.0440	-0.0440
-0.0314	-0.0502	-0.0864	-0.1162	-0.0197	0.0292	-0.0655	-0.0409	-0.0402	-0.0402
-0.0321	-0.0499	-0.0868	-0.1166	-0.0207	0.0299	-0.0660	-0.0431	-0.0375	-0.0375
-0.0324	-0.0506	-0.0874	-0.1136	-0.0199	0.0294	-0.0668	-0.0455	-0.0340	-0.0340
-0.0323	-0.0503	-0.0893	-0.1115	-0.0188	0.0310	-0.0662	-0.0459	-0.0299	-0.0299
-0.0329	-0.0491	-0.0918	-0.1088	-0.0179	0.0312	-0.0653	-0.0466	-0.0263	-0.0263
-0.0334	-0.0490	-0.0950	-0.1062	-0.0169	0.0319	-0.0661	-0.0474	-0.0212	-0.0212
-0.0335	-0.0448	-0.0967	-0.1027	-0.0168	0.0332	-0.0649	-0.0478	-0.0186	-0.0186

-0.0344	-0.0391	-0.0982	-0.0980	-0.0159	0.0343	-0.0647	-0.0470	-0.0153	-0.0153
-0.0340	-0.0303	-0.1002	-0.0887	-0.0155	0.0356	-0.0655	-0.0476	-0.0132	-0.0132
-0.0337	-0.0175	-0.1005	-0.0741	-0.0147	0.0378	-0.0640	-0.0483	-0.0098	-0.0098
-0.0325	0.0014	-0.1007	-0.0531	-0.0139	0.0408	-0.0622	-0.0469	-0.0083	-0.0083
-0.0307	0.0238	-0.0989	-0.0221	-0.0132	0.0440	-0.0604	-0.0453	-0.0069	-0.0069
-0.0257	0.0533	-0.0940	0.0176	-0.0128	0.0513	-0.0536	-0.0387	-0.0018	-0.0018
-0.0196	0.0856	-0.0862	0.0682	-0.0097	0.0593	-0.0457	-0.0282	0.0044	0.0044
-0.0079	0.1217	-0.0728	0.1243	-0.0048	0.0694	-0.0305	-0.0129	0.0147	0.0147
0.0083	0.1608	-0.0517	0.1890	0.0008	0.0812	-0.0125	0.0081	0.0333	0.0333
0.0285	0.2016	-0.0244	0.2567	0.0100	0.0962	0.0114	0.0327	0.0568	0.0568
0.0543	0.2389	0.0109	0.3257	0.0214	0.1142	0.0424	0.0651	0.0885	0.0885
0.0823	0.2779	0.0546	0.3922	0.0381	0.1328	0.0799	0.0990	0.1294	0.1294
0.1141	0.3109	0.1035	0.4535	0.0563	0.1520	0.1191	0.1376	0.1754	0.1754
0.1480	0.3389	0.1596	0.5035	0.0771	0.1737	0.1639	0.1785	0.2246	0.2246
0.1840	0.3631	0.2181	0.5453	0.1000	0.1931	0.2085	0.2218	0.2738	0.2738
0.2195	0.3817	0.2785	0.5772	0.1261	0.2130	0.2533	0.2634	0.3232	0.3232
0.2541	0.3944	0.3369	0.5978	0.1520	0.2299	0.2960	0.3035	0.3681	0.3681
0.2874	0.4015	0.3921	0.6090	0.1773	0.2445	0.3325	0.3405	0.4044	0.4044
0.3170	0.4020	0.4420	0.6100	0.2031	0.2565	0.3643	0.3729	0.4340	0.4340
0.3419	0.3977	0.4851	0.6032	0.2263	0.2663	0.3893	0.3989	0.4553	0.4553
0.3638	0.3889	0.5195	0.5898	0.2485	0.2717	0.4051	0.4205	0.4679	0.4679
0.3800	0.3770	0.5439	0.5702	0.2681	0.2741	0.4158	0.4322	0.4723	0.4723
0.3906	0.3620	0.5600	0.5470	0.2840	0.2754	0.4190	0.4392	0.4702	0.4702
0.3978	0.3453	0.5664	0.5211	0.2965	0.2723	0.4165	0.4400	0.4628	0.4628
0.3987	0.3277	0.5657	0.4927	0.3043	0.2672	0.4100	0.4349	0.4493	0.4493
0.3954	0.3095	0.5586	0.4618	0.3084	0.2605	0.3984	0.4253	0.4321	0.4321
0.3898	0.2916	0.5446	0.4294	0.3090	0.2530	0.3838	0.4130	0.4119	0.4119
0.3806	0.2729	0.5264	0.3975	0.3068	0.2434	0.3679	0.3970	0.3889	0.3889
0.3675	0.2533	0.5045	0.3671	0.3009	0.2354	0.3494	0.3813	0.3646	0.3646
0.3531	0.2344	0.4800	0.3350	0.2946	0.2252	0.3297	0.3623	0.3387	0.3387
0.3384	0.2162	0.4532	0.3030	0.2860	0.2156	0.3103	0.3433	0.3109	0.3109
0.3212	0.1963	0.4237	0.2723	0.2754	0.2050	0.2884	0.3236	0.2844	0.2844
0.3034	0.1782	0.3936	0.2423	0.2640	0.1947	0.2688	0.3025	0.2574	0.2574
0.2848	0.1602	0.3626	0.2119	0.2516	0.1839	0.2476	0.2827	0.2318	0.2318
0.2661	0.1436	0.3299	0.1831	0.2394	0.1736	0.2276	0.2627	0.2069	0.2069
0.2469	0.1281	0.2985	0.1535	0.2274	0.1643	0.2099	0.2426	0.1825	0.1825
0.2285	0.1126	0.2678	0.1262	0.2136	0.1535	0.1912	0.2244	0.1607	0.1607
0.2089	0.0990	0.2365	0.1000	0.2020	0.1442	0.1733	0.2070	0.1401	0.1401
0.1898	0.0872	0.2057	0.0772	0.1895	0.1353	0.1567	0.1874	0.1222	0.1222
0.1719	0.0767	0.1762	0.0581	0.1774	0.1271	0.1401	0.1700	0.1066	0.1066
0.1531	0.0678	0.1475	0.0400	0.1661	0.1194	0.1252	0.1508	0.0937	0.0937

0.1354	0.0605	0.1202	0.0258	0.1543	0.1125	0.1111	0.1323	0.0842	0.0842
0.1201	0.0549	0.0941	0.0142	0.1422	0.1075	0.0976	0.1163	0.0766	0.0766
0.1050	0.0506	0.0718	0.0052	0.1306	0.1021	0.0850	0.1009	0.0731	0.0731
0.0913	0.0490	0.0483	-0.0004	0.1200	0.0986	0.0747	0.0867	0.0704	0.0704
0.0805	0.0477	0.0298	-0.0034	0.1120	0.0968	0.0640	0.0764	0.0702	0.0702
0.0701	0.0478	0.0119	-0.0052	0.1050	0.0948	0.0576	0.0680	0.0722	0.0722
0.0612	0.0504	-0.0020	-0.0035	0.0987	0.0935	0.0511	0.0600	0.0760	0.0760
0.0552	0.0531	-0.0141	-0.0001	0.0941	0.0934	0.0464	0.0537	0.0806	0.0806
0.0502	0.0557	-0.0238	0.0031	0.0918	0.0939	0.0451	0.0506	0.0844	0.0844
0.0467	0.0598	-0.0295	0.0100	0.0886	0.0940	0.0437	0.0473	0.0891	0.0891
0.0456	0.0619	-0.0322	0.0152	0.0858	0.0953	0.0431	0.0476	0.0933	0.0933
0.0447	0.0645	-0.0346	0.0224	0.0852	0.0958	0.0452	0.0486	0.0970	0.0970
0.0464	0.0669	-0.0327	0.0291	0.0843	0.0981	0.0477	0.0515	0.1003	0.1003
0.0485	0.0683	-0.0293	0.0347	0.0865	0.0991	0.0515	0.0548	0.1031	0.1031
0.0507	0.0707	-0.0256	0.0401	0.0868	0.1018	0.0553	0.0581	0.1027	0.1027
0.0531	0.0719	-0.0198	0.0443	0.0876	0.1032	0.0576	0.0615	0.1022	0.1022
0.0573	0.0726	-0.0125	0.0460	0.0899	0.1049	0.0615	0.0652	0.1004	0.1004
0.0612	0.0720	-0.0067	0.0478	0.0921	0.1049	0.0639	0.0682	0.0948	0.0948
0.0637	0.0721	0.0015	0.0449	0.0941	0.1058	0.0668	0.0717	0.0900	0.0900
0.0674	0.0699	0.0100	0.0419	0.0975	0.1057	0.0694	0.0756	0.0844	0.0844
0.0704	0.0667	0.0172	0.0375	0.0989	0.1050	0.0722	0.0778	0.0775	0.0775
0.0717	0.0629	0.0246	0.0304	0.1004	0.1040	0.0719	0.0788	0.0702	0.0702
0.0744	0.0597	0.0300	0.0238	0.1014	0.1029	0.0735	0.0805	0.0612	0.0612
0.0756	0.0576	0.0339	0.0180	0.1016	0.0997	0.0713	0.0799	0.0523	0.0523
0.0768	0.0528	0.0380	0.0090	0.1018	0.0981	0.0694	0.0786	0.0437	0.0437
0.0769	0.0491	0.0410	0.0017	0.1007	0.0952	0.0677	0.0777	0.0354	0.0354
0.0761	0.0454	0.0410	-0.0067	0.0998	0.0922	0.0639	0.0752	0.0279	0.0279
0.0747	0.0419	0.0421	-0.0160	0.0986	0.0900	0.0603	0.0713	0.0193	0.0193
0.0716	0.0371	0.0416	-0.0246	0.0956	0.0867	0.0551	0.0660	0.0128	0.0128
0.0694	0.0321	0.0395	-0.0337	0.0927	0.0837	0.0478	0.0614	0.0043	0.0043
0.0655	0.0261	0.0378	-0.0422	0.0885	0.0821	0.0426	0.0570	-0.0028	-0.0028
0.0619	0.0211	0.0350	-0.0507	0.0845	0.0803	0.0355	0.0510	-0.0099	-0.0099
0.0575	0.0150	0.0310	-0.0587	0.0796	0.0780	0.0276	0.0452	-0.0169	-0.0169
0.0539	0.0093	0.0264	-0.0651	0.0759	0.0759	0.0214	0.0392	-0.0247	-0.0247
0.0498	0.0020	0.0208	-0.0721	0.0702	0.0729	0.0148	0.0331	-0.0309	-0.0309
0.0463	-0.0027	0.0145	-0.0797	0.0660	0.0708	0.0082	0.0282	-0.0364	-0.0364
0.0424	-0.0080	0.0095	-0.0854	0.0611	0.0683	0.0024	0.0215	-0.0426	-0.0426
0.0377	-0.0122	0.0025	-0.0929	0.0558	0.0652	-0.0038	0.0150	-0.0477	-0.0477
0.0341	-0.0157	-0.0038	-0.0987	0.0518	0.0627	-0.0089	0.0092	-0.0525	-0.0525
0.0302	-0.0193	-0.0096	-0.1043	0.0471	0.0612	-0.0135	0.0037	-0.0558	-0.0558
0.0256	-0.0239	-0.0167	-0.1102	0.0429	0.0583	-0.0198	-0.0017	-0.0600	-0.0600

0.0220	-0.0265	-0.0234	-0.1146	0.0397	0.0562	-0.0226	-0.0064	-0.0638	-0.0638
0.0174	-0.0281	-0.0282	-0.1174	0.0360	0.0553	-0.0268	-0.0113	-0.0654	-0.0654
0.0120	-0.0307	-0.0346	-0.1219	0.0334	0.0522	-0.0300	-0.0164	-0.0689	-0.0689
0.0084	-0.0317	-0.0394	-0.1228	0.0297	0.0514	-0.0326	-0.0187	-0.0707	-0.0707
0.0040	-0.0325	-0.0448	-0.1250	0.0266	0.0496	-0.0349	-0.0214	-0.0720	-0.0720
-0.0010	-0.0338	-0.0512	-0.1257	0.0235	0.0487	-0.0379	-0.0270	-0.0725	-0.0725
-0.0033	-0.0345	-0.0543	-0.1264	0.0204	0.0480	-0.0392	-0.0304	-0.0712	-0.0712
-0.0067	-0.0342	-0.0573	-0.1254	0.0187	0.0476	-0.0419	-0.0349	-0.0697	-0.0697
-0.0104	-0.0357	-0.0620	-0.1246	0.0164	0.0463	-0.0436	-0.0385	-0.0663	-0.0663
-0.0121	-0.0347	-0.0641	-0.1230	0.0161	0.0459	-0.0449	-0.0402	-0.0630	-0.0630
-0.0151	-0.0338	-0.0671	-0.1218	0.0143	0.0470	-0.0479	-0.0420	-0.0590	-0.0590
-0.0168	-0.0343	-0.0690	-0.1188	0.0138	0.0463	-0.0493	-0.0434	-0.0553	-0.0553
-0.0187	-0.0331	-0.0700	-0.1170	0.0128	0.0470	-0.0495	-0.0422	-0.0531	-0.0531
-0.0200	-0.0325	-0.0711	-0.1149	0.0111	0.0473	-0.0516	-0.0434	-0.0504	-0.0504
-0.0216	-0.0321	-0.0724	-0.1117	0.0103	0.0471	-0.0512	-0.0428	-0.0481	-0.0481
-0.0231	-0.0314	-0.0723	-0.1094	0.0102	0.0461	-0.0516	-0.0425	-0.0461	-0.0461
-0.0249	-0.0302	-0.0742	-0.1052	0.0095	0.0477	-0.0527	-0.0427	-0.0421	-0.0421
-0.0246	-0.0291	-0.0740	-0.1003	0.0104	0.0468	-0.0510	-0.0442	-0.0379	-0.0379
-0.0260	-0.0271	-0.0730	-0.0966	0.0102	0.0482	-0.0510	-0.0438	-0.0357	-0.0357
-0.0266	-0.0234	-0.0730	-0.0917	0.0117	0.0500	-0.0499	-0.0445	-0.0319	-0.0319
-0.0267	-0.0184	-0.0718	-0.0853	0.0132	0.0531	-0.0491	-0.0426	-0.0290	-0.0290
-0.0252	-0.0080	-0.0665	-0.0757	0.0167	0.0578	-0.0491	-0.0403	-0.0259	-0.0259
-0.0215	0.0059	-0.0565	-0.0611	0.0207	0.0635	-0.0468	-0.0350	-0.0214	-0.0214
-0.0145	0.0234	-0.0423	-0.0391	0.0293	0.0717	-0.0434	-0.0260	-0.0136	-0.0136
-0.0043	0.0467	-0.0188	-0.0093	0.0397	0.0819	-0.0369	-0.0131	-0.0016	-0.0016
0.0111	0.0756	0.0107	0.0289	0.0548	0.0945	-0.0261	0.0043	0.0152	0.0152
0.0304	0.1082	0.0488	0.0762	0.0716	0.1099	-0.0118	0.0287	0.0391	0.0391
0.0543	0.1461	0.0936	0.1315	0.0917	0.1265	0.0083	0.0577	0.0708	0.0708
0.0814	0.1853	0.1450	0.1934	0.1147	0.1436	0.0331	0.0923	0.1085	0.1085
0.1115	0.2248	0.2017	0.2591	0.1395	0.1624	0.0646	0.1315	0.1536	0.1536
0.1441	0.2654	0.2595	0.3267	0.1660	0.1797	0.1009	0.1717	0.2018	0.2018
0.1788	0.3027	0.3173	0.3929	0.1922	0.1974	0.1422	0.2154	0.2516	0.2516
0.2124	0.3354	0.3739	0.4535	0.2159	0.2133	0.1852	0.2591	0.3004	0.3004
0.2440	0.3635	0.4258	0.5082	0.2402	0.2273	0.2309	0.2991	0.3466	0.3466
0.2747	0.3868	0.4712	0.5518	0.2623	0.2384	0.2738	0.3358	0.3878	0.3878
0.3017	0.4043	0.5101	0.5855	0.2798	0.2479	0.3141	0.3674	0.4206	0.4206
0.3249	0.4159	0.5401	0.6095	0.2949	0.2545	0.3514	0.3931	0.4463	0.4463
0.3450	0.4211	0.5599	0.6213	0.3056	0.2578	0.3819	0.4142	0.4644	0.4644

7.3 RESULTS

Tables below show the result of correlation of the pulses with respect to other fingers of same person and same finger of others. Correlation between two pulses is found by taking maximum value of correlation between 120sample wide window sliding over 200 sample wide fixed window. This process is repeated 80 times by sliding window by 1 sample. There by getting 80 correlations. The maximum of these correlations is taken as final correlation between these pulses It is seen that correlation of each finger is different from each other. By correlation we can find out that whether every finger has same profile or it varies from finger to finger or person to person.

Table 7.3 – Correlation with subject 1

subject 1	rightindex	rightmiddle	rightring	rightlittle	leftindex	leftmiddle	leftring	leftlittle
rightindex	**0.9976**	0.993	0.982	0.9957	0.9919	0.986	0.9824	0.9653
rightmiddle	0.993	**0.9938**	0.9577	0.9843	0.9862	0.9784	0.9732	0.9565
rightring	0.982	0.9577	**0.9951**	0.991	0.9786	0.9757	0.977	0.9581
rightlittle	0.9957	0.9843	0.991	**0.9962**	0.9926	0.9915	0.9913	0.9724
leftindex	0.9918	0.9862	0.9785	0.9926	**0.9983**	0.9869	0.9856	0.9669
leftmiddle	0.986	0.9784	0.9757	0.9915	0.9868	**0.9943**	0.9922	0.992
leftring	0.9823	0.9732	0.977	0.9913	0.9856	0.9922	**0.9932**	0.9807
leftlittle	0.9653	0.9565	0.9581	0.9724	0.9669	0.992	0.9809	**0.9925**
subject 2	0.9648	0.9553	0.9813	0.9568	0.9315	0.9496	0.9544	0.9601
subject 3	0.9721	0.9205	0.9629	0.9587	0.9669	0.9672	0.93	0.9523
subject 4	0.97	0.9308	0.9643	0.9661	0.9057	0.9467	0.958	0.9415
subject 5	0.9725	0.9002	0.9725	0.963	0.9304	0.9746	0.9479	0.9805
subject 6	0.9225	0.8739	0.9483	0.922	0.9093	0.9406	0.9153	0.9353
subject 7	0.9839	0.9062	0.9221	0.9828	0.9761	0.9777	0.9268	0.9563

Table 7.4 – Correlation of subject 2

subject 2	rightindex	rightmiddle	rightring	rightlittle	leftindex	leftmiddle	leftring	leftlittle
rightindex	**0.9966**	0.993	0.9926	0.9963	0.9856	0.989	0.9753	0.988
rightmiddle	0.993	**0.9988**	0.9982	0.9976	0.9775	0.9708	0.9797	0.9903
rightring	0.9926	0.9982	**0.9986**	0.9971	0.9835	0.9764	0.9814	0.9921
rightlittle	0.9963	0.9976	0.9971	**0.998**	0.9853	0.9767	0.9868	0.9948
leftindex	0.9862	0.9788	0.9843	0.986	**0.9959**	0.981	0.9863	0.988
leftmiddle	0.9904	0.9736	0.9774	0.9808	0.9803	**0.99**	0.949	0.9728
leftring	0.9786	0.9831	0.9839	0.9898	0.986	0.95	**0.9989**	0.9906
leftlittle	0.9885	0.9908	0.9924	0.9951	0.9877	0.9706	0.9904	**0.9948**
subject 1	0.9848	0.9915	0.9916	0.9959	0.9722	0.9777	0.9779	0.974
subject 3	0.971	0.919	0.9592	0.9599	0.9673	0.9666	0.9252	0.9532
subject 4	0.9838	0.9784	0.988	0.983	0.9453	0.9375	0.9673	0.9671
subject 5	0.9951	0.9942	0.9934	0.9798	0.9754	0.9788	0.9829	0.9672
subject 6	0.9728	0.985	0.9864	0.975	0.9628	0.9482	0.9793	0.9755
subject 7	0.9911	0.9941	0.8932	0.9886	0.9869	0.9755	0.8683	0.9456

Table 7.5 – Correlation of subject 3

subject 3	rightindex	rightmiddle	rightring	rightlittle	leftindex	leftmiddle	leftring	leftlittle
rightindex	**0.9935**	0.9904	0.9931	0.9933	0.9833	0.9912	0.9848	0.9887
rightmiddle	0.9904	**0.999**	0.9972	0.9904	0.9928	0.994	0.9959	0.9913
rightring	0.9931	0.9972	**0.9975**	0.9935	0.9932	0.9959	0.9956	0.9947
rightlittle	0.9933	0.9904	0.9935	**0.9968**	0.9943	0.996	0.9911	0.9846
leftindex	0.9833	0.9928	0.9932	0.9943	**0.9981**	0.997	0.9937	0.9802
leftmiddle	0.9912	0.994	0.9959	0.996	0.997	**0.9987**	0.9961	0.989
leftring	0.9848	0.9959	0.9956	0.9911	0.9937	0.9961	**0.9976**	0.9935
leftlittle	0.9887	0.9913	0.9947	0.9846	0.9802	0.989	0.9935	**0.9968**
subject 1	0.9848	0.9912	0.9916	0.9957	0.975	0.9784	0.9799	0.9742
subject 2	0.9649	0.9541	0.9803	0.9571	0.9317	0.9492	0.955	0.9601
subject 4	0.9885	0.9804	0.9789	0.9795	0.965	0.9832	0.9913	0.9876
subject 5	0.9925	0.9793	0.9897	0.9878	0.9909	0.9921	0.9859	0.9847
subject 6	0.9814	0.9701	0.9742	0.9813	0.9845	0.984	0.9845	0.9658
subject 7	0.9905	0.9844	0.9237	0.9899	0.9595	0.9447	0.88	0.9784

CHAPTER-8 Conclusion and Future scope

8.1 Conclusion

For providing proper healthcare the primary stage is to diagnose the health problem. Detecting the health problem requires several physical, chemical or even radiological tests which are time consuming, costly and sometimes even contradictory. While many advances are made in field of medical diagnosis we are still far away from getting a quick, low-cost, holistic and accurate diagnosis.

Amongst several endeavors made by the researchers worldwide some point to rejuvenating the dying art of diagnosing three basic Ayurvedic human constituents. These are known as doshas namely vata, pitta and kapha. Many Ayurvedic physicians used to diagnose these doshas by feeling the radial artery in the wrist region under the thumb. A preliminary study has been made in this thesis work to rediscover the documented facts of Ayurvedic medicinal system. In due course it was found that along with Ayurveda certain yogic postures known as Mudras that involve touching certain fingers of hand in well defined positions are able to provide relief for different diseases related to asthma, bronchial, heart etc.

The study inspired us to undertake the pulse profile of all the 10 fingers in 7 healthy subjects. To establish the uniqueness of pulse profile for a given subject, it was first normalized on time-scale to eliminate any differences on account of difference in beat to beat interval. This was done by taking 200 pulses from peak to peak of two alternative pulses (between peak1 and peak 3). Correlation between two pulses was found by taking maximum value of correlation between 120 sample-wide window sliding over 200 sample-wide fixed window as shown in fig 8.1 and fig 8.2.

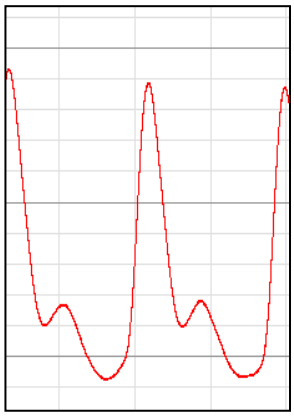


fig 8.1- 200 sample-wide fixed window

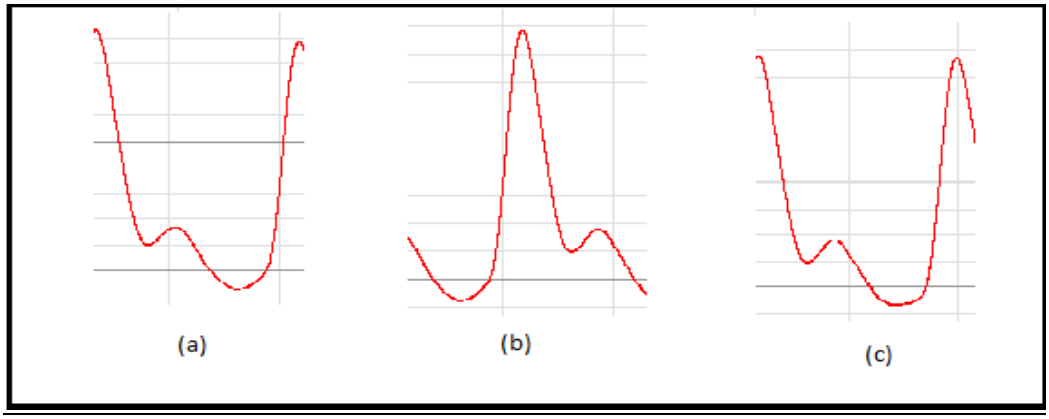


fig 8.2- 120 sample-wide sliding window

This process is repeated 80 times by sliding window by 1 sample, there by getting 80 correlations. The maximum of these correlations is taken as final correlation between these pulses.

The three main conclusions are listed as under:

1. For a given subject the auto correlation (correlation of index finger pulse with another index finger pulse taken subsequently) was found to be higher than correlation between different fingers (say between index finger and middle finger) in most of the cases. Total 7 subjects were observed for all 10 fingers each and it was found that auto correlation was highest in each finger in 67 out of 70 cases. We may thus safely conclude that the profile of a given subject is unique for the specific finger. This preliminary study opens up a possibility of studying the pulse profile of different fingers in the same person to find the relative features leading to detection of different doshas in a given person.

2. The correlation between the corresponding fingers of subject was studied after time scaling to remove variation on account of different peak to peak period. For example the correlation was found between the pulse profile of right index finger of subject 1 with the pulse profile of right index finger of subject 2. Similarly correlation was found between the pulse profile of right index finger of subject 1 with that of subject 3 and so on. Finally auto correlation of the subsequent pulses of pulse profile of right index finger of subject 1 was found. This exercise was repeated for all 10 fingers of the subject and for all 7 subjects thereby making a total of 70 cases under study. We came across startling results i:e in all 70 cases without exception the auto correlation for a given finger of subject was always higher than correlation with corresponding finger of any other subject. This study therefore may result in

establishing uniqueness of the duly time-scaled pulse profile of given subject and it may be used for establishing the three doshas based on ancient Ayurvedic science.

3. On basis of the uniqueness of duly time-scaled pulse profile of subject, there exists a possibility of using PPG finger pulse profile of subject as an alternative biometric parameter in addition to finger print scan traditionally being used. This may result in higher security and reliability of biometric system.

8.2 Future Scope

The present work is limited only to time domain study of finding correlation of finger pulse profile acquired by commercially available state of art PPG sensors along with Biopac MP150 data acquisition system. This being preliminary investigation it was limited to the 10 fingers of 7 subjects only.

There is scope of extending studies to higher number of subjects say 100 or so to confirm the results obtained above. There is a need to go for frequency component analysis using suitable transform like discrete wave transform etc and to establish the uniqueness in the same manner as described in the work.

If a proper Ayurvedic dosha classifier is available that makes use of parameters that can be extracted by analyzing questionnaire filled by subject, then these doshas can be correlated to the features extracted in time and frequency domain of finger pulse profile.

Further for establishing the pulse profile signal as a biometric parameter the same study may be extended to large number of samples say 1000 and more.

References

[1] Vasant lad, “Secrets of pulse: the ancient art of ayurvedic pulse diagnosis” , Motilal Banarsidass publisher, 2005.

[2] Priya Devi R, “Yoga Mudras For A Healthy You!”, available at *http://living.oneindia.in/yoga-spirituality/yoga/2010/yoga-mudra-types-cure-body-ailments-250610.html*

[3] “Types of Yoga Mudra” Types of Mudras for overall well being of human being, available at *http://www.indianetzone.com/1/types_mudra.htm*

[4] “Lotus Mudra” lotus mudra drains out all the misunderstanding, helps releasing tension, practiced to enhance fire element in the body, available at *http://www.indianetzone.com/38/lotus_mudra.htm*.

[5] “Detoxification Mudra” available at *http://www.crystallotus.com/Mudras/32mudra.htm*

[6] “Chin Mudra”, Chin Mudra stimulates a "nadi" when the hands are placed on the knees, merges individual soul with the universal soul available at *http://www.indianetzone.com/38/chin_mudra.htm*

[7] Kher S., Jain A., Ojha M.K and Sharma G.N., “Intelligent Diagnosis of Human Disorders Based on Ayurveda”, *International Session Papers Proceedings of the 35 th SICE Annual Conference (SICE '96).* pp. 1209-1214, 1996.

[8] Yoon Y., Lee M.H. and Soh K.S., “Pulse Type Classification by Varying Contact Pressure”, IEEE ENGINEERING IN MEDICINE AND BIOLOGY.2000.

[9] Hankey Alex “The Scientific Value of Ayurveda”, The Journal of Alternative and Complementary Medicine, volume 11, number 2, 2005, pp. 221-225, 2005.

[10] Chen L., Atsumi H., Yagihashi M., Narita F. and Fujimoto H., "A preliminary Research on Analysis of Pulse Diagnosis IEEE/ICME International Conference on Complex Medical Engineering (CME), Beijing, 23-27 May 2007, pp. 1807– 1812, 2007 .

[11] Joshi A., Kulkarni A., Chandrani S., Jayaraman V.K. and Kulkarni B.D., "Nadi Tarangini: A Pulse Based Diagnostic System", Proceedings of the 29th Annual International Conference of the IEEE EMBS, Lyon (France), August 23-26, 2007, pp.2207-2210, 2007.

[12] Abhinav., Sareen M., Kumar M. and Anand S.,"Nadi Yantra: A Robust System Design to Capture the Signals from the Radial Artery for Non-Invasive Diagnosis" , The 2nd International Conference on Bioinformatics and Biomedical Engineering (ICBBE 2008) , Shanghai, 16-18 May 2008, pp 1387-1390, 2008.

[13] Prakhash P., Sareen M., Anand R., Abhinav and Anand S., "Application of Wavelets Based Multiresolution Analysis to Detect Relevant Points of Interest from Finger-tip Photoplethesmography and Pressure Signal from the Radial Artery", Proceedings of the 2008 IEEE, Cairo International Biomedical Engineering Conference (CIBEC), Cairo,18-20 Dec. 2008.

[14] Sareen M., Abhinav., Prakash P. and Anand S.,"Wavelet Decomposition and Feature Extraction from Pulse Signals of the Radial Artery", International Conference on Advanced Computer Theory and Engineering (ICACTE '08), Phuket, 20-22 Dec. 2008, pp. 551-555, 2008.

[15] Selvaraj N., Jaryal A., Jayashree S., Deepak K. and Anand S.,"Assessment of Heart Rate Variability Derived from Finger-tip Photoplethysmography as Compared to Electrocardiography", Journal of Medical and Engineering Techonology, 2008, pp. 479-484, 2008.

[16] Abhinav., Sareen M., Kumar M. and Anand S., "Nadi Yantra: A Robust System Design to Capture the Signals from the Radial Artery for Assessment of the Autonomic Nervous System Non-Invasively", J. Biomedical Science and Engineering, 2009, 2, pp 471-479, 2009.

[17] Ivy & Malini, "Traditional Indian Medicine", 2nd International Conference on Advanced Computer Control (ICACC) , Shenyang, Volume 5, 27-29 March 2010, pp. 25-29, 2010.

[18] Nawaz G. M., Laxmi S. and Jayasudha., "E- Health Analysis Element for SupportingTherapeutic through Ancient Indian Medical Science", International Journal of Computer Applications, 2010, Volume 1- No. 17, pp. 75-80, 2010.

[19] "Photoplethysmograph", Wikipedia, the free encyclopedia available at *http://en.wikipedia.org/wiki/Photoplethysmograph*.